SAND2010-7310P

Assessment of BP Response to RFI 3.2 Item 5 - Flange Connector Spool Assembly Design Review Follow Up

July 09, 2010

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Overview

- This report documents the assessment of information provided to the National Laboratories Team by BP in response to RFI 7.2 Item 5 – Flange Connector Spool Assembly Design Review Follow-up.
- Majority of information provided was documented in BP Doc. No. 2200-T2-DO-RP-4134 “Technical Assurance Report Well Cap with Triple-Ram Stack”
- Information on the utilization of buoyancy mechanisms was documented in BP Macondo Technical Note titled “Use of Buoyancy to Counter Capping Stack Design Stresses”

Summary Results

- Four of the five findings identified during the design review have been adequately addressed. The fifth will be addressed once shut-in or closed-well procedures are developed.
- It has been determined that the Single Valve Manifold will be a contingency to the 3-ram stack. Therefore, further analysis and procedure development would occur prior to any decision for installation and usage.
- It is the Government's position that the critical concerns regarding the design and functionality of the Flange Connector Spool Assembly have been adequately addressed and therefore support installation and usage.

Results of Request #1

- Provide responses to the 5 findings and 14 recommendations generated by the DOE review team. DOE concurrence is required on the responses for the findings.

Finding	Result
BP must monitor the tilt of the combined stack to ensure that the induced load limit is never exceeded.	Partially Addressed
Since overpressure can lead to catastrophic failure, the selection of the burst disk must be approved by the DOE team.	Not Addressed
Detailed bolt analysis (material property, preload and torque information, etc.) was not presented - only individual bolt load capability was available. This information must be provided and inserted into the record.	Addressed – See Section 5.3.2 in 2200-T2-DO-RP-4134

Results of Request #1 - cont

Finding	Result
Since the Transition Spool is expected to be stressed near yield, BP must either present relevant quality data (material certification / inspection records and manufacturing) for the as-built component, or perform proof testing to demonstrate margin.	Addressed – See Section 5.3 in 2200-T2-DO-RP-4134
Details on glycol injection during installation were not provided during the review. These must be provided to the DOE team.	Addressed – See Section 4.2 in 2200-T2-DO-RP-4134

Results of Request #1 - cont

Recommendation	Result
Ensure that an analysis of the allowable worst case combination of loads (eg. largest tilt, highest temperature, highest pressure) is included in the record.	Incorporated - See Section 3.2 in 2200-T2-DO-RP-4134
Measures should be taken to limit maximum pressure during well integrity testing and well shut-in operations.	Planned Incorporation thru Procedures
Given the many possible loading conditions, supporting analysis capability should remain engaged to quickly evaluate actual operational conditions as events unfold.	Planned Incorporation thru Procedures
Although not presented during the design review, BP's evaluation of the ability of all added components to withstand the maximum expected internal pressure, should be included for the record (include as-built documentation to ensure proper bolt pre-load).	Incorporated – See 2200-T2-DO-RP-4134

Results of Request #1 - cont

Recommendation	Result
An elastic/plastic finite element model should be run to predict ultimate failure mode and pressure of the stack system (eg Flex Joint, G Flange and Transition Spool).	Incorporated - See Section 5.4 in 2200-T2-DO-RP-4134
A calculation should be performed prior to installation in order to determine the effect of having five or fewer bolts restraining the G-flange and/or increased differential pressure.	Incorporated - See Section 5.4 in 2200-T2-DO-RP-4134
Connection between the combined BOP stack to collection operations vessels on the surface should recognize new limitations in the shimmed Flex Joint.	Not-Incorporated – Out of scope
Use of shims to limit rotation of the flex joint will alter the load path and requires further analysis (including installation loads on the bolts) prior to installation.	Incorporated - See Section 3.2.2.2 and 3.2.2.3 in 2200-T2-DO-RP-4134

Results of Request #1 - cont

Recommendation	Result
Installed bolt torque on Mud Boost valve flange should be confirmed, if possible via documentation of the as-built configuration.	Not-Incorporated
BP should monitor for leaks around the Mud Boost valve flange during any high pressure operation.	Planned Incorporation thru Procedures
BP should consider injecting a pressure sensitive sealant into the Mud Boost valve flange in order to reduce the possibility of leakage at the flange.	Not-Incorporated
Generate a complete system level analysis of the estimated accuracy of pressure measurement	Not-Incorporated
Once a correlation between the three pressure measurements is made, transmit only one of the three pressure measurements so that higher frequency sampling rate can be obtained.	Not-Incorporated

Results of Request #1 - cont

Recommendation	Result
Attention should be given to potential bolt issues during riser flange removal and FCS installation such as tool access/engagement, possible need for captive nut replacement, and alternate means of providing flange clamping force.	Partially Incorporated

Results of Request #2

- Provide the analyses on system function and integrity (under loading) of the assembly using the single valve manifold (in its various potential configurations) instead of the 3 ram BOP (i.e. stress analysis, instrumentation, etc. – equivalent to the analysis performed on the assembly with the 3 ram BOP).
  - Information has not been provided on the system function and integrity of the single valve manifold. This capping option has been identified as a contingency to the 3-Ram Stack. Procedures for use and supporting analyses are still being developed. Information will be provided to the National Laboratories Team prior to installation and usage.
  - A HAZOP on Integrated Closed System review will be held on July 15th where configuration and sizing of pressure protection systems will be discussed.

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Results of Request #3

- Have buoyancy mechanisms to counter the stresses created by the mass of the flange spool connector assembly been considered and can such mechanisms be used to minimize stresses in the system?
  - The use of buoyancy mechanisms has been considered and is documented in BP Macondo Technical Note "Use of Buoyancy to Counter Capping Stack Design Stresses"
  - Ability to reduce vertical compression loads was considered against operational concerns introduced by the complexity of buoyancy systems
  - It has been concluded that buoyancy will not be used to reduce the vertical compression loads introduced from the 3-ram stack as the supporting analyses indicate that the existing structure will adequately handle the loads

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Supporting Information Slides

RFI Request #1

- **Finding #1:** BP must monitor the tilt of the combined stack to ensure that the induced load limit is never exceeded.
  - BP has indicated that this issue will be covered by procedures (installation and operation).
  - In addition to planned monitoring, steps have been taken to decrease the inclination of the flexjoint thereby increasing their margin to allowable limits. The overall flexjoint flange inclination has been decreased to 2.4 deg total, bringing it within 0.4 deg of the BOP. Fourteen restraint blocks have been placed into the flexjoint which will prevent the flexjoint from moving further off-center due to the attachment of the capping stack and other components. Furthermore, a detailed structural analysis has been performed considering the loading due to the capping stack at larger flangejoint angles. The calculated stresses in casing sections and bending moments of connectors were shown to be within allowable limits for nominal cases.

RFI Request #1 - cont

- **Finding #2:** Since overpressure can lead to catastrophic failure, the selection of the burst disk must be approved by the DOE team.
  - Sizing or the incorporation of a burst disk over pressurization system into the current Flange Connection Spool Assembly has not occurred. Current thinking is to land the flange spool and 3 ram stack in the open condition and land TH#7 to begin collecting hydrocarbon. Prior to well shut-in or other backpressure operations, an appropriate pressure protection system will be designed and installed, with sizing concurrence from the DOE team.

RFI Request #1 - cont

- **Finding #3:** Detailed bolt analysis (material property, preload and torque information, etc.) was not presented - only individual bolt load capability was available. This information must be provided and inserted into the record.
  - Additional details have been provided on the flange bolts.
  - Bolts are ASTM A193 Grade B7 - 95 ksi yield
  - Preload (625 ksi) and torque (17,000 ft-lbs) information is provided including a recommendation to increase the torque by 5-10% to ensure that at least 75% of design bolt preload is achieved. This accounts for the uncertainty in lubrication performance and variability of coefficients of friction due to subsea prep and mating of bolts.

RFI Request #1 - cont

- **Finding #4:** Since the Transition Spool is expected to be stressed near yield, BP must either present relevant quality data (material certification / inspection records and manufacturing) for the as-built component, or perform proof testing to demonstrate margin.
  - Original material certifications and full history of the current X80 spool pipe are not available
  - Samples have been tensile tested and have properties typical of X80 pipe
  - Representative section of X80 pipe was burst tested, failing at 10,546 psi, which is further representative of typical properties and establishes an upper limit
  - Transition spool was hydrotested to 7,500 psi

RFI Request #1 - cont

- **Finding #5:** Details on glycol injection during installation were not provided during the review. These must be provided to the DOE team.
  - Focused on preventing hydrate formation on flange and seal surfaces
  - Grease, effective in hydrate disassociation, will be applied to these surfaces
  - An ROV mounted injection system will provide hydrate inhibitor locally to support installation processes
  - Rapid installation will reduce exposure to hydrate formation and deposition
  - Active hydrate inhibitor injection into the 3 ram stack bore and HC connector will suppress formation during installation

RFI Request #1 - cont

- **Recommendation #7:** Connection between the combined BOP stack to collection operations vessels on the surface should recognize new limitations in the shimmed Flex Joint.
  - Not in scope for current capping stack installation. No specific configuration has been detailed allowing production other than the landing of TH#7 on the H4 connection stub protruding from the 3-ram stack.
- **Recommendation #9:** Installed bolt torque on Mud Boost valve flange should be confirmed, if possible via documentation of the as-built configuration.
  - No documentation available showing the as-built configuration. Not able to establish preloading in-situ.

RFI Request #1 - cont

- **Recommendation #11:** In addition, BP should consider injecting a pressure sensitive sealant into the Mud Boost valve flange in order to reduce the possibility of leakage at the flange.
  - No information provided on planned use of injected sealant. Potential leak paths are judged to be small paths between shafts and metallic housings.
- **Recommendation #12:** Generate a complete system level analysis of the estimated accuracy of pressure measurement.
  - No information provided.

RFI Request #1 - cont

- **Recommendation #13:** Once a correlation between the three pressure measurements is made, transmit only one of the three pressure measurements so that higher frequency sampling rate can be obtained.
  - No information provided.

RFI Request #1 - cont

- **Recommendation #14:** Attention should be given to potential bolt issues during riser flange removal and FCS installation such as tool access/engagement, possible need for captive nut replacement, and alternate means of providing flange clamping force.
  - Elements of the recommendation have been incorporated.
  - A magnet system will be used to ensure the captive nuts remain in place during landing and re-insertion of flange bolts.
  - Two different tools have been developed to split the flange connection apart.
  - Spare bolts are available in the ROV baskets.