Agenda

• **Multiphase Pumping**
  • Case Study: TOTAL Moho-Bilondo Project, Congo

• **Subsea Separation**
  • Case Study: TOTAL PAZFLOR Project, Angola

• **Subsea Storage & Chemical Injection Station**
  • Enabler of very long subsea tiebacks
Subsea Multiphase Pumping
Multiphase Pumping

- Field proven technology
- Facilitates:
  - Increased initial production rates when installed at start of field life
  - Enhanced recovery when MPPs are installed at end of field life
  - Production of heavy oil reservoirs
  - Production of low-pressure reservoirs
- Avoids bottom hole gas lift
- Increased field life due to longer production plateaus

BUT!

- Positioning the MPP is important!
Early Field Life - Impact on Network Pressures

**Early Life**

- WHFP = 150 bar
- Xmas Tree
- $P_{\text{reservoir}} = 300$ bar
- $P_{\text{riserbase}} = 100$ bar
- $P_{\text{choke}} = 130$ bar

**Surface Facility**
- $P_{\text{surface}} = 15$ bar

**Riser**

**Addition of MPP Increases Initial Production**

- WHFP = 130 bar
- Xmas Tree
- $P_{\text{inlet}} = 55$ bar
- $P_{\text{outlet}} = 110$ bar
- $\Delta P = 55$ bar
- $P_{\text{riserbase}} = 110$ bar

**Surface Facility**
- $P_{\text{surface}} = 15$ bar

**Riser**
Early Field Life - Boost Oil Recovery

MPP installed at start of field life

Oil boost

Time

Oil flowrate

Without MPP  With MPP
Late Field Life - Impact on Network Pressures

Late Life

Surface Facility

*P_{\text{surface}} = 15 \text{ bar}*

Riser

WHFP = 115 \text{ bar}

Xmas Tree

*P_{\text{dsChoke}} = 105 \text{ bar}*

Riser Base

*P_{\text{riserbase}} = 95 \text{ bar}*

Reservoir

*P_{\text{reservoir}} = 200 \text{ bar}*

Addition of MPP Extends Production

Surface Facility

*P_{\text{surface}} = 15 \text{ bar}*

Riser

WHFP = 100 \text{ bar}

Xmas Tree

*P_{\text{dsChoke}} = 85 \text{ bar}*

Riser Base

Reservoir

*P_{\text{reservoir}} = 200 \text{ bar}*

MPP

\Delta P = 35 \text{ bar}

P_{\text{inlet}} = 70 \text{ bar}

P_{\text{outlet}} = 100 \text{ bar}

Reservoir

P_{\text{riserbase}} = 105 \text{ bar}
End of Life - Enhanced Oil Recovery

MPP installed at end of field life

- Initial oil plateau
- New oil plateau
- Production increase
- Installation of the MPP
- Extension of field life

Oil flowrate

Time

Without MPP  With MPP
Case Study:

TOTAL Moho-Bilondo
• **FEED phase covering**
  – Subsea tie-back on Moho Bilondo
  – Hybrid loop architecture, jumpers and XTs
  – MPP integration onto new hybrid loop

• **Main activities**
  – Flow Assurance
  – MPP system design
  – Flowline design
  – SPS Equipment functional specification
  – Contracts & Interfaces Packages preparation

• **Main highlights**
  – Fast track project
Moho-Bilondo MPP System Layout
Pump Unit & MPP
Subsea Separation
Subsea Separation

- The term refers to complete separation units installed on the seabed as fully integrated and remotely operated facilities.

- Operations benefits:
  - Stabilised flow regime in risers
  - Improved artificial lift
  - Possibility of disposal or re-injection of water subsea

- Cost savings:
  - Reduced thermal insulation and MEG / methanol requirements
  - Potential size reduction of downstream facilities
  - Reduced size of first stage separator
Case Study:

TOTAL Pazflor
PAZFLORE Field Layout

**FPSO:**
- Oil storage: 1.9 million barrels
- Oil production: up to 220,000 bpd
- Water injection: 382,000 bwpd
- Gas compression: 4.3 MSm³/d
- Power generation: 120 MW

**Wells:**
- 49 wells (23 at First Oil)
- Oligocene: 7 producers, 5 water injectors and 2 gas inj.
- Miocene: 18 producers, 17 water injectors

**Drilling Campain:**
- 2 Dynamic positioning Rigs starting in 2009
- Estimated duration campaign: 2700 days

**Offloading Terminal:**
- 6,600 m³/hour with innovative Trelleborg solution

**SSPS (Subsea Separation and Production System):**
- 49 horizontal Christmas trees
- 3 SSU including related umbilicals and topside modules
- 3 four slot manifolds

**Total length of pipelines:** 175 km
**Total length of umbilicals:** 90 km
Qualification Tests

Test 1: Scale model with model oil (Cranfield University)
- **Equipment**: transparent unit to monitor flow pattern using model oil with viscosity from 40cP to 2500cP
- **Outcome**: Vertical separator selected for sand management purpose, and objective of 15% GVF for liquids being pumped in normal operation. Completed January 2007.

Test 2: Scale model with real oil (Institut Français du Pétrole)
- **Equipment**: steel unit, vertical separator, mixture of Dalia/Sincor oils
- **Outcome**: GVF objectives confirmed. Completed June 2007

Test 3: Scale model with Pazflor oil (Institut Français du Pétrole)
- **Equipment**: Same test rig as Step 2, Pazflor Miocene oil
- **Outcome**: GVF objectives confirmed. Completed January 2009
From Conceptual to As-built

SSU Concept (DORIS)

As-Built SSU (Technip)
Subsea Storage & Chemical Injection Station
Limitations for Long Tiebacks

- Subsea tiebacks rely on umbilicals to convey flow assurance chemicals and hydraulic fluid services.
- Long subsea tieback means larger tubes or hoses and therefore larger cross-sections ...

<table>
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<th>Distance</th>
<th>Size</th>
<th>Conversion</th>
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<td>OD = 160mm / 6”</td>
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Subsea Station for Chemical Storage and Injection

**Water depth**
500m – 3,000m
1,600 ft – 10,000 ft

**Production**
Oil: 4 x 15k Sblpd
Gas: 4 x 150 MMScfd

**Tie-back length**
Oil: 100km / 60mi
Gas: 500km / 300mi

**Wellhead pressure**
200bar – 450bar
3,000psi – 6,500psi
Pressure-balanced tank design

Protective Shell:
- Structural support, protection, level monitoring and leak detection

Bladders:
- designed for material compatibility
- shape is selected for constructability and design life
Corrosion inhibitor – Oil field:

- 150 m³ (40,000 gal) - 1 year
- 75 m³ (20,000 gal) - 6 months
- 37 m³ (10,000 gal) - 3 months
- 12 m³ (3,000 gal) - 1 month

Biocide – Gas field:

- 3.8 m³ (1,000 gal) - 6 months
- 0.4 m³ (100 gal) - 3 months

Chemical Storage and Refilling
Economic Benefit

**CAPEX**
- Cost of Station
- Refill hardware
- Umbilical
- Topside Chemical Skids

**OPEX**
- Refill operation
- Maintenance

- This is an innovative system that is cost effective for long SSTB.
- The next step is a foundation case study and pre-qualification program to verify the feasibility.
- Our goal is to support a fully autonomous "Subsea Plant"
Pushing the boundaries of energy production with integrated engineering.