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HISTORY OF WASTE TANK 16 1959 THROUGH 1974

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Introduction

Alkaline radioactive wastes resulting from the chemical separation of fission products from plutonium and uranium at the Savannah River Plant are stored underground in carbon steel tanks having capacities that range from 0.75 to 1.3 million gallons. The waste falls into two general categories: high heat waste (HW), which contains the majority of the fission products, and low heat waste (LW), which results from purification processes and from dissolving aluminum cladding from reactor fuels. Some tanks equipped with cooling coils are for storage of high heat waste while other tanks without cooling coils are for low heat waste.

Tank 16 is a 1,030,000 gallon, Type II tank located in H Area and used for storage of high heat waste (figure 1). It is 85 ft in diameter, 27 ft high, and has 40 vertical cooling coils in the upper part. At the bottom, where the sludge and most of the fission products concentrate, there are four horizontal cooling coils. The tank is constructed from type ASTM A-285-B steel with nonstress-relieved welds, and is inside a concrete vault with an annular space surrounding the tank. Lining the bottom of the vault is a 5-ft-high steel annulus pan (secondary container) to collect leakage from the primary tank. There were originally 8 risers providing access to the tank interior and 4 risers to the annulus. An additional 12 annulus risers were added to allow approximately 100% primary wall inspection.

Events in the history of tank 16 are listed chronologically in figure 2 and discussed briefly in this report. Listing of a date by month and year at any place in this report serves as a reference to the Works Technical Report for that month. Other sources of information include DPSP 61-1357, *History of Waste Tank 16*, T. S. McMillan to R. M. Girdler, March 1961, and DP-1358, *Leakage from Waste Tank 16 - Amount, Fate, and Impact*, by W. L. Poe, November 1974. The period this history covers is from May 1959 through December 1974.

Summary

Tank 16 was placed in service as a receiver of fresh HW on May 9, 1959, and was filled to capacity in May 1960. Approximately half the tank contents were transferred to tanks 14 and 15 during September and October 1960 because of leakage into the annulus. Use of tank 16 was resumed in October 1967 when authorization (TA 2-603) was obtained to receive LW, and the tank was filled to capacity by June 1968. Subsequently, supernate was removed from the tank, and a blend of fresh LW and evaporator bottoms was added. In March 1972, the supernate was transferred to tank 13 because leakage had resumed. The sludge was left in the tank bottom and the use of tank 16 for any additional waste storage was discontinued.

Waste leakage into the annulus was first discovered after 5 months service. The leakage increased and in September 1960 liquid waste overflowed the annulus pan. A few tens of gallons of this waste breached the tank concrete encasement and entered the surrounding soil. Leakage essentially stopped after the tank liquid level was lowered below the middle horizontal weld. After exhaustive study, tank cracking and resultant leakage was concluded to have been caused by stress corrosion due to the action of NaOH or NaNO₃ on areas of high local stress in the steel plate such as welds. Subsequent SRL studies have isolated NaNO₃ as the corrosion cause. Since the 1960 annulus overflow, maximum salt depth in the annulus has been about 15 in.

Inspections of the tank interior and annulus were made by direct observation, by closed circuit television, and by using a 40-ft optical periscope. Samples of sludge, supernate, tank vapors, and leaked material in the annulus were analyzed, and tank temperature and radiation profiles were taken. Two disk samples were cut from the primary tank wall for metallurgical examination. Test coupons of various metals were exposed to tank 16 waste to aid new tank design and to study stress corrosion and hydrogen embrittlement. In addition, samples of SRP bedrock were placed in tank 16 to study reactions between bedrock and HW.

Discussion

OVERALL CHRONOLOGY

On May 29, 1959, tank 16 was placed in service as a receiver of neutralized HW from the HM separations process in Building 221-H. The tank was full by May 1960, and remained in this condition until major leakage was detected in September 1960 and some waste was transferred to other tanks. The tank was not used again until October 1967 when it first was used to store LW and later miscellaneous waste such as blended HW and evaporator bottoms. In March 1972, the supernate was removed because leakage resumed. The sludge was left in the tank bottom and the use of tank 16 for additional waste storage was discontinued.

Significant events, including all entries discussed below, are shown on the tank liquid level plot in figure 2. Sludge and supernate temperatures are also shown in figure 2, along with annulus liquid level during the period when standing liquid was present.

Chronology of Events

May 1959	Tank 16 was placed in service as a receiver of HM process HW on May 29 immediately after receiving 3400 gallons of 50% NaOH solution. The caustic heel was provided to neutralize any inadvertant transfer of acidic waste from Building 211-H.
Jun 1959	The operating set of cooling coils was valved into service after being flushed to remove air.
Aug 1959	The auxiliary set of cooling coils was placed in service, and both sets of coils were flushed to remove air. Tank thermocouple connections were corrected.
Sep 1959	Two small transfers of incompletely neutralized waste were received due to an operating error. Tank liquid level was 130 in.
Oct 1959	Six cooling coils found to be air locked were flushed. Tank temperatures did not decrease after flushing. The annulus "necklace" liquid alarm sounded almost continuously. The alarms were thought to be caused by rainwater inleakage.
Nov 1959	Radioactive liquid was discovered on the annulus floor, and white, solid deposits on the tank wall were sampled and determined to be dried radioactive waste. The dehumidification system was shut down to prevent spread of radioactivity to the atmosphere by the dehumidification air which, at the time, was released directly to the atmosphere. A tank auxiliary blower was installed to purge the vapor space of gaseous radiolytic decomposition products.

- Dec 1959 Leaks along the bottom horizontal weld were inspected using closed circuit television. Pictures of the leaks were obtained by photographing the television monitor screen.
- Mar 1960 Reactor fuel processed in Building 221-H was changed from the Mark VI to Mark VI-J type, reducing the waste generation rate per day by about 60%.
- May 1960 Tank 16 was filled to capacity at 303 in. liquid level.
- Jun 1960 Building 221-H was shut down from June to October 1960, and only a minimum crew was maintained for surveillance of the H-Area tank farm.
- Jul 1960 Hydrogen concentration in the tank vapor space reached 40% of the lower explosive limit (LEL) after the tank purge blower had been shut off for 3 days.
- Aug 1960 The annulus appeared dripping wet during routine annulus inspection. The annulus dehumidification system was modified to purge the annulus and tank in series, and dehumidification was resumed for 9 days. Dehumidification was discontinued because contaminated air leaked from the annulus through defective seals on the annulus access port plugs.
- Sep 1960 Liquid waste overfilled the annulus pan on September 7 due to increasing leakage, and several tens of gallons of waste breached the concrete encasement entering the soil. An annulus jet was installed on an emergency basis and excess annulus liquid transferred to tank 14.
- Oct 1960 A jet assembly was installed in the tank and waste transferred to tank 15. Leakage essentially ceased when the tank liquid level reached the middle horizontal weld, so the transfer was discontinued.
- Oct 1961 A primary tank wall sample was removed at the top horizontal weld. Metallurgical examination of the sample revealed that waste tank cracking was probably caused by NaOH or NaNO₃ induced stress corrosion in high stress areas of the steel plate such as welds (subsequent SRL studies isolated NaNO₃ as the cause).
- Feb 1962 Mild steel "pillow specimens" were removed from HW in tank 16 and examined for evidence of hydrogen penetration.
- May 1962 Samples of SRP bedrock were suspended in tank 16 waste to investigate reactions between bedrock and HW.
- Jul 1962 Specimens of several metals and alloys were placed in tank 16 to obtain corrosion data to aid tank design.
- Jun 1963 Specimens of mild steel were placed in tank 16 to study stress corrosion.
- Jan 1965 An annulus dehumidification exhaust filter and permanent tank purge and exhaust contamination alarm were installed. Annulus dehumidification was successfully resumed without spreading contamination out of the annulus access port plugs.

- Oct 1967 Transfer of LW to tank 16 was started (TA 2-603) since there has been no recurrence of leakage and self-sealing capability of leaks with proper dehumidification had been demonstrated.
- Apr 1968 Both LW headers from Building 221-H were routed to tank 16.
- Jun 1968 The tank was filled to reduced capacity at a level 18 in. below the top horizontal weld.
- Sep 1968 Tank 16 supernate was transferred to tank 13. A steam leak in the jet assembly developed during the transfer.
- Jul 1969 Supernate was transferred to tank 13 in July and August 1969.
- Aug 1969 A blend of fresh HW and concentrated supernate from salt tanks was added to and withdrawn from tank 16 between August 1969 and July 1970.
- May 1970 Authorization (TA 2-716) was obtained to store fresh HW supernate decanted from its radioactivity and thermally hot sludge and to increase the filling rate limitation from 45,000 to 150,000 gallons per day.
- Aug 1970 The tank was probed for salt deposits, and liquid specific gravity was measured. No salt deposits were found.
- Feb 1972 The annulus salt layer was probed with a coring tool.
- Mar 1972 Use of tank 16 for storage of additional waste ceased because leakage resumed. The 768,000 gallons of supernate were transferred to tank 13 leaving a sludge heel of 68,000 gallons in the tank. About 1000 gallons of liquid were extracted from core holes in the annulus salt crust and transferred to tank 14 using the annulus jet.
- Oct 1973 A dewatering jet was installed in the annulus and operated for 13 days. Tank sludge sampling using the "clam shell" sampler was started for SRL waste solidification studies.
- Jan 1974 A vertical weld inspected with dye penetrant in 1962 was sandblasted and re-examined. Cracks observed in 1962 were found not to have increased in size.

LEAKAGE INTO ANNULUS

Tank 16 initially received HW from the enriched uranium recovery (HM) process in Building 221-H. Waste sent to the tank included HW from 1AW, head end evaporator condensate, 805 tank waste, LW from solvent recovery and second cycle raffinates, head end cake waste, and an assortment of wastes from rerun. Immediately before the first receipt of waste, 3400 gallons of 50% NaOH was added to the tank.

On November 13, 1959, the first radioactive waste was found in the tank annulus under the north riser. On September 9, 1960, the annulus liquid level rose above the secondary container, a 60-in.-high steel annulus pan, by an estimated 700 gallons of waste. Most of the overflow was contained by the concrete encasement, but an estimated few tens of gallons may have leaked into the ground. By March 1962, periscopic inspections had revealed 145 identifiably leaks in the primary tank wall. Subsequent inspections through 1972 disclosed additional leak sites and salt deposits, and the total number of leak sites was estimated to be 350 in 1974. Comparison of photographs obtained in February 1972 with those taken in 1961 indicated that additional seepage took place since the 1961 inspections. In March 1972, 768,000 gallons of waste supernate was transferred to tank 13 leaving a 32.5-in. heel of sludge in tank 16. The tank has not been used for storage of liquid waste since that time.

All entries in the chronology below are also shown in figure 2 along with liquid levels of the tank and annulus. Figure 3 is a face diagram of the tank wall which indicates the location of known leak sites and salt deposits.

Chronology of Events Related to Leakage into Annulus

- May 1959 A heel of 3400 gallons of 50% NaOH solution was placed in tank 16 prior to receiving HW from Building 221-H.

- Sep 1959 Two small transfers of incompletely neutralized (nearly neutral) waste were received due to an operating error. Damage to the tank could not have resulted because of the caustic heel.

- Oct 1959 Difficulty with the "necklace" liquid alarm was experienced but no waste was visible in the annulus. The alarms were believed to be caused by rainwater leakage into the annulus since this had occurred in other tanks. Routine visual inspection of the annulus was started.

- Nov 1959 Liquid was observed below the north and south annulus risers on November 5 but it was thought to be rainwater. Radioactivity was detected in liquid below the north riser on November 13. In addition, white, solid material was observed protruding from the tank wall below the south riser. Annulus dehumidification was stopped to prevent spread of radioactivity to the atmosphere by the dehumidification air which, at the time, was released directly to the atmosphere, and on November 19, the deposits were sampled and confirmed to be dried radioactive waste.

- Feb 1960 The leaks along the bottom horizontal weld under the south riser were inspected using closed circuit television. Comparison of photographs of the monitor screen with construction x-ray pictures indicated leakage was occurring at patched areas in the weld (figures 4 and 5). The x-ray pictures indicated the weld was repaired satisfactorily.

- May 1960 Tank 16 was filled to capacity at 303 in. liquid level.

- Aug 1960 The annulus was found to be dripping wet during routine inspection on August 1, and no salt deposits were visible. Annulus dehumidification was resumed on August 12 after modifying the system to purge the annulus and tank in series, and the annulus appeared much drier on August 19. The dehumidifier was shut off on August 21 because of contamination from air leaks around access port plugs. The dehumidifier subsequently was operated for 7 and 8 hours on August 25 and 30, respectively, to purge the tank vapor space.
- Sep 1960 The annulus liquid was found to be 4½ ft and rising on September 7 from leakage in excess of 1½ gallons/minute which had developed in the previous few weeks. Before an annulus jet assembly could be fabricated and installed, liquid waste rose above the annulus pan by an estimated 700 gallons on September 8. Several tens of gallons in turn may have leaked through the concrete encasement into the soil (figure 6). The annulus jet was installed on September 9 and operated intermittently until October 15 to maintain the liquid level below the top of the pan. Figure 7 shows the tank liquid level, annulus liquid level, and tank leakage rate between September 7 and October 16. Leakage continued to increase up to a rate of about 4 gallons/minute and then subsided to a steady 3½ gallons/minute rate as the tank level was lowered below the top horizontal weld. This indicated the size and number of leaks at the top weld was increasing. Four monitoring wells were drilled through the construction pad around tank 16 on September 19-21. Radioactivity, principally cesium, was detected on October 4 in ground water from well HPM-3. Dip samples were obtained from the other wells, and figure 8 shows the sampling results from all wells. The $^{137}\text{Cs}/^{134}\text{Cs}$ ratio in the contaminated water identified tank 16 as the source of contamination.
- Oct 1960 A jet assembly was installed, and approximately 350,000 gallons of waste was transferred from tank 16 to tank 15 on October 12-15. The leakage rate decreased stepwise during the transfer indicating that major leakage areas existed at about the 233-in., 192-in., and 160-in. tank levels. Most of the leakage ceased at a liquid level slightly above the middle horizontal weld, and the transfer was discontinued at a liquid level slightly below the middle weld (147 in.). A total of about 185,000 gallons of waste had leaked into the annulus and was transferred to tank 14.
- Nov 1960 Ground water was pumped continuously from the water addition (an interconnected drain field under the bottom of the waste tank) system between November 1960 and May 1961 to determine the extent of contamination below the construction pad. Radioactivity was detected immediately at a concentration about ten times that found above the pad at well HPM-3. The ground water contamination is thought to have come from waste that overflowed the tank 16 annulus pan in September.
- Dec 1960 New test wells were drilled around the upper tank farm to a depth of 45 ft. No significant amount of radioactivity has been detected, indicating that any migration from the tank area has not reached these wells.
- Jan 1961 Routine visual inspection revealed that the annulus was dry and waste on the floor had solidified.

- Feb 1961 A systematic examination of the tank wall by closed circuit television was started by Engineering Assistance Section (EAS). Most of the leak sites found were located near seam welds.
- Mar 1961 Design Division compared photographs of three leaks at the top horizontal weld with construction x-ray pictures and was able to correlate the leaks with weld repairs. Leaks at the top weld occurred after only 6 months' exposure to supernate at a maximum temperature of 54°C. There was evidence of minor, continued leakage at the bottom horizontal weld.
- Oct 1961 Trepanning of a 6-in.-dia tank wall sample from the top horizontal weld indicated through metallurgical examination that tank cracking was probably caused by NaOH or NaNO₃ induced stress corrosion of the plate in high stress areas such as welds (subsequent SRL studies isolated NaNO₃ as the cause). Two midplate leaks not associated with seam welds were discovered. Reflectoscope examination of one leak revealed the leak was located near an attachment on the tank wall.
- Sep 1964 Soil samples obtained below the construction pad between September 1964 and April 1965 indicated that contamination had migrated downward no further than 20 ft below the pad.
- Jan 1965 Tank purge equipment and a filter on the annulus dehumidifier exhaust were installed, and annulus dehumidification was resumed.
- Oct 1967 LW waste transfer to tank 16 was resumed.
- Jun 1968 The tank was filled to reduced capacity to a level 18 in. below the top horizontal weld.
- Jan 1972 New leak sites and enlarged salt deposits on the tank wall and annulus floor were observed during inspections in January and February 1972.
- Mar 1972 The supernate was transferred to tank 13 and the sludge was left in the tank bottom. The use of tank 16 for additional waste storage was discontinued.
- Nov 1974 Report DP-1358, Leakage from Waste Tank 16 — Amount, Fate, and Impact, was published. This report describes in detail waste leakage into the annulus and ground, and migration of contamination in the soil and ground water.

INSPECTION OF TANK INTERIOR AND ANNULUS

Inspections of the interior and annular space of tank 16 were made by direct observation and by lowering a 40-ft-long optical periscope into access ports in the roof. In addition, direct photography and closed circuit television were used on several occasions to inspect the annulus. Special inspection techniques such as sandblasting and dye-penetrant inspection of portions of the tank exterior also were used in June 1962 and January 1974.

Routine visual inspections of the annulus were started in October 1959. These are made by reflecting sunlight through an access port with a mirror or by using a high intensity electric light. A comprehensive inspection of the annulus was made by Engineering Assistance Section using closed circuit television from February through May 1961, and by periscope in June 1961 and February 1972. In addition, numerous other inspections were performed to follow tank leakage and corrosion and waste accumulation in the annulus. Two disk samples were removed from the tank wall in 1961-1962 for metallurgical examination. Cracks in the samples were concluded to have been caused by stress corrosion resulting from the action of NaOH or NaNO_3 in areas of high local stress in the steel plate, such as seam welds. Subsequent SRL studies isolated NaNO_3 as the cause.

Composite photos of horizontal welds were made from periscopic pictures taken in the 1972 annulus inspection. These are shown in figures 13 through 16 and were obtained by fitting together black and white prints of color photographs. The top, middle, and bottom welds are shown as seen from the annulus riser indicated. Extreme distortion results in an illusion that half of the tank periphery is visible whereas less than 10% is actually visible from each riser. The distortion is due to the great difference between the periscope lens and the near wall (12 to 18 in.) and between the lens and the visual point of tangency with the tank wall (10 to 12 ft). As a result, the horizontal weld visible in most picture segments can be seen to occupy 5 to 30% of the height of the central portion of each composite, diminishing to a faint line at the visual point of tangency. The dehumidifier duct and dried waste are visible in the bottom strip of each figure. Table 1 lists the color photographs that are available.

Chronology of Events Related to Inspection

- Oct 1959 Routine visual inspection of the annulus was started.

- Nov 1959 Routine inspection on November 5 revealed liquid below the north and south annulus risers. On November 15, white, solid material was observed protruding from the tank wall below the south riser, and radioactivity was detected in annulus liquid below the north riser. Mirrors and a telescope were set up on November 19 at the south riser for a more detailed inspection of the deposits. They appeared to have increased in size, and seven salt deposits were observed along the bottom horizontal weld. Attempts to obtain clear photographs of the leak sites using the mirrors and telescope were unsuccessful. Inspection by closed circuit television was started on November 30. Annulus dehumidification was shut off to prevent spread of contamination to the atmosphere by the dehumidification air which, at that time, was released directly to the atmosphere.

- Dec 1959 Inspection by mirrors and telescope revealed five areas of suspected leakage at the bottom horizontal weld below the south annulus riser.

- Jan 1960 Visual inspection of the annulus indicated no change.

- Feb 1960 Leaks below the south annulus riser were inspected using closed circuit television on February 11. Clear pictures of the leaks were obtained by photographing the television monitor screen. The inspection was discontinued because of equipment difficulties. Visual inspection of the annulus on February 17 showed no change.

- Apr 1960 Visual inspection below the north riser on April 7 revealed salt deposits at the bottom horizontal weld and about 2 ft² of liquid on the annulus floor. Visual inspections below the north riser on April 18 and April 28 showed essentially no change. Annulus liquid level was below the "necklace" alarm wires or less than ½ in.
- Aug 1960 Annulus surfaces were found to be dripping wet during visual inspection below the north riser on August 1. No salt deposits were visible. Annulus dehumidification was resumed on August 12 following modifications to purge the annulus and tank in series, and the annulus appeared much drier during visual inspection below the north riser on August 19. Salt was crystalline on the liquid surface, and the liquid level appeared to be the same as on August 1.
- Sep 1960 The annulus liquid level was found to be much higher (4½ ft) and rising during visual inspection on September 7.
- Jan 1961 The annulus appeared dry during visual inspection and waste at the bottom was solidified.
- Feb 1961 A systematic examination of the tank wall using closed circuit television was started by EAS. Nineteen suspected leaks were found below the south riser in an area comprising 8 to 10% of the tank wall. All but three leaks were located near horizontal welds and were about evenly distributed between the top, middle, and bottom horizontal welds.
- Mar 1961 Twelve more leaks at horizontal welds were found below the west riser in the EAS inspection. Periscopic inspection of three leaks at the top weld below the south riser showed the salt consisted of a yellow, bead-like material. Design Division compared photographs of these leaks with construction x-ray pictures and were able to correlate the leaks with weld patch areas. Two leaks occurred at sites where an alignment plate was attached during construction and the other occurred where extra weld metal was deposited on the interior.
- Apr 1961 Two leaks at the top horizontal weld below the south riser were cleaned by sandblasting and inspected using dye penetrant. No cracks were detected.
- May 1961 Eight more leaks near horizontal welds were found below the east riser in the EAS inspection.
- Jun 1961 Periscopic inspections of the tank wall below the south riser and inspection ports 65, 118, and 259 were made. Six leaks were found below inspection port 65 mostly at the bottom horizontal weld. One leak and one possible leak were found at the bottom weld below inspection port 118. Several small leaks were detected at the top horizontal welds below the south riser, and one large leak and several small leaks were observed at the top weld below inspection port 259.
- Jul 1961 Periscopic inspection below inspection port 151 revealed 15 leaks which were nearly equally distributed between the three horizontal welds and upper vertical weld. Inspection below inspection port 207 revealed nine leaks at the middle and bottom horizontal welds.

- Aug 1961 Six top horizontal weld leaks and two middle horizontal weld leaks were discovered during periscopic inspection and photography below the west riser.
- Sep 1961 A new boom-mounted television camera was used in selecting a site for tank wall sampling. The site selected contained several leaks and was located at the top horizontal weld at port 262.
- Oct 1961 A 5¼-in.-dia sample was removed from the primary tank wall. Metallurgical examination revealed that the sample contained two cracks completely penetrating the plate and two others visible only from the interior side. The cracking was concluded to have been caused by stress corrosion, induced by NaOH or NaNO₃ in the waste, in areas of high local stress in the plate such as welds (subsequent SRL studies isolated NaNO₃ as the cause). Inspection by closed circuit television below the south riser and inspection port 259 revealed evidence of extensive leakage along the upper vertical weld at position 252. Of special interest were two midplate leaks.
- Nov 1961 One of the two midplate leaks was sandblasted and examined by periscope and reflectoscope. The reflectoscope inspection revealed an attachment on the tank wall near the leak site.
- Feb 1962 Periscopic inspection below inspection port 42 revealed 27 leaks, two of which were midplate leaks.
- Mar 1962 One midplate leak and 19 seam weld leaks were found during periscopic inspection below inspection ports 35 and 39.
- Apr 1962 A 5¼-in.-dia primary tank wall sample was obtained at the top horizontal weld at position 39. This sample contained one leak completely penetrating the plate and another small crack which did not penetrate the plate.
- Jun to
- Jul 1962 The upper vertical weld near inspection port 151 was sandblasted, inspected with dye penetrant, and photographed. This weld had leaked extensively, and after sandblasting 10 large cracks were visible without magnification. Four of the cracks were 4 to 6 in. long (figures 9, 10, and 11).
- Oct 1962 Periscopic inspection of the top and middle horizontal welds and upper vertical weld below inspection port 85 revealed 10 leaks. Seven leaks were located at the top weld and were small. The largest leak existed at a 3-in. crack at the vertical weld.
- Nov 1962 Periscopic inspection revealed 11 leaks below inspection port 85 and 19 leaks below inspection port 18.
- Sep 1965 The annulus appeared dry during visual inspection.

- Mar 1968 Visual inspection revealed minor seepage at the middle horizontal weld on the south side of the tank. The dehumidification airflow was found to be below nominal. The annulus exhaust filter was replaced and seepage stopped within 3 days.
- Feb 1972 A thorough inspection of the annulus by periscope and direct color photography was performed below inspection ports 42, 118, 151, and 259. Composite pictures of the horizontal welds which were constructed from the annulus photographs are shown in figures 13, 14, 15, and 16. Leaks were observed which had developed since the EAS inspection in 1961, and salt deposits generally appeared larger than in 1961 (figure 12). The salt layer on the annulus floor was probed with a coring tool for salt depth determination.
- May 1973 Visual inspection of the annulus revealed the salt layer on the floor was 8 to 12 in. deep. Periscopic inspection inside the tank revealed only a small amount of salt on the walls and cooling coils.
- Nov 1973 The upper vertical weld below inspection port 18 was photographed to determine a location for sandblasting. Large salt deposits were found along the weld.
- Dec 1973 Inspection by direct photography below inspection port 65 revealed massive salt deposits which obscured leak sites at the vertical, upper, and middle horizontal welds.
- Jan 1974 The upper vertical weld near inspection port 151 was sandblasted, reinspected using dye penetrant, and photographed. Cracks at the weld did not appear to have increased in size since the 1962 inspection.
- Feb 1974 Periscopic inspection revealed 21 leaks below the east riser, 17 leaks below inspection port 207, and 17 leaks below the south riser.
- Mar 1974 A periscopic inspection was performed below inspection port 35 to locate a sandblasting site.
- Dec 1974 A periscopic inspection of the tank interior below riser 2 was performed for SRL. No unusual conditions were found.

SAMPLES OF TANK AND ANNULUS CONTENTS

Radioactivity was first detected in the annulus in November 1959, and tank and annulus contents were sampled several times between then and April 1974. The available analytical results are listed in table 2. High hydrogen concentrations in tank vapors were measured several times in 1960. Three sludge samples were obtained in 1973 and 1974 for SRL waste solidification studies using the "clam shell" sampler. These entries are shown in figure 2.

Chronology of Events Related to Sampling

- Nov 1959 A swab dipped in liquid below the north annulus riser radiated 12 R/hr at 3 in., while no radioactivity was detected below the other annulus risers. White, solid material from the tank wall below the south riser was sampled. A 0.038-g portion of the sample dissolved partially in 30 ml of water causing a solution pH of 10.6. Analysis of the solution indicated the salt sample originally contained 4.3×10^6 α d/min/g radiation, 1.9×10^7 β c/min/g radiation, and 9.3×10^6 γ c/min/g radiation. The radiation field at the south riser opening was 30 R/hr.
- May 1960 Sludge and supernate samples were obtained (table 2).
- Jul 1960 An "Explosimeter" reading revealed the hydrogen concentration in the tank vapors was 40% of LEL. The high concentration was attributed to the tank purge blower having been shut off for 3 days.
- Aug 1960 The hydrogen vapor concentration was found to be 35% of LEL. The annulus dehumidifier which had been shut down because contaminated air leaked from the annulus through defective seals on the annulus access port plugs was operated for 8 hours to purge the tank vapor space.
- Five days later the dehumidifier was operated for 7 hours to reduce the hydrogen concentration from 30 to 0% of LEL.
- Sep 1960 Analyses of dip samples of tank and annulus liquid confirmed that the annulus liquid was radioactive waste from tank 16 (table 2).
- Apr 1965 A supernate sample was obtained (table 2).
- Mar 1972 Salt from the annulus floor and top ledge was sampled and found to be highly radioactive and mostly water soluble. Comparison of $^{137}\text{Cs}/^{134}\text{Cs}$ ratios between the two samples confirmed that the salt on the ledge was different and some 10 years older than the top layer of salt on the floor (table 2).
- Oct 1973 Sludge sampling for SRL waste solidification studies was started. The first sampling attempt using the "clam shell" sampler was unsuccessful.
- Nov 1973 Tank 16 sludge was successfully sampled using the "clam shell" sampler.
- Dec 1973 A second sludge sample was obtained.
- Apr 1974 A third sludge sample was obtained.

PHYSICAL MEASUREMENTS

Vertical temperature profiles in the annulus or tank were taken in December 1959, September 1960, November 1966, July 1969, and July 1970. Vertical radiation profiles were made in December 1959 and October 1972. Annulus salt depth was measured in August 1967. In August 1970, liquid specific gravity in the tank was measured. In February 1972, the annulus salt layer was probed with a coring tool and salt depth determined. Vertical temperature profiles of the ground near tank 16 were obtained in October 1974. These and other entries are shown in figure 2.

Chronology of Events Relating to Physical Measurements

- Sep 1959 Tank liquid level was 130 in.
- Dec 1959 Temperature and radiation profiles were taken in the annulus that indicated the sludge level in the tank was 6 to 9 in. (figures 17 and 18).
- May 1960 Tank 16 was filled to capacity at 303-in. liquid level.
- Aug 1960 Annulus pressure increased to about 1-in. H₂O after modifying the dehumidification system.
- Sep 1960 A temperature profile of the tank was taken that was similar to the profile made in December 1959. Annulus liquid level was rodded on September 7 and measured 4½ ft.
- Oct 1960 Tank level records indicate a total of 185,000 gallons of waste leaked into the annulus at a maximum rate of 4 gallons/minute. Tank liquid level was 147 in. after a supernate transfer.
- Nov 1966 A temperature profile was taken at tank riser 1 that indicated the sludge level was 14 in. (figure 17).
- Aug 1967 The depth of salt on the annulus floor below inspection port 85 was found to be 5 in. The depth was found by determining the penetration of a small diameter pipe through which water was run to dissolve and corrode the salt.
- Mar 1968 Dehumidification airflow was measured to be 3100 cfm after replacing the annulus exhaust filter. Tank purge flow was 190 cfm.
- Jul 1969 Temperature profiles were taken at tank risers 1 and 8 (figure 17).
- Jul 1970 A temperature profile was taken at tank riser 8 (figure 17).
- Aug 1970 The tank was probed for salt deposits. Soft sludge but no significant salt deposits were detected. Liquid specific gravity was measured and ranged from 1.51 at the sludge/liquid interface (10 to 12 in. from the bottom) to 1.40 at the 250-in. level.

- Feb 1972 The salt layer on the annulus floor was probed with a coring tool below inspection port 118. The upper 5 to 6 in. of the salt had a mushy consistency and the lower 8 to 9 in. was firmer. The core holes slowly filled with liquid to a depth of 8 to 9 in.
- Oct 1972 A radiation profile was taken at the north annulus riser (figure 18).
- Oct 1974 Profiles of ground temperature were taken in monitoring wells near tank 16. This was done as part of a study of waste tank nil ductility transition temperatures by SRL.

COOLING COIL FAILURES

There are no known failures of cooling coils in tank 16.

TESTS CONDUCTED

Cooling-water flow through the tank 16 cooling coils was established in November 1959. In February 1962, mild steel "pillow" specimens were removed from tank 16 waste and examined for hydrogen penetration. Samples of bedrock were placed in tank 16 in May 1962 to study reactions of bedrock with HW. In July 1962, specimens of several metals were exposed to HW to obtain corrosion data for new tank design. Carbon steel test coupons were placed in tank 16 in July 1963 to study stress corrosion. A tank heatup test was conducted in October 1973. These entries are shown in figure 2.

Chronology of Events Relating to Tests Conducted

- Nov 1959 Tests were conducted to establish the rate of cooling-water flow through the cooling coils. A flow of 200 gpm was calculated from the pressure drop of 38 in. H₂O across the reflux condenser.
- Feb 1962 Several "pillow" specimens of mild steel exposed to HW for 6 months were removed from tank 16 and subjected to metallurgical examination. The specimens showed no swelling or distortion indicating that hydrogen diffusion through the steel was negligible and therefore hydrogen embrittlement could not be a major cause of waste tank cracking.
- May 1962 Bedrock samples obtained 1800 ft below grade at SRP were suspended in the tank to investigate possible reactions between bedrock and HW. After 75 days' exposure, sample weight increased about 1% presumably from water absorption. This weight gain was similar to that observed in SRL tests with synthetic wastes. There was no weight gain in an additional exposure of 92 days.
- Jul 1962 Specimens of 304L stainless steel, "Incoloy," "Inconel," and nickel were exposed to HW below tank riser 5 to obtain corrosion data for new tank design.
- Jul 1963 Mild steel test coupons were placed in tank 16 waste to study stress corrosion.
- Oct 1973 Cooling-water flow was throttled in a tank heatup study.

EQUIPMENT MODIFICATION AND REPAIRS

Thermocouple connections in tank 16 were corrected in August 1959. In August 1960, operation of the annulus high liquid level probes was modified. In September and October 1960, transfer jets were installed in the annulus and tank, respectively. In September 1961 and March 1962, additional annulus inspection ports were installed. Disk samples were removed from the tank wall in October 1961 and April 1962. Permanent tank purge and alarm equipment and annulus exhaust filter were installed in January 1965. A second tank transfer jet was installed in March 1968, and an annulus dewatering jet was installed in October 1973. These and other entries are shown in figure 2.

Chronology of Events Relating to Equipment Modification and Repairs

- Aug 1959 Tank thermocouple connections were corrected. Earlier tank temperature readings were in error.
- Aug 1960 Operation of the annulus high level probes was modified, and the probes were checked, adjusted, and repositioned. The annulus dehumidification system was modified to purge the annulus and tank in series. However, dehumidification had to be discontinued because contaminated air leaked from the annulus through defective seals on the annulus access port plugs.
- Sep 1960 A 75-gpm transfer jet was fabricated and installed in the annulus on an emergency basis. The jet discharge was piped to tank 14.
- Oct 1960 A 75-gpm transfer jet was installed in tank 16 and the discharge piped to tank 15.
- Jan thru
- Dec 1961 Twelve additional annulus risers were installed to allow approximately 100% primary wall inspection.
- May 1961 Guide flanges were positioned and a blower installed to provide additional ventilation for drilling annulus inspection ports.
- Sep 1961 An 8-in.-dia annulus inspection port was installed at position 262.
- Oct 1961 The reel tape was repaired. A 5¼-in.-dia disk sample was removed from the primary tank wall for metallurgical examination. The sample was taken from the top horizontal weld at position 262.
- Apr 1962 A 5¼-in.-dia primary tank wall sample was obtained from the top horizontal weld at position 39. The resulting hole was covered with a stainless steel metal patch attached to the wall by magnets.
- Jan 1965 Permanent tank purge equipment and exhaust air contamination alarm were installed in tank 16 along with a permanent exhaust filter for the annulus dehumidification system. Dehumidifier airflow was resumed after not having been operated since 1960.

- Mar 1968 A 75-gpm transfer jet was installed below riser 7 of tank 16 and the discharge piped to tank 13. The annulus exhaust filter was replaced causing dehumidification airflow to increase to a satisfactory rate.
- Sep 1973 The reel tape cable was replaced and calibrated. The old cable had slipped off the upper pulley causing the indicated tank liquid level to be 10 in. high.
- Oct 1973 A 10-gpm dewatering jet was installed below annulus inspection port 118 to remove liquid from the annulus floor and return it to the tank. The jet intake was positioned approximately 1 in. above the floor. The jet was operated daily between October 5 and October 18, but little liquid was removed.
- Nov 1973 The reel tape zero was corrected by -5.3 in. to agree with the hand-held tape. Modified annulus inspection port plugs were installed which were self-sealing against rainwater and easier to handle. Two new annulus leak detection probes were installed, and annulus level alarm probes were relocated inside the valve house for weather protection.

TABLE 1
TANK 16 COLOR PHOTOGRAPHS

Date	Access Port	Object of Photo	PRD Number	Separations Technology File Location	
				Box	Slots
6/16/61	65	Annulus	7525-1 thru -4	1	77-80
6/20/61	118	Annulus	7525-5 thru -26	1	1-22
6/22/61	South	Annulus	7528-1 thru -14	1	23-36
6/23/61	259	Annulus	7534-1 thru -7	1	37-43
6/23/61	259	Annulus	7534-8 thru -19	1	59-70
6/26/61	259	Annulus	7538-1 thru -6	1	71-76
7/21/61	151	Annulus	7602-1 thru -16	1	44-58
7/24/61	151	Annulus	7606-7 thru -16	2	1-10
7/26/61	207	Annulus	76-7-1 thru -4 -8 thru -21	2	11-31
8/1-2/61	West	Annulus	7630-1 thru -5 -7 thru -13	2	32-43
9/19/61	262	Annulus	7704-1 thru -13	2	59-71
9/22/61	259	Annulus	7709-1 thru -2	2	72-73
9/22/61	262	Annulus	7709-3 thru -20	2	74-91
9/22/61	262	Annulus	7717-1 thru -16	2	92-107
9/27/61	262	Annulus	7721-1 thru -21	2	108-128
10/10/61	262	Annulus	7761-1 thru -7	2	129-136
10/12/61	262	Annulus	7765-1 thru -6	2	136-141
10/16/61	262	Annulus	7787-1 thru -4	2	142-145
11/09/61	262	Annulus	7846-1 thru -9	2 3	146-150, 1-4
11/10/61	262	Annulus	7847-1 thru -33	3	5-37
2/20/62	42	Annulus	8080-1 thru -18 -20 thru -30,32	4	25-54
3/08/62	35	Annulus	8129-1 thru -10,12	4	108-117
3/15/62	39	Annulus	8143-1 thru -9	5	33-41
3/16/62	39	Annulus	8130-1 thru -34	4	118-150
3/20/62	39	Annulus	8144-1 thru -18	5	2-19
3/22/62	39	Annulus	8147-1 thru -13	5	20-32
3/30/62	39	Annulus	8184-1 thru -4	5	42-47
4/03/62	35	Annulus	8187-1 thru -19	5	48-66
6/14/62	151	Annulus	8347-1 thru -17	6 7	142-150 1-8A
7/02/62	151	Annulus	8384-1 thru -10 -12 thru -18	7	9-23A
7/12/62	151	Annulus	8395-1 thru -18	7	24A-18B
10/05/62	85	Annulus	8662-1 thru -9 8717-1,2,4 -6 thru -11 -13 thru -22 8718-1 thru -10	7	19B-6D
11/03/62	18	Annulus	8779-1 thru -36	7	7D-17E
1/31/72	118	Annulus	15595-1 thru -28	16	123-150
2/01/72	151	Annulus	15587-1 thru -23	17	1-23
2/09/72	259	Annulus	15608-1 thru -23	17	26-48
2/10/72	42	Annulus	15609-1 thru -25	17	51-75
9/15/72	151	Annulus, Salt Mass, Cracks at Vertical Weld	16279-1 thru -18	29	114-131
9/18/72	151	Cracks at Vertical Weld	16314-1 thru -3	29	133-135
5/10/73	2	Interior Wall	16971-1 thru -40	40	45-80
11/08/73	18	Annulus	17511-1 thru -28	45	43-70
12/04/73	65	Annulus	17571-1 thru -23	45	96-118

TABLE 1 (contd)
TANK 16 COLOR PHOTOGRAPHS

Date	Access Port	Object of Photo	PRD Number	Separations Technology File Location	
				Box	Slots
1/18/74	151	Crack at Vertical Weld	17641-1 thru -18	45	120-137
1/9-10/74	151	Crack at Vertical Weld	17642-1 thru -34	47	1-34
1/27/74	151	Crack at Vertical Weld	17678-1 thru -18	47	36-53
1/11/74	151	Crack at Vertical Weld	17623-5 thru -14	46	134-143
1/25/74	151	Crack at Vertical Weld	17675-2 thru -21	46	113-132
1/16/74	151	Crack at Vertical Weld	17674-2 thru -28	46 48	145-150 1-19
2/11/74	East	Annulus	17734-1 thru -25	47	101-125
2/12/74	207	Annulus	17747-1 thru -27	49	1-27
2/13/74	South	Annulus	17735-1 thru -25	47	126-150
3/05/74	35	Annulus	17806-1 thru -24	49	71-94
11/27/74	2	Interior Wall	18601-1 thru -31	53	97-127
3/20/62	039	Annulus	8144-1 thru -18	5	2-19
3/22/62	039	Annulus	8147-1 thru -13	5	20-32
3/30/62	039	Annulus	8184-1 thru -4 2 extra	5	42-47
4/03/62	035	Annulus	8187-1 thru -19	5	48-66
6/14/62	151	Annulus	8347-1 thru -17	6 7	142-150 1-8A
7/02/62	151	Annulus	8384-1 thru -10 -12 thru -18	7	9-23A
7/12/62	151	Annulus	8395-1 thru -18	7	24A-18B
10/05/62	85	Annulus	8662-1 thru -9 8717-1 thru -2,4, -6 thru -11 -13 thru -22 8718-1 thru -10	7	19B-6D
11/03/62	18	Annulus	8779-1 thru -36	7	7D-17E
1/31/72	118	Annulus	15595-1 thru -28	16	123-150
2/01/72	151	Annulus	15587-1 thru -23	17	1-23
2/09/72	259	Annulus	15608-1 thru -23	17	26-48
2/10/72	42	Annulus, Leak	15609-1 thru -25	17	51-75
9/15/72	151	Annulus, Salt Mass, Cracks at Vertical Weld	16279-1 thru -18	29	114-131
9/18/72	151	Cracks at Vertical Weld	16314-1 thru -3	29	133-135
5/10/73	2	Interior Wall	16971-1 thru -40	40	45-80
11/08/73	18	Annulus	17511-1 thru -28	45	43-70
12/04/73	65	Annulus	17571-1 thru -23	45	96-118
1/18/74	151	Crack at Vertical Weld	17641-1 thru -18	45	120-137
1/9-10/74	151	Crack at Vertical Weld	17642-1 thru -34	47	1-34
1/27/74	151	Crack at Vertical Weld	17678-1 thru -18	47	36-53
1/11/74	151	Crack at Vertical Weld	17623-5 thru -14	46	134-143
1/25/74	151	Crack at Vertical Weld	17675-2 thru -21	46	113-132
1/16/74	151	Crack at Vertical Weld	17674-2 thru -28	46 48	145-150 1-19
2/11/74	East	Annulus	17734-1 thru -25	47	101-125
2/12/74	207	Annulus	17747-1 thru -27	49	1-27
2/13/74	South	Annulus	17735-1 thru -25	47	126-150
3/05/74	35	Annulus	17806-1 thru -24	49	71-94
11/27/74	2	Interior Wall	18601-1 thru -31	53	97-127

TABLE 2
TANK 16 SAMPLE ANALYSES

Date Reported	5/60	5/60	9/60	4/65
Description of Sample	Supernate	Sludge	Annulus	Supernate
Date Sampled	5/25	5/25	9/17	3/30
Total Solids	45.5 wt %	50.3 wt %	42 wt %	31.48%
Specific Gravity	1.37		1.36	1.385
pH	> 11	> 11	> 11	11.7-12.3
NaNO ₃				4.74 wt %
NaOH				5.80 wt %
NaAlO ₃	64.8 g/l	300 g/l		0.44 wt %
Na ₂ CO ₃				0.39 wt %
Na ₂ SO ₄				0.75 wt %
U	2.4 X 10 ⁻³ g/l	1.1 X 10 ⁻³ mg/mg		
Cl ⁻	0.6 g/l			29 ppm
PO ₄ ⁻⁻⁻				< 0.02 g/l
Fe ⁺⁺⁺				0.011 g/l
Al	25.5 g/l			
Gross Alpha d/m/ml	7.6 X 10 ³	3.4 X 10 ⁴	5.2 X 10 ³	3.23 X 10 ³
Pu Alpha d/m/ml	8.7 X 10 ³	3.2 X 10 ⁴		1.71 X 10 ³
241Am Alpha d/m/ml	< 2.5 X 10 ³	500		
237Np Alpha d/m/ml	22	16.6		
Gross Beta c/m/ml	1.6 X 10 ⁸	2.5 X 10 ⁷	2.1 X 10 ⁸	1.45 X 10 ⁸
Gross Gamma c/m/ml	1.1 X 10 ⁸	1.3 X 10 ⁶	1.2 X 10 ⁸	6.97 X 10 ⁷
95Zr-Nb c/m/ml	8.6 X 10 ⁶	5.8 X 10 ⁵		
90Sr c/m/ml	4.4 X 10 ⁶	1.3 X 10 ⁶		4.63 X 10 ⁵
144Ce c/m/ml	1.1 X 10 ⁵	460		
103,106Ru c/m/ml	4.5 X 10 ⁶	2.7 X 10 ⁵		
137Cs c/m/ml	8.0 X 10 ⁷	3.9 X 10 ⁵		6.67 X 10 ⁷

TABLE 2 (contd)
TANK 16 SAMPLE ANALYSES

Date Reported	3/72		3/72		3/72	
Description of Sample	Salt From Top of Crust on Annulus Floor		Salt From Edge of Annulus Pan Ledge		Salt From Top of Annulus Pan Ledge	
Water Solubility, wt %	82		99		99	
Cations	<u>Soluble</u>	<u>Insoluble</u>	<u>Soluble</u>	<u>Insoluble</u>	<u>Soluble</u>	<u>Insoluble</u>
Major (10-100%)	Na	AL Ca Si	Na	AL Ca Si	Na	
Minor (1-10%)	Cr		AL	Cr Ca Cd Fe Ni	Si	
Trace (0.1-1%)	AL Ca		Ca Cd Fe Si Cr	Mg Pb	Li Mo Pb	
Faint Trace (0.01-1%)	Mg		Mg	Cu Mn	Ca Mg	
Anions, %						
NO ₃	34		45		38	
OH	0		1.7		0.1	
SO ₄	0.1		0.7		0.8	
CO ₃	0.6		3.2		0.5	
Radiation, R/hr	2		0.3		0.1	
¹³⁷ Cs, d/m/g	1.5 x 10 ⁹		8.3 x 10 ⁸		4.5 x 10 ⁸	
¹³⁷ Cs, d/m/g	2.5 x 10 ⁸		5.5 x 10 ⁶		3.7 x 10 ⁶	
¹³⁷ Cs/ ¹³⁴ Cs Ratio	6		151		122	
Age, Years (Assuming X yrs. at ¹³⁷ Cs/ ¹³⁴ Cs Ratio = 6)	X		X + 10.6		X + 9.9

FIGURE 1. WASTE STORAGE TANK 16

FIGURE 2 (contd)

FIGURE 2 (contd)