Innovative Options for Flexible Pipeline & Caisson Repair

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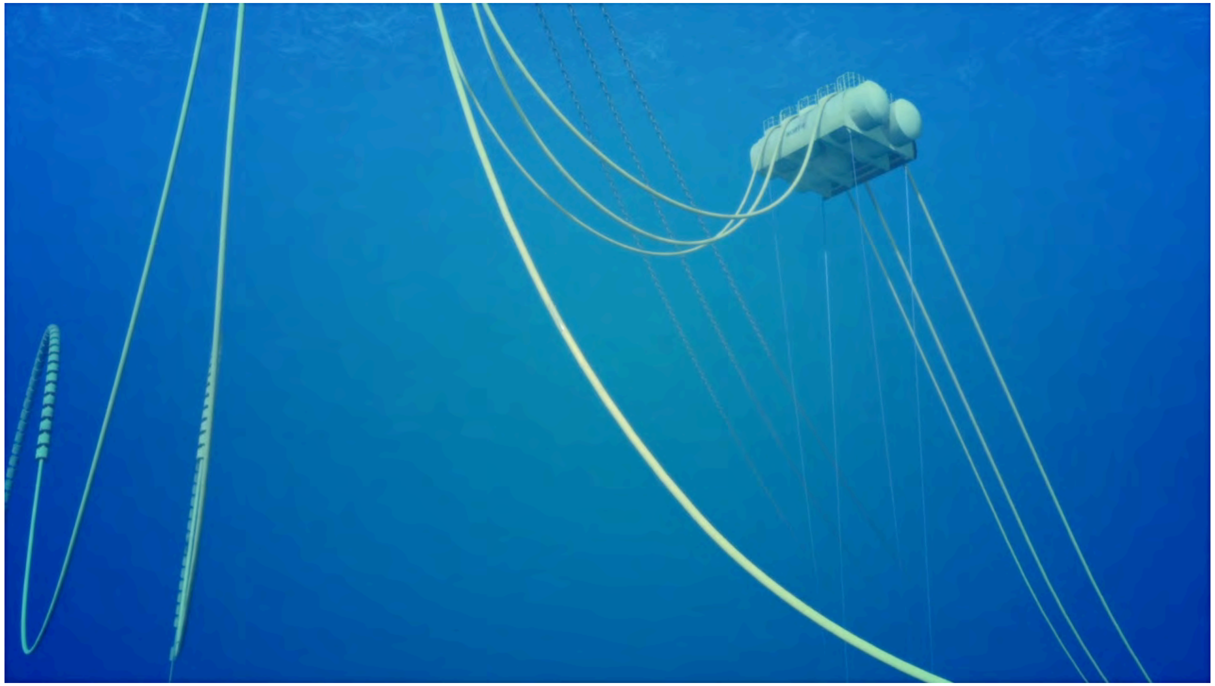
FLEXLIFE
shaping subsea™

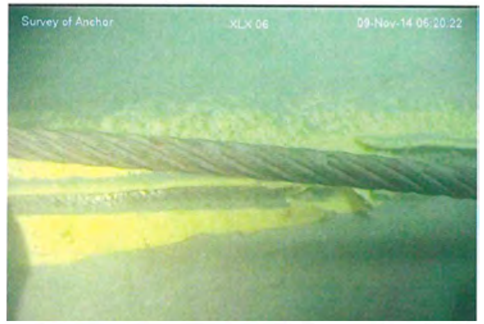
Agenda

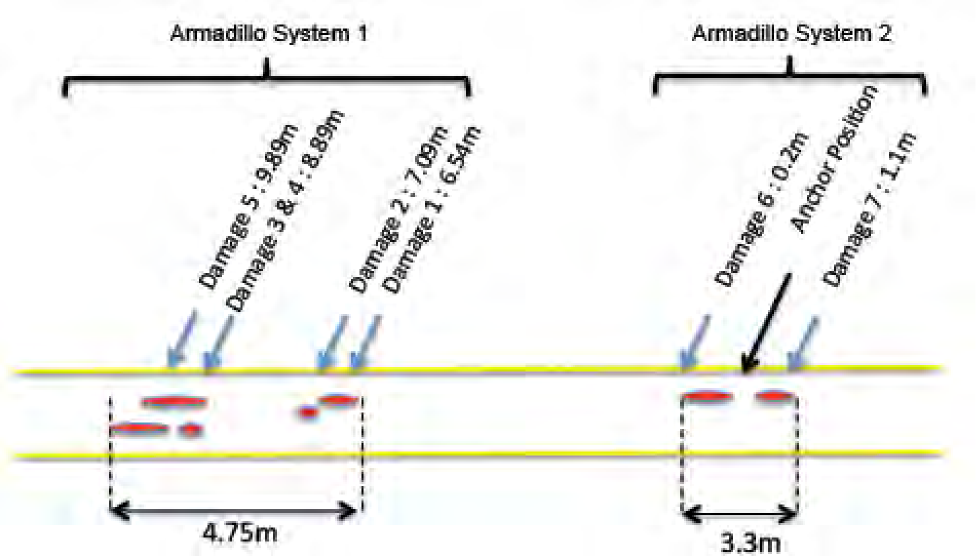
- Armadillo® Technology Overview
- Case study 1
  - Flowline anchor damage
- Case study 2
  - Blocked riser vent ports
- Caisson repair solutions
- Case study 3
  - Riser repair in I-tube
- Case study 4
  - Low pressure pipeline Leak sealing
- Current developments
  - Cross-linking polymer repair solutions
- Q&A



Case Study 1: Flowline Anchor Damage

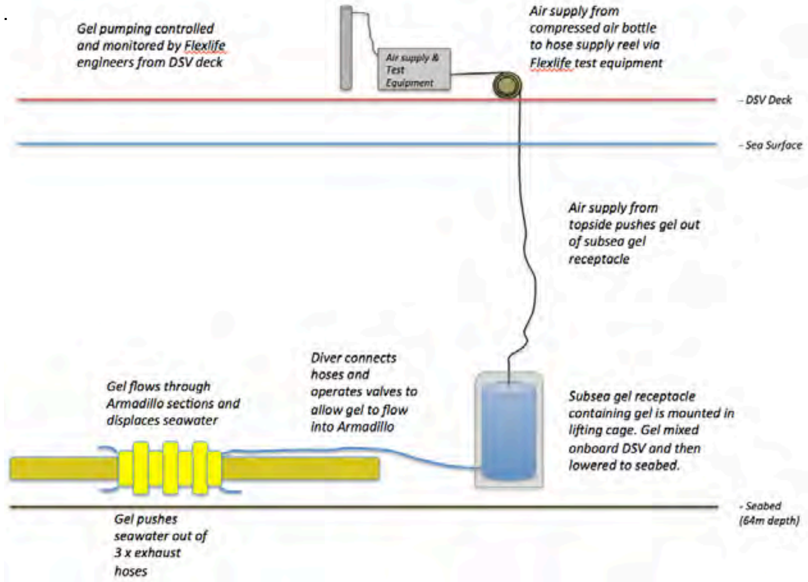
- 12” Production Flowline
- GE Oil & Gas manufacture
- Traditional rough bore static design with HDPE outer sheath
- Flowline outer diameter 359mm
- 3.3 km long, laid in 64m water depth
- Post install dropped object (anchor) damage
- Multiple perforations of flowline outer sheath
- Annulus metallic layers exposed
- Manufacturers recommendation that the outer sheath be repaired.
- Option to recover to deck, repair and re-lay
    - Higher risk, higher cost.
- Or, repair in-situ
    - Lower risk, lower cost

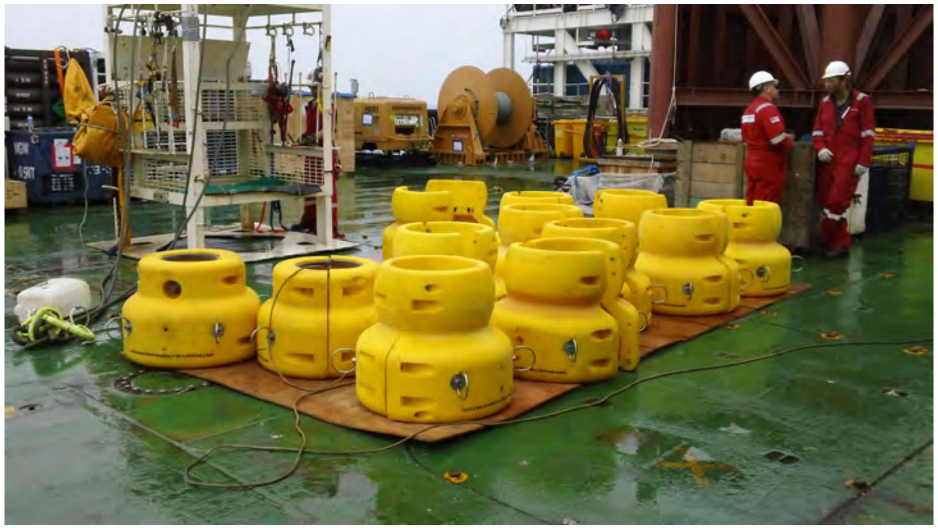




Case Study 1: Flowline Anchor Damage

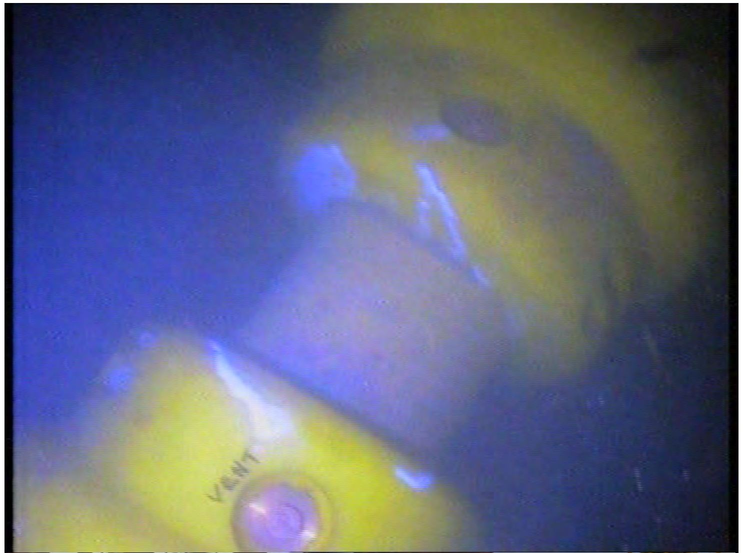
- Modular design of Armadillo® facilitates the repair to long areas of outer sheath damage
- Flowline lifted using subsea A-frame
- Diver installed, segment by segment over damage location
- Post-install, flowline has one end lowered to seabed
- FlexGel-A™ is then filled from highest point
- Controlled from topsides by Flexlife engineers
- FlexGel-A™ is lighter than seawater
- Displaces seawater within the Armadillo annulus
- Re seals the flowline outer sheath





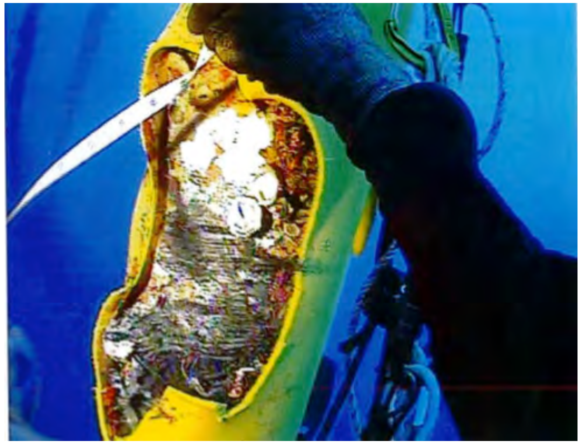
Case Study 1: Flowline Anchor Damage

- Lessons learned
- Prudent to carry additional segments.
- Original damage length was indicated to span 8.25m
- On installation, spare segments were used to cover 10.3m
- Once FlexGel-A™ is activated, vessel SIMOPS should be avoided



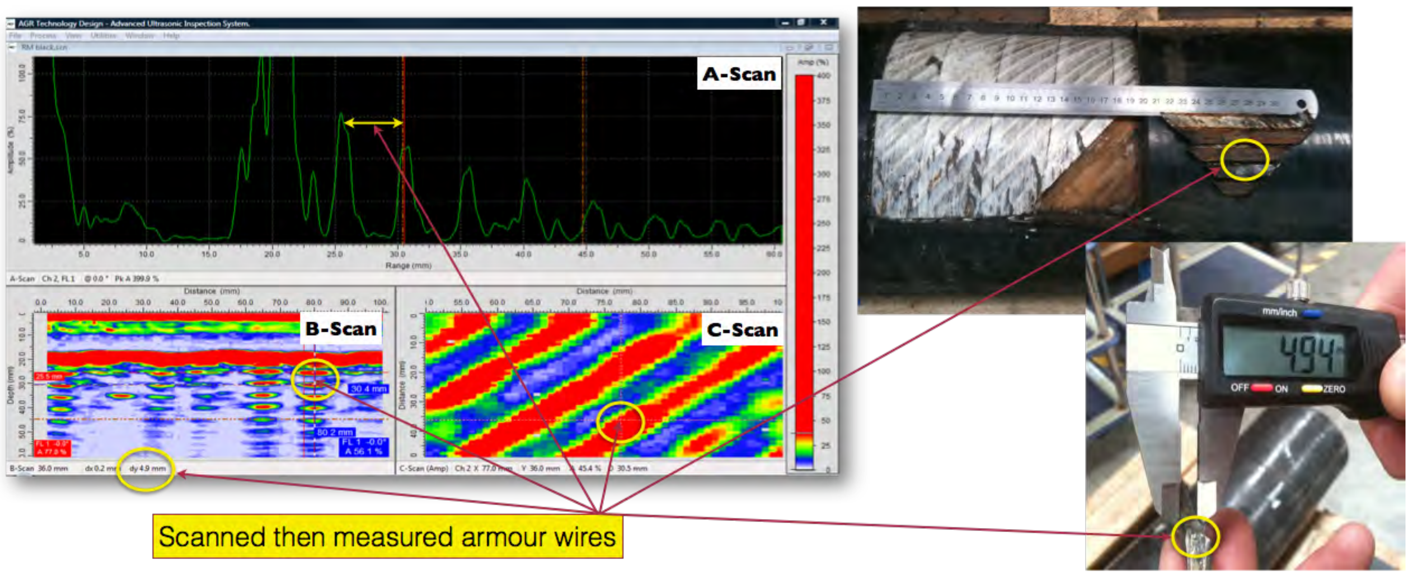
Case Study 2: Blocked Annulus Vent Ports

- Turret moored FPSO operating in 60m water depth, SE Asia
- ROV fly-by highlighted serious outer sheath damage on riser
- Located 1m below bend stiffener location
- Suspected to have been caused by vent port blockage
  - Leading to annulus overpressurisation
  - Subsequently to outer sheath rupture
  - Metallic tensile and pressure wires exposed to seawater
  - Risk of general corrosion
  - Risk of corrosion fatigue



Case Study 2: Blocked Annulus Vent Ports

- Detailed inspection data
- Decision to use ROV deployed ultrasonic inspection
- Patented FlexScan™ technology
- Using Neptune UT scanner
- UT offers clear information regarding transitions between and through materials
- The speed of sound through a known material enables accurate thickness measurement
- Used to reduce conservatism in life extension study
  - Global dynamic analysis
  - Local fatigue analysis

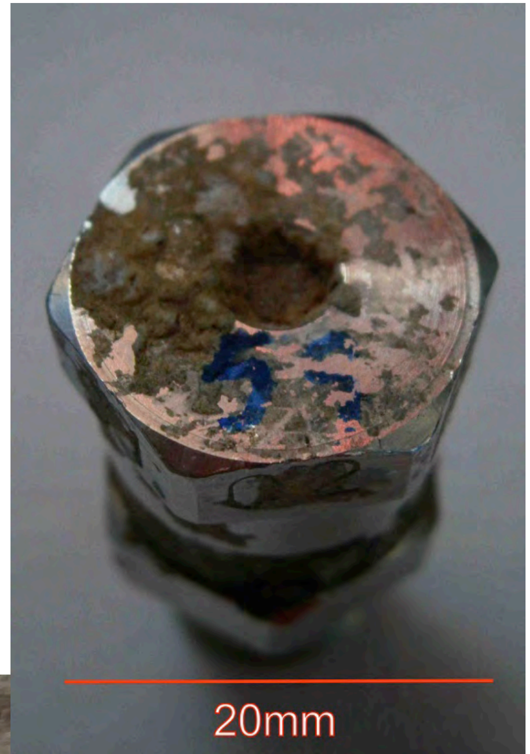


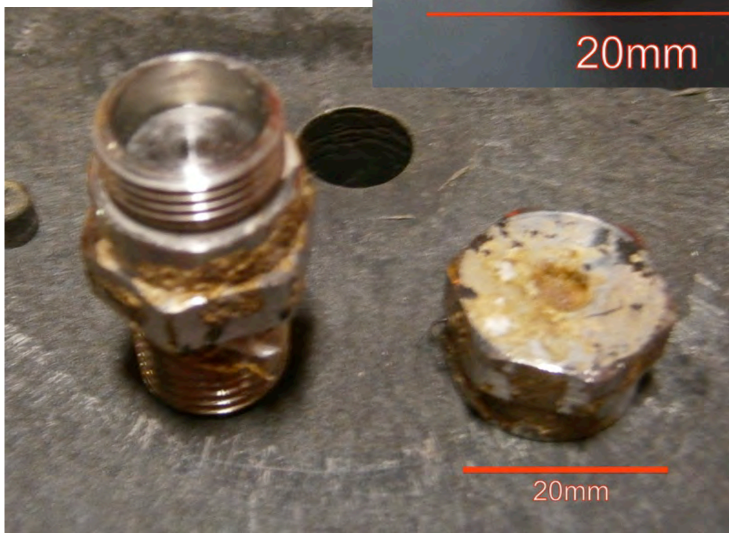
Case Study 2: Blocked Annulus Vent Ports

- Armadillo® is designed to accommodate small discrepancies in riser o/d
- Constructed from polymer, typically HDPU
- Failure root cause, in this instance, was sheath over-pressurisation caused by marine growth induced vent port blockage
- Post install on the riser, additional venting system was installed through Armadillo® repair clamp
- Armadillo® annulus was then injected with FlexGel-A™ to provide an isolation between the seawater and the riser annulus
- Riser End-Fitting Pressure Relief Valves were also replaced
- This exercise allowed residual pressure to be released on two adjacent risers, BEFORE the outer sheaths ruptured

Case Study 2: Blocked Annulus Vent Ports

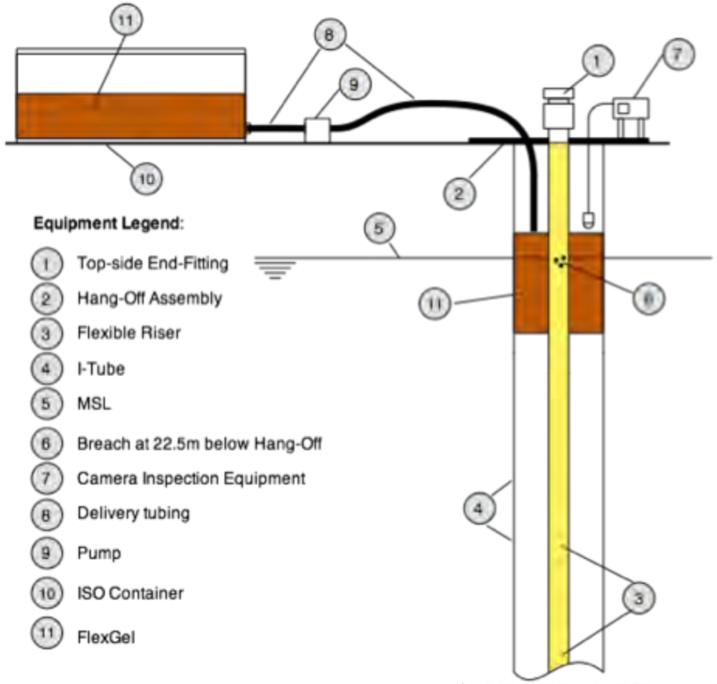
- Lessons learned
- Tolerance fit is essential to repair a deformed outer sheath
    - Ovality was in excess of 20%
- Metrology is especially complex where a riser has been subject to overpressurisation
    - Once damaged sheath had been stripped back, damage length was 50% greater than anticipated
- The build up of marine growth requires careful maintenance, particularly on risers with subsea end-fittings.
- Routine removal of marine growth, particularly around Pressure Relief Valves (PRV) is essential.

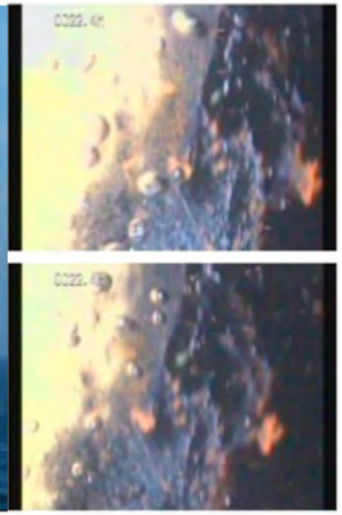




Case Study 3: Flexible Riser Repair in I-Tube

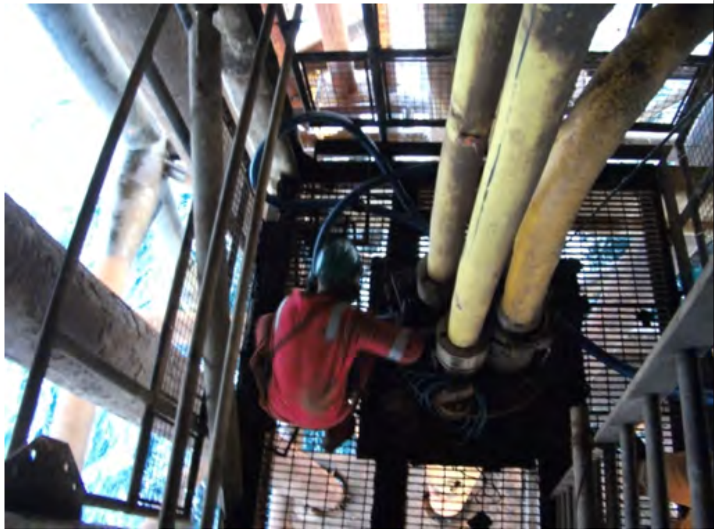
- Riser positive pressure annulus testing indicates a loss of outer sheath integrity at 13m below MSL
- Confirmed by CVI
- Inaccessible location
- No apparent marketplace solution
- FlexGel® developed to address corrosion concerns
  - Tuned SG
  - Tuned viscosity
  - Immiscible
  - Thixotropic
  - Non flammable
  - Replaces seawater with benign gel
  - Environmentally approved by CEFAS, OCNS
  - Mitigates splash zone corrosion

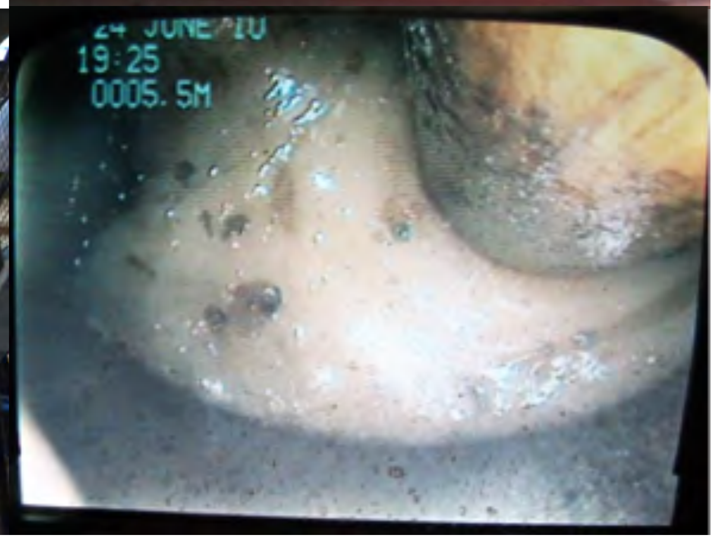




Case Study 3: Flexible Riser Repair in I-Tube

- Lessons Learned
- Coupon samples should be collected at install to allow ongoing chemical monitoring of gel
- Inspection of gel level within I-tube should be regularly monitored and referenced with tidal state
- Compatibility testing may be required pre-install, e.g. neoprene coatings, high temperatures, etc.





Case Study 4: J-Tube Polymer Leak Prevention

- UIC occurs in stuffing gland between in gas tight floor of CONDEEP platform leg
- Leads to leak in rundownline
- Inaccessible location
- Production shut-in from platform and linked fields
- No apparent marketplace solution
- FlexGel-PS™ developed to seal leak
  - Tuned SG
  - Injected as liquid
  - Tuned cure time
  - Replaces bore fluid becoming an elastic solid
  - Seals leak location internally
  - Enabling permanent external repair to be facilitated
  - Can be chemically ‘broken’ into component liquids

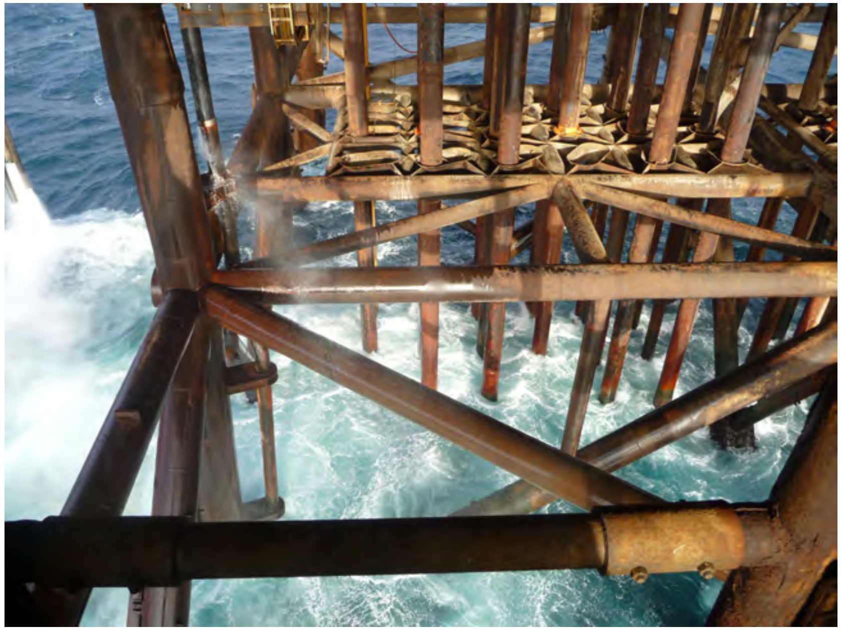
Case Study 4: J-Tube Polymer Leak Prevention

- Lessons Learned
- Coupon samples should be collected at install to allow chemical monitoring of polymer plug
- Chemical breaking of FlexGel-PS™ requires an oxidising agent
- Volume injected should be engineered to the minimum required to achieve objective in order to simplify the, post repair, removal process

Current Developments

- During operational life, leaking J-tube seals can lead to issues with corrosion within caissons, I-tubes, J-tubes
- Dosing regime compromised by seawater leaching/dilution
- If unchecked can, and has, resulted in riser failures

- Current developments
- Adapt FlexGel-PS™ by tuning SG heavier than seawater
    - Inject through J-tube to form a heavier than seawater elastic plug
    - Reinstate J-tube seal
    - Reinstate design dosing regime
    - Adapt inspection frequency and continue to operate



Q&A

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