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HISTORY OF WASTE TANK 9 1955 THROUGH 1974

D. W. THARIN
Separations Technology Department

D. R. LOHR
Student, Cooperative Education Program
Virginia Polytechnic Institute

E. I. du Pont de Nemours & Company
Savannah River Plant

MASTER

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FIGURE 2. TANK 9 LEVELS AND TEMPERATURES

FIGURE 2 (contd)

FIGURE 2. (contd)

FIGURE 2. (contd)

Oct. 1955* The specific gravity end point for the HLW evaporator in Building 221-H was increased from 1.21 to 1.23 to reduce waste volume. The auxiliary cooling coils in tank 9 were valved off.

Nov. 1955* The specific gravity end point for the HLW evaporator was increased from 1.23 to 1.26 to further reduce waste volume. The tank 9 "necklace" alarm indicated moisture in the annulus but a dip tube level determination showed no liquid. Subsequently, the annulus was visually inspected and appeared dry.

Dec. 1955* The tank 9 level reached 264.5 inches, and HLW was diverted into tank 10. During this initial filling, Purex waste was generated at a high rate because acid recovery in the canyon did not begin until later.

Jan. 1956* Filling of the tank continued (in additional small quantities) to a level of 268 inches.

Aug. 1956 The tank was isolated from Building 221-H by removing the pipe jumper in diversion box 1 (DB-1). Orifices were installed in each operating cooling coil feeder line to equalize and limit flows to about 1 gpm per coil.

Sept. 1956 Explosimeter readings in the vapor space were positive, and a mass spectrometer analysis indicated hydrogen at 130% of the lower explosive limit (LEL). A Coppus blower was used to purge the tank vapor space, after which the hydrogen concentration was reduced to less than 5% LEL.

Feb. 1957* Radiation (15 to 20 mR/hr at 2 in.) was discovered at the annulus exhaust duct. Contaminated air was thought to have blown back from the tank into the annulus through an interconnecting purge duct at the time of a power failure.

Oct. 1957 The annulus exhaust duct radiation increased to 50 mR/hr on October 18; a dip tube check was made which indicated no liquid present in the annulus. However, on October 29, 4 to 5 in. of liquid was measured using the same annulus dip tube.

Dec. 1957* To correct for depletion of free caustic in the stored waste, attributed to CO_2 formed by radiolysis of gluconic acid used in Building 221-H processing, 17,000 gallons of 50% caustic was added to provide 1% free NaOH in the waste supernate. The annulus liquid level remained constant.

Jan. 1958* 8500 gallons of 50% caustic was added to provide 1% free NaOH. The first of a series of annulus flushes was completed; this program continued for over a year and involved nine annulus flushes (table 1).

June 1958	Hydrogen concentration in the vapor space reached 20% LEL and was purged by a temporary blower.
July 1958	Hydrogen concentration in the vapor space again built up (to 15% LEL) and was purged.
Aug. 1958	Approximately 7½ in. of liquid was transferred to tank 14 to provide room in tank 9 for additional material from the annulus flushing program.
July 1961	Waste leakage into the annulus resumed at a rate of 120 gallons per day (figure 2).
Oct. 1962	The annulus exit air prefilters and CWS filters were replaced due to contamination. Radiation rates were 125 and 25 mR/hr at 3 in., respectively. (It is not known when the filters were installed.)
Oct. 1963	Airflow, temperature, and moisture data from a study of the dehumidifier system were reported.
Feb. 1965	The first cooling coil leak developed. The coil was isolated from the cooling water supply and return headers.
April 1965	Annulus dehumidification and tank purge data were reported. At this time, annulus airflow was reduced to effect a savings of steam.
Dec. 1965	In preparation for sludge removal, the liquid level in tank 9 was reduced to 56 in. (152,000 gallons) by transfer of 200 in. (542,000 gallons) of liquid to tank 13.
March 1966	Temperature profiles were taken (figure 3). Following heavy rains the leak detection probes were activated, possibly by either water leaking into the annular space or by water entering the probe junction box at the top of the riser. (The original "necklace" alarm was shorted out earlier by the waste in the annulus and was replaced by pendant-type probes suspended a short distance above the annulus liquid level.)
July 1966	42,000 gallons (15½ in.) of sludge was slurried and pumped to tank 13 using high pressure water jets to mobilize the sludge and submersible pumps to effect the transfer. 240,000 gallons of water was used in this operation, and the final tank liquid level after pumpdown was 2¾ in. (figure 4).
Dec. 1966	A reel jet with flexible piping was installed to permit adjustment of the jet suction level as the depth of crystallized waste salts rose in the tank during its planned use as concentrated waste receiver, and to permit raising the jet above the liquid between transfers.

TABLE 1
TANK 9 ANNULUS FLUSHES

Flush No. +	1	2	3	4	5	6 ^a	7 ^a	8 ^a	9 ^a
Solution in annulus before dilution, gal	1150	1300	1150	1400	1050	900			
Solids in heel, %	52	30	22	12	8.5	5.5			
Water added, gal	2000	2000	2000	2000	2000	2000			
Time in annulus, days	8	12	15	10	11				
Date jetted to tank 9	2/12/58	2/25/58	3/13/58	3/27/58	4/8/58	8/8/58	1/7/59	2/5/59	2/19/59
Solids, %	30	22	12	8.5	5.5	6.8	9.02	4.9	1.85
Received in tank 9, gal	1620	1690	1700	2590	2160	716	1650	1850	2250
Solids dissolved during flush, ^b lb	1550	2010	1300	550	440	585	1320	850	352

^a Data from unpublished informal notes were used for flushes 6, 7, 8, and 9.

^b The total of solids dissolved, about 9000 pounds, is that which would be dissolved in about 3000 gallons of waste.

FIGURE 3. TANK 9 TEMPERATURE PROFILES

March 1967	The evaporator bottoms jumper was changed to deliver concentrate to tank 9 via the newly completed gravity drop line. Tank 9 began service as a salt receiver with the receipt of evaporator concentrate on March 22.
May 1967	Crystallized salts bridged and plugged the 2-ft-dia riser below the discharge end of the concentrate inlet pipe, causing waste to overflow to the ground (figures 5 and 6). An estimated 100 to 200 gallons of mixture of evaporator concentrate (8 to 10 Ci/gal ^{137}Cs) and backflush water flowed onto the ground.
June 1967	Several 6-yard pans of dirt from the spill at riser 6 were transported to the burial ground, as decontamination at riser 6 continued. A 6-in. layer of concrete was poured around all sides of the riser to a depth of eight feet to shield and contain residual contamination. A new riser plug was built, with provisions for a liquid level alarm probe and easier inspection of the riser interior.
Sept. 1967	The tank 9 reel jet was connected in diversion box 1 (DB-1) to discharge to tank 10, and the first inspections of residual salt were made after transferring supernate to tank 10. The DB-1 sump jet, formerly discharging to tank 10, was connected to tank 9.
Jan. 1968	Extension of the gravity drop line from tank 9 to tank 10 was completed.
July 1969	Hot water failed to cause salt to release its hold on a simulated vertical cooling coil. See "Tests Conducted," p36 of this report.
Oct. 1969	The salt reached an equivalent level of approximately 201 in.
March 1972	Probings with a coring tool revealed 3 in. of liquid in the annulus below a relatively dry salt crust. The total salt depth was 8 to 10 in.
June 1972	The tank contains the following equivalents. Supernate - 8 in. or 22,000 gallons Salt - 199.5 in. or 541,000 gallons Sludge - 1.5 in. or 4,000 gallons
July 1973	The liquid level in tank 9 was lowered 3 in. by a transfer to tank 13 to make space for contaminated ground water from the sump near riser 6, where concentrate overflowed to the ground in 1967.
Jan. 1974	A new, lower estimate of salt volume in the tank (500,000 gallons) was made.

FIGURE 4. TANK 9 BOTTOM AFTER SLUDGE REMOVAL.
Lower horizontal coil is below liquid level. Upper horizontal
coil is about half submerged. Approx 1/4X, DPSPF 11339-1.

- Feb. 1974 Liquid level decrease during this period was apparently caused by continued cooling. Cooling water was valved off on January 29 because the low temperature supernate did not require additional cooling.
- Oct. 1974 A thermocouple bundle was attached to the tank walls to provide data relating to control of wall-steel temperatures above the nil-ductility transition temperature.

LEAKAGE INTO ANNULUS

Tank 9 was the first high level waste tank to be used in H Area and was placed in service on July 19, 1955. All waste received in the tank between 1955 and 1967 was Purex HLW. During the initial filling period (July 1955 to January 1956) the most noteworthy processing features related to waste were the use of gluconic acid in head-end treatment, periodic increases in the specific gravity of bottoms from the Building 221-H high activity waste evaporator, and a foaming problem in the high activity waste evaporator. The foaming was found to be associated with organic material in the evaporator, which necessitated the addition of silicone antifoam agents.

Tank 9 leakage was discovered in October 1957, about two years after the tank was filled. (This is different from tanks 14 and 16, both of which began leaking before filling was completed.) It is possible that leakage from tank 9 occurred as early as November 1955 when the "necklace" alarm shorted out permanently, but evidence of leakage was not conclusive until October 1957 when liquid waste was found in the annulus. There has been some evidence of continued leakage from the tank (see figure 2), but the rate has been very slow. Currently, 8 to 10 in. of salt and liquid waste is present in the annulus pan. The tank itself is filled with salt containing unknown but presumably relatively small amounts of saturated liquid waste, thus reducing the potential for gross leakage into the annular space.

All entries in the chronology below are also shown chronologically in figure 2 along with liquid levels of the tank and annulus.

Chronology of Events Related to Leakage Into Annulus

- July 1955* A heel of 1000 gallons of 50% NaOH was placed in the tank prior to receipt of the first HLW from Building 221-H.
- Nov. 1955* The annulus "necklace" alarm came on, but a dip tube level determination showed no liquid. Subsequently, the annulus was visually inspected and appeared dry; the alarm was assumed due to ground-water inleakage or rain incursion. However, the alarm could not be reactivated because it was shorted to ground.
- Feb. 1957* Radiation at the annulus exhaust duct was 15 to 20 mR/hr at 2 in. Contaminated air was thought to have blown back from the tank through a purge duct and to the annulus at the time of a power failure.

FIGURE 5. RISER 6 PLUGGED WITH SALT.
Approx 1/7X, DPSPF 11938-1.

FIGURE 6. MAP OF SPILLAGE AT RISER 6

Sept. 1957*	An increase in radiation was detected at the annulus dehumidifier exhaust duct.
Oct. 1957*	The annulus exhaust radiation increased to 50 mR/hr, suggesting the possibility of liquid in the annulus pan. However, a dip tube check was made on October 18, and no liquid was present; but on October 29, 4 to 5 in. of liquid was measured at the same dip tube. A dip sample of this liquid was yellow and radiated 7 R/hr at contact. See "Samples of Tank and Annulus Contents," p 27 and table 2. On October 31, the annulus liquid level by manometer was 5.6 in.
Nov. 1957	Color photographs were taken in the annulus (figure 7). A radiation profile was also taken (figure 8). Data indicated that the leakage amounted to approximately 16,000 gallons, based on tank level changes. However, the amount of solids returned to the tank during the annulus flushing program (conducted February 1958 to March 1959), indicated only about 3000 gallons (table 1). The discrepancy is thought to be due to evaporation by the annulus dehumidifier system.
Dec. 1957*	17,000 gallons of 50% caustic was added to the tank to attain 1% free NaOH. The liquid level in the annulus remained constant.
Jan. 1958*	2300 gallons of water was added to the tank to start a program to raise the level to find the source of leakage; however, the program was discontinued. Records show 8500 gallons of 50% caustic was added to the tank but the reason was not recorded.
Feb. 1958	2000 gallons of water, the first of 9 flushes, was added to the annulus and allowed to soak for 8 days. 1400 gallons of solution containing 32% solids was then jetted from the annulus (table 1).
March 1958	The second, third, and fourth annulus flushes (2000 gallons each) were made. A visual inspection of the annulus showed the presence of liquid, but no solids were visible.
April 1958	The fifth annulus flush was made.
Aug. 1958*	Approximately 7½ in. of liquid was transferred from tank 9 to tank 14 to allow room for additional material from the annulus flushing program.
June 1960*	A study of liquid level in the tank 9 annulus was started. See figure 2.

TABLE 2
TANK 9 SAMPLE ANALYSES

Date Reported	9/56	9/56	9/56	8/57	10/57	11/57	4/58	4/58	4/58	4/58	4/58	3/60	3/60	11/63	11/63	4/65	12/65
Type of Sample	Vapor Before Purge	Vapor After Purge	Supernate	Supernate	Annulus	Supernate	Supernate	Annulus	Annulus	Annulus 1st Flush	Annulus 5th Flush	Supernate	Sludge	Supernate	Supernate	Supernate	Supernate
Radiation, mR/hr					7000							500	20,000	800-1000	800-1000		3000
Date Sampled				8/22	10/30	11/4	4/8					2/19	2/23	11/7	11/7	1/20	
Wt % Solids			35.4		55.2	30.4	26.2	55.2	56.0	52.2	3.37	31.3	37.4	1.235	1.245	1.264	
Sp Gr			1.234		1.50	1.124	1.238	1.503	1.467	1.46	1.025	1.226	1.342	1.235	1.245	1.264	
pH			10		11		> 11		11			> 11	> 11	> 11	> 11	11.7-12.3	
NaNO ₃								0.659M	0.59M					21.2 wt %	24.4 wt %	21.99 wt %	
NaOH			0.59m	0 g/l	0 g/l	0 g/l	9.74 g/l					21.5 g/l	13.3 g/l	0.8 wt %	0.8 wt %	0.55 wt %	
NaAlO ₂														0.1 wt %	0.1 wt %	0.03 wt %	
Na ₂ CO ₃			a	33 g/l	69.8 g/l	33.9 g/l	35.4 g/l					43.4 g/l	32.5 g/l				
Na ₂ SO ₄														1.2 wt %	1.0 wt %	0.82 wt %	
NaNO ₂																0.89 wt %	
NaHCO ₃			a	21 g/l	20.1 g/l	35.2 g/l	0 g/l					0 g/l	0 g/l				
U, g/l			1.9x10 ⁻²	5.2x10 ⁻³	1.4x10 ⁻³	3.4x10 ⁻³	2.0x10 ⁻²	0.240	0.380			1.86x10 ⁻³	9.3				
Cl ⁻							0.02 g/l					<0.02 g/l				25 ppm	
PO ₄ ---																< 0.02 g/l	
H ₂	5.3%	0.2%															
O ₂	47.9%	18.8%															
N ₂	46.4%	81.0%															
CO ₂	0.4%	0.1%															
Gross α, d/m/ml			1.36x10 ³		4.4x10 ⁴	1.22x10 ³	1.20x10 ⁵	4.43x10 ⁴	2.12x10 ⁴		6.43x10 ³	2.52x10 ³	9.14x10 ⁵			503	
Pu α, d/m/ml			848		636	1.97x10 ³						504	4.17x10 ⁵	500	500		
Am α, d/m/ml												< 252					
²³⁷ Np α, d/m/ml							< 5										
Gross β, c/m/ml			1.61x10 ⁸	3.1x10 ⁷	1.4x10 ⁸	3.13x10 ⁷	2.56x10 ⁷	1.40x10 ⁸	1.34x10 ⁸		2.18x10 ⁶	2.34x10 ⁷	1.34x10 ⁹	2.25x10 ⁷	2.28x10 ⁷	2.3x10 ⁷	
Gross γ, c/m/ml			5.44x10 ⁷	1.6x10 ⁷	7.6x10 ⁷	1.52x10 ⁷	1.44x10 ⁷	7.61x10 ⁷	7.15x10 ⁷	7.02x10 ⁷	1.93x10 ⁶	1.38x10 ⁷	3.49x10 ⁷	1.06x10 ⁷	1.07x10 ⁷	1.1x10 ⁷	
¹³⁴ Cs, d/m/ml														1.0x10 ⁶	3.0x10 ⁶	2.0x10 ⁵	
¹³⁷ Cs, d/m/ml												7.5x10 ⁸	9.2x10 ⁸	5.8x10 ⁸	5.8x10 ⁸	6.0x10 ⁸	
^{141,144} Ce, d/m/ml						3.78x10 ⁵	7.66x10 ⁵					1.34x10 ⁴	2.13x10 ⁸	ND	ND	ND	
^{89,90} Sr, d/m/ml			4.00x10 ⁶			1.91x10 ⁴						3.04x10 ⁴	3.08x10 ⁸	6.21x10 ⁵	6.19x10 ⁵	4.61x10 ⁵	
Ru γ, d/m/ml			2.78x10 ⁶			2.56x10 ⁶	1.80x10 ⁶					2.00x10 ⁵	7.07x10 ⁶				
Zr-Nb γ, d/m/ml			1.48x10 ⁶			2.18x10 ⁵	1.22x10 ⁶					7.24x10 ⁴	1.81x10 ⁶				

a If Na₂CO₃ and NaHCO₃ were not specifically requested, they might have been reported with NaOH results.

May 1961*	Tank liquid level (reel tape) measurements decreased steadily from 268 to 265 in. (8000 gallons) between October 1960 and May 1961. The annulus readings indicated leakage of only 1600 gallons. Annulus depth readings were taken daily and two new conductivity probes were installed to warn of any liquid level increases.
July 1961	Waste leakage into the annulus continued, at a rate of 120 gallons per day.
Aug. 1961	The waste leak rate decreased to 30 gallons per day.
Sept. 1964	Annulus was dry; however, a solid residue of several inches remained.
March 1972	Probing with a coring tool revealed a 5- to 7-in. layer of hard salt over a layer of softer material continuing to the annulus pan bottom. Liquid slowly filled the cored 8- to 10-in.-deep hole to a measured depth of 3 in.
Sept. 1972	The annulus salt level was 9 in.
May 1973	Production personnel made inspections of the waste salt in the annulus of tank 9 and reported 2-in. depth and liquid present below the east riser and 4- to 6-in. depth and liquid trace below the west riser. These measurements were inaccurate and vary from the data reported by Separations Technology in 1972; no additional leakage is implied.
Dec. 1974	A newly installed leak detection probe in the west annulus riser indicated no accumulation of liquid under the salt.

INSPECTION OF TANK INTERIOR AND ANNULUS

Inspections of the interior and annular space of tank 9 have been made by direct observation and by lowering a 40-ft-long, 2½-in.-OD optical periscope into existing access risers. From November 1955 through January 1961, five direct visual inspections of the annulus were made to look for any leakage which may have occurred. Visual inspections are usually made by reflecting sunlight into the riser with a mirror or by using a high-powered electric light. Beginning in March 1961, three inspections were made using the periscope to observe for leakage. Photographs were taken during the third inspection in July 1961 (table 3).

In August 1966, the first of a series of nine interior inspections of salt accumulation were made. During some of these inspections, photographs were taken (table 3). In March 1972, an annulus inspection was made through three risers in tank 9 as part of a comprehensive tank inspection program. All inspections were noted chronologically on figure 2. No leakage sites have been found on the approximately 32% of the tank wall that can be seen through the available access risers.

FIGURE 7. LEAKAGE IN ANNULUS OF TANK 9

FIGURE 8. TANK 9 ANNULUS RADIATION PROFILES

TABLE 3
TANK 9 COLOR PHOTOGRAPHS

<u>Date</u>	<u>Riser</u>	<u>Object of Photo</u>	<u>PRD No.</u>	<u>Separations Technology</u>	
				<u>File Location</u>	
				<u>Box</u>	<u>Slots</u>
7/7/61	ER	Annulus, welds	7569-1 through -16	1	89-96
7/12/61	SR	Annulus, welds	7576-1 through -21	1	111-129
3/17-20/67	5	Interior, coils	11836-1 through -20	7	B,1-21
9/21/67	5	Interior, salt, coils	12217-1 through -12	7	E,16-25 F,1-2
10/30/67	8	Interior, coils	1296-1 through -12	8	D,4-15
10/31/67	8	Interior, coils	12309-1 through -13	8	D,16-25 E,1-3
12/1/67	8	Interior, salt	12369-1 through -15	8	F, 12-25
1/8/68	8	Interior, salt	12421-1 through -16	9	1-16
6/21/68	8	Interior	12816-1 through -18	10	82-99
8/5/68	8	Interior, salt	12935-1 through -12	11	5-16
10/14/68	8	Interior, salt	13008-1, 3-13, and 20-31	11	44-67
3/11/69	8	Interior, salt	13285-1 through -6, and 8-13	12	90-101
2/29/72	E	Annulus, welds	15666-1 through -24	18	1-24
2/29/72	W	Annulus, welds	15667-1 through -24	18	26-49
3/2/72	S	Annulus, welds	15668-1 through -23	18	51-73
8/9/73	5	Inleakage, riser	17241-1 through -18	43	83-100
2/20/74	W	Annulus, Welds	17753-1 through-15, 20 through-29, & 31, 32.	48	21-47

Composite photos were made from the periscopic pictures taken in the 1972 annulus inspection. These are shown in figures 9, 10, and 11 and were obtained by fitting together black and white prints of color transparencies. Each picture shows the top, middle, and bottom welds 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 in distance 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 feet). 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 annulus duct and dried leakage are visible in the bottom strip of each figure.

Chronology of Events Related to Inspection

Nov. 1955*	The tank annulus was visually inspected and found dry following a leak detection alarm.
Oct. 1957*	Annulus exhaust radiation increased to 50 mR/hr. Subsequently, a visual inspection indicated the annulus was dry. On October 29, liquid was discovered in the annulus.
Nov. 1957	The annulus was inspected and color photographs were taken (figure 7).
March 1958	A visual inspection of the annulus showed the presence of liquid, but no solids were observed.
Jan. 1961	A visual inspection showed generally no change in the annulus since the previous inspection. The liquid beneath the west riser was rodged at 4.5 in.
March 1961	A periscopic inspection of the annular space indicated 7¼ in. of liquid in the pan.
June 1961	Inspection with the periscope through the west annulus riser revealed no evidence of leaksites.
July 1961	Periscopic inspection through the east and south annulus risers of tank 9 revealed no leaksites. Color photographs of select areas were made (table 3).
Aug. 1966	A limited periscopic inspection of the tank interior following sludge removal, showed that an unevenly distributed quantity of sludge remained, equivalent to about 1½ in. average depth (figure 4).
March 1967	Several efforts were made to locate some of the leaks in five coils of tank 9. Dripping from the largest leak could be heard, but the leaks could not be observed directly or with a periscope.

FIGURE 9. TANK WALL FROM SOUTH ANNULUS RISER. These composite photographs show the top, middle, and bottom horizontal welds of the steel tank wall.

FIGURE 10. TANK WALL FROM WEST ANNULUS RISER

FIGURE 11. TANK WALL FROM EAST ANNULUS RISER

- Sept. 1967 A periscopic inspection during a pumpout of the first evaporator concentrate indicated no salt accumulation on the vertical coils and only a small mound of crystals about $4 \times 8 \times 1$ ft high under the inlet riser. These crystals were covered with a thin layer of dark brown sediment, presumably sand and mud from the ground water pumped into the tank from the riser 6 spill. A mound of sludge about 1 ft deep was observed near the east side wall.
- Nov. 1967 Following the second removal of evaporator concentrate (to tank 10), a periscopic inspection of the tank interior revealed no appreciable salt adhering to the vertical cooling coils and only a small mound of salt under the inlet riser.
- Dec. 1967 The salt accumulation in tank 9 was inspected and photographed with the periscope installed in riser 8 after removal of supernate. Salt accumulation on the tank bottom ranged from less than 13 in. (the existing liquid level) over most of the tank to a mound 10 ft high and 17 ft wide at the base beneath the inlet riser 6 (figure 12). A coating of salt about 2 in. thick covered exposed areas of vertical cooling coils. With the aid of photographs, the total salt volume was estimated at 50,000 gallons, of which 26,000 gallons was in the mound beneath the inlet, 22,000 gallons was in the 8-in. bottom layer, and 2000 gallons was clinging to vertical coils.
- Jan. 1968 After a supernate transfer, the accumulated salt was photographed with the periscope installed through riser 8. From the photographs, it was estimated that the salt mound at riser 6 was about 12 ft 9 in. high at the peak, about 52 in. high at a 15-ft radius, and 19 in. high at a 30-ft radius. Most of the remaining tank bottom was covered by 15 to 19 in. of salt. Below the 30-in. level, the vertical coils were encrusted with 6 in. or more of salt. Above that level, the 2-in. salt layer observed previously had completely dissolved. See figure 13. The salt volume in the tank was estimated to be 73,000 gallons.
- Aug. 1968 Following supernate removal, salt deposits in the tank were inspected via periscope through riser 8. See figures 14 and 15. The photographs indicated that salt on the vertical cooling coils increased by about 4100 gallons and that the volume of salt in the mound remained constant.
- Oct. 1968 Periscopic photographs of salt deposits on the vertical cooling coils were taken (figure 16).
- March 1969 Periscopic photographs of the tank interior were taken while the liquid level was at 128 in.

- March 1972 Complete sets of periscopic photographs were made through the south, east, and west annulus risers for comparison with those taken in 1961. No leaksites were observed on the tank wall. Composites constructed from these annulus photographs are shown in figures 9, 10, and 11.
- Aug. 1973 An unexplained 3-in. increase in the liquid level was attributed to the shifting of elevated salts and/or liquids; in November 1973, this analysis was refuted — see below. A periscope inserted into riser 5 to look for possible sources of ground water inleakage revealed only damp spots and an area of paint deterioration inside the riser. Further inspection of the tank interior showed no salt above the liquid level.
- Oct. 1973 Because of repeated, unexplained increases in the liquid level, the periscope was left installed to observe the tank interior as the liquid level rose, to determine the input source. The reel tape probe was set just above the liquid surface to provide an alarm if the level increased.
- Nov. 1973 The liquid level did not increase after the automatic pump in a ground water well was disconnected. This surface water well was installed following the evaporator concentrate spill at riser 6. The pump discharged slightly contaminated ground water into tank 9, usually in negligible quantities. The volume increases noted in tank 9 were attributed to the ground-water pump.

SAMPLES OF TANK AND ANNULUS CONTENTS

Tank and annulus contents were sampled and analyses were made several times between August 1957 and April 1967. All samplings are shown in figure 2 and all available analyses are summarized in table 2. In September 1956, analysis of the tank vapor revealed a hydrogen concentration of 120% of the lower explosive limit (LEL). Samples also were obtained for extensive chemical and fission product analyses, to measure caustic deficiency, to study the waste in the tank annulus, and to further investigate the cause of cooling coil failure.

Chronology of Events Related to Sampling

- Sept. 1956* Explosimeter readings above the liquid in the tank showed excessive hydrogen concentration. Mass spectrometer analysis of a gas sample showed 5.3% hydrogen (130% LEL). A supernate sample indicated 0.59N NaOH.
- Aug. 1957 Supernate analysis indicated no free caustic.
- Oct. 1957* The pH of the tank supernate was 11, same as a dip sample of yellow liquid from the annulus that radiated 7 R/hr at contact.

FIGURE 12. SALT MOUND BENEATH INLET RISER 6.
The vertical pipes are 2-3/8-in. OD. DPSPF 12367-4.

FIGURE 13. COMPOSITE PHOTO OF SALT MOUND. Composite photo shows salt mound centered below the concentrate inlet at Riser 6. The mound was estimated to be approximately 13 ft high by 60 ft diameter at its base. DPSPF 12430-1.

FIGURE 14. SALT ON VERTICAL COILS. The flat tops of the salt pillars are at about 118 inches from the tank bottom. A portion of the salt mound under the inlet riser can be seen in the foreground. Azimuth 30°, elevation 12'3". DPSPF 12853-2.

FIGURE 15. CLOSEUP OF CRYSTALS.
Azimuth 20°, elevation 9'8". DPSPF
12853-17.

Nov. 1957	Both the tank and annulus liquids were sampled and analyzed.
April 1958	Supernate and annulus flush samples were taken and analyzed.
Sept. 1959*	Sludge samples were taken for an analytical development program, but no analyses were reported. Radiation from the 8-ml vials of black material was 20 rads/hr at 3 in.
Jan. 1960*	Sludge samples radiating 10 to 15 rads/hr at 3 in. from a vial and supernate samples radiating 0.6 rad/hr were taken using the sludge sampler.
Feb. 1960	Sludge and supernate samples were taken.
Nov. 1963	Radiation from two 2-oz supernate samples taken with the portable sampler was 800 to 1000 mR/hr at 3 in.
Jan. 1965	Two 10-ml supernate samples were taken for extensive chemical and fission product analyses. Indicator solution showed the pH was between 11.8 and 12.5.
Dec. 1965	A 200-ml sludge sample was taken adjacent to a section of vertical cooling coil 6 which had developed a leak in February 1965. The sample radiated 3 R/hr at 3 in., but analytical results were never recorded.
April 1967	A liquid sample was taken of residual slurry water following sludge removal. The sample was obtained to investigate the cause of cooling coil failure in tanks following sludge removal. The clear, colorless sample contained traces of brown particles.
Oct. 1972	A profile of radiation intensity at different elevations (figure 8) in the annulus was taken beneath the east annulus riser of tank 9. Thermoluminescent dosimeter badges were lowered to various depths for given time intervals to measure radiation.
Oct. 1974	Thermocouples were installed on tank 9 walls, and temperature data were accumulated to determine normal operating temperatures. Tests were initiated to determine if temperature could be controlled above nil-ductility transition temperature (figure 17).

FIGURE 16. SALT DEPOSITS. Note tapered columns around vertical cooling coils. DPSPF 12996-29.

FIGURE 17. TANK 9 ANNULUS THERMOCOUPLE LOCATIONS

PHYSICAL MEASUREMENTS

Temperature profiles (figure 3) were taken by incrementally lowering a thermocouple in existing thermowells. In November 1957, May 1958, and September 1972, radiation intensity profiles were obtained in the annular space (figure 8). In December 1967, September 1968, and March 1969 soundings were made to determine salt depth. Tensile forces on vertical cooling coils embedded in salt were estimated in January 1968. In March 1972 the annulus salt was probed with a coring tool. Measurement dates are shown chronologically on figure 2.

Chronology of Events Related to Physical Measurements

Nov. 1957	Radiation intensities were measured in the annular space following the discovery of 4 to 5 in. of liquid in the annulus on October 29 (figure 8).
Jan. 1961	The annulus liquid level was 4¼ in., obtained by rodding (figure 2).
March 1961	The annulus liquid level was 7¼ in.
April 1961*	The annulus liquid level was 7-1/8 in.
May 1961*	The annulus liquid level was 8½ in. Annulus rodding continued periodically through August 1964 at which time the annulus was found dry.
March 1966	A temperature profile was taken in the tank at riser 1 (figure 3).
Dec. 1967	A sounding at riser 2, nearly opposite the evaporator bottoms inlet at riser 6, indicated 5 in. of salt on the tank bottom. About 2 in. of salt had accumulated on the surfaces of the vertical cooling coils.
Jan. 1968	Settling of a simulated vertical coil at riser 7 was measured. The settling was interpreted in terms of force on nearby vertical coils embedded in the salt to obtain an estimated force per coil loop (two vertical pipes). These ranged from 140 to 330 pounds from December 11 to January 19. The maximum permissible load on the tank roof is 2800 pounds per coil loop (200 lb/sq ft). Additional test coil settling data and corresponding liquid levels in tank 9 are given in figure 18; see also figure 19. See DPSPU 70-11-2 for additional discussion.
Sept. 1968	Five soundings of salt depth indicated 23 to 125 in. Salt volume was not estimated because of lack of information about salt thickness on the cooling coils.

FIGURE 18. TEST COIL SETTLEMENT

FIGURE 19. SALT RELEASE TEST SYSTEM

March 1969	Soundings of salt depth indicated 59 in. beneath riser 1, 112 in. beneath riser 2, 78 in. beneath riser 4, and 144 in. beneath riser 6. The 112-in. reading for riser 2 was questionable because salt on the vertical coils probably prevented contact with the salt bed.
Oct. 1969	A temperature profile was taken in riser 5 (figure 3).
March 1972	Probing with a coring tool revealed a 5- to 7-in. layer of hard salt over a layer of softer material continuing to the annulus pan bottom. Liquid slowly filled the cored 8- to 10-in.-deep hole to a measured depth of 3 in.
Oct. 1972	A temperature profile was taken in riser 5 (figure 3).

COOLING COIL FAILURES

In February 1965, about 9½ years after tank 9 was placed in service, the first of eight cooling coil leaks developed. A second coil leak occurred in March 1965. In the nine months between sludge removal in July 1966 and evaporator bottoms addition in April 1967, five coils, including one horizontal and four vertical, leaked and were blanked off. One additional coil (the second of two horizontal coils) failed in August 1967. An analysis of cooling coil failures in all tanks presented in September 1972 showed that most failures have followed soon after sludge removal, by mechanisms yet undefined, and that the failure rate can be attenuated by addition to the tank of waste with a high concentration of nitrate salts and caustic (e.g., evaporator bottoms).

The coil failures discussed below are also shown chronologically in figure 2. Cooling coil leaks are denoted by a triangle with the enclosed number indicating which coil failed. See figure 20 for coil location.

Chronology of Events Relating to Cooling Coil Failures

Oct. 1955*	The auxiliary cooling coils were valved off. Although no temperature data has been found for this period, this act indicates that the temperature was low.
Feb. 1956*	The cooling water was valved off for two days during which time the rate of temperature rise was 2°C per day.
April 1956*	The water to the cooling coils was turned off for several days during a test.
Aug. 1956*	1/8-in. orifices, intended to avoid cooling water stagnation but still limit the flow to 1 gpm per coil, were installed in the cooling coils.
March 1960*	The cooling water was valved off for eight days during which no increase in tank temperature was detected.

FIGURE 20. TANK 9 VERTICAL COOLING COIL LAYOUT

Feb. 1965	Pressure tests revealed a leak in vertical coil 6. Initially, the leak rate was 1 gpm, but had increased to 6 gpm on the date the leaking coil was identified and the coil blanked off. An estimated 4000 gallons of water entered the tank through the leaking coil.
March 1965	Leaking vertical coil 8 was blanked following a loss of about 250 gallons of chromate-treated water to tank 9.
Aug. 1966	Following sludge removal in July 1966, lower horizontal coil 18 began to leak at an estimated rate of 2 to 3 gph. The coil was blanked.
Jan. 1967	Leaking vertical cooling coil 17 was blanked.
Feb. 1967	Auxiliary vertical cooling coil 1-A was blanked because of leakage.
April 1967	Auxiliary vertical coil 17-A and upper horizontal coil 18 leaked and were blanked.
Aug. 1967	A large, 25-gpm leak developed in vertical coil 1. When it was valved off, a previously noted small cooling water loss also stopped. The major leak began during a period when cooling water pumps were being turned on and off. These pressure surges may have caused the slow leak to increase abruptly.

TESTS CONDUCTED

In July 1963, stress corrosion coupons were installed to study tank wall and cooling coil corrosion. During July 1968, two-stage concentrate transfer testing began. In March 1968, two simulated cooling coils were installed in risers 1 and 7. A summary of this test-coil data was presented in the WT report for June 1970 and in DPSPU 70-11-2, Waste Tank Roof Loading by Solid Salt, by B. S. Johnson and D. W. Tharin. Heating a test coil did not free it from the salt in which it was embedded in a test conducted in July 1969. These entries are shown chronologically in figure 2.

Chronology of Events Relating to Tests Conducted

July 1963	A set of carbon steel stress-corrosion coupons was placed in tank 9 for SRL to study tank wall and cooling coil corrosion.
March 1967	Two test sections of cooling coils supported by force gages were installed to simulate thermal conditions surrounding the tank's vertical coils and to provide an indication of the force transmitted to the tank roof by salt adhering to the tank coils.

- Dec. 1967 In a five-day test during the fourth filling of tank 9, the evaporator bottoms specific gravity was reduced from 1.5 to 1.4 in an attempt to reduce the salt mounding tendency under the inlet riser. The mound height had grown to 16.5 ft. During the first three days, the height directly below the riser was reduced to 13.7 ft, but over the next two days, no further reduction was measured by soundings.
- Jan. 1968 To promote the spread of salt and thus curtail mound buildup, cooling water was shut off to coils 5 through 14 on January 18. These coils serve the region about the inlet riser. The remaining coils were valved off on January 29 to allow the temperature of the tank contents to rise preparatory to tests of the two-stage concentrate transfer system.
- July 1968 225,000 gallons of supernate from hot evaporator bottoms was transferred from tank 9 to tank 10 in the two-stage concentrate transfer test (TA 2-650).
- July 1969 Hot water was circulated through the simulated cooling coil at riser 1 (installed in March 1967) to determine if this would release the bond between the coil and the salt in which it is embedded (figure 20). The coil was not released from the salt.
- June 1970 A summary of test coil data was presented. Observations indicated a roof loading due to salt of 75 lb/ft^2 . The maximum test-coil settling (due to downward movement of the salt bed) was 0.149 in. for the riser 1 test coil and 0.152 in. for the riser 7 test coil. See figure 18. This deflection would induce a tension of about 1070 pounds in each hairpin loop of the regular vertical coils, two of which are supported from each $3\frac{1}{2} \times 8$ -ft roof area. The maximum additional roof load recommended by the Engineering Department for 75-ft-dia tanks is 200 lb/ft^2 , i.e., 2800 pounds per coil loop.

EQUIPMENT MODIFICATION AND REPAIRS

Several reel tape repairs and replacements were made between August 1955 and September 1967. In November 1955, the leak detection alarm shorted to ground and could not be returned to service. The prefilters and CWS filters on the annulus exit air duct were replaced in October 1962 due to high radiation. From November 1965 to September 1967, a number of equipment modifications were made relative to installation of the gravity drop line (GDL) from the evaporator, and to prepare tanks 9 and 10 for the two-stage concentrate transfer test (TA 2-650 and supplements A through D). In January 1968 and July 1969 reel jet leaks were repaired. In November 1968, a leak in the riser 6 GDL jumper was repaired with "Viton" O-rings. Again in February 1971 and in April 1972, leaks occurred in the riser 6 GDL jumper, and were repaired. All entries are shown chronologically in figure 2 along with tank levels.

Chronology of Events Relating to Equipment Modification and Repairs

Aug. 1955*	The reel tape probe was replaced, but the instrument continued to malfunction and was used infrequently during 1956 and 1957.
Oct. 1955*	The reel tape was serviced, and readings agreed within 0.5% with dip tube measurements.
Nov. 1955*	The "necklace" leak detection alarm activated, indicating possible moisture in the annulus. However, a subsequent dip tube liquid level determination indicated no liquid. The "necklace" alarm could not be returned to service.
Dec. 1955*	The reel tape was recalibrated. The tank liquid level was 265.5 in.
Oct. 1956	A bypass line was installed from the dehumidifier blower to the tank to provide about 35 cfm continuous purging of the tank vapor space.
Oct. 1957*	The reel tape was replaced.
Dec. 1957*	Jet assemblies were installed to transfer from tank 9 annulus to tank 9 and from tank 9 to diversion box 1 (DB-1).
Jan. 1960	The reel tape was damaged. The repair shortened the tape 0.8 in.
May 1961	Two new conductivity probes were installed in the annulus.
Oct. 1962	The prefilters and CWS filters on the annulus exit air were replaced due to radiation of 150 and 25 mR/hr, respectively, at 3 in.
Nov. 1965	Jumper changes were made in DB-1 to connect the transfer jet to pump tank 3.
Dec. 1966	A reel jet was installed permitting easy selection of the suction level and storage of the jet above the liquid between waste transfers.
March 1967	The GDL was completed from the evaporator to tank 9. The evaporator bottoms jumper was changed to deliver the first concentrate to tank 9.
Sept. 1967	The reel jet discharge was connected to tank 10, and the DB-1 sump jet was connected to tank 9. A new reel tape was installed.

- Jan. 1968 A leaking "Teflon" seal in the rotating steam joint of the reel jet was replaced with a rigid spoolpiece. After poor jet performance (36 to 21 gpm) continued, a 3-in. longitudinal split was found at the lower end of the flexible discharge hose. The split was patched with epoxy resin and a metal sleeve. A "Viton"-packed rotary joint was substituted for the original "Teflon"-sealed joint in the reel jet discharge line.
- The GDL extension from tank 9 to tank 10 was completed by Construction.
- Feb. 1968 A crossover jumper was installed in riser 6, to connect with the GDL to tank 10.
- Nov. 1968 The riser 6 jumper connecting the GDL to tank 10 leaked and was repaired with "Viton" O-rings.
- July 1969 A leak developed in the flexible discharge hose of the reel jet just above the epoxy repair made previously. The new leak was repaired in a manner similar to the previous one.
- Feb. 1971 Leakage in the GDL jumper flange was repaired by installing "Viton" O-rings. The failed O-ring gasket was hardened and broken.
- April 1972 Leakage occurred again at the O-ring seals of the GDL flange and was repaired.
- Dec. 1972 The valved 3-connector jumper [19, 20 (HDB-1) 13], which connected the jets at tank 9 and 10 to either HPT-3 or tank 9, was found to leak. It was replaced with a 2-connector jumper [19 (HDB-1) 13], which connects to HPT-3 only.
- May 1973 The east and west annulus leak detection probes were lowered to the pan floor.
- Nov. 1973 Modified plugs were installed in annuli to facilitate handling by one man for annulus inspections. The plugs have self-sealing gaskets and raised mounts to help keep moisture out of the annulus.
- Modifications to the leak detection probes included replacement of two probes in the tank, movement of the alarm relay to inside the valve house, and installation of relay test switches.
- Jan. 1974 A tank level decrease of 1.25 in. was attributed to volumetric contraction of waste caused by a 20°C reduction in chromated cooling water temperature due to cleaning the Building 241-H heat exchangers.
- Jan. 1974 A leak detection probe was installed through a hole drilled in the salt layer under the west annulus riser.