Flexible Riser Integrity Management Experience West of Shetland

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West of Shetlands
Foinaven

- Located 190 km West of Shetland in 330 - 520 m water depth
- Petrojarl FPSO, operated by Teekay
- Startup 1997
- Oil export by shuttle tanker
- Gas export via 20” WOSPS to Sullom Voe
- 10 flexible risers
  - 4 off 9.1” production
  - 4 off 7.2” production/test
  - 1 off 7.5” gas lift/export
  - 1 off 10” water injection
Schiehallion

- Located 175 km West of Shetland in approx 400 m water depth
- Schiehallion FPSO
- Startup 1998
- Oil export by shuttle tanker
- Gas export via 20” WOSPS to Sullom Voe
- 15 flexible risers
  - 7 off 9.5” production
  - 3 off 7.4” production/test
  - 1 off 7.1” gas disposal/export
  - 1 off 7.4” gas lift/export
  - 2 off 9.5” water injection
  - 1 off 11” water injection
West of Shetlands Integrity Management

- BP operator of subsea system for both Foinaven and Schiehallion
- Significant attention to riser integrity since installation
  - Monitoring and inspection
  - Risk-based pipeline integrity management system, PIMS
  - BP Integrity Management Standard
- Key contractors
  - Aker Solutions = subsea engineering contractor
  - MCS = flexible riser engineering contractor
  - Technip = flexible risers, flowlines, jumpers
  - Wellstream = flexible flowlines, jumpers
  - Subsea7 = IRM contractor (Subsea Viking)
Schiehallion Bend Stiffeners

- Schiehallion bend stiffeners are large, two-part design
- Recent experience of slippage of inner bend stiffener

Bend stiffener connector

Outer bend stiffener

Inner bend stiffener

Riser
Schiehallion Bend Stiffeners

Stiffener Intact  Partial Slippage  Fully Slipped
Schiehallion Bend Stiffeners

- Bend stiffener change-outs performed 2007
  - 6 bend stiffeners replaced on existing risers
  - 1 bend stiffener installed with new riser

Recovered bend stiffeners

Replacement bend stiffeners
Riser Monitoring

- Riser Anchor Monitoring System (RAMS)
- Sonar system to monitor anchor system, risers and bend stiffeners
- Field trial Foinaven, July 2007
  - Sonar monitoring tool developed by SRD
  - Deployment system through spare I-tube
  - Deployment system developed by SP1
Riser Monitoring (RAMS)

Deployment system

RAMS screen display
Sheath Damage

- Sheath damage on both Foinaven and Schiehallion risers
- Annual monitoring through annulus vacuum testing
- Detection using fluorescent dye and laser leak detection
- Repair clamps developed for known breaches

- Example
  - Foinaven R10
  - Repair clamp installed 2007
Sheath Damage

- Example
  - Foinaven R2
  - Just below upper tether clamp
  - Repair clamp installed 2007
Corrosion-Fatigue

- Fatigue of armours is becoming more of a concern
  - Historical sheath damage leading to annulus flooding
  - Increasing H₂S levels
  - Fatigue criteria
- Key issues
  - Monitoring of annulus condition
  - Monitoring of process conditions
  - Protection of annulus
    - Flushing with inhibiting fluid
Corrosion-Fatigue

- Foinaven R8 riser case history
  - Pre-installed 1996
  - First operation 1997
  - Various sheath breaches identified and clamped between 1997-2003
  - Flushing with inhibitor fluid initiated in 1997
  - Approx. 95,000 litres flushing fluid consumed up to 2003
- Fatigue assessed at design and early 2000
- Fatigue reassessed in 2007/8 due to increasing fatigue concerns
Corrosion-Fatigue

- Clamp at -301 m, Oct 1997
- Clamp at -80 m, Sep 2003
- Clamp at seabed, May 2002
Corrosion-Fatigue

- Annulus environment
  - H₂S production increasing since 2002
  - Permeation calculations performed by Technip to determine H₂S concentration in annulus
  - Predicted annulus H₂S levels 7 mbar
Corrosion-Fatigue

- Fatigue testing
  - FI-09 SN curve data currently available for flushed (sweet) conditions
  - No data available for flushed (sour) conditions
  - Wire fatigue testing programme initiated for sour service conditions
    - Work performed by Marintek
    - Wire samples/dissection of representative stock
**Corrosion-Fatigue**

- One year fatigue assessment programme
  - SN curve derived from Marintek tests
  - Global riser analysis performed by MCS
  - Local fatigue analysis performed by Technip
  - Quantitative risk assessment performed by Marintek
- Conclusions:
  - Riser fatigue life was unacceptable for remaining field life
- Riser changed out with spare riser in 2008
- Foinaven dynamic umbilicals
  - As-built in black
  - As-found 2007
Marine Growth

Before cleaning

After cleaning
Marine Growth

• Specific marine growth
  – Particularly heavy (circa. 3000 kg/m³)
  – Significantly heavier than considered in design
    – No known industry experience of this type of problem on risers
  – Rapid (exponential) expansion of growth over last few years

• Current status
  – Extensive marine growth removal program resulted in re-floating
  – Outer sheath damage identified close to RGB touchdown (‘08 repair)
Conclusions

- Extensive operating experience West of Shetland
  - Foinaven field 11 years operation
  - Schiehallion field 10 years operation
  - More than 250 riser-years operation in both fields
- Key integrity management issues
  - Monitoring of bend stiffeners
  - Annulus monitoring to identify sheath damage
  - Monitoring of annulus to identify potential for corrosion-fatigue
  - Fatigue prediction and management