

**A VIABILITY PROGRAM FOR THE SAFETY SYSTEMS UNDER THE
SAVANNAH RIVER REMEDIATION CONTRACT AT THE SAVANNAH
RIVER SITE - 10440**

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ABSTRACT

Radioactive waste has been stored and transported at the Savannah River Site tank farm facility for over 50 years. These systems are exposed to harsh chemical and ambient environments and have undergone varying degrees of degradation. It is anticipated that the facility infrastructure will be needed until 2032 when removal closure activities are completed. Engineers are developing a program that will manage the level of degradation of the aging passive safety class and safety significant structures, systems and components in the facility so that they remain viable throughout their projected mission life. This program will implement some of the same fundamental principles used to assess the viability of aging nuclear power plants. The program will also leverage current programs designed to ensure the structural integrity of the systems.

The viability program was piloted in 2009 with consideration of the waste tank purge ventilation system. This ventilation system is used to circulate air through the tank in order to prevent the build-up of hydrogen gas within the tank. Within the past five years, components within this system have begun to fail on certain tanks. Of particular concern is the carbon steel ventilation duct, which has shown evidence of nitrate stress corrosion cracking near the welds. Currently as defined in the closure plan this system will need to remain viable for the next 11 to 19 years. The desired outcome of the pilot program was to recommend preventative actions, parameters for monitoring and inspection, and a representative ventilation system that could be used to monitor for aging effects.

The program recommended that the carbon steel duct on one of the tanks be inspected periodically. Based on several environmental variables it was determined that the waste in this tank would generate the harshest vapor environment that would be experienced by any of the ventilation ducts in the facility. Visual and magnetic particle inspections will be performed on this duct to assess the degree of degradation every five years.

The viability program has been successfully piloted. The facility views implementation of this program on a facility wide basis as a critical step in the demonstration of a safe and functional safety related infrastructure.

INTRODUCTION

Radioactive waste has been stored and transported at the Savannah River Site (SRS) tank farm facility for over 50 years. The tank farm facility consists of large underground storage vessels (approximately 1 million gallons), a network of underground piping to transfer waste between the tanks, process water and steam system piping, and ancillary equipment designed to ensure safety (e.g., HEPA filters). These systems have undergone varying degrees of degradation dependent upon the material of construction/exposure environment combination. It is anticipated that the facility infrastructure will be needed until the completion of tank closure activities, which is currently scheduled for 2032. Engineers have developed a viability program that will manage the level of degradation of the aging passive safety class and safety significant structures, systems and components in the facility so that they remain viable throughout their projected mission life. This program will implement some of the same fundamental principles used to assess the viability of aging nuclear power plants. The program also leverages current programs designed to ensure the structural integrity of the systems. This paper outlines these fundamental principles and then provides an example of how the program has been applied to a specific component.

THE VIABILITY PROGRAM AT THE SRS TANK FARM FACILITY

In the commercial nuclear power industry, aging plants are obtaining renewed 20-year operating licenses. The license is renewed after it has been demonstrated that the facility structures and components will remain in an acceptable condition or are in an aging management program to assure they perform their required function for the duration of the license. Ensuring that aging passive safety significant Structures, Systems, and Components (SSCs) will be available through the life cycle of these plants is a requirement of 10 CFR Part 54 [1-3]. The active SSCs are evaluated using principles outlined in system reliability programs as outlined in Reference 4. The SRS tank farm facilities face a similar issue, having some facilities that are as much as 50 years old, yet still are required to remain operable until final tank closure, now scheduled for 2032. SRS must be able to demonstrate that active and passive vital safety systems are viable through the predicted mission life.

SRS has a number of existing programs that manage and monitor important Structures, Systems, and Components (SSCs). Each program provides key parameters for the system engineer to accomplish system performance monitoring and viability evaluations. These programs include:

- Structural Integrity (SI)
- Technical Safety Requirements (TSR) surveillances
- Installed Process Instrumentation (IPI)
- Preventive Maintenance
- Predictive Maintenance
- Corrective Maintenance
- Quality Assurance

- Spare Parts Management Practices
- Cable Aging
- Materials Shelf Life
- Conduct of Operations, Maintenance, and Engineering

While these programs strongly contribute to ensuring SSC viability, none are specifically designed to identify the life cycle need date, compare the predicted SSC life expectancy to that need, and to establish a process to ensure that the SSCs will be able to meet their safety function/mission need for the remaining SSC life cycle requirement. Therefore, additional guidance is necessary to effectively implement viability evaluations for active and passive SSCs for safety and key mission goals.

The current SRS active SSC system performance monitoring process follows the INPO AP-913 Equipment Reliability Process [4]. Implementation requirements for the life-cycle management at SRS are listed below:

- Scoping and Identification of Critical Components
- Performance Monitoring
- Continuing Equipment Reliability Improvement
- Corrective action
- Preventative Maintenance (PM) Implementation

Revised viability evaluation guidance will be established within the SRS structural integrity program, to assess SSC performance with respect to their safety/mission function for the remaining mission life. This will provide the needed attributes to assess both active and passive SSCs against the life-cycle segment of the reliability process and 10CFR54. Key attributes of the viability determination will include:

- **Extrapolation of historical system performance.** Historical system performance data, inspection information and trends extrapolated to future performance expectations
- **Active component degradation**-Ability of active components to perform reliably in the future considering active component failure and degradation mechanisms (e.g. bearing failures, instrument detector failures, etc)
- **Equipment obsolescence** considerations for major equipment (e.g. variable frequency drives, distributive control systems, logic controllers)
- **Passive SSC aging management**-Passive system age and service related degradation mechanisms (e.g. erosion/corrosion of piping, radiation impact, concrete cracking, etc) must be considered.

Integration of the collected information, addressing these key attributes, will enable the system engineer to assess whether an SSC can confidently be expected to remain viable for the remaining mission life. The information and resulting conclusions will be documented in the viability section of the appropriate system health report.

Assessment of these items addresses the forward looking consideration of active and passive system aging risks. Consideration of these potential concerns requires that the system engineer evaluate whether the conditions are possible adverse aging and degradation and then respond by ensuring that there are programs in place to mitigate these mechanisms.

Current system health reporting processes at the SRS tank farm facility are focused primarily on active safety systems (Vital Safety Systems) and selected mission critical non-safety active SSCs. Each of the SSCs that are currently included in the system health reporting process will have expanded system viability reviews as outlined in this report. In addition, system viability evaluations will be required for all safety significant (SS) and safety class (SC) passive SSCs and new system health reports will be developed for these passive systems when not contained within an existing system being reported. When the passive component is contained within an existing system being reported, the passive SSC viability information will be integrated into the same system health report as the active components. Each facility will also determine viability evaluations to be performed for non-safety related passive systems and identify those to the Structural Integrity Manager. The inclusion of any non-safety systems in the review will be based on the judgment of the facility engineering personnel. The decision of which non-safety systems to include in the evaluation should include items whose failure could impact the function of a SS/SC SSC (interaction effects) or cause marginal mission level impact.

Systems requiring viability review may be grouped into a consolidated single system health report. It is also envisioned that these reports will focus solely on passive components, will be greatly abbreviated, and will reference other more detailed reports for specific system reviews conducted by the Structural Integrity Program (e.g. Waste Tanks). The definition and grouping of systems for system health and viability evaluations will be included in a facility technical report that defines systems requiring system health reviews.

Most active SSCs are designed to be maintainable and readily replaceable. The design implicitly recognizes that these active SSCs are not expected to last for the life of the facility mission. As a result, they are properly monitored to detect the need for repair or replacement. There is no specific need to identify a life expectancy vice the facility mission life for such SSCs, but a program must be in place to ensure that preventative maintenance and spare parts are considered and applied and are robust enough to ensure consistent performance and ease of addressing system/component failures during the remaining system life. In some instances, a more detailed aging evaluation, reviewing the service conditions, material of construction and degradation mechanisms, structural integrity inspections may be warranted to validate the SSC will meet safety and mission needs for the remaining SSC mission duration. The system engineer will be responsible for reviewing the active SSCs, determining the age related considerations for the system against the expected life, and ensuring that appropriate studies, inspections, surveillance and recommended corrective actions are in place to support viability expectations for the system.

Major equipment obsolescence is a key consideration that will be included in the enhanced viability reviews. Obsolescence is the inability to obtain parts or components due to the lack of support of available manufacturers or the introduction of new technology. This will be a focus for active components. Where a component is a relay or simple switch, no real obsolescence risks will likely exist and no detailed reviews or corrective actions would be warranted. In situations where complex instrumentation such as gas concentration monitors or variable frequency drives where vendor specific parts are the only components that will work to maintain a system functional, obsolescence issues can be a significant long term considerations. System viability evaluations will consider such risks and identify the appropriate mitigation strategies for the identified obsolescence. Such strategies may be an increase in spare parts inventories, specific contracts with vendors to continue to provide needed spares or replacement projects for major components such as distributive controls. The strategies selected by the system engineer would be tracked as actions (where not fully implemented) as part of the system health report process.

Some passive SSCs are very difficult or impossible to replace. In comparing the mission life requirements to the SSC expected life, mission critical passive SSCs may be identified that do not meet life cycle needs. Facility personnel need to know of such cases well in advance, so that long-lead modifications, procurements, major repair outages, or even changes in mission schedules can be planned and identified risks appropriately addressed. This is accomplished through a passive component Aging Management evaluation that formally considers the principles of NEI 95-10 [2] to validate system aging risks and to identify the appropriate mitigation action to address the identified risks (e.g. structural integrity inspections and trending, corrosion chemistry control, scheduled replacement, accept risk, etc.).

A critical activity is to set criteria so that engineers can determine which SSCs should be included in a detailed passive component Aging Management Program (AMP). Aging evaluation is required for all Vital Safety Systems (VSS) passive SSCs and SS/SC supporting structures, some of which are not currently included in the system performance monitoring/system health programs. Going beyond 10CFR54, it may also be required for non-VSS systems containing mission critical SSCs. The result of the evaluation is a set of SSCs to be included in the Aging Management Review.

Items that will be considered in an AMP will include:

- All SC/SS Passive SSCs.
- All non-safety related systems, structures and components whose failure could prevent the satisfactory accomplishment of the safety and mission critical SSCs (e.g. seismic II/I interaction effect systems).
- Mission Critical Process Support (PS/GS) SSCs selected based on mission need to require more formal passive component aging management evaluations.

The passive component evaluation will be required for passive SSCs that are part of a safety related active system (e.g. sample tubing and instrument cabling for a safety related flammable gas monitor).

The SRS tank farm facility will leverage existing programs, databases, and records to accomplish passive SSC viability. When required for passive SSCs a distinct aging analysis document will be created or referenced. AMP elements from NUREG-1801 will be implemented by the System Performance Monitoring Program (SPM), the Structural Integrity Program (SIP), and the Lessons Learned program.

Identifying these elements in the SPM and SI programs for the selected SSCs will constitute the detailed aging analysis process. Many of these elements already exist in the SI program. They will typically need to be annotated to indicate applicability to aging effect, prevention, monitoring, detection, and evaluation.

There will be no requirement to develop a comprehensive, documented aging evaluation for each CLI in the selected systems. For safety related SSCs and selected mission critical SSCs, if formal detailed aging evaluations are not considered necessary (e.g. in the case of the conductivity probe cable), these may be documented directly in the system health reports. The system health reports will capture appropriate evaluations by the system engineers that demonstrate all components of the pertinent system were considered in the aging considerations and identify those that need more formal evaluations only. The annual update will ensure that no additional components require formal aging evaluations as continuous review of system viability.

For each SSC requiring detailed aging management analysis, this shall be formally documented through an independent report/calculation or handled with in the structural integrity data sheets. Each aging management element must be addressed.

A System Viability status will be provided within the system health report. In addition to the annual system health report incorporation of findings from the previous year, the SRS Lessons Learned program will provide the Operating Experience element from NUREG-1801 [1]. New information learned about SSC aging, detection, mitigation, and corrective actions will be communicated to others through the SRS Lessons Learned program.

Inherent in the existing system health reporting process is an identification of necessary parameters to monitor for the systems chosen to perform system health reviews. The parameters chosen provide the framework to ensure system performance is adequately being monitored by the system engineer. Areas to consider are:

- Predictive Results
- Equipment Test Program Results
- Operator Rounds
- System Engineer Walkdowns
- Maintenance Results

Extrapolation of historical system performance is a key step in determining the necessary steps for monitoring the system. Trending of the parameter monitoring, surveillance results, and preventive maintenance and as found conditions to assure the suite and frequency of activities will be performed to gather data for extrapolation purposes. The system engineer will define corrective actions to address deficiencies identified from the trending of information to ensure viability issues are addressed.

The culmination of the reviews for obsolescence, passive component aging will be the system viability evaluations for the selected systems. The system health reports will document the surveillance, formal aging evaluations used to assess viability, the robustness of these programs, and the results of the evaluations to support viability determinations and actions. Each report will assess the validity of the monitored attributes and ongoing actions for the system to ensure a robust suite of surveillance, aging evaluation are in place to assure the validity of the viability assessments. The viability evaluations will clearly articulate the expectation for the system to be able to perform the required safety function for the expected mission life and identify any actions necessary to address identified vulnerabilities for both the active and passive portions of the respective SSCs.

System viability information will also be fed into the system stoplight charts to reflect overall status for the system. For example, it may be appropriate to indicate that a system has a short-term health issue, but show long-term viability is not a concern and vice versa. The system engineer may determine alternate approaches to communicate system status in the stoplight charts to most effectively manage any risks identified.

APPLICATION OF VIABILITY PROGRAM: PURGE VENTILATION SYSTEM

The viability program was piloted in 2009 with consideration of the waste tank purge ventilation system (see Figure 1). This ventilation system is used to circulate air through the tank in order to prevent the build-up of hydrogen gas within the tank. Within the past five years, components within this system have begun to fail on certain tanks. Of particular concern is the carbon steel ventilation duct downstream from the HEPA filters, which has shown evidence of nitrate stress corrosion cracking near the welds. Currently as defined in the closure plan this system will need to remain viable for the next 11 to 19 years. The desired outcome of the pilot program was to recommend preventative actions, parameters for monitoring and inspection, and a representative ventilation system that could be used to monitor for aging effects.

Evaluation of System Components

The demister is a stainless steel component that has internal bundled stainless steel strips to remove mist from the passing tank vapors. This component has no known failures and should be viable for the life cycle of the tanks as defined above. The demister is contained within a standard carbon steel pipe. The confinement pipe is embedded in a concrete riser on the type III (and IIIA) tanks. The piping is inaccessible for inspection.

Thinning or pitting of the piping would have limited consequences as the pipe is fully confined in the concrete riser. This pipe should not be impacted by the corrosive environment based upon the extensive ultrasonic testing (UT) work performed on the tank wall (minimal thinning/pitting). Structural integrity inspection will continue on this vessel in the future. Any breach could be quickly repaired or the shell completely replaced.

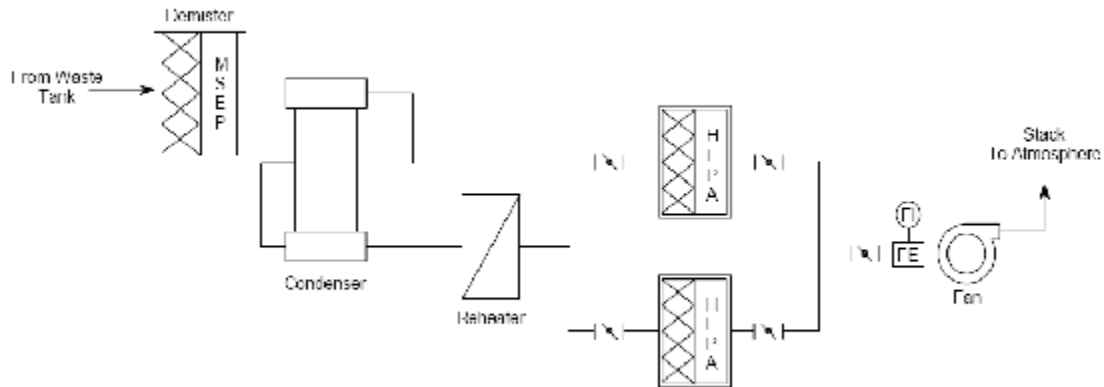


Figure 1. Typical Type III Group Arrangement

The condenser is a mixed material and system component. It interfaces with the chromate cooling water system and is constructed from stainless steel and carbon steel. This component is a pressure vessel and is thus inspected through visual and ultrasonic testing. The service history of the condensers was reviewed and the condensers are considered viable through the life cycle of tanks as defined above. In general, the condensers have been in service for greater than 30 years with limited wall thinning as documented in the inspection reports. There has been a singular case in the facility where the condenser shell experienced significant pitting corrosion. It is believed that this attack was due to depletion of the chromate inhibitor as the cooling water remained stagnant for a long period of time. To minimize any unplanned attack from stagnant chromate cooling water a mitigation strategy will be established to minimize the time chromate can remain in the condenser to preclude thinning and pitting.

The re-heater is constructed of stainless steel, aluminum and copper. This component interfaces with the steam system for heat. As mentioned above, the component has an extensive history of failures, a situation that has been addressed by the facility through a path forward document. Implementation of the recommendations within this document resolves all viability issues. The principal recommendation is that all new re-heater coils be fabricated from stainless steel.

The HEPA isolation valves are cast iron and stainless steel and easily replaced. There have been no known failures of this component and should therefore be viable for the life cycle of the tanks. Spare valves are available for replacement. No specific viability action was required.

The HEPA box is stainless steel and has no known failures. The HEPA filters are on a regular preventative maintenance (PM) and surveillance program that ensures the viability of this component through the life cycle of the tanks. The HEPA filters have been subject to break through potentially due to re-heater failures or condenser outages. The re-heater is being addressed and additional surveillances are required when the condenser is down. No specific viability action was required.

Fan internals are monitored through PMs and have adequate spare parts and temporary fans for emergency processing. Vibration PMs are performed on the fans monthly and adequate spare parts are available for replacement. No specific viability action was required.

The fan motor is a key component and is regularly checked through PMs. The motors are replaced every five years to preclude failure. There are adequate spare parts for motor replacement. No specific viability action was required.

The flow elements have no history of failure and are monitored through PMs. These components are easily replaced and in stock. Other instruments are in supply and easily replaced. The tubing on many of the instruments is being replaced due to a local failure. EM-SR-WSRC-FTANK-2008-006 NOC: 4A1 was issued following failure of the purge exhaust flow gauge at FDB-2. Copper tubing attached to the gauge failed and was replaced with stainless steel tubing. Tubing for other purge ventilation instrumentation was evaluated following the incident and work packages were prepared to have copper tubing replaced with stainless tubing.

Connecting duct work is both stainless steel and galvanized carbon steel for these tanks. The stainless steel duct is considered viable for the remaining life cycle of the F-tank farm. The integrity of the galvanized carbon steel required a more extensive evaluation as described below due to historical failures.

The appurtenance piping, tubing and valves are readily replaced and will continue to be reviewed in the structural integrity program. No specific viability action was required.

Evaluation of the Ventilation Ductwork

The ventilation duct consists of a fabricated galvanized steel duct, two fabricated reducers, a fabricated elbow and flanges at either end. Several instances of cracking of the ventilation ductwork have been observed in the SRS tank farm facility. An example of the cracks is shown in Figure 2. The cracks were beneath thermal insulation and were found during planning for upgrading of the exhaust flow monitoring system. Cracks

occur from the inside, are in the heat affected zones of both seam and girth welds, and have a circumferential orientation.



Figure 2. Section of ventilation ductwork removed from the exhaust of the purge ventilation system. Two cracks are evident. A third crack, located on the opposite side of the weld, occurred on the inside surface but did not penetrate to the exterior. Magnification is 1.25 X.

Definite evidence of intergranular fracture was observed upon examination of the fracture surface by scanning electron microscopy. Part of the explanation for the short cracks along the seams is that shrinkage related to welding would result in tensile loading in the axial direction within the weld zone. The intergranular nature of the cracking also involves a yet undefined chemistry and chemical mechanism, but the direction of crack growth is driven by those residual stresses. The tensile stress and mechanical drive for cracking at the girth joints is also axially oriented. This is probably related to steps in the fabrication process, whereby the flange locations must be fixed, setting up an axial constraint. As a consequence, the shrinkage at the girth welds is axial and the residual tensile stress is also axial. The large gap occurring at the center girth joint indicates prior existence of a very large strain and stress.

The intergranular aspect is most certainly chemically driven. Analysis of deposits associated with the corrosion products indicate that nitrate species is the likely culprit. Condensation in the exhaust piping may be anticipated, especially in winter and therefore dissolve these solids and initiate nitrate stress corrosion cracking. Additionally, cyclical

variation in humidity may provide a means for increasing concentration, as salts entrained in the vapor may deposit with condensation.

The stress corrosion cracks initiated on the interior of the duct work were associated with nitrate-rich deposits. Therefore, it is clear that the tank vapors played a significant role in the degradation mechanism. It has been hypothesized that the generation of NO_x vapors from the tank waste potentially create a corrosive environment for the duct work. This hypothesis was assessed based on previous duct work failures. If the hypothesis is reasonable, the tank waste that produces the highest NO_x generation rate will be recommended for the inspection.

All purge ventilation systems that have had or currently have galvanized carbon steel duct work were considered in the assessment. Inspection reports were utilized to verify which tanks have had ventilation systems with galvanized carbon steel ducts and which ones have experienced failures.

A review of the affects that different environmental variables have on NO_x generation within waste tanks was performed. These variables include:

- 1) A high dose rate, as determined by gross gamma measurements, results in higher generation rates.
- 2) A high concentration of nitrate and nitrite results in a high generation rate.
- 3) A high supernate temperature results in thermal degradation of NO_x, and therefore depresses the generation rate. Conversely, a low supernate temperature does not depress the generation rate as much.
- 4) Dissolved oxygen in the supernate reacts with NO_x and therefore depresses the NO_x generation rate. Dissolved oxygen concentration decreases as the sodium salt concentration increases.
- 5) Organics present in the waste serve as reducing agents, and therefore increase the production of NO_x.
- 6) Above pH 11, NO_x generation is facilitated.

Chemistry and thermal histories of the tanks were examined for information on these variables. It was observed that all tanks have a pH > 13, therefore factor 6 does not discriminate. Additionally, data for the concentration of organic compounds in the wastes was incomplete, and therefore were also not considered. Thus, the first 4 variables were considered for this assessment. Variables 1) and 2) accelerate the NO_x generation rate, while variables 3) and 4) depress the generation rate. Each of the variables was rated on a scale of 1 to 4, with 1 representing the conditions for higher NO_x generation rates. The assessment was performed assuming that each of the variables had an equal influence on the NO_x generation rate. The assessment also assumed that the purge ventilation rate for each tank is the same. For each tank ventilation system, the sum of the rankings for all four variables was divided by 4 to calculate an average ranking. The lower average ranking was indicative of a system that is likely to have been exposed to higher concentration of NO_x.

The results of the analysis showed that six of the eight systems that have experienced cracking were exposed to vapors from wastes with higher NO_x generation rates (i.e., they are ranked in the upper 50% of the tanks). Thus as a general predictor of the most vulnerable purge ventilation system, this approach appears to be reasonable.

The tank with the lowest average ranking was selected for system monitoring. The inspection will include wall thickness measurement of all galvanized carbon steel confining duct and components. Visual inspection will also be conducted on the surface for cracks. A magnetic particle test or equivalent will be performed at each weld and at least 3 inches adjacent to the weld. Any suspected cracks should be foam leak tested. This inspection will be used as a commodity group that is representative of all the tank exhaust ventilation systems in the facility. If the inspection fails the acceptance criteria then all carbon steel duct sections must be inspected or replaced. The replacement material of construction for the duct will be stainless steel.

CONCLUSIONS

A system viability program has been implemented at the SRS tank farm facility. The viability program considers both active and passive safety significant and safety class structures, systems and components. The program was piloted in 2009 with an evaluation of the waste tank purge ventilation system. Recommendations were made for monitoring the system components.

REFERENCES

- 1) NUREG-1801, "Generic Aging Lessons Learned (GALL) Report", Rev. 1
- 2) NEI 95-10, "Industry Guidelines for Implementing the Requirements of 10CFR Part 54 – The License Renewal Rule", Rev. 6
- 3) 10 CFR 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants"
- 4) INPO AP-913, "Equipment Reliability Process Description", Rev. 2