DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

January 24, 2022

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

Dear Secretary Granholm:

As part of its statutory role, the Defense Nuclear Facilities Safety Board (Board) reviews the design of new Department of Energy (DOE) facilities before and during their construction to make recommendations to the Secretary to ensure adequate protection of public health and safety. The Board recognizes DOE's approval of Critical Decision-1 for the Savannah River Plutonium Processing Facility (SRPPF) at the Savannah River Site, which marks completion of the project definition phase and the conceptual design.

The Board has completed a review of the SRPPF conceptual design package. The enclosed report, provided for your information and use, describes eight safety observations that should be addressed as the project advances into preliminary design to further improve safety at SRPPF. The Board and its staff will continue to evaluate the facility design as it develops.

Sincerely,

Joyce L. Connery

Joyce L. Connery
Chair

Enclosure

c: Mr. Joe Olencz

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Report

November 5, 2021

Conceptual Design Review of the Savannah River Plutonium Processing Facility

Summary. The Defense Nuclear Facilities Safety Board's (Board) staff reviewed safety basis and design information supporting the Critical Decision-1 (CD-1) milestone[1] for the Savannah River Plutonium Processing Facility (SRPPF). The staff identified eight safety observations that should be addressed as the project progresses into preliminary design. A brief summary of these safety observations is included below:

1. *Approach to Facility Worker Protection Following an Accident Is Underdeveloped*—The conceptual design does not provide sufficient information to determine that facility worker protection following an accident was adequately considered.

2. *Seismic Qualification of Sand Filter Media Is a Project Safety Risk*—The sand filter media must maintain its filtering capability during and following an earthquake, but the method to ensure this safety requirement is met is not well defined.

3. *Portions of the Accident Analysis Underestimate the Radiological Release from a Seismic Event*—The selected airborne release fraction (ARF) and respirable fraction (RF) for dispersible powder in a seismic event are nonconservative.

4. *Use of Type A Waste Container in the Safety Analyses Is Not Protected*—Contrary to the Department of Energy's (DOE) safety requirements, transuranic (TRU) waste containers are not credited as an initial condition in the safety analyses.

5. *Safety Analyses Inadequately Document Potential Explosion Events*—The current safety analyses provide insufficient documentation of assumptions supporting the overall accident progression for some explosion events, the resulting amount of radiological material released, and the basis for selecting safety controls.

6. *Facility Structure Has Life Safety Challenges that Present Project Risk*—Because the SRPPF structure was originally designed for low occupancy for the Mixed Oxide Fuel Fabrication Facility project, the as-constructed layout must be shown capable of supporting the egress of the substantially increased number of occupants needed for the pit manufacturing mission.

[1] CD-1 is the second of five critical decisions that mark milestones toward project completion. Each CD has prerequisites for advancement defined in DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*[1]. The order states: "CD-1 approval marks the completion of the project definition phase and the conceptual design."

7. *Glovebox Systems May Warrant Classification as Safety Systems*—The safety analyses do not credit the gloveboxes, glovebox ventilation, or glovebox inerting systems as safety controls, which is nonconservative for the conceptual design.

8. *Code of Record Does Not Include Some Consensus Standards*—Project personnel removed some consensus documents used to design structures, systems, and components (SSC) from the code of record, which does not meet its intent as a complete set of source documents used to design and construct the facility.

Background. SRPPF is a new hazard category 2 defense nuclear facility with a design life of at least 50 years. Its mission is to annually produce at least 50 war reserve plutonium pits—a critical component of modern nuclear weapons. The National Nuclear Security Administration (NNSA) plans to repurpose the partially constructed building for the Mixed Oxide Fuel Fabrication Facility (i.e., Building 226-F located at the F-Area of the Savannah River Site) for the SRPPF project (see Figure 1). NNSA also plans to construct new support facilities and repurpose several others that are constructed or partially constructed surrounding Building 226-F. In October 2020 and March 2021, NNSA completed design and independent project reviews of the conceptual design, as required prior to CD-1 per DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*. NNSA approved CD-1 on June 25, 2021.

Figure 1. *An aerial photograph of the existing structures at the SRPPF site.*

The staff observed NNSA's design and independent project review meetings virtually. The staff transmitted two review agendas to NNSA—one on April 23, 2021, and another on May 10, 2021. On June 14–15, July 26–28, and August 2, 2021, NNSA, contractors, and the staff held virtual meetings on the two agendas. NNSA and its lead contractor, Savannah River Nuclear Solutions, LLC (SRNS), provided written responses to more than 200 lines of inquiry in the staff's agendas. The staff found that NNSA and SRNS were well prepared for all meetings, cooperative, and fully transparent. On September 23, 2021, the staff conducted a factual accuracy meeting with NNSA and SRNS to conclude its review.

Discussion. The staff reviewed the safety basis and design documents associated with the CD-1 milestone, which included the safety design strategy [2], the conceptual safety design report (CSDR) [3], hazard and accident analyses [4, 5], and other supporting documents. The objective of the review was to understand and evaluate how NNSA integrated safety into the design of the facility. The staff identified eight safety observations that are discussed below:

Observation 1: Approach to Facility Worker Protection Following an Accident Is Underdeveloped—The magnitude of postulated accidents considered in the CSDR suggests that airborne contamination levels surrounding the facility could still be elevated following mitigation by safety systems. Following accidents, the A-Wing and P-Wing will house facility workers and have ventilation systems that will draw approximately 25 percent of their airflow from the outside (see Figure 2). However, these ventilation systems contain no air cleaning equipment to remove airborne radioactive material.

Figure 2. *The three wings of Building 226-F at the Savannah River Site. A-Wing and P-Wing have non-safety recirculation ventilation systems and will house workers following an accident.*

The A-Wing of the facility contains an area of refuge that will house an estimated 700 facility workers, who will evacuate from M-Wing process areas following accidents. The CSDR credits the area of refuge as a safety significant[2] control to "[m]itigate radiological material releases to evacuated FW [facility worker] following accidents for which the appropriate protective action would be evacuation…." The P-wing contains the central control room, which according to project documents will "act as an emergency management center in the event of an incident [6]."

DOE Order 151.1D, *Comprehensive Emergency Management System*, and its associated guides provide applicable requirements and guidance for protection of workers following

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[2] Safety significant controls are intended to provide a major contribution to defense-in-depth and/or worker protection from accidents. These controls supplement safety class controls designed to protect the public.

accidents [7]. DOE Order 151.1D states that DOE facilities must identify protective actions for workers that are commensurate with potential hazards. It states: "Protective actions must be predetermined and serve to minimize emergency-related consequences and maximize life safety and health." DOE Guide 151.1-4, *Response Elements Emergency Management Guide*, states: "People who remain inside a shelter where the air is contaminated by infiltration from the passing plume will ultimately receive about the same cumulative inhalation dose or exposure as would an unprotected person exposed to the same plume [8]."

Project personnel stated that they plan to increase the height of the facility exhaust stack to reduce airborne radioactive material concentrations at the ventilation intakes to an acceptable level following an accident. Such an approach would need to ensure a sufficient reduction in contamination levels at the ventilation intakes for bounding atmospheric conditions. If this approach is shown to be infeasible for any reason, it would pose a project risk such that additional means of protecting workers would be required.

Observation 2: Seismic Qualification of Sand Filter Media Is a Project Risk—The CSDR credits the active confinement ventilation system, including its sand filter, as safety class. A safety class control is intended for public protection. The active confinement ventilation system is required to "provide filtration during and following a seismic event with subsequent fires and explosions [3]." Accordingly, the active confinement ventilation system is being designed to seismic design category-3.

DOE Order 420.1C, *Facility Safety*, states that safety SSCs "must be designed to perform their safety functions when called upon [9]." The order specifies American Society of Mechanical Engineers (ASME) AG-1, *Code on Nuclear Air and Gas Treatment*, as a code for safety-related filtration systems [10]. ASME AG-1 states: "The DBS [deep bed sand] filter shall be designed to survive and maintain operability through all natural phenomena hazards applicable to the location of the DBS filter (e.g., tornados, earthquakes, and hurricanes)." ASME AG-1 does not specify design criteria for the sand filter media, but includes guidance stating: "A large-scale DBS filter mock-up is needed to support seismic calculations….Testing of the mock-up will provide validation of the response of the DBS filter structure and media to a design basis earthquake." Figure 3 provides an example of typical sand filter media.

In October 2020, NNSA's design review team identified a safety risk associated with seismic qualification of the sand filter media. At that time, SRNS dispositioned the comment by stating it would document a project risk and validate that sand filter media testing was included in the project schedule [11]. During discussions with the staff, project personnel communicated a changed position. Project personnel indicated that they would use analytical methods instead of performing sand filter media testing. Project personnel identified numerous failure modes of the sand filter media and stated that they plan to evaluate or disposition these failure modes in a manner similar to other sand filters deployed at the Savannah River Site. Seismic qualification of a sand filter has not been performed at the Savannah River Site for more than 25 years. In the absence of experimental validation specific to the SRPPF design, the staff concludes that the sand filter media seismic qualification is not well defined and represents a project risk.

Figure 3. *A vertical slice of a sand filter design used at the Hanford Site. Air enters the bottom and rises up through the sand filter media. The bottom layers of the sand filter media are composed of course rock with subsequent layers made of smaller material followed by a cap layer at the top.*

Observation 3: Portions of the Accident Analysis Underestimate the Radiological Release from a Seismic Event—The accident analysis calculation for an earthquake is generally conservative, but the staff identified one non-conservative aspect involving the ARF and RF selected for dispersible powders (i.e., plutonium oxide, plutonium hydride, and uranium oxide). ARFs and RFs are selected from DOE Handbook 3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, based on their applicability to the accident scenario [12]. ARFs and RFs are an important parameter in determining the unmitigated doses to the public and co-located worker, which are used to determine whether safety class or safety significant controls are required.

For a seismic event, project personnel selected ARF and RF values for dispersible powder defined in DOE Handbook 3010-94 as applicable to "vibration of substrate from shock-impact to powder confinement (e.g., gloveboxes, cans) due to falling debris or external energy (e.g., seismic vibrations)." From a review of the experimental setup used to derive these data, the staff concludes that these ARF and RF values would be applicable to seismic scenarios where gloveboxes containing the powder remained upright but could be impacted from falling objects. The CSDR does not credit gloveboxes containing these powders for remaining upright during and after a bounding seismic scenario.

There are other ARF and RF values for dispersible powder from the handbook that are applicable to a free fall that could occur when a glovebox topples in a seismic event. These ARF and RF values are six times higher than the ones selected by SRPPF project personnel. The staff concludes these values are the more conservative choice in the unmitigated analysis since gloveboxes could topple and subject the powder to a free fall.

DOE Standard 3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, states: "Calculations shall be made based on technically-justified input parameters and underlying assumptions such that the overall consequence calculation is conservative. Conservatism is assured by the selection of bounding accident scenarios, the use of a conservative analysis methodology, and the selection of source term and input parameters that are consistent with that methodology [13]." It also states: "The initial conditions and assumptions for the analysis shall be documented and evaluated to determine if controls are needed to maintain the validity of the evaluation."

Project personnel stated that significant amounts of these dispersible powders are not expected to be in open containers, which justifies using the lower ARF and RF values. Additionally, with proper anchoring, glovebox toppling during a seismic event may be precluded. The staff concludes that the ARF and RF values selected by project personnel would be valid if the design precluded gloveboxes from toppling during an earthquake, or if operations personnel controlled the amount of radioactive powders outside of securely closed and credited containers. Project personnel would need to document these assumptions and analyze the need to protect them in the safety analyses according to the requirements in DOE Standard 3009-2014.

Observation 4: Use of Type A Waste Containers in the Safety Analyses Is Not Protected—Initial conditions are used in hazard and accident analyses, which determine the need for safety controls to protect the public and workers. DOE Standard 3009-2014 defines initial conditions as "specific assumptions regarding a facility and its operations that are used in defining accident scenarios" and requires that they be "documented and evaluated to determine if controls are needed to maintain the validity of the evaluation." The accident analysis uses release parameters from DOE Standard 5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, for accidents involving containers of TRU waste [14]. According to this standard, these parameters apply to Type A containers of sound integrity, which the staff concludes is an initial condition that is not identified or protected in the safety analyses.

DOE Standard 3009-2014 provides the following specific example of an initial condition in hazard and accident analyses: "Solid transuranic waste is contained in a certified Department of Transportation (DOT) Type-A drum." Additionally, a revised version[3] of DOE Standard

[3] DOE Standard 5506-2021 was issued after NNSA's CD-1 approval and was not included in the code of record for the SRPPF project at the time of the staff's review.

5506 was issued in August 2021 [15]. It states: "The integrity of the outer waste container…should be classified as SS [safety significant] or SC [safety class] in accordance with DOE-STD-3009-2014 if relied on to prevent significant consequences."

The Savannah River Site already mandates use of Type A containers through a site-wide safety management program. However, the SRPPF CSDR does not identify the containers as an initial condition or evaluate whether the containers should be credited as a safety-related control. Designating the containers as safety significant would drive formal surveillances that the staff concludes are important for verifying the container integrity and safety function (e.g., lid torque, container and filter condition, etc.). Some other sites in the DOE complex credit containers in their safety analyses but this practice has not yet been adopted at the Savannah River Site. Project personnel stated that crediting the containers as an initial condition is currently under consideration for consistent site-wide application.

Observation 5: Safety Analyses Inadequately Document Potential Explosion Events—The current safety analyses provide insufficient documentation of assumptions supporting the (1) overall accident progression for some explosion events, (2) resulting amount of radiological material released, and (3) basis for selecting safety controls. The following are provided as examples:

- Hydrogen explosion events are assumed to not result in a module fire without explanation. Project personnel clarified that this is due to the assumed limited amounts of hydrogen fuel that would burn too rapidly to ignite combustibles. The CSDR does not document this assumption.

- A steam explosion in a foundry furnace is assumed to not result in a module fire. The CSDR does not document this assumption or its basis. Combining the explosion and the module fire consequences could result in a need for safety class controls. Project personnel stated that this event will be re-evaluated for plausibility in preliminary design once additional furnace design information is available.

- The accident progression for a thermal excursion in an ion exchange column does not explain why only one of the two columns experiences a high-pressure venting. Project personnel clarified that the event progression assumed that one column experiences a thermal excursion that ruptures the first column. The explosion in the first column ruptures the second column, which causes the resin in the second column to undergo a thermal excursion. Because the second column is already ruptured, it cannot undergo high-pressure venting. Additionally, this event is assumed to not result in a module fire. The CSDR does not document these assumptions.

- Several explosion events involve furnaces containing molten plutonium. The CSDR does not document assumptions used in determining whether the furnaces maintain confinement. Project personnel clarified that they considered the energy available for the explosion and the location/orientation of the furnaces. The CSDR does not document this basis. Additionally, the safety control set for a seismic event with fire and explosions includes a safety class control—catch pan/safety can. This control has the safety function of "confining a spill of molten Pu [plutonium] metal to prevent a release from the glovebox during and following a seismic event with subsequent fire and explosion." This control is absent from the hazard evaluation tables for the individual explosion events containing molten plutonium.

DOE Standard 3009-2014 states: "The initial conditions and assumptions for the analysis shall be documented and evaluated to determine if controls are needed to maintain the validity of the evaluation." Project personnel agreed that documentation could be improved.

Observation 6: Facility Structure Has Life Safety Challenges that Present Project Risk—The SRPPF structure was originally designed for low occupancy for the Mixed Oxide Fuel Fabrication Facility project. SRPPF project personnel are analyzing whether the as-constructed facility can support the egress of the substantially increased number of occupants needed for the pit manufacturing mission during accident conditions. DOE Standard 1189-2016, *Integration of Safety into the Design Process*, requires important safety functions, including life safety, to be "addressed" during the conceptual design phase [16]. DOE Standard 1066-2016, *Fire Protection*, states that new facilities shall meet the applicable parts of the International Building Code and National Fire Protection Association standards for life safety [17].

Project personnel completed a proof of concept for a performance-based design, which is an approved alternative to meeting prescriptive life-safety code requirements (e.g., maximum egress travel distances). A performance-based design evaluates the development of fire conditions and determines whether occupants will be able to evacuate safely, given the available points of egress. The proof of concept concluded that the proposed models for fire and evacuation could be reasonably applied to analyze life safety at SRPPF. However, the proof of concept was based on a facility layout that has since changed and the models require refinement as the project's design advances. Project personnel identified multiple risks involving this approach, including one high safety risk, and plan to continue refining the effort early in preliminary design. The staff agrees that life safety is a project risk. If the performance-based design approach cannot demonstrate the safety of egressing occupants, then additional means of egress may be required.

Observation 7: Glovebox Systems May Warrant Classification as Safety Systems—The SDS identified the gloveboxes, glovebox ventilation, and glovebox inerting systems as potential safety systems, but at this stage, the CSDR has not identified them as safety systems. The staff finds that classifying some or all of these systems as safety-related at the conceptual design phase would be more consistent with DOE standards based on the following:

- DOE Standard 1189-2016 states: "At early stages of the design, lack of information on final approaches to safety suggests that conservative assumptions should be made to avoid costly changes later on." It also states: "To ensure that the initial cost estimates are realistic, the hazards analysis and the selection of major safety SSCs should be conservative. Initial selection of major safety SSCs and their design margins, therefore, should account for a wide range of uncertainties in hazards analyses and technology readiness." The standard includes confinement and fire protection systems as "major safety SSCs," which are "major contributors to project cost and schedule." The staff concludes that the gloveboxes, glovebox ventilation, and glovebox inerting systems likely meet this definition.

- DOE Standard 3009-2014 provides criteria for classification of systems as safety significant for major contribution to defense-in-depth. Notably, the standard includes a specific example where a glovebox ventilation system "provides a second mitigative SSC to back up a facility-level ventilation system." Gloveboxes are an integral part of such a system.

- DOE Standard 1189-2016 includes DOE's hierarchy of controls that prefers preventive rather than mitigative controls. For some accident scenarios (e.g., fires), the CSDR does not identify preventive safety controls and instead credits mitigative controls. While these are appropriate safety controls, the hierarchy of controls and the concept of defense-in-depth suggests supplementing them with preventive safety controls, if possible. Inerting systems provide a preventive control for fires within gloveboxes, particularly those initiated from pyrophoric materials like plutonium. The design includes glovebox inerting, but the CSDR does not include it as a safety control.

- The hierarchy of controls in DOE Standard 1189-2016 also includes a preference for controls closer to the hazard. The CSDR assumes facility workers can protect themselves during certain accident scenarios. Therefore, for these scenarios, the CSDR does not designate safety controls that are close to the hazard to protect the facility worker. Designating the gloveboxes, glovebox ventilation, and glovebox inerting systems as safety controls is a more reliable method for ensuring facility worker protection as compared to relying on the facility worker's ability to detect the hazard and quickly evacuate. The staff concludes that some potential scenarios may develop too quickly for the facility worker to avoid significant exposure before they evacuate.

- The staff reviewed other facilities in the DOE complex with plutonium glovebox operations and found that these facilities designate their gloveboxes and glovebox ventilation system as safety significant (see Table 1 below). Some of these facilities also have safety-related glovebox fire controls. SRPPF has similar hazards and operations, so similar considerations should apply.

Project personnel stated that these SSCs may be reclassified in the future as safety significant if warranted by safety analyses. There is a documented project risk that covers SSCs that may need to be upgraded by future safety analyses.

Table 1. *Facilities in the DOE complex with plutonium glovebox operations and the safety classification of the gloveboxes, glovebox ventilation, and glovebox fire control systems.*

Site	Facility	Gloveboxes	Glovebox Ventilation	Glovebox Fire Control Systems
SRS	SRPPF	Non-safety	Non-safety	Non-safety[4]
	Surplus Plutonium Disposition	Safety Significant	Safety Significant	Safety Class—Automatic extinguishment
	K-Area Interim Surveillance	Safety Significant	Safety Significant	Not Applicable—Safety significant room (vault) fire suppression only
LANL	Plutonium Facility	Safety Significant	Safety Significant	Non-safety—Mix of inert gas, manual extinguishment, automatic extinguishment
LLNL	Plutonium Facility	Safety Significant	Safety Significant	Safety Significant—Inert gas; Non-safety—Oxygen monitors
NNSS	Device Assembly Facility	Safety Significant	Safety Significant	Safety Significant—Oxygen analyzer; Non-safety—Inert gas

Observation 8: Code of Record Does Not Include Some Consensus Standards—Project personnel stated that certain consensus documents used to design SSCs (e.g., American Glovebox Society guidelines) will be removed from the code of record and recorded in lower-tier documents such as system design descriptions. The staff concludes this approach misses the intent of the code of record to be the complete set of source documents used to design and construct the facility. The staff also identified some discrepancies with the flow-down of requirements and criteria from the code of record to system design descriptions. The following statements apply:

- DOE Order 413.3B states that "the code of record shall serve as the management tool and source for the set of requirements used to design, construct, operate, and decommission nuclear facilities over their lifespan."
- DOE Standard 1189-2016 states: "The Code of Record (COR) and its supporting documents should be organized in a manner that supports accessibility, traceability, and maintainability."

Project personnel stated that the code of record would be limited to orders, codes, and standards. Project personnel also stated that they resolved the issues with the flow down of requirements to the system design descriptions with new document revisions.

Conclusion. The staff reviewed safety basis and design information supporting the CD-1 milestone for SRPPF. The staff identified eight safety observations that should be addressed as the design advances to preliminary design.

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[4] The CSDR credits an oxygen sensor and alarm as safety significant to "prevent radiological consequences to the FW [facility worker] from a hydrogen gas explosion inside of a glovebox by alerting the FW to take necessary actions." This control covers a small number of gloveboxes where hydrogen gas is used and does not address the pyrophoric hazard present in other gloveboxes.

References

[1] Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B, Change Notice 6, January 2021.

[2] Savannah River Nuclear Solutions, *Safety Design Strategy for Savannah River Plutonium Processing Facility*, N-SDS-F-00001, Revision 0, May 2019.

[3] Savannah River Nuclear Solutions, *Conceptual Safety Design Report for the Savannah River Plutonium Processing Facility*, S-CSDR-F-00001, Revision 0, October 2020.

[4] Savannah River Nuclear Solutions, *Preliminary Consolidated Hazards Analysis for the Savannah River Plutonium Processing Facility (SRPPF) Project*, S-CHA-F-00024, Revision 2, August 2020.

[5] Savannah River Nuclear Solutions, *Preliminary Accident Analysis for SRPPF Project*, S-CLC-F-00712, Revision C, August 2020.

[6] Savannah River Nuclear Solutions, *Savannah River Plutonium Processing Facility (SRPPF) Facility Design Description (FDD)*, P-FDD-F-00001, Revision 2, September 2020.

[7] Department of Energy, *Comprehensive Emergency Management System*, DOE Order 151.1D, Change 1, October 2019.

[8] Department of Energy, *Response Elements Emergency Management Guide*, DOE Guide 151.1-4, July 2007.

[9] Department of Energy, *Facility Safety*, DOE Order 420.1C, Change 3, November 2019.

[10] American Society of Mechanical Engineers, *Code on Nuclear Air and Gas Treatment*, AG-1, 2019.

[11] Stephens, W.D., *Response to NNSA-SRPPF-21-0002, SRPPF Conceptual Design Review Comments*, Letter to Mr. Scott Cannon, SRNS-P0000-2020-00108, October 27, 2020.

[12] Department of Energy, *Airborne Release fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, DOE Handbook 3010, Reaffirmed 2013.

[13] Department of Energy, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*, DOE Standard 3009, November 2014.

[14] Department of Energy, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, DOE Standard 5506, April 2007.

[15] Department of Energy, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, DOE Standard 5506, August 2021.

[16] Department of Energy, *Integration of Safety into the Design Process*, DOE Standard 1189, December 2016.

[17] Department of Energy, *Fire Protection*, DOE Standard 1066, December 2016.