



Framing the Issue – Connector Reliability

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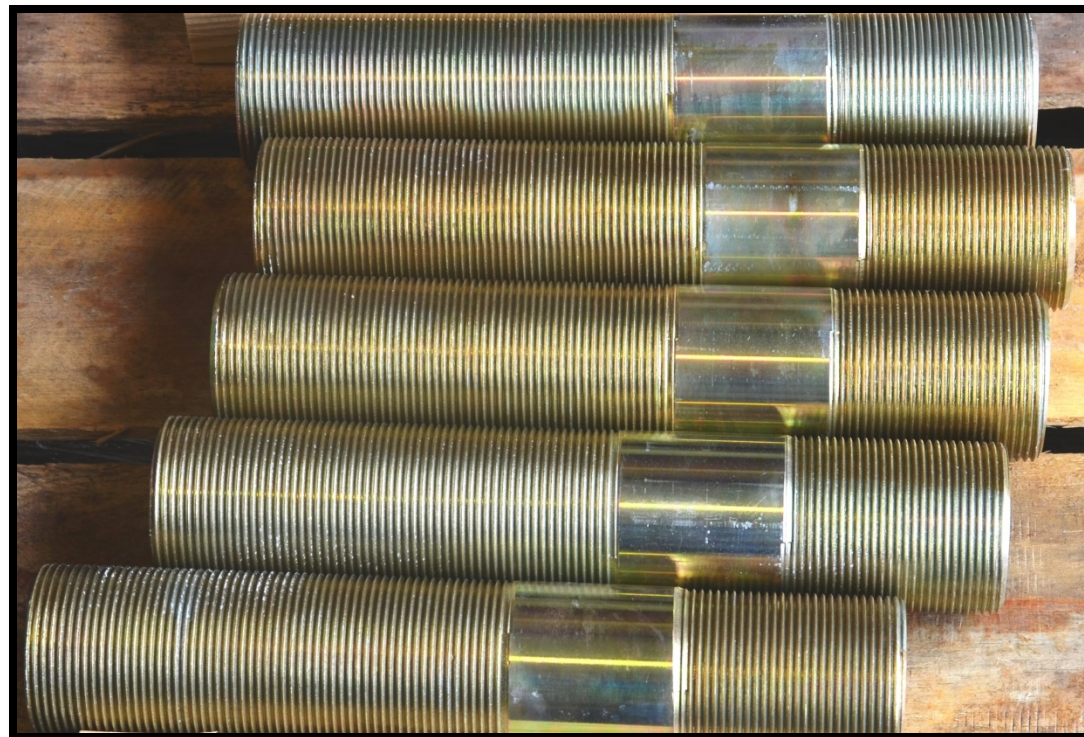
Washington DC

“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

- <https://www.bsee.gov/sites/bsee.gov/files/reports/drilling/bolt-report-final-8-4-14.pdf>

- HC Connector Bolt Failures (addendum)

- <https://www.bsee.gov/sites/bsee.gov/files/memos/public-engagement/qc-fit-bp-bolts-report-final.pdf>



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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
 - Nuclear
 - Refineries
 - Military
 - Pipelines
 - Automotive
 - Civil aviation
 - 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

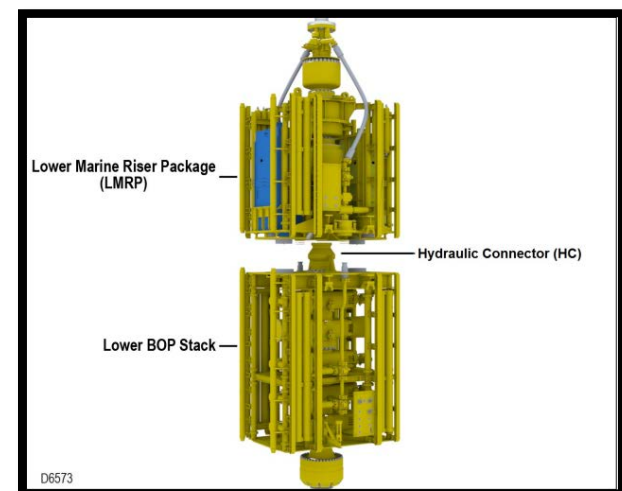
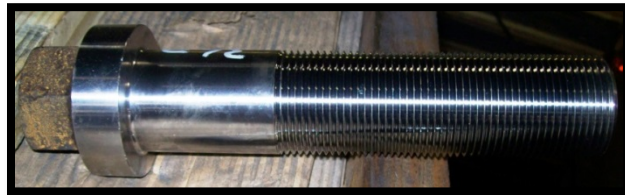
Operational Procedures

- 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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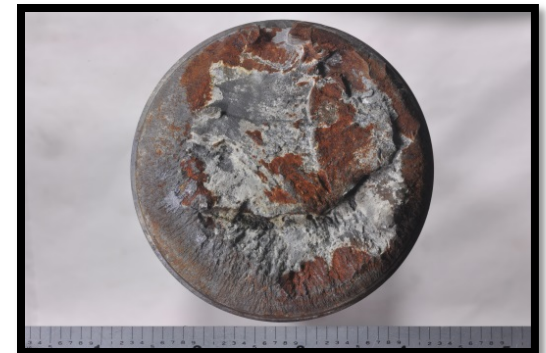
QC-FIT H4 Connector Evaluation – Key Findings

- 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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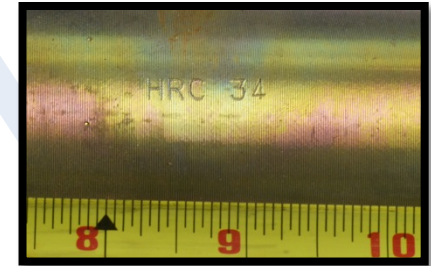
QC-FIT HC Connector Evaluation – Key Findings

- 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



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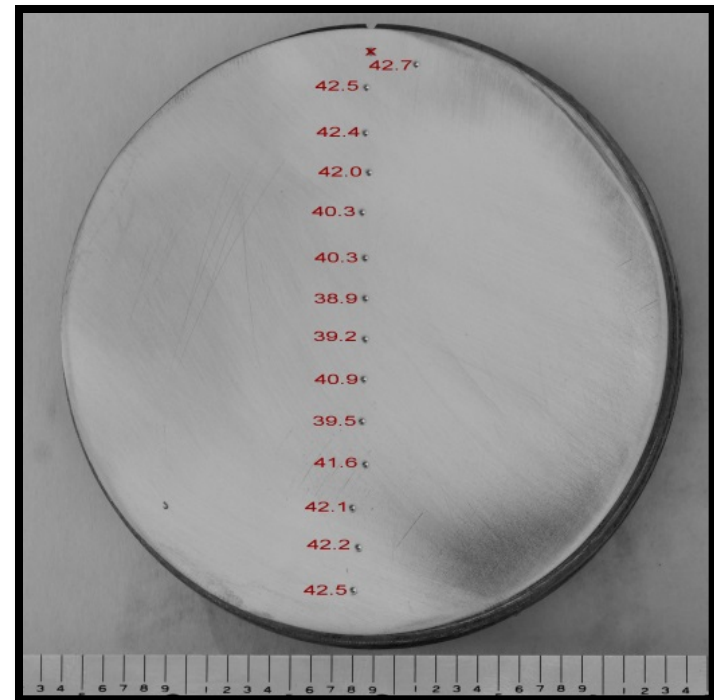
Connector Design Standards

- Inconsistent material property requirements in industry standards
 - API 6A, API 16A, API 16F, API 17A
 - NACE MR0175, Norsok M-001, ASTM B633, ASTM B849, ASTM B850, ASTM 1137, ASTM F1941
- 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

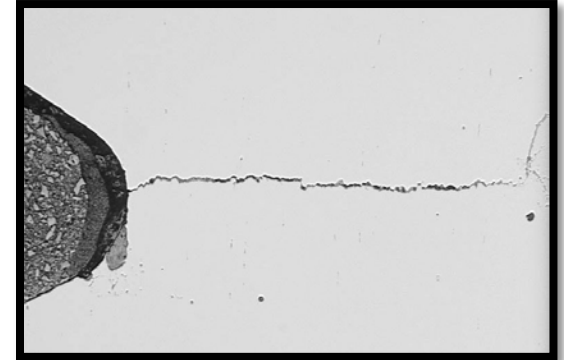
Need for improved control of connector manufacturing and material properties for critical subsea applications



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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



(Thread root crack)

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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



(Common lubricant)

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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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