Independent Oversight Review of Hanford Tank Farms Safety Basis Amendment for Double-Shell Tank Ventilation System Upgrades

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Office of Safety and Emergency Management Evaluations
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Acronyms

DOE	U.S. Department of Energy
DSA	Documented Safety Analysis
DST	Double-Shell Tank
FRED	Functions and Requirements Evaluation Document
HSS	Office of Health, Safety and Security
LCO	Limiting Condition for Operation
LFL	Lower Flammability Limit
ORP	Office of River Protection
PER	Problem Evaluation Request
PTV	Primary Tank Ventilation
SSCs	Structures, Systems, and Components
TOC	Tank Farms Operations Contractor
TSRs	Technical Safety Requirements
VFD	Variable Frequency Drive
WRPS	Washington River Protection Solutions

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1.0 PURPOSE

The U.S. Department of Energy (DOE) Office of Enforcement and Oversight, within the Office of Health, Safety and Security (HSS), conducted an independent oversight review of the draft amendment to the Hanford Tank Farms safety basis for upgrading the double-shell tank (DST) primary tank ventilation (PTV) systems to safety-significant designation. The Tank Farms are Hazard Category 2 DOE nuclear facilities. The review was performed during the period July 25 – August 12, 2011 by the HSS Office of Enforcement and Oversight's Office of Safety and Emergency Management Evaluations.

The review of the safety basis focused on the safety functions of the PTV systems and the proposed engineering upgrades to those systems. The purpose of this review was to identify any deficiencies or issues and communicate them to the DOE Office of River Protection (ORP) and to the Tank Farms Operations Contractor (TOC) prior to ORP's approval of the safety basis amendment.

The review was conducted in accordance with the HSS *Office of Safety and Emergency Management Evaluations Protocol for Small Team Oversight Activities*, dated May 2011. Appendix B provides supplemental information about the HSS review.

2.0 BACKGROUND

The Tank Farms facilities are comprised of 177 large underground tanks (149 single-shell tanks and 28 double-shell tanks), containing over 50 million gallons of high-level radioactive and hazardous wastes that were generated during production of defense-related materials at the Hanford Site from the 1940s through the late 1980s. The nuclear facility safety basis that is the subject of the proposed amendment primarily addresses specific mission activities, which include the continued safe storage of tank waste, single-shell tank retrieval, and DST-to-DST waste transfers. A major aspect of the safe storage of tank waste is the control of flammable gasses that are generated by the wastes through several mechanisms, including radiolysis, chemical reactions, and corrosion, in order to minimize the potential for deflagrations, which could release radioactivity to the environment. The primary means to affect this control are active tank exhaust ventilation systems, which extract the flammable gases as they are generated and dilute, with incoming air, the gas concentrations in the tanks to less than 25 percent of the lower flammability limit (LFL).

The DSTs are distributed in varying numbers among six Tank Farms (241-AN, -AP, -AW, -SY, -AY, and -AZ). There are five PTV systems associated with these six DST Tank Farms (there is a common PTV – 702-AZ – for the 241-AY and 241-AZ Tank Farms). The DST PTV systems have redundant trains capable of providing airflow through the headspace of each tank. The five DST PTV systems may be segregated into two groups, depending on the proposed planned improvements and the process to be used in designating the systems as safety-significant. The first group, 241-AN and 241-AW, will be designated as safety-significant through evaluation and resulting planned improvements, as necessary, of the as-installed systems. However, because of the limited time allowed, the system evaluations for this group have not been completed. Planned improvements have been designated to retrieve or reconstitute these system evaluations. The second group, 241-AP, 241-SY, and 702-AZ, will receive replacement systems that are expected to be fully compliant with the requirements necessary to be designated as safety-significant. For this reason, there are no plans to evaluate the as-installed systems for this group. In addition to the planned system evaluations, the planned design and operational safety improvements

include safety-significant electrical power; upgraded safety-significant control systems; safety-significant instrumentation to monitor exhaust airflow from each DST; evaluations of below grade PTV system ductwork; system interaction evaluations; and design improvements to eliminate single active failures in interfacing systems that could disable both trains of 241-AN and 241-AW PTV systems.

These changes were initiated in response to a Defense Nuclear Facilities Safety Board letter of August 5, 2010, to the Assistant Secretary for Environmental Management expressing concern with "…a number of analytical and implementation deficiencies in the DSA that limit the effectiveness of the prescribed safety controls in preventing and mitigating certain postulated accident scenarios."

3.0 SCOPE AND APPROACH

As part of its review, the HSS team assessed the draft Tank Farms safety basis amendment package, which included revisions to the Tank Farms documented safety analysis (DSA) and the technical safety requirements (TSRs), as well as to several supporting technical documents associated with pending upgrades of the DST PTV systems and their reclassification to safety-significant designation. The key supporting technical documents included flammable gas release calculations for steady-state and solids dissolution, hazard evaluation database, the PTV Functions and Requirements Evaluation Document (FRED), and associated drawings. References to these documents are provided in Appendix A.

The HSS team developed written comments that were discussed with the TOC and ORP staff during a site visit, August 9 through 12, 2011. The discussions during this visit centered on pending upgrades to these ventilation systems and the corresponding draft amended safety basis documents (DSA and TSRs) and their supporting analyses. The visit included a brief tour of one of the Tank Farms. Subsequently, the HSS team submitted a list of follow-up comments, which were further discussed and resolved by the TOC and ORP staff, resulting in a few follow-up actions.

4.0 RESULTS

The HSS review of the safety basis and supporting analyses indicated clear, well thought out, and appropriate plans for upgrading the Tank Farms PTV systems. The TSR changes included two new limiting conditions for operation (LCOs) for DST PTV systems and the corresponding action statements and surveillance test requirements for flammable gas control. One LCO addressed DST ventilation systems operation and operability for steady-state conditions, and the other addressed the same subjects for induced gas release events associated with water addition, chemical addition, or waste transfer. Corresponding changes were also made in the TSR's specific administrative controls and administrative controls. All of these changes were found to be adequate to provide the required level of protection to prevent the accumulation of flammable gasses in the tanks beyond the established limit ($\leq$ 25 percent of the LFL).

A majority of HSS's written review comments were readily resolved after technical discussions with ORP and TOC staffs. Several comments led to recommended document clarifications, for example, clearer statement of an LCO action or a more accurate description of the qualitative evaluation of consequences from multiple accidents due to seismic events. In a few significant areas, additional review, follow-up comments, and further discussions were necessary to adequately resolve issues. These issues are discussed in more detail in the following paragraphs.

Vacuum relief protection classification. The HSS review considered the potential, during certain off-normal conditions, for the PTV exhaust systems to create tank vacuum exceeding their analyzed capabilities, which could result in structural failures. The vacuum relief valves and other tank vacuum

protection devices are not classified as safety-significant. The HSS team's concern involved the effects that tank failures caused by high vacuum potentially might have on the capabilities of the safety-significant PTV exhaust systems to perform their safety functions. More specifically, this concern focused on the effects high vacuum might have on the systems due to tank failures, which might include suction line breach at the point of connection to the tanks, or potentially other points in the system up to the suction side of the fans. Such failures could occur because of the mechanical loads that may be induced due to the tank failures and/or crimping of any lines in the flow path that might constrict the flow – either of which might have the potential to degrade the systems' performance. (The concern was not for the potential direct radioactive release consequences from failure of the tanks themselves, which have been evaluated as within guidelines, or for the direct effects of the high vacuum on the safety-significant exhaust systems, which the exhaust systems are likely capable of withstanding.) If such potential structural effects of tank failures are credible, the tank vacuum relief devices would be performing the safety-significant function of protecting the functional capability of the safety-significant exhaust systems and, therefore, should also be classified as safety-significant.

Subsequently, the HSS concern with potential damage to the DST PTV systems caused by tank failures due to excessive vacuum was forwarded to the TOC structural design authority responsible for the DSTs. A thorough review of the design criteria of the DSTs, the construction drawings related to the physical configuration of the riser connections to the DSTs, and the buckling analysis of the DST primary liner shell subject to negative pressure was completed. The 12-inch risers used for the exhausters are constructed of rolled ½ inch steel. The risers are physically attached to the concrete dome of the DSTs with concrete anchors. The risers are not welded to the primary liner of the tank. The conclusion was that the riser would not be subject to buckling under negative pressure (i.e., tank vacuum). The riser's attachment to the concrete dome and lack of attachment to the primary liner precludes any impairment of the riser due to potential buckling of the primary liner. This review and conclusion confirmed that the DST failure mode due to excessive vacuum (e.g., possible uplifting of the tank bottom and buckling of the primary tank wall) would not affect the DST PTV system safety function. Therefore, the DST vacuum protection systems are not required to have safety-significant designation to protect the safety-significant PTV systems.

Tank isolation from their relief devices. The HSS review identified a potential weakness of tank vacuum relief protection in the 241-AN PTV system in that the tanks could be isolated from their relief devices. This Tank Farm's relief protection for its six tanks is provided by two relief valves on the air inlet station for Tanks AN-101 and AN-102, by virtue of all the tanks being interconnected through the exhaust system's common suction header. (A similar design was being planned for 241-AP Tank Farms.) An analysis (RPP-7171, Rev. 1) demonstrated that, with the relief valves open, the vacuum in all of the tanks, including those not provided with their own individual relief valves, would not exceed their ratings. However, each of the tanks was provided with its own ventilation system suction isolation valve. If the two tanks with the relief valves were to be isolated from the suction header by closure of these valves, for maintenance or any other reason, the remaining four tanks would be thus isolated from their relief protection. This is contrary to applicable codes and good engineering design practice, which prohibits locating any isolation device, such as a valve, between the relief protection device and the vessel(s) it is intended to protect. The analysis appears to substantiate the concern; it states, "The vacuum relief valves (VRVs) for Tanks 241-AN-101 and 241-AN-102 can provide vacuum relief for the entire AN Tank Farm *if* [emphasis added] the exhaust isolation valves for these two tanks are disabled to prevent their isolation from the primary tank ventilation system exhaust header." The analysis also contains other similar statements. Presently, no controls are in place for the relief valves.

The TOC initiated a problem evaluation request (WRPS-PER-2011-1709, dated 08-11-2011) to determine whether there are any issues with the design of vacuum protection for DST 241-AN and 241-AW Tank Farm tanks where vacuum relief valves are only provided on two of the tanks, but these tanks can be

isolated from the DST PTV system. The resolution of this PER (e.g., configuration management of the tank exhaust vent isolation valves) is not considered a safety basis issue since the DST failure mode due to excessive vacuum does not result in releases requiring safety structures, systems, and components (SSCs) or TSR controls.

Tank vacuum protection from fan overspeed. Currently, some of the tanks are ventilated by exhaust systems that contain fans driven by variable frequency drive (VFD) electric motors. Such arrangements allow adjustment of fan speeds, and flow rates through the systems, by varying the frequency of the electric power being supplied. The TOC's tank vacuum analyses examined the vacuum protection capabilities for tanks with VFD exhaust fans. These analyses were based on fan performance at less than their rated speeds; it was not clear if they analyzed the vacuum that could be generated at the fans' significantly higher flow and static pressure capabilities at rated speeds or for overspeed conditions as a result of failure of the VFD controls, which could likely produce conditions that would exceed the installed relief protection devices' capabilities. These conditions could result in damage to the tanks.

Follow-up of this concern with potential impacts from DST PTV system exhauster VFD failures (i.e., overspeed conditions that may increase tank vacuum) revealed that this issue had been previously identified (PER-2005-0183) and closed out. The increase in tank vacuum was not a safety basis issue as discussed previously. The corrective actions for PER-2005-0183 included the performance of technical evaluations of the DST PTV systems with exhausters driven by VFDs to determine whether VFD failures that increase the tank vacuum could impact tank integrity. While PER-2005-0183 provides references to the technical evaluations performed to close the corrective actions, the PER does not provide any pertinent discussion of the results of these technical evaluations that verified the adequacy of the vacuum protection systems for postulated overspeed conditions due to VFD failures. The cognizant ORP staff have committed to follow up the resolution of this issue and prepare a summary documenting the technical rationale for closure of this issue.

Controls for seismic induced gas release events. In the case of a seismic event, a few tanks (Group A and B) could have an induced flammable gas release that would exceed 100 percent of the LFL. The discussion of DST flammable gas evaluation (DSA, Sec. 3.3.2.4.1.2) states the conclusion that "without controls a DST headspace deflagration could result in significant facility worker consequences…. Accordingly, safety-significant SSCs and/or TSRs are required to protect the facility worker." While the draft DSA amendment is clear on the preventive and mitigative abilities of the PTV systems for steady state and certain non-steady state conditions, there is insufficient explanation for lack of safety SSC or TSR controls to prevent or mitigate seismic induced flammable gas release events. For example, it is not clear how and why, for the seismic event, these systems and other mitigative and preventive measures considered were judged impractical or incapable of providing the required prevention or mitigation. Further, in certain places of the DSA (e.g., Table 3.3.2.3.2-1, Item No. 7) and Hazard Evaluation Database (Appendix B, ID FG-DST-04), it is noted or implied that safety SSCs or controls are not required, and there are discussions of an induced gas release event (e.g., DSA, Sec. 3.3.2.4.1 and Table 3.3.2.3.2-3) where seismic induced hazardous condition is not explicitly included.

Discussions with the TOC and ORP staff clarified that ventilation is not an effective control for seismic induced events because the gas would be released very rapidly; thus, the gas release is conservatively assumed to be instantaneous. Even if ventilation for this hazard was credited, the tank could still exceed 100 percent of the LFL. Certain other preventive and mitigative controls were also previously considered and rejected. The primary reason for seismic qualification of the PTV is for the ventilation to continue to run after the event so it continues to protect against the steady state build up. The steady state hazard applies to all the tanks, while the seismic induced gas hazard only apples to a small subset.

While the DSA does not generally provide justification for why particular controls may not be selected, it is necessary to explain the rationale in the DSA in this instance, especially because there appears to be an inconsistency between the preventive or mitigative limitations for a seismic event and the requirement that the systems be qualified to withstand and remain functional for a seismic event. It is reasonable to expect that the DSA would explain why no preventive or mitigative control for this event is selected beyond the simple, unsupported statement presently in the DSA that no control is practical. The explanation would be relatively straight-forward and reasonable, based on HSS discussions with TOC and ORP staff. The ORP staff proposes to resolve this issue by providing appropriate additional discussion of this topic in a separate, anticipated safety basis amendment to define the emergency preparedness program as a Key Element to protect facility workers. This approach is reasonable because the control strategy for the seismically induced hazards is not impacted by the present safety basis amendment.

Design for volcanic ashfall. The Tank Farms draft DSA amendment addressed the designs of the PTV exhaust systems as they relate to surviving the volcanic ashfall event, which, because of the proximity of the Cascade Mountain Range containing 13 volcanoes, is an important design consideration. The discussion of natural phenomena hazards mentions structural failures due to ashfall loads, as well as equipment failure. However, the discussions of system evaluations of DST PTV systems, as well as the supporting FRED, do not specifically address the potential adverse effects of exposure to ash particulates. Further, this review found that none of the TOC design standards specifically identify any volcanic ash threats besides structural loading, which include, but are not limited to, rapid plugging of filters, such as those directly associated with the tank ventilation systems, and those indirectly associated, such as for the backup diesel generators planned as systems upgrades; breakdown of electrical insulation; equipment overheating due to thermal blanketing (ash degrades conductive, convective, and radiant heat transfer); mechanical abrasion of bearings, hydraulic actuators, and compressor and engine internals; and contamination of fuels, lubricants, and other such materials essential to proper systems operations. Also, a spot check of the current draft purchase specification for the diesel generators revealed that none of these additional design considerations had been specifically addressed.

The requirement to evaluate failures of safety SSCs due to volcanic ash is contained in the TOC engineering design procedure, TFC-ENG-DESIGN-C-45. A PER (WRPS-PER-2011-1698) was written in response to HSS team's inquiry to enhance this standard with respect to guidance on the ashfall environmental condition specifically to address exposure to ash particulates and the potential adverse effects mentioned above. Also the FRED would be revised appropriately to recognize these ashfall effects in referencing the revised engineering standard for evaluation. The required evaluation of DST PTV systems for failures due to volcanic ash will be performed as part of the planned improvements. Further, as explained to the team, since the DST PTV systems would be the only active safety-significant SSCs at Tank Farms, an extent of condition determination is not necessary to ensure that other Tank Farms safety equipment designed and/or procured without the benefit of the revised standard is not vulnerable to volcanic ashfall environmental conditions.

5.0 CONCLUSIONS

The changes currently in process for the DST PTV systems and their attendant safety bases and supporting documents appear to be generally adequate to address the concerns for which these systems will be upgraded and designated as safety-significant. This review identified some corrections and enhancements needed in the safety basis amendment and supporting documents, as well as a few issues that were adequately resolved by identifying appropriate follow-up actions, which are not required to be completed prior to approval of the amendment. These issues include (1) the potential isolation of some 241-AN tanks (and possibly others in the current designs) from their vacuum relief protection devices, which is contrary to applicable codes and good engineering practice; (2) adequacy of the vacuum protection systems for ventilation fan overspeed conditions due to VFD failures (an issue previously

identified by TOC for which results of previous technical evaluations and corrective actions were not readily known); (3) the lack of explanation in the DSA for why no practical control is available for a seismic induced flammable gas release event; and (4) the lack of specific design requirements for evaluating all of the potential adverse effects of volcanic ashfall on safety systems and equipment, specifically their exposure to ash particulates.

As discussed in the Results section, the first two issues are potential engineering design issues but not safety basis issues, while the third is a documentation issue not directly pertinent to the proposed safety basis amendment. The last issue is resolved by appropriately revising an engineering standard that would guide evaluations and specifications as part of planned system improvements.

6.0 ITEMS FOR FOLLOW-UP

The review identified the following items for follow-up by independent oversight:

- **Tank vacuum protection device isolation.** Follow up on closure of WRPS-PER-2011-1709. Review to verify that appropriate measures have been implemented to address the concern that, contrary to applicable code requirements, isolation devices exist in the 241-AN Tank Farm ventilation system between the vacuum relief valves and some of the tanks they are intended to protect.

- **Tank vacuum protection from fan overspeed due to VFD failures.** Follow up on closure of WRPS-PER-2005-0183, and review the summary of technical evaluations and protective actions taken to ensure that the impact of VFD failures on tank vacuum protection is adequately addressed.

- **Controls for seismic induced gas release events.** Verify that adequate explanation has been provided in the DSA for why no practical control exists for seismic induced flammable gas release design basis events, and how the systems for flammable gas controls, which are not capable of preventing or mitigating releases exceeding the LFL for this event, are acceptable. The additional explanation is expected to be included in the next anticipated safety basis amendment for designating Tank Farms emergency preparedness program Key Element.

- **Volcanic ashfall design considerations.** Follow up on closure of WRPS-PER-2011-1698. Verify that the applicable TOC engineering standard(s) is revised to include expanded considerations for the design of the PTV systems with respect to all of the potentially detrimental effects of volcanic ashfall, and that these additional considerations are also appropriately reflected in the designs and procurement specifications for these systems.

Appendix A
References

RPP-13033, July 25, 2011, *Tank Farms Documented Safety Analysis*, Rev. 4-TBD (Draft Amendment), ECN 10-001414, Washington River Protection Solutions, Richland, Washington.

HNF-SD-WM-TSR-006, July 20, 2011, *Tank Farms Technical Safety Requirements*, Rev. 7-TBD (Draft Amendment), ECN 10-001414, Washington River Protection Solutions, Richland, Washington.

RPP-13033, 2011, *Tank Farms Documented Safety Analysis*, Rev. 4-G, Washington River Protection Solutions, Richland, Washington.

RPP-15188, 2011, *Hazard Evaluation Database Report*, Rev. 9-I (Draft), Washington River Protection Solutions, Richland, Washington.

RPP-5926, 2011, *Steady-State Flammable Gas Release Rate Calculation and Lower Flammability Level Evaluation for Hanford Waste Tank*, Rev. 12 (Draft), Washington River Protection Solutions, Richland Washington.

RPP-RPT-47933, 2011, *Flammable Gas Release Rate from Double-Shell Tank Solids Dissolution*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

RPP-RPT-49447, Rev. D, Safety-Significant DST Primary Tank Ventilation Systems - Functions and Requirements Evaluation Document, Washington River Protection Solutions, Richland, Washington.

TFC-ENG-DESIGN-C-45, Rev. D-2, Control Development Process for Safety-Significant Structures, Systems, and Components, Washington River Protection Solutions, Richland, Washington.

TFC-ENG-STD-07, Rev. F, “Ventilation System Design Standard,” Washington River Protection Solutions, Richland, Washington.

Appendix B
Supplemental Information

Dates of Review

July 25 – August 12, 2011

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