DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

August 26, 2013

Mr. Bruce Held
Acting Administrator
National Nuclear Security Administration
U. S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0701

Dear Mr. Held:

The Defense Nuclear Facilities Safety Board (Board) has reviewed updated safety basis and design information for the Uranium Processing Facility (UPF) project at the Y-12 National Security Complex and concludes that the National Nuclear Security Administration (NNSA) has made progress in addressing prior issues communicated in an April 2, 2012, letter to the NNSA Administrator; nevertheless, additional action is needed to improve the integration of safety in the UPF design. The Board believes that NNSA must continue to improve the effectiveness of UPF's safety controls and strengthen oversight to ensure planned controls can reliably perform their safety functions.

The Board's recent review identified a number of issues that warrant timely corrective action to ensure compliance with Department of Energy (DOE) requirements. These issues are described in the enclosed report. The Board is concerned that NNSA's safety basis review and approval process did not identify and address a series of issues that involve weaknesses in planned UPF safety controls. However, the Board notes that staff-level discussions with NNSA and UPF project personnel have produced positive initial steps in defining resolution strategies for most of these problems. Additionally, moving forward the Board will carefully review the safety implications of continued facility re-design to address space/fit issues.

The enclosed report also documents technical deficiencies in UPF's atmospheric dispersion modeling, which is a key input to accident consequence calculations that determine the functional classifications for UPF safety controls. While the Board's independent analysis of current UPF project data concludes that correcting these technical deficiencies in atmospheric dispersion parameters will not alter the classification of NNSA's planned safety controls, the technical problems with atmospheric dispersion modeling are not unique to the UPF project. Therefore, the Board calls your attention to our atmospheric dispersion-related input into the ongoing revision process for DOE Standard 3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses*, as referenced in the Board's letter to Secretary Moniz dated July 24, 2013. The Board believes this information will aid

NNSA in ensuring future atmospheric dispersion modeling efforts are technically sound and reasonably conservative.

Early and effective integration of safety into design is critically important for the success of the UPF project. Therefore, pursuant to 42 U.S.C. § 2286b(d), the Board requests a report and briefing within 60 days of receipt of this letter describing (1) NNSA's plan and schedule for addressing the issues detailed in the section titled, "Open Issues with the UPF Safety Basis," in the enclosed report and (2) NNSA's plan to strengthen oversight of control selection and evaluation processes for the UPF project.

Sincerely,

Peter S. Winokur, Ph.D.
Chairman

Enclosure

c: Mr. Steven C. Erhart
Mr. Robert B. Raines
Mr. John R. Eschenberg
Mrs. Mari-Jo Campagnone

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

July 24, 2013

MEMORANDUM FOR: S. A. Stokes, Acting Technical Director

COPIES: Board Members

FROM: B. Broderick

SUBJECT: Summary of Open Issues with the Safety Basis for the Uranium Processing Facility Project, Y-12 National Security Complex

The staff of the Defense Nuclear Facilities Safety Board (Board) has reviewed updated safety basis and design documentation for the Uranium Processing Facility (UPF) project at the Y-12 National Security Complex (Y-12). This report summarizes open issues with the UPF safety basis. Open issues are defined as areas where the Board's staff believes that additional management attention and action are necessary to bring aspects of existing UPF safety analysis and control strategies into full compliance with Department of Energy (DOE) requirements. Open safety basis-related issues documented in this report include concerns identified during reviews performed by the Board's staff, as well as previously communicated Board concerns that have not yet been successfully resolved. This list of open issues reflects the current state of the Board's staff review of the UPF project. The list will continue to evolve as project personnel complete corrective actions and as the Board's staff conducts future reviews to evaluate changes to the UPF safety basis and design as the project matures.

Background. On April 2, 2012, the Board issued a letter to the Administrator of the National Nuclear Security Administration (NNSA) that highlighted a number of areas where the UPF project's existing safety analysis and control strategies did not satisfy DOE requirements, resulting in inadequate integration of safety in the UPF design. NNSA management provided a final response to the Board's letter on June 27, 2012, and committed to implement a number of corrective actions. A critical component of NNSA's corrective action plan called for UPF project personnel to revise the Preliminary Safety Design Report (PSDR), which serves as the project's safety basis for the current stage of design. UPF project personnel submitted Revision 1 of RP-EF-801768-A004, *Preliminary Safety Design Report for the Uranium Processing Facility* (PSDR Rev. 1), to the NNSA Production Office (NPO) in September 2012. NPO management approved this revision via PSVR-9226-R0, *Preliminary Safety Validation Report for the Uranium Processing Facility (Building 9226) Preliminary Safety Design Report September 2012* (PSVR), in March 2013. The Board's staff evaluated PSDR Rev.1 and its supporting documentation in an onsite review conducted in March 2013 and held a follow-up teleconference with UPF and NNSA personnel in May 2013.

Open Issues with the UPF Safety Basis. The Board's staff notes that constructive interactions with NNSA and UPF project personnel during recent review activities have resulted in positive initial steps in defining effective resolution strategies for many of the open issues documented below. UPF personnel have begun executing some of these resolution strategies, e.g., submitting a proposed revision to RP-FS-801768-A003, *Safety Design Strategy for the Uranium Processing Facility*. Additionally, NPO management included in their PSVR a set of Conditions for Proceeding to the Next Stage of Design that are relevant to several of the fire- and explosion-related open issues described below.

Fires Involving Staged Canned Sub-Assemblies—Several UPF process areas will house staging locations for Canned Sub-Assemblies (CSAs). Some CSAs contain highly hazardous toxic materials that can be released or react energetically if subjected to sufficient thermal energy from a fire. The safety-significant fire protection system is credited to control fires to prevent energetic events or significant releases of toxicological material. DAC-EF-801768-A049, *Assessment of UPF Fires to Support the Preliminary Safety Design Report (U)*, indicates that for some fire scenarios involving CSAs, the fire protection system would not actuate or actuation would be delayed. For these scenarios, UPF safety analysis has not demonstrated that the fire protection system's current functional requirements and performance criteria are sufficient to ensure that the system will perform its credited safety function to prevent energetic events or significant releases of toxicological material. This situation does not comply with the UPF code of record, DOE Order 420.1B Change 1, *Facility Safety*, Section 3.b.(7), which states, "Safety SSCs [structures, systems, and components] and safety software must be designed, commensurate with the importance of the safety functions performed, to perform their safety functions when called upon ..."

Glovebox Fires—Gloveboxes in UPF's disassembly and quality evaluation process areas can house pyrophoric materials and CSA components that contain highly hazardous and thermally-reactive materials. Under normal operating conditions, these gloveboxes are provided with an inert gas atmosphere that does not allow combustion. However, the features that provide this inert atmosphere are not credited safety controls, and the inert environment can be lost under credible accident conditions (e.g., a seismic event that breaches the confinement integrity of a glovebox). If the inert environment is lost, oxygen intrusion into the glovebox could cause pyrophoric material to ignite, initiating a glovebox fire. If seismically-induced common cause failures result in multiple glovebox fires, then hazardous material releases from CSA components could exceed public or collocated worker toxicological consequence thresholds defined by Appendix B of DOE-STD-1189, *Integration of Safety into the Design Process*. The safety-significant fire protection system is credited to prevent significant fire-driven toxicological releases. However, sprinklers associated with the fire protection system are located outside of gloveboxes, so they cannot be relied upon to protect CSA components from being compromised by fires inside gloveboxes. This situation does not comply with Section 3.b.(7) of DOE Order 420.1B Change 1.

Aircraft Crashes—PSDR Rev. 1 analyzes an aircraft crash as a design basis accident for the UPF main building but does not analyze aircraft crash scenarios for ancillary UPF structures such as the Highly Enriched Uranium Materials Facility Connector, the Loading Dock/Truck Bay, or the Enclosed Dock/Dock Vestibule. PSDR Rev. 1 concludes that aircraft crash evaluation for ancillary structures is not required because, individually, the frequency of an aircraft impacting each structure would be below the guideline of 10^{-6} per year established by DOE-STD-3014, *Accident Analysis for Aircraft Crash into Hazardous Facilities*. However, the standard defines a facility to include "the collection of such structures that could be affected by a single aircraft impact." PSDR Rev. 1 did not account for the potential of a single aircraft to impact multiple structures, which may require that ancillary structures be designed for aircraft crash impacts. This situation does not comply with Section I.1.1 of DOE-STD-1189 which states that a PSDR must demonstrate that "the analysis of DBAs [design basis accidents] identifies the functional requirements and accident conditions (e.g., environmental qualifications) that the safety SSCs need to address."

Project personnel have indicated that recent evaluations performed by UPF analysts concluded that the estimated frequencies of aircraft crashes involving these ancillary structures exceed the DOE-STD-3014 guideline. UPF safety analysts therefore concluded that aircraft crash scenarios must be analyzed as design basis accidents for ancillary UPF structures.

Non-Seismic Natural Phenomena Hazards and Man-Made External Events—PSDR Rev. 1 credits UPF structures to provide protection against a broad range of natural phenomena hazards and man-made external events. However, PSDR Rev. 1 does not clearly link the identified functional requirements and performance criteria for UPF structures to the specific accident stresses that they are credited to protect against for all design basis accidents. Important structural attributes may not be effectively captured and incorporated into the design if functional requirements and performance criteria for UPF structures are not clearly linked to the accident-driven environmental conditions these structures are credited to withstand. For example, PSDR Rev. 1 credits the UPF main building structure to protect hazardous materials and safety systems from external fires and explosions. The accident analysis identifies vehicle impacts and wildfires as potential initiators for external fires and explosions, but these accident initiators and their associated environmental stresses are not captured in the UPF main building's functional requirements or performance criteria to be factored into the design of the structure. This situation does not satisfy Section 4.3.X.3 of DOE-STD-3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses,* which states that "[f]unctional requirements specifically address the pertinent response parameters or nonambient environmental stresses related to an accident for which the [credited control's] safety function is being relied upon."

Concurrent Releases of Multiple Hazardous Materials—Some UPF fire scenarios (e.g., disassembly or quality evaluation process area glovebox fires) can concurrently release multiple hazardous chemicals. PSDR Rev. 1 and its supporting analyses do not evaluate the potential for concurrently released chemicals to have compounding toxicological effects. As a result, PSDR Rev. 1 determines the need to credit controls to prevent or mitigate toxicological hazards based solely on the potential for any single chemical to exceed public or collocated worker exposure thresholds. DAC-EF-801768-A049, *Assessment of UPF Fires to Support the Preliminary Safety Design Report (U)*, acknowledges that this approach is not conservative and notes that UPF analysts will assess potentially compounding toxicological effects from concurrently released chemicals in future safety basis documentation. However, the existing PSDR Rev. 1 analysis does not comply with the provisions for analyzing chemical mixtures described in Section B.4 of

DOE-STD-1189 and could result in the need to credit additional controls when the cumulative consequence effects of concurrently released chemicals are evaluated.

Dust Explosions—Processing activities in disassembly, quality evaluation, and Saltless Direct Oxide Reduction (SDOR) gloveboxes can generate suspended pyrophoric or reactive dusts. According to existing UPF Hazard Evaluation Studies, these suspended dusts can produce explosions that could seriously injure facility workers. PSDR Rev.1 credits safety-significant controls to protect facility workers from dust explosion hazards associated with these gloveboxes. Under normal operating conditions, affected gloveboxes are provided with an inert gas atmosphere that prevents the rapid combustion reaction necessary to produce a dust explosion. However, the features that provide this inert atmosphere are not credited safety controls, and the inert environment can be lost under credible upset or accident conditions.

PSDR Rev. 1 credits the safety-significant lathe cutting control interlock to prevent a dust explosion by securing cutting operations if upset or accident conditions cause significant amounts of oxygen to enter disassembly or quality evaluation gloveboxes when suspended dust is present. Securing cutting operations removes one ignition source; however, current UPF safety analysis has not ruled out the potential for pyrophoric material to ignite suspended dust if the inert glovebox atmosphere is lost, initiating a dust explosion. Therefore, PSDR Rev. 1 has not demonstrated that the safety-significant lathe cutting control interlock is sufficient to prevent a dust explosion in disassembly and quality evaluation gloveboxes. This situation does not comply with Section 3.b.(7) of DOE Order 420.1B Change 1.

PSDR Rev. 1 credits the design of certain SDOR gloveboxes to protect facility workers from serious injuries resulting from dust explosions. These safety-significant SDOR gloveboxes are credited to confine dust explosion overpressures. However, UPF analysts have not demonstrated that polymer gloves associated with these gloveboxes are capable of surviving a dust explosion. Facility workers could be seriously injured if dust explosion overpressures are vented through glovebox openings created by failed gloves. This situation does not comply with Section 3.b.(7) of DOE Order 420.1B Change 1.

Violent Chemical Reactions—Chemical dissolution activities associated with basket dissolver and beaker leaching unit operations in the special oxide production process area can result in violent chemical reactions that forcefully expel heated chemical agents from process vessels. PSDR Rev. 1 does not identify any credited controls to protect facility workers from chemical burns resulting from these violent chemical reactions. The current UPF safety basis has not demonstrated how this approach complies with Appendix C of DOE-STD-1189 that identifies "chemical or thermal burns to a FW [facility worker] that could reasonably cover a significant portion of the FW body where self-protective actions are not reasonably available due to the speed of the event" as a hazardous condition that warrants consideration of safety-significant controls.

Organic Material Combustion in the Calciner—Chemical recovery processes upstream of the high temperature calciner contain organic material used for solvent extraction. If combustible organics are introduced into the calciner when heated to its normal operating temperature (roughly 1400 °C), rapid combustion of the organic material could release enough energy to rupture the calciner unit and injure facility workers. Earlier in UPF's design evolution, upstream phase separators were credited as safety-significant controls to prevent bulk transfer of organic material into heated equipment. Recently, UPF project personnel downgraded the functional classification of phase separators and instead credited more reliable and effective temperature interlocks to protect heated equipment. However, a temperature interlock is not feasible for the calciner which is designed and intended to operate at very high temperatures. This leaves the calciner without a credited control to prevent the introduction of organics that could rapidly combust, over-pressurize the system, and seriously injure facility workers. This situation does not comply with Section 3.b.(7) of DOE Order 420.1B Change 1.

Steam Overpressure in Casting Furnaces—Water intrusion into a casting furnace vessel during high-temperature operations can cause a violent steam overpressure event that could seriously injure facility workers. PSDR Rev. 1 credits the primary system integrity of the casting furnace vessel and its supporting equipment to prevent water ingress. The safety-significant primary system integrity control establishes a water-tight boundary formed by the shell of the furnace vessel and its connected piping and equipment. This boundary prevents water that originates outside the system from entering the high temperature furnace. However, PSDR Rev. 1 also identifies mechanisms for water to enter the heated furnace from sources inside the system's water-tight boundary due to credible upsets in ventilation or utility gas systems that are plumbed directly into the furnace vessel. PSDR Rev. 1 does not demonstrate how the safety-significant primary system integrity control can effectively prevent steam overpressure events caused by water ingress from these internal sources. This situation does not comply with Section 3.b.(7) of DOE Order 420.1B Change 1.

Hydrogen Explosion in the Hydrogen Reduction Fluidized Bed Reactor—A hydrogen explosion could occur in the enriched uranium purification and metal production process if oxygen is present when pure hydrogen gas is introduced into the fluidized bed reactor vessel to begin a hydrogen reduction evolution. The current UPF safety strategy relies on operator action to purge oxygen from the reactor vessel using inert gas prior to starting reduction operations to prevent a hydrogen explosion. However, PSDR Rev. 1 does not credit this operator action as a Specific Administrative Control (SAC), even though it is relied upon to prevent an event that could result in serious facility worker injuries. This situation does not comply with Section 1.2 of DOE-STD-1186, *Specific Administrative Controls*, which states that "an SAC exists when an AC [administrative control] is identified in the Documented Safety Analysis (DSA) as a control needed to prevent or mitigate an accident scenario, and has a safety function that would be SS [safety-significant] or SC [safety-class] if the function were provided by an SSC."

Hydrogen Explosion in the Assembly Environmental Room—Hydrogen would be released if water reacted with lithium hydride or lithium deuteride compounds used in the UPF assembly process area. A significant quantity of these water-reactive materials will be present in the assembly environmental room that is equipped with a wet pipe fire suppression system. PSDR Rev. 1 did not evaluate the potential for a hydrogen explosion in the assembly environmental room if credible upset conditions allow water to interact with lithium compounds, causing hydrogen to accumulate inside the enclosure. Appendix C of DOE-STD-1189 identifies deflagrations or explosions within confinement structures that may result in serious facility worker injuries as a hazardous condition that warrants consideration of safety-significant controls.

Damage Ratio of 0.1—PSDR Rev. 1 assumes that only 10 percent of enriched uranium metal material at risk (MAR) located in storage racks would be impacted and made available for release by seismically-induced fires. The PSDR implements this assumption by assigning the Damage Ratio (DR) variable a value of 0.1 for uranium metal in storage racks. This DR value is derived from the empirical results from a series of experiments conducted at Los Alamos National Laboratory (LANL) where uranium metal specimens were heated for two hours under controlled laboratory conditions.

The Board's staff believes that these experimental conditions are not a reasonably conservative representation of the unmitigated seismically-induced UPF fire environment for several reasons. First, the postulated seismically-induced fire scenario analyzed in PSDR Rev. 1 assumes MAR is exposed to fire temperatures for three hours, whereas the referenced LANL experiments only subjected uranium to elevated temperatures for two hours. Increasing the amount of time uranium metal is exposed to high temperatures tends to result in greater oxidation and higher DRs. Second, the cited LANL experiments subjected uranium specimens to controlled temperatures, and thus did not account for the significantly increased uranium oxidation that can result from temperature fluctuations that thermally cycle the exposed material. The unmitigated seismically-induced UPF fire environment could exhibit significant temperature fluctuations as burning combustibles are consumed and new combustibles ignite. Therefore, the Board's staff believes that the UPF project does not have adequate data to support the use of a DR of 0.1 as a reasonably conservative input parameter consistent with Section A.3 of DOE-STD-3009.

Atmospheric Dispersion Modeling. The results of UPF accident consequence calculations depend heavily on the degree of dispersion and dilution that a plume of released material is assumed to experience in the atmosphere as it travels from the facility in an accident. Atmospheric dispersion effects are represented by the relative concentration factor (χ/Q). Changes to χ/Q affect accident consequence calculations used to determine the functional classification of UPF safety controls. In an April 2, 2012, letter to the NNSA Administrator, the Board communicated concerns with the conservatism of the analysis used to derive a Y-12 site-specific dry deposition velocity value of 1.0 cm/s. Dry deposition velocity is a key input parameter for calculating χ/Q. In response to the Board's concerns, UPF project personnel requested that the NNSA Administrator, as NNSA's Central Technical Authority (CTA), review and concur on the project's derivation and selection of dry deposition velocity and χ/Q values. In June 2012, the NNSA Administrator issued a memorandum providing formal concurrence with the UPF project team's selection of atmospheric dispersion parameter values. The Board's staff has reviewed the CTA concurrence memo and its supporting documentation and believes that for UPF, a dry deposition velocity value of 1.0 cm/s is not reasonably conservative or consistent with recent DOE guidance on deposition velocity calculations. As a consequence, the Board's staff believes the resulting χ/Q value is not technically justified. The rationale for this conclusion is presented below. Despite continued concerns that UPF values for dry deposition velocity and χ/Q are not reasonably conservative per Section A.3 of DOE-STD-3009, the Board's staff performed independent analysis of current UPF project data and concluded that correcting these non-conservatisms would not increase postulated accident consequences enough to require the functional classification of UPF safety controls to be upgraded to safety-class.

PSDR Rev. 1 uses a χ/Q value of 1.4×10^{-4} s/m^3 to calculate accident consequences to the public from releases of hazardous particulates. UPF project personnel calculated this χ/Q value using MACCS2 computer software and the statistical post-processing code POSTMAX. This analysis used a site-specific dry deposition velocity value of 1.0 cm/s as a key input parameter. UPF project personnel also prepared a separate confirmatory analysis that is nominally based on Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants.* The NRC approach used in the confirmatory analysis does not require dry deposition velocity as an input and was intended to bolster confidence in the technical credibility and conservatism of the 1.4×10^{-4} s/m^3 result produced by the MACCS2/POSTMAX analysis.

In Safety Bulletin 2011-02, *Accident Analysis Parameter Update*, the DOE Office of Health, Safety and Security recommended that safety analysts use a model like GENII2 to calculate reasonably conservative site-specific dry deposition velocity values. The Y-12 site-specific deposition velocity calculation applies the equations that underpin the GENII2 code, but the calculation departs from the GENII2 default treatment of important parameters related to transfer resistance and displacement height. The GENII2 default value for the transfer resistance of particles is 100 s/m. The Y-12 analysis uses a scaling equation to produce a less conservative value of approximately 25 s/m, but no technical derivation or rationale is provided by site analysts to justify the use of this scaling equation. The Y-12 deposition velocity analysis also applies a displacement height of roughly 8 m. GENII2 inherently assumes a displacement height of 0 m and does not give the user the option of inputting a non-zero value. The Y-12 analysts' selection of a non-zero displacement height produced a less conservative dry deposition velocity value. Displacement height is a wind profile parameter. The displacement height assumptions used in the Y-12 site-specific deposition velocity analysis are not consistent with actual wind profiles measured at Y-12. Finally, Savannah River Site personnel commissioned a deposition velocity sensitivity study by the atmospheric dispersion experts from Pacific Northwest National Laboratory (PNNL) who created and maintain the GENII2 code. For conditions applicable to Y-12, the PNNL sensitivity analysis would produce a significantly lower and more conservative dry deposition velocity value that would fall near 0.2 – 0.3 cm/s.

The UPF confirmatory χ/Q analysis is nominally based on the methodology established by NRC Regulatory Guide 1.145. However, this confirmatory analysis uses Briggs Urban dispersion parameters in most wind directions, while many of the methods and equations in the Regulatory Guide were developed for Pasquill-Gifford parameters and are not applicable for use with other sets of dispersion parameters, such as Briggs Urban. The UPF confirmatory analysis also uses the solar radiation/delta temperature method for assigning atmospheric stability classes, rather than the delta temperature method prescribed by the Regulatory Guide. Finally, the UPF confirmatory analysis statistically infers the 95th percentile χ/Q value rather than calculating it directly, as expected by the Regulatory Guide.

Conclusion. Early and effective integration of safety into design is critically important for the success of this multibillion-dollar project that is needed to establish a modern, safe, and secure replacement facility for uranium processing and manufacturing capabilities currently housed in aging or unsound Y-12 facilities. The Board's staff concludes that the open issues discussed above warrant additional management attention and action to ensure effective integration of safety in the UPF design and to achieve full compliance with DOE requirements. For many of these open issues, the safety analysis has not demonstrated that credited controls are capable of effectively performing their safety functions. The Board's staff believes that this common theme highlights an opportunity to strengthen the UPF project's processes governing control selection and evaluation and NNSA's oversight of these processes.

The Board's staff also concludes that a dry deposition velocity value of 1.0 cm/s is not reasonably conservative for UPF, and that the associated χ/Q value of 1.4×10^{-4} s/m^3 has not been technically justified. However, the Board's staff performed an independent analysis of current UPF project data and concluded that correcting the non-conservatisms in atmospheric dispersion modeling would not increase postulated accident consequences enough to require the functional classification of UPF controls to be upgraded to safety-class.