DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

May 9, 2019

The Honorable James Richard Perry
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Secretary Perry:

The Defense Nuclear Facilities Safety Board received a letter from the Department of Energy's Office of River Protection on October 24, 2018, regarding three open Board issues related to the High Level Waste Facility at Hanford's Waste Treatment and Immobilization Plant.

The Board agrees that DOE has identified acceptable strategies for resolution for these three issues but notes that, in some cases, further analysis may be required to validate or clarify assumptions underpinning those strategies. The Board will review the relevant technical documentation as it becomes available.

Please refer to the enclosure for further details on each of the three issues. The Board is providing this information for your information and use during the design process.

Yours truly,

Bruce Hamilton
Chairman

Enclosure

c: The Honorable Anne Marie White
Mr. Brian Vance
Mr. Joe Olencz

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Report

February 19, 2019

Waste Treatment and Immobilization Plant High Level Waste Facility Technical Issues

This report summarizes the Defense Nuclear Facilities Safety Board's (Board) position as of February 2019 on the three outstanding technical issues related to the Safety Design Strategy (SDS) for the High Level Waste Facility (HLW) at Hanford's Waste Treatment and Immobilization Plant (WTP). These issues pertain to unanalyzed melter accidents, hydrogen control strategy, and seismic categorization of safety controls. The Board transmitted these issues to the Department of Energy (DOE) in three letters dated December 5, 2014, January 21, 2015, and February 2, 2015, respectively [1] [2] [3]. Bechtel National, Incorporated (BNI) submitted the HLW Preliminary Documented Safety Analysis (PDSA) for DOE approval on September 14, 2017 [4], and DOE's Office of River Protection (ORP) transmitted the formal response letter to the Board's three letters on October 24, 2018 [5].

Unanalyzed Melter Accidents. The Board identified in 2014 that the SDS did not include analysis for several accident scenarios involving the facility's melters. The scenarios specifically noted in the letter were: (1) melter steam explosions; (2) simultaneous spills of molten glass and water; (3) simultaneous spills of molten glass and nitric acid; and (4) loss of melter cooling.

After reviewing BNI's PDSA submittal and DOE's response letter, the Board's staff agrees that DOE has addressed these specific scenarios, resolving the issue raised in 2014. However, the Board's staff concludes that there are opportunities for improvement related to the documentation and justification of DOE's safety strategy. The Board is providing the following information for DOE's consideration during the design process.

Melter Steam Explosions—The Board noted in 2014 that the SDS did not identify a melter steam explosion initiated by a molten salt and water interaction. A molten salt layer can develop when the melter feed chemistry is out of specification and could allow for premixing of water and molten salt due to the salt layer's low viscosity [1]. DOE's response letter notes that the PDSA now identifies and analyzes this accident scenario [5]. Section 2.2.1 in Appendix C evaluates the potential for an explosion resulting from a salt layer formation on top of the glass pool interacting with a water addition [4]. The Board's staff agrees that DOE has resolved the specific concern outlined in the Board's 2014 letter by including this scenario in the PDSA hazard tables.

However, a limited-scope review of the available documentation leads the Board's staff to conclude that the current analysis could benefit from further development. BNI determined that a melter steam explosion initiated by a molten salt and water interaction is beyond extremely unlikely. Consequently, BNI does not assign preventive or mitigative controls. The Board's staff did not perform a detailed evaluation of BNI's frequency determination, but notes that this

determination relies on two assumptions, the underlying bases of which may necessitate more rigorous analysis. First, salt layer formation is contingent on a series of operator errors and specific physical conditions. Second, any salt-water interactions would not be explosive (i.e., would result in only limited steam formation) primarily because the maximum rate of water addition is very low. It would be prudent for DOE to validate both of these assumptions later in the design process when more information is available. For example, documentation prepared for BNI includes literature reviews and calculations related to general salt-water interactions, but does not contain rigorous study of the physical, chemical, or operational conditions specific to the HLW melters. Such analyses would provide further confidence that BNI has adequately characterized the hazard and support its decision to not designate safety-related controls.

The Board's staff further notes that the hazards analysis associated with melter steam explosions would benefit from additional documentation in other areas. For example, while the hazard analysis clearly addresses salt layer formation and sub-surface injection of liquid into the melt pool during steady state conditions, it does not clearly address these scenarios during startup and shutdown conditions. Further, a broader treatment of melter steam accidents, in general, would improve confidence in the hazard control set. It also may be prudent to consider existing controls (such as the confinement ventilation system, melter shell, or restrictions on feed chemistry) as defense-in-depth features to prevent or mitigate these accident scenarios.

Simultaneous Spills—The Board noted in 2014 that, during a seismic design basis accident (DBA), failure of the melter along with other systems could result in simultaneous spills of molten glass and other substances, including water and nitric acid [1]. Section 4.4.1.1.4 of the revised PDSA classifies the melters as seismic category (SC) II. BNI's implementation of this classification in the design provides appropriate assurance that the melters would survive a seismic DBA and therefore prevent the postulated accident scenario [4]. Consequently, the Board's staff agrees that this action resolves the concern.

Loss of Melter Cooling Function—The Board observed in 2014 that the SDS had not identified nuclear safety controls for a melter cooling panel rupture or loss of cooling to the melter [1]. DOE's response letter notes that the PDSA now identifies and analyzes this accident scenario. Sections 3.2.12 and 3.2.12a in Appendix C evaluate the potential effects of melter cooling panel failure. The PDSA now identifies the melter shell as a safety significant control for confinement. The Board's staff agrees that DOE has resolved the specific concern outlined in the Board's 2014 letter by including such a scenario in the PDSA hazard tables and identifying appropriate controls. The Board's staff expects that BNI will be able to validate the melter shell's ability to perform this safety function per the normal design process.

However, the Board's staff notes that, in addition to the molten glass leak described in the hazard analysis, it may be prudent to expand the hazard analysis to consider cooling panel failure as a potential initiator for a steam explosion because of water ingress into the glass pool. The controls described in DOE's response letter focus primarily on degradation of the refractory and confinement of the glass pool, and do not focus on water ingress. Although the Board's staff did not perform a detailed evaluation of the event's consequence and frequency determinations, the manufacturer's system description for the HLW melter noted the following [6]:

> *The refractory package has been designed to provide adequate containment of glass in the event of a temporary loss of cooling water flow. However, during a sustained loss of cooling water flow, the cooling panels will eventually boil dry.…Special procedures will need to be developed for restoring cooling water flow following longer cooling interruption times to assure against steam condensate induced water hammer damage.*

In other words, if cooling is lost, restoration of flow could damage the cooling system and allow water to enter the melter refractory or molten glass pool. DOE could consider administrative controls that prevent restoration of flow and thus preclude this accident initiator.

Hydrogen Control Strategy. The Board identified in 2015 that BNI did not define a nuclear safety control strategy for hydrogen explosion hazards following the loss of mixing in process vessels containing non-Newtonian waste. In particular, the Board noted that BNI eliminated spargers from the HLW control strategy, but did not designate a replacement control to perform that safety function [2]. Although DOE since has directed BNI to retain the spargers as part of the HLW design, the PDSA currently does not credit the spargers as safety controls [7]. Rather, DOE's 2018 response to the Board's letter discusses a combination of preventive and mitigative strategies to control the hazards related to hydrogen explosions [5]. As a preventive strategy, the updated PDSA designates several safety-significant controls—including the process vessel air purge and mechanical agitators—to reduce the probability of a hydrogen explosion [4]. As a mitigative strategy, the PDSA (section 3.3.3.2.1) asserts that hydrogen explosions in the process vessels will not challenge the C5 confinement boundary. As the PDSA states, "[t]he C5 confinement boundary is augmented by the HOP [HLW melter offgas treatment process system] HEPA [high efficiency particulate air] filters, which are credited with ensuring that an unfiltered pathway from the vessel headspace to outside of the boundary is not realized following the explosion (see Section 3.3.2.3.1)." Therefore, the PDSA credits the C5 ventilation (C5V) system with mitigating process vessel explosions using active filtration [4].

The Board's staff concludes that this revised control strategy is conceptually viable, and agrees that DOE and BNI have identified an acceptable path forward for resolving the original concern. However, the Board's staff notes that this approach is technically challenging, and that BNI still needs to design the equipment and methods necessary to implement the strategy. For example, BNI must be able to show that the mechanical mixers and the process vessel air purge systems will perform reliably, as expected, or provide an additional method for agitating the waste in the event of a mechanical mixer failure. Additionally, section 3.3.2.3.1 states that BNI needs to perform additional design analysis to demonstrate the vessel agitator performance in post-seismic conditions. As another example, section 3.3.2.3.1 titled "Planned Design and Safety Improvements" states that a dynamic structural response is required to demonstrate that the HOP HEPA filters and other C5 confinement boundary features (e.g., glass former reagent lines and isolation valves) will remain intact following a process vessel explosion. The Board's staff will perform additional reviews when the appropriate information is available.

Seismic Categorization of Safety Controls. The SDS designated two key elements of the HOP system—the submerged bed scrubber and HEPA filters—as SC-III. Designing to the SC-III seismic category does not provide adequate assurance that the equipment will withstand a

seismic DBA; therefore, such equipment may not be able to perform its safety functions on demand. Because the exhaust path for the HOP system penetrates the C5 confinement boundary, failure of equipment in the HOP system during a DBA could create a pathway for unfiltered air to pass through the C5 confinement boundary. The Board's 2015 letter noted that the C5V system would be unable to perform its safety function following such an event, which is not consistent with requirements in DOE Order 420.1B, *Facility Safety* [3].

Section 4.4.1.1.4 of the updated HLW PDSA now categorizes the submerged bed scrubber and HOP HEPA filters, as well as melter and HOP service piping, as SC-I [4]. Section 4.4.6.2.4 of the PDSA further states that piping penetrations into the C5 boundary greater than 4" (including the HOP system exhaust piping that penetrates the C5 boundary) are qualified to SC-I up to the isolation valve outside the C5 boundary [4]. The Board's staff agrees that this categorization resolves the original issue.

The Board's staff notes, however, that DOE implies in its response letter that the HOP system as a whole is SC-III, contrary to the information contained in the HLW PDSA [5]. Subsequent clarifying discussions between DOE personnel and the Board's staff members determined that the description contained in the response letter was unintentionally broad and ORP did not intend to apply the general system classification to any components, contrary to the assignment contained in the PDSA. Consequently, the categorization in the HLW PDSA is correct; the Board's staff therefore is basing its decision to close the issue on the information contained in the HLW PDSA.

References

[1] Defense Nuclear Facilities Safety Board, *Melter Accident Unanalyzed in the Safety Design Strategy for the High-Level Waste Facility,* December 5, 2014.

[2] Defense Nuclear Facilities Safety Board, *Hydrogen Control Strategy in the Safety Design Strategy for the High-Level Waste Facility,* January 21, 2015.

[3] Defense Nuclear Facilities Safety Board, *Seismic Control Strategy Deficiencies in the Safety Design Strategy for the High-Level Waste Facility,* February 2, 2015.

[4] Bechtel National, Incorporated, *CCN-298893, BNI Letter from K.D. Irwin to W.F. Hamel, ORP, "Supercedes CCN 296651 and CCN-298892 - Regulatory Deliverable 9.1 - PDSA Change Package for the PDSA to Support Construction Authorization",* September 14, 2017.

[5] Department of Energy Office of River Protection, *Resolution of DNFSB Issues: Concerns Regarding the SDS for the WTP HLW Facility, 18-NSD-0026,* October 24, 2018.

[6] Duratek, *HLW Melter System Description, 24590-101-TSA-W000-0010-407-566,* 2002.

[7] Department of Energy Office of River Protection, *Direction to Retain the Spargers in the High-Level Waste Facility Melter Feed Preparation/Melter Feed Vessel Design Until Further Evaluation, 17-WTP-0233,* 2018.