Experiences from design and operation, learning and improvements

Tim Crome, Director Sales and Business Development
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A World Leader Bringing Innovative Solutions to the Energy Industry

- A world leader in project management, engineering and construction for oil & gas, chemicals and energy companies
- Revenues driven by services provided to clients Onshore/Offshore and Subsea
- Over 36,500 people in 48 countries
- 2012 Revenues: €8.2 billion; Operating margin\(^1\) of 10% for the 4\(^{th}\) year

\(^1\) from recurring activities
Presence in Norway

- Operating in Norway since 1985
- ~675 employees
- Revenue ~5 BNOK

2012 Employees

<table>
<thead>
<tr>
<th>Employees</th>
<th>%</th>
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<tbody>
<tr>
<td>Total Group</td>
<td>36,500</td>
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<tr>
<td>Technip Norway</td>
<td>&lt;2%</td>
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<tr>
<td>Rest of the Group</td>
<td>~98%</td>
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National Headquarters
- Spoolbase

Satellite operating centers
- Orkanger
- Haugesund
- Stavanger
- Oslo
Subsea: worldwide leading integrated player

Services
- Deep water installation & construction
- Flexible/rigid pipelaying
- Inspection, repair & maintenance

Products
- Flexible pipe (in house manufacturing)
- Rigid pipelines
- Umbilicals (in-house manufacturing)

Architecture
- Vertical integration
- In-house technologies
- Worldwide leadership
- First class assets
A few of the Flexible Riser Projects on the NCS

- Åsgard B, C, A
- Balder
- Njord
- Visund
- Norne
- Snorre TLP+B
Flexible Risers have been a major enabler in the development of floating production
Technology development last 30+ years
Flexible Technology - Since the Early 70’s

- Technip have delivered >10,000 km of Flexible Pipes
- Equipped With More Than 25,000 End Fittings:
  - Internal Diameter from 1.5” up to 22”
- Down to 3000m Water Depth
- Up to 20,000 psi Working Pressure
- Design temps from -190°C up to 150°C
- Static, Dynamic, Subsea & Topsides applications
Experience - UTC 2004

- Norwegian projects have pushed the development of larger dia. HPHT risers
More recently, Skarv has pushed this further + GOM and WAF projects
Norwegian Experience - UTC 2004

EXPERIENCE WITH FLEXIBLES - INCIDENTS

- Offshore Norway has experienced a number of incidents directly related to flexibles, including:
  - Collapse of internal layers of high pressure 3-layer gas injection risers
  - Slippage of plastic layers in end-fittings resulting in leakage
  - Degradation of plastic layers due to operation outwith their design
  - External damage during installation or operation leading to flooding of annulus and uncertainty with respect to fatigue life
  - Bursting of external sheaths
  - Pig tailing of flexibles on drag chains

- These incidents have lead to a greater understanding of the limits of flexible design and the importance of control of details
3 Layer Coflon Design

- Reasons for multi layer design:
  - PVDF Plastics for HPHT application susceptible to:
    - Creep
    - Crack propagation
  - Need for plasticiser to enable extrusion
  - Pre-deplastified in end-fittings to prevent volume loss

- Outer sheath
- Axial armours
- Pressure armours
- Anti-creep sheath
- Pressure sheath
- Sacrificial sheath
- Carcass
3 Layer Coflon Design

- Shortcomings with this design have been recognised since ~2000

- First failures in mid 1990s due to pull-out of sheath in end-fitting ➔ change of design and procedures for end-fitting mounting, 3-layer design maintained

- R&D efforts have been maintained last ~15 years to develop a mono-layer PVDF dynamic riser

- Not a simple process but now virtually complete

- Coflon XD monolayer dynamic riser completed 2,000,000 cycle dynamic test, with Pressure and Temperature cycles, last week
More Norwegian Experience with 3-Layer Risers

- Lack of friction between plastic layers → axial loads taken by carcass → load condition outside design
- Clear influence of operating regime
- Failure of carcass has resulted in damage to sacrificial and pressure sheaths leading to leakages
Advantages with monolayer CoflonXD design (without tape above carcass):
- No spaces between plastic layers allowing gas build-up $\Rightarrow$ collapse eliminated
- Mechanical interlock between pressure sheath and carcass $\Rightarrow$ weight of carcass taken by pressure sheath firmly anchored in end-fitting
- Use of highly ductile PVDF material ensures that surface roughness, due to extrusion directly above carcass, does not result in crack initiation sites
- Shrinkage due to loss of plasticiser eliminated
- Simplified design and manufacturing

Challenges with design (solved):
- Extrusion of CoflonXD requires large forces and specially designed heads
- NDT of extrusion process to identify unacceptable defects (whatever the type of plastic sheath)
Monolayer CoflonXD Qualification Status

- Final dynamic test for Statoil complete 18\textsuperscript{th} Nov.
- 2 Million bending cycles, 4th Integrity Test with Pressure at 638bar, 21\textsuperscript{st} Nov
- Dynamic bending test performed with 130\textdegree{}C bore temperature at >400bar,
  - 60 temperature and pressure cycles in addition
- First 1.5M cycles to qualify for field service life, last 500k cycles to push theoretical Zeta fatigue damage to 1.0
- Dissection of sample outstanding
- Most extreme Qualification test at LT
External sheath damage

- Abrasion / damage of external sheath experienced;
  - Due to internal pressure build up
  - Lack of care during handling / installation
  - Within guide tubes due to rough inside surface,
  - On seabed due to very many small movements

- Prevention
  - Venting at end-fittings (and mid line)
  - Good procedures, well followed
  - Adequately specified and fabricated guide tubes
  - Additional external protection, eg double sheath or external prot.
More Norwegian Experience

- Vortex Induced Noise & Vibration
Vortex Induced Noise & Vibration

- Riser systems which have experienced FLIP:
  - Åsgard Gas Export System
  - Gjøa
  - Norne
  - Kristin

- A dry gas flow problem (not yet fully understood?)

- Only proven solution that fully eliminates FLIP is the Technip Smoothbore GE Riser
  - Used on Åsgard, Gjøa and Norne
  - It also reduces pressure loss through the riser
Service life re-assessment

- More and more client requests about prolongation of flexible pipe service life when reaching the end of design service life

- Main checks performed for service life re-assessment:
  - Check of operating conditions from field data (fluid composition, injection of chemicals, operating pressure & temperature, any abnormal event?, etc.)
  - Analysis of inspection / monitoring available data (ex: annulus tests, polymer coupons, etc.)
  - Check of all flexible pipe layer integrity vs. operating conditions
  - Fatigue / corrosion fatigue assessment

- This way the service life of flexible pipes can be extended

⇒ Importance of monitoring and inspection tools
Integrity systems and services for flexible Risers

### Annulus Conditions
- Flooding monitoring:
  - RACS: Vent gas monitoring from topside
  - DTS: Flooding detection through integrated optical fiber

### Site inspection
- Annulus testing: Annulus free volume measurement / Outer sheath damage detection
- Gas analysis

### Tensile Armour Breakage Detection
- Acoustic Emission Monitoring
- Real time detection of Armor Wire Failure

### Flexible « In Bore » Inspection
- “In Bore” visual inspection
- Internal pipe geometry measurement
# Technical Challenges & Key R&D Programmes

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<tr>
<th>Category</th>
<th>Programmes</th>
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<td><strong>UDW</strong></td>
<td>- Carbon Fibre Armours and Psi vault</td>
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<td>- Armour wire anchoring</td>
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<tr>
<td><strong>Fatigue and Corrosion Fatigue</strong></td>
<td>- Fatigue curves</td>
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<td>- Fatigue softwares and dynamic analysis</td>
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<td>- Reinforced top riser</td>
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<td><strong>Corrosive Fluids</strong></td>
<td>- Material qualification</td>
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<td></td>
<td>- Prediction of annulus composition</td>
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<td>- Anti H2S Layer</td>
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<tr>
<td><strong>HP- HT</strong></td>
<td>- New vault wires</td>
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<td>- New Polymers</td>
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<td>- New pipe designs and Thermal Screens</td>
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<td><strong>Flow Assurance</strong></td>
<td>- Active Heating</td>
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<td>- High performance Insulation</td>
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<tr>
<td><strong>Cost Reduction and Volume Growth</strong></td>
<td>- New suppliers (steels and polymers)</td>
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<td>- New grades (steels and polymers)</td>
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<tr>
<td><strong>Integrity Management</strong></td>
<td>- Monitoring systems</td>
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<td>- Inspection systems and services</td>
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Key innovations to support our flexible pipe Technology…

- Flexible Riser
  - 30 years experience
  - for 3,000m water depth

- Smooth Bore
  - Eliminate vortex induced noise
  - Increase gas flow

- Carbon Fiber Armors
  - Reduction of deepwater riser weight by 50%

- Riser with Anti H₂S sheath
  - Exclusive technology
  - Cost effective solution for highly corrosive fluids

- Integrated Production Bundle
  - Improve flow assurance

Better design (probabilistic approach, reduce over conservatism)
More FEA and medium scale tests
More monitoring and quality control, improved reliability
Conclusions / Summary

- Flexible products essential for floating production
- Norway has lead floating / subsea production and hence development of flexible risers, esp. for large dia. HP/HT applications
- Some solutions adopted, in consultation together with clients, as best practice subsequently demonstrated new failure modes
- Extensive R&D required to design and qualify new solutions
- Increased focus on Life Extension and Asset Integrity Management ➔ special need for focus on material degradation
Thank you

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