DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

August 21, 2015

Dr. Monica Regalbuto
Assistant Secretary for
Environmental Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-1000

Dear Dr. Regalbuto:

From our review of the Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Documented Safety Analysis (PDSA), the Defense Nuclear Facilities Safety Board identified technical deficiencies in the methodology used to determine the uranium metal concentration in Engineered Container SCS-CON-230 and a hydrogen accident scenario not identified in the PDSA. Even though the radiological dose consequences to workers or the public due to a hydrogen explosion are not significant, these deficiencies have the potential to impact the final design of the auxiliary ventilation system and could require additional controls to protect the facility worker. The enclosed report discusses these weaknesses in detail and is transmitted for your consideration and use in ensuring that the final design adequately meets Department of Energy safety requirements.

Sincerely,

Joyce L. Connery
Chairman

Enclosure

c: Ms. Stacy Charboneau
Mr. Joe Olencz

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

June 17, 2015

MEMORANDUM FOR:	S. A. Stokes, Technical Director
COPIES:	Board Members
FROM:	P. Migliorini, J. Abrefah, F. Bamdad, and J. Meszaros
SUBJECT:	Review of the Sludge Treatment Project Preliminary Documented Safety Analysis Hydrogen Hazards

Members of the Defense Nuclear Facilities Safety Board's (Board) staff identified safety issues during a review of Revision 1 of the Sludge Treatment Project (STP) Engineered Container Retrieval and Transfer System (ECRTS) Preliminary Documented Safety Analysis (PDSA) at the Hanford Site. The staff members conducted their review at Hanford during the week of February 23, 2015. The staff team held a follow-up discussion and closeout teleconference with the Department of Energy Richland Operations Office (DOE-RL) and the STP contractor, CH2M HILL Plateau Remediation Company (CHPRC), on April 16, 2015. The issues include technical deficiencies in the methodology CHPRC used to determine the uranium metal concentration in Engineered Container SCS-CON-230 and a hydrogen accident scenario not identified in the PDSA. The technical deficiencies could result in a larger than expected hydrogen generation rate, and consequently, an insufficiently designed auxiliary ventilation system. Furthermore, the unidentified accident scenario may require additional controls to protect the facility worker.

Background. The STP is a subproject of the K Basins Closure Project at the Hanford Site. The mission of the STP is to dispose of the radioactive sludge currently stored at the 105-K West (KW) Basin. The sludge is a combination of metallic spent fuel corrosion products (i.e., particulates of uranium oxides and uranium metal), debris from fuel storage racks and containers, windblown dust, and spallation products from the fuel basin concrete walls and floors. The sludge is stored underwater in six engineered containers within the KW Basin. Phase I of the STP, also known as ECRTS, will transfer approximately 27 cubic meters of sludge in multiple batches as slurry through a hose-in-hose transfer system into the Sludge Transport and Storage Containers (STSCs) located in the Sludge Loading Bay of the KW Basin Annex. The KW Basin Annex is currently under construction, located approximately 12 meters north of the KW Basin and approximately 500 meters from the near bank of the Columbia River. Once loaded, the STSCs will be transported by truck in Sludge Transport System casks to T-Plant for interim storage.

Pressurized spray leaks and hydrogen explosions are the two major hazards identified in the ECRTS PDSA. These accidents can be initiated by operational events, a facility fire, natural phenomena, or external events. Hydrogen gas is continuously generated when the uranium metal particulates contained in the basin sludge react exothermally with water. Consequently, hydrogen produced by the sludge in the STSC or other process enclosures could accumulate to concentrations that can support a hydrogen explosion. For all the hazard events analyzed, the radiological dose consequences are bounded by an explosion that causes a release of sludge originating from Engineered Container SCS-CON-230 [1]. The project analyzed hydrogen deflagration events and found that the radiological dose consequences do not exceed the thresholds for co-located workers and public receptors defined in the Hanford Safety Analysis and Risk Assessment Handbook [2]. However, there is a potential for serious injury or death to a facility worker due to the physical impact of a hydrogen explosion event. Accordingly, the project credits safety significant controls to prevent hydrogen explosions. In Revision 1 of the ECRTS PDSA, the project credited a passive ventilation flowpath for preventing a hydrogen explosion in an STSC. In the safety evaluation report for the PDSA revision, DOE-RL imposed a condition of approval that requires the project to revise its hydrogen control strategy to ensure that the hydrogen concentration in the STSC headspace remains less than 25 percent of the lower flammability limit [3]. During the closeout teleconference with the Board's staff, DOE-RL personnel stated that the project will revert back to the strategy detailed in Revision 0 of the PDSA, which includes a safety significant auxiliary ventilation system with nitrogen purge [4]. The design details of this system are not yet available. The staff team believes the following concerns merit consideration by project analysts.

Unsupported Technical Assumptions. During its review of the revision of the PDSA, the staff team identified two safety issues concerning assumptions made to determine the total uranium and uranium metal concentration in Engineered Container SCS-CON-230. The staff team determined that the project team has not provided an adequate technical basis for the assumptions. Invalid assumptions could lead to an understatement of the amount of uranium metal or an incorrect determination of the uranium distribution in SCS-CON-230. Either deficiency could result in the design of an auxiliary ventilation system that is insufficient to control hydrogen concentrations to below the lower flammability limit.

Statistical Treatment of Uranium Metal Measurements—To determine the total uranium and uranium metal concentration in Engineered Container SCS-CON-230, the project performed core sampling at four locations in the container [5]. The project homogenized the core samples and separated them into 12 sub-samples. The project determined the safety basis values for total uranium and uranium metal concentration by performing a regression analysis and assuming that the 12 sub-samples were independent data. The four measurement locations were not equally represented by the 12 sub-samples. For example, location B4 had five subsamples, location A3 had three subsamples, and locations A2 and B2 had two sub-samples. During onsite interactions, the staff review team questioned if the project considered whether it was more conservative to average all sub-samples associated with each of the four core samples, propagate associated uncertainties, and perform the same regression analysis on the resulting four samples. In response to this line of inquiry, the project recalculated the prediction upper limit values for uranium metal concentration by averaging the sub-samples at each location and performing the statistical analysis for the four average measurements. The new calculation showed that this approach predicts larger values for the uranium metal concentration because it does not skew the result to the location with the most sub-samples (i.e., location B4). The project did not carry the results through to the calculation of the average uranium metal concentration in SCS-CON-230. Additionally, the contractor has not repeated this new process for the total uranium concentration to determine if the value used in the accident analyses is bounding. Appendix A to DOE

Standard 3009-94, *Preparation Guide for U. S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, states that the material at risk (MAR) "should represent documented maxima" [6].

Applicability of the Inverse Square Law—To extrapolate the uranium metal concentration measurements to the rest of the contents of Engineered Container SCS-CON-230, the project applied the "inverse square law" and a regression analysis around the inlet nozzle of the container [5]. The contents of the container are comprised of a distribution of particle sizes and materials that include sand and other non-radioactive particles. The staff review team believes that application of the inverse square law to this particular case is not valid because the particles in the Engineered Container do not exhibit uniform physical characteristics, which is the principal assumption for the applicability of the inverse square law. The staff review team believes that this assumption is unverified for this particular case.

Unanalyzed Hazard Scenario. In addition to unjustified assumptions, the staff team identified an accident scenario that was not considered in the ECRTS PDSA. To prevent a seismically-induced spray leak from occurring, the PDSA credits safety significant seismic shut-down switches to terminate slurry transfer during sludge retrieval operations [1]. The switches are also credited for preventing a seismically-induced hydrogen explosion in the Transfer Line Service Box and shielded hose chase. However, the PDSA does not address the potential radiolytic hydrogen hazards that may exist within the stagnant slurry in the pipes and other components after the pumps are shut off. Hydrogen generated in piping and other components may lead to a post-seismic (or general loss of power) hydrogen explosion hazard that is not identified nor controlled in the PDSA, with potentially unacceptable consequences for facility workers.

Conclusions. During review of the recent revision of the STP ECRTS PDSA, the Board's staff team identified two areas of concern related to the project's analysis of hydrogen hazards. The first area of concern includes two unjustified assumptions used to determine the concentration of total uranium and uranium metal used in safety basis calculations. The total uranium concentration in the sludge is used to define the MAR. If this value is not bounding, the MAR value used in the accident analysis will not be bounding. The uranium metal concentration is used to determine the radiolytic hydrogen generation rate. An underestimated uranium metal concentration could lead to larger than expected hydrogen generation rates in the STSCs and result in an insufficiently designed auxiliary ventilation system. Additionally, the staff team identified an unanalyzed hazard that could require additional controls to prevent or mitigate a post-seismic (or general loss of power) hydrogen explosion.

References.

[1] CH2MHILL Plateau Remediation Company, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Documented Safety Analysis*, PRC-STP-00718, Rev. 1, March 5, 2015.

[2] CH2MHILL Plateau Remediation Company, *Hanford Safety Analysis and Risk Assessment Handbook (SARAH),* PRC-STD-NS-8739, Rev. 0, Change 1, 2011.

[3] Department of Energy, Richland Operations Office, Nuclear Safety Division, *Safety Evaluation Report for the Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Documented Safety Analysis*, 15-NSD-0027 and Attachment, January 2015.

[4] CH2MHILL Plateau Remediation Company, *Sludge Treatment Project Engineered Container Retrieval and Transfer System Preliminary Documented Safety Analysis*, PRC-STP-00718, Rev. 0, November 20, 2013.

[5] CH2MHILL Plateau Remediation Company, *Safety Basis Uranium Metal Concentration Derivation for Sludge in Engineered Container SCS-CON-230*, PRC-STP-CN-CH-00545, Rev. 1, March 2012.

[6] Department of Energy, *Preparation Guide for U. S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses,* DOE-STD-3009-94, CN 3, March 2006.