DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

September 8, 2021

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

Dear Secretary Granholm:

The Defense Nuclear Facilities Safety Board (Board) continues to have safety concerns regarding the H-Canyon Exhaust Tunnel at the Savannah River Site. The Board shared its initial concerns with the Department of Energy (DOE) on December 16, 2015 and highlighted that the tunnel may not be capable of performing its safety-class confinement function during and after a design basis seismic event. The Board continued its oversight of H-Canyon and transmitted its observations in two further letters on May 17, 2018, and September 7, 2018. The contractor, Savannah River Nuclear Solutions, proposed an alternate safety strategy and updated its Documented Safety Analysis (DSA) in 2019. The DSA was subsequently approved by DOE in December 2019.

This new safety strategy relies on seismic structural qualification of the process vessels and their connectors, reduction in the material at risk, and a seismically evaluated portable compressed air system to remove flammable gases generated from radiolysis of the vessels' contents in a post-seismic condition to prevent detonation or deflagration events. These controls are to be maintained by implementation of Technical Safety Requirements (TSR) to ensure that members of the public and the workers are adequately protected from the hazards caused by a seismic event.

Recently, the Board's staff conducted a review of the DSA, TSR, and their supporting documents, identifying shortcomings that are described in detail in the enclosure to this letter. The staff's report is enclosed for your information and use.

Sincerely,

Joyce L. Connery

Joyce L. Connery
Chair

Enclosure

c: Mr. Joe Olencz

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Report

May 6, 2021

Savannah River Site H-Canyon Safety Basis Review

Summary. The Defense Nuclear Facilities Safety Board (Board) communicated its concerns to the Department of Energy (DOE) regarding structural inadequacies of the H-Canyon Exhaust (HCAEX) Tunnel, which affect its ability to satisfy its safety function, in letters dated December 16, 2015, and May 17, 2018. The site management and operating contractor, Savannah River Nuclear Solutions (SRNS), submitted a revised Documented Safety Analysis (DSA) for H-Canyon in 2019 that relies on reduced material at risk (MAR), structural integrity of the process vessels containing radioactive materials, and a portable compressed air system to purge the flammable gases generated as a result of radiolysis of the vessels' contents. This new safety strategy no longer relies on the exhaust system to provide a clear path for filtration of the released materials during and after an earthquake. The exhaust tunnel, however, remains credited to provide a filtration pathway for non-seismic events in the DSA.

A Board's staff team (F. Bamdad, D. Andersen, Z. McCabe, D. Cleaves, and M. Randby) reviewed the DSA and its companion Technical Safety Requirements (TSR) document, along with their associated references, to ensure that the proposed strategy would adequately protect members of the public and the workers from hazards generated in a seismic event. The team identified the following weaknesses:

- The proposed strategy does not demonstrate that the MAR is bounding, and it does not ensure that a seismic event would not result in consequences exceeding the calculated values since the number of vessels involved is limited to those that result in a deflagration within the first 96 hours.

- The post-seismic purge air system relies on a general service portable air compressor and power supply that are not functionally classified as safety-significant, which calls into question their ability to adequately and reliably remove the generated flammable gases during and after a seismic event.

Background. Members of the Board's staff conducted a review of the structural analysis of the HCAEX Tunnel at the Savannah River Site (SRS) in 2015. The Board sent a letter to the DOE Assistant Secretary for Environmental Management (EM-1) on December 16, 2015, stating its concern that the HCAEX Tunnel may not be capable of performing its safety-class confinement function during and after a design basis earthquake (DBE) [1]. The attachment to the Board's letter described the issues identified by the Board's staff from its review of the HCAEX Tunnel structural analyses.

In 2017, the staff team followed up with a review to document the progress that the DOE Savannah River Operations Office (DOE-SR) and SRNS had made to resolve the issues raised in the Board's letter. The staff report described a new potential safety issue concerning low concrete compressive strength test results and the potential impact on the conclusion of the H-Canyon fragility analysis (i.e., that the structure can meet its performance goal). The Board communicated its concern related to the preliminary results of the concrete testing in a letter to DOE dated May 17, 2018. The Board requested a written response "on the path forward to ensure the continued structural integrity of the H-Canyon Exhaust Tunnel at the Savannah River Site or any alternatives being evaluated to replace the exhaust tunnel." The DOE response, dated August 20, 2018, listed several actions including continued remote visual inspections of the tunnel, and completing a comprehensive nonlinear structural analysis of the tunnel.

SRNS issued a potential inadequacy in the safety analysis, which resulted in a positive Unreviewed Safety Question determination. SRNS then submitted a Justification for Continued Operation (JCO) in February 2018, which included several compensatory measures. The JCO contained a mitigative compensatory measure to reduce MAR to less than 1000 plutonium-239 equivalent curies (PEC). SRNS believed that this reduction in MAR would reduce the offsite consequences to acceptably low values so that the exhaust tunnel would temporarily no longer need to be relied on as a safety-class control for seismically induced accidents. The Board's staff reviewed the JCO and its set of proposed controls, along with other information obtained from discussions with the DOE-SR and SRNS representatives, and summarized its observations in a report that was enclosed with the Board's letter to DOE dated September 7, 2018.

In 2019, DOE and SRNS completed a nonlinear fragility analysis of the HCAEX Tunnel, which determined that the tunnel currently meets the acceptance criteria for the probability of surviving a seismic event, but also noted that there is limited margin under gravity loads should there be additional degradation beyond the concrete loss considered in the analysis [2]. As a result, DOE pursued an alternate control strategy that would not require the HCAEX Tunnel to survive a seismic event and still assure adequate protection of the public. The evaluation is captured in the H-Canyon DSA, Revision 14 [3], which DOE approved in December 2019.

Introduction. The HCAEX Tunnel is constructed of reinforced concrete and is located underground for some portions, and with no soil cover in others. It connects the H-Canyon hot and warm canyon air, vessel headspace exhaust, and former HB-Line exhaust to the sand filter and the exhaust stack. DOE constructed the original HCAEX Tunnel in 1953 and built a second sand filter and tunnel extension in the 1970s. Since 1990, the degradation of the HCAEX ventilation system has been recorded and monitored visually using pole cameras and robotic crawlers. Inspections have revealed that the HCAEX Tunnel degradation is severe and may impact its ability to perform its safety function during and following a DBE. SRNS developed a set of calculations intended to demonstrate that the HCAEX Tunnel is able to perform its safety function. The staff team reviewed the set of calculations, and on December 16, 2015, the Board transmitted a letter describing concerns associated with the structural analysis of the HCAEX Tunnel [1]. The issue report attached to the letter described the Board's safety issues involving concrete strength, the degradation assumed, and the analytical methodology used in analysis of the HCAEX Tunnel.

The HCAEX Tunnel had previously been a critical part of the H-Canyon facility safety-class and the HB-Line safety-significant ventilation systems. The ventilation systems were credited in the DSA to mitigate the dose consequence during and after a DBE to the maximally exposed off-site individual (for H-Canyon) and co-located worker (for H-Canyon and HB-Line). Revision 14 of the DSA, issued in 2019, relies on a new alternate control strategy; the MAR is reduced such that the dose consequences for a DBE no longer require a safety-class control for protection of the public. Consequently, the HCAEX Tunnel is not relied on to survive a seismic event and ensure adequate protection of the public. Primary contributors to the methodology under the MAR reduction strategy are:

- Removal of the plutonium oxide mission, thus plutonium oxide is no longer authorized to be in the canyon.

- Product/waste is no longer transferred to/from HB-Line.

- Revised/reduced MAR used in the new seismic analysis.

- Application of structural analyses to credit 70-ton casks, jumpers, and vessels during and following a seismic event:

    - The 70-ton cask performs a safety-significant function during and following a seismic event to protect irradiated fuel within the cask while the lid is secured,

    - Process transfer jumper design performs a new safety-class function achieved by the material of construction and the design of the jumper itself,

    - Safety-significant design features of the vessel air purge jumpers and dissolver sparge/purge jumpers are the material (e.g., stainless steel) and construction (e.g., welded) per applicable codes and standards, and

    - Process vessel design's safety function is increased from safety-significant to safety-class, achieved by relying on the process vessels' materials of construction, which resist corrosion and have high strength.

Revised Safety Basis and Strategy. Members of the Board's staff reviewed the DSA, TSR [4], and their supporting documents submitted to and approved by DOE in 2019. These safety basis documents describe the SRNS alternate safety strategy to not rely on the HCAEX for protection of the public due to its structural uncertainties during a seismic event. The control strategy relies on reduced MAR and seismic evaluation of the process vessels and their connectors to ensure that the radioactive materials are confined and to prevent any structural damage that would lead to the release of hazardous material to the H-Canyon environment. The radioactive materials contained in these process vessels, however, produce flammable gases typically due to radiolysis of their contents. These flammable gases would need to be removed during and after an earthquake to prevent deflagration or detonation hazards that would result in release of the materials inside the facility. The DSA relies on operators to purge the generated gases in a post-seismic condition using a portable air compressor.

The DSA relies on a dose consequence analysis to determine the unmitigated consequences of a process vessel deflagration or detonation on the public and the co-located workers at 100 meters from the facility [5]. The unmitigated consequences to the public and the co-located workers are estimated to be about 0.1 and 98.4 rem total effective dose (TED), respectively. There are two sub-accidents that contribute significantly to the unmitigated co-located worker dose (98.4 rem): fire in the truck well or warm shop (68.8 rem) and tank explosion (28.8 rem). DOE Standard 3009-2014 sets a co-located worker dose threshold of 100 rem for designation of safety significant controls. The DSA states that safety significant controls are not required for these sub-accidents, but SRNS retained them in the current DSA. However, the DSA states that SRNS may remove the safety significant designation in a future DSA revision. Given the concerns about safety margin for conservatism in the calculation as discussed below, the staff team concludes that safety significant designation of controls is warranted.

Embedded in the dose consequence analysis are the values used for radioactive material that can be released as a result of such an event. This amount, known as MAR, is the total inventory of all radioisotopes in the process vessels that may be subject to a hazardous event; in this case deflagration or detonation due to a seismic event. The dose consequence analysis [5] provides a table of the amounts of radioactive materials in the process vessels in terms of liters, and their radioactive contents in terms of PEC. The process vessels, accounted for in the DSA, are assumed to contain radioactive materials to the overflow level, thus maximizing the liquid contents of the vessels.

The staff team identified the following weaknesses and inconsistencies that need to be addressed to ensure compliance with DOE requirements and provide adequate protection of the public and the workers as mandated by the DOE rule, *Nuclear Safety Management* (10 CFR 830), and its safe harbor standards:

Inadequate MAR Control—The DSA acknowledges that the inventory has to be controlled at the TSR level to support the dose consequence estimates and comply with the DOE requirements. Consequently, a Specific Administrative Control (SAC) is identified consistent with the requirements of Standard 1186-2016, *Specific Administrative Controls*. The TSR identifies SAC 5.7.2.15, *Process Controls Required to Protect Process Hazardous Material*, to satisfy this requirement. It states:

> *Radiological Material Inventory Control – Radiological material shall be maintained less than or equal to the plutonium-239 equivalent curie concentrations for MAR streams or the plutonium-239 equivalent curie values per radiological shipment/container/area listed in DSA Chapter 3, Table 3-12.*

Table 3-12 of the DSA provides the concentration of the contents of process vessels in the H-Canyon (e.g., high activity waste, 9.69E-02 PEC/liter); not the total inventory. The staff notes that typically an inventory limit corresponds to the total mass inventory, which would be the amount used for calculation of the source term, plume dispersion, and dose consequences. SRNS clarified that using concentrations results in the bounding amount of MAR because the liquid volume of the vessels is assumed to be at the maximum level. The DSA accounts for the contents of all the vessels that would reach the composite lower flammability limit (CLFL) within 96 hours after the initiation of the event. It is assumed that this time is adequate for the site to take necessary actions to recover from the event. A total of 32 vessels[1] are identified [3] to contribute to the consequence analysis.

In general, DOE defines MAR as the "documented maximum" inventory for a given activity involved in an event. The methodology used for determination of the consequences of an explosion in this DSA equates the MAR to be the same as the source term calculated using the TNT equivalent approach. The bounding event of concern is an explosion in the vessels due to accumulation of flammable gases generated by radiolysis of the contents. The methodology prescribed by DOE in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, and implemented in the DSA, is to equate the amount of material released to the quantity of TNT that would generate the same amount of energy as the flammable gas detonation in the vessels. Using this methodology implies the amount of material released is a function of the amount of flammable gases accumulated in the air space of the vessels. That is, a larger number of flammable gas molecules in the air space would result in higher explosive energy and thus a larger TNT equivalent value. The source term is determined to be equivalent to the gram quantities of TNT calculated based on equivalency to the flammable gas energy. The DSA assumes that the vessels explode at a flammable gas concentration equal to the CLFL. Under this assumption, larger air space would result in a larger TNT equivalent, and in turn, a larger source term. The larger air space would also result in a longer time to CLFL. On the other hand, a smaller air space would lead to a lower TNT equivalent and a lower source term, even though this implies a larger amount of radioactive material in the vessel. With a smaller air space, there would be a shorter time to CLFL.

There are other parameters that can affect the TNT equivalent calculation. For example, as stated earlier, the H-Canyon DSA analysis for the explosion event incorporates an assumption that the vessels explode at a flammable gas concentration equal to CLFL. However, this assumption is neither part of the TNT equivalent source term model (as described in DOE-HDBK-3010-94), nor does it result in a bounding source term. The DSA does not provide justification for why the explosion occurs when the tank reaches CLFL and not some amount of time later when the concentration of flammable gas in the vapor space could be greater than CLFL. If this greater flammable gas concentration were to be used in the TNT equivalent source term method, the explosive energy would be greater, and the resulting source term would be larger. Because the hydrogen generation rate is proportional to the amount of liquid volume, larger liquid levels would result in higher rates of hydrogen generation. Some vessels at their maximum liquid level reach CLFL quickly (e.g., 27.2 hours for Tank 11.8), and continue to produce flammable gas after that point. SRNS has not demonstrated that it is bounding to assume that the explosion occurs at a flammable concentration equal to the CLFL.

Another parameter is the number of vessels involved. The exposure consequences of concern in this analysis relate to the site workers and the need for safety-significant controls for their protection. Additionally, the dose received by those workers would be cumulative over the

[1] This includes the tank recently added to this set as a result of a recent PISA (Potential Inadequacy in Safety Analysis).

time analyzed, that is, assuming that the flammable gases result in detonation of many vessels at the same time would be comparable with successive reactions and cumulative receipt of the consequential doses. A significant number of workers would be expected to remain onsite to perform actions required by the emergency response protocols or procedural steps required for ensuring safe condition of the facilities. The DSA limits the vessels included in the accident to those that will reach CLFL within 96 hours, and assumes that all such vessels would detonate at the same time. The contractor and DOE representatives informed the staff team that this is a conservative assumption. However, the staff team determined that there is no technical basis provided for limiting the number of vessels contributing to the unmitigated dose consequence analysis to those that reach CLFL within 96 hours.

Overall, the staff team concludes that the DSA does not demonstrate that the MAR control specified by the SAC would conservatively determine the amount of radioactive material that would be released due to a post seismic explosion in the vessels. Consequently, a parametric or other analysis is needed to determine the maximum source term to be released. The DSA, and its supporting calculation [5], do not present a parametric or other analysis to demonstrate that the source term determined for plume dispersion and dose consequence analysis is the maximum, as required by DOE standards. As a result, it is not clear that the dose consequence values presented in the DSA are bounding for an explosion in the vessels due to a loss of normal purge air during a seismic event. The staff acknowledges that the assumption of detonation instead of deflagration at the CLFL concentration is likely conservative; however, the existing calculation does not demonstrate that the conservative detonation assumption makes up for the other non-conservative assumptions.

Inadequate Safety-Significant Designation—Flammable gases generated in the process vessels during normal operation are removed by the instrument air system. This system, however, is not seismically qualified. If the instrument air system compressors or headers fail during a seismic event, a portable air compressor with backup power supply is identified to provide compressed air for purging the vessels. A safety significant SAC is identified to perform this function: "Following a seismic event, the response to a loss of vessel(s) purge airflow provided by the instrument air system through the vessel liquid level jumpers shall be the connection of the portable compressed air to the required vessels at the liquid level piping to be purged and the operation of the equipment identified in LCO 3.1.10 to re-establish and maintain the required air purge." "The safety function of the seismically qualified vessel air purge equipment/piping is to provide a flow path for the portable compressed purge air to the canyon vessels to maintain the flammable gas concentration in the vessel vapor space below the CLFL after a seismic event. The portable compressor/power supply and portable tubing are functionally classified as general service."

The equipment that provides the passive air flow paths such as wall nozzles and piping, flex hose with quick disconnect, isolation valves and portable rotameter are identified as safety significant. The supplied air flow for the removal of flammable gases, however, is provided by a general service self-contained fuel operated portable air compressor, which is crucial to the function of the mitigative system. Failure to provide compressed air would deny the process vessels the purge air needed to remove the flammable gases; and could lead to a potential deflagration or detonation event with significant consequences to the co-located workers. The staff team identified the following weaknesses and inconsistencies related to the post-seismic response and the adequacy of the identified control:

- **DOE Standard 3009-94 Change Notice 3**, the safe harbor for the H-Canyon DSA, describes SACs and their basic principles: "SSCs [structures, systems, and components] whose failure would result in losing the ability to complete the action required by the SAC… would also be considered safety-class or safety-significant based on the significance of the SAC safety function." The safety function provided by the portable air compressors is to purge and remove the flammable gases in the process vessels after an earthquake. Failure of the air compressor would lead to the lack of air flow and accumulation of flammable gases in the vessels, which could lead to a detonation or deflagration with significant consequences to the co-located worker.

- While **DOE Standard 3009-2014** is not yet in the SRNS contract, it clarifies DOE expectations by requiring: "SSCs whose failure would result in losing the ability to complete an action required by a SAC shall be identified. These SSCs shall be designated as safety-class or safety-significant based on the SAC safety function, or justification provided if not so designated." The DSA/TSR contain the following discussion regarding safety function: "The vessel air purge response is designated as SS [safety significant] SAC because it is credited as a secondary preventive control to protect the facility and co-located workers from flammable gas explosion events caused by the loss of instrument air due to a seismic system failure (loss of compressors, failure of piping). The safety function of the vessel air purge response is to prevent the hydrogen concentrations from reaching the CLFL in a vessel vapor space by providing backup compressed air to purge the canyon vessels." However, the "backup compressed air" is provided by a general service seismically evaluated portable air compressor that is not identified as safety-significant to provide this "secondary preventive" function in place of a non-seismically qualified instrument air system. Despite the lack of safety significant designation, the DSA states that "[t]he system is required to be operational after a seismic event."

- DOE and SRNS representatives stated that Attachment 8.10 to Procedure 2.25, *Safety Item Selection Precedence*, in **Manual E7**, allows the portable air compressors to be designated as general service even though they support a safety-significant function. It states: "…if there are additional [more than 2] alternate methods to perform the action specified by the SAC then the supporting SSCs should not have to be classified at the same level as the SAC safety function." This site procedure declaration, as applied to the portable air compressors, is in contrast to and inconsistent with the requirements in DOE Standard 1186-2016: "Where multiple SSCs are available, at least one SSC would typically be classified as a safety SSC unless adequate technical justification can be provided. Such a justification should consider a number of factors such as the reliability and diversity of the SSCs when they are required to function, and the time needed to perform the SAC using alternate support SSCs if failure is detected."

- During the discussions with the site personnel, DOE and SRNS representatives stated that although the portable air compressor is not designated as safety-significant, it is maintained under a preventative maintenance program (e.g., oil changes) and is started on a weekly basis, which increases the likelihood of identifying operability issues. Although the TSR requires periodic visual inspection and functional test of the system, not all the surveillance and maintenance requirements are identified in the TSR document since the air compressors are not designated as safety-significant. It is important to note that the site reported seven failures for the three seismic portable air compressors during their routine start up tests since 2014, mainly due to failed batteries or failed starters, based on the data provided during the discussions.

- According to site personnel, there are three portable compressors available to service the 32 process vessels after an earthquake, providing purge air to each in the order of their time to reach CLFL. Some of these vessels are expected reach the CLFL in less than 24 hours based on the contractor's analysis. The contractor believes that availability of three such systems will increase the reliability of having the capability to purge the vessels, as they can be moved around when any one is found to be inoperable after an earthquake. However, two of these portable compressors would have to be towed (see Figure 1 below) some distance (hundreds of meters), with the travel path potentially obstructed by debris and downed power lines in a post-seismic condition, creating an unpredictable and unreliable environment in which any mitigating action must be taken.

- The DSA contains planned safety improvements, and states: "Use of a stand-alone, seismically qualified vessel air purge system has been proposed to improve the control strategy for preventing an accumulation of flammable gases in the headspace of the canyon vessels following a seismic event. This would be a preventive SS control for design basis seismic events. As an interim control, the H-Canyon vessel air purge response (also referred to as the Seismic Event Response Program) is credited with preventing an accumulation of flammable gases in the vessels following a seismic event." It is not clear what DOE's plans are for implementing this proposed improved safety strategy to strengthen the reliability of the system and the safety posture of the facility.

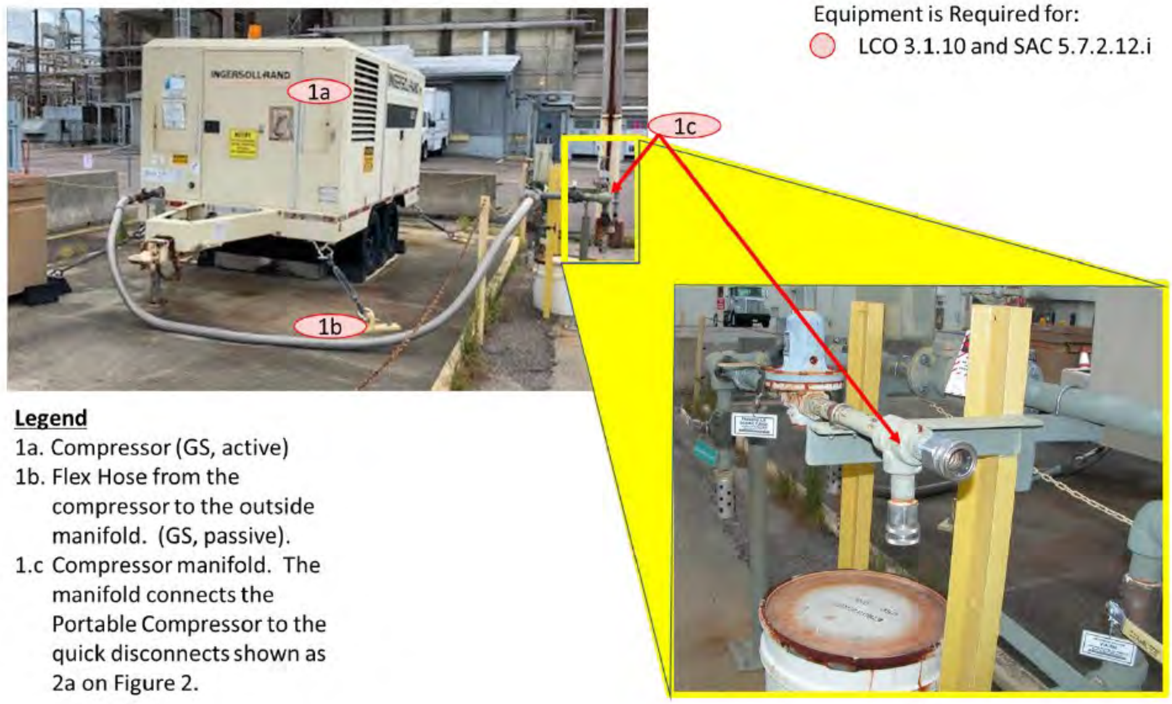

Figure 1. *Portable Air Compressor and Associated Equipment*

Structural Analysis. In addition to reviewing the revised safety basis, the staff team also reviewed the recently completed fragility analysis for the H-Canyon exhaust tunnels. This analysis included evaluations of the tunnels for both seismic and static loads. As discussed earlier, although the current safety strategy relies on seismic qualification of the canyon process equipment and the purging of vessel headspaces, the tunnels remain credited as a safety-class control for non-seismic events in the DSA. The staff team reviewed the technical adequacy of both the seismic and static analysis.

H-Canyon process vessel headspace and canyon room air are exhausted separately from H-Canyon through the Center Section Exhaust (CSEX) and Canyon Exhaust (CAEX) systems. The exhaust airs streams exit the east side of the main H-Canyon structure, Building 221-H, through a buried, reinforced concrete double tunnel configuration. This configuration changes from a double to a single tunnel when the CSEX exhaust is routed, via a cross-over tunnel, into the fan house, Building 292-H, where it then passes through high-efficiency particulate air filters. The CAEX exhaust continues to the sand filter buildings via a single tunnel configuration. A new sand filter building, Building 294-1H, was constructed in the 1970s to replace the old sand filter building, Building 294-H. Due to issues with the grating that supports sand media in the older building, exhaust ports for Building 294-H were eventually sealed and all exhaust air was directed to Building 294-1H. After CAEX air is sand filtered, it is drawn to the fan house and eventually discharged via the H-Canyon stack, Building 291-H. In addition to the main tunnels, there is a sealed bypass tunnel for old HB line exhaust ductwork that branches off from the double tunnel and there is an exhaust duct from the decontamination facility, Building 299-H, that enters the tunnels near the sand filter buildings. A plan view of the tunnel configuration is shown in Figure 2.

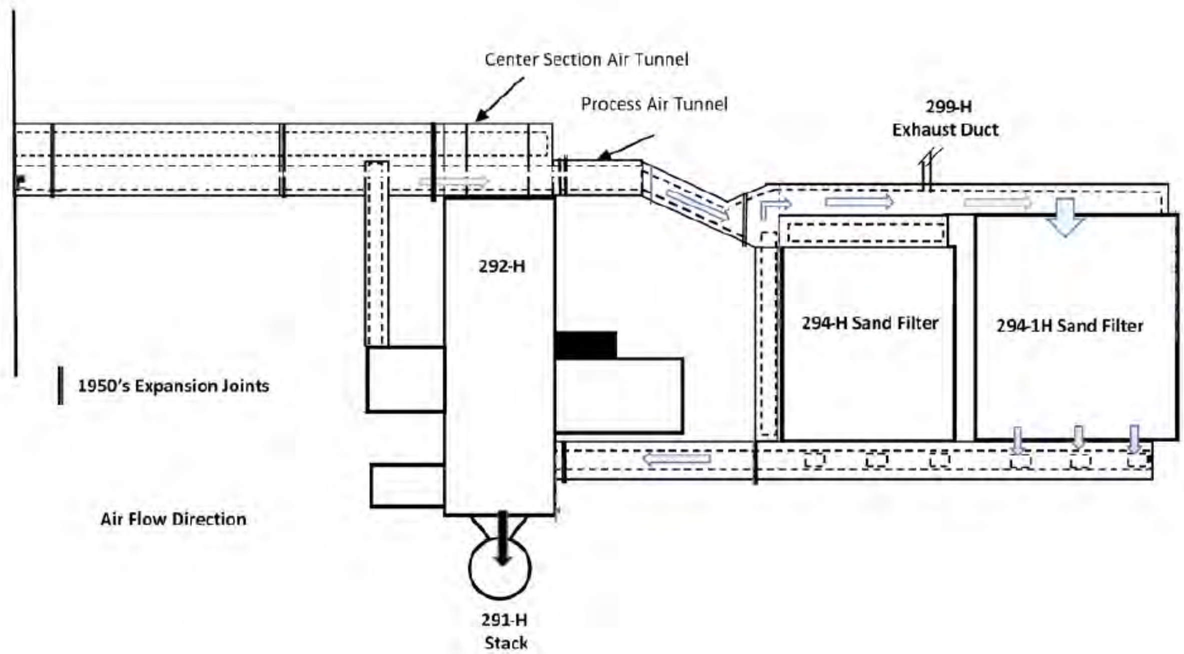

Figure 2. *H-Canyon Exhaust Tunnel Layout* [2]

SRNS documented the seismic and static analysis of the H-Canyon exhaust tunnels in a series of calculations and summarized the results in a summary fragility report [2]. The focus of the fragility analysis was on the two main tunnel configurations, the double tunnel and the single tunnel. For the dynamic analysis, seismic racking loads were derived from the site response analysis using strain compatible properties and the Seismic Design Category 3 response spectra from the most recent 2014 SRS probabilistic seismic hazard analysis [6]. The seismic design category was appropriate for the safety class tunnel designation and the use of racking displacement loads was appropriate for the single and double tunnel buried configurations.

In recent years, SRNS has observed, through remote tunnel inspections, severe degradation on the inner faces of the H-Canyon exhaust tunnel walls. Thus, to determine tunnel response sensitivity to degradation, the fragility analysis analyzed different levels of reinforced concrete degradation. SRNS modeled the tunnel beyond the elastic response using nonlinear hinge properties at the center of tunnel walls and at wall intersections. When deriving hinge and gross cross-section wall properties, SRNS assumed all inner reinforcing steel of the tunnel walls was ineffective and concrete from zero to two inches beyond the inner reinforcing steel layer was degraded. These levels of degradation were conservative when compared to those observed in remote structural inspections. SRNS determined that the tunnels will remain stable even without the inner reinforcing steel of the walls and that they meet the seismic performance goals of ASCE 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities* [7].

SRNS's analysis of the single and double tunnel configuration is technically defensible. However, if the tunnels are ever again credited to withstand the design basis seismic event, more sophisticated dynamic interaction analysis of the segments of the tunnels with adjacent facilities is needed. The fan house building, although a short and stout structure (i.e., essentially rigid from a dynamic perspective), would still be anticipated to impart inertial loads on the tunnel, particularly at the cross-over portion of the tunnel. Also, in this area the embedment of the tunnel is small and inertial effects may dominate over racking displacement loads. For the sand filter buildings, which neighbor significant lengths of the tunnels, complex soil-structure interaction response could be expected. These interactions would be between the sand filter structure, soil berms, the sand within the structure, and the neighboring tunnels; the current response of the sand filter buildings are based on simplified equivalent static methods.

The H-Canyon exhaust tunnels have experienced severe degradation in more than 60 years of use and this degradation will continue. DOE and SRNS should continue to monitor the condition of the tunnels and establish a firm timeline for both periodic re-inspection and eventual end of service. For the former, although the tunnels are currently credited as safety-class features for non-seismic events, the TSRs do not establish a required inspection periodicity of these design features. The TSRs do identify the SRS Structural Integrity Program as an administrative control; however, given that the tunnels are credited as safety-class for non-seismic accidents, an enforceable requirement for inspection periodicity is warranted.

A rigorous monitoring program is needed to not only observe degradation, but also detect wall movements that could be an indicator of the start of tunnel failure. This is particularly important since the current static analysis of the degraded tunnels [8] shows no margins for the code-based evaluations of ACI 349-13, *Code Requirements for Nuclear Safety-Related Concrete Structures* [9]. The staff team understands that three dimensional scans of the tunnels are planned, which will help supplement visual examinations and provide indications of worsening conditions. Based on the difficulties encountered during past remote inspections, future monitoring should include strategies to observe portions of the tunnel that are more difficult to observe, such as those obstructed by ductwork or hidden by tight corners. Lastly, since the static analysis of the tunnel indicates no margins when compared to code capacities, the staff believes SRNS should continue to enforce traffic restrictions over the tunnels to prevent unnecessary loading.

Conclusion.

- The proposed strategy for not relying on the H-Canyon Exhaust Tunnel during a seismic event has the following shortcomings:
  - The amount of radioactive material dispersed in the unmitigated post seismic explosion, involving radioactive contents of the vessels, is neither demonstrated in the DSA to be bounding, as required by DOE standards; nor is it appropriately protected in the TSR.
  - The need for a safety-significant control to purge flammable gases from the vessels (and prevent deflagration or detonation) is accommodated by a SAC. The motive force for the purge air is provided by general service portable

compressors; instead of a safety-significant one. DOE Standard 1186-2016 does provide for situations in which it might be acceptable to not designate a functional classification for a component, but this would require a technical justification, which is not currently provided in the DSA.

- The structural analysis of the H-Canyon tunnels technically defensible. As the tunnels will continue to degrade, they will eventually reach end of life.

    - A conservative estimate for the end of life for the tunnels is needed and should be incorporated into a long-term strategy to stop using the tunnels. This end of life timeline should be firmly established in the safety basis and enforced to prevent continued life extensions.

    - A monitoring program, with a firmly established and enforced inspection periodicity defined in the TSRs, is needed to not only detect degradation, but also excessive wall movements, which could be an indicator of the start of tunnel failure. In addition, future monitoring should include strategies to observe portions of the tunnel that are more difficult to observe, such as those obstructed by ductwork or hidden by tight corners. Proposed three-dimensional tunnel scanning would not only help the site understand if the degradation is worsening, but could also identify worsening tunnel wall movements.

    - Traffic restrictions should be maintained over the tunnel to prevent unnecessary loading.

If the tunnels are ever again considered for being credited for the seismic accident scenario, a more rigorous dynamic structural analysis of the interaction of the tunnel with the H-Canyon fan house and sand filter buildings is needed. This is particularly important for the sand filter buildings (old and new), which will be more excited by seismic motions. The current static analysis of these facilities is insufficient to understand the response impacts they may impose on the tunnels.

Cited References

1. Defense Nuclear Facilities Safety Board, *H-Canyon Seismic Performance and Condition*, December 16, 2015.

2. Savannah River Nuclear Solutions, *Summary Report for H-Canyon Exhaust (CAEX) Tunnel Nonlinear Probabilistic Fragility Analysis*, T-ESR-H-0036, October 22, 2019.

3. Savannah River Nuclear Solutions, *Savannah River Site H-Canyon & Outside Facilities, H-Area Documented Safety Analysis*, S-DSA-H-00001, Rev. 14, Nov. 2019.

4. Savannah River Nuclear Solutions, *H–Canyon & Outside Facilities Technical Safety Requirements*, S-TSR-H-00006, Revision 14.

5. Savannah River Nuclear Solutions, *Radiological Consequences for H-Canyon NPH Event to support Closure of JCO U-JCO-H-00003*, S-CLC-H-01302, Rev. 0, April 2019.

6. Savannah River Nuclear Solutions, *SRS Probabilistic Seismic Hazard Analysis (PSHA) Update – 2014*, K-ESR-G-00021, Revision 0, November 2014.

7. American Society of Civil Engineers, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*, ASCE 43-05, 2005.

8. Savannah River Nuclear Solutions, *H-Canyon Exhaust (CAEX) Tunnel Evaluation for Shear under Static Loads*, T-CLC-H-01297, Revision 1, October 22, 2019.

9. American Concrete Institute, *Code Requirements for Nuclear Safety-Related Concrete Structures*, ACI349-13, 2013.