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TANK 16 DEMONSTRATION
WATER WASH AND CHEMICAL CLEANING RESULTS

SUMMARY AND CONCLUSIONS

In the tank 16 demonstration over 99.9% of the radioactive waste initially present in the tank interior was removed. The tank floor is now covered with only a thin layer of dried residue. The earlier hydraulic cleaning steps, which used long-shafted pumps to slurry and transfer over 99% of the waste, were described in references 1 and 2. An additional hydraulic cleaning step, two water wash steps, three acid washes and a final water rinse are discussed in this report. Test conditions for each of these steps are summarized in Table 1; equipment arrangement is shown in Figure 1.

The steps followed in this demonstration were not planned to expedite waste removal from tank 16, but to provide maximum data and experience to evaluate various options available for waste removal from other tanks. Leakage from the tank interior during water and oxalic acid spraying and mixing was observed only where the tank wall had been patched after specimens were removed in 1961 for metallurgical examination. Demonstration of equipment and techniques in tank 16 provided a firm basis for design and operation of facilities for the Tank Replacement/ Waste Transfer Program. Design of facilities for the sludge removal phase is now underway (Project S-2081). Other phases are still being planned.

Performance and reliability of the slurry pumps, the key equipment in the program, was very satisfactory throughout the demonstration. The pumps used are still in excellent condition and will be removed for use in other waste removal operations.

Very detailed inspections of the tank interior are underway. Equipment is being developed to allow brush cleaning the thin residue from the tank floor for closeup periscopic inspection to determine if pitting has occurred. Additional cooling coil sections will be removed for study. Another annulus cleaning demonstration is planned. The tank will then be in a suitable condition for a future demonstration of decontamination techniques.

DISCUSSION

Test Description

This second phase of the tank 16 demonstrations included two water washes, three acid washes and a final water rinse (See Table 1).

Prior to water washing, a final multipump slurrying test was done to remove several small piles of sludge remaining under riser 3. These piles contained 150 gallons of the estimated 1,380 gallons of sludge still remaining in the tank; the other sludge was in a dilute slurry heel.

About 58,000 gallons of supernate from tank 22 was added to prime the three slurry pumps and provide a slurrying medium. The slurry pump in riser 6 was rotated during the test, while the slurry pump discharges in risers 2 and 4A were alternately directed at the small piles of sludge under riser 3. Slurry pump 4A was shut down after 56 hours of operation because the pump motor bearing failed. The slurry was transferred to tank 21, leaving less than 1% of the original sludge. Wide-angle photographs showed that no significant sludge remained in tank 16 after this step.

During the first water wash, 63,000 gallons of water at 90°C was sprayed into tank 16 alternately through each of the five rotary spray jets. Table 2 summarizes spraying data. Pluggage in the water tank discharge line reduced the flow and pressure of water to the sprays in risers 4 and 7. The slurry pumps were started during spraying when the liquid level covered the pump volute (16 inches). However, the slurry pump in riser 6 was shut down because of excessive vibration after 42 hours of operation. The liquid was transferred to tank 21 after being neutralized to pH>12 with 50% NaOH added in pump tank 4 (HPT-4).

Seventy thousand gallons of water (total) at 90°C was added alternately through the five rotary spray jets during the second water wash. Since a salt deposit on cooling coils beneath the valve house remained after the first water wash, the quantity of water sprayed through riser 1 was increased. Periscopic inspections after this spraying showed the salt deposit was only partially dissolved. Table 3 summarizes spraying data.

Slurry pumps were started when the liquid level covered the volute. After mixing the tank contents for 30 hours, the water wash liquid was transferred to tank 21. Caustic was added to HPT-4 during the transfer to neutralize the water to a pH of 12.

For the first oxalic acid wash, about 37,000 gallons of water at 90°C was sprayed through riser No. 1 rotary spray. This spraying reduced the volume of the one remaining salt deposit under the valve house by about one-half. Then 12,600 gallons of 4 wt.% oxalic acid at 90°C was pumped directly to the tank bottom. The acid was added directly to dissolve residual sludge, so that activity removed from the bottom could be distinguished from activity removed from coils and tank walls by later acid sprays. The acid system was flushed with 4500 gallons of 90°C water. The slurry pumps were started when the volutes became submerged.

After agitation with the slurry pumps for two days, the solution was transferred to tank 21. Fifty percent NaOH was added to HPT-4 to neutralize the solution to a pH above 12.

In the second oxalic acid wash, 41,000 gallons of 90°C water was sprayed through the riser No. 1 rotary spray. Then 1800-2000 gallons of 4 wt.% oxalic acid at 90°C was sprayed through each of the five rotary sprays. The acid system was flushed with 5,400 gallons of water. The slurry pumps were started when the volutes became submerged. After 40 hours of slurrying, the solution was transferred to tank 21. The solution was continuously neutralized by adding 50% NaOH to HPT-4. Inspection after the acid wash showed the salt deposit on a cooling coil beneath the valve house near riser 1 was reduced to about one cubic foot.

The third acid wash began with 9000-12,000 gallons of 4% oxalic acid at 90°C sprayed through each rotary spray. The system was then flushed with 5,800 gallons of water. The acid solution was agitated by the slurry pumps for 48 hours. The solution was transferred to tank 22 after being neutalized in HPT-4 with 50% NaOH.

Photographic inspection in riser 8 after the third acid wash revealed about 100 gallons of sludge-like material remaining on the tank bottom. This material was in a roughly circular pile, 10 feet in diameter and one to three inches high. During earlier supernate slurrying steps, a slurry pump in riser 8 was only nine feet from the center of the pile. This pump was moved to riser 6, 25 feet farther from the pile, to allow installation of a rotary spray in riser 8. This material was sampled and analyzed (Table 4). Analysis indicated the solid material was mostly hematite (Fe_2O_3) and boehmite ($Al_3O_3 \cdot H_2O$). The solid was not soluble in oxalic acid at 50°C. It was dense and settled at a rate of one inch per hour. The Pu^{239} concentration (0.14 g/ℓ sludge) was about twice that of the original sludge, but well below the concentration of Pu^{239} required for criticality (7 g/ℓ). Sr^{90} concentration was about 3 times that of the original sludge.

Relocation of the pump from riser 6 to riser 8 was necessary to remove this deposit of sludge. Prior to this relocation, about 22,000 gallons of 90°C water was sprayed into tank 16 through the rotary spray in riser 8 to rinse coils and the tank wall in this vicinity. This spray jet was then removed and the slurry pump was relocated to riser 8.

After the slurry pump was relocated, about 34,000 gallons of water at 90°C was sprayed through the rotary sprays in risers 1,3,4 and 7. The slurry pumps were started when the volutes became submerged (16 in. level). The riser 8 slurry pump was indexed toward the sludge pile to suspend the sludge. After four days of slurrying, the solution was transferred to tank 15. The solution was neutralized during the transfer in HPT-4 with 50% NaOH. When the tank level reached 16 inches, about 56,000 gallons of water at 25°C was sprayed through the rotary sprays. This allowed the slurry pumps to continue suspending the fast-settling sludge during the transfer, thereby removing more of the sludge. Inspection after the tank bottom had dried revealed no significant sludge or salt deposits. The bottom has a thin coat of yellow material, which was probably ferrous oxalate.

Transfer data are summarized in Table 5. Samples analyzed for these tests are reported in Table 6. Three samples were taken for each acid washing and the water rinsing test.

Tank Interior Condition After Tests

Photographic inspection of the tank interior and annulus during and after each test are summarized in Waste Management Monthly Reports. Periscopic, direct and wide-angle photographs of the tank interior were taken.

Radiation profiles were made after the second multipump test and each succeeding test in the tank interior and annulus. The profiles were made using a probe, which only measures gamma radiation, lowered through riser openings. Results are reported in References 3 to 10. The profile results from riser 4 at 34" and 274" above the tank bottom are plotted in Figure 2 and indicate a decreasing trend in radiation levels in the tank interior. The readings are increased by radiation from waste in the tank annulus. Radiation profiles will be made again when annulus cleaning is completed.

A section of the cooling water header pipe going to auxiliary cooling coil No. 12 was removed using a hydraulic cutter inserted through riser 1. The coil section was then cut into pieces and used to evaluate the effectiveness of various tank cleaning steps. SRL used one piece to measure the initial contamination level and the effect of cleaning solutions. Three other pieces were inserted into the tank interior at riser 5 where they were washed by rotary sprays located about 15 feet away in risers 4 and 7, One piece was removed for SRL testing after the last water wash, another was removed after the oxalic acid washes, and the last one will be removed at a later date. Radiation intensity readings (made at SRL) are summarized in Table 7 (Reference 11).

The tank floor was allowed to dry after the third acid wash and after the water rinse to allow inspection of the tank floor. A 4-inch diameter flexible hose was attached to the purge air inlet and lowered to about one foot above the tank floor. This hose increased the evaporation rate from about 120 gallons/day to 150 gallons/day. With four vertical coils heated to 80°C and the flexible hose installed, the 3700 gallons heel left after the third wash evaporated in less than two months.

A 3-inch diameter sample pan was installed on the tank bottom under riser 3 prior to the water rinsing test. This pan remained in the tank until the tank bottom dried. When the pan was removed, it was coated with a dull yellow-orange material and radiated 80 rad/100 mR per hour at two inches from the pan. Analyses of material deposited in the sample pan are shown in Table 8. The majority of the activity remaining in the tank is strontium-90.

Heat Balance

The calculated heat transfer rates to the environment, and rate of increase and maximum temperature of the liquid during the tests are shown in Table 9. The heat transfer rates were calculated by using the apparent soil temperature found from a least squares fit of the data from each test. Transfer rates are not included for the second water wash and the water rinse tests because the data are inconsistent. Average temperatures of the tank vapor, liquid and annulus during each test are plotted in Figures 3-9. The cooling coils were valved-off during all tests. However, four coils were heated to 80°C for the acid washes and the water rinse. These coils were heated to determine if additional cleaning of the coils could be achieved during the chemical cleaning tests. No significant difference in cleaning between heated and unheated coils was observed based on photographic inspection. Liquid temperature increases similar to the second multipump test (0.2°C/hr) were observed during the last multipump test. The liquid temperature decreased during the water washes. The liquid temperature would probably have also decreased during the acid washes and the water rinse except the heated coils added 2000-3000 Btu/minute of heat to the liquid.

Activity Balance

Slurry samples were taken before each transfer to a receipt tank and analyzed for cesium-137 (Cs^{137}) and strontium-90 (Sr^{90}) (Table 6). The total curies in the liquid prior to transferring the slurry for each test are plotted in Figure 10. Estimates were made of the curies of Cs^{137} washed off the tank walls and coils during spraying (Table 10). The curies of Cs^{137} washed from coils and the tank wall were estimated by subtracting the curies of Cs^{137} left in the heel of the preceeding test from the curies of Cs^{137} in the liquid prior to transferring the solutions. The same calculations were made for Sr^{90}, however, the interpretation is not as straight forward since Sr^{90} is not very soluble in water or acid and will settle after the slurry pumps are shut down toward the end of a transfer.

Tank 16 Ventilation

The tank 16 ventilation system was modified to prevent radioactive releases to the atmosphere during chemical cleaning tests (Figure 11). The modifications included:

- Removal of existing teapot filter.
- Installation of an 8-inch butterfly valve to regulate the purge air rate.
- Installation of a reheater coil to maintain the condenser exit vapor above the dew point temperature to keep the HEPA filter dry.

The modified tank 16 ventilation system is similar to upgraded ventilation systems (Ref. 12) provided on other tanks by Project S-2108. Activity in the air exhausted from tank 16, the solution receipt tanks and diversion box HDB-2 was not significantly more than during normal operations (less than 25uCi/week). The tank 16 HEPA filter element was replaced twice during the first water wash, but not during the other steps. The reheater coil is designed to increase the condenser air exit temperature by 20°C. However, during the first water wash the increase was only 10°C (Figure 12). The pressure drop across the HEPA increased as moisture from the air deposited on the filter. When the filter was changed after spraying hot water into the tank, the filter was wet. After completion of the first water wash, the filter was changed again and appeared to have been wet. The filter was not abnormally contaminated either time. During the remaining steps, the reheater was set to maintain the reheater coil temperature at least 20°C higher than the condenser exit temperature (Figure 13). With the higher reheater temperature, it was not necessary to replace the HEPA filter.

The tank interior pressurized during spraying of hot solutions. During the first water wash, the tank ventilation exhaust rate was throttled to 150 cfm to be representative of the other tank ventilation systems. The exhaust rate was increased to 700 cfm shortly after spraying began, because tank pressure increased to +1.3 in. H_2O (versus a normal of -0.3 in. H_2O). During this pressurization, hot water was being sprayed at 120 gpm through the rotary spray in riser 1 (Figure 14). A small amount of slightly contaminated water leaked onto the tank top from openings around the risers. Pressurization occurred also at the start of each spraying step except when the spray in riser 4 was started. The riser 4 spray was started at 100 psig water pressure versus 160 psig for the other sprays.

During the second water wash, the tank ventilation purge rate was maintained at 200 cfm. The spray was started with spray water supplied at less than 100 gpm to prevent tank pressurization. However, even when starting at a 65 gpm spray rate, the tank pressurized to 0.4 in. H_2O (Figure 15). The tank remained pressurized for about 10 minutes while operating the rotary spray in riser 1. Pressurization occurred for shorter periods at the start of each spray during the remainder of the wash.

For the three acid washes, the air purge rate was at 200 cfm. Flow to the sprays was throttled initially to reduce tank pressurization. However, the tank pressurized to 0.55, 1.5 and 1.35 in. H_2O for each acid wash, respectively. Contaminated water (2000-3000 c/m) leaked from around risers during the third acid wash.

During the water rinse, flow to the sprays was throttled to reduce tank pressurization. With an air purge rate of 600 cfm, the maximum tank pressure was a brief increase to 0.9 in. H_2O. During the transfer of the initial water rinse solution to tank 15, cold water (25°C) was sprayed into tank 16 to allow the slurry pumps to continue to suspend the fast settling sludge. Spraying of this cooler water into the tank caused the tank pressure to decrease to -1.5 in. H_2O.

At the beginning of each washing step, pressurization of the tank occurred because of the rapid heating and humidification of the tank vapor. The temperature increase (1.25°C/min) at the beginning of spraying is equivalent to an expansion rate for the tank contents of 1200 cfm.

Since the tank purge blower was operating from 200-600 cfm, pressurization of the tank occurred. After the tank vapor reached about 50°C and 100% humidity, the expansion rate was reduced to about 300 cfm and was equivalent to a vapor temperature increase of 0.1°C/min. These results indicate overloading of the tank ventilation system will occur at the start of a spraying operation. However, the air expansion rate will decrease quickly to acceptable levels as the tank vapor temperature and humidity increase quickly.

A method to prevent pressurization of the tank will be tested in tank 16 (Reference 13). Low pressure steam will be added slowly to the tank vapor space to bring the air to the same operating temperature and humidity expected during spraying. This should prevent air expansion from pressurizing a tank when the sprays are initially operated.

Leak Detection

A periscope was installed in either annulus inspection port IP 35 or 151 during all steps while spray jets were operating to observe annulus conditions. No leakage into the annulus was observed during the multipump test, acid washes or the water rinse. However, a small amount of leakage through a tank wall patch was observed during both water washes. This water evaporated from the tank wall before reaching the annulus pan bottom. The patch covered a hole made in the tank wall where a sample was removed for metallurgical examination. Very slight leakage was observed at one crack in the tank wall (near IP 151) during the water washes. The annulus conductivity probes did not alarm during the tests. Ground water sampled around tank 16 showed no significant increases in activity during the demonstration (Figure 16).

Pump Performance

The slurry pumps (described in reference 1) performed well. Operating data are shown in Table 11.

Some slurry pump motor problems developed during the third multipump test and the first water wash. The motor on the riser 4A slurry pump was shut down during the final multipump test because of excessive motor heat. The slip rings were found to be badly corroded and the top thrust bearing was worn.

The motor ammeter on the riser 6 slurry pump indicated high amperage (greater than 175) during the first water washing test. The slurry pump was shut down due to excessive vibration. The motor shaft was found to be broken. The shaft sheared where the coupling hub is keyed to the motor shaft. A metallurgical examination indicated the motor shaft failed due to fatigue (Reference 14).

Modifications were made to all motors to prevent water from entering the motor thrust bearing oil reservior. Also, the broken motor shaft was replaced with a improved shaft as suggested by reference 14. Shaft couplings were replaced on the other pumps to ensure the coupling-shaft fit was correct. The keyway design will be modified on future orders. The average slurry pump seal leakage rates were 1.5 gpm for the multipump test and 1.9-2.3 gpm for the water and acid cleaning tests. The seal water was inhibited during the multipump test, but not during the water or acid cleaning tests. The total operating time of the three slurry pumps during the tank 16 demonstration was about 2300 hours.

The tank 16 transfer pump is described in Reference 1. Operating data are shown in Table 11. The transfer pump discharge was throttled during all tests to match the rate of the pump tank 4 transfer pump. During the multipump test, the water washes, and the first two acid washes, the pump tank pumping rate was lower (60-75) than earlier tests (150 gpm). The reduced rate was the result of transferring to tank 21, versus tank 15 during earlier tests, which is at a higher elevation and requires a longer transfer route.

A tank heel of less than two inches was obtained after each test except the first water wash. An interlock prematurely shut down the tank 16 transfer pump below the pump priming level, leaving a heel of 3 inches (10,500 gallons). The tank 16 transfer pump operated about 160 hours without any apparent problems during the demonstration.

The slurry pump in riser 6 was raised above the tank top for radiation and contamination measurements after the completion of the second water wash and after the third acid wash. Some of the resulting data is shown in Figure 17. The pump housing had a tenfold reduction in smearable contamination and twofold reduction in radiation levels between the second multipump test (Reference 2) and after the last water wash. Slurry pump contamination was further reduced by the acid washes. The smearable contamination and radiation levels were reduced to 2mRad/hr and 30/10 mRad/mR per hour at 2" from the pump, respectively. However, the lowest flanged section and the pump volute contamination were at much higher levels. These higher levels are probably due to the dried residue of material on the pump housing and material left in the pump volute which was not flushed as was done earlier.

The estimated exposure to personnel during the three pump relocations was a total of 0.24 man-rem of penetrating radiation and about 2.4 man-rem dose to the skin. Most of the dose to the skin was from the Sr^{90} in the waste deposited on the pump housing. Based on these exposures, plans are acceptable for relocating pumps from tank to tank during waste removal operations.

Slurry pump seal water leakage versus pressure tests were performed on slurry pumps 2 and 8 during the water rinse test.

The leakage rate decreased as expected as the pressure on the seal was decreased. At 40 psig (on the seal), the leakage was 2.3 gpm; at 25 psig, leakage was 1.7 gpm. These tests indicate some reduction in seal leakage can be achieved by reducing the seal water pressure.

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3. Memo, Tank 16 Radiation Profiles, R. L. Boyleston to O. M. Morris, June 6, 1979.

4. DPSP-79-21-11, Waste Management Monthly Report, Table 19, November 1979.

5. DPSP-79-21-12, Waste Management Monthly Report, Table 21, December 1979.

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11. Letter to be issued by N.E. Bibler on Tank 16 cooling coil sections.

12. DPSP-79-17-14, Tank 16 Chemical Cleaning-Tank Purge System Improvements, J. C. Bailey to D. B. Jett, June 7, 1979.

13. Memo, Tank 16 Demonstration-Steam Preheating Test, K. R. Crow to G. M. Johnson, October 1, 1980.

14. 200-H Area Metallurgical Report, Failed Bingham Pump Motor Shaft, February 19, 1980.

TABLE 1

TANK 16 TEST CONDITIONS

Test	Method and Type Solutions Added to Tank	Volume of Solution (gal)	Comments
Third multipump	Transferred supernate	58,000	From tank 22
First water wash	Sprayed 90°C water	63,000	-
Second water wash	Sprayed 90°C water	70,000	-
First acid wash	Sprayed 90°C water Pumped 90°C 4 wt.% oxalic acid	42,000 12,000	Combined concentration of solutions about 1 wt.% oxalic acid. Acid was pumped directly to tank bottom.
Second acid wash	Sprayed 90°C water Sprayed 90°C 4 wt.% oxalic acid	46,000 10,000	Combined concentration of solutions about 1 wt.% oxalic acid.
Third acid wash	Sprayed 90°C 4 wt.% oxalic acid	50,000	-
Water rinse	Sprayed 90°C water Sprayed 25°C water	56,000 56,000	Water at 25°C was sprayed during transfer to allow slurry pumps to operate longer during transfer.

TABLE 2

TANK 16 SPRAYING DATA

FIRST WATER WASH

RISER NO.	AVG., FLOW gpm	VOLUME gal.	PRESSURE psig	TANK TEMP.°C Vapor	Liquid
1	113	12,418	166	46	47
4	116 (137.5)	12,418	100 (160)	48	46
7	108 (147)	12,516	113(158)	54	47
8	137.5	13,245	162	53	51
3	120	12,418	176	53	53
	119 avg.	63,015			

1) Numbers in parentheses are data for unthrottled flow.

2) The Sellers spray was in riser 3; all other risers contained Orbijet sprays.

3) Sprays are operated alternately one at a time.

TABLE 3

TANK 16 SPRAYING DATA

SECOND WATER WASH

RISER NO.	AVG., FLOW gpm	VOLUME gal.	PRESSURE psig	TANK TEMP. °C Vapor	Liquid
1	97.6 (163)	23,900	(150)	53	45
4	117.4 (141)	12,500	(140)	56	--
7	114.7 (151)	11,238	(150)	58	48
8	121.5 (145)	11,177	(160)	47	54
3	85.0 (94)	11,310	(174)	59	56

1) Numbers in parentheses are data for unthrottled flow.

2) The Sellers spray was in riser 3; all other risers contained Orbijet sprays.

3) Sprays are operated alternately one at a time.

TABLE 4

ANALYSIS OF SOLID RESIDUE LEFT ON TANK FLOOR (after third acid wash)

Date sampled	5/9/80
Riser sampled	8
Sample Volume, ml	40
Gross α, d/m/ml	5.55×10^{8}
Gross β, γ, d/m/ml	2.34×10^{11}
Cs^{137}, mCi/ℓ of Sludge	2.6
Ce^{144}, mCi/ℓ of Sludge	112
Eu^{154}, mCi/ℓ of Sludge	88
Co^{60}, mCi/ℓ of Sludge	4,000
Sr^{90}, mCi/ℓ of Sludge	28,000
Pu^{238}, mCi/ℓ of Sludge	210
Pu^{239}, mCi/ℓ of Sludge	8.8

NOTE: Analysis converted from mCi/g to mCi/ℓ using 400 g of solids/liter of slurry. This was determine by centrifuging the sample.

TABLE 5

TANK 16 SLUDGE REMOVAL STEPS

Test Type	Multipump	Water Wash		Acid Wash			Water Rinse
Step	3	1	2	1	2	3	1
Dates of operation	11/5-11/10/79	11/15-11/20/79	12/10-12/14/79	2/11-2/15/80	2/25-2/29/80	3/17-3/21/80	8/5-8/12/80
Hours of operation-Pump #2	71.5	83.0	57.3	47.5	46.0	48.0	106.3
Hours of operation-Pump #4A	56.0	70.5	50.6	47.5	46.0	48.0	128.3
Hours of operation-Pump #6	71.5	42.0	57.6	38.5	44.0	48.0	133.8[a]
Sealwater added during test, gal	25,716	31,093	23,853	22,937	27,220	20,307	72,500
Supernate additions from tank 22, gal	58,188	-	-	-	-	-	-
Spray water added, gal	-	63,015	70,125	41,596	46,477	5797	112,446
4 wt.% oxalic acid added, gal	-	-	-	12,611	9865	50,545	-
Concentration of oxalic acid resulting from water and acid sprayed in tank 16,wt.%	-	-	-	1	1	4	-
Caustic added to neutralize slurry, gals	-	1,766	2594	4503	2473	3059	2289
Slurry transferred, gal	80,973[b]	82,483[b]	104,478[b]	80,150[b]	82,768[b]	77,300[c]	195,038[d]
Heel volume, gal	5,250	10,500	3,500	3,500	2,800	3675	1,000
Vol% solids in slurry, based on 1 hr centrifuging	4.0	1.2	3.1	< 1.0	< 1.0	<1.0	<0.5

NOTES:
a. Slurry pump was in riser 8
b. Sent to tank 21
c. Sent to tank 22
d. Sent to tank 15

TABLE 6

SAMPLE ANALYSIS

Test Type		Multipump	Water Wash	
Run No.		3	1	2
Riser No.		4	4	4
Tank volume Sampled, gal		87,750	91,000	91,000
Heel volume, gal		5,250	10,500	3,500
Physical Properties				
Density, g/ml		1.2	1.0	1.0
Vol% solids		4.0	1.2	3.1
Chemical Analysis				
NO_3^-	M	2.3	0.34	0.055
NO_2^-	M	0.12	0.0063	0.0018
OH^-	M	1.1	0.007	$<10^{-4}$
$C_2O_4^=$	M	NM	NM	NM
H^+	M	NM	NM	NM
Fe^+	M	NM	NM	NM
Al^+	M	NM	NM	NM
Mn^+	M	NM	NM	NM
pH		12.8	12.1	9.8
Radiochemistry Analysis				
Gross α, d/m/ml		7.7×10^7	5.6×10^5	1.5×10^6
Gross β, γ, d/m/ml		1.8×10^8	3.1×10^8	6.0×10^7
Gross γ, d/m/ml		1.5×10^8	1.7×10^7	1.5×10^7
^{137}Cs mCi/ℓ of slurry		65	5.0	1.0
^{106}Ru mCi/ℓ of slurry		2.1	ND	0.6
^{144}Ce mCi/ℓ of slurry		2.2	1.6	4.6
^{154}Eu mCi/ℓ of slurry		0.6	0.2	0.2
^{95}Nb mCi/ℓ of slurry		ND	0.2	0.1
^{90}Sr mCi/ℓ of slurry		110	50	26
^{238}Pu mCi/ℓ of slurry		30	0.3	0.5
^{239}Pu mCi/ℓ of slurry		ND	ND	ND

TABLE 6 (contd)

SAMPLE ANALYSIS

Test Type	Acid Wash[a]					
Run No.	1	1A	1B	2	2A	2B
Riser No.	4	4	4	4	4	4
Tank volume sampled, gal	43,750	62,300	77,000	45,500	63,000	77,000
Heel volume, gal	-	-	5,500	-	-	2,800
Physical Properties						
Density, g/ml	1.00	1.00	1.00	1.00	1.00	1.00
Vol% solids	<1	<1	<1	<1	<1	<1
Chemical Analysis						
NO_3^- M	0.071	0.32	0.025	0.0076	0.0072	0.0060
NO_2^- M	NM	NM	NM	NM	NM	NM
OH^- M	NM	NM	NM	NM	NM	NM
$C_2O_4^=$ M	ND	0.088	0.051	0.0062	0.085	0.048
H^+ M	ND	0.16	0.029	NM	0.22	0.054
Fe^+ M	NM	NM	2.1×10^{-2} [b]	NM	NM	1.1×10^{-2}
Al^+ M	NM	NM	4.0×10^{-3} [b]	NM	NM	7.2×10^{-3}
Mn^+ M	NM	NM	9.9×10^{-3}	NM	NM	6.5×10^{-4}
pH	NM	NM	NM	NM	NM	NM
Radiochemistry Analysis						
Gross α, d/m/ml	2.2×10^4	9.5×10^5	4.8×10^5	3.5×10^4	4.5×10^5	3.1×10^5
Gross β,γ, d/m/ml	8.3×10^6	5.2×10^8	2.6×10^8	1.1×10^7	6.9×10^7	1.3×10^8
Gross γ, d/m/ml	2.9×10^5	1.5×10^6	2.4×10^6	3.3×10^5	4.2×10^5	6.1×10^5
^{137}Cs mCi/ℓ of slurry	0.13	0.5	0.6	0.15	0.19	0.27
^{106}Ru mCi/ℓ of slurry	ND	0.2	0.2	ND	ND	ND
^{144}Ce mCi/ℓ of slurry	ND	ND	0.3	ND	ND	ND
^{154}Eu mCi/ℓ of slurry	ND	ND	<0.1	ND	ND	ND
^{95}Nb mCi/ℓ of slurry	ND	ND	ND	ND	ND	ND
^{90}Sr mCi/ℓ of slurry	2.3	106	60	9	15	43
^{238}Pu mCi/ℓ of slurry	0.009	0.1	0.73	0.02	-	0.15
^{239}Pu mCi/ℓ of slurry	ND	ND	0.1	ND	ND	ND

TABLE 6 (contd)

SAMPLE ANALYSIS

Test Type	Acid Wash[a]			Water Rinse[c]		
Run No.	3	3A	3B	1	1A	1B
Riser No.	4	4	4	4	4	4
Tank volume sampled, gal	59,000	66,500	78,000	59,500	73,500	56,000
Heel volume, gal	-	-	3,675	-	-	1,000
Physical Properties						
Density, g/ml	1.02	1.02	1.02	1.00	1.00	1.00
Vol% solids	<1	<1	<1	<0.5	<0.5	<0.5
Chemical Analysis						
NO_3^- M	0.012	0.0045	0.0028	NM	NM	NM
NO_2^- M	NM	NM	NM	NM	NM	NM
OH^- M	NM	NM	NM	NM	NM	NM
C_2O_4 M	0.43	0.36	0.31	0.0061	0.0065	0.0057
H^+ M	0.82	0.63	0.49	NM	NM	NM
Fe^+ M	NM	NM	4.0×10^{-2}[b]	NM	NM	NM
Al^+ M	NM	NM	4.6×10^{-3}	NM	NM	NM
Mn^+ M	NM	NM	7.4×10^{-5}[b]	NM	NM	NM
pH	NM	NM	NM	NM	NM	NM
Radiochemistry Analysis						
Gross α, d/m/ml	1.57×10^5	3.4×10^5	6.2×10^5	1.78×10^5	1.22×10^5	8.4×10^4
Gross β, γ, d/m/ml	1.19×10^8	6.8×10^7	1.4×10^8	2.78×10^8	2.18×10^8	2.20×10^8
Gross γ, d/m/ml	3.7×10^5	5.5×10^5	6.2×10^5	5.11×10^5	1.78×10^5	2.0×10^5
^{137}Cs mCi/ℓ of slurry	0.052	0.075	0.10	0.23	0.08	0.09
^{106}Ru mCi/ℓ of slurry	0.032	0.045	0.07	ND	ND	ND
^{144}Ce mCi/ℓ of slurry	0.083	0.13	0.11	ND	ND	ND
^{154}Eu mCi/ℓ of slurry	ND	ND	ND	ND	ND	ND
^{95}Nb mCi/ℓ of slurry	ND	ND	ND	ND	ND	ND
^{90}Sr mCi/ℓ of slurry	16	40	64	40	38	31
^{238}Pu mCi/ℓ of slurry	ND	ND	0.24	0.04	0.016	0.025
^{239}Pu mCi/ℓ of slurry	ND	ND	ND	ND	ND	ND

TABLE 6 (contd)

NOTES:

a. For first acid wash:

Sample 1 was taken after spraying hot water into tank. Sample 1A was taken after acid was sprayed and 10 minutes of slurrying and sample 1B was taken prior to transferring the solution.

For the second and third acid washes:

Samples 2 and 3 were taken after the acid was sprayed and 10 minutes of slurrying, samples 2A and 3A were taken at an intermediate point in the test, and samples 2B and 3B were taken prior to transferring the solution.

b. Concentration in solution, not slurry

c. Sample 1 was taken after 10 minutes of slurrying, sample 1A was taken at intermediate point in the test and sample 1B was taken after 56,000 gallons of cold water was sprayed into the tank while transferring at a rate to keep the tank volume at 56,000 gallons.

N.M. - Not measured

N.D. - None detected

TABLE 7

TANK 16 COIL SAMPLE RADIATION

Sample Identification	Radiation Level @ 3cm, count/hr	Percent Activity Removed
After hydraulic slurry	174	-
After water washing	138	20.7
After acid cleaning	25	85.6

TABLE 8

ANALYSIS OF RESIDUE DEPOSITED AFTER WATER RINSE

Radioisotope	Concentration mCi/g
Sr^{90}	87
Cs^{137}	0.004
$Pu^{238, 239}$	0.006

NOTE: Based on a 0.082 gm sample obtained from a 3-inch diameter sample pan.

TABLE 9

HEAT BALANCE DATA

Test number and type	Heat transfer rate, Btu/hr.°C	Apparent soil temperature, °C	Maximum liquid temperature (°C) during slurrying	Rate of change in liquid temperature, °C/hr
Third Multipump	17,580	13.5	44	0.19
First Water wash	19,440	28.0	53	-0.08
Second Water wash	-	-	56	-0.11
First Acid wash	10,800	15.7	66	0.09
Second Acid wash	10,980	12.5	59	0.17
Third Acid wash	9,460	16.2	62	0.10
Water rinse	-	-	65	0.12

\- Data inconsistent

TABLE 10

CURIES BALANCE DATA

Type Test		Multipump	Water Wash		Acid Wash			Water*
Test Number		3	1	2	1	2	3	Rinse
Curies in liquid prior to transfer	Cs^{137}	21,938	1,750	350	178	80	30	22.6
	Sr^{90}	37,125	17,500	9,100	17,769	12,735	19,200	10,742
Curies removed by transfer	Cs^{137}	20,625	1,548	337	170	77	29	22.3
	Sr^{90}	34,904	15,481	8,750	16,961	12,272	18,295	10,596
Curies remaining in heel	Cs^{137}	1,313	202	13	8	3	1	0.3
	Sr^{90}	2,271	2,019	350	808	463	905	146
Curies washed down by spraying	Cs^{137}	-	437.5	148	165	72	27	21.6
	Sr^{90}	-	15,279	7,081	17,419	11,927	18,737	9,837

* Curies of Cs^{137} and Sr^{90} calculated from water rinse sample 1A. (See Table 6, Note c.)

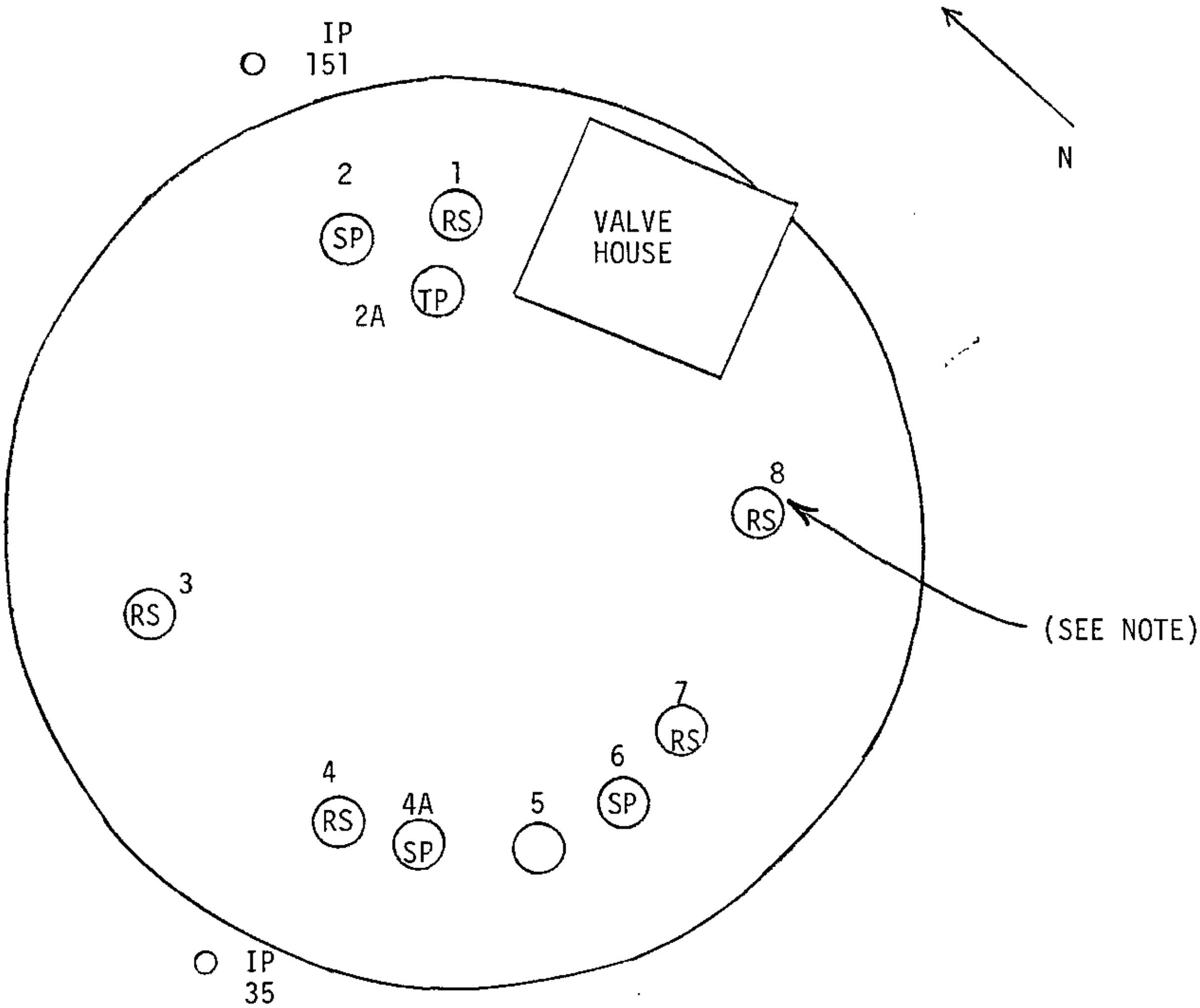
TABLE 11

TANK 16 PUMP OPERATING DATA

Test Type	Multipump	Water Wash		Acid Wash			Water Rinse
Test Number	3	1	2	1	2	3	
SLURRY PUMPS							
Amps	140-165	112-125	82-120	90-120	95-120	95-115	105-115
Volts	445-495	395-500	395-500	415-480	410-480	410-450	440-475
RPM	1800	1800	1800	1800	1800	1800	1800
Delivered Hp	130-138	105	77-100	71-104	74-99	73-97	86-98
Avg. sealwater Leak rate, gpm	1.5	2.0	1.9	2.3	2.0	2.0	2.3
Max. sealwater pressure, psig	27	27	20	25	22	20	20
TRANSFER PUMP							
Bearing water rate, gpm	1.0	1.7	1.5	1.8	2.0	2.2	3.0
Avg. transfer rate, gpm	65	70.5	70.4	70.0	75	143	1.06
Operating time, hrs	20.7	19.5	24.7	19.1	18.4	9.0	30.7
Heel volume, gals	5,250	10,800	3,500	3,500	2800	3675	~1000

FIGURE 1

TANK 16 EQUIPMENT ARRANGEMENT



RS	Rotary Spray Jet
SP	Slurry Pump
TP	Transfer Pump

Note: Rotary Spray (RS) in riser 8 was removed and slurry pump in riser 6 was moved to riser 8 during the final water rinse.

FIGURE 2

RADIATION PROFILES
(RISER 4)

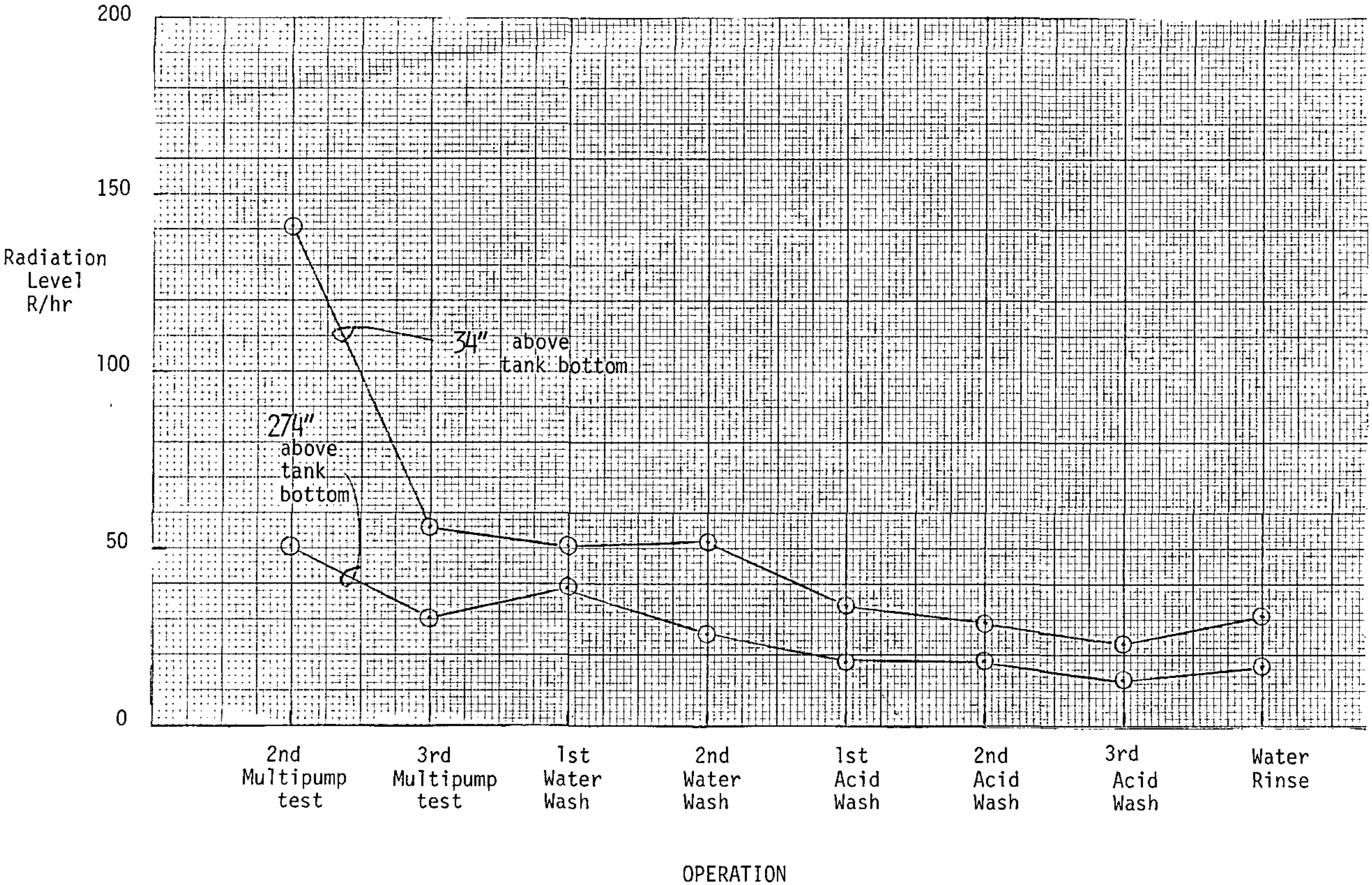


FIGURE 3

Point	Event
A	58,188 gallons of tank 22 supernate transferred to tank 16
B	Riser 2, 4A and 6 slurry pumps started
C	Riser 2 slurry pump stopped
D	Slurry samples taken after 67 hours of slurrying
E	Transferred 80,973 gallons of slurry to tank 21
F	Riser 4A and 6 slurry pumps stopped

FIGURE 3
Temperature Versus Time
Final Multipump Test

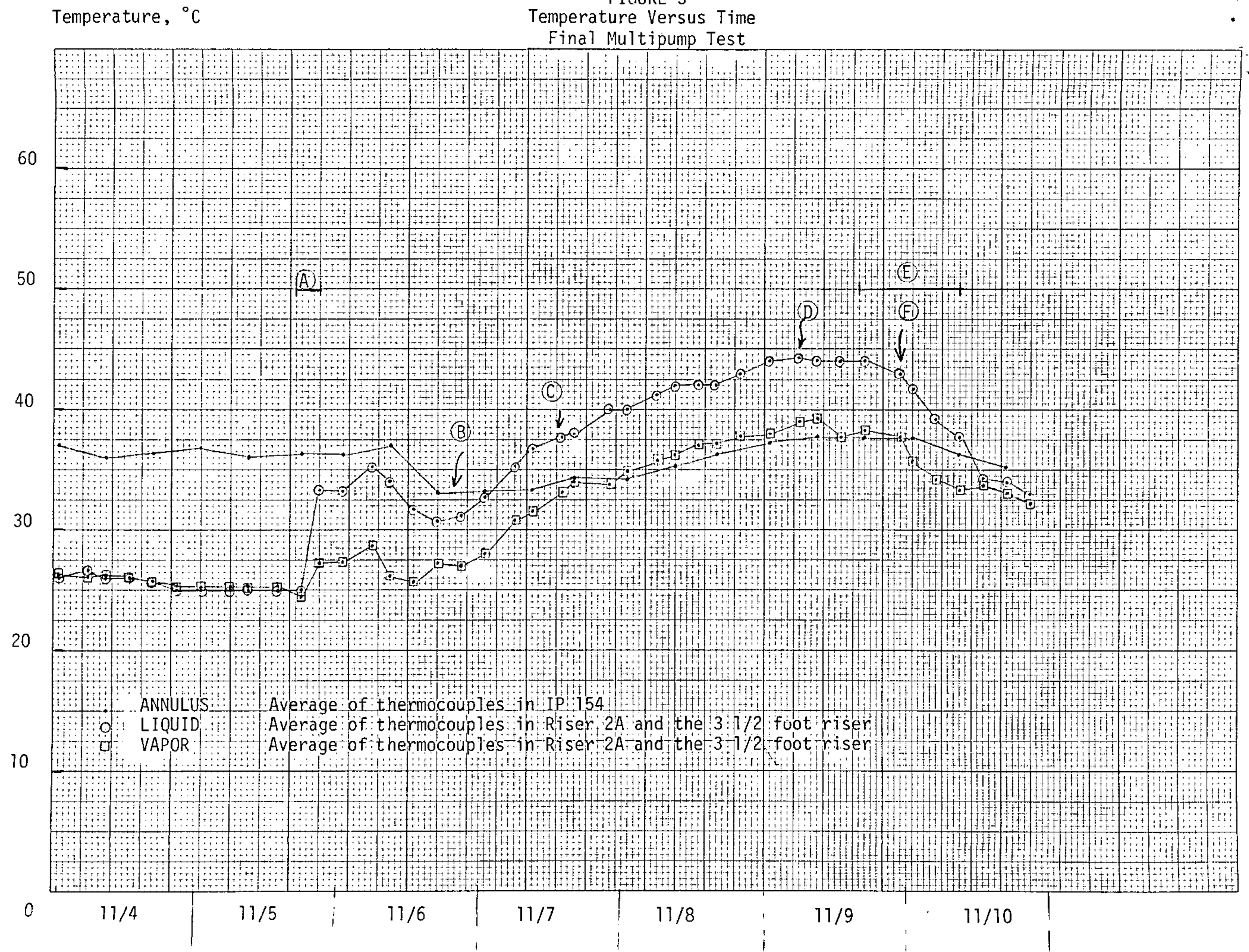


FIGURE 4

Point	Event
A	Spraying from rotary spray in riser 1
B	Spraying from rotary spray in riser 4
C	Spraying from rotary spray in riser 7
D	Spraying from rotary spray in riser 8 (interrupted)
E	Spraying from rotary spray in riser 3
F	Riser 2, 4A and 6 slurry pumps started
G	20 hour slurry sample taken
H	Riser 6 slurry pump stopped
I	Riser 2 and 4A slurry pump stopped
J	67 hour slurry sample taken
K	Riser 2 slurry pump started
L	Transferred 82,483 gallons of slurry to tank 21
M	Riser 4A slurry pump started
N	Riser 2 and 4A slurry pump stopped

FIGURE 4
TEMPERATURE VERSUS TIME
FIRST WATER WASH TEST

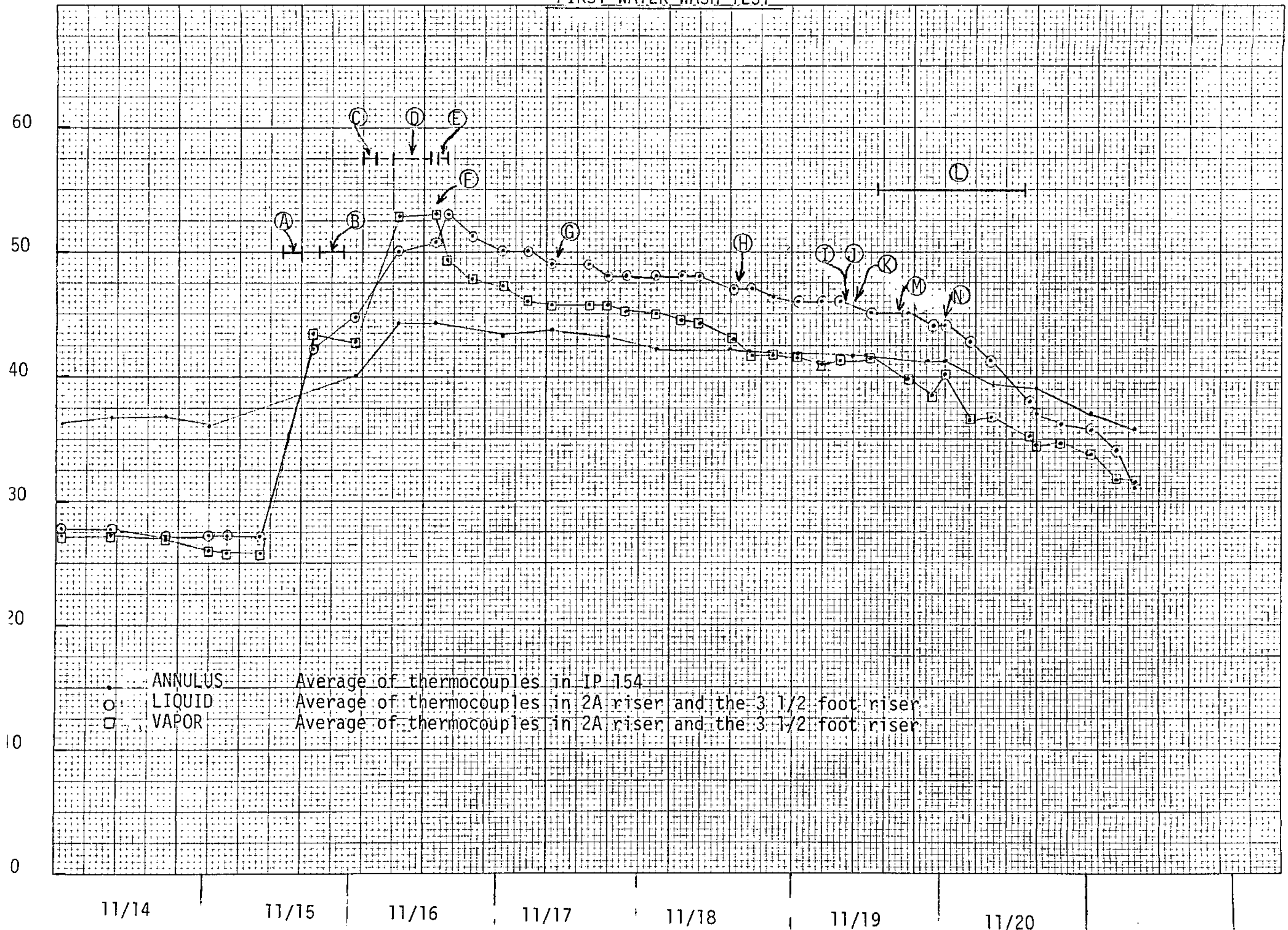


FIGURE 5

Point	Event
A	Spraying from rotary spray in riser 1
B	Spraying from rotary spray in riser 4
C	Spraying from rotary spray in riser 7
D	Spraying from rotary spray in riser 8
E	Riser 2, 4A and 6 slurry pump started
F	Spraying from rotary spray in riser 3
G	Riser 4A slurry pump stopped
H	Riser 4A slurry pump started
I	58 hour slurry sample taken
J	Riser 2, 4A and 6 slurry pumps stopped
K	Transfer of slurry to tank 21 (stopped because of a possible transfer line leak)
L	Transfer of slurry to tank 21 (both transfers 104,478 gallons)

FIGURE 5
TEMPERATURE VERSUS TIME
SECOND WATER WASH TEST

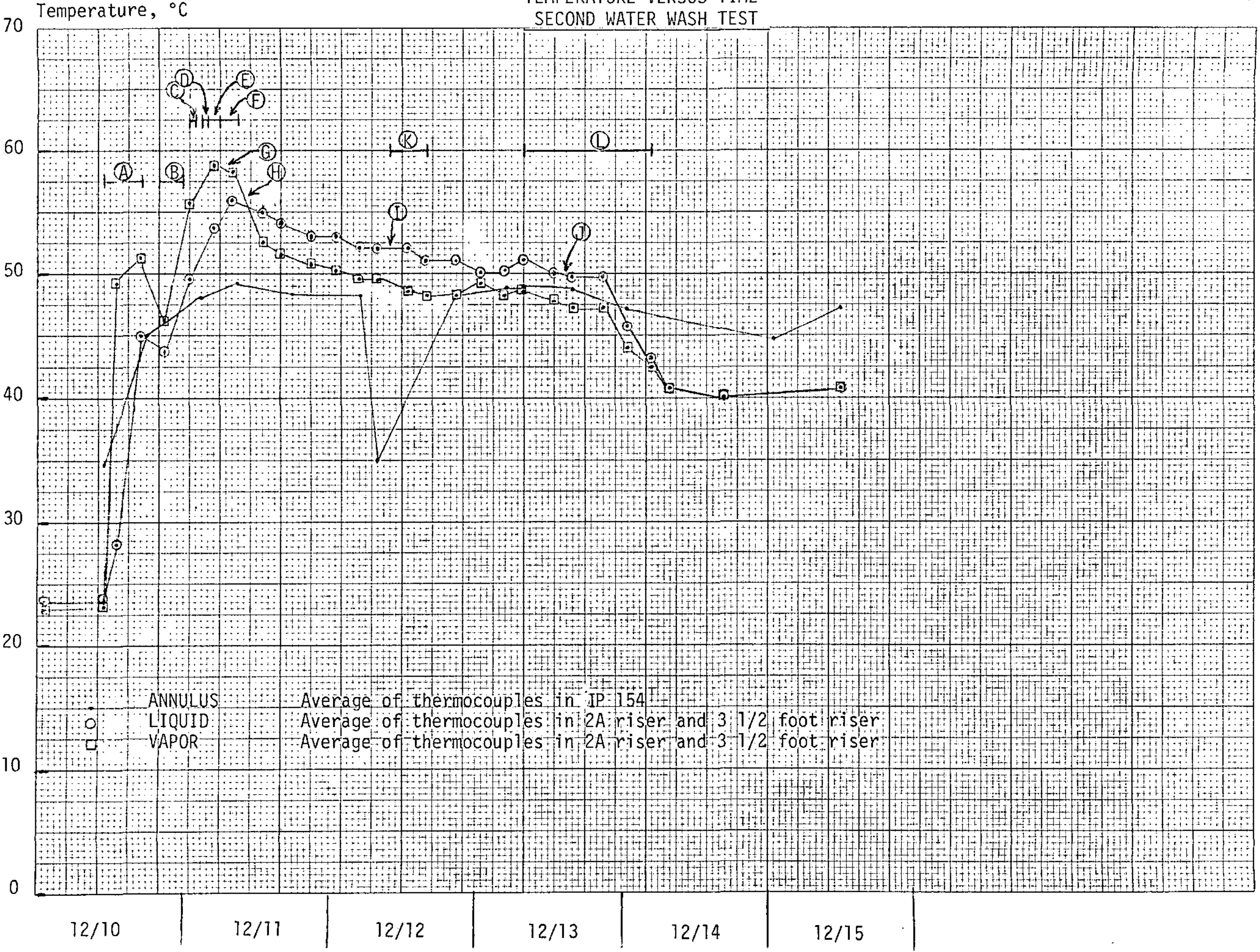


FIGURE 6

Point	Event
A	Spraying from rotary sprays in risers 1, 4, 7, 3 and 8
B	Slurry sample taken
C	12,611 gallons of 4% acid added in riser 3
D	Slurry pumps in risers 2, 4A, and 6 started
E	10-minute slurry sample taken
F	Slurry pump in riser 6 stopped
G	Slurry pump in riser 6 started
H	42-hour slurry sample taken
I	Slurry pumps in risers 2,4A, and 6 stopped
J	Transferred 80,150 gallons of solution to tank 21

FIGURE 6
TEMPERATURE VERSUS TIME
FIRST ACID WASH

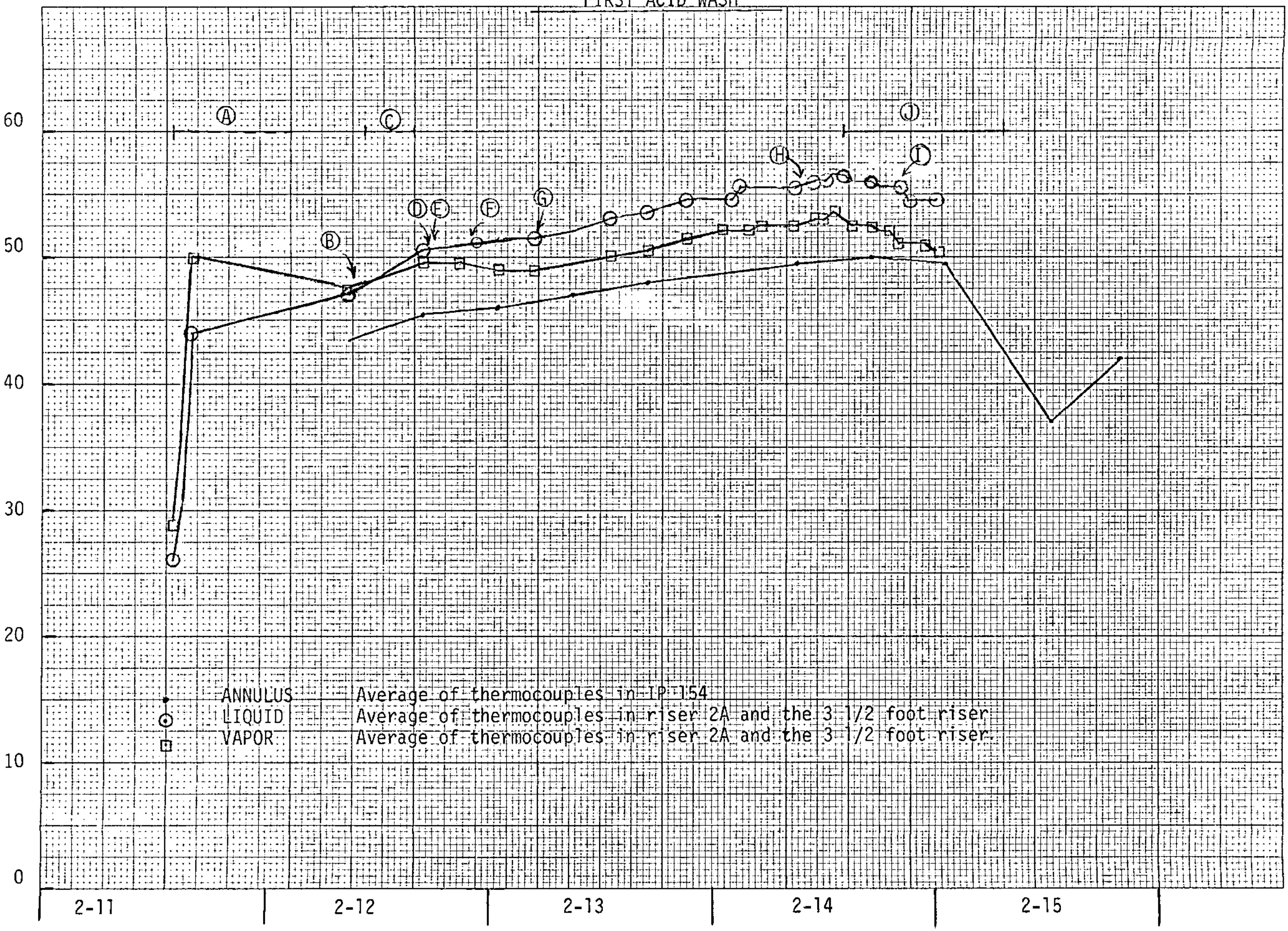


FIGURE 7

Point	Event
A	Spraying from rotary spray in riser 1
B	Spraying from rotary spray in riser 4
C	Spraying from rotary spray in riser 7
D	Spraying from rotary spray in riser 8
E	Spraying from rotary spray in riser 3
F	Spraying from rotary spray in riser 1
G	Spraying from rotary spray in riser 8
H	10 minute slurry sample taken
I	Slurry pumps started in risers 2, 4A, and 6
J	24 hour slurry sample taken
K	42 hour slurry sample taken
L	Slurry pumps stopped in risers 2, 4A, and 6
M	Transferred 82,768 gallons of solution to tank 21

FIGURE 7
TEMPERATURE VERSUS TIME
SECOND ACID WASH

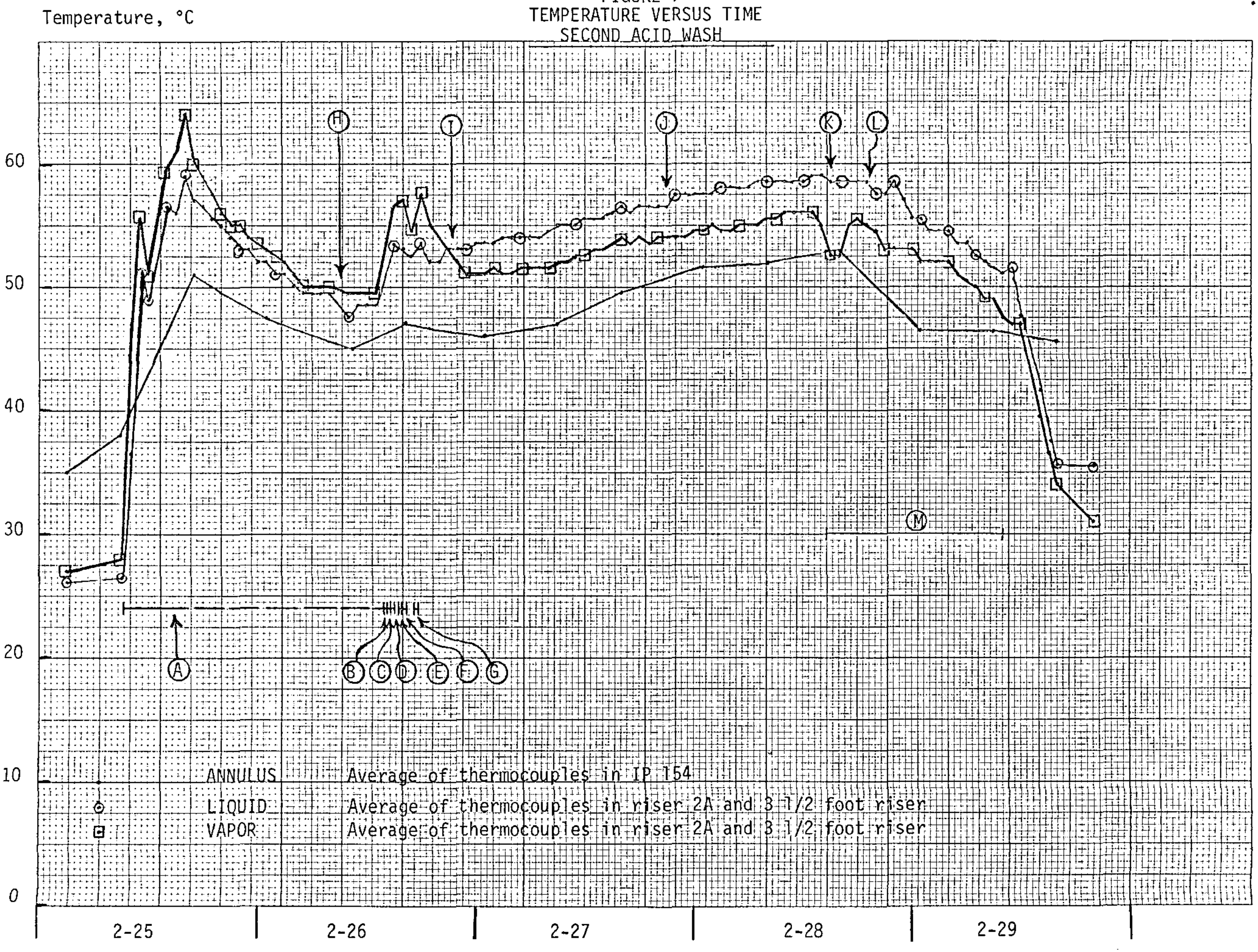


FIGURE 8

Point	Event
A	Spraying from rotary spray in riser 1
B	Spraying from rotary spray in riser 4
C	Spraying from rotary spray in riser 7
D	Spraying from rotary spray in riser 3
E	Spraying from rotary spray in riser 8
F	Spraying from rotary spray in riser 1
G	Slurry pumps started in risers 2, 4A, and 6
H	35 minutes slurry sample taken
I	24 hour slurry sample taken
J	44 hour slurry sample taken
K	Slurry pumps stopped in risers 2, 4A, and 6
L	Transferred 77,300 gallons of solution to tank 22

FIGURE 8
TEMPERATURE VERSUS TIME
THIRD ACID WASH

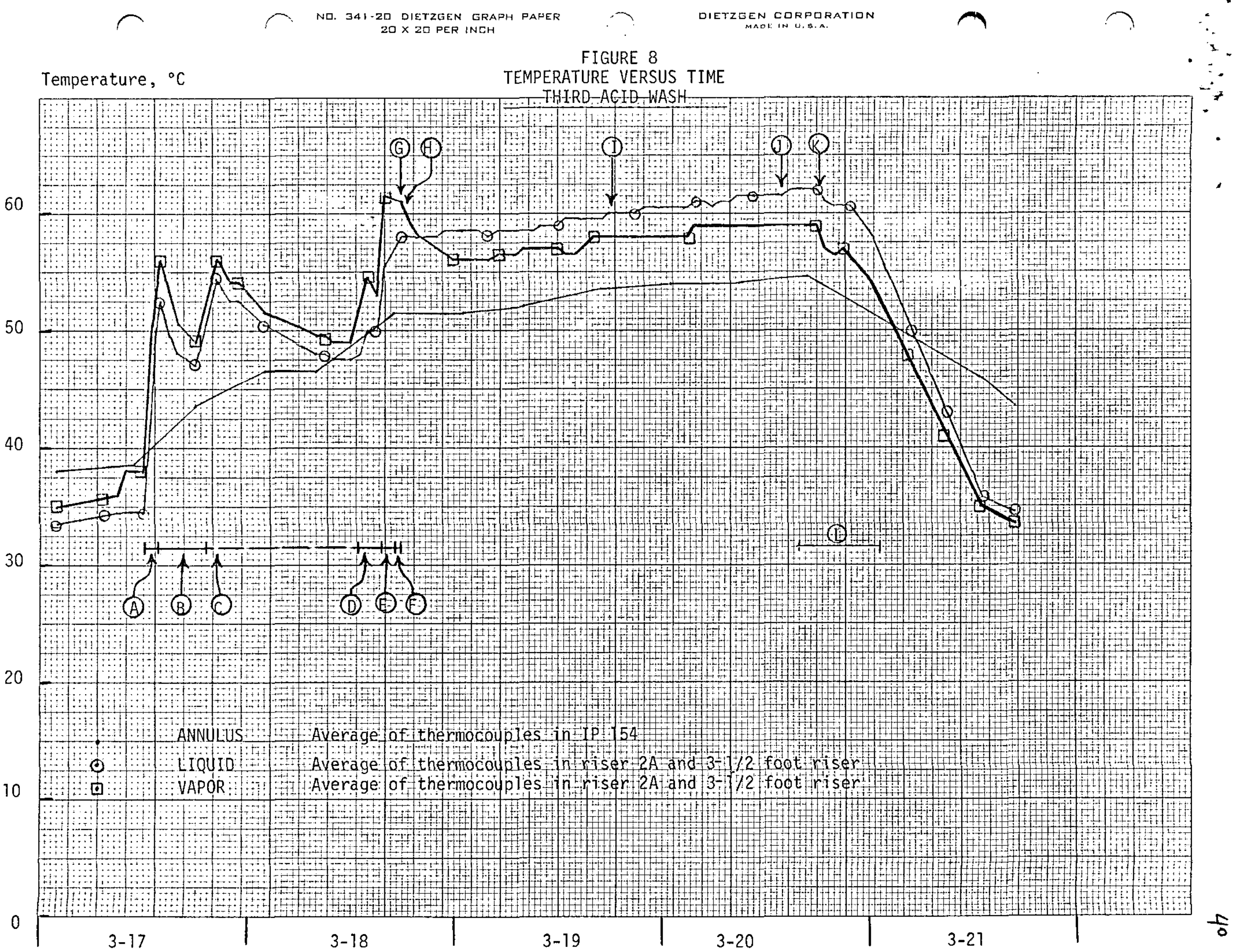


FIGURE 9

Point	Event
A	Spraying from rotary spray in riser 8
B	Slurry pump moved from riser 6 to riser 8
C	Spraying from rotary spray in riser 4
D	Spraying from rotary spray in riser 7
E	Spraying from rotary spray in riser 3
F	Spraying from rotary spray in riser 1
G	Slurry pumps started in risers 4A, and 8
H	10 minute slurry sample taken
I	Slurry pump stopped in riser 8
J	Slurry pump started in riser 8
K	Slurry pump stopped in riser 4A
L	Slurry pump stopped in riser 8
M	42 hour slurry sample taken
N	Slurry pumps started in risers 2, and 8
O	Slurry pump started in riser 4A
P	Transferred 195,038 gallons of slurry to tank 15 (Transfer interrupted due to HPT-4 pump problems)
Q	Spraying from rotary spray in riser 4
R	Spraying from rotary spray in riser 7
S	Spraying from rotary spray in riser 3
T	Spraying from rotary spray in riser 1
U	153 hour slurry sample was taken
V	Slurry pumps stopped in risers 2, 4A, and 8

FIGURE 9
TEMPERATURE VERSUS TIME
WATER RINSE

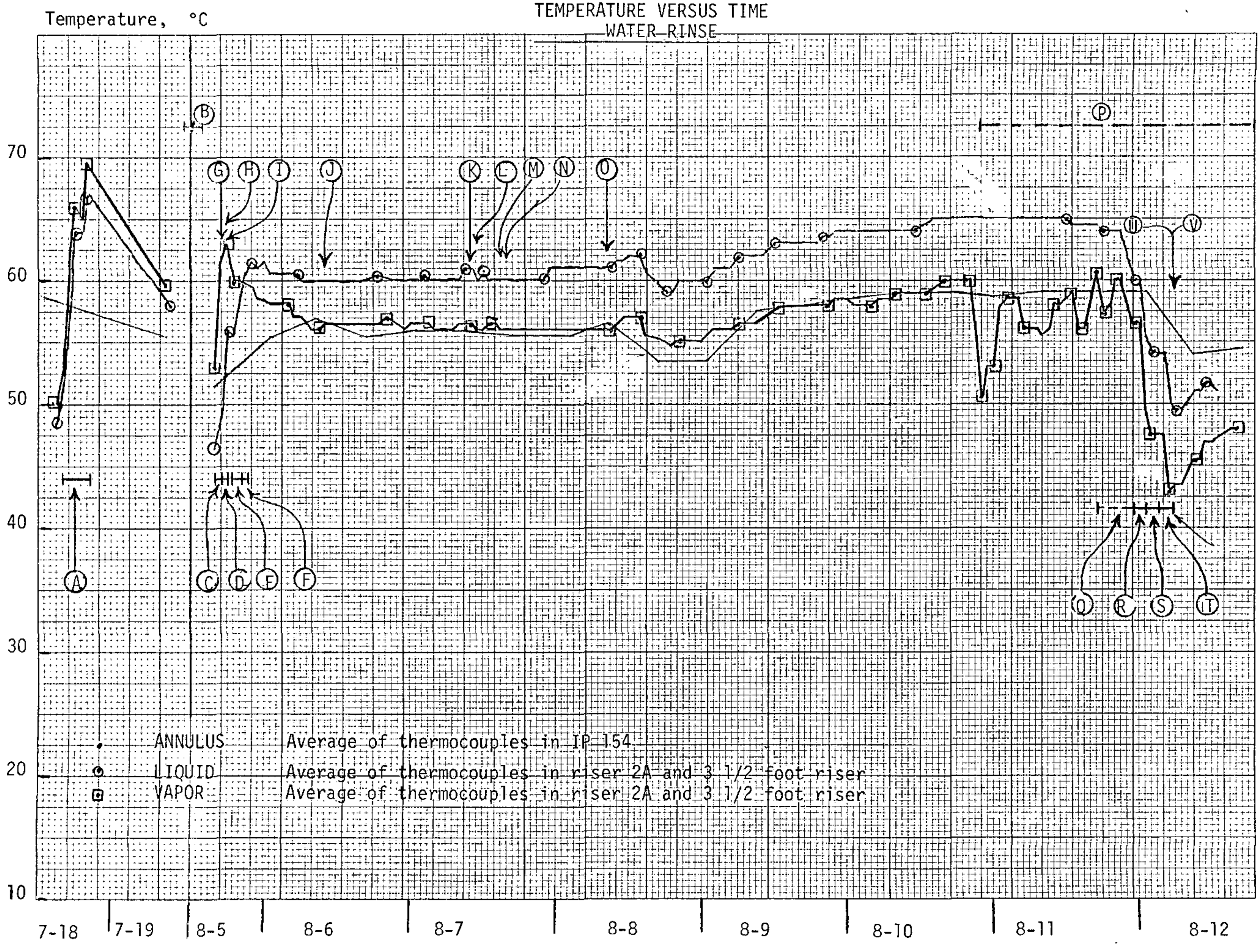


FIGURE 10

CURIES IN LIQUID PRIOR TO TRANSFER

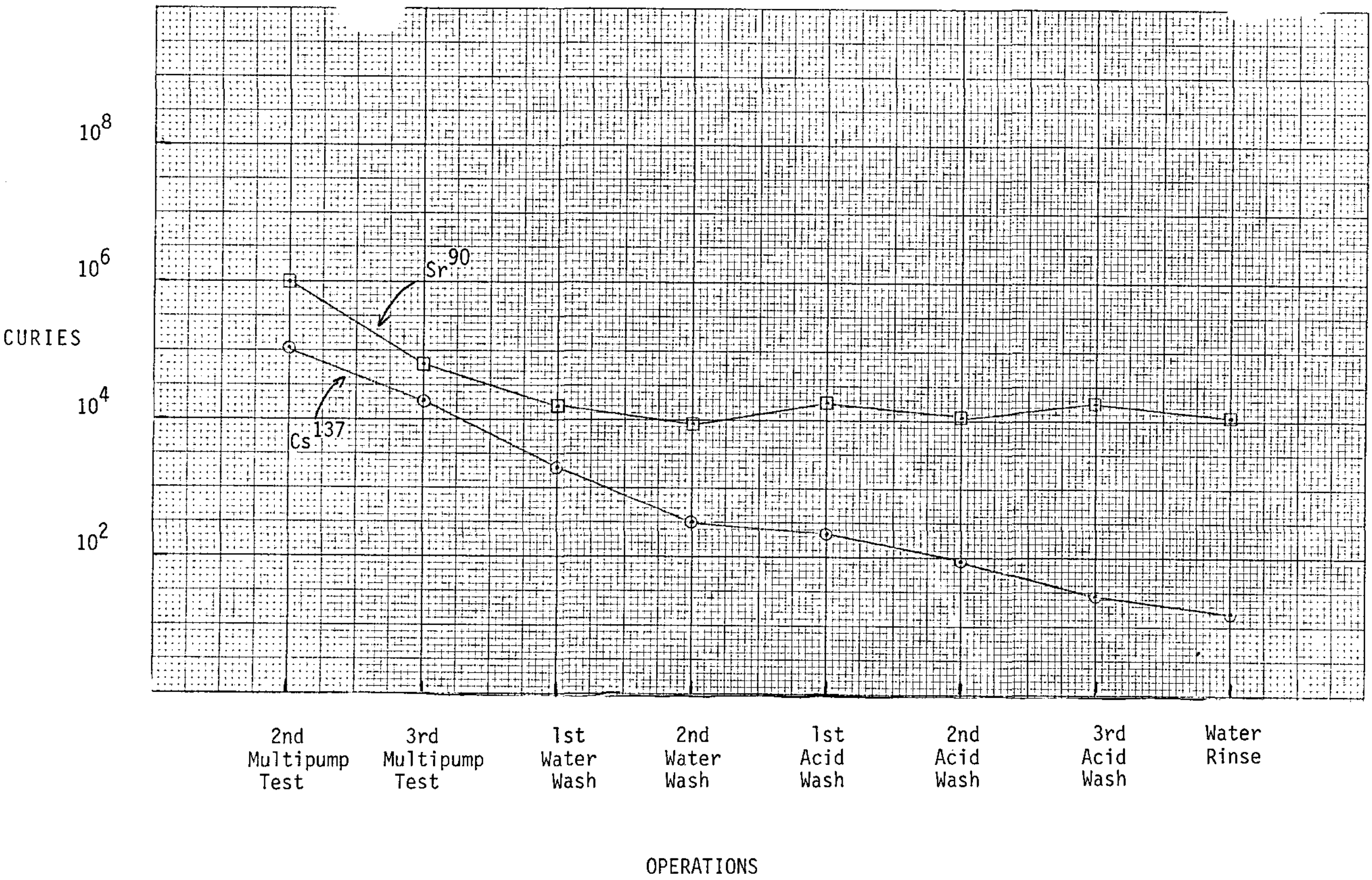


FIGURE 11

TANK 16-MODIFIED VENTILATION SYSTEM

(SEE SSK-5-2-3424)

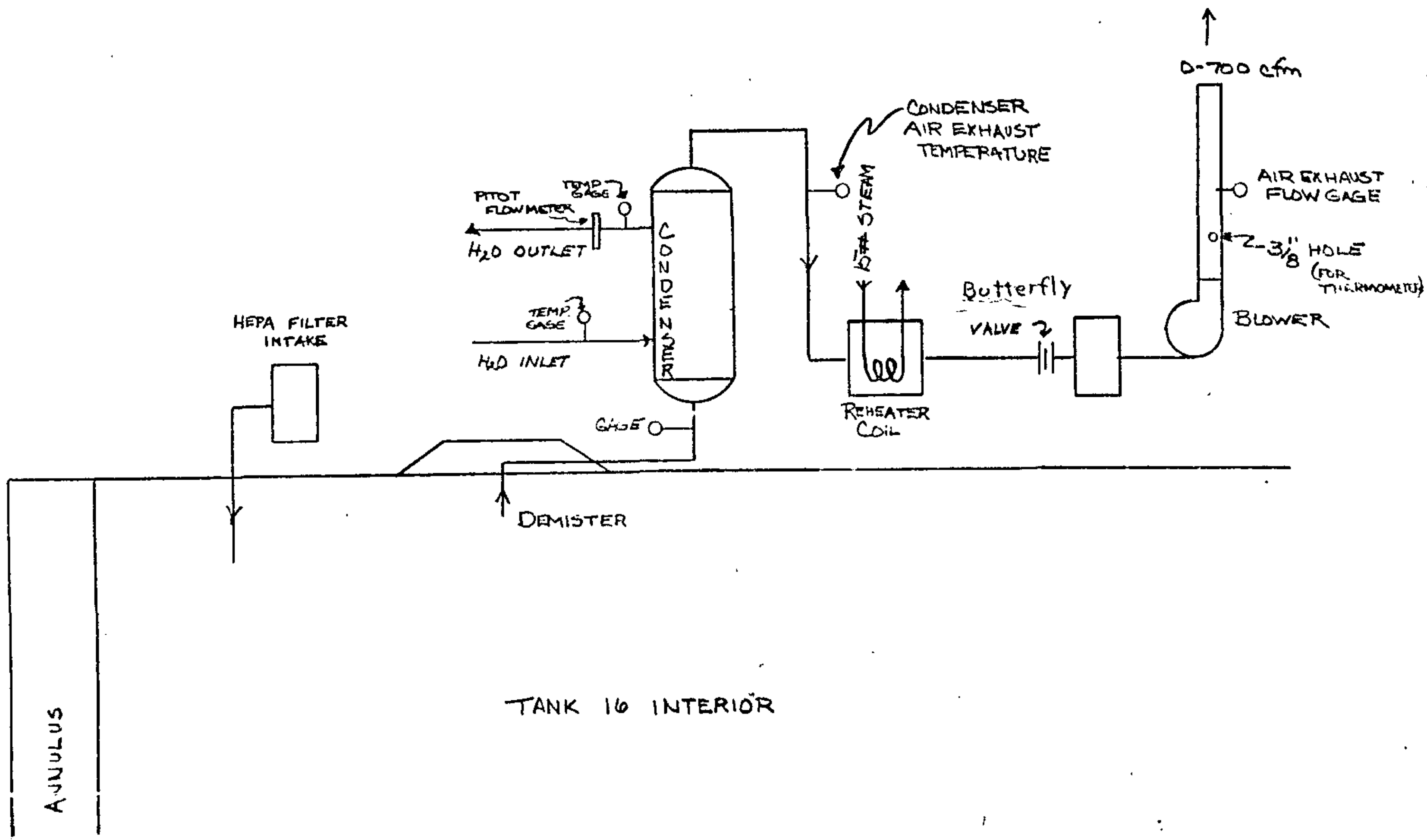


FIGURE 12
TANK VAPOR CONDITIONS
DURING FIRST WATER WASH

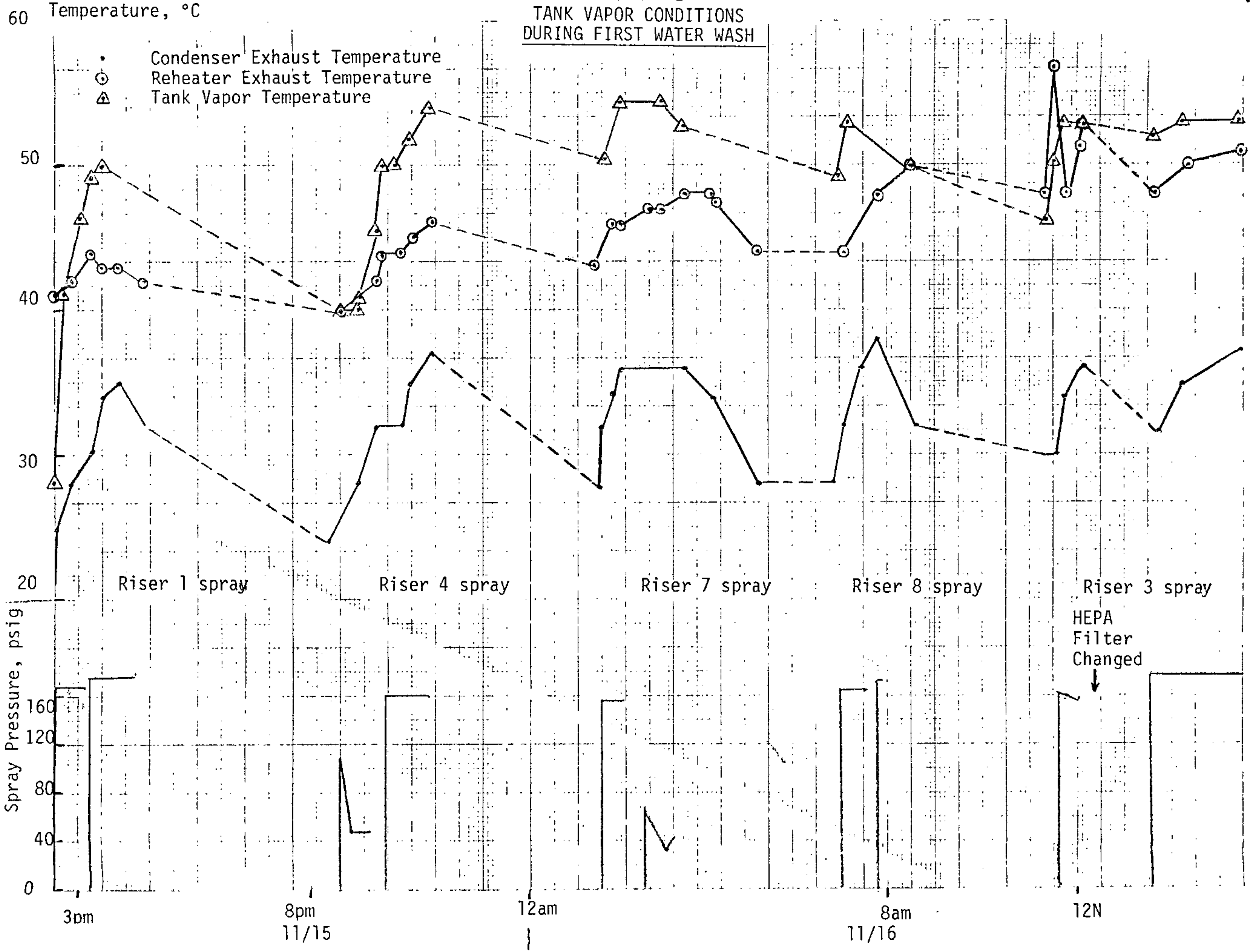


FIGURE 13
Tank Vapor Conditions
During Second Water Wash

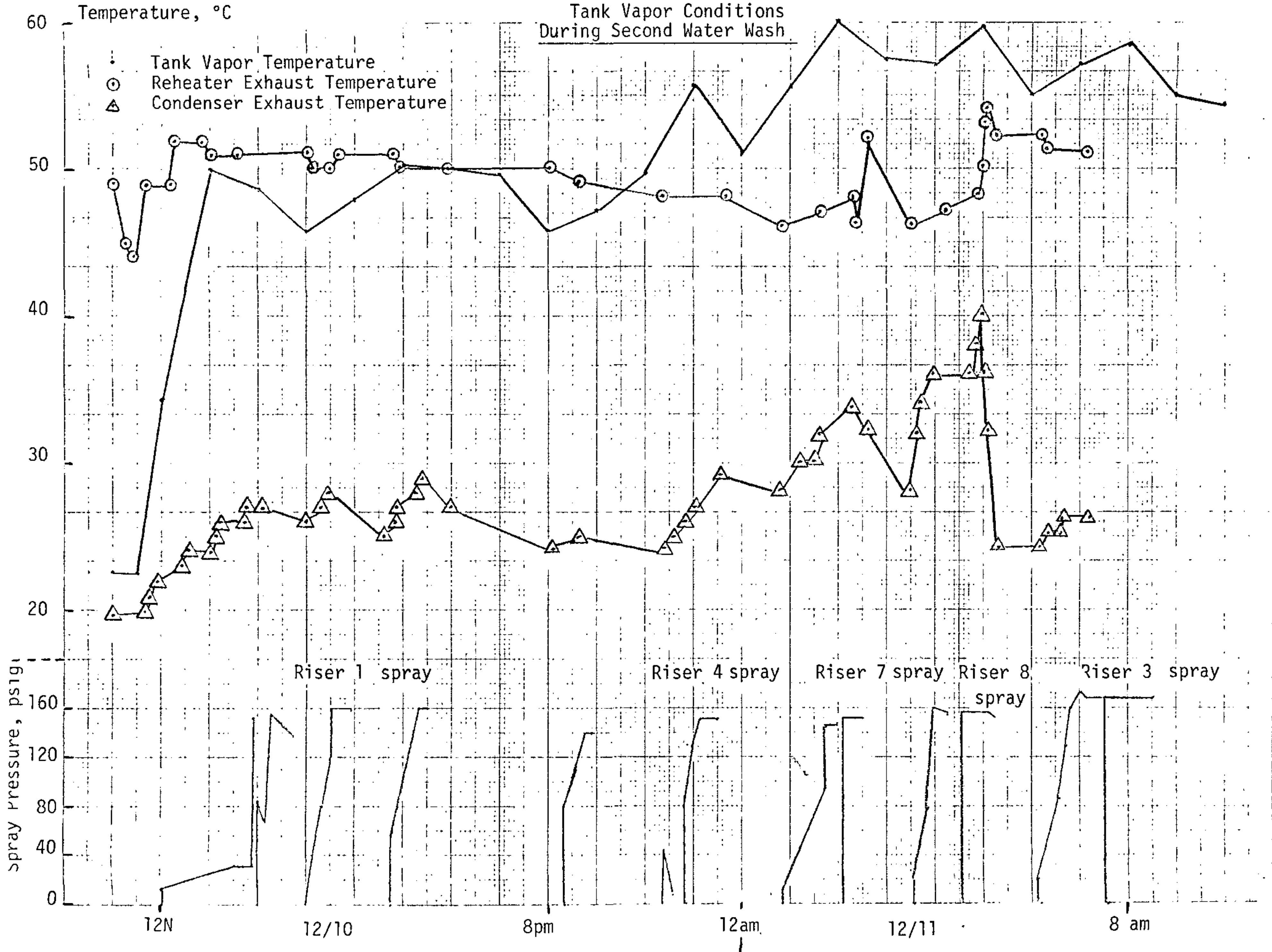


FIGURE 14

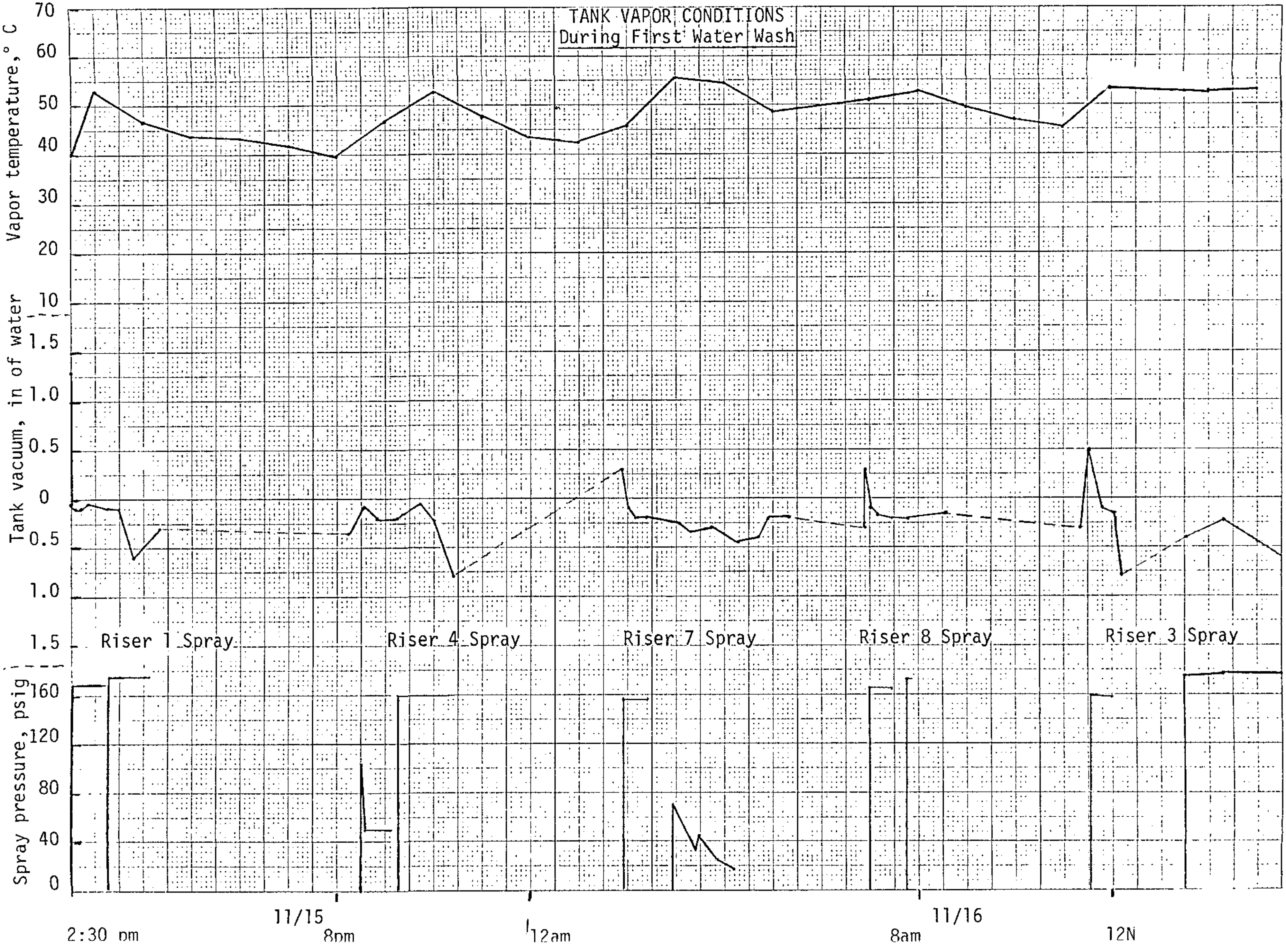

TANK VAPOR CONDITIONS
During First Water Wash
Vapor temperature, ° C
70
60
50
40
30
20
10
Tank vacuum, in of water
1.5
1.0
0.5
0
0.5
1.0
1.5
Riser 1 Spray
Riser 4 Spray
Riser 7 Spray
Riser 8 Spray
Riser 3 Spray
Spray pressure, psig
160
120
80
40
0
2:30 pm
11/15
8pm
12am
11/16
8am
12N

FIGURE 15
TANK VAPOR CONDITIONS
DURING SECOND WATER WASH

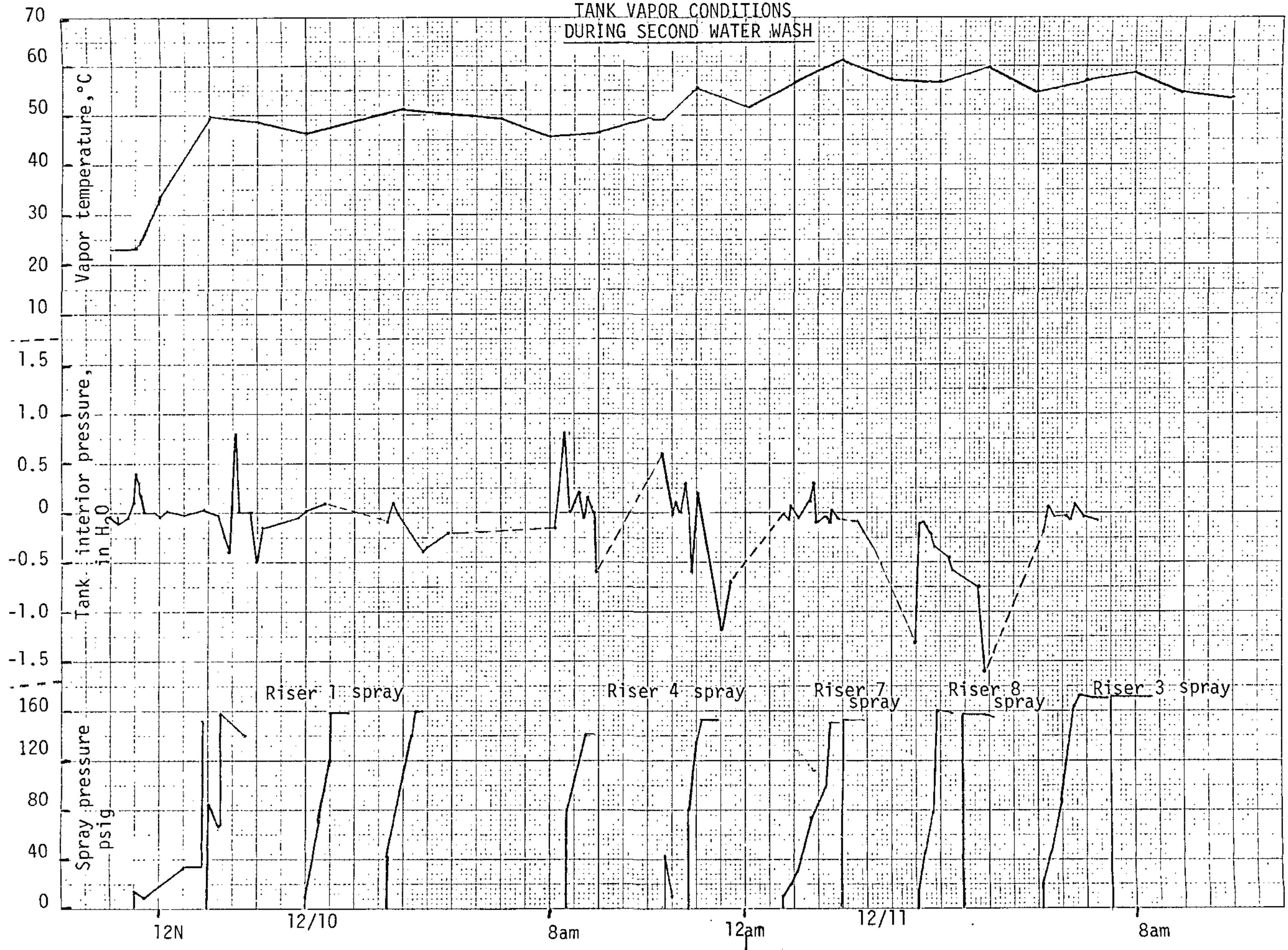


FIGURE 16
GROUNDWATER ACTIVITY-Cs^{137}
(Based on samples from HP well below construction pad for tanks 13-16)

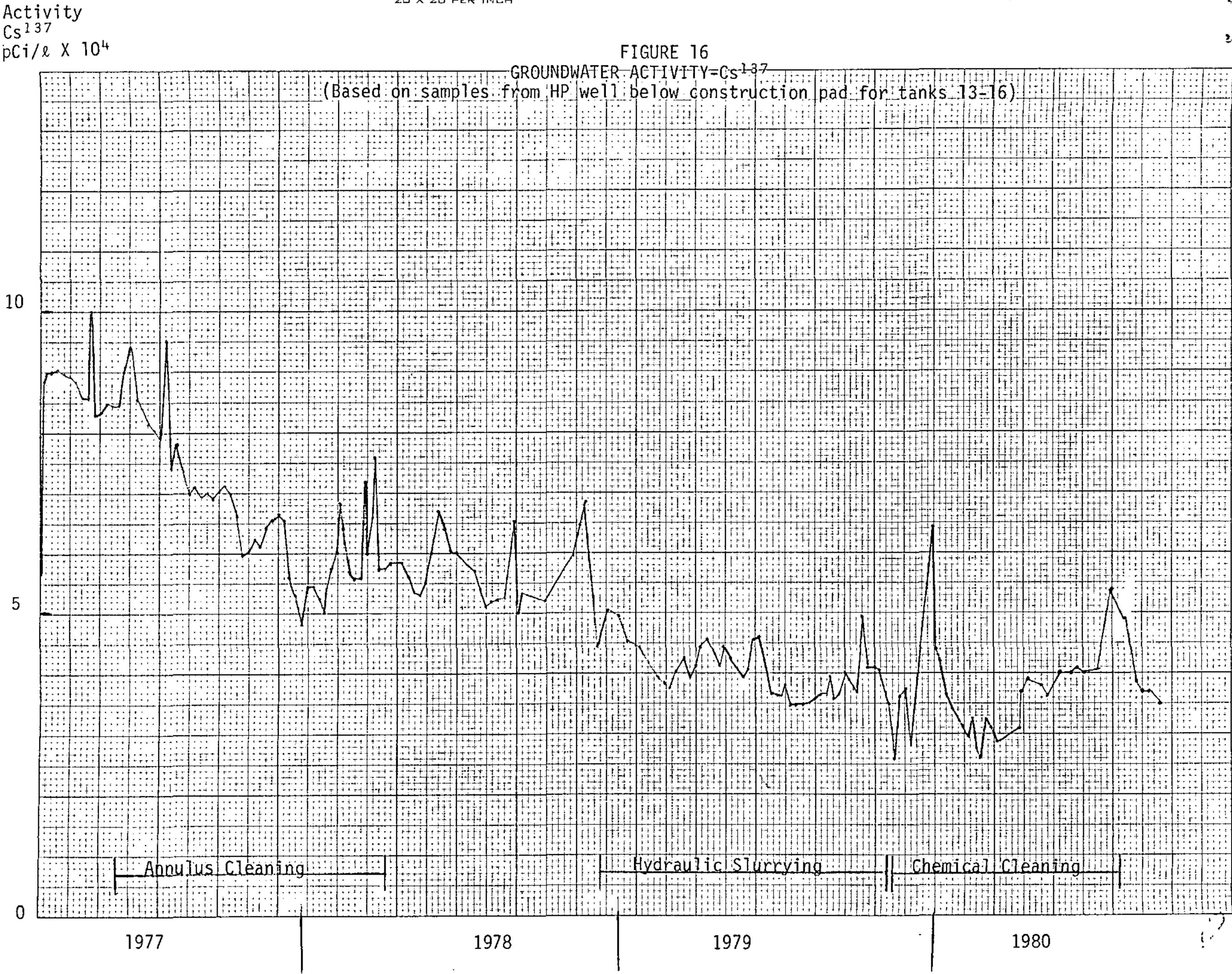
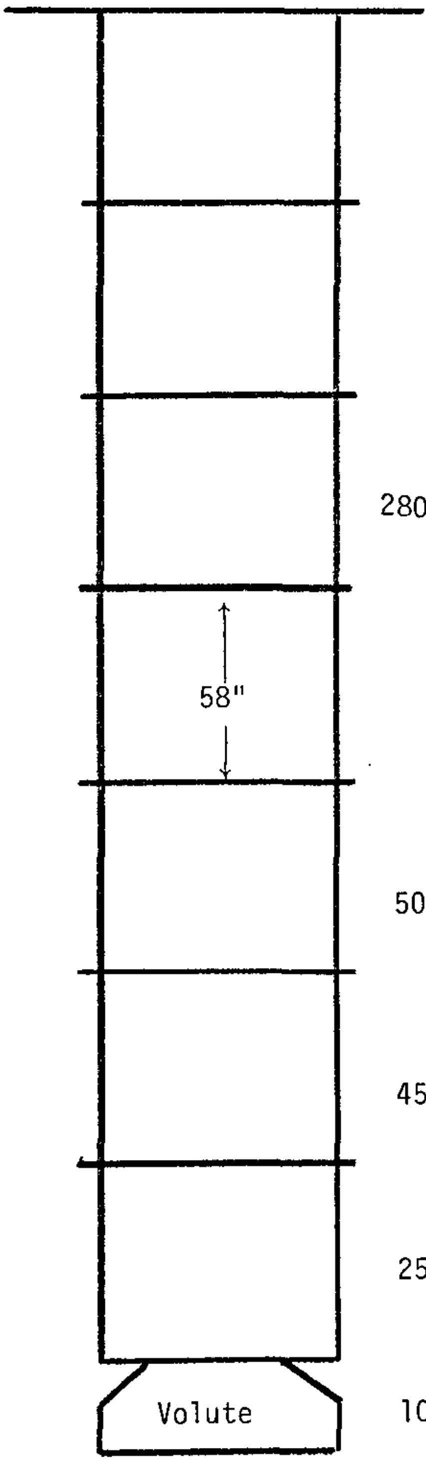


FIGURE 17

SLURRY PUMP SURVEYS



Smearable Contamination mRad/hr: After Water Washes	Smearable Contamination mRad/hr: After Acid Washes	Radiation mRad/mR per hr. @ 5cm: After Water Washes	Radiation mRad/mR per hr. @ 5cm: After Acid Washes[a]
40	15	<5/<5	20/20
100-200	500	200/5[b]	50/10
200-2000	1	2800-800/100-150	40/10
80-1400	2	10,000/30[b]	30/10
400-1000	2	5000-8000/25[b]	30/10
100-1500	2	4500-8000/-	20/5
80-100	200	2500-4000/-	3000/10
1500-4000 (Volute)	3000	10,000-25,000/200-80[b]	100,000/500

NOTE: a. Volute was not flushed prior to surveying pump. The volute was flushed in earlier surveys.

b. Gamma exposure at 12 inches.

\- Not measured.