DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

October 6, 2022

The Honorable Jennifer M. Granholm
Secretary of Energy
US Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Granholm:

In October 2021, the Department of Energy (DOE) conducted a contractor readiness assessment to determine if Washington River Protection Solutions (WRPS) was ready to start up the Tank Side Cesium Removal (TSCR) system at the Hanford site. The scope of the readiness assessment included a demonstration of an ion-exchange column (IXC) removal from the TSCR process enclosure followed by installation of a replacement IXC. While performing the IXC removal, operations and maintenance personnel noted damage on a TSCR IXC threaded connection. The IXC, which is a safety-significant component, was determined to be inoperable.

A Defense Nuclear Facilities Safety Board (Board) staff team subsequently evaluated work performed by WRPS to restore operability of the IXC. The Board's staff identified safety deficiencies in WRPS actions to evaluate and repair the damaged components. Additionally, the team identified a safety weakness in a technical safety requirement (TSR) specific administrative control associated with the IXC.

Based on the staff review, the Board determined:

- Contrary to DOE and WRPS procedures and expectations, the WRPS evaluation and repairs were not performed consistent with safety requirements of the American Society of Mechanical Engineers' nuclear quality assurance (NQA)-1 standard, *Quality Assurance Requirements for Nuclear Facility Applications*. This less rigorous approach resulted in information gaps related to the condition of the threaded connections that introduced uncertainty into the adequacy of the repairs and the capability of the connections to perform their safety function.
    - WRPS did not perform a rigorous cause analysis to determine the cause of the damage discovered on multiple threaded connections. Consequently, WRPS's corrective actions may not be sufficient to prevent reoccurrence of the condition.

  - o Because the WRPS condition evaluation was limited to a visual examination, the disposition may not consider damage that can affect the strength or durability of the connection. Consequently, the repairs may not be sufficient to ensure that the repaired connections will satisfactorily perform their structural integrity safety function throughout their 50-year design life. WRPS did not implement any compensatory measures to address the potential for unknown conditions.

- The TSR safety control that is credited for ensuring workers are not injured by dislodged IXC components during or after a postulated flammable gas explosion event does not require a quantitative verification that would ensure that a connection is fully engaged to support compliance with the TSR. Instead, it relies solely on "skill of the craft" to ensure connections have adequate thread engagement to prevent separation caused by the explosion.

Pursuant to 42 United States Code §2286b(d), the Board requests a briefing within 90 days of receipt of this letter that identifies actions DOE will take to ensure that the repaired connections will satisfactorily perform their safety function over their 50-year design life and shows that corrective actions implemented by WRPS are sufficient to address the potential causes of the damage so that similar conditions will not occur in the future. Additionally, the briefing should discuss any actions DOE intends to take to ensure that WRPS appropriately applies NQA-1 for evaluation, disposition, and repair of damaged safety-significant components, and address the Board's concerns regarding reliance on "skill of the craft" as the sole measure for implementation of a TSR control designed to ensure worker safety.

Sincerely,

Joyce L. Connery
Chair

Enclosure

c: Mr. Joe Olencz

Enclosure
Hanford TSCR Ion-Exchange Column Connection Issues

Summary. In October 2021, a Department of Energy (DOE) team conducted a contractor readiness assessment to determine if Washington River Protection Solutions (WRPS) was ready to start up the Tank Side Cesium Removal (TSCR) system. The scope of the readiness assessment included a demonstration of an ion-exchange column (IXC) removal from the TSCR process enclosure followed by installation of a replacement IXC. While performing the IXC removal, operations and maintenance personnel noted damage on a male TSCR IXC ChemJoint™ connection. Operators halted the IXC changeout demonstration and declared the IXC, which is a safety-significant component, inoperable. WRPS performed an extent of condition (EOC) review for all the TSCR IXC process piping and hose connections.

WRPS engineers documented the result of the of the EOC, as well as the evaluation and disposition of the damaged threaded connections, in technical report RPP-RPT-63511, *TSCR IXC A/B/C and Process Hose Connection Thread Evaluation and Resolution* (Report 63511). The report indicates that operators visually inspected each threaded connection and graded the associated thread condition as "Good" (no wear), "Minimal Roughness" (normal wear), or "Notable Roughness" (significant wear). Of the 71 connections inspected, WRPS classified 13 as having "Notable Roughness" (significant wear).[1] Two of the connections with significant wear were HART type connections. The remaining 11 connections were ChemJoint™ type connections. In every case, it was the male half of the connection that sustained the thread damage. The report concluded that "The cause for the thread wear is unknown."[2]

WRPS engineers dispositioned the two HART connections "use as-is."[3] However, they dispositioned the 11 ChemJoint™ connections for repair. Repair of the ChemJoint™ connections involved having "their threads restored to as new conditions following thread chasing and new lubrication application."[4,5] WRPS engineers determined that the evaluation and repair actions were sufficient to conclude that "all connections are deemed acceptable for use."[4] While the original report and all retest activities focused on leak tight performance of the connections WRPS engineers did not address the safety function related to structural integrity of the connections.

The Tank Farms documented safety analysis (DSA) states the ChemJoint™ connections and the piping between each ChemJoint™ connection and the pressure vessel support the TSCR IXC and TSCR IXC Vent Stack safety functions. Therefore, the safety analysis assigns a safety-

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[1] RPP-RPT-63511 Rev-1, *TSCR IXC A/B/C and Process Hose Connection Thread Evaluation and Resolution*, Section 3.0, page 3-2.
[2] Ibid., Section 6.1 and 6.2, page 6-1.
[3] Ibid.

[4] Ibid., Section 7.0, page 7-1.
[5] The process of "chasing threads removes some material. All threads were observed to be worn." Additionally, per NQA-1, a repair is "the process of restoring a nonconforming characteristic to a condition such that the capability of an item to function reliably and safely is unimpaired, even though that item still does not conform to the original requirement." Therefore, stating that the repair restored the threads to "as new condition" is incorrect.

significant classification to the ChemJoint™ connections.[6] Further, the Tank Farms technical safety requirements (TSR) note that the ChemJoint™ connections are design features that are credited to protect the facility worker from flammable gas deflagrations and detonations in a loaded or spent IXC by maintaining structural integrity and preventing the production of hazardous projectiles.[7] Consequently, while leak tightness is important for preventing spray leaks and spills in the TSCR process enclosure, structural integrity is the safety function that is the Board's staff team's (staff team) primary concern because of its importance for protecting facility workers from injury due to a flammable gas deflagration or detonation.[8]

Following discussions with the staff team during the review, WRPS issued a revised report that did address the structural integrity safety function of the ChemJoint™ connections. The revised report concluded that the restored ChemJoint™ connections can withstand the postulated design basis accident and will continue to perform their safety function.[9] However, the staff team determined that the conclusions in the report are still based on incomplete information regarding the post-repair thread condition. The lack of information precludes a sufficient understanding of how the repaired ChemJoint™ connections will perform under accident conditions.

The staff team held virtual meetings with WRPS and DOE on February 28, 2022, and March 31, 2022, to further understand the approach WRPS and DOE used to conclude that the restored ChemJoint™ connections can withstand the postulated design basis accident and will continue to perform their safety function. Additionally, the staff team has communicated its observations and concerns to both WRPS and DOE representatives in person and through unofficial correspondence on several occasions since it identified potential safety issues associated with the TSCR connection non-conformance disposition. Although those efforts did result in a clear understanding of the conditions, the actions taken to address them, and the reasoning behind the decisions made by WRPS and DOE, as well as some changes in approach and the final report, they did not result in a satisfactory resolution of the staff team's safety concerns, listed below.

- Contrary to DOE and WRPS procedures and expectations, WRPS did not perform the evaluation and repairs consistent with the requirements of the American Society of Mechanical Engineers' (ASME) nuclear quality assurance (NQA) standard NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications.* WRPS's less rigorous approach resulted in information gaps related to the structural condition of the threaded connections that introduced uncertainty into the adequacy of the repairs and the ability of the connections to perform their safety function.
    - WRPS did not perform a rigorous analysis to determine the cause of the damage discovered on multiple threaded connections. Consequently, WRPS's

[6] RPP-13033, Revision 08A, *Tank Farms Documented Safety Analysis,* Section A.4.4.1.2, page A.4.4.1-2.
[7] HNF-SD-WM-TSR-006, Revision 10, *Tank Farms Technical Safety Requirements,* Section 6.10, Design Features, Tank Side Cesium Removal Ion-Exchange Column, pages 6.10-1 and 6.10-2.
[8] Ibid.
[9] RPP-RPT-63511 Rev-1, *TSCR IXC A/B/C and Process Hose Connection Thread Evaluation and Resolution*, Section 7.0, page 7-1.

corrective actions may not be sufficient to prevent reoccurrence of the condition.

  - Because the condition evaluation performed by WRPS was limited to a visual examination, the disposition may not consider damage that can affect the strength, durability, and, therefore, the performance of the connection. Consequently, the repairs may not be sufficient to ensure that the repaired connections will satisfactorily perform their structural integrity safety function throughout their 50-year design life. WRPS did not implement any compensatory measures to address the potential for unknown conditions.

- The TSR control that is credited for ensuring workers are not injured by dislodged IXC components during or after a postulated flammable gas explosion event does not require a quantitative verification that would ensure a connection is fully engaged to support compliance with the TSR. Instead, it relies solely on "skill of the craft" to ensure connections have adequate thread engagement to prevent separation caused by the explosion.

The above potential safety issues do not introduce a new accident or increase the frequency or consequences of an existing unmitigated analysis. However, for the three IXCs that were damaged, the potential safety issues could reduce the effectiveness of a hazard control that DOE has determined is important to worker safety. Additionally, under different conditions, a similar lack of rigor in the evaluation and repair of other safety-significant components could have more significant consequences.

Background. The TSCR TSR includes the ChemJoint™ connections as one of the IXC passive safety-significant design features. One of the safety functions assigned to the design feature is to protect the facility worker from postulated flammable gas deflagrations and detonations by maintaining structural integrity during and after a deflagration or detonation in a loaded IXC or spent IXC. Maintaining the IXC structural integrity eliminates or prevents the production of hazardous projectiles and limits the amount of loaded crystalline silicotitanate media released during a deflagration or detonation. The TSR states, "This safety function is achieved by ensuring the IXCs are **designed, fabricated, and maintained** to ensure the IXCs will maintain their structural integrity within a flammable gas deflagration or detonation in the IXC without producing projectiles" (Emphasis added).[10]

The DSA supports assignment of the safety function identified in the TSR, by also stating "IXCs are required to be **designed, fabricated, and maintained** to ensure the IXCs will maintain their structural integrity in a flammable gas deflagration or detonation within an IXC without producing projectiles" (Emphasis added).[11] The DSA also states that the connections are within the TSCR IXC boundary and are classified as safety-significant.[12]

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[10] HNF-SD-WM-TSR-006, Revision 10, *Tank Farms Technical Safety Requirements*, Section 6.10, Design Features, Tank Side Cesium Removal Ion-Exchange Column, page 6.10-2.
[11] RPP-13033, *Tank Farms Documented Safety Analysis*, Revision 08A, Table A.4.4-1, page A.T4.4-2.
[12] Ibid, Section A.4.4.1.2, pages A.4.4.1-1 through A.4.4.1-3.

Discussion. The staff team review identified deficiencies in the approach that WRPS used to evaluate and disposition damage to the threaded connections. In this case, the deficient performance affects only three IXCs. However, consequences could be larger if WRPS continues to use a similar approach for resolving nonconforming conditions for other safety-significant systems.

ASME NQA-1 Requirements Were Not Correctly Applied for Evaluation, Disposition, and Repair of Nonconforming Items—NQA-1 requirements and other ASME codes are credited in RPP-RPT-61195, *Functions and Requirements Evaluation Document for the Tank Side Cesium Removal Ion Exchange Column and Ion Exchange Column Vent Stacks* (FRED), to provide assurance that the ChemJoint™ connections will perform as required in accordance with safety analyses. WRPS implements NQA-1 using TFC-PLN-02, *Quality Assurance Program Description*. The program description largely echoes the requirements contained in NQA-1. WRPS generally uses a graded approach for application of NQA-1 quality assurance requirements, with safety-significant components receiving a more rigorous application than general service components. However, WRPS did not initially recognize that these stringent NQA-1 requirements applied to TSCR IXC safety-significant components. Because of this, some of the applicable NQA-1 requirements were not met.

WRPS personnel initiated an action request using the process described in TFC-ESHQ-Q_C-C-01, *Problem Evaluation Request,* when the damaged threads were discovered, but did not document the non-conformance as required by NQA-1. Implementation of the NQA-1 requirements for nonconformance reporting are governed by the WRPS non-conforming report (NCR) procedure. Since they did not document the non-conformance under procedure TFC-ESHQ-Q_ADM-C-02, *Nonconforming Item Reporting and Control*, they did not perform a technical evaluation for use-as-is or repair disposition as required for safety-significant items when there is a physical deviation from the original design. In this case, since the threads were repaired rather than reworked, the physical configuration of the threads deviated from the original design; specifically, some metal was lost because of the damage and the thread repairs.

The directions for performing a technical evaluation are described in TFC-ENG-FACSUP-C-03, *Technical Evaluations*. The general approach requires identification of critical characteristics which define the required performance of the item under evaluation in terms of identifiable and measurable attributes or variables appropriate for the safety function. Once the attributes are defined, acceptance criteria and allowable tolerances are established, and an inspection plan is developed. In general, acceptance criteria and tolerances are measured against criteria established by the original design or an appropriate code or standard to show adequacy of the repaired component. Additionally, if necessary, test requirements are identified, and a test plan is developed. The inspection plan and test plan are used to support the evaluation. The described process appears to be compliant with NQA-1.

However, since an NCR was not initiated, evaluation and disposition were defined in a condition report and documented in a general report developed under TFC-ENG-DESIGN-C-52, *Technical Document Control.* This resulted in an approach without the rigor of establishing and evaluating attributes that are important to the safety function of the threaded connection. As a result, the disposition focused on the leak tightness of the components, which is not a safety function; it did not address structural integrity, which is a safety function. The conclusion contained in the "IXC Evaluation and Path Forward" attachment to Condition Report WRPS-CR-2022-0111 supports this evaluation. It states "Cleaning and restoring the threads on the male ChemJoint™ and HART Union connections will ensure the high integrity connections will remain leak free and allow maintenance personnel the ability to easily thread the connections together. Hydrostatic leak testing the vessels and connections will provide objective evidence the IXC ChemJoint™ connections remain a high integrity component that will remain leak tight for operational use."

During discussions with the staff team, WRPS acknowledged that an NCR should have been initiated. They stated that the error was caused by deficient procedures. To resolve this problem, WRPS revised its NCR and problem evaluation report procedures to change the guidance that led to their failure to identify the need for an NCR. However, the use of the revised procedure still might not have resulted in the initiation of an NCR for this situation since it excludes the use of an NCR under most operational circumstances, even when the equipment performs a defined safety function within the safety analysis. Such exclusions result in alternate disposition paths that may not provide adequate rigor for addressing non-conforming conditions in safety equipment, similar to this situation.

In this case, WRPS subsequently issued an NCR to mitigate their error. However, this action was ineffective since, it did not follow through with the required ASME NQA-1 non-conformance disposition process. Instead, the new NCR simply referenced RPP-RPT-63511 as its disposition.

Cause Analysis Not Performed—Both NQA-1 and WRPS' quality assurance program description state "In the case of a significant condition adverse to quality, the cause of the condition shall be determined and corrective action taken to preclude recurrence." The staff team considers the condition found to be a significant condition adverse to quality since the condition resulted in the declaration that a safety-significant component was inoperable. Consequently, the stated requirement would apply.

Failure to perform a proper cause analysis can be traced to the initial (mis)identification of the issue and, in particular, the failure to recognize that this was a significant condition adverse to quality. Errors in performing the problem evaluation request procedure reduced the likelihood of a satisfactory evaluation and disposition of the thread damage. The related action request was screened and became a condition report. The condition report was given a low-level ranking (Level-C). TFC-Charter-76, REV A-5, *Problem Evaluation Request Screening Meeting,* defines a Level-C issue as an "issue of minor risk where actions may be needed to correct the condition without the need to determine cause." This classification generally allows for an EOC review to be performed but can be closed with nothing more than an entry in the "actions taken" block – essentially, the deficiency is simply tracked until it is fixed, without a cause analysis or action plan. In this case, no formal cause analysis was performed. However, this condition represented a deficiency associated with a safety-significant component, which requires a cause analysis. Further, since the affected IXCs were declared inoperable, a condition adverse to quality existed that notably diminished the original operability of an installed item. Both circumstances are criteria for the assignment of a higher, Level-B ranking to the issue. Under

WRPS procedures, a Level-B issue warrants an apparent cause evaluation and might have resulted in a more robust evaluation of the condition and the extent of condition.

WRPS stated that the lower classification was appropriate based on its procedural requirements and what WRPS personnel knew at the time. However, the classification error was not corrected (i.e., by reclassifying to a higher level resulting in a cause analysis) as new information indicated that the problem had a broader scope and a potentially larger impact than WRPS had first realized. The initial misclassification of the issue may have resulted in a failure to explore other available options – such as control and segregation of these units and the use of other IXC's from stock while an effective cause analysis and repair resolution was performed on the damaged IXCs.

A similar issue was uncovered and reported as a finding by a DOE Enterprise Assessment Team in December 2021. In its report entitled, *Independent Assessment of the Washington River Protection Solutions, LLC Management of Safety Issues at the Hanford Site*, the DOE team noted that "WRPS inappropriately under-categorized a few of the issues reviewed. For example, the most significant nuclear safety issues identified by WRPS since January 1, 2019, were not categorized as required to ensure the adequate management (resolution)."

During final factual accuracy discussions, WRPS notified the Resident Inspector that they had issued a new (Level-B) problem evaluation request related to the threaded connections. This action will result in the completion of an apparent cause evaluation. The apparent cause analysis has value since it will help ensure similar issues do not occur in the future. However, it is unlikely that resolution of the new problem evaluation request will influence the evaluation of the existing condition of the IXCs that have been placed on the storage pad or alter the associated disposition. The following discrepancies, with respect to performance to the IXCs placed on the pad, were observed by the board's staff, and will most likely not be addressed in a follow up apparent cause analysis.

- Report 63511, the report that provides the final disposition for the damaged connections, states for all the damaged connections that "The cause for the thread wear is unknown."

- WRPS did not perform any cause analysis to determine the causes of the damage found on all 13 damaged components. WRPS representatives stated that, based on visual inspection, they determined that the "most likely" cause was impact damage. However, that determination was not fully justified in their report. Additionally, based on a review of the photographic evidence provided, there are substantial differences in conditions found on different connections. An appropriate justification would identify the differences and provide a clear case for their evaluation that the cause was impact damage despite the varying appearances presented in the photographs.

- Inspection of the connections was limited to a simple visual inspection. A visual inspection would neither detect, nor rule out, certain damage initiators.

- WRPS's corrective actions do not address potential initiators of the damage other than damage caused by impact. Other potential initiators could include corrosion, lack of cleanliness, friction resulting from damage to the dry film lubricant, galling, etc. WRPS did not provide technical justification for its decision to rule out the other potential initiators.

Instead of performing the required cause analysis, WRPS based its cause evaluation on engineering judgment. The evaluation is documented in the "IXC Evaluation and Path Forward" attachment to Condition Report WRPS-CR-2022-0118. It states, "The majority of the roughness/damage noted in the thread inspection is due to unprotected thread connections and mishandling." Based on that observation, WRPS established procedural direction that requires protecting all threaded connections with caps and plugs during handling and transport. Additionally, WRPS evaluated training and procedures to see if additional work step modifications are necessary to reduce the risk of future damage.

WRPS' actions are credible however, without firmly establishing the cause of all thread damage, these actions may not be sufficient to preclude reoccurrence of similar damage. Such damage could jeopardize the safety function of the affected connections by reducing component strength, preventing adequate thread engagement, or creating cracks, pits, or localized high stress regions that can serve as initiation points for corrosion, and reduce component strength and integrity over the long term.

As noted previously, after discussions with the staff team, WRPS issued a new (Level-B) problem evaluation request related to the threaded connections. This action will result in the completion of an apparent cause evaluation. Although not a root cause analysis, which would be preferred, a rigorously performed apparent cause analysis could identify a more robust set of corrective actions compared to those that were developed based on an ad hoc review of limited information. A more robust set of corrective actions would provide greater assurance that similar events do not occur in the future.

Inadequate Evaluation and Potentially Inadequate Repair—WRPS dispositioned the ChemJoint™ connections for "repair." Per NQA-1, "Repaired items shall be reexamined in accordance with applicable procedures and with the original acceptance criteria unless the disposition has established alternate acceptance criteria," and "Technical justification for the acceptability of a nonconforming item dispositioned repair or use-as-is shall be documented."

WRPS's nonconforming item reporting and control procedure states the same requirements, indicating that the original acceptance criteria are the preferred standard for acceptance of a repair.[13] If it is not feasible to use the original acceptance criteria, alternate acceptance criteria may be defined. For a safety-significant component, the alternate acceptance criteria would be based on attributes, criteria, and tolerances defined by the required technical evaluation, as discussed earlier in this report. However:

- Per NQA-1, a repair is the process of restoring a nonconforming characteristic to a condition such that the capability of the item to function reliably and safely is

[13] TFC-ESHQ-Q_ADM-C-02, *Nonconforming Item Reporting and Control*, page 9.

unimpaired even though that item still does not conform to the original requirements. Therefore, it is acceptable that the repairs, as performed by WRPS, left the threads in a different condition than the original acceptance criteria if they can still perform their safety function. However, WRPS engineers did not make the necessary comparison between the original design requirements and repaired thread condition to quantify any differences in performance, as required by NQA-1.[14] Alternatively, as allowed by NQA-1, they could have defined alternate acceptance criteria as part of their disposition, but they did not, nor did they provide technical justification that shows that their accepted conditions for the repaired connections will still result in adequate strength to reliably and safely perform their safety function.

- WRPS repaired the threads by "chasing" them, performing a passivation process, and then reapplying a required dry film lubricant but use of that process means that some material is still missing from the ChemJoint™ connection threads. The process WRPS used to quantify the missing material was relatively crude and lacked precision. Standard thread gauge measurements (e.g., thread pitch diameter and major diameter measurements) were not taken. Consequently, WRPS has not adequately defined the actual amount of missing material resulting in a situation where it cannot make an adequate comparison to the applicable thread standard with the existing information.

- WRPS did not perform non-destructive examination (such as liquid penetrant testing) to determine whether there were any cracks/surface defects adjacent to the damage area. Small cracks or other defects can propagate, weakening the thread, and can provide an initiation site for crevice corrosion by nullifying protection provided by passivation and the dry film lubricant. These connections are designed with straight threads. The sealing function of the connection is not provided by the threads, but by the internal design. Straight threads are not leak tight and, in an external environment, are susceptible to moisture, water, and contaminant intrusion, increasing the potential for corrosion within the connector. Further, there are no coatings or coverings that would preclude intrusion of water or contaminants into the connection, nor is there any requirement to ensure that the components are free of chloride contamination prior to assembly.[15] Although there is a TSR surveillance[16] that requires an inspection of the IXC's external surface every 730 days to identify any visible corrosion or damage to the vent stacks other than surface scratches, the inspection is only applicable to the external surfaces of the vent stacks and is unlikely to identify corrosion damage within the connector. This combination of factors,

[14] NQA-1 requires "technical disposition of the non-conformance" with repairs "reexamined in accordance with applicable procedures and with the original acceptance criteria unless the disposition has established alternate acceptance criteria." Report 63511 did not provide a technical disposition for the structural integrity adequacy of the repaired connections and no comparison of the threads to the original thread manufacturing standard was performed.

[15] NQA-1 Subpart 2.1 provides for maintenance of installation cleanliness and states "Where environmental contamination could cause degradation of quality; seals shall be installed to prevent contamination of interior surfaces."

[16] HNF-SD-WM-TSR-006, Revision 10, *Tank Farms Technical Safety Requirements*, Surveillance Requirement 3.17.2.

along with the 50-year design life, gives rise to a concern that, due to corrosion, the components may lose the ability to perform their safety design function over time.

WRPS contends that the type of material used for the components, the low service temperatures, and the lack of chloride sources make the risk of pitting or crevice corrosion over the 50-year life of the components extremely low, despite the potential for cracks or local stress concentrations that might remain in the material. Additionally, WRPS believes that the risk of introducing contaminants (e.g., moisture from rain, snow, humidity, or dust/pollution containing sulfides and chlorides) from the environment is very low. WRPS also cited the wide use of these connections on tank farm applications and a lack of evidence of failure due to corrosion over time. Additionally, WRPS asked the Tank Integrity Expert Panel to provide a second opinion, which generally agreed on WRPS's position with respect to the propensity for chloride induced corrosion. DOE representatives concur with the WRPS evaluation.

The above evaluation regarding corrosion is based on engineering judgement and is founded on assumptions that have not been verified or defended. However, although the staff team agrees that the probability may be low, the potential for corrosion failure due to pitting or crevice corrosion cannot be ruled out. WRPS should consider compensatory measures to further reduce the likelihood of corrosion failure unless it can be shown cracks or other defects do not exist.

- The original connections were passivated and had a dry film lubricant applied. WRPS found it necessary to use a different dry film lubricant on the repaired hose connections than the one called out in the original specification due to concerns that the high cure temperature used with the original lubricant would damage the hoses to which the connections are attached. Although WRPS did consult with the vendor regarding this change, the disposition did not evaluate or provide a technical justification for the change.

- The evaluation performed by WRPS, as well as post-repair testing, address the leak-tightness of the joint, which does not necessarily ensure structural integrity. Since, as previously stated, an accurate measurement of the amount of missing thread was not determined, and an evaluation of the amount of thread required to achieve structural integrity has not been performed, it is not possible to provide technical justification for how the leak-tightness test of the repair supports the structural integrity safety function of the connection.

- WRPS engineers dispositioned the two HART connections for "use-as-is." Although WRPS procedures[17] allow this disposition without performance of a technical evaluation for acceptance of minor damage and scratches, that exception would not appear to apply based on the inspection category assigned to the two connections [Notable Roughness (significant damage)]. Additionally, this is in direct

[17] TFC-ESHQ-Q_ADM-C-02, *Nonconforming Item Reporting and Control*, page 8.

contradiction to NQA-1, which requires technical justification for items dispositioned as use-as-is or repair. However, WRPS did not perform the required technical evaluation, nor did it provide any other justification that addressed the structural integrity of these connections before they were placed in service.

The above concerns were discussed with both WRPS and DOE representatives. WRPS subsequently performed strength testing using a new connection with a portion of a thread removed. WRPS stated that the amount of material removed from the test connection bounds the existing thread damage on the repaired connections (though the staff team notes a complete review of thread condition has not been performed). Per WRPS engineers, the test showed that the connector retains adequate strength to perform its assigned safety function

Based on the strength testing described above and a computation that WRPS states assesses the worst-case loss of thread engagement, WRPS revised Report 63511 to include the following conclusion:

"Based on the minimal reduction of thread engagement, the distribution of the thread loss, and the large degree of conservatism built into the Maximum Damage calculation, it's concluded that the restored connectors will withstand the postulated flammable gas detonation as analyzed in RPP-CALC-64098 and will continue to perform their safety function."

That conclusion continues to be based on a flawed evaluation. In the revised report, WRPS asserts that, at most, only 5% of the thread engagement is missing and considers this "minimal." However, that evaluation does not appear to address all factors that may affect the strength of the threads. Consideration of relevant factors may result in the calculation of a higher percentage of lost thread engagement. Examples of factors other than visual damage that could affect the thread engagement value and merit consideration are provided below:

- The affected IXCs were used for a significant number of training installations and removals. Consequently, as demonstrated by visual examination and loss of dry lubricant, the threads on these IXCs had significant pre-existing wear. Based on theoretical calculations, a loss of 0.010 inch at the thread pitch diameter can result in a loss of half the thread strength.[18] However, in this case, a measurement of the thread pitch was not taken, so the actual amount of wear is unknown.

- Additional thread defects could have been introduced by the mechanism that caused the thread damage. These defects could further weaken the threaded joint. Such defects might not be observable via the unmagnified visual inspection. Other inspection techniques would be required to rule out the presence of defects, but WRPS did not use other available methods.

- The repair process included thread chasing. Chasing damaged threads removes some material, further weakening the threads. Since WRPS did not accurately measure the threads before or after the repair, the amount of material removed was not quantified.

[18] John A. Bickford, *An Introduction to the Design and Behavior of Bolted Joints*, Third Edition, 1995.

The staff team notes ASME PCC-2, *Repair of Pressure Equipment and Piping*, is a resource for specifying repairs to ASME code components that are in-service. PCC-2 does not provide any recommended repair for male threads. With respect to female threads, thread chasing is only allowed to remove corrosion products or residue. It is not allowed if there is substantial damage to the threads.[19]

- Accurate measurements are critical to understanding the remaining capability of the connection threads after repair. In this case, the measurements that were taken did not use precision instruments intended for measuring thread parameters. Consequently, the measurements that are used to inform WRPS's evaluation are incomplete or inaccurate.

Further, WRPS has not determined what constitutes acceptable thread engagement to ensure the connection would survive the postulated design basis accident. Consequently, even if the length of intact threads were known, there is no basis for comparison to determine whether the remaining thread provides the required strength with an appropriate safety margin.

Ideally, this type of design information would be provided by the vendor. However, WRPS was neither able to provide information regarding a manufacturer's rating for shear load nor a minimum thread engagement required to withstand that shear load. Additionally, the staff team was unable to locate any information that would indicate that the connections would withstand the expected load resulting from a flammable gas explosion in an IXC; review of available vendor sources indicate test and rating values that are much lower than the design value for the event.

In cases where vendor rating information is not available, the expected performance of the connection can be calculated using guidance from ASME PCC-2, which also cites ASME B1.1, *Unified Inch Screw Threads (UN and UNR Thread Form)*, for parts under consideration that are not governed by the rules of the ASME Code, another applicable construction code or post-construction code. ASME B1.1 provides thread strength formulas and length of thread engagement formulas. Per the cited ASME guidance, the force to strip threads is based on the ultimate shear strength for the material of construction and the cross section of the thread material at the thread pitch diameter. Other factors must also be considered in the analysis to maintain conservatism. These include any out of roundness or taper, whether the threads are at minimum or maximum specification, dilation of the female connector due to tightening, the class of fit between the male and female threads), and whether the threads were formed by cutting or rolling.

Once the maximum allowed force is calculated, it can be compared to the axial load placed on the connection during a detonation or deflagration in the IXC. This will determine if there is margin in the current design. The margin available determines how much damage can be accommodated by the design.

WRPS has not performed the above evaluation. Therefore, the available margin is not known. Additionally, because of the insufficient condition evaluation discussed earlier, the

[19] ASME PCC-2-2018, *Repair of Pressure Equipment and Piping*, 303-2.2 Retapping Existing Holes.

remaining capability of the connection is not known. A determination regarding whether margin still exists cannot be performed without both pieces of information. Consequently, there is no basis other than engineering judgement for the conclusion that the repaired connections can perform their safety function.

Revision 1 to Report 63511 also states that the acceptability of the damaged connections is partly based on "the distribution of the thread loss." The report further states that the 5% thread loss "is distributed throughout the connection and not concentrated in one location, providing stress distribution across the connection."[20] However, the report does not provide any evaluation that supports this assertion. Additionally, as previously discussed, measurements of the threads were not taken (i.e., thread pitch diameter), so it is not feasible to fully evaluate the damage distribution. Lastly, the photographs reviewed by the staff team do not support the assertion. Consequently, the damage distribution argument cannot be defended.

Revision 1 to Report 63511 also concludes the hose connections and the damaged ChemJoint™ connections on the IXCs had their threads, "restored to as new condition."[21] The report further concludes, "These restored IXC connections provide the fit, form, and function necessary for a high-integrity mechanical connection for TSCR operations and are acceptable for use."[22] Neither of these conclusions are supported. The connections had visible material loss, visible wear, and material removed when the damaged threads were chased. Therefore, it is highly unlikely that the connection threads meet the original thread specification. Therefore, they are not "as new." The "fit" of the connector comprises the size and dimensional aspects of the connection. As the thread dimension is a key attribute that does not meet the original thread specification, the fit has certainly been compromised.

Inadequate Definition of Technical Safety Requirement Performance Criteria—Specific Administrative Control (SAC) 5.8.16 of the TSR "…protects the facility worker from flammable gas deflagrations and detonations in a spent IXC by ensuring proper installation of the process flow outlet line plug, inlet vent stack, outlet vent stack, and IXC gas sample port." The SAC requires installation of the process flow outlet line plug, TSCR IXC inlet vent stack, and outlet vent stack. The DSA lists five functional requirements. One of the functional requirements states that the components noted above are required to be installed in a configuration that will support analyses showing the components will maintain their structural integrity in a deflagration or detonation. To ensure that the functional requirement is met, the DSA establishes a performance criterion that states that the ChemJoint™ connections are required to be installed according to the manufacturer's directions. The performance criterion is implemented using Tank Farms Procedure TO-270-723, *TSCR IXC Disconnect, Preparation for Storage, and Transport to Storage Pad*.

TO-270-723 directs use of the manufacturer's directions, which are provided as an attachment to the procedure. The manufacturer's directions require the ChemJoint™ connection to be threaded hand tight and then allows two methods of torque measurement to finish the

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[20] Ibid, Section 6.3, page 6-3.
[21] RPP-RPT-63511 Rev-1, *TSCR IXC A/B/C and Process Hose Connection Thread Evaluation and Resolution,* Section 7, page 7-1.
[22] Ibid.

assembly. Per TO-270-723, the ChemJoint™ connection is assembled hand tight plus one to one and a half notches of the nut or 40 to 45 foot-pounds of torque. The assembly is observed by a quality assurance technician who must initial the work package indicating that the connection was established per the manufacturer's directions. Unlike other performance criteria in the procedure, the actual torque value is not recorded, nor is the observation recorded on a data sheet requiring a quality assurance technician's signature. This does not meet the full intent of NQA-1 requirements.[23]

With respect to structural integrity of the component, the amount of thread contact required to ensure the threads do not shear during a deflagration or detonation event is the critical characteristic. "Hand tight" is different for every individual, resulting in a different finishing position for the assembled connection. Additionally, torque does not necessarily guarantee that a connection is fully assembled since factors such as connector alignment, hose/pipe length, IXC positioning, type and quality of lubrication, condition of threads, and presence of dirt or other foreign material can affect torque. Furthermore, neither specification accounts for the presence of any foreign material or defect that would prevent full make-up of the connection. Therefore, from a structural integrity perspective, torque has limited value as a measurement of performance since the performance of the connection is contingent on the final configuration of the connection. It is possible under some conditions to believe the connection is fully engaged when it is not.

The staff team communicated the above concerns to WRPS and DOE managers. Subsequently, WRPS added steps to its procedure that require inspection and, if necessary, cleaning[24] of the threaded components prior to assembly to reduce the potential for increased friction that might result in a faulty torque measurement, leading to incomplete connection assembly. This action represents an improvement and does address some, but not all, of the potential failure modes.

Because of the above issue, a performance criterion that requires a quantitative determination of thread engagement or similar measurement would be preferable since it would provide positive assurance that the structural integrity safety function is met. However, when asked to address this observation and as previously noted, WRPS engineers were not able to state how many threads need to be engaged for the connection to perform its safety function. Additionally, they stated that, based on consultation with the connection vendor, there is no need for quantitative verification of thread engagement to ensure the connections are correctly assembled. Instead, they will continue to rely on "skill of the craft" to identify cases where the threads may not be fully engaged. DOE representatives concurred with the WRPS evaluation.

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[23] Per NQA-1, "Characteristics subject to inspection and inspection methods shall be specified. Inspection results shall be documented. Inspection for acceptance shall be performed by qualified persons other than those who performed or directly supervised the work being inspected." Additionally, "Appropriate records shall be established, maintained, and as a minimum, identify: (a) item inspected; (b) date of inspection; (c) inspector; (d) type of observation; (e) results or acceptability; (f) reference to information on action taken in connection with nonconformances."

[24] NQA-1 Subpart 2.1 provides cleanliness requirements for fluid systems and associated components during manufacturing, construction, repair, and modification. Subpart 2.1 discusses cleanliness consideration for crevices, an example of which is provided as "the annular spaces in threaded connections…."

Individuals tasked with assembling the mechanical connections are experienced pipefitters. While their error rate is expected to be low, they are still fallible, and experience has shown that even the best trained and qualified individuals make mistakes or errors in judgment. Experience has also shown that providing individuals with clear criteria for task performance will reduce the error rate. In this case, a clear criterion is used but is not directly linked to the safety function of concern, creating an error-likely situation that should be eliminated. Identification and implementation of a task completion criterion that quantitatively validates the final physical configuration of the connection, can be readily used by the pipefitter, and can be quantitatively evaluated by a quality assurance technician would provide better assurance that the connections are fully assembled and capable of performing their safety function.

If the component assembly criterion is not modified, the procedure changes that require inspection and, if necessary, cleaning of the threads prior to assembly become more important. However, neither the DSA nor the TSR discuss factors that could result in less than complete thread engagement in the TSR, the TSR evaluation, or in the performance criteria. Consequently, there are no definitive criteria to support future unreviewed safety question process evaluations and there is no assurance that the steps will survive future procedure changes. The importance of this function would warrant better protection in the safety basis.

Conclusion.

Based on the above review:

- Contrary to DOE and WRPS procedures and expectations, the WRPS evaluation and repairs were not performed consistent with the requirements of ASME NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications.* WRPS's less rigorous approach resulted in information gaps related to the condition of the threaded connections that introduce uncertainty into the adequacy of the repairs, leading to a similar uncertainty in the long-term capability of the connections to perform their safety function.

  - WRPS did not perform a rigorous analysis to determine the cause of the damage discovered on multiple threaded connections. Consequently, WRPS's corrective actions may not be sufficient to prevent reoccurrence of the condition.

  - Because the WRPS condition evaluation was limited to a visual examination, the disposition may not consider damage that is not easily visible but can still affect the strength or durability of the connection. Consequently, the repairs may not be sufficient to ensure that the repaired connections will satisfactorily perform their safety function throughout their 50-year design life. WRPS did not implement any compensatory measures to address the potential for unknown conditions.

- The TSR control that is credited for ensuring workers are not injured by dislodged IXC components during or after a postulated flammable gas explosion event does not require a quantitative verification that would ensure a connection is fully engaged to support compliance with the TSR. Instead, it relies solely on “skill of the craft” to ensure connections have adequate thread engagement to prevent separation caused by the explosion.

The above potential safety issues do not introduce a new accident or increase the frequency or consequences of an existing unmitigated analysis. However, for the three IXCs that were damaged, the potential safety issues could reduce the effectiveness of a hazard control that DOE has determined is important to worker safety. Additionally, under different conditions, a similar lack of rigor in the evaluation and repair of other safety-significant components could have more significant consequences.