DEFENSE NUCLEAR FACILITIES SAFETY BOARD

August 9, 1996

MEMORANDUM FOR:	G. W. Cunningham, Technical Director
COPIES:	Board Members
FROM:	Tonya M. Huntley
SUBJECT:	Defense Waste Processing Facility and In-Tank Precipitation Vessel Erosion/Corrosion Evaluations, and F-Canyon and H-Canyon Vessel Integrity, Savannah River Site

1. **Purpose:** This trip report documents the Defense Nuclear Facilities Safety Board (Board) technical staff review of the corrosion rates and predicted service lives of the Defense Waste Processing Facility (DWPF), In-Tank Precipitation (ITP), and F-Canyon and H-Canyon vessels conducted at the Savannah River Site (SRS) by W. Yeniscavich and T. Huntley, July 31, 1996 through August 2, 1996.
2. **Summary:**

    a. ***F-Canyon and H-Canyon Vessels***: A general corrosion rate of up to 10 mils per year has been observed in high temperature F-Canyon and H-Canyon vessels. This rate of wall thinning could make these vessels structurally unstable after ten years of service. SRS has not performed a service life prediction for the canyon vessels.

    b. ***F-Canyon and H-Canyon Coils***: SRS does not have service life predictions for canyon vessel coils even though 143 coils have failed during service. Coil failures now require the replacement of the vessel and coil as a unit, since the practice of only replacing coils in the vessels was discontinued in the early 1980s because of radiation exposure to the workers.

    c. ***Potential Delays regarding F-Canyon and H-Canyon***: Canyon vessel and coil failures are not a direct safety concern because of mitigating systems to contain radioactivity. However, the vessels and coils have been in service for many years and may be nearing the end of their service lives. When the available replacement vessels are used, long delays in canyon operations may occur until new vessels are procured. Delays in canyon operations would mean delays in processing spent fuels and targets in the L and K basins at SRS.

    d. ***ITP***: Tank No. 48, which is used to conduct in-tank precipitation, is a double shell, carbon steel tank of the newest design. Corrosion of Tank No. 48 is prevented by maintaining a high pH chemistry and by control of impurities within the tank. Special corrosion tests showed sodium tetraphenylborate (TPB) did not increase tank wall corrosion. Furthermore, ultrasonic wall thickness measurements of Tank No. 48 were performed during the last two years. Results showed negligible decreases in nominal wall thickness, indicating the tank is experiencing little or no corrosion.

    e. ***DWPF***: Ultrasonic wall thickness measurements were performed on DWPF vessel walls prior to and after one year of non-radioactive hot operations. Also, corrosion test coupons were suspended in the vessels during these hot operations. No significant changes in vessel wall thicknesses or test coupons occurred during this one year test. However, some erosion occurred on cooling coils and selected piping associated with high flow of glass frit solutions. Corrective measures were taken to reduce the erosion, and an inspection and replacement program was instituted. No major shutdowns are anticipated at DWPF as a result of corrosion or erosion of vessels or their components.

3. **Background:**

   a. ***F-Canyon and H-Canyon Vessels***: The F-Canyon and H-Canyon each have seventy five process vessels of various sizes. The majority of the vessels are made of 304L stainless steel. Since startup of the F-Canyon and H-Canyon in the mid-1950s, there have been 4 vessel leaks and 143 coil leaks. The 4 vessel leaks occurred in evaporators and were attributed to accelerated corrosion near welds or at the bottom radius of the vessels. Prior to 1980, when a coil leaked, the vessel was cut open and the coil was replaced. A number of vessels were scrapped during these coil replacement operations because of wall thinning caused by general corrosion. For example, when a vessel with an original wall thickness of 0.375 inch was reduced to 0.275 inch or less, that vessel was considered structurally unstable for further service.
   b. ***F-Canyon and H-Canyon Coils***: Since the mid-1950s, 143 heating/cooling coils within the F-Canyon and H-Canyon process vessels have failed. The coil failure rate reached a maximum of 16 per year in 1980. A variety of failure mechanisms for these coils were conjectured, but, in general, the most prominent was accelerated general corrosion attack in heat-affected zones of the coil welds. As a result, changes were made to reduce coil failures in the early 1980's. Changes to mitigate coil failures were the following: reducing thermal shock in the coils, reducing fluoride concentration in the process solutions, reducing the use of the coils, and replacing coils entirely instead of repairing them. Since the improvements were made, the failure rate has been approximately two coils per year during operating periods.

      An attempt was made by the Savannah River Technology Center (SRTC) to perform a statistical analysis of the failure rates to predict lifetimes for the coils, but this analysis provided unreliable predictions because of the lack of a specific, detailed database. For example, coils showed a 70% statistical probability for failure during the current operating mission. So, this statistical analysis approach was abandoned.

   c. ***ITP***: Corrosion of High Level Waste Storage Tanks (HLWST) is mitigated by the addition of nitrites and hydroxides and by the the control of impurities in the tank contents. This chemistry control has been successful in arresting internal corrosion in the HLWST at SRS. (An identical approach is used for preventing corrosion in the Hanford HLWSTs.) The chemistry control results are confirmed by internal visual inspections of tanks and by ultrasonic wall thickness measurements. Tank No. 48, a HLWST, was converted to conduct in-tank precipitation.
   d. ***DWPF***: Prior to the introduction of radioactive materials into DWPF, a one year, non-radioactive operational hot run was conducted to verify operations. During

this hot run, corrosion test coupons were exposed within the vessels to vapor, liquid, and mixed vapor-liquid phases. After the hot run, the vessels were internally inspected for corrosion and erosion. In addition, ultrasonic wall thickness measurements were made before and after the hot run.

The majority of the DWPF vessels are made of nickel base alloy 276 and a few are made of 304L and 316L stainless steel. These highly corrosion-resistant alloys were selected to provide a long service life. In addition, design features such as removable heating/cooling coils were included because of the high coil failure rate experienced in the F-Canyon and H-Canyon vessels.

4. **Discussion/Observations:**

a. ***F-Canyon and H-Canyon Vessels***: The general corrosion rate of F-Canyon and H- Canyon vessels is dependent on the service temperature. The estimated corrosion rate is 10 mils per year for all vessels that experience high temperatures (250oF). These vessels include evaporators and dissolvers. Other vessels exposed to temperatures of 150o F have a predicted corrosion rate of one mil per year. In addition, storage vessels exposed to ambient temperature have a predicted corrosion rate of less than one mil per year.

Based on these estimates, evaporators and dissolvers would become structurally unstable due to wall thinning after 10 years of service (when wall thickness is reduced from 0.375 inch to 0.275 inch.)

SRS does not have a service life prediction for F-Canyon and H-Canyon vessels, but site personnel have stated that they are working on a prediction with a target completion date of about 6 months.

A vessel failure is not a major safety concern because the leaking contents would be collected in a sump and pumped into a holding tank. However, a large number of vessel failures could delay or stop canyon operations while the vessels are being replaced.

b. ***F-Canyon and H-Canyon Coils***: The recent failure rate for coils has been about two per year. However, since the attempt to predict service life based on statistical analysis was unsuccessful, no service life predictions are available for coils. The in- service inspection program previously proposed is still at the initial feasibility stage and no actual inspections are expected to be conducted on vessel coils within the next few years. The concern is that a large number of coils may be close to the end of their service lives and a large increase in the number of coil failures may be imminent. Without a service life prediction or actual measurements, this concern cannot be resolved.

A leaking coil does not cause a direct safety concern because of mitigating safety features. An automatic diversion system has been designed for both the F-Canyon and H-Canyon Cooling Water Systems and will be installed within the next 6 months. However, a high number of coil failures could result in shutdown of the canyons for an extended period to replace vessels. Furthermore, many failures would stop the processing of target and fuel elements currently being stored in SRS basins.

Vessel replacement is necessary when a coil fails because, starting in the early 1980s, the procedure for replacing the coils in the vessels was discontinued due to radiation exposure to workers. The concern is that an increased rate of coil leakage may result in a large number of vessel replacements. For evaporators, five replacement evaporators are available and a sixth evaporator could be modified for service. Six coils failures in the first year would use the supply of spares. Typically, it takes 3 years to obtain a replacement vessel.

c. ***ITP***: In-tank precipitation is being conducted in Tank No. 48 at SRS. Tank No. 48 is of the newest design and is a double shell, carbon steel tank which has been stress relieved to mitigate accelerated and intergranular corrosion. By maintaining the pH of Tank No. 48 between 12 and 14, by adding nitrite and hydroxide, and by control of impurities, corrosion is arrested. This chemistry control has been used successfully to arrest corrosion in all of the carbon steel tanks at SRS.

A study was completed adding sodium TPB and its chemical decomposition products to the normal tank chemistry. The results showed no significant increase in corrosion due to the addition of TPB. Hence, no significant corrosion is expected to occur in Tank No. 48 during ITP operations.

In order to confirm that no significant corrosion is occuring, ultrasonic wall thickness measurements were made of the primary shell of Tank No. 48 through the access ports surrounding the tank. The original wall thickness of about a half of an inch showed no decrease, indicating the tank experienced essentially no corrosion. Future ultrasonic wall thickness measurements will be conducted to verify continued tank integrity. Therefore, there does not appear to be any concerns with corrosion causing structural degradation in ITP Tank No. 48 due to corrosion as long as proper chemistry control is maintained.

d. ***DWPF***: Both the ultrasonic wall thickness measurements and the test coupon results showed negligible corrosion in the DWPF vessels. However, some erosion of cooling coils at the lower supports and selected piping (e.g., risers) occurred, which was associated with high flow rates of solutions containing glass frit. The melter head instrument ports show corrosion due to the presence of oxygen at high temperatures. Corrective actions for these concerns are currently in progress.

In order to reduce erosion, Stellite hard face coating was applied to susceptible areas. Also, most vessels in DWPF are designed so that the cooling coils and affected piping can be replaced. Replacements can be accomplished within a time period of 2 shifts to 2 weeks, depending on the specific component.

Based on the data provided, it appears that DWPF vessels will last the design life of the facility, approximately 20-30 years. Some minor components may have shorter design lives, however, no significant shutdowns are anticipated due to corrosion or erosion because a good inspection and replacement program is in place. Future activities for the Structural Integrity Program at DWPF include development of eddy current or ultrasonic inspection techniques for in-service inspection of the process vessels.

5. **Future Staff Actions:** The Board staff will review the SRS effort to predict the service lives for F-Canyon and H-Canyon vessels and coils until it is completed.