Subsea Multiphase Boosting in Deep Waters

Kuala Lumpur, 11 July 2008
Kjell Garvik
Presentation Overview

- The BP King Project
- Challenges and System Solution
- Technical features
  - Pumping System
  - Pressure Casing
  - Lube Oil Pressure Control
  - Power System
  - Installation & Tie-in
- Up and Running
Malaysia hub for Aker Solutions expansion in Asia Pacific – high tech manufacturing centre

- **Fully Integrated Execution Hub**
  - **Field Development:**
    - Deep water front end engineering
    - Detail engineering
  - **Subsea Business Streams:**
    - Subsea Systems
    - Trees & Boosting
    - Controls
    - Umbilicals & Risers
    - Aftermarket
  - **Best Value Procurement Hub**
  - **High Tech Manufacturing Centre**
Plant Combined Achievement

- **Reliance Project: MA-D6 MAJOR MILESTONE**

  “One Stop Shop”

- Fabrication, Manufacture and Testing of MA-D6 Manifold.
- Fabrication, Machining, Assembly and Test of MA-D6 Xmas Tree.
- Assembly Test MA-D6 Mounting Bases and SCM’s.
**BP King Subsea Pump Project**

**Highlights**

- Optimize Oil Recovery from the King Field Reservoirs
- New deep water enabling technology (deepest booster ever)
- Tied into the existing King subsea infrastructure (longest ever)
BP King Subsea Pump Project

Key Facts

- 1600 – 1700 m Water Depth at Pump Locations
- 27 km step-out to the D6 Pump Location
- 2 off 1 MW Installed Power without Subsea Transformers
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Key Challenges

- Water Depth & Shut-In Pressure
  - Pumping system
  - 5000 psi Rating at 1700 m WD
  - Installation/Serviceability

- High Voltage Power System
  - Step-out distance
  - Combined Power/Control Umbilical
  - Cross-talk and Electrical Interference

- Barrier Fluid/Lube Oil System
  - Supply and Pressure Maintenance
  - Pressure Control
King MultiBooster system

Client: BP
Location: King, Gulf of Mexico
Water depth: 1700 m
Step out: 27 km
Design temp: -29 to 82.2°C
Pressure increase: 50 bar
Design pressure: 5000 Psi

Scope of work
- Management & engineering
- Pump modules & Pump manifolds
- Topside & subsea control system
- Topside lube oil power unit
- High voltage power supply system
- System integration test
Pump Station

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>Length x Width x Height (ft and m)</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUMP MODULE</td>
<td>17 x 9,8 x 14 (5,2 x 3 x 4,3)</td>
<td>50 Te</td>
</tr>
<tr>
<td>PUMP MANIFOLD</td>
<td>31,5 x 11,8 x 19,7 (9,6 x 3,6 x 6,0)</td>
<td>40 Te</td>
</tr>
<tr>
<td>SCM (Control Module)</td>
<td>5 x 3,5 x 4 (1,5 x 1 x 1,2)</td>
<td>1 Te</td>
</tr>
<tr>
<td>COMPLETE PUMP STATION</td>
<td>31,5 x 11,8 x 23 (9,6 x 3,6 x 7,0)</td>
<td>90 Te</td>
</tr>
</tbody>
</table>
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Twin Screw Multiphase Pump – Technology Features

- Pump Core Technology by Bornemann Pumps
- Volumetric Pumping Principle - Transportation inside closed screw chambers.

Liner

Screws

Direction of Rotation
Twin Screw Multiphase Pump Benefits

- Keep up pressure at very high GVF (0 - 98 %)
  - The pump takes whatever comes in and just moves it
  - Self-priming

- Efficient slug-dampening
  - The pump inlet and outlet are separated by internal pump chambers

- Easy Operation
  - Flow is controlled by speed

- Very little risk for emulsion
  - Very low shear forces on the fluid inside the pump

- Handle heavy and viscous fluid
  - Typ. 1 to >1000 cSt
Pump Performance Envelope – 335 Version

Performance Map
Bornemann Multiphase Booster

General Data:
- Inlet pressure: 15 barg
- GVF: 70 %
- Viscosity: 5 cSt

King Pump Operational Window

Pump Capacity in am³/h at Pump Inlet

Differential Pressure in bar

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Subsea Pump & Motor Casing

**Purpose**
- Seal towards sea (1700 m WD)
- Maintain pressure integrity (5000 psi)

**Extensive Design Work and Testing**
- Pressure vessel design
- Seal design and testing
- Material selection
- Limited penetrations in pressure shell
- Internals are included as cartridges

King Motor/Pump Casing under Pressure Testing
Complete BP King Pump Casing and Valves
Complete BP King Pump Module
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Lube Oil/Barriere Fluid System

**Purpose**
- Lubrication
- Cooling
- Barrier towards process
- Pressure control

**Robust design**
- Separate lube pump
- Redundant, retrievable mechanical pressure regulator
- Accumulator bank for back-up and installation pressure support
Key Elements in Lube Oil System

- Cooler
- Redundant Retrievable Pressure Regulators
- Instrumentation
- Accumulator Bank
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King Power System
Key Features of Power System

- World Record on Subsea Power Distribution Step-out (27 km)
- Extensive System Simulations and Evaluations in Design Phase
  - Successful co-operation between several parties: Aker Solutions, BP, Siemens, Nexans, Sintef
- 2 off 2.2MVA SIEMENS Perfect harmony drives in Containerized house (2 halves)
- No transformer between drive and motor – 8.2kV umbilical input voltage
- 12kV/320A subsea HV connection system - Tronic
- Pump
  - 1.0MW AKS MultiBooster™
  - 6.6kV / 120A

VSD Container Installed at Marlim
Subsea Umbilical Termination Assemblies

- Three UTAs for Project: 1 Main & 2 In-Field
- Integration Test conducted with all flying leads to confirm

D6 Infield UTA

Steel Tube Flying Lead Junction Plates
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Pump Modules being Installed
King MultiBooster Hook-Up and Tie-in

- Same pump station at both locations, fully assembled unit, 90 tons
- Hook-up by ROV connected flying leads:
  - HV and LV Power
  - Instruments
  - Hydraulic Supply
  - Lube Oil
  - Methanol
- Retrievable Modules:
  - Pump
  - Pressure controller
  - Control Module
  - Manifold
- Hook-up to Xmas Tree
  - DES MARS™ Choke Insert System
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BP King Pumps Up and Running

Snap-shot from Operator’s Room on February 26th 2008
BP Press Release December 4th 2007

- The two pumps will enhance production from the King field by an average of 20 per cent.
- After its 2002 start-up, the King field reached peak production in 2004, with recent production averaging 27,000 barrels of oil equivalent a day.
- In addition to the increase in production, this project will allow a seven per cent increase in recovery, extending the economic life of the field by five years.
February 13, 2008

Mr. Sven Ivar Fure
Aker Kvaerner Subsea A/S
PO Box 73
N-3401 Lier Joseph Kellersvei 20, Tranby
Norway

Subject: King Subsea Pump Project – Letter of Appreciation

Dear Mr. Fure,

BP Americas Inc. wishes to express our sincere appreciation to Aker Kvaerner Subsea A/S (AKS) for their participation in the successful development and completion of the King Subsea Pump Project.

The AKS supply of two Multi-Booster subsea pump systems was fully commissioned in the King Field in late November 2007, and has operated reliably since start-up.

AKS provided a superlative project team that developed and delivered forefront technology in this record-breaking subsea project development. BP wishes to recognize the great efforts of the AKS Project Manager, Ms. Karine Kierulf, and the very capable and dedicated engineering team leaders: Andreas Larsen, Klas Eriksson, Sonja Hauge, Truls Normann, and Sigmund Aandalstid.

BP also wishes to recognize Mr. Gunter Homstvedt, whose clear vision for subsea pumping supported the King Subsea Pump Project from beginning to end.

AKS also provided excellent technical field support during the installation and commissioning phases of the project. It is BP’s expectation that this relationship will continue to support the operation of the King subsea pumps.

Please pass our appreciation the AKS suppliers, including Bornemann Pumps, Loher Motors, Ottestad Breathing Systems, and all the other AKS suppliers who participated in making this project a success.

BP looks forward to building on the technology and relationships forged in this project in future subsea field developments.

Best Regards

[Signature]

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BP King Pumping System

The Front-runner for Deep Water Boosting Success

Thank You for Your Attention
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