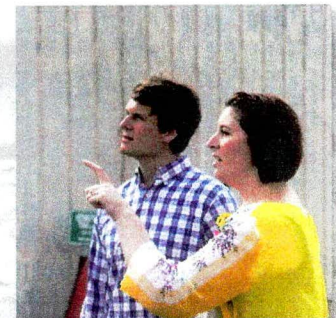
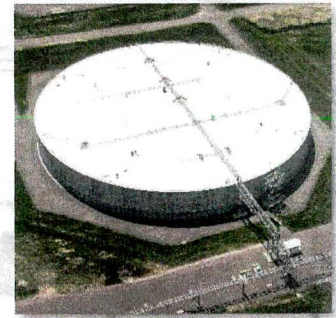


April 25, 2018

STATUS AND OPERATION OF THE 242-25H EVAPORATOR SYSTEM

Steve Thomas / Bill Barnes /
Keith Liner / Chuck Keilers

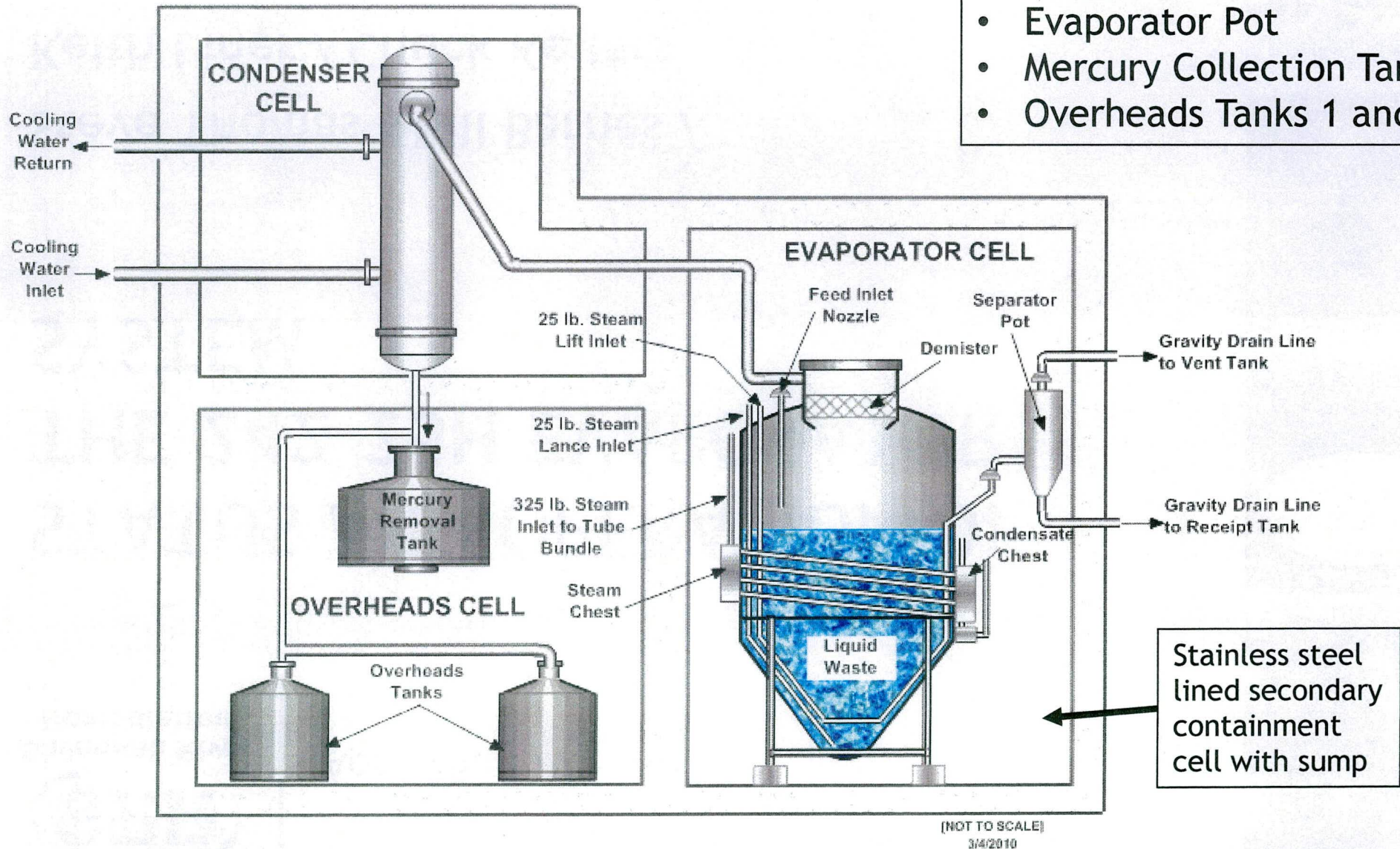
SRR-CWDA-2018-00022



3H Evaporator System

FFA, Appendix B lists:

- Evaporator Pot
- Mercury Collection Tank
- Overheads Tanks 1 and 2



Stainless steel lined secondary containment cell with sump

3H Evaporator Overview

- Waste in the LW Evaporator Systems must be segregated due to nuclear criticality concerns:
 - 2H principally handles DWPF Recycle
 - 3H handles everything else (e.g., sludge batch wash water, tank closure liquids)
- The 3H is the largest evaporator system in Liquid Waste and is designed to process greater than one million gallons of salt waste per year
- The pot and the steam chest are manufactured from Alloy G-3 (Hastelloy®)
 - Design Life was 30 years
 - Initial Operations began in 2000



Normal Operating Level - 95"

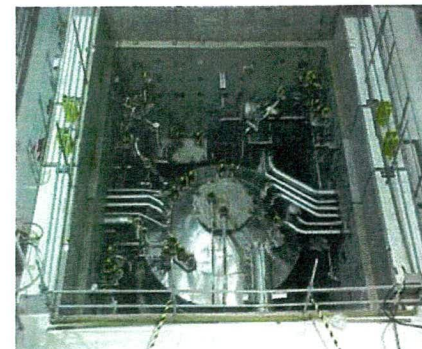
Center of Steam Chest - 76"

Bottom of Opening - 62"

Stiffener Band - 37"

Stiffener Band - 0"

Levels are approx indicated level



3H Evaporator Pot Leak Discovered

- On February 17, 2016, the 3H was shutdown after salt waste was discovered in the stainless steel-lined concrete cell
 - Leaked ~3000 gallons into secondary containment
 - Leak rate 150 gallons/day
- Extensive testing was performed to pinpoint the source of the leak
 - Including the remote removal of the encased insulation on the cone of the pot using robotics
- Leak site location was confirmed on February 28, 2017 after insulation removal



Picture taken during removal of the stainless steel-wrapped insulation on the cone of the evaporator pot

3H Evaporator Repair of Original Leak Site

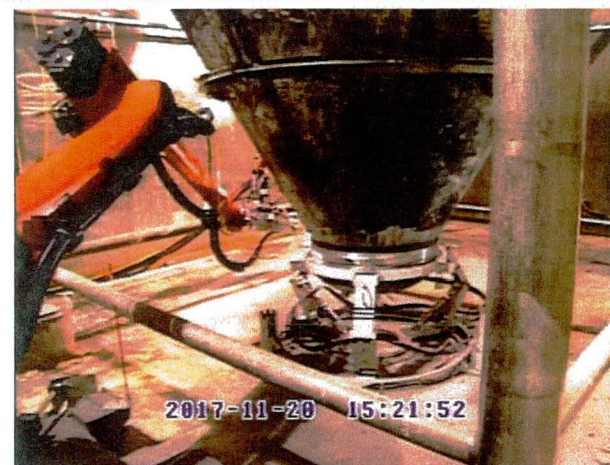


Original Leak Sites

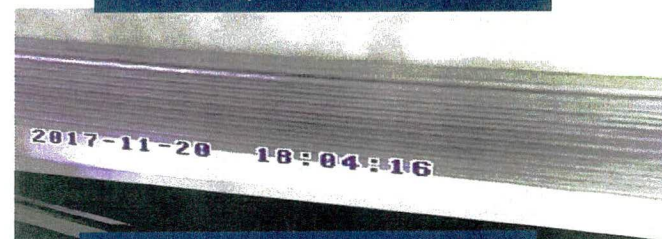


Robotic Welding of Cap to Evaporator Vessel

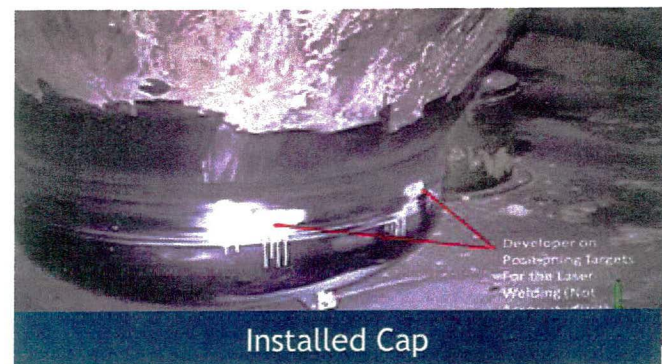
- Cause determined to be erosion initiated by steam lance
- Installed repair cap using robotically deployed powder-injection laser welding
- Post maintenance test with heated water and subsequent In-Service Leak test with waste at normal operating conditions showed no leakage
- **RESTART**
- Completed normal evaporator start-up December 13 and operated ~55 hours
- **Identified two new leak sites 3-5 feet above the repair cap at weld seams**
 - No leaks in repair cap area
- Inspections showed no free-liquid or accumulation on cell floor beneath new leak sites



Robotic Welding of Cap to Evaporator Vessel

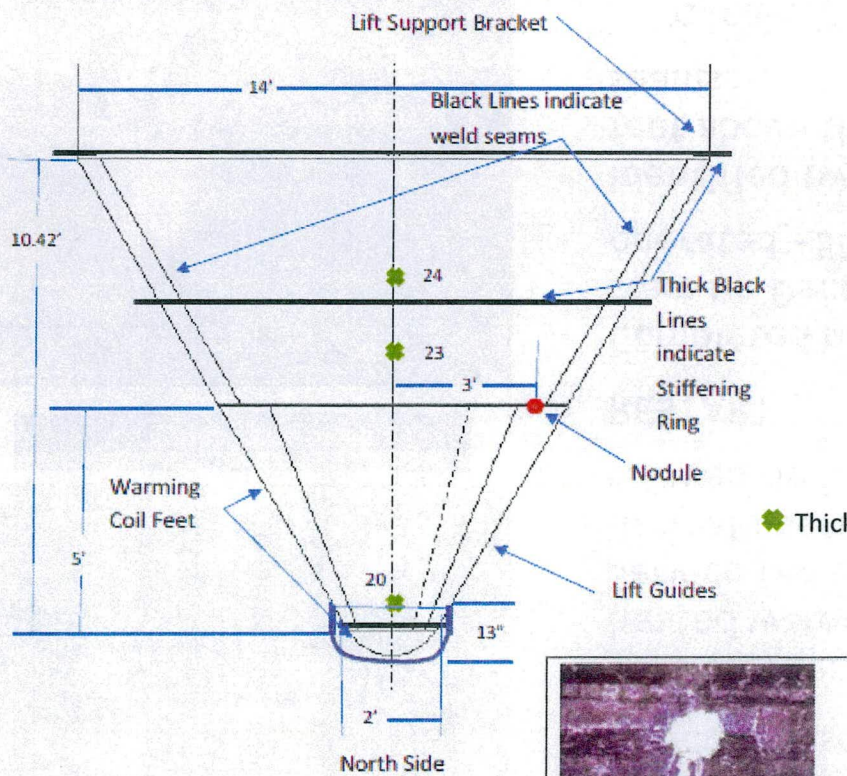


Final Weld

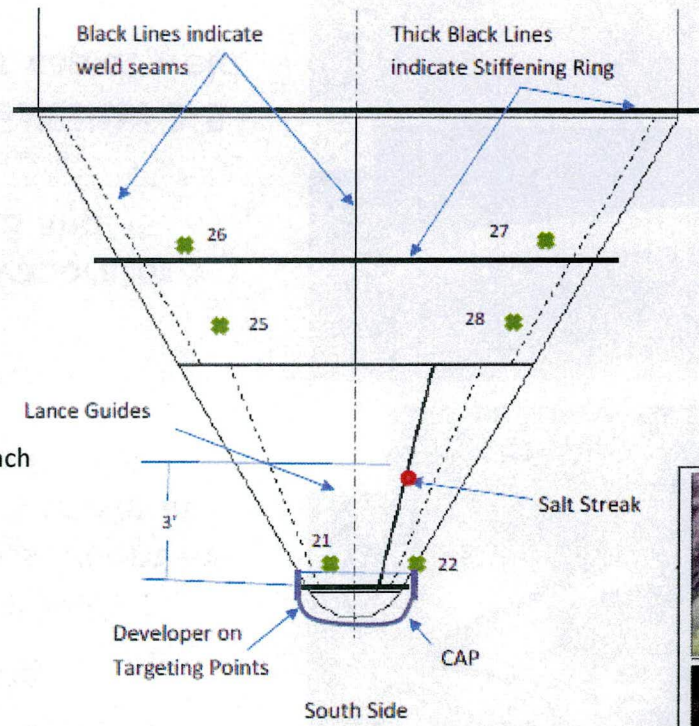


Installed Cap

Two Newly Identified Leak Sites

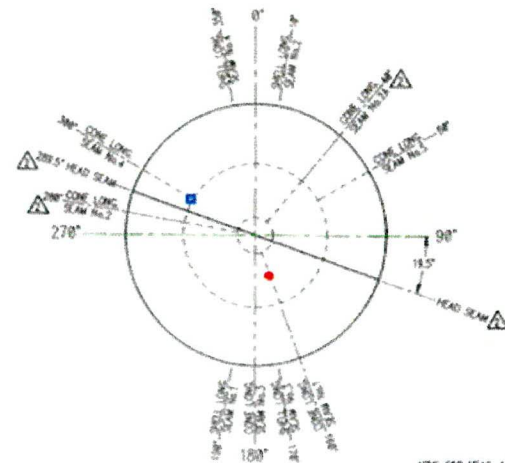
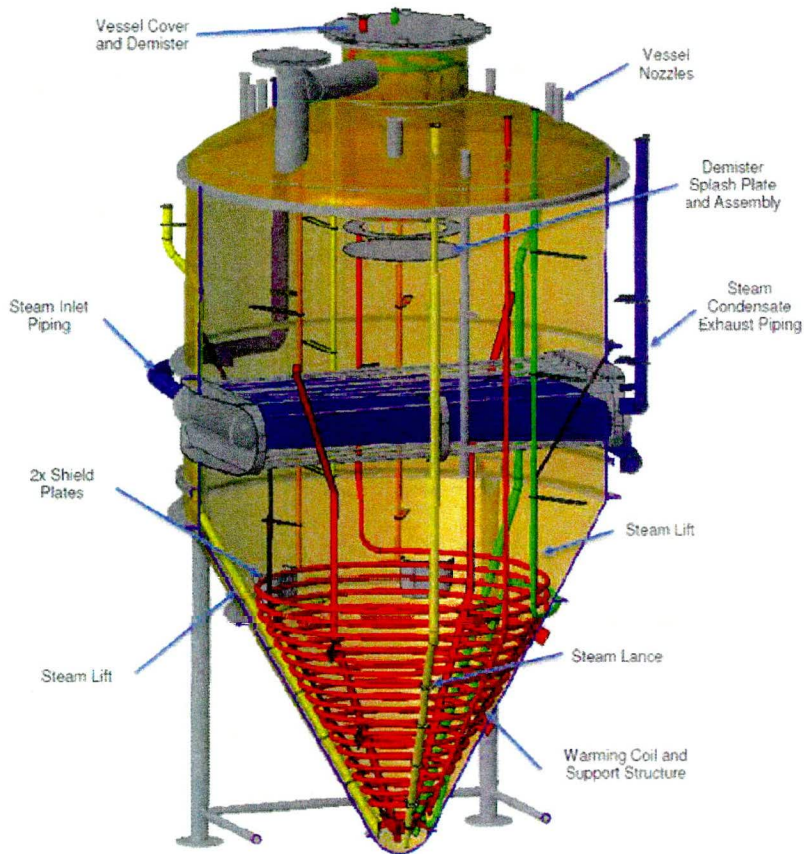


North Leak-site (the nodule)

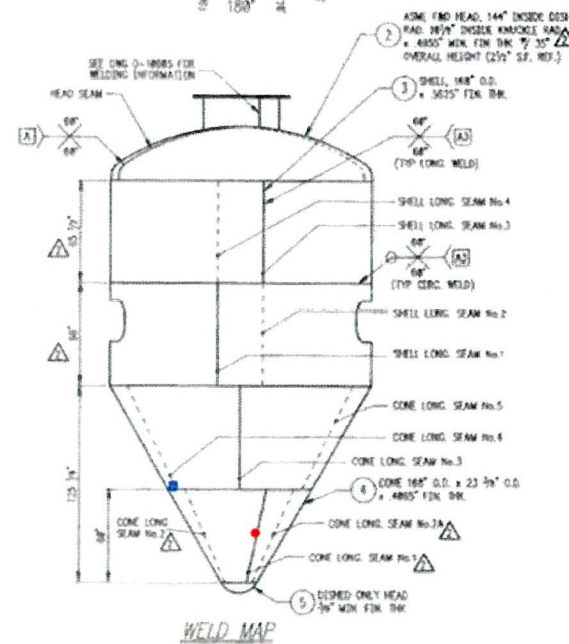


South Leak-site (the salt streak)

Newly Identified Leak Sites



■ North leak-site
● South leak-site



- Leaks are at welds
- Leaks are approximately the diameter of a human hair (~3 mils); calculated leak rate of $<1/10^{\text{th}}$ gallon per day per leak site
- Inspections showed dry material and salt nodule formation, minimizing the amount of salt waste outside of the pot
- Most likely cause is undetected weld discontinuities or defects during original manufacture
- Leaks sites will not grow during continued operation; if they are cracks, there is insufficient energy to drive crack growth
- The vessel is still structurally sound

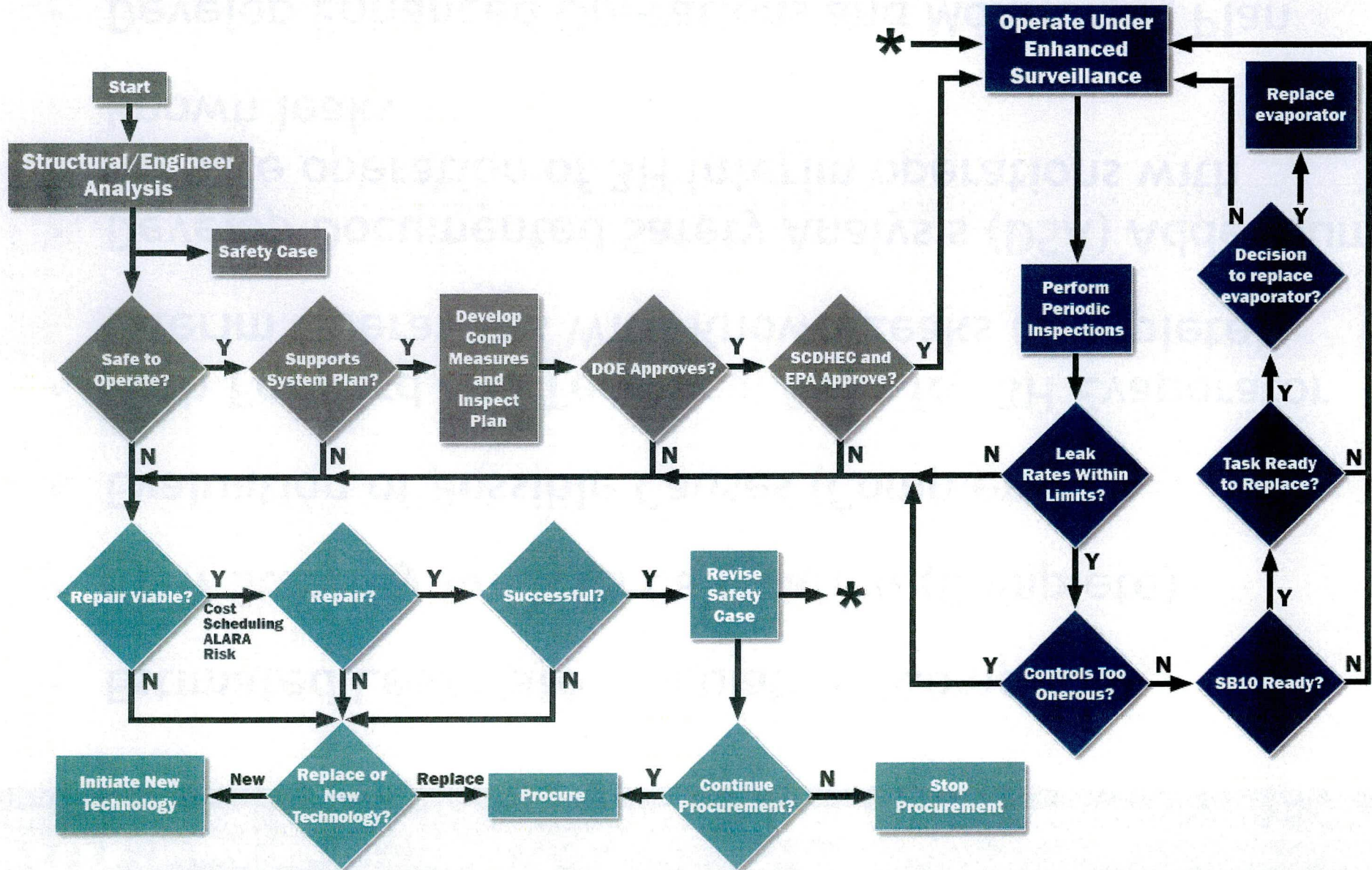
Why We Won't Have Impact to Human Health or the Environment?

- Unlike previous LW evaporators, the 3H System is fully enclosed within a building to prevent contamination events during cell entries and to minimize impacts of weather
- The evaporator pot sits within a concrete cell that is fully lined with stainless steel to ensure containment and to facilitate decontamination
 - The capacity of this secondary containment cell is > 30,000 gallons and the 3H pot has working volume of ~10,000 gallons
- The cell contains a sump which has dip tube level indication as well as a conductivity probe for liquid detection
 - The liquid detection probe is hard wired to an alarm in the continuously manned control room
 - Cell sump can be emptied to a waste tank via a steam jet
- The cell also has an under-liner sump with a conductivity probe
- The cell ventilation system includes HEPA filtration and is continuously monitored for contamination in the discharge
- Area radiation monitors would detect increased radiation rates

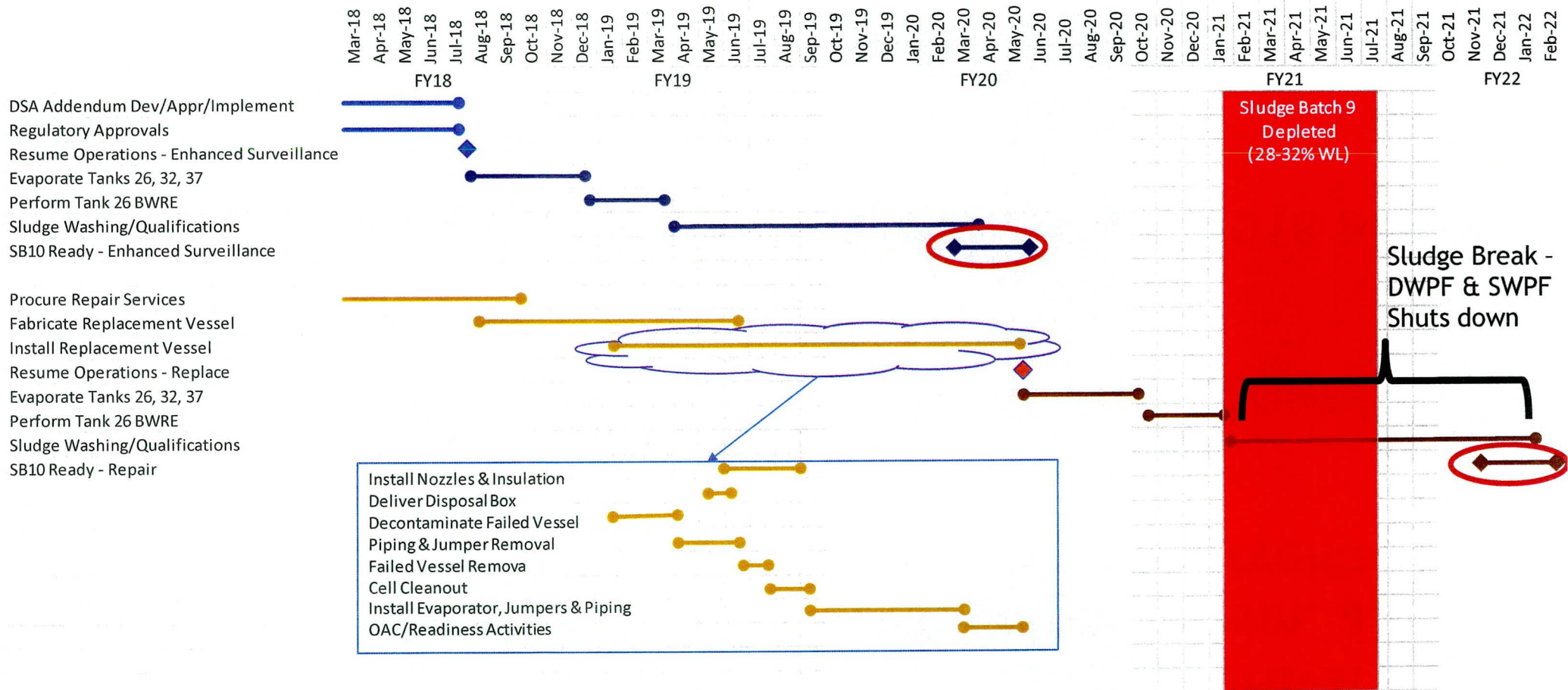
- **Federal Facility Agreement Requirements**
 - DOE is to notify SCDHEC and EPA of leaks discovered from waste tank systems
 - Appendix B, 5.(b): *If the leak was from the primary tank system into the secondary containment system, the system shall be repaired prior to returning to the tank system to service, or the DOE must demonstrate, subject to the approval of SCDHEC, that returning the system to services without repair would not threaten human health or the environment.*
- **SCDHEC Industrial Wastewater Construction Permit #17,424-IW**
 - Special Condition 6: *Once waste removal begins on a tank with a leak or crack and the waste is removed to a level below the lowest known leak or crack, that level shall become the maximum operating level of the tank and shall not be exceeded unless the exceedance is a temporary result of the waste removal process*
 - Special Condition 7: *No tank that leaks or has leaked shall be used for waste receipt without prior approval from this Department. This condition does not apply to the necessary addition of waste for waste removal purposes*
 - Special Conditions 6 & 7 are not applicable to the 3H Evaporator System (i.e., pot) since this is a treatment system dedicated to waste removal

- **Estimated Leak Rate Calculation (Complete)**
- **Flaw Stability Analysis Calculation (Complete)**
- **Evaluation of Possible Causes (Complete)**
- **Path Forward and Technical Basis for 3H Evaporator Interim Operations With Known Leaks (Complete)**
- **Develop Documented Safety Analysis (DSA) Addendum for safe operation of 3H interim operations with known leaks**
- **Develop Enhanced Operations and Monitoring Plan**

3H Evaporator Decision Logic



Liquid Waste System Plan Considerations



Following successful preparation of Sludge Batch 10, DOE will evaluate replacement of the 3H pot. Procurement of materials and fabrication of a replacement pot will continue during sludge batch preparation.

- DOE intends to submit a letter requesting approval to continue operation of the 3H Evaporator System, a leaking waste tank system, with enhanced surveillance as described herein
- DOE will seek regulatory approval from the SCDHEC and EPA FFA Managers
- Anticipated restart of the 3H system is July 2018 based on current execution schedule
- Request regulatory approval within 30 days of receipt of DOE's request

- The original discovered leak site at the bottom of the cone area of the 3H pot has been successfully repaired
- Two new small weep sites have been discovered on the cone
- The 3H pot is specifically listed in the SRS Federal Facility Agreement, Appendix B, as a *high-level radioactive waste tank system*
- Operation of the 3H will be compliant with FFA and Industrial Wastewater Permit

Enclosure 2

Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

Purposes of Liquid Waste Evaporator Systems

The 242-25H Evaporator System (also colloquially known as the *3H Evaporator*) is a key component within the Savannah River Site Liquid Waste System. It is one of two operational evaporator systems designed to volume reduce radioactive salt solutions to facilitate waste storage and treatment, and tank closure activities. The 3H Evaporator System is of importance in the preparation of sludge macrobatches. The macrobatches are washed to remove residual salts, qualified to meet glass standards and fed to the Defense Waste Processing Facility (DWPF) in small microbatches for vitrification along with the high-activity salt streams produced in the Actinide Removal Process (ARP) and Modular Caustic Side Solvent Extraction Unit (MCU) facilities. The washing of these salts from the sludge solids in these macrobatches will typically require 1,000,000 or more gallons of additional water to be added to the Liquid Waste System. The 3H Evaporator is critical to reducing this large volume of sludge batch wash water over the relative short period of time that it is produced.

The other operational evaporator system is the 242-16H Evaporator System, which is also referred to as the *2H Evaporator*. To minimize the formation of sodium aluminosilicates, the Liquid Waste Program segregates the waste stream that returns to the Tank Farms from DWPF – typically referred to as DWPF recycle – from other “canyon-like” waste streams. The DWPF recycle stream includes silica from the borosilicate frit used as a component in the glass formulation, as well as an abrasive cleaning agent when the filled canisters are power washed to remove any residual contamination prior to being moved to storage. The DWPF recycle stream is the principal feed to the 2H Evaporator System.

Summary of 3H Evaporator Construction and Repair

The 3H System was designed and constructed in the early 1990s and began radiological service in January 2000. It is the newest, and by far the largest, of the five evaporator systems that have been utilized in the Liquid Waste System beginning in 1961. Although the basic components of the system remain the same, the 3H System was designed to incorporate many of lessons learned from earlier evaporator operations and to handle significantly larger volumes of waste that were associated with the startup and operation of DWPF (i.e., sludge batch preparation and recycle management). The evaporator pot for the 3H System is significantly larger than the previous evaporator systems with a working capacity of approximately 10,000 gallons, about four times larger than the 2H Evaporator pot working capacity. Another significant difference is the materials of construction for the 3H evaporator pot and steam tubes. Unlike its predecessors that were constructed of 304L stainless steel, the 3H pot and steam tubes are manufactured from Alloy G-3 (Hastelloy®). Alloy G-3 is highly resistant to corrosive environments, both oxidizing and reducing, even at high temperatures. Based on decades of operational history of previous smaller evaporator systems, which had tube bundles made of 304L stainless steel, the predominant failure mechanism has been hot-wall corrosion or thermally-induced fatigue of the relatively thin-walled (0.083 inches) stainless steel tubes within the evaporator’s steam tube bundle, which provides heat to the system. The design of the 3H evaporator pot and thicker-walled (0.1455 inches) steam tubes emphasized prevention of these failures. With the use of this specialized metal alloy, the design life of the 3H evaporator pot was 30 years.

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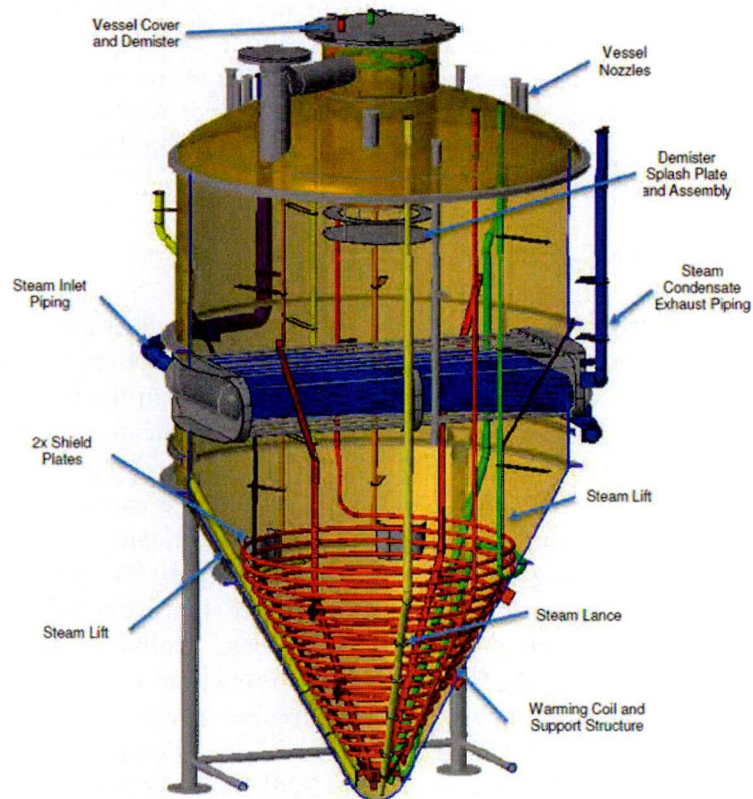
Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

The 3H evaporator pot, shown in Figure 1, is a single-staged “pot” evaporator. It is about 26.7 feet high by 14 feet in diameter, and the wall thickness of the conical section is ~0.41 inches. The vessel shell consists of:

- A pressure vessel head at the top with multiple nozzle penetrations;
- An upper cylindrical section with a horizontal steam tube bundle;
- A lower conical section supported by four legs and a support ring; and
- A small spherical head at the bottom.

The tube-bundle has hundreds of slightly curved tubes running between two thick vertical tube-sheets on opposite sides of the vessel. A steam lance injects steam into the vessel bottom to keep the waste suspended. Two sets of steam and lift lines also run to the bottom of the vessel cone to remove concentrated waste. The pot was surrounded by two inches of calcium silicate insulation that was sealed with 16-gauge (1/16-inch thick) stainless steel sheathing.

Figure 1: Major Components of the 242-25H Evaporator Pot



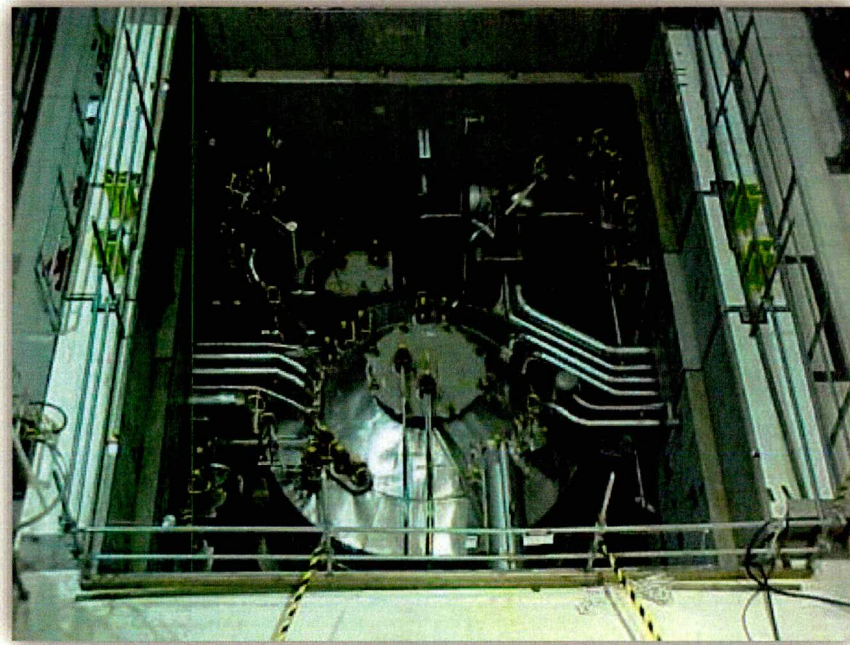
Enclosure 2

Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

On February 17, 2016, the 3H System was shut down after salt waste was discovered in the stainless steel-lined secondary containment cell that houses the 3H evaporator pot. The features of the 3H System worked as designed and all waste was contained within the cell, preventing any hazard to personnel or any release to the environment. The leak manifested itself by draining from where the legs penetrated the sheathing, indicating that the area between the pot and the sheathing (i.e., the insulation material) was filled with liquid. It is estimated that the leak rate reached approximately 150 gallons per day.

Pinpointing the exact location and cause of the leak site was challenging due to presence of the insulation and sheathing on the outside of the pot and the high radiation levels prohibiting personnel from entering the evaporator cell. Ultimately, the sheathing and insulation had to be removed from the conical portion of the pot to reveal the leak site. The removal of this insulation and sheathing itself was very challenging due to the high radiation rates and relatively tight space restrictions within the cell (Figure 2). A subcontractor, AREVA, was hired to perform the removal of the insulation from the pot. A BROKK 100™ remote excavator with a KUKA robot arm was used to perform this difficult task.

Figure 2: 3H Evaporator Pot and Associated Evaporator Secondary Containment Cell (Cell Covers Removed)

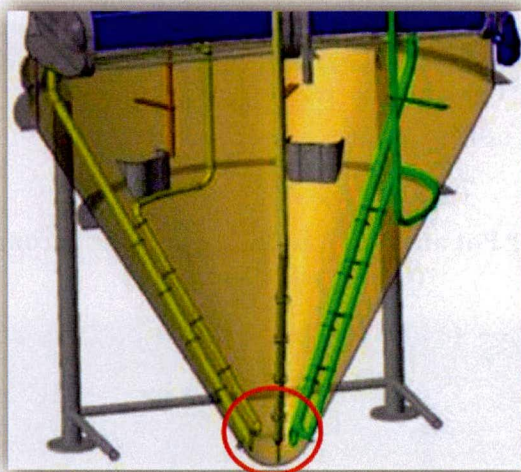


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Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

In February 2017, approximately one year after being shut down, multiple leak sites were clearly identified through visual observation once the insulation below the support ring was removed and the evaporator's steam lance was activated. Leakage was not observed without the activation of the steam lance; this has been attributed to the plugging of the leak sites by debris. Ultrasonic measurements of the pot wall thickness confirmed general thinning in the area where the steam from the lance impinges on the vessel wall. Following an extensive assessment, it was concluded that the loss of material, and ultimately the development of leak sites, was due to erosion from abrasive impingement of steam and salt solids on the vessel wall through the operation of the lance during the 16 years of operation at a steam flow rate of approximately 1,200 lb_m/hour (Figure 3).

Figure 3: Site of Erosion



Because the thinning of the vessel was restricted to the bottom portion of the evaporator cone, it was determined that a cap could be remotely welded to the bottom of the vessel sealing the leak sites. A ½-inch thick Alloy G-30 cap was designed and fabricated for this function. In November 2017, following extensive full-scale mock-up testing, this cap was successfully welded to the bottom of the vessel and on December 11, 2017, the Savannah River Remediation LLC (SRR) Professional Engineer certified that the cap was successfully installed per the design. This activity utilized all remote/robotic equipment and powder injection laser welding, a first-of-a-kind achievement in the industry. This welding technique was implemented by feeding Hastelloy® beads/fines from a hopper on the cell cover down approximately 35 feet into the evaporator cell to a laser head operated by the robot, with weld paths pre-programmed into the robot and operations controlled by an operator in a remote control room.

Prior to restarting the 3H Evaporator System, the 3H lance supply orifice was resized to reduce the mass flow rate for the steam lance by more than one-half — down to 500 lb_m/hour from the original 1,200 lb_m/hour. It was determined that evaporator operations would not be impacted by this reduction. By physically resizing the 3H lance steam gang valve orifice to reduce the mass flow rate to 500 lb_m/hour, the nominal erosion rate seen by the vessel wall is reduced by a factor

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Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

of 16, considering the erosion rate is proportional to fluid power (i.e., velocity cubed). At this reduced flow rate, if all other factors are equal, it would take more than 250 years to repeat the level of erosion seen during the first 16 years of 3H operation. This physical modification to the evaporator system to limit the steam mass flow rate of the lance, coupled with the fact the replacement cap is thicker than the original vessel wall, provides high confidence that this failure mechanism will not be repeated during the future operating life of this evaporator pot. In addition, calculations showed that the evaporator could function effectively without the insulation on the conical section of the pot. For this reason, there are no current plans to replace the insulation in this area.

New Technical Information

Following successful post-maintenance testing of the 3H pot following repair, the 3H Evaporator System was restarted on December 13, 2017. After 55 hours of operation, salt deposits were observed on the conical section of the evaporator pot at two locations. The evaporator was immediately shutdown and has not operated since that time. The two leak sites were located at weld seams three to five feet above the cap repair site. Visual inspections did not find any free-liquid or fresh salt accumulations on cell floor beneath the leak sites. Rather, the only indication of the leak sites were relatively small salt accumulations on the outside of the pot.

The first leak site (“South Leak Site”) is located on the south side, about one-third the way up the conical section of the evaporator pot. Figures 4 and 5 show the location of the leak site and the salt present.

Figure 4: Location of South Leak Site

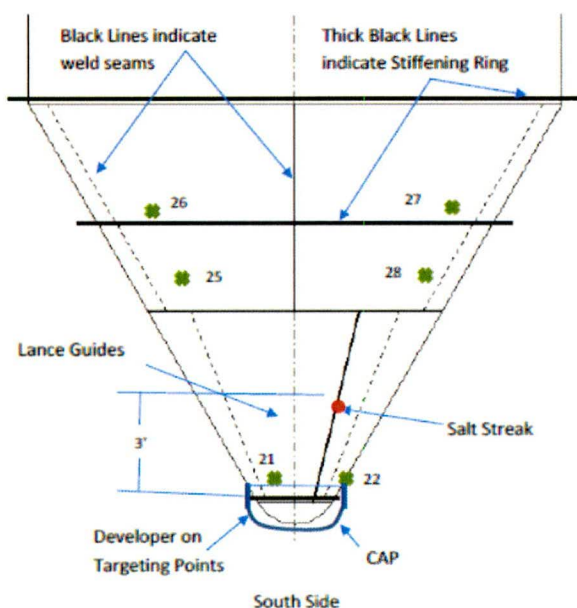


Figure 5: Salt Streak from South Leak Site



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Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

The second leak site (“North Leak Site”) is located on the northwest side, about half way up the conical section of the pot. Figures 6 and 7 show the location of the leak site and the salt nodule present.

Figure 6: Location of North Leak Site

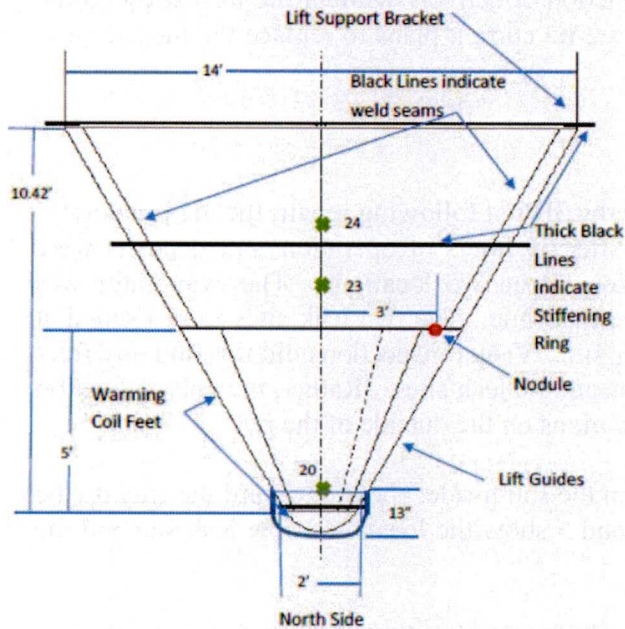


Figure 7: Salt Nodule from North Leak Site



The newly discovered leak sites were not apparent during visual inspections in 2017 prior to the installation of the repair cap, nor following the repair during post-maintenance testing; they only became apparent after operating the evaporator at higher temperatures and specific gravity, 135°C and 1.5 g/cm³ respectively. Since their discovery, it has been determined that these two sites are located on or near welds and have an equivalent hydraulic diameter of about 3 mils (0.003 inches) – roughly the size of a human hair. The calculated leak rate from these two leak sites during normal operations of the evaporator is calculated to be less than 1/10 gallon per day per leak site. This calculated leak rate assumes that no dry salt is present at the leak site, which would likely further reduce the leak rate. This very slow, drop-like rate is more than four orders of magnitude lower than the rate that was seen from the erosion-induced leaks at the bottom of the evaporator pot after the insulation and sheathing were removed. The presence of the insulation and sheathing around the vessel hid the presence of these defects during its 16 years of initial operation.

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Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

Justification for Operation with Known Leak Sites

The most likely cause of these recently discovered leak sites has been determined to be undetected weld discontinuities or defects during the original vessel manufacturing process. Due to the nature of these defects, the leak sites will not grow through the continued operation of the evaporator system. Further, it has been shown even if these sites were actually cracks, there is insufficient energy present at these sites to induce further crack growth. Despite the presence of these weld defects, the 3H evaporator pot is structurally sound in its present state.

As described earlier, the 3H Evaporator System is a critical element of the Liquid Waste System. It provides a unique function within Liquid Waste Operations and there is no alternative equipment or processes that can readily replace its function. Unavailability of the system would interrupt sludge and salt feed preparation, ultimately resulting in extended shutdowns of DWPF and the salt treatment facilities, ARP/MCU or the new Salt Waste Processing Facility. Of immediate concern, if the 3H System is not available to reduce the supernate volume in Tank 26, then bulk waste removal of Tank 26 sludge and transfer to Tank 51 (the sludge batch preparation tank) will be delayed. Once this Tank 26 sludge is transferred, it will be mixed with the Tank 15 sludge already in Tank 51 to form the next sludge macrobatch (Sludge Batch 10). Prior to being qualified to be fed to DWPF, extensive washing of the salts from this material is required, and this very large volume of wash water must be quickly volume reduced in the 3H System. If this series of activities cannot be completed in accordance with current execution schedules, Sludge Batch 9, the current qualified sludge batch feed material will be depleted, resulting in a breaking in feeding DWPF. Due to the integrated nature of our waste treatment systems, any break in feeding DWPF also results in a shutdown of our salt treatment facilities since the high-activity streams resulting from these treatment processes are sent to DWPF for incorporation into its sludge feed for vitrification.

In Appendix B of the Savannah River Site Federal Facility Agreement (FFA), *High-Level Radioactive Waste Tank System(s)*, a list of *high-level waste tank system(s)* that are subject to the requirements of the FFA is included. The 242-25H Evaporator Pot is specifically listed as a high-level waste tank system that is subject to these requirements. In Section D of Appendix B, entitled *Disposition of Leaking Tank(s)*, subsection 5.(b) states:

If the leak was from the primary tank system into the secondary containment system, the system shall be repaired prior to returning to the tank system to service, or the DOE must demonstrate, subject to the approval of SCDHEC, that returning the system to services without repair would not threaten human health or the environment.

Further, Appendix B, Section C, *Standards for Containment/Release Detection*, provides the minimum requirements for secondary containment system(s) for the high-level waste tank system(s). These requirements include such things as:

- Being compatible with the hazardous or radioactive materials being contained in the primary vessel;
- Being placed on a foundation or base capable of providing support to the secondary containment system, resistance to pressure gradients, and capable of preventing failure due to settlement, compression or uplift;

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Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

- Being designed to have the capacity of at least 100 percent the capacity of the largest tank within its boundary;
- Being designed to be sloped in such a manner as to collect and remove liquids resulting from leaks or precipitation; and
- Being designed to provide a leak-detection system capable of detecting a failure of either the primary or secondary containment structure.

The design of the 3H Evaporator System was predicated on ensuring that the operation of the system would not threaten human health or the environment, even in the presence of a substantial breach in the evaporator pot. Its design meets or exceeds the design requirements for secondary containment presented in Appendix B. The original significant leak (discovered in February 2017) in the 3H pot to its secondary containment cell clearly demonstrated that these design features are robust and effective in continuing to protect the human health of the occupational workers at the Savannah River Site and the surrounding public, as well as ensuring that no associated waste reached the environment outside the 242-25H structure.

Unlike the previous high-level waste evaporators, the 3H System is entirely enclosed within a building structure to further prevent contamination from reaching the surrounding environment during cell entries and to minimize the impact of weather conditions on operations and maintenance activities. The building has a robust ventilation system designed to minimize the spread of contamination outside the evaporator cell. The 3H ventilation system includes high-efficiency particulate air filtration and continuously monitored stack emissions.

The 3H evaporator pot sits in the evaporator cell that is fully covered with a welded stainless-steel liner. The stainless-steel liner provides robust protection should a leak occur and further facilitates the flushing of the cell to remove any buildup of contamination or waste accumulation. Integral to the stainless-steel liner, the cell contains a sump that collects any free liquids in the cell and a steam jet that can transfer this liquid to an adjacent waste tank. This sump also contains liquid level detection in the form of dip tube level indication, as well as a conductivity probe that is hard-wired to an alarm in the central control room that is continuously manned. The evaporator cell has an under-liner sump that also contains a conductivity probe hard-wired to an alarm in the control room. Area radiation monitors are strategically placed within the 242-25H building to provide an additional layer of protection in alerting personnel of unexpected conditions.

The design and operation of the 3H Evaporator System is included in the Department of Energy's Documented Safety Analysis (DSA) program. The DSA is a document that provides a description of the hazards of a facility during its design, construction, operation, and eventual cleanup and the bases to prescribe operating and engineering controls required to safely operate the facility. In support of these nuclear safety requirements, SRR has completed: (1) an estimated leak rate calculation; (2) a flaw stability analysis calculation; and (3) an evaluation of possible causes. In addition, SRR has developed a DSA Addendum for safe operation of the 3H Evaporator System with known leak sites, and has submitted this addendum package to the Department of Energy for review and approval. The 3H Evaporator System cannot be restarted until this document is reviewed and approved by the Department and fully implemented by SRR.

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Technical Justification for Operation of 242-25H Evaporator Pot with Known Leak Sites

As part of this implementation, SRR is preparing a series of activities to increase surveillances and the reliability of the safety features. The Technical Safety Requirements for operation of the 3H Evaporator System will now require remote surveillances within the cell at a minimum of every 90 days of operation. Additionally, the evaporator cell ventilation system, and cell sump's conductivity probe and associated alarm will be upgraded to the category of *Safety Significant*, invoking additional maintenance controls and pedigree to ensure increased system reliability. The program will also require enhancements to the 242-25H *Event Response* and *Emergency Response* required actions and protocols.

Consistent with subsection D.5.(d) of Appendix B of the Savannah River Site FFA, the Department of Energy is requesting regulatory approval of the continued operation of the 3H Evaporator System as-is and defined as follows:

- With installed ½-inch thick G-30 Alloy cap covering original leak site;
- With known leak sites as described above;
- With modified lance supply orifice that reduces the mass flow rate;
- With enhanced remote surveillances within the secondary containment cell; and
- With an upgraded safety pedigree of the secondary containment cell sump's conductivity probe and associated alarm.

The Department will continue to provide a routine status to South Carolina Department of Health and Environmental Control and the U.S. Environmental Protection Agency of the 3H Evaporator System operations and conditions through the FFA Quarterly Meeting process, and will further notify the agencies between these routine updates if any unexpected conditions were to arise.