Framing the Issue – Connector Reliability

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“To promote safety, protect the environment and conserve resources offshore through vigorous regulatory oversight and enforcement.”
Framing the Issue – Connector Reliability

Today’s Discussion

- Systems Reliability Section (SRS)
- Quality Control Failure Incident Team (QC-FIT)
- QC-FIT connector evaluations
- Bolt studies
- QC-FIT findings
- Areas of concern
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Systems Reliability Section: QC-FIT

- The Systems Reliability Section (SRS) conducts quality control failure incident team (QC-FIT) evaluations
  - Failure of a piece of equipment or system – fitness for purpose
  - Collaboration with industry
  - Distinct from 2010 Incident Investigations or Regional panel investigations
    - District/Regional investigations can result in enforcement actions (INC’s, Civil penalties)
    - QC-FIT are fact finding evaluations
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Systems Reliability Section: QC-FIT Goals

- Evaluate equipment's “life cycle” and if it is “fit for service”
- Provide an independent validation of manufacturer recommendations/specifications that impact QA/QC, performance, and reliability
- Provide recommendations
  - Changes to BSEE policies, procedures, Notice to Lessees (NTLs), regulations
  - Current/new industry standards
  - Issuance of Safety Alerts
  - Initiation of technical research studies
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QC-FIT Connector Evaluations

- H4 Connector bolt failures
  - Discovered following a release of synthetic-based drilling fluids into the Gulf of Mexico during drilling operations (December 2012)

- HC Connector bolt failures
  - Discovered during between-well maintenance (July 2014)

- Blind Shear Ram (BSR) actuator bolt failures - ongoing
  - Discovered during BOP high pressure stack testing (October 2015)
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Published QC-FIT Connector Evaluations

- H4 Connector Bolt Failures

- HC Connector Bolt Failures (addendum)
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BSEE Funded Bolt Studies

- Lawrence Berkeley National Laboratory (LBNL)
  - Global standards evaluation/gap analysis
  - Mechanical testing
  - Coating/corrosion analysis

- National Aeronautics and Space Administration (NASA)
  - Quantitative Risk Assessments
  - Best Available Safest Technology
  - Failure analysis and testing services

- Industry Bolt JIP (Spring 2015)
  - Six industry participants and BSEE
  - Industry withdrew
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BSEE Funded Proposed Bolt Study

- National Academy of Science (NAS) Bolts Root Cause Analysis (RCA) Workshop and Study (Fall 2016??)
  - Evaluate connectors currently in use for offshore oil and natural gas operations
  - Draw on bolt usage across other industries
    - Onshore oil and gas
    - Refineries
    - Pipelines
    - Civil aviation
    - Nuclear
    - Military
    - Automotive
  - Focus on industry wide and global impacts
  - Identify gaps in industry requirements, best practices, standards, and regulations
  - Suggest alternatives to BSEE and the industry
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Areas of Concern

Design Standards
- Significant Gaps
- Inconsistencies
- Harmonization

Manufacturing Processes/Procedures
- Raw Material Processing
- Machining
- Heat Treatment
- Coating

Quality Control/Auditing
- Second/Third tier subcontracted vendor oversight
- Specification Compliance
- MOC

Operational Procedures
- Assembly
- Installation
- Torque
- Cathodic Protection
- In-service Inspection
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QC-FIT H4 Connector Evaluation – Bolt Failures

- December 18, 2012, a lower marine riser package (LMRP) separated from the blowout preventer (BOP)
- Release of approximately 432 barrels of synthetic drilling fluids
- Approximately 11,000 connectors affected globally
- Thirty-six connector bolt failures were discovered on the H4 connector
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QC-FIT H4 Connector Evaluation – Key Findings

- Environmentally-assisted cracking identified as failure mode
  - Hydrogen embrittlement, hydrogen induced stress cracking
  - Cathodic protection, coating concerns

- Material properties
  - High Material Hardness (>34 HRC), Yield Strength, Ultimate Tensile Strength

- OEM Quality Control manufacturing process concerns
  - Non-compliance to OEM manufacturing specifications
  - Quality control oversight of second and third-tier subcontracted vendors
  - No post-bake after coating
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QC-FIT HC Connector Evaluation – Bolt failures

- June 30, 2014 a subsea engineer discovered a loose bolt while conducting scheduled between-well BOP maintenance

- Connectors were in service for four months

- Nine of twenty connectors failed on a LMRP hydraulic connector flange

- Considered a near miss event
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QC-FIT HC Connector Evaluation – Key Findings

- Environmentally-assisted cracking identified as failure mode
  - Failure mechanism was not fully understood

- Material properties
  - High Material Hardness (>34 HRC), Yield Strength, Ultimate Tensile Strength

- OEM Quality Control manufacturing process concerns
  - Non-compliance to OEM manufacturing specifications
  - Quality control concerns of second/third-tier subcontracted vendors
  - Improper raw material casting
  - Inadequate heat treatment
  - Latest edition of ASTM B633 (2007) post bake requirements were not followed
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QC-FIT Ongoing Evaluation – BSR bolt failures

- In-service connectors with high material hardness were identified

- Material property concerns

- Hydrogen embrittlement identified as possible failure mode

- OEM Quality Control manufacturing process concerns
  - Latest edition of ASTM B633 (2007) post bake requirements were not followed
Inconsistent material property requirements in industry standards
- API 6A, API 16A, API 16F, API 17A

Need harmonized requirements across industry standards for bolts used for subsea service
- Hardness, yield/tensile strength
- Coating
- Cathodic protection
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Connector Manufacturing

Need for improved control of connector manufacturing and material properties for critical subsea applications
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Connector Manufacturing – Reliability Impacts

- Design factors
  - Environment
  - Fatigue loading
  - Raw material selection

- Manufacture processes/procedures
  - Casting
  - Machining
  - Heat treatment
  - Coatings

- Material properties
  - Mechanical properties (Material Hardness, Yield Strength, Ultimate Tensile Strength)
  - Corrosion performance, cathodic protection
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Connector Quality Control/Auditing

Quality Control
- Non-compliance with OEM manufacturing specifications
- Use of older revisions of standards containing different requirements
- Subcontracted vendor manufacturing processes
  - Heat treat
  - Coating

Quality Auditing
- Currently auditing only first-tier subcontracted vendors
- Need for improved auditing of second/third-tier subcontracted vendors
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Operational Procedures

- Connector installation
  - Equipment assembly
  - Required torque
  - Torque procedure (pattern)
  - Lubricant
  - Torque gun calibration

- Connector inspection
  - Are BOP connector inspections periodic?
  - Are bolts examined and/or replaced when stack is brought to surface?

- Cathodic protection
  - Can possibly contribute to connector corrosion and degradation
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Closing

Questions ???

Comments

Discussion
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Contacts

◉ BSEE website
  ◆ https://www.bsee.gov/

◉ SRS page
  ◆ https://www.bsee.gov/whatwedo/regulatory-safety-programs/systems-reliability-section/goals-process

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