Innovation of a Flexible Riser for Ultra-Deepwater Application

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Imagination at work.
Innovation of a Flexible Riser for Ultra-Deepwater Application

- Introduction
- GE Oil & Gas Wellstream
- Ultra-Deep Water Challenge
- Technology Innovation
- GE Wellstream Innovation Centers
- Summary
Welcome to GE Wellstream!

GE

Oil & Gas

WELLSTREAM
GE’s Portfolio

Employees: ~300,000 • ‘10 revenue: ~$150B • Operating 125+ years

Energy
- Power & Water
- Energy Management
- Oil & Gas

Technology Infrastructure
- Aviation
- Healthcare
- Transportation

GE Capital
- Aviation Financial
- Commercial Finance
- Energy Financial
- GE Money
- Treasury

Home & Business Solutions
- Appliances & Lighting
- Software & Services
- Controls
GE Energy

25% of GE revenue
Technology partner for customers

Oil & Gas
- Drilling & Surface
- Global Services
- Measurement & Control Solutions
  - Dresser
  - Wayne
- PII Pipeline Solutions
- **Subsea Systems**
- Turbomachinery

Power & Water
- Aero
- Gas Engines
- Nuclear
- Power Generation Services
  - Parts & Repair Services
- Renewables
- Thermal
  - Environmental Services
- Water

Energy Management
- Digital Energy
- Industrial Solutions
  - Lineage Power
- Power Conversion

**Energy is a global scale business**
GE Oil & Gas today

Employees: ~33,000
Operating in more than 130 countries

Drilling & Surface
- Drilling risers
- Blow-out preventers
- Electric submersible pumps
- LWD and wireline tools
- Surface wellheads & flow control
- Logging services

Subsea Systems
- Subsea trees & wellheads
- Subsea power & processing
- Controls
- Manifolds
- **Flexible risers**
- **Flow lines**
- Specialty connectors & pipes
- Floating production systems

Measurement & Control
- Asset condition monitoring, control, sensing & inspection solutions
- Optimization & diagnostic software
- Control & safety relief valves
- Blowers, compressors, flow & NG Pipeline Solutions
- Fuel dispensers & payment terminals
- Fuel control & retail systems
- CNG compression

Turbomachinery
- Gas & steam turbines
- Axial, centrifugal & reciprocating compressors
- Reactors & heat exchangers
- Turbo-expanders
- Pumps, valves & systems
- Control panels
- Industrial modules

Global Services
- Transactional outage services
- Contractual services
- Conversions, modifications, and upgrades
- Remote monitoring & diagnostics
- Pipeline inspection & integrity services ... a JV with Al Shaheen

We now have a portfolio that spans from upstream to downstream with service & process solutions at our core
Production Facilities

**Newcastle, UK**
- Operational since 1997
- Capability and experience to manufacture the full range of offshore products from 2” - 16” ID
- Annual production capacity 300nKm
- Proven track record of operating at highest standards required by industry

**Rio & Niterói, Brazil**
- Serving Petrobras since the early 1990’s (Rio Office)
- Commenced manufacturing on schedule in May 2007
- Annual production capacity of 270nKm
- Product range: 2” to 12” ID
- Manufacturing systems replicate Newcastle
GE Wellstream Flexible Pipe Structure

- **Flexbarrier™** - Polymer HDPE, PA11/PA12, PVDF
- **Flexlok™** Carbon Steel
- **Flexinsul™** Syntactic Foam
- **Flexxtensive™** Carbon Steel
- **Flexshield™** - Polymer TPE, HDPE, PA11/PA12
- **Flexbody™** Alloy steel
- **Flexbarrier™** - Polymer HDPE, PA11/PA12, PVDF
Wellstream flexibles...

- Infield Flowlines
- Well Jumpers
- Risers
- Offloading Lines
- Fluid Transfer Lines
- Topside Jumpers
Ultra-Deepwater Challenges
Economic Challenges
• Oversupply vs demand
• Depressed price
• Difficult to predict for recovery time
• It is the world’s most important commodity

It is vital to our standard of living, no easy substitutes for it!

Impact on Operators and Suppliers
• Cost saving
• More Efficient
• More Reliability
Challenges of Ultra Deepwater Application
- *Flexible Riser Technology*

- **Weight!!**
  combined with high pressure and temperature

- **Hash Environment**
  Combined with large surface vessel excursion

- **Collapse Resistance**

- **Lateral and Radial Birdcage Failure**

- **Etc.**

Ensure safe and environmentally responsible production in an economically viable manner!
Challenges of Ultra Deepwater Application

- Flexible Riser Technology

High top tension loads Impacts:

- Limiting Installation Vessel Selection
- High Load Bearing Requirement on Host Vessel
  
  For Example, Unable disconnectable turret
- Riser strength capacity
- Fatigue Damage and Service Life
- Etc.
Challenges of Ultra Deepwater Application
- *Flexible Riser Technology*

Technology Innovation Goals

- Developing “enabling” technologies
- Enhancing existing technologies
- Ensure product safety/reliability and cost effective
GE O&G Wellstream
Technology Innovation
GE Innovation - Composite Pipe

Design Concept - Bonded Pressure Armour

**Composite Armor**
- Optimized fiber angles and thicknesses to meet design requirements with minimum mass; fewer layers for easier inspection

**Thermoplastic Matrix**
- PVDF - qualified pipe material

**Carbon Fiber**
- Not susceptible to environmental stress corrosion; chemically resistant

**Metallic Carcass**
- High temperature collapse resistance; well characterized performance

**Bonded Liner/Barrier**
- PVDF - with high chemical resistance; reduced permeated gas risks; easier inspection

**Metallic Tensile Armor**
- Straightforward means to attach mature end fitting technologies; stable dynamics; industry experience; impact damage tolerance

**Smooth Bore Option**
- For smaller diameter / lower temperature applications - low pressure drop & improved flow assurance
GE Innovation - Composite Pipe

Bonded Pressure Armour - Cont.

- Reduced Weight (30 – 40%)
- 8 inch ID @ 3000 mWD
- Design Pressure 12ksi
- Maximum Temperature 120 °C
GE Innovation – UDW Carcass

Manufacture Capacity

- Up to 22 mm formed thickness
- Target: 11 inch @ 2000m WD
- Key for the future Pre-salt developments
GE Innovation – UDW Carcass

• Prototype tests for product qualification - Collapse
• Tests show >2000mWD for 11 inch ID pipe sample
GE Innovation – Waved Stepped Riser

- Utilize buoyancy to reduce top tension loads!
- Handle additional weight by UDW carcass
- Form quasi-dynamic riser section for composite pipe qualification
- Reduced top tension enable disconnectable turret
- Reduced top tension widen installation vessel selection
- Based on known and proven technology
GE Innovation – Waved Stepped Riser

Design Concepts

• Target over 100 ton net buoyancy
• Exerting the buoyancy at mid-line end fitting connection

![Diagram of Waved Stepped Riser](image-url)

- Tension along riser length – Free Hanging Riser
- Tension along riser length – Stepped Riser
- Targeted Maximum Tension Load
- Net Buoyancy required at each step
- Targeted Minimum Tension Load
- Position of 1st Step
- Position of 2nd Step

OrcaFlex 9.4d: Ab-Far-2-R4.sim (modified 7:00 PM on 10/20/2008 by OrcaFlex 9.1d)

Range Graph: 3A Effective Tension, Static State

Effective Tension

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<tr>
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![Graph showing Effective Tension and Net Buoyancy](graph-url)
GE Innovation – Waved Stepped Riser

Mid-line Buoyancy System Design
• Based on proven syntactic foam technology for deepwater
• Custom buoyancy module design based on moon pool size
• Installation friendly
• Assembled during riser installation
Example of 6 inch - *Waved* Stepped Riser

- Turn Deep Water into Shallow Water Application
- 3000 mWD
- Dynamic Responses @ Hs=13.4m, Tz=11.12s
- No noticeable dynamic responses at TDZ
GE Innovation – Waved Stepped Riser

Model Test

- Simulating 250mWD, 8” ID
- Investigating VIV of Mid-Line Buoyance System
- Investigating riser responses w/wo MDMS
GE Innovation – Waved Stepped Riser

Stepped riser is a practical solution for deep water application based on known/proven technologies to achieve high structure reliability.

Stepped riser allows designers to control riser tension ranges within a desirable range to:

- Gain longer service life by reducing mean stress
- Increases installation vessel competition
- Increases host vessel section
- Enable a disconnectable turret in ultra deepwater

Stepped riser inherits high compliance with large surface vessel motion, i.e. FPSO:

- Relaxed constraint on vessel offset and mooring requirements

Lower installation cost and risk by using traditional methods

Predictable performance and cost (historical data)
Research & development facility

- Rio Innovation Center (RIC) opened in Nov. 2014
- Newcastle Innovation Center (NIC) Opened in Jun. 2015
- Both are dedicated to Flexible Pipe Technology development
- Facilities will include both full scale and small scale test rigs
- Total investment over 35m USD
GRC Rio Technology Centre Capabilities

Full Scale Test Facilities

- Hyperbaric Chamber
  (7500psi / 1.1m ID / 6m long)
- Tension-Tension Test Rig
  (900tn / H₂S and CO₂ Capability)
- Bending & Tension Dynamic Rig
  (700tn dynamic / 1250tn Static)

Small Scale Test Facilities

- Autoclaves for Corrosion Tests
  (2 x 5ksi / 1 x 15ksi)
- Polymer Ageing Stoves
  (6 x 300°C)
- Fume Hoods for testing
  with harmful gases
Newcastle Innovation Centre Capabilities

- Co-locate all existing testing equipment and pilot lines into a single site:
  - Dynamic Bending with Tension,
  - Dynamic Tension-Tension
  - Dynamic Thermal Cycle (Bending with Pressure)
  - Material testing laboratory

Bird Caging Rig (Compression and Bending)

Rotating Fatigue Rig (Full-scale Carcass Barrier testing)
Summary

Ultra-deepwater application requires safe and cost effective technologies and methods

• Developing “enabling” technologies to expand existing capability
• Enhancing existing technologies to ensure reliable operation in a ultra-deepwater environment
• Leveraged with improved product safety and reliability, and overall cost effective

Ultra-Deepwater requires the integration of technologies of:

• Material
• Pipe Structure
• Manufacture Capacity
• Riser System, FPSO
• Installation Capability
• and etc.
Questions?