Ormen Lange
Well Delivery

Big bore, deep water, high flow rate gas wells

Location: Mining Institute of Scotland, BP, Aberdeen.
8 November 2006
Presenter: Jimmy Edgar
Ormen Lange Field

- Location: 125 km offshore Norway
- Water depth: 700-1100 m
- Area: 350 km² (44 x 8)
- Thickness: 50 m
- Reservoir depth: 2600-2950 m
- Reservoir temperature: 93 °C
- Seabed temperature: -2 °C
- Reservoir pressure: 289 bar
- Fluid type: lean gas condensate (80 m³/Mm³)
- Recoverable Volume: 397 billion m³

Participating Interest

<table>
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<th>Company</th>
<th>Interest</th>
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<tr>
<td>Hydro</td>
<td>18.1%</td>
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<tr>
<td>Shell</td>
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<tr>
<td>Petoro</td>
<td>36.5%</td>
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<td>Statoil</td>
<td>10.8%</td>
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<td>DONG</td>
<td>10.3%</td>
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<td>ExxonMobil</td>
<td>7.2%</td>
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Development Concept

Production Rate = 70Mm3/day

20% of UK’s Domestic Gas Supply from 8 Wells

42” Northern Pipeline

44” Southern Pipeline

2 x 30” Production Pipelines
Challenges due to Extreme Conditions

- Uneven seabed
- Storms
- Subzero seabed temperatures
- Strong sea currents
Seabed Conditions

- 8000 yr old Storegga Slide
- Volume = 5600 km$^3$
- Distance = 800km, back edge = 300km
- Subsea peaks = 30m to 60m
Seabed profile pipeline route
Pipeline Routing Nearshore
Rock installation

Total quantity of rock required approx. 3 million tonnes
Remotely operated Spiders
Dredging by Spider over the Storegga escarpment

More than 5,000 m³
Excavation with JetProp/ Clay Cutter
JetProp/ClayCutter

More than 12,000 m³ removed
Ormen Lange Field with Wells

Egga Sand 69m

7-1  8-1  5-1  4-1

GWC -2913m

44 km

-2500m
7" versus 9 5/8" wells

Phase 1, pre-drilling
- 14 x 5 = 70MSm³/day
- 14 x 7" wells = 700 MUSD
- 8 x 10 = 80MSm³/day
- 8 x 9 5/8" wells = 400 MUSD

Cost savings of 300 MUSD

Ormen Lange wells will be the largest deep water wells in the world.
Well design risks

- Bigger wells
  - Well control incidents, blow-out, barriers
  - Internal loads
  - Well interventions

- Higher flow rates
  - Maximum gas velocities versus erosion
  - Vibrations and water hammer effects
  - Lower completion constraint

- Fewer wells
  - More dependent on each well, reliability
West Navigator

- 5th Generation dual activity drillship
- Build year: 2000
- Dual Ramrig
- Dynamically positioned - Class 3
- Dimensions: 254m long, 42m wide
- Variable deck load: 5500MT
- Fully mechanised riser & tubular handling systems
- Cranes: 1 x 70 ton, 2 x 35 ton, 1 x 12 ton knuckle boom, 1 x 10 ton
Interface Management

- Have dedicated staff looking into Interfaces

- Rig Selection and Operations
  - Design: NS WE
  - Equipment selection: NH SS
  - Fabrication/purchase: NH SS
  - Installation: NS WE

- XT, Tubing hanger, LRP/EDP
  - Design: Responsibility
  - Equipment selection: NH SS
  - Fabrication/purchase: NH SS
  - Installation: NS WE

- Well Head & template interface
  - Design: Responsibility
  - Equipment selection: NH SS
  - Fabrication/purchase: NH SS
  - Installation: NS WE

- Well Upper Completion Equipment and Design
  - Design: NS WE
  - Equipment selection: NS WE
  - Fabrication/purchase: NS WE
  - Installation: NS WE

- Lower Completion (OHGP)
  - Design: Responsibility
  - Equipment selection: NH SSur/ NS SSur
  - Fabrication/purchase: NS SSur
  - Installation: NS WE

- XT, Tubing hanger, LRPLRP/EDPEDP
  - Design: NS WE
  - Equipment selection: NS WE
  - Fabrication/purchase: NS WE
  - Installation: NS WE

- Rig Selection and Operations
  - Design: NS WE
  - Equipment selection: NS WE
  - Fabrication/purchase: NS WE
  - Installation: NS WE
Critical Issues

- Safety
- Reliability
- Deepwater
- DP Drillship
- Partner Interface
Value Drivers and KPIs

Ormen Lange Phase I
Well Delivery

Safe Installation
- 8 x Wells
- 10 MSm3/day/well
- Low Intervention

TRCF | HMRIF | Spills
Discharges | Waste
Management

Well Engineering
- Cuttings
- 30° Inclination
- 20° Setting Depth
- 13 5/8” Depth
- 9 5/8” Depth
- 7” Lower Comp
- Tangent Angle

Template Stability
- 30° Cementation
- 20° Cementation
- 13 5/8” Cement
- 9 5/8” Cement
- Reservoir Entry
- Reservoir Inc

Logging Program
- Logging Quality
- Well Test
- Lower Completion
- Gauges
- TD 8 1/2” Section
- Mechanical Skin

NPT | Milestones | Time/Depth

AFE/Actual

HSEQ
Quality
Schedule
Cost

Well Delivery Team
HYDRO
Ormen Lange Completion

- Completion Overview and Qualification Testing
Sand Screens

Drivers for Ormen Lange sand control selection:
- Robust and reliable
- Up to 30 year operational life
- Inflow performance

Challenges:
- Fines
- High flowrate
Sand Screens

- DNV RP A203 Qualification of New Equipment Process selected as design basis for project

- 5 vendors selected: Baker Oil Tools, Halliburton, Reslink, Schlumberger, Weatherford

- 3 screens types selected for testing at OL conditions

- Small scale samples tested at DNV Høvik for erosion, plugging and mechanical strength
Sand Screens

- SWW screens selected as optimum for OL
- Weatherford selected for OL after technical and commercial evaluation
- QA plans for screen manufacture adopted to include specific slot width tolerance acceptance using photometric measurement
Formation Isolation Valve (FIV)

- ‘Sand Bridging’ test
  8.00” OD FIV inside 9-5/8” casing (8.50” ID)
  Matrix of pump rates, concentrations, angles etc
  No issue seen with bridging

- Gas Test of ball sealing
  ISO 14310 equivalent test at reservoir temperature
  Note – This was on request

- Testing of N2 chamber at low temperature (-2 deg C)

- Onshore test of mechanical shift tool (Contingency opening of FIV)

- QA plans developed to specifically address materials, NDE, dimensional checks and assembly.
GP Packer Straddle

- Concern over closure (short and long term) of sleeve below GP packer
- Straddle to be set in packer head with seal extension
- Onshore interface testing to be carried out
Production Packer

- 7” x 9-5/8” Halliburton HHC (Hydrostatic set) packer qualified to ISO 14310 V0
- Standard, widely used packer
**Liner Hanger**

- 9-5/8” x 13-5/8” Flexlock LH with ZXP packer qualified to ISO 14310 V0

- ZXP contingency tie-back packer and seals qualified to ISO 14310 V0

- All LH system equipment delivered using service provider ‘critical well group’ with focus on manufacture, onshore assembly and offshore installation procedures
Control Line Protectors

- 7” and 9-5/8” required plus X/O & SSSV specials
- Significant size and weight for 9-5/8” protectors
- Re-design of existing protectors (Weight of 6kg vs. 16kg for cast clamps)
- Qualification in Norway:
  - Make-up tightness
  - Clamp stress
  - Cable grip
  - Axial load
  - Sideways load
  - Hang-up testing
  - Running wear
SSSV

- Tandem hot-stacked arrangement (ref: Exprosoft Report)

- 4 phases of testing completed

- Phase 1 & 2 tested a non-equalising valve
  Tests included 4 x production rates slams & 1 blow out slam

- Outcome of Phase 1 & 2 was qualification of BOT 7” Non-Equalising valve

- Due to concerns about effects of MEG on reservoir, phase 3 initiated - 7” Self-Equalising valve

- Phase 3 – BOT valve failed due to loss of self equalising poppet
SSSV

- Phase 4 – 150 equalisation cycles and 4 x production rates slams & 1 blow out slams.

- Additional testing of retention feature using Loctite™ and “peening” of screw head

- Fully qualified in March 2006.
Tubing Hanger

- 110ksi tubing material vs. 75ksi TH material
- ‘Non-matched’ connection
- API 5C5 Testing – cyclic loads of internal & external pressure, combined with tension, compression, temperature and bending

Results were:
- Limits on compression and external pressure
- Specific make-up torque requirements
Tubing Connections

- 9-5/8” 53.5# P110 Super 13Cr Vam Top ND qualified fit within the Ormen Lange service envelope (using Jet Lube API modified dope)

- 7” 32# P110 Super 13Cr Vam Top HC qualified fit within the Ormen Lange service envelope (using Jet Lube API modified dope)
**Fluids**

- Full suite of compatibility tests being carried out
- Packer fluid will be brine with added MEG for hydrate inhibition
- Elastomer compatibility study by MERL
Ormen Lange Subsea Overview

- Subsea Architecture
- Template versus Cluster
- Xmas Tree Selection
- Workover/Intervention Riser
Main technical challenges

- Deep water and environmental conditions
- Cold seawater, -2°C at seabed
- Flow assurance and hydrate prevention
- Very high gas well flow rates (10 MScm/day)
Phase 1: Subsea Architecture

Template A

Template B

Pipeline End Termination PLET

In-line Tees
**Template components**

Template system

- Manifold module
- X-mas tree
- Foundation bottom structure (FBS)
Heerema’s Thialf – Templates and PLET installation August/September 2005
Hooking on lifting slings
Removal of transportation barge
Xmas Tree Selection

- Horizontal versus Conventional versus Concentric
  - Conventional eliminated due to impact on casing design.
  - Concentric eliminated due to impact on template design.
  - Horizontal chosen
    - ease of annulus access
    - ease of access for workover
    - accommodation of big bore gas concept
Horizontal Xmas Tree system

Choke module (15 tonnes)  Xmas tree (45 tonnes)
Workover/Intervention Riser

- Subsea Test Tree versus Open Water Riser

"the assessment showed the major risk contributor came from the time taken for gas releases to be successfully shut in. Large bore high flow rate wells release sufficient volumes of gas to cover the installation in less than 30 seconds. This type of massive gas release, in combination with a burning test flare with likelihood of ignition, was identified as an unacceptable risk. The analysis revealed that it was the detection and shut in time that was the driving safety parameter, and not the reliability of the barriers."

- So, we have a workover riser system....
ORMEN LANGE WORKOVER SYSTEM

10k, -20°C to 85°C
Weak Link

- Wholly new product
- Releases in tension only
- ROV armed/disarmed
- Compensator lock-up
- Significant design challenge
- Consequences of release
  - Rapid expansion of gas
  - “Rocket effect”
  - Temperature decrease
Storm Hang-off

- Global Analysis
  - Need to disconnect before 2.6m Hs, 1 year Storm
  - Collision with moonpool
  - Hs > 2m since rig entered field
  - WOR is unusable

- Storm hang-off solution (next slide)
  - 10 ideas considered
  - Riser Centraliser
  - Additional slick joint
What are we up against?

- Storm hits Ormen Lange field 10.01.2006
- Norne reports:
  - 17 meter significant
  - 27.1 max
- 100 year storm is 16 meter significant!
- Similar storm reported in 2005
- West navigator not in storm, sheltered in fjord. (previous slide)
Current Status

- Langeled pipeline officially opened on 16 Oct 2006
- On target for first gas in Oct 2007
- 4 wells drilled down to just above reservoir
- Xmas trees onboard West Navigator ready for deployment
- Completion and Well Tests in March/April 2007
Additional Material
Ormen Lange Field Development

Field Potential
(current well schedule)

Plant Capacity 70 M &
85% ASF

Sales acceleration

Date
## Template versus Cluster

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<th>Issue</th>
<th>Template</th>
<th>Cluster</th>
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<td>CAPEX</td>
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<td>Flexibility for addt’l wells</td>
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<td>Jumpers/Flowlines</td>
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<td>Hydrate Risk</td>
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<td>Ease of MEG Injection</td>
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<td>Schedule Flexibility</td>
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<td>Volume of hardware</td>
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<td>Ease of start-up</td>
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<td>Technical complexity</td>
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