RPP-ASMT-39155
Revision 0

Tank 241-C-111
Leak Assessment Report

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EXECUTIVE SUMMARY

Tank 241-C-111 is a 530,000 gallon capacity, 75-foot diameter, mild steel-lined concrete shell tank located at the northwest perimeter of the 16-tank C Tank Farm. The tank was placed in service in August, 1946, and continued to receive and store waste until the second quarter of CY 1975 when it was removed from service. At that time, the tank was classified as a "Questionable Integrity" tank.

Between October 1, 1965 and December 26, 1969 there was an unexplained 8.5 in surface level decrease in the tank, equivalent to a 23,400 gallon loss. In 1968 the tank was declared to be a "Questionable Integrity" tank. During the fourth quarter of 1969, 350,000 gallons of supernatant were removed from the tank. No further liquid level decreases were reported once the transfer was made, and the liquid level appears to have remained stable until tank C-111 received catch tank waste in the second quarter of CY 1972.

Four independent teams reviewed the 1965 – 1969 data between June, 1980 – April, 1981 as part of a coordinated review of six single-shell tanks classified as "Questionable Integrity" tanks. Three of the four teams recommended that the tank C-111 leak integrity status be changed from "Questionable Integrity" to "Confirmed Leaker"; the fourth team recommended that the existing Questionable Integrity classification be retained. According to the ground rules in effect, the teams' recommendations had to be unanimous to change the Questionable Integrity classification to "Confirmed Leaker".

In 1984 the "Questionable Integrity" and "Confirmed Leaker" tank classifications were combined and changed to "Assumed Leaker". A leak volume estimate was not made until 1989, when a 5,500 gallon volume was assigned.

In 2007 tank C-111 was again reviewed for purposes of retrieval technology selection and closure. Process history records that had not been reviewed during the 1981 evaluation identified exceptions to the earlier data set. If the records had been available during the earlier review, they would have possibly altered the teams' recommendation:

- During the period immediately before the liquid level decrease began, tank C-111 was not receiving low-level waste as the 1981 evaluation believed. Records show that from July, 1962 through June, 1964, tank C-111 received 194,000 gallons of strontium purification waste from the Hot Semiworks facility. Records show that the waste from the purification process would have contained approximately 6.4 megacuries of ^{144}Ce, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964.

- The tank bulk solution temperature was not 100^{o}F as the 1981 evaluation believed. Between January, 1963 and September, 1964 the tank's bulk waste temperature increased from 80^{o}F to 190^{o}F as the strontium purification waste heated the tank.

Between 1975 and 1994 the five drywells surrounding tank C-111, and nearby drywells, were routinely monitored for gross gamma ray soil contamination that would indicate a tank leak. None of the drywells showed evidence of a tank leak during the surveillance period. Spectral Gamma analyses completed during February and March, 1997 confirmed the earlier results.

The leak assessment used a panel of experienced CH2M HILL Hanford Group, Inc. engineers and managers to review the tank 241-C-110 historical data and re-evaluate the basis for declaring the tank an “Assumed Leaker”. The panel consisted of: D. J. Washenfelder, (Assessment Coordinator, Technical Integration Program Manager); D. G. Baide, (West Systems Engineering Manger); D. A. Barnes, (Surveillance System Engineer, in-tank and ex-tank surveillance); D. W. Brown (C Tank Farm Maintenance and Facility Operations Manager); L. S. Krogsrud (C Tank Farm Single-Shell Waste Tank System Engineer); and P. C. Miller (Environmental Support and Assessment Program Manager).

Based on review of the in-tank and ex-tank data, the panel developed plausible hypotheses for the observed tank behavior:

Leak Hypothesis:

“The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak).”

Non-Leak Hypothesis:

“The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F.”

The team concluded that the most probable explanation for the 1965 – 1969 surface level decrease in tank C-111 was evaporation of the thermally hot waste. Calculations showed that a passive breathing rate of about 2.3 cubic feet per minute of 190^{o}F saturated air would account for the loss, when combined with the thermal contraction as the waste began to cool during the latter part of the 1965 – 1969 period. The 2.3 cubic feet per minute passive breathing rate is small compared to single-shell tank passive breathing rates measured during the 1990’s.

The consensus of the assessment team is that the 8.5 inch surface level decrease observed during the 1965 – 1969 time period was the result of evaporation and thermal contraction, and that tank C-111 did not leak.

The recommendation of the assessment team is that the tank C-111 leak integrity status be revised from “Assumed Leaker” to “Sound”.

The results of this assessment were presented to the Executive Safety Review Board on September 11, 2008. The Board accepted the recommendation of the assessment team.

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Abbreviations and Acronyms

DOE-GJO	U.S. Department of Energy Grand Junction Office
DOE-RL	U.S. Department of Energy Richland Operations Office
QI	Questionable Integrity
SGLS	Spectral Gamma Logging System
SL	surface level
SHMS	Standard Hydrogen Monitoring System
SST	single-shell tank
UOR	Unusual Occurrence Report

Units

cfm	cubic feet per minute
Ci	curie
ft	foot
gal	gallon
in	inch
kgal	kilogallon (1,000 gallons)
MCi	megacurie (1,000,000 curies)

1.0 INTRODUCTION

This document provides the results of a formal leak assessment performed on tank 241-C-111 (tank C-111). The leak assessment process is described in Engineering Procedure TFC-ENG-CHEM-D-42, Rev. A-1, *Tank Leak Assessment Process*. The commitment for a formal tank C-111 leak assessment was made by reference in Letter 08-TPD-015, S. J. Olinger, Office of River Protection to J. A. Hedges, State of Washington Department of Ecology, "Hanford C Farm Leak Assessments," April 9, 2008.

Tank 241-C-111 is a 530,000 gallon capacity, 75-foot diameter, mild steel-lined concrete shell tank located at the northwest perimeter of the 16-tank C Tank Farm. The tank was placed in service in August 1996, and continued to receive and store waste until the second quarter of CY 1975 when it was removed from service. At that time, the tank was classified as a "Questionable Integrity" tank.

Between October 1, 1965 and December 26, 1969 there was an unexplained 8.5 in surface level decrease in the tank, equivalent to a 23,400 gallon loss. In 1968 the tank was declared to be a "Questionable Integrity" tank. During the fourth quarter of 1969, 350,000 gallons of supernatant were removed from the tank. No further liquid level decreases were reported once the transfer was made, and the liquid level appears to have remained stable until tank C-111 received catch tank waste in the second quarter of CY 1972.

Four independent teams reviewed the 1965 – 1969 data between June, 1980 – April, 1981 as part of a coordinated review of six single-shell tanks classified as "Questionable Integrity" tanks. Three of the four teams recommended that the tank C-111 leak integrity status be changed from "Questionable Integrity" to "Confirmed Leaker"; the fourth team recommended that the existing Questionable Integrity classification be retained. According to the ground rules in effect, the teams' recommendations had to be unanimous to change the Questionable Integrity classification to "Confirmed Leaker".

In 1984 the "Questionable Integrity" and "Confirmed Leaker" tank classifications were combined and changed to "Assumed Leaker". A leak volume estimate was not made until 1989, when a 5,500 gallon volume was assigned.

In 2007 tank C-111 was again reviewed for purposes of retrieval technology selection and closure. Process history records that had not been reviewed during the 1981 evaluation identified exceptions to the earlier data set. IF the records had been available during the earlier review, they would have possibly altered the teams' recommendation:

- During the period immediately before the liquid level decrease began, tank C-111 was not receiving low-level waste as the 1981 evaluation believed. Records show that from July, 1962 through June, 1964, tank C-111 received 194,000 gallons of strontium purification waste from the Hot Semiworks facility. Records show that the waste from the purification process would have contained approximately 6.4 megacuries of ^{144}Ce, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964.

- The tank bulk solution temperature was not 100°F as the 1981 evaluation believed. Between January, 1963 and September, 1964 the tank's bulk waste temperature increased from 80°F to 190°F as the strontium purification waste heated the tank.

Between 1975 and 1994 the five drywells surrounding tank C-111, and nearby drywells, were routinely monitored for gross gamma ray soil contamination that would indicate a tank leak. None of the drywells showed evidence of a tank leak during the surveillance period. Spectral Gamma analyses completed during February and March, 1997 confirmed the earlier results.

Figure 1-1. 241-C Tank Farm Plot Plan

Tank C-111 is located on the northwest side of 241-C tank farm, the second tank in the C-110, C-111, C-112 cascade. Drywells illustrated in the plan are identified by their associated tank number and clock position from North. In addition to the five drywells surrounding tank C-111, drywells 30-00-10, 30-08-12, 30-10-01, and 30-10-02 are considered part of the tank's drywell baseline (GJ-HAN-93).

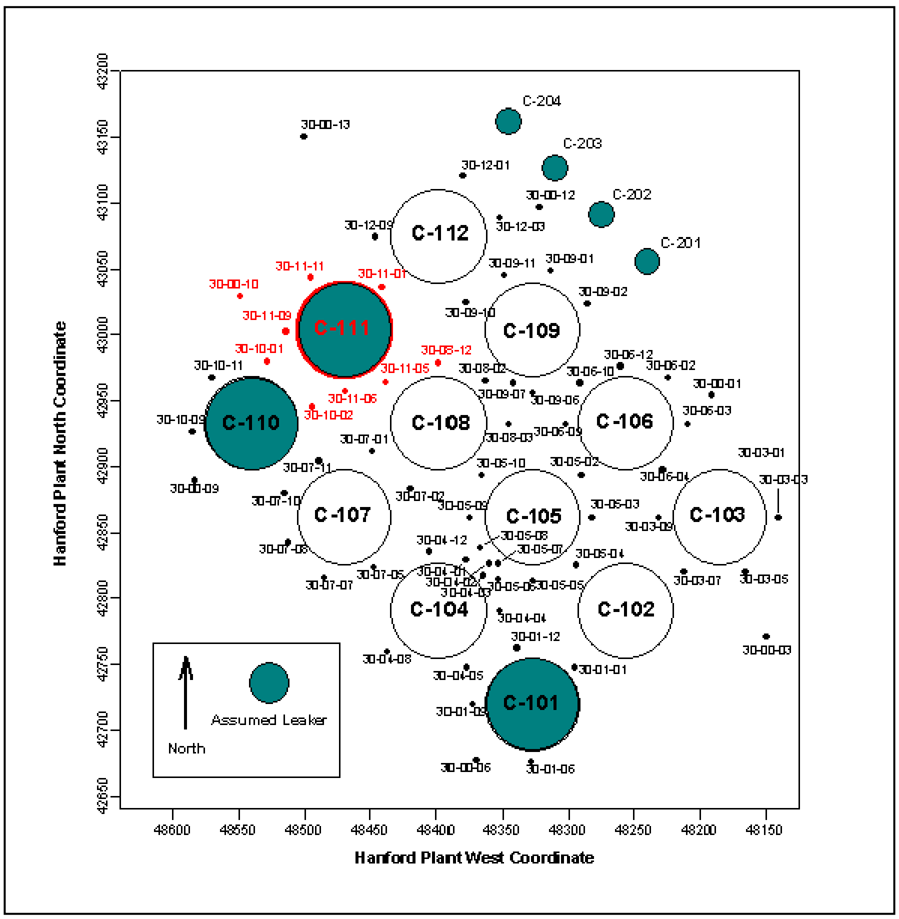
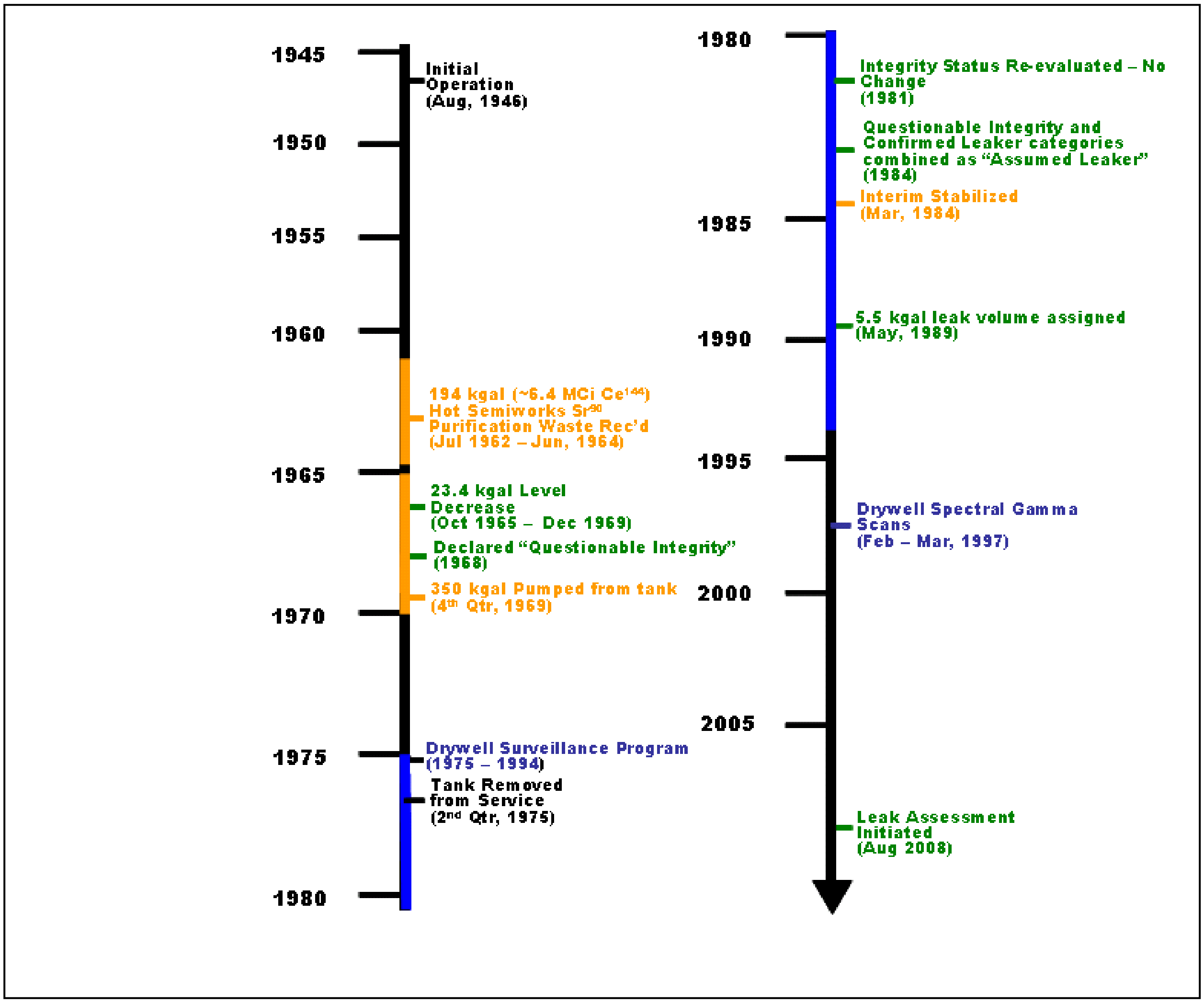


Figure 1-2. Tank C-111 Event Timeline



2.0 METHOD OF ANALYSIS

The method of analysis used was Engineering Procedure TFC-ENG-CHEM-D-42, *Tank Leak Assessment Process*. The formal leak assessment process is based on probabilistic analysis to assess the mathematical likelihood (probability) that a specific tank is leaking or has leaked. The technical basis for the process and additional details and examples of the methodology for implementing the process can be found in HNF-3747 *Tank Leak Assessment Technical Background*. For each step, a description of the process, products, and responsibilities is provided.

The leak assessment used a panel of experienced CH2M HILL Hanford Group, Inc. engineers and managers to review the tank C-111 historical data and re-evaluate the basis for declaring the tank an “Assumed Leaker”. The panel consisted of: D. J. Washenfelder, (Assessment Coordinator, Technical Integration Program Manager); D. G. Baide, (West Systems Engineering Manger); D. A. Barnes, (Surveillance System Engineer, in-tank and ex-tank surveillance); D. W. Brown (C Tank Farm Maintenance and Facility Operations Manager); L. S. Krogsrud (C Tank Farm Single-Shell Waste Tank System Engineer); and P. C. Miller (Environment Support and Assessment Program Manager). The team met between August 6, 2008 and August 21, 2008 to gather and review information, develop the Leak and Non-Leak Hypotheses, and reach a consensus recommendation for tank C-111.

3.0 TANK HISTORY

Tank 241-C-111 is a 530,000 gallon capacity, 75-foot diameter, mild steel-lined concrete shell tank located at the northwest perimeter of the 16-tank C Tank Farm. The tank was placed in service in August, 1946, and continued to receive and store waste until the second quarter of CY 1975 when it was removed from service. At that time, the tank was classified as a "Questionable Integrity" tank. Of the twelve 100-Series C Farm tanks, three – C-101, C-110, and C-111 – are presently classified as an "Assumed Leaker".[1]

In August, 1946 Tank C-111 received first cycle waste (1C) from the bismuth phosphate process cascading from tank C-110 into tank C-111. In November, 1946, the tank was declared full and the waste cascaded into tank C-112.

In 1952, the supernatant was transferred out of the tank, and it began to receive uranium recovery waste. Beginning in 1955, tank C-111 served primarily as the settling tank for ferrocyanide waste resulting from in-farm scavenging of ^{137}Cs. During 1956, that ferrocyanide waste was transferred and the tank received plutonium-uranium extraction (PUREX) organic wash waste and cladding waste.

Between July, 1962 and July, 1964, the Hot Semi-Works plant transferred 194,000 gallons (194 kgal) of strontium purification waste into the tank, containing approximately 6.4 megacuries (MCi) of ^{144}Ce decay-corrected to July, 1964. The ^{144}Ce concentration in the waste was approximately 150 Ci/l, with a heat generation rate of 175,000 BTU/hr. The strontium purification waste caused the tank's bulk waste temperature to increase from ~ 80^{o}F to 190^{o}F by September, 1964, according to the last available temperature record (RHO-CD-1172 Rev. 0).

During the fourth quarter of 1969, 350,000 gallons of supernatant were removed from the tank. No other transfers occurred until the tank received ~ 22 kgal of 241-C-301 catch tank waste in the second quarter of CY 1972.

In 1984 the "Questionable Integrity" and "Confirmed Leaker" tank classifications were combined and changed to "Assumed Leaker". A leak volume estimate was not made until 1989, when a 5,500 gallon volume was assigned.

The tank was declared interim stabilized March 9, 1984 (SD-WM-TI-356). Tank C-111 currently holds 57 kgal of sludge, with no free supernatant. It is equipped with an ENRAF surface level instrument for water intrusion detection, and is passively ventilated. There is no Liquid Observation Well.

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[1] The leak integrity of Tank C-110 was reevaluated in RPP-ASMT-38219 Rev. 0, *Tank 241-C-110 Leak Assessment*, July, 2008. It is pending an integrity revision from "Assumed Leaker" to "Sound".

4.0 TANK LEAK ASSESSMENT HISTORY

Between October 1, 1965 and December 26, 1969 there was an unexplained 8.5 in surface level decrease in tank C-111. According to SD-WM-TI-356 Rev. 0 *Waste Storage Tank Status and Leak Detection Criteria*, the tank was classified as a "Questionable Integrity" (QI) tank in 1968 as a result of the unexplained decrease. Four independent teams reviewed the historical data during the June 1980 – April 1981 period as part of a coordinated review of six single-shell tanks classified as QI tanks. Three of the four teams recommended that the leak integrity status be changed from QI to "Confirmed Leaker" (CL); the fourth team recommended that the existing QI classification be retained. According to the ground rules in effect, the teams' recommendations had to be unanimous to change the QI classification to CL. Tank C-111 remained classified as a QI tank (RHO-CD-1193).

The 1981 evaluation noted that from 1957 to at least January 1, 1965 that tank C-111 liquid level remained stable at about 191 in. Between October, 1965 and December 1969 – the period of surface level decrease – the tank served as a low-level waste storage repository for feed solution. After this period, about 100 kgal of supernatant waste remained in the tank, and the liquid level remained stable for the next 55 months.

The 1981 evaluation noted that the tank bulk solution temperature was less than 100^{o}F during the 1965 – 1969 period, and that the tank was not connected to an operating exhauster. Thus evaporative loss was discounted as a possible explanation for the liquid level decrease.

In 1984 the "Questionable Integrity" and "Confirmed Leaker" tank classifications were combined and changed to "Assumed Leaker". In May, 1989 a leak volume of 5.5 kgal was assigned to tank C-111 [8901832B R1].

In 2007 tank C-111 was reviewed for purposes of retrieval technology selection and closure. Process history records that had not been reviewed during the 1981 evaluation identified exceptions to the earlier data set. If the records had been available during the earlier review, they would possibly have altered the outcome:

- During the period immediately before the liquid level decrease began, tank C-111 was not receiving low-level waste as the 1981 evaluation believed. Records show that from July, 1962 through June, 1964, tank C-111 received 194 kgal of strontium purification waste from the Hot Semiworks. Records show that the waste from the purification process would have contained ~ 6.4 MCi of ^{144}Ce, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964.

- The tank bulk solution temperature was not 100^{o}F as the 1981 evaluation believed, but closer to 190^{o}F according to RHO-CD-1172 Rev. 0, *Survey of the Single-Shell Tank Thermal Histories*, reflecting the high heat content of the ^{144}Ce waste.

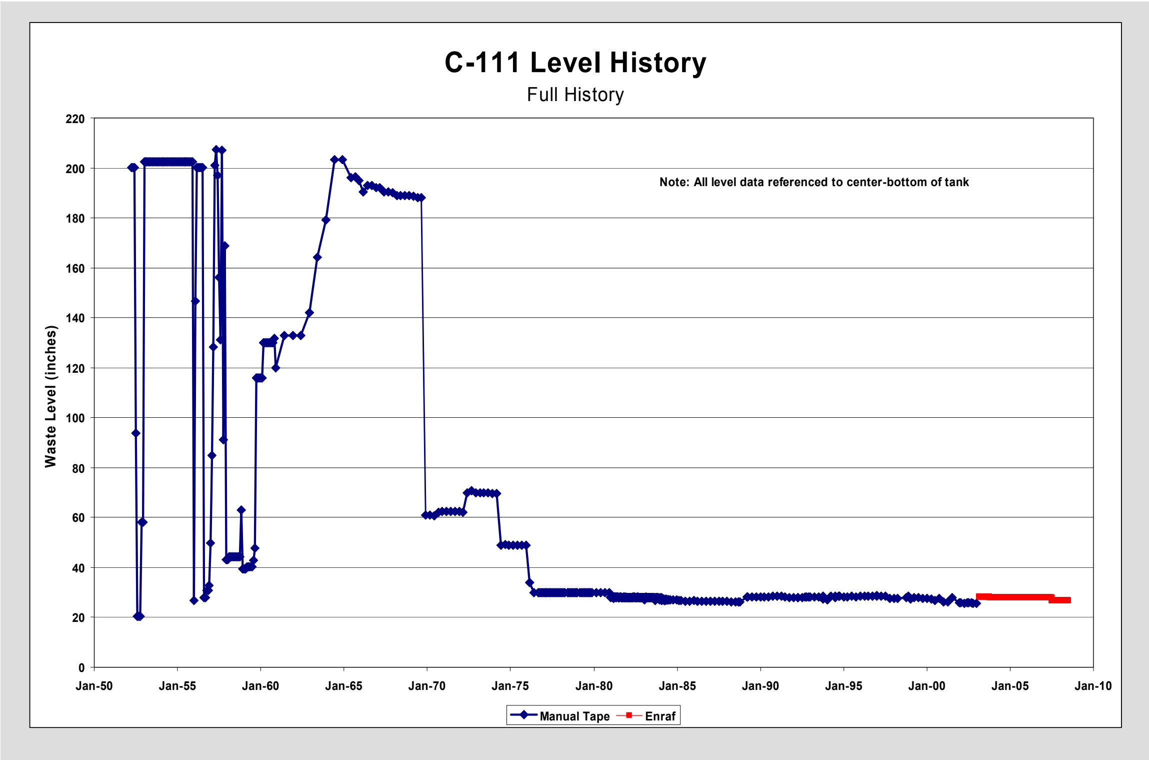
5.0 IN-TANK DATA

5.1 SURFACE LEVEL BEHAVIOR

Figure 5-1 shows that following the 1965 – 1969 loss, tank C-111 experienced extended periods of surface level stability: December, 1969 – March, 1972 when the tank contained 66 kgal of supernatant and 81 kgal of sludge; June, 1972 – March, 1974 following receipt of ~ 22 kgal of waste from catch tank 241-C-301 in the 2nd quarter of CY 1972; June 1974 – December 1975; and June 1976 – present following further transfers from the tank.

Figure 5-1. Tank C-111 Surface Level History 1950 – Present

With the exception of the 1964 – 1969 time period when tank C-111 held strontium purification waste, the tank surface level has been stable for extended periods of time. The original manual tape data used to prepare the chart were referenced to the base of the vertical sidewall, and did not account for the 12 in dished bottom. The manual tape levels shown in the chart have been adjusted by adding 12 in to be consistent with current level monitoring standards (e.g., center-bottom dish). The ENRAF data are referenced to center-bottom, so no adjustments are necessary.

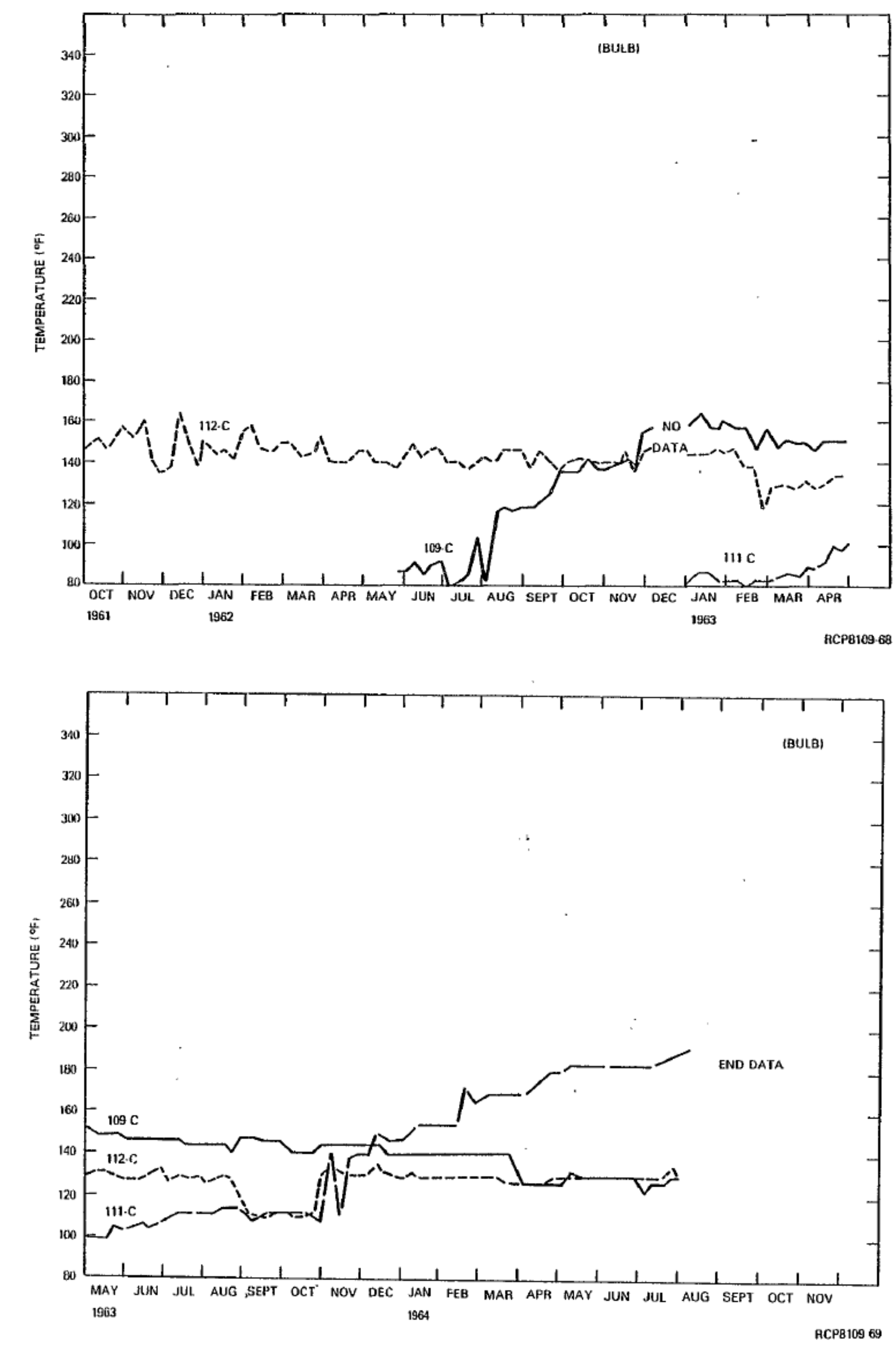


5.2 WASTE TEMPERATURE BEHAVIOR

Between July, 1962 and July, 1964, the Hot Semi-Works plant transferred 194,000 gallons (194 kgal) of strontium purification waste into the tank, containing approximately 6.4 megacuries (MCi) of ^{144}Ce decay-corrected to July, 1964. The ^{144}Ce concentration in the waste was approximately 150 Ci/l, with a heat generation rate of 175,000 BTU/hr. The strontium purification waste caused the bulk waste temperature to increase from ~ 80^{o}F to 190^{o}F by September, 1964, according to the last available temperature record (RHO-CD-1172 Rev. 0).

Figure 5-2. Tank C-111 Waste Temperature May 1963 – September 1964

Tank C-111 waste temperature rose from ~ 80°F at the beginning of January, 1963 to ~190°F by September, 1964. This period corresponds to the receipt of strontium purification waste from the Hot Semiworks facility. The strontium purification waste contained approximately 6.4 MCi of ^{144}Ce, and generated about 175,000 BTU/hr from radiolytic decay (RHO-CD-1172, RPP-ENV-33418).

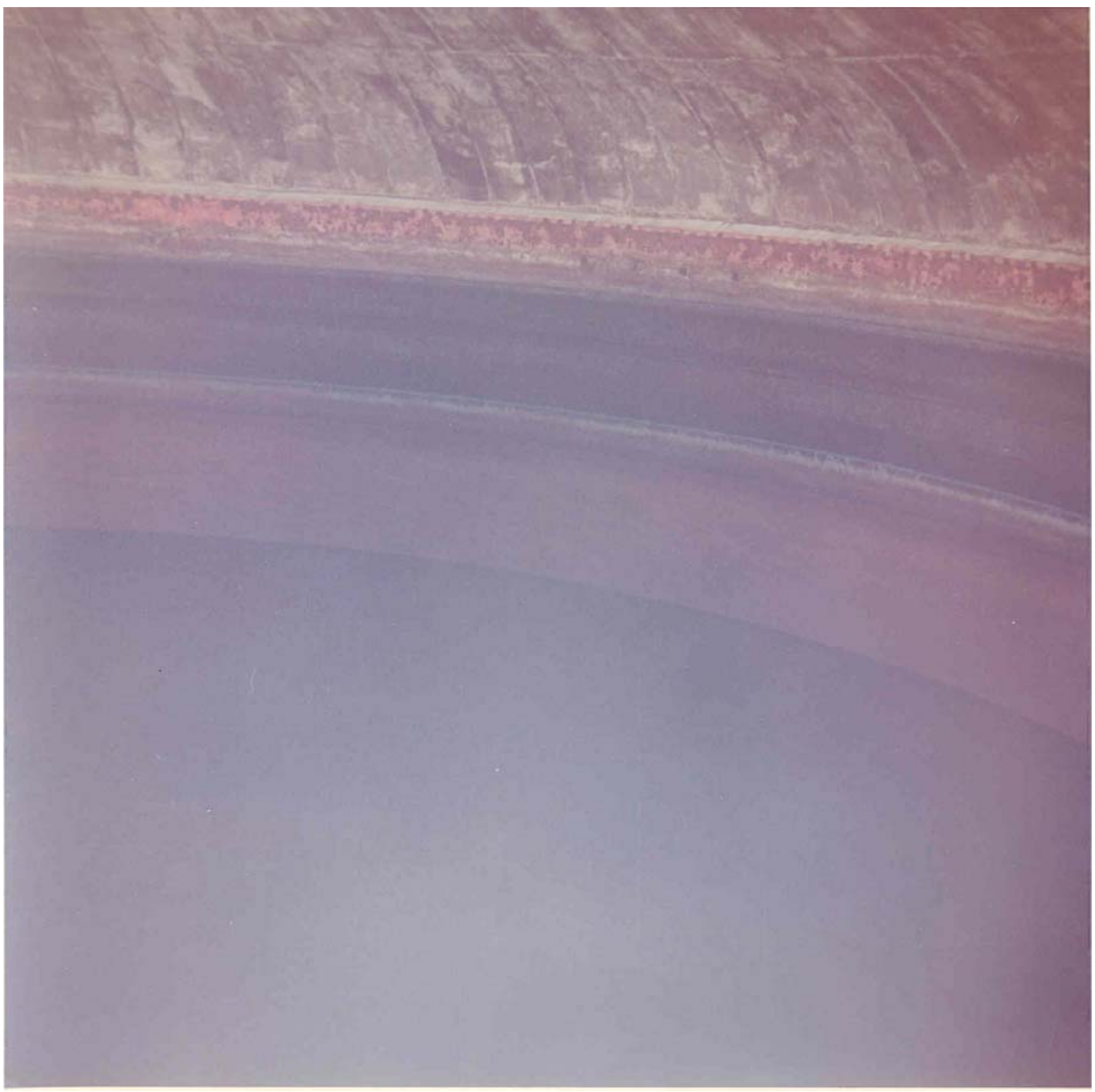


5.3 IN-TANK PHOTOS

The last in-tank tank C-111 photos were taken in February, 1970. Interior features are obscured by fog or mist. The presence of fog suggests the tank headspace was still saturated with water vapor at that time. By 1970 the remaining ^{144}Ce in the strontium purification waste would have been nearly completely decayed, and the bulk waste temperature in the tank would have been returning to the pre-1963 level of ~ 80^{o}F.

Figure 5-3. Tank C-111 Interior Photograph – 1970

By the time this February 25, 1970 photograph was taken, the ^{144}Ce in the strontium purification waste transferred into tank C-111 between July, 1962 and July, 1964 was essentially decayed away. The tank's bulk waste temperature was decreasing, and returning the pre-transfer temperature of ~ 80^{o}F. Even at the reduced temperature, the presence of fog or mist in the tank's headspace is apparent. This was being created by continuing waste evaporation.



6.0 EX-TANK DATA

6.1 TANK C-111 DRYWELLS

6.1.1 Drywell Historical Gross Gamma Logs 1975 - 1994

There are nine drywells surrounding tank C-111: 30-11-01, 30-08-12, 30-11-05, 30-11-06, 30-10-02, 30-10-01, 30-11-09, 30-00-10, and 30-11-11. Drywells 30-10-01 and 30-10-02 associated with tank C-110 and drywell 30-08-12 associated with tank C-108 have been traditionally used to monitor tank C-111 because of their proximity. The drywells are highlighted in red in Figure 6-1.

Historical gross gamma logs for the period 1975 – mid-1994 are compiled in RPP-8321 Rev. 0 *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm – 200 East Area*. The time-sequenced gross gamma scans for drywells 30-11-01, 30-11-05, 30-11-06, 30-11-09, and 30-11-11 are presented in Figure 6-2.

Since 1995 the Spectral Gamma Logging System has supplanted the Gross Gamma system.

Figure 6-1. Plan Map of Tanks and Drywells in 241-C Tank Farm (GJ-HAN-93)

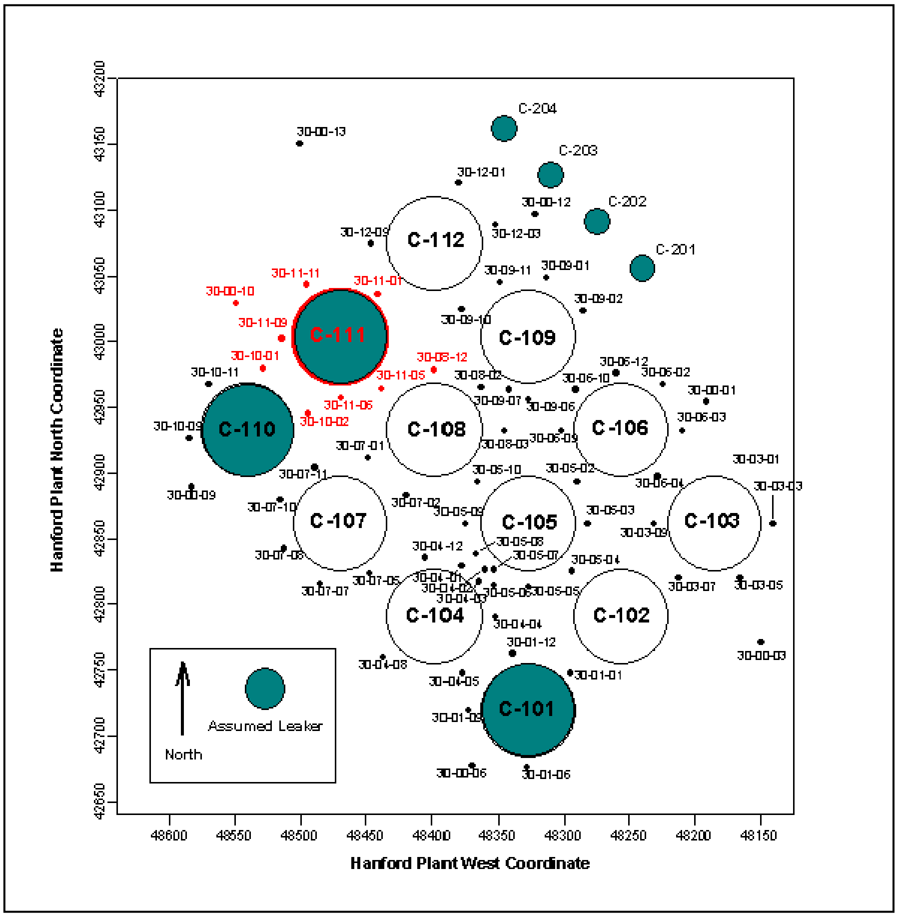


Figure 6-2. Tank C-111 Time-Sequenced Gross Gamma Logs – 1975 – 1994

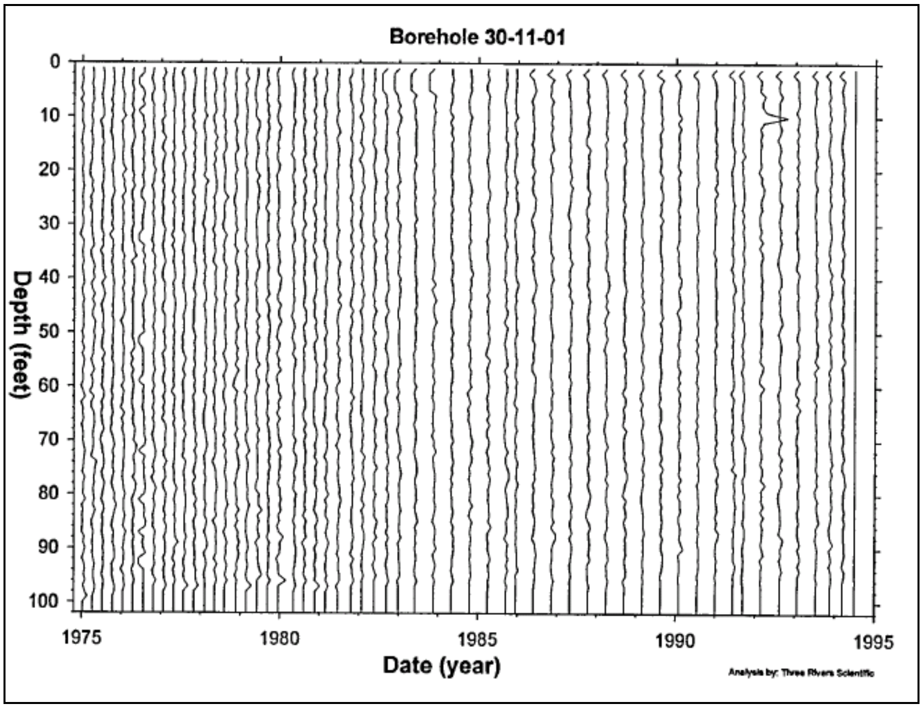
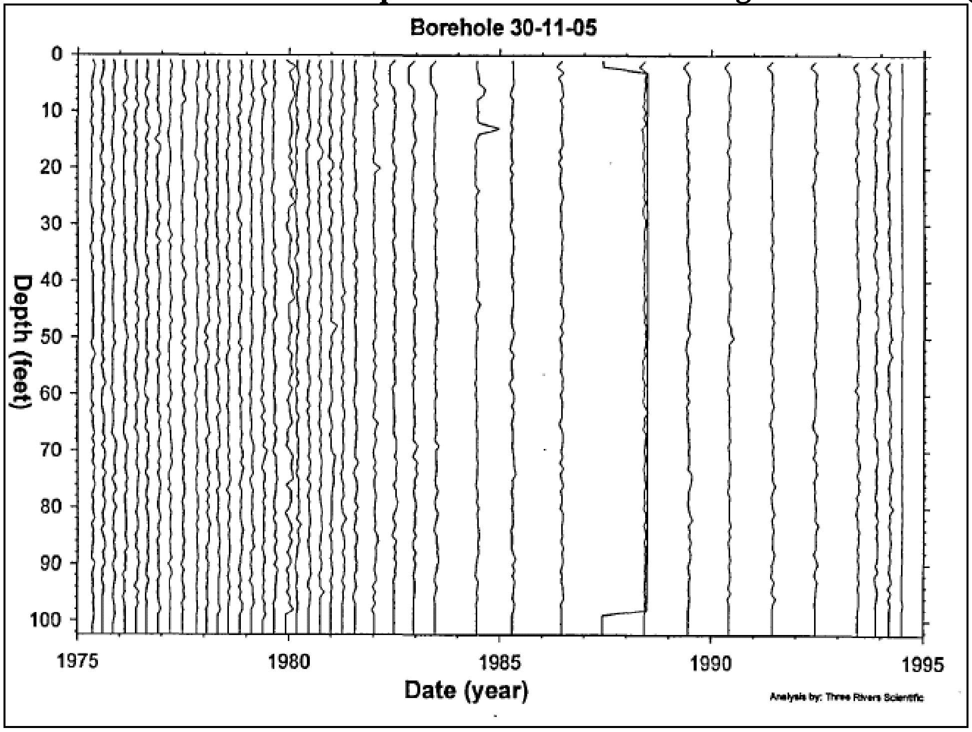


Figure 6-2. Tank C-111 Time-Sequenced Gross Gamma Logs – 1975 – 1994 (cont.)



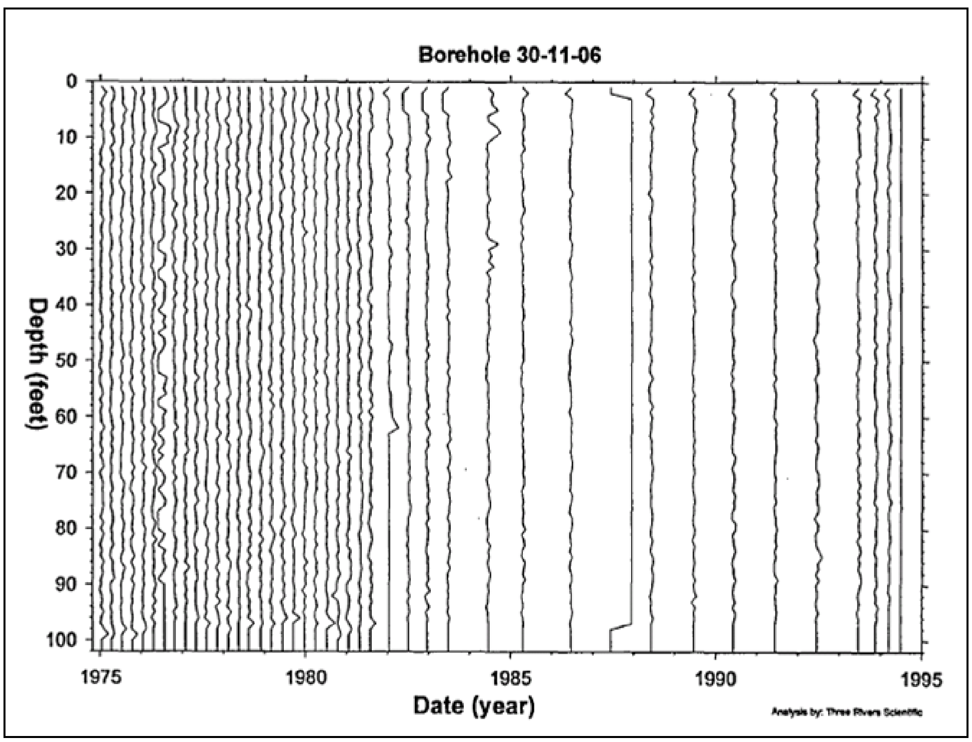
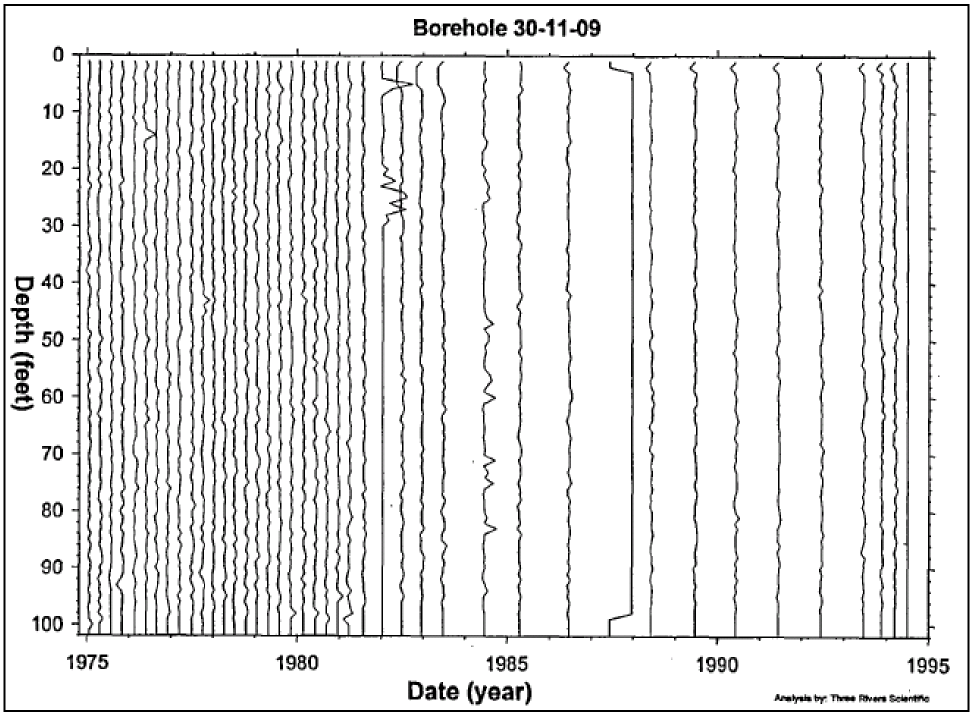
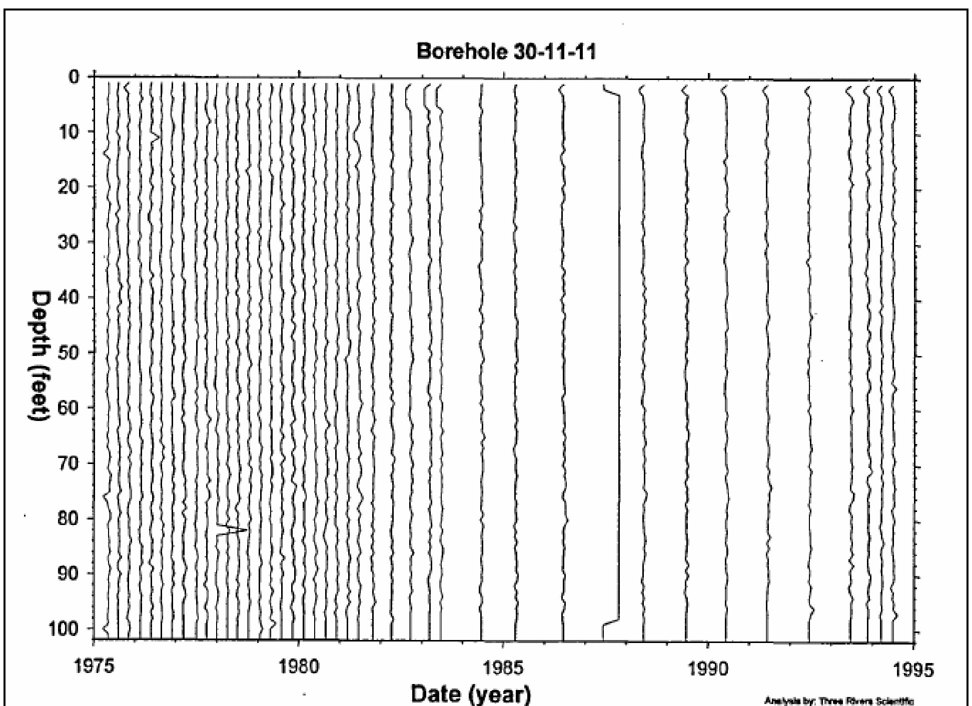


Figure 6-2. Tank C-111 Time-Sequenced Gross Gamma Logs – 1975 – 1994 (cont.)





Gross Gamma Log Plots Reference:
RPP-8321 Rev. 0 *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm – 200 East Area* June 2001 (Accession #D6875724]

6.1.2 Drywell Spectral Gamma Logs 1998

Beginning in 1995, the DOE Grand Junction Office (GJO) performed a baseline characterization of the gamma-ray-emitting radionuclides that are distributed in the vadose zone sediments surrounding the single-shell tanks (SSTs) at the Hanford Site. Occurrences of these radionuclides were measured by monitoring the drywells positioned around the SSTs with a spectral gamma logging system (SGLS). This system employs a high-purity germanium detector and is capable of producing laboratory-quality assays of the gamma-emitting radionuclides in the vicinity of a borehole. The spectral gamma-ray logging results obtained from the monitoring the drywells surrounding tank C-111 were reported in 1998 (GJ-HAN-93). Portions of the results are presented in Figure 6-3.

Figure 6-3. Tank C-111 Spectral Gamma Logs – 1998

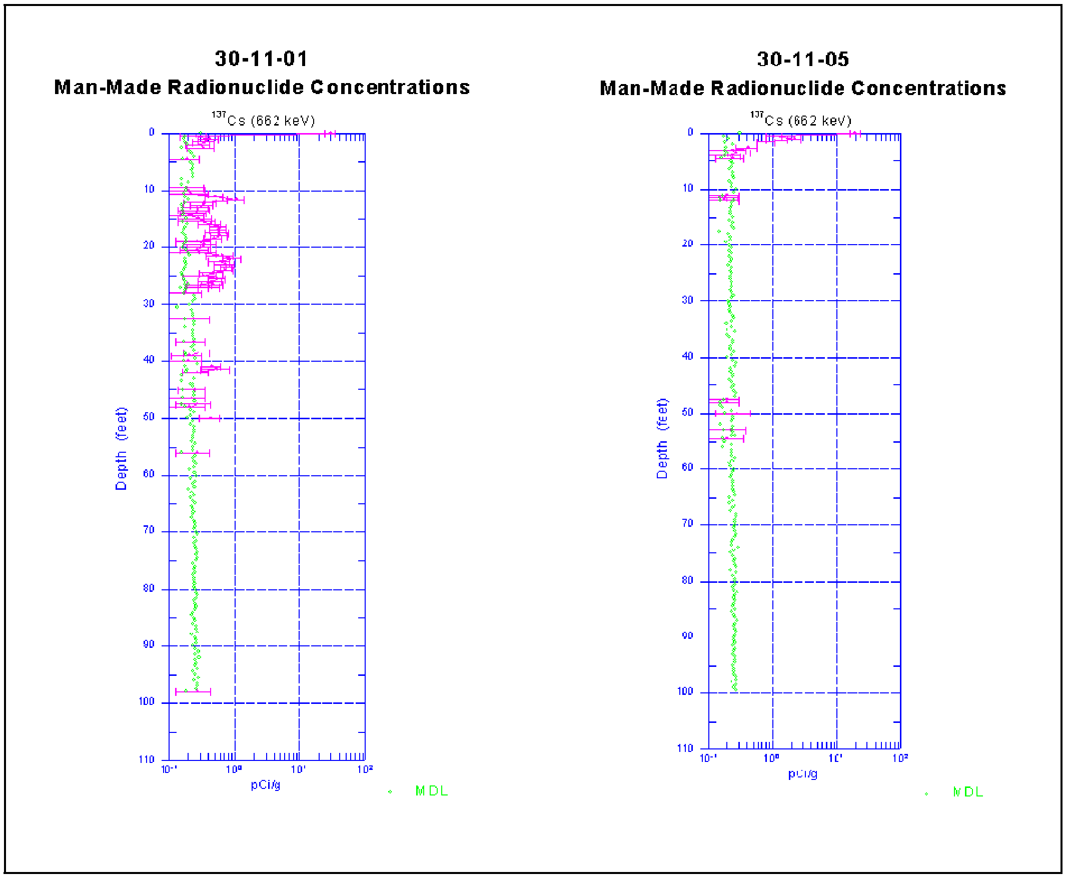


Figure 6-3. Tank C-111 Spectral Gamma Logs – 1998 (cont.)

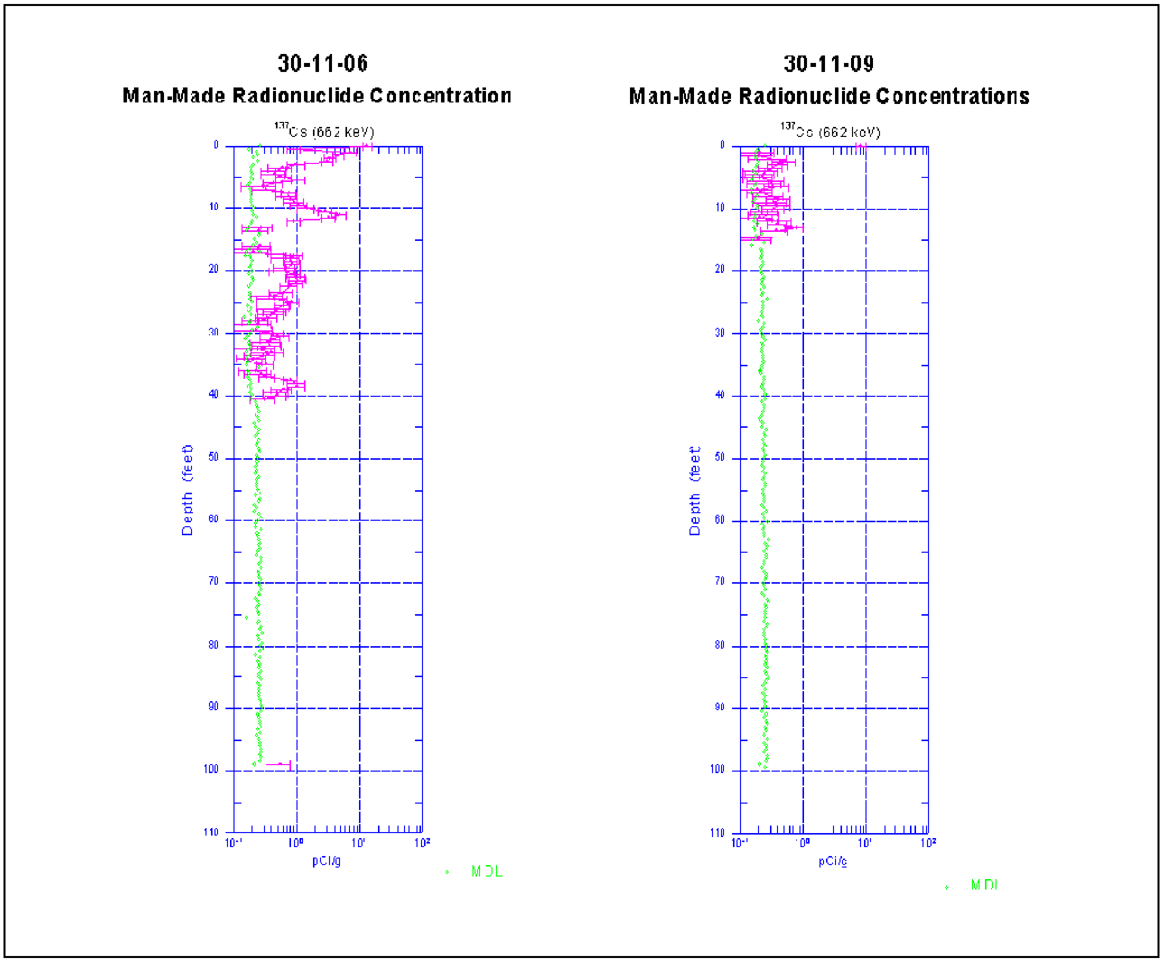
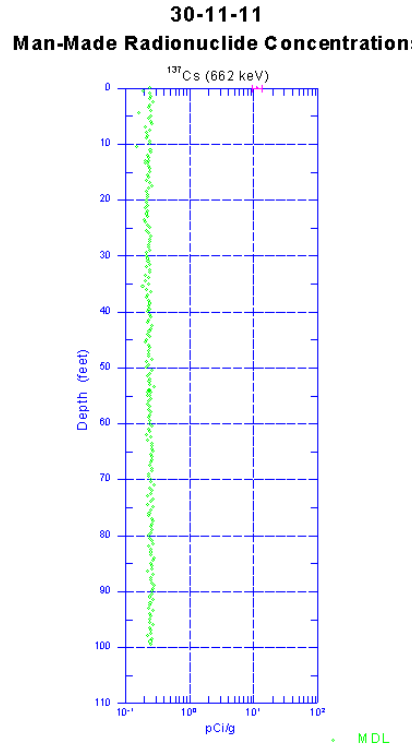


Figure 6-3. Tank C-111 Spectral Gamma Logs – 1998 (cont.)



6.1.3 Drywell Gross Gamma and Spectral Gamma Logs Interpretation

The GJO tank farm summary report GJPO-HAN-18, *Vadose Zone Characterization Project at the Hanford Tank Farms C Tank Farm Report* summarized the results of the tank C-111 SGLS scans as follows:

> According to the Tank Summary Data Report for tank C-111 (DOE 1998a),
>
> **"8.6.10 Boreholes Surrounding Tank C-111**
>
> "The Cs-137 from 32 to 66 ft around borehole [drywell] 30-11-01 was carried down during the construction of this borehole or later migrated down the outside of the casing. This contamination was removed from the visualization data set.
>
> "Cs-137 was detected in isolated occurrences at or just above the MDL [Minimum Detection Level] in borehole 30-11-05 at about 12 ft and in borehole 30-11-06 at about 13 ft. If the Cs-137 is truly present, then it represents contamination that is most likely localized to the borehole casing; therefore, this contamination was removed from the data set.

> "The Cs-137 detected at the surface of borehole 30-11-11 is most likely direct gamma rays from nearby contaminated equipment.
>
> "Isolated occurrences of Cs-137 were detected in the bottom of boreholes 30-11-01 and 30-11-06. This contamination is interpreted to be from particulate matter that has fallen into the bottom of the borehole."

The GJO report concluded the following with respect to the drywells surrounding tank C-111:

> "The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-111 was completed using the SGLS. There is no indication in the data obtained from the SGLS, historical gross gamma-ray logs, and other available information of residual radionuclide contamination from a past or present leak from tank C-111. Data leading to the determination that this tank leaked in the past should be re-evaluated. However, the data considered in this report indicate that surface spills have occurred in the past and that minor leaks from pipelines or other service facilities may have also occurred. The contamination detected at and below the base of the tank farm excavation in boreholes 30-08-12 and 30-10-02 is indicative of a plume(s) that probably originated from tanks C-108 and C-110."

7.0 HYPOTHESES

Based on review of the in-tank and ex-tank data, the leak assessment panel developed plausible hypotheses for the observed tank behavior:

Leak Hypothesis:

"The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leak Hypothesis:

"The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

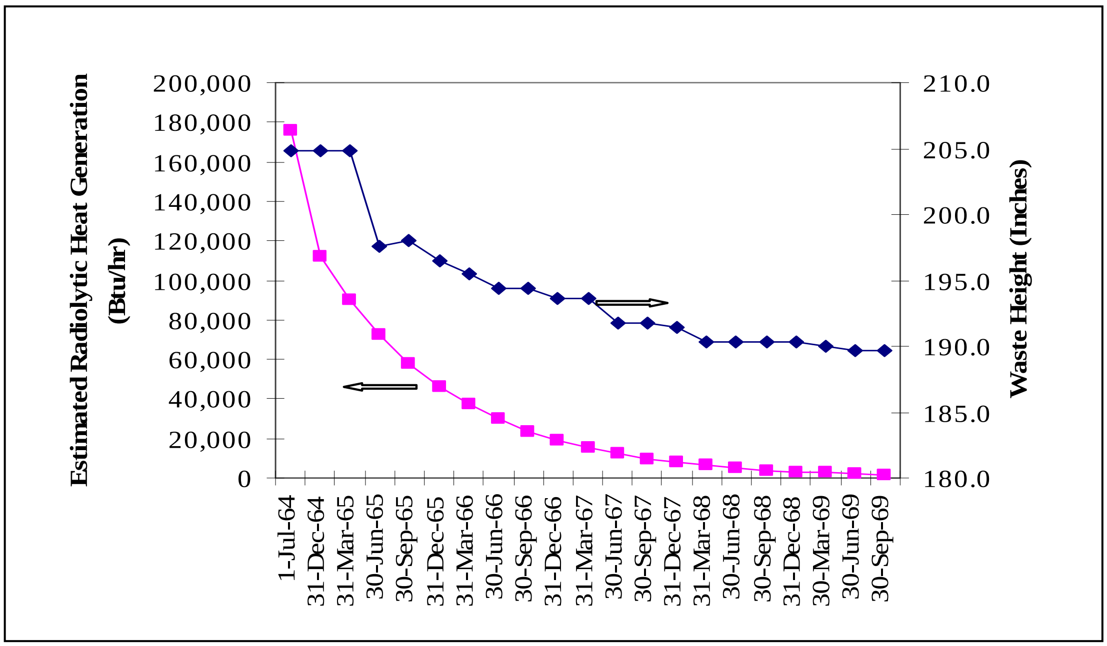
8.0 EVALUATION

8.1 SURFACE LEVEL DECREASE AND WASTE HEAT GENERATION RATE

The accompanying figure shows the time-based waste surface level loss from tank C-111, plotted with the decay-corrected radiolytic heat generation from the remaining inventory of ^{144}Ce in the tank. Within the limits of error, the two curves have virtually the same shape, and the same rate of change, strongly suggesting that the 8.5 in surface level decrease – equivalent to a 23.4 kgal loss – was linked to the ^{144}Ce content of the strontium purification waste received in tank C-111 during the July, 1962 – June, 1964 time period.

Figure 8-1. Tank C-111 Surface Level Decrease and Estimated Heat Generation Rate – 1964 – 1969

The tank C-111 surface level decrease and the radiolytic heat generation from the remaining ^{144}Ce in the waste have nearly the same shape and rate of change (from RPP-ENV-33418 Rev. 1).



The shape of the liquid level decrease in Figure 8-1 would be expected if the tank was leaking at about the 190 in level, as well as if the ~ 6.4 MCi of short-lived ^{144}Ce were heating the tank and causing bulk liquid evaporation at a rate proportional to the remaining ^{144}Ce inventory. However, before the strontium purification waste was transferred into the tank, and after the ^{144}Ce had decayed, there were extended periods of surface level stability as shown previously in Figure 5-1.

In the 4th quarter of CY 1969, about 350 kgal of supernatant was transferred from tank C-111 to tank C-104, leaving 66 kgal of supernatant in the tank. No further liquid level decreases were reported once the transfer was made, and the surface level appears to have remained stable until tank C-111 received catch tank waste in the 2nd quarter of CY 1972.

8.2 PASSIVE BREATHING RATE AND EVAPORATION

The magnitude of the passive breathing rate of tank C-111 is an important consideration if the 1964 – 1969 supernatant loss was the result of evaporation. Calculations in Appendix C show that the tank would have to have a ~3.5 cfm breathing rate at the 190^{o}F waste temperature and 100% relative humidity during the October, 1965 – December, 1969 time period to account for the 23.4 kgal loss via evaporation.

Single-shell tank passive breathing rates measured during the 1990's indicate that 3.5 cfm is toward the low end of the measured range, and realistic:

- RPP-5660 *Collection and Analysis of Selected Tank Headspace Parameter Data* Table 3-15 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics", and Table 3-16 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics from Monthly Reports" list the passive breathing rates for SSTs equipped with Standard Hydrogen Monitoring System (SHMS). The breathing rates ranged from 1.8 to 52.5 cfm, depending on bulk waste temperature.
- Tracer gas studies of SSTs using sulfur hexafluoride showed breathing rates consistent with those measured with the SHMS. For the nine passively ventilated SSTs (AX-102, AX-103, BY-105, TX-104, U-102, U-103, U-105, U-106, and U-111) reported in RPP-5660 Table 3-17 "Submitted Ventilation Rate References" and Table 4-1 "Tank Headspace Parameter Summary", measured breathing rates varied from a low of 2 cfm for low temperature tanks (U-102 [82^{o}F], U-103 [83^{o}F], and U-111 [77^{o}F] to a high of 53 cfm (SX-103 [143^{o}F]).
- Further analysis of Table 4-1 indicates that for tanks <110^{o}F, the breathing rate was generally 3 – 5 cfm; for tanks >110^{o}F, the rate was 7 – 9 cfm.
- RPP-5660 *Collection and Analysis of Selected Tank Headspace Parameter Data* p68 indicates that tank C-111 had a calculated passive breathing rate of 7 cfm. The calculated value was based on a calculated average passive exchange rate of 0.45% of the headspace volume per day rather than a measured rate. If this calculation is correct, then the 7 cfm breathing rate was well above the rate necessary to evaporate the 23.4 kgal during the 1965 – 1969 period.

8.3 THERMAL CONTRACTION OF WASTE

Figure 5-2 indicates that prior to receipt of the strontium purification waste the tank C-111 bulk waste temperature was about 80^{o}F. Following receipt of the strontium purification waste the temperature increased to at least 190^{o}F. There are no temperature records available for the post-September, 1964 period showing the temperature decrease as the radiolytic heat generation from the remaining ^{144}Ce decayed. From an initial value of 175,000 BTU/hr, the heat generation rate decayed to about 1,400 BTU/hr by December, 1969, and the temperature would have decreased accordingly.

The supernatant in tank C-111 would have thermally contracted as the waste cooled. Appendix D uses a Low Activity Waste (LAW) temperature – density correlation developed by the Savannah River Site to calculate the density change that would have occurred as the waste cooled from the highest recorded temperature – 190^{o}F – back to 80^{o}F. The correlation was selected because the waste characteristics of the LAW were similar to the waste in tank C-111 during the period when the loss occurred

The density change resulted from the temperature change from 190^{o}F to 80^{o}F was calculated to be 1.75% using the LAW correlation. During the time period in review, tank C-111 contained 166.5 in of supernatant. As the supernatant cooled to 80^{o}F, it lost 1.75% of its liquid column through contraction, or about 2.9 in.

Based on thermal contraction of the waste as it cooled, the 8.5 in waste surface level surface level decrease should be corrected for the 2.9 in change. This in effect reduces the 23.4 kgal loss to 15.4 kgal before accounting for evaporation.

8.4 PASSIVE BREATHING RATE CORRECTION

Calculations show that the 166.5 in of liquid waste would have contracted 1.75% or 2.9 inches as a result of waste cooling from 190^{o}F to 80^{o}F. In other words, the 8.5 inch recorded surface level decrease consisted of an actual 5.6 inch loss and a 2.9 inch contraction. Instead of a 23.4 kgal loss, the loss was 15.4 kgal.

If the 15.4 kgal were evaporated at ~ 190F and 100% relative humidity as the leak assessment team believes occurred, then the required passive breathing rate would be reduced to 2.3 cfm, from the 3.5 cfm reported in the Appendix C calculation.

The lowest measured passive breathing rate in the SSTs is 1.8 cfm; the reported range for measured tanks is 2 - 53 cubic feet per minute. So a 2.3 cfm passive breathing rate for tank C-111 is realistic.

9.0 SUMMARY OF ANALYSTS ASSESSMENT

Expert Opinion: D. G. Baide

Estimated Probability of Observed In-Tank and Ex-Tank Data if tank C-111 had leaked = 0.01

Basis for Opinion:

> "The surface level drop equivalent to a loss of 23.4 kgal is a significant drop. Even with the Ce-144 waste probably contributing to evaporation, the calculations that all of the loss was due to evaporation would have to be convincing. It is possible that evaporation would mask a leak, for example.
>
> "Most of the gamma peaks in the drywell scans were near the surface, indicative of surface spills. The five drywells' behavior over time show no change in peaks as would be expected for an active leak. The 23.4 kgal leak would have been a substantial volume. With 5 drywells around the tank, the plume from a leak of this size should have been intercepted by a least one of the drywells."

Expert Opinion: D. A. Barnes

Estimated Probability of Observed In-Tank and Ex-Tank Data tank C-111 had leaked = 0.07

Basis for Opinion:

> "Losses started immediately after introducing hot waste and seeing temperature increase; evaporation modeling supports evaporative loss, as long as 3-5 cfm breathing rate is realistic (Most documented breathing rates in SSTs are >10 cfm.); loss rate follows decay curve of radionuclides; and no further loss after pumpdown and short-lived radionuclides decay away.
>
> "No contamination spikes noted in any drywells. Indicates sound tank, but small leak could be missed by drywells. A loss of 23000 gallons is less likely to be missed by a drywell."

Expert Opinion: D. W. Brown

Estimated Probability of Observed In-Tank and Ex-Tank Data tank C-111 had leaked = 0.01

Basis for Opinion:

> "For the four year period after the addition of the Hot Semi-Works waste, the level dropped. This was most likely the result of evaporation based on the leak assessment team's review and the evaporation model prepared during the assessment.
>
> "The 20 years' of drywell gross gamma scans show no leakage. At least one of the drywells should have shown contamination based on the 23.4 kgal leak size."

"Lack of documentation of the 1964 - 1969 surface level change suggests that the facility staff was aware of the circumstances and concluded that the loss was the result of evaporation. Probability is consistent with this explanation."

Expert Opinion: L. S. Krogsrud

Estimated Probability of Observed In-Tank and Ex-Tank Data tank C-111 had leaked = 0.08
Basis for Opinion:

"The asmytotic appearance of the surface level decrease could be accounted for by either a hydraulic-driven leak, or be the result of evaporation of the liquid being driven by the short-lived Ce-144 waste.

"Drywell scans not consistent with ~ 23 kgal leak.

"GJPO report indicates SGLS hits were most likely from surface leaks, or from a nearby plume, or carried down during construction."

Expert Opinion: P. C. Miller

Estimated Probability of Observed In-Tank and Ex-Tank Data tank C-111 had leaked = 0.10

Basis for Opinion:

"Based on data and modeled evaporation, it is likely that the level drop was caused by evaporation.

"Nothing in ex-tank gross gamma scan data supports a leak."

Expert Opinion: D. J. Washenfelder

Estimated Probability of Observed In-Tank and Ex-Tank Data tank C-111 had leaked = 0.07

Basis for Opinion:

"High-heat Ce-144 waste storage contributed to evaporation, but it is possible that the evaporation could have masked a leak. The 23.4 kgal loss experienced during the 1964 - 1969 period was equivalent to a passive breathing rate of ~ 3.5 cfm at 100% relative humidity. The He and SF_6 tracer gas measurements conducted on passively ventilated SSTs during the 1990's show that the 3.5 cfm rate is at the low end of the measured breathing rates, and therefore credible. The most recent photo, taken in 1970, shows the headspace fogged, indicating that the 100% RH is a reasonable assumption for the evaporation calculation.

"When C-111 was reevaluated in 1981, and the Questionable Integrity designation retained, the four independent teams did not consider the evaporative impact of the ^{144}Ce waste. There is no indication from the review record that they were aware that the tank waste temperature had risen to 190F because of the high-heat waste inventory."

Summary:

The consensus of the assessment team is that tank C-111 was not leaking during the 1965 – 1969 period when the surface level decrease occurred. The most likely explanation for the observed behavior is that ^{144}Ce waste transferred into the tank during the 1962 – 1964 period heated the tank to at least 190°F, and resulted in significant evaporation. A passive breathing rate of ~ 2.3 cfm at 190°F and 100% relative humidity combined with thermal contraction of the waste as it cooled, accounts for the -8.5 in surface level decrease.

10.0 CONCLUSIONS

The process for assessing the leak status of a tank is designed to estimate a leak probability. Probability is defined as a measure of the state of knowledge or belief about the likelihood that a specific state of nature (e.g., a tank has leaked or is leaking) is true. Probability must be between 0 (absolute certainty that the state of nature is not true) and 1 (absolute certainty that the state of nature is true). The process starts with a prior probability independent of the available data. This establishes any pre-evaluation bias and is typically established at 0.5 that the tank is leaking or has leaked without consideration of the specific data initiating this process (i.e., no pre-evaluation bias, either for or against a leak). Then reviews of in-tank data and ex-tank data are used to establish conditional probabilities for whether the leak hypothesis or the non-leak hypothesis is supported by the data. The conditional probabilities are used to adjust the leak probability toward a leak hypothesis (probability > 0.5) or a non-leak hypothesis (probability < 0.5).

There was consensus among the members of the assessment team that the available in-tank and ex-tank data indicated that the no-leak hypothesis was more consistent with the data, and that tank C-111 was not leaking during the 1965 – 1969 period when the surface level decrease was observed.

The most likely cause of the surface level decrease was a combination of evaporation and thermal waste contraction that occurred when Hot Semiworks strontium purification waste containing ~ 6.4 MCi ^{144}Ce was transferred into the tank during the 1962 – 1964 period. When the waste was transferred into tank C-111, it was generating ~ 175,000 BTU/hr. The tank heated to at least 190^{o}F based on available temperature records, resulting in significant waste evaporation. The 2.3 cfm passive breathing rate needed to remove the 190^{o}F saturated water vapor from the tank and account for the majority of the surface level decrease is at the low end of single-shell tank passive breathing rate measurements made during the 1990's. Evaporation accounted for ~ 5.6 in of the 8.5 in surface level decrease.

Evaporation was not the only contributor to the 8.5 in surface level decrease observed during the 1965 – 1969 period. The radioactive half-life of ^{144}Ce caused the heat generation in tank C-111 to decrease from the initial ~175,000 BTU/hr to ~1,400 BTU/hr by December, 1969. As the waste cooled, its density increased ~ 1.75%, causing the 166.5 in deep liquid waste layer to contract. Thermal contraction has the waste cooled accounted for ~ 2.9 in of the 8.5 in surface level decrease.

It was the combined effects of evaporation and thermal waste contraction the caused the observed 8.5 in surface level decrease in tank C-111 during the 1965 – 1969 period. The recommendation of the leak assessment team is that the integrity status of tank C-111 be changed from "Assumed Leaker" to "Sound".

The results of this assessment were presented to the Executive Safety Review Board on September 11, 2008. The Board concurred with the recommendation of the assessment team.

11.0 UNRESOLVED LEAK ASSESSMENT OBSERVATIONS

11.1 TIMELY DOCUMENTATION OF 1965 – 1969 SURFACE LEVEL DECREASE

There are no contemporary leak documentation records for the tank C-111 1965 – 1969 surface level decrease, even though the 8.5 in decrease could have represented a 23.4 kgal leak. The tank was first categorized as "Questionable Integrity" in 1968 according to SD-WM-TI-356 Rev. 0 *Waste Storage Tank Status and Leak Detection Criteria*, but no reference for the classification is given.

It is possible that when the strontium purification waste was transferred into tank C-111 the technical and operating staffs anticipated the both the waste temperature and evaporation increases in the tank. They may have been prepared for the surface level decrease once it began, and would not have identified a need for event documentation. By the time of the 1981 leak re-evaluation occurred nearly twenty years later, the process history of the strontium purification waste had apparently been lost, since the thermal history during the 1965 – 1969 storage period was not considered relevant to the review.

11.2 1981 LEAK RE-EVALUATION WASTE TEMPERATURE DATA

The 1981 leak re-evaluation of tank C-111 described in RHO-CD-1193 Rev. 0 *Review of Classification of Hanford Single-Shell Tanks 110-B, 111-C, 103-T, 107-TX, 104-TY, and 106-U* assumed that the waste temperature was less than 100^{o}F based on tank temperature data:

> "Tank temperature data taken during the time that the tank served as a receiver of Hot Semiworks low-level wastes show that the temperature of the bulk solution was less than 100^{o}F at the time that the tank was filled to the 191-inch level."

According to Figure 5-2 from RHO-CD-1172 Rev. 0 *Survey of The Single-Shell Tank Thermal Histories*, the tank solution temperature began to increase from 80^{o}F in January, 1963, and reached 190^{o}F by September, 1964, the last data date reported in the document. It is uncertain how the 1981 leak re-evaluation missed the temperature data, especially since the RHO-CD-1172 *Thermal History* report was published in December, 1981, just nine months after the RHO-CD-1193 leak re-evaluation.

However, the *Thermal History* document describes the difficulty in locating the temperature data needed to recreate the SST thermal histories:

> "The collection of single-shell tank thermal history data included Department of Energy – Richland Operations Office's records from the storage warehouse in Seattle, Washington, and discussions with 14 Rockwell Hanford operations employees... From these personal contacts and the contents of recorded data, the conclusion is that liquid levels were of primary importance and

> temperatures secondary until the self-boiling concept of in-tank solidification was started.
>
> "... Of the 12 [single-shell] tank farms, only the four associated with the Redox (241-S and -SX) and Purex (241-A and -AX) processes have a significant amount of retrieved [temperature] data. The data for the remaining eight tank farms are very limited and essentially nonexistent."

It seems likely that the 1981 leak re-evaluation effort used only the limited temperature data that were readily at hand, and therefore missed some important clues about the evaporation and thermal contraction phenomena at work on the tank waste, and that are now believed to have caused the 8.5 in surface level decrease.

11.3 1989 ASSIGNED LEAK VOLUME

The 1981 leak re-evaluation in RHO-CD-1193 did not estimate a leak volume. The first record of a leak volume is in May, 1989 correspondence, 8901832B R1 *Single-Shell Tank Leak Volumes*. The letter established an estimate of 5.5 kgal. The conflict between the 23.4 kgal apparent loss and the published 5.5 kgal leak estimate was not addressed by the correspondence.

It is likely that the 5.5 kgal leak estimate was rationalized by the tank C-111 drywell data that had been collected since 1975 – about 14 years' of accumulated data by the time that the letter was prepared. None of the drywells showed the presence of soil contamination indicating a leak.

According to HNF-3136 Rev. 0 *Analysis Techniques and Monitoring Results, 241-SX Drywell Surveillance Logs*, October, 1999 [D8109566]/WMNW/TRS-ES-VSMA-001, *Analysis Techniques Applied to The Dry Well* [sic] *Surveillance Gross Gamma Ray Data at the SX Tank Farm*:

> "The tank leak detection program was designed to identify tank failures in which a rapid release of at least 19,000 L (5,000 gal) of liquid entered the subsurface soils..."

Since none of the tank C-111 drywells showed evidence of a tank leak, the 1989 correspondence must have rationalized the leak size as no greater than 5,000 gallons; the additional 500 gallons may have been a 10% plus-up for added for conservatism.

12.0 REFERENCES

8901832B R1 *Single-Shell Tank Leak Volumes*, May 1989 [Accession Number D3688064]

GJ-HAN-93 *Vadose Zone Characterization Project at the Hanford Tank Farms: Tank Summary Data Report for Tank C-111*, January 1998 [\\hanford\data\Sitedata\HLANPlan\Geophysical_Logs\index.html]

GJPO-HAN-18 *Vadose Zone Characterization Project at the Hanford Tank Farms C Tank Farm Report*, July 1998 [\\hanford\data\Sitedata\HLANPlan\Geophysical_Logs\index.html]

HNF-SD-WM-CN-116 Rev. 0A *Calculation Note: Hydrogen Generation Rates at Steady-State Flammable Gas Concentrations for Single-Shell Tanks* September 1997 [Accession Number D197262773]

Measurements of the Passive Ventilation Rates of High-Level Radioactive Waste Tanks using Tracer Gases, 25th DOE/NRC Nuclear Air Cleaning and Treatment Conference [http://www.hss.energy.gov/CSA/CSP/hepa/Nureg_25th/waste4.pdf]

RHO-CD-1172 Rev. 0 *Survey of The Single-Shell Tank Thermal Histories,* December, 1981 [Accession Number D196031179]

RHO-CD-1193 Rev. 0 *Review of Classification of Hanford Single-Shell Tanks 110-B, 111-C, 103-T, 107-TX, 104-TY, and 106-U* March 1981 [Accession Number 292-001007]

RPP-5660 Rev. 0 *Collection and Analysis of Selected Tank Headspace Parameter Data* April 2000 [D8285501]

RPP-8321 Rev. 0 *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm – 200 East Area* June 2001 (Accession Number D6875483]

RPP-ENV-33418 Rev. 1 *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Releases*, February 2008 [Accession Number NA06755116]

SD-WM-TI-356 *Waste Storage Tank Status and Leak Detection Criteria* Volume 2 March 1990 [Accession Number D197006846]

WHC-MR-0132 *A History of the 200 Area Tank Farms* June 1990 (Accession Number D196015712)

APPENDIX A
TANK C-111 LEAK ASSESSMENT TEAM
MEETINGS #1 – #3 MEETING MINUTES

A1 INTRODUCTION

The minutes from the Leak Assessment Team meetings were prepared as a cumulative set of minutes that were incremented each week in order to maintain the records of the most recent and all previous meetings as a single record.

MEETING MINUTES

SUBJECT: 241-C-111 Leak Assessment Meeting #3				
TO: Distribution	BUILDING: 2750-E/B-225			
FROM: DJ Washenfelder	CHAIRMAN: Same			
DEPARTMENT-OPERATION-COMPONENT	AREA	SHIFT	DATE OF MEETING	NUMBER ATTENDING
Process Analysis/Technical Integration	200-E		08/21/2008	

Distribution:
DG Baide*‘
DA Barnes*‘
DW Brown*‘
TR Farris‘
LS Krogsrud*‘
PC Miller*
RN Ni
RG Quirk
WB Scott‘

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*Leak Assessment Team Members
‘Attendees

Discussion from August 21st Meeting #3:

Additional Passive Breathing Rate Considerations:

The magnitude of the passive breathing rate of tank C-111 is an important consideration if the 1964 – 1969 supernatant loss is to be explained by evaporation. The breathing rate would have to be ~ 3.5 cfm to account for the ~ 23.4 kgal loss over that time period.

References that include measured SST passive breathing rates indicate that 3.5 cfm is toward the low end of the measured range, and realistic:

- RPP-5660 *Collection and Analysis of Selected Tank Headspace Parameter Data* Table 3-15 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics", and Table 3-16 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics from Monthly Reports" list the passive breathing rates for SSTs equipped with SHMS. The breathing rates ranged from 1.8 to 52.5 cfm, depending on bulk waste temperature.
- Tracer gas studies of SSTs using sulfur hexafluoride showed breathing rates larger than those measured with the SHMS. For the nine passively ventilated SSTs (AX-102, AX-103, BY-105, TX-104, U-102, U-103, U-105, U-106, and U-111) reported in RPP-5660 Table 3-17 "Submitted Ventilation Rate References" and Table 4-1 "Tank Headspace Parameter Summary", measured breathing rates varied from a low of 2 cfm for low temperature tanks (U-102 [82^{o}F], U-103 [83^{o}F], and U-111 [77^{o}F] to a high of 53 cfm (SX-103 [143^{o}F]).
- Further analysis of Table 4-1 indicates that for tanks <110^{o}F, the breathing rate was generally 3 – 5 cfm, with a bounding flow of 7 cfm; for tanks >110^{o}F, the rate was 7 – 9 cfm, with a bounding flow of about 10 cfm.

Time-Sequenced Gross Gamma Scans 1975 – 1994

RPP-8831, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm – 200 East Area*, provides the gross gamma logs for the drywells surrounding tank C-111 for the period 1975 – 1994. Review of the gross gamma scans of the drywells shows no hits during the monitoring period and no evidence of contamination from a tank C-111 leak. The time-sequenced scans are included at the end of the meeting minutes.

In-Tank Photos

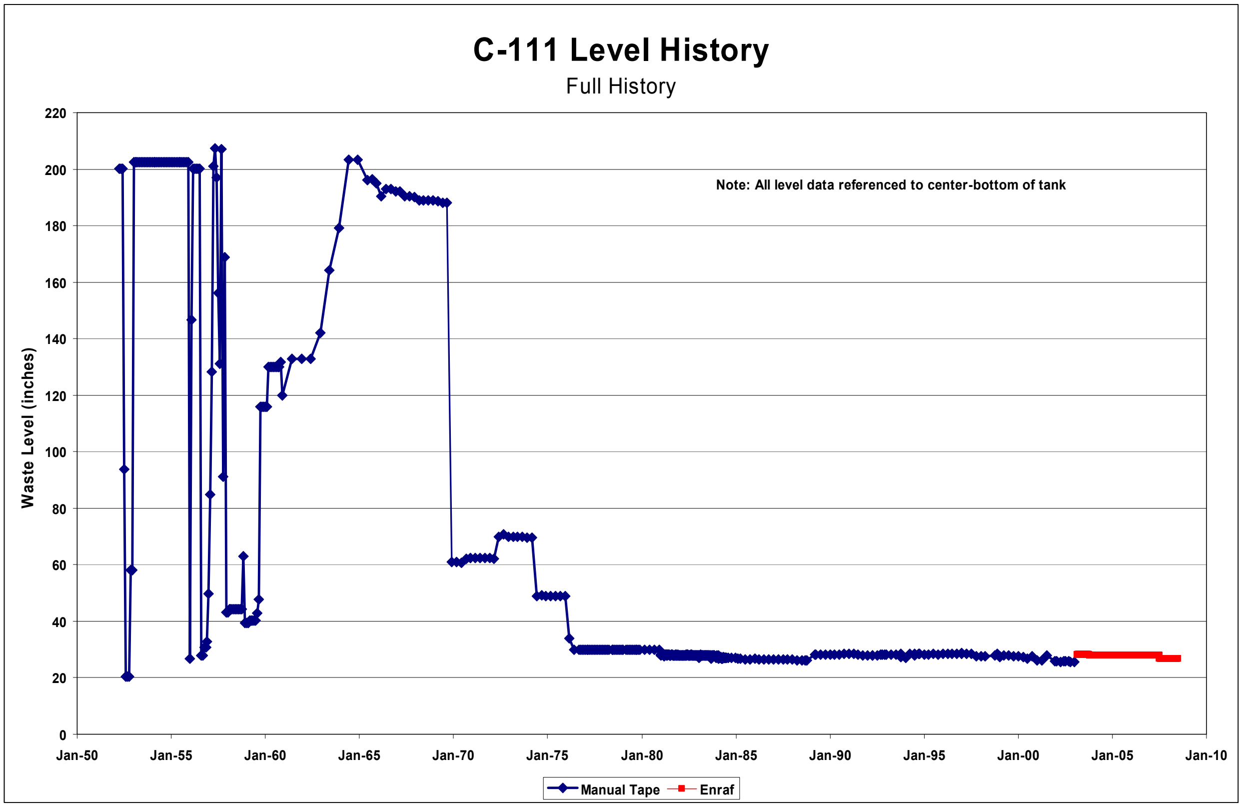
The latest available in-tank photos were taken in 1970. Interior features and the waste are badly obscured by thick fog. The fog suggests the tank headspace was fully saturated with water vapor, supporting the 100% relative humidity assumption used in the 3.5 cfm estimate of waste loss.

Post-Loss Surface Level History

The accompanying chart shows that following the 1964 – 1969 loss tank C-111 experienced extended periods of surface level stability: January 1972 – March 1973, when the tank contained 66 kgal of supernatant and 81 kgal of sludge; June 1972 – March 1974 following receipt of ~ 22 kgal of waste from catch tank 241-C-301 in the 2nd quarter of CY 1972; and June 1974 – December 1975 and June 1976 – present following further transfers from the tank. Tank C-111 was declared interim stabilized March 9, 1984 (SD-WM-TI-356 D197006846).

The original manual tape data was referenced to the base of the vertical sidewall, and did not account for the 12" dished bottom. The manual tape levels shown in the chart have been adjusted by adding 12 in to be consistent with current level monitoring standards (e.g., center-bottom dish). The ENRAF data are referenced to center-bottom when installed, so no adjustments are necessary.

Figure A-1. Tank C-111 Surface Level History



Discussion from August 14th Meeting #2:

Tank C-111 Leak / Non-Leak Hypotheses

The Leak / Non-Leak Hypotheses were presented for consideration:

Leak Hypothesis:
"The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leak Hypothesis:
"The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

The shape of the liquid level decrease in figure **Tank C-111 Liquid Level Decline and Estimated Heat Generation Rate (1964 – 1969)** presented below would be expected if the tank was leaking at about the 190 in level, as well as if the ~ 6.4 MCi of short-lived Ce^{144} was heating the tank and causing bulk liquid evaporation at a rate proportional to the remaining Ce^{144} inventory.

In the 4th quarter of CY 1969, about 350 kgal of supernatant was transferred from tank C-111 to tank C-104, leaving ~ 66 kgal of supernatant and ~ 84 kgal of sludge, ~ 54 in. No further liquid level decreases were reported once the transfer was made, and the liquid level appears to have remained stable until tank C-111 received catch tank waste in the 2nd quarter of CY 1972. This suggests that, if the liquid level decrease at the 190 in level was caused by a leak from the primary structure, the leak site was high than the ~ 54 in stable liquid level in the tank.

It is possible that a liner leak above the 54 in level was created by thermal stress when the Ce^{144} was introduced to the tank. The leak assessment team discussed splitting the assessment into two sections that would separately assess the leak / non-leak hypotheses for waste levels above 54 in and for waste levels below 54 in. After further discussion, the team judged that the best course of action was to consider the only a single set of hypotheses, and the reflect the > 54 in and < 54 in uncertainty in the expert elicitation probabilities. The decision to keep them combined principally reflected the belief that a leak resulting in an 8.5 in decrease in the liquid level would have had a volume of 23.4 kgal. A leak of this size should have been detected in one or more of the drywells surrounding the tank since it is much greater than the frequently cited rule-of-thumb that a 5 kgal leak is the detection threshold.

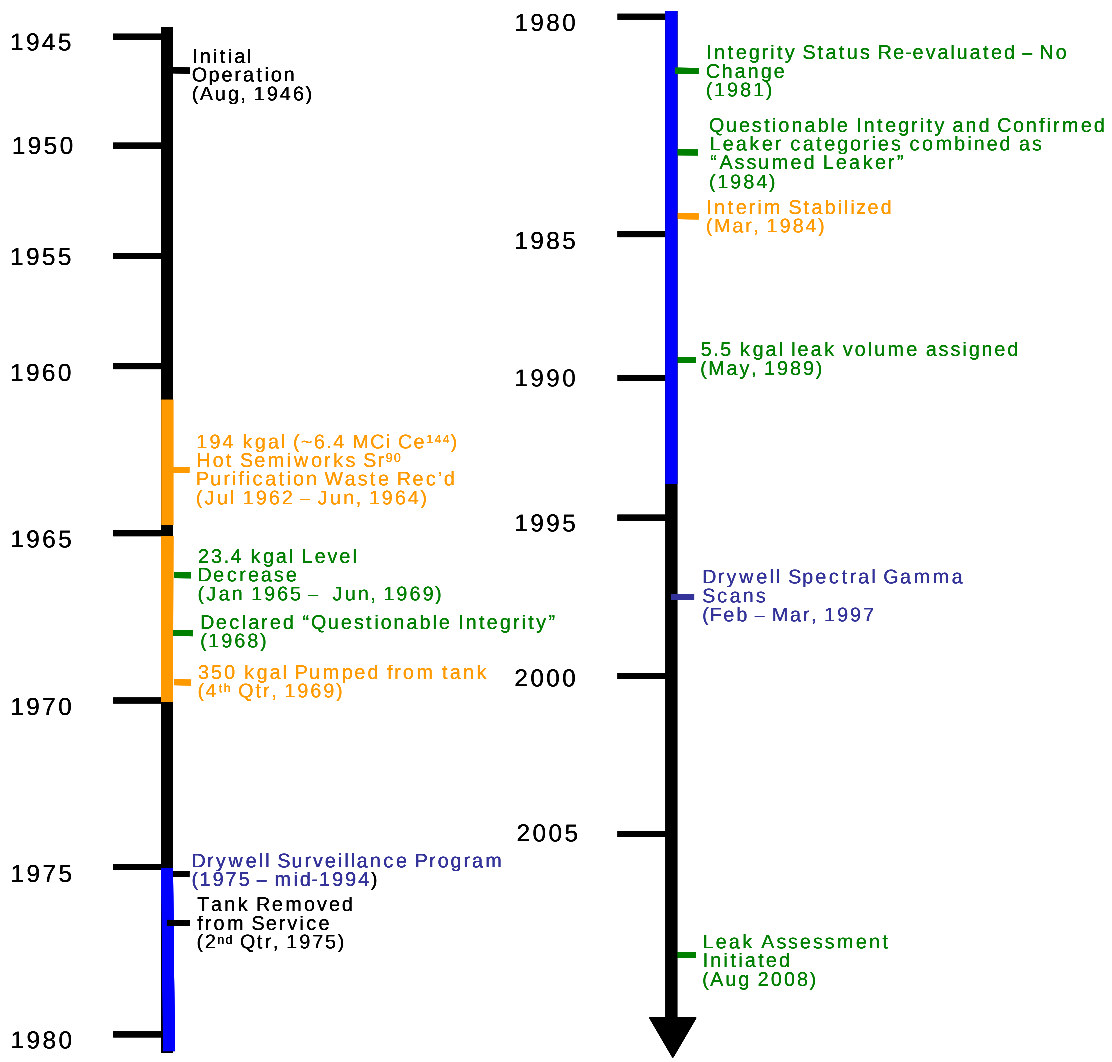
To establish whether the split hypothesis would have a dependable basis, the available surface level data for the period 1969 – 1972 will be replotted and examined for previously unreported changes by the leak assessment panel.

The team also considered another possibility - that the observed evaporative effect of transferring the Ce^{144} solution into tank C-111 was anticipated by the technical and operating staff. This would account for the fact that there is no unusual occurrence report or environmental deviation report available that documents the loss. Additionally, while the -8.5 in loss is readily converted to a 23.4 kgal volume, a tank loss was not assigned until May 1989, about 20 years after the loss; and the assigned leak volume was 5.5 kgal, "...based on liquid level calculations" [8901832B R1]. The reference does not record the liquid level calculation. It is more likely that the 5.5 kgal estimate was somehow related to the 5 kgal drywell leak detection threshold. The leak assessment team concluded that the lack of occurrence documentation was speculative and its presence or absence should not be a expert elicitation consideration. It is possible that the loss was documented and has been lost in the intervening years.

Passive Breathing Rate

It was concluded that the passive breathing rate from tank C-111 should assume that the dome space air is completely saturated in the absence of forced ventilation. Calculations reviewed at the August 6th meeting demonstrated that the 23.4 kgal loss could be accounted for by a breathing rate of 3.5 cfm if the bulk waste supernatant temperature was 190 ^{o}F (last recorded value). RPP-5660 *Collection and Analysis of Selected Tank Headspace Parameter Data* p68 indicates that tank C-111 had a passive breathing rate of 7 cfm. This value was based on a calculated average passive exchange rate of 0.45% of the headspace volume per day [D197262773] rather than a measured rate. If this calculation is correct, the breathing rate would have been well above the rate necessary to evaporate the 23.4 kgal during the 1964 – 1969 period.

Figure A-2. Tank 241-C-111 History Timeline



Discussion from August 6th Meeting #1:

Tank C-111 Characteristics and Operating History:

Between July, 1962 through June, 1964, tank C-111 received about ~ 6.4 MCi of Ce^{144} from Hot Semiworks Sr^{90} purification waste, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964. Tank C-111 showed a decrease in waste volume from October, 1965 through June, 1969, of between 1 and 5 kgal per quarter, and a total loss of ~ 23.4 kgal. At the time, the bulk solution temperature was at least 190^{o}F, driven by the radiolytic heat generation of the Ce^{144} [RPP-ENV-33418 and RHO-CD-1172 Rev. 0].

The half-life of Ce^{144} is 284.3 days; by the end of the October 1, 1965 – December 26, 1969 period of the unexplained 8.5 in liquid level decrease, the ~ 6.4 MCi of Ce^{144} would have decayed to 0.8% of it's original inventory, with a corresponding heat load of ~ 1,400 BTU/hr.

Tank C-111 Leak Integrity Status History:

Between October 1, 1965 and December 26, 1969 there was an unexplained 8.5 in liquid level decrease in the tank. According to SD-WM-TI-356 Rev. 0 *Waste Storage Tank Status and Leak Detection Criteria*, the tank was classified as a "Questionable Integrity" (QI) tank in 1968 as a result of the unexplained decrease. Four independent teams reviewed the historical data during the June 1980 – April 1981 period as part of a coordinated review of six single-shell tanks classified as QI tanks. Three of the four teams recommended that the leak integrity status be changed from QI to "Confirmed Leaker" (CL); the fourth team recommended that the existing QI classification be retained. According to the ground rules in effect, the teams' recommendations had to be unanimous to change the QI classification to CL. Tank C-111 remained classified as a QI tank (RHO-CD-1193).

The 1981 evaluation noted that from 1957 to at least January 1, 1965 that tank C-111 liquid level remained stable at about 191 in. Between October, 1965 and December 1969 – the period when the level loss was noted - the tank served as a low-level waste storage repository for feed solution. After this period, about 100 kgal of supernatant waste remained in the tank; the liquid level remained stable for the next 55 months.

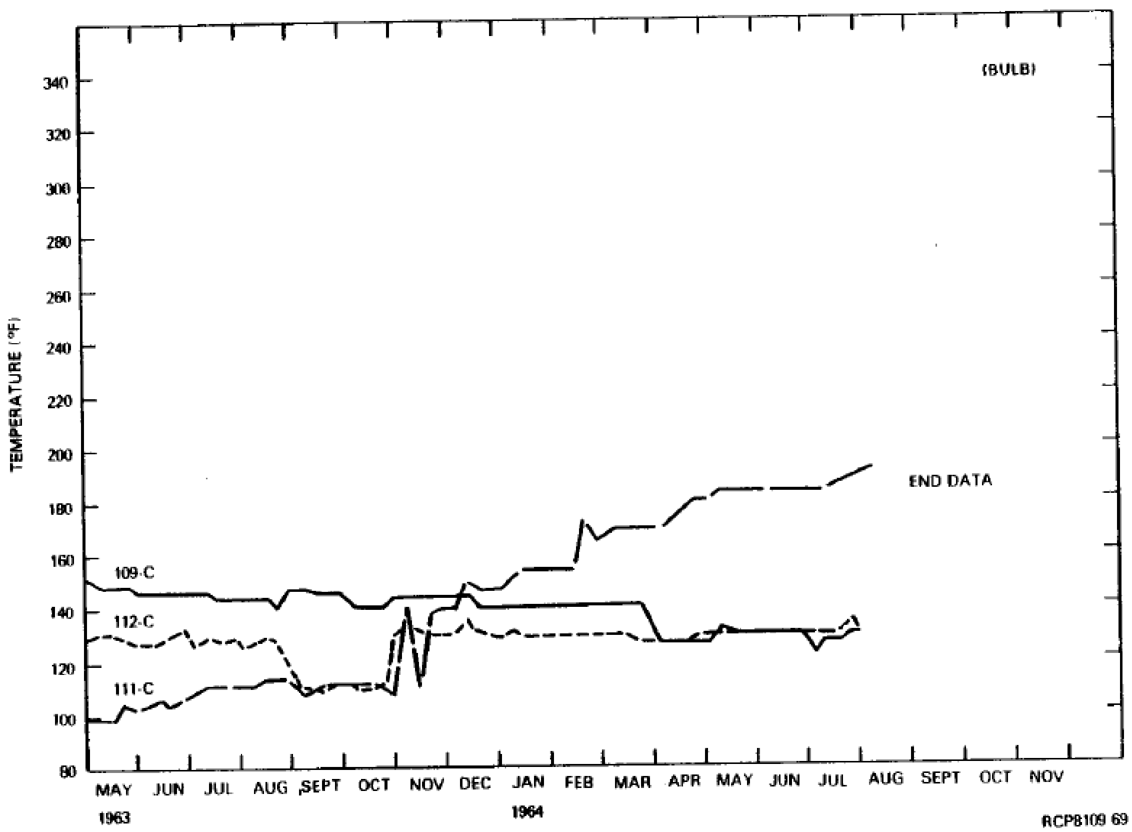
The 1981 evaluation noted that the tank bulk solution temperature was less than 100^{o}F during the 1965 – 1969 period, and that the tank was not connected to an operating exhauster. Evaporative loss was discounted as a possible explanation for the liquid level decrease.

In 1984 the "Questionable Integrity" and "Confirmed Leaker" tank classifications were combined and changed to "Assumed Leaker"[8901832B R1]. In May, 1989 a leak volume of 5.5 kgal was assigned to tank C-111 [8901832B R1].

In 2007 tank C-111 was again reviewed for purposes of retrieval technology selection and closure. Process history records that had not been reviewed during the 1981 evaluation identified exceptions to the earlier data set, that, if available during the earlier review, would possibly have altered the outcome:

- During the period immediately before the liquid level decrease began, tank C-111 was not receiving low-level waste as the 1981 evaluation believed. Records show that from July, 1962 through June, 1964, tank C-111 received 194 kgal of Sr^{90} purification waste from the Hot Semiworks. Records show that the waste from the purification process would have contained ~ 6.4 MCi of Ce^{144}, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964.
- The tank bulk solution temperature was not 100°F as the 1981 evaluation supposed, but closer to 190°F according to RHO-CD-1172 Rev. 0, *Survey of The Single-Shell Tank Thermal Histories*, reflecting the high heat content of the Ce^{144} waste. The bulk solution temperature during the period May, 1963 – August, 1964 is shown below.

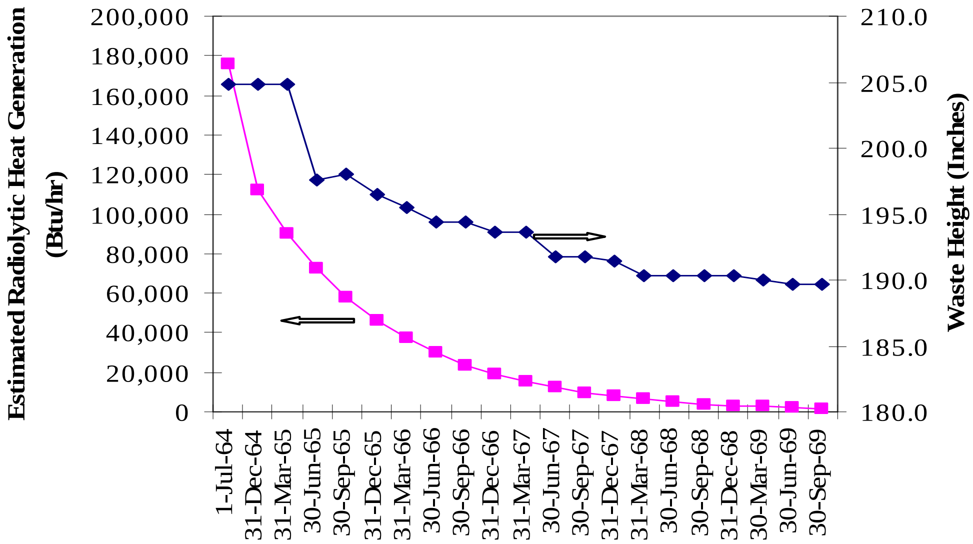
FigureA-3. Tank C-111 Temperature Chart for May 1963 – September 1964.



Evaluation:

The accompanying chart shows the time-based liquid level loss from tank C-111, plotted with the decay-corrected remaining inventory of Ce^{144} in the tank. Within the limits of error, the two curves have virtually the same shape, and the same rate of change, strongly suggesting that the 23,400 gallon loss resulted from evaporation rather than a leak through the tank liner.

Figure A-4. Tank C-111 Liquid Level Decline and Estimated Heat Generation Rate (1964 – 1969)



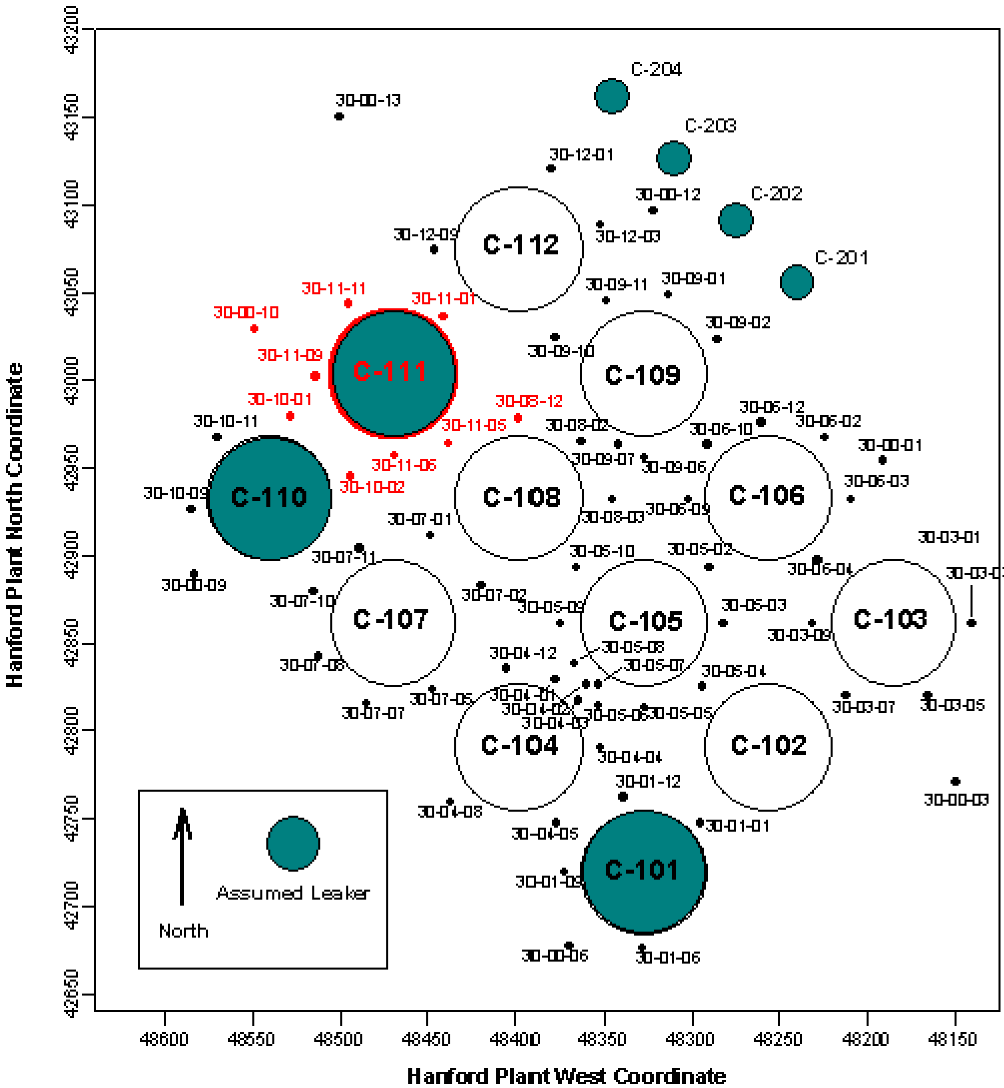
If the bulk waste supernatant temperature was 190 ^oF (last recorded value) and the air exiting the tank was 100% saturated, then the exhaust rate needed to satisfy the observed 23,400 gal loss is only 3.5 cfm. Similarly, if the waste temperature was 200 ^oF and the air existing the tank was 100% saturated, then the exhaust rate needed is only 1.4 cfm. These rates are within the expected natural breathing rate range for unventilated single-shell tanks.

Drywell Data:

The DOE Grand Junction Office (GJO) performed a baseline characterization of the gamma-ray-emitting radionuclides that are distributed in the vadose zone sediments surrounding the single-shell tanks (SSTs) at the Hanford Site. Occurrences of these radionuclides were measured by monitoring the drywells positioned around the SSTs with a spectral gamma logging system (SGLS). This system employs a high-purity germanium detector and is capable of producing laboratory-quality assays of the gamma-emitting radionuclides in the vicinity of a borehole. The spectral gamma-ray logging results obtained from the monitoring the drywells surrounding tank C-111 were reported in 1998 [GJ-HAN-93].

There are nine drywells surrounding tank C-111: 30-11-01, 30-08-12, 30-11-05, 30-11-06, 30-10-02, 30-10-01, 30-11-09, 30-00-10, and 30-11-11. Drywells 30-10-01 and 30-10-02 associated with tank C-110 and drywell 30-08-12 associated with tank C-108 have been traditionally used to monitor tank C-111 because of their proximity. The drywells are highlighted in red in the figure.

Figure A-5. Plan Map of Tanks and Drywells in 241-C Tank Farm [GJ-HAN-93]



The GJO report concluded the following with respect to the drywells surrounding tank C-111: "The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-111 was completed using the SGLS. There is no indication in the data obtained from the SGLS, historical gross gamma-ray logs, and other available information of residual radionuclide contamination from a past or present leak from tank C-111. Data leading to the determination that this tank leaked in the past should be re-evaluated. However, the data considered in this report indicate that surface spills have occurred in the past and that minor leaks from pipelines or other service facilities may have also occurred. The contamination detected at and below the base of the tank farm excavation in boreholes 30-08-12 and 30-10-02 is indicative of a plume(s) that probably originated from tanks C-108 and C-110."

The GJO tank farm summary report GJPO-HAN-18, *Vadose Zone Characterization Project at the Hanford Tank Farms C Tank Farm Report* summarized the results of the tank C-111 SGLS scans as follows:

According to the Tank Summary Data Report for tank C-111 (DOE 1998a),
"8.6.10 Boreholes Surrounding Tank C-111

The Cs-137 from 32 to 66 ft around borehole 30-11-01 was carried down during the construction of this borehole or later migrated down the outside of the casing. This contamination was removed from the visualization data set.

Cs-137 was detected in isolated occurrences at or just above the MDL in borehole 30-11-05 at about 12 ft and in borehole 30-11-06 at about 13 ft. If the Cs-137 is truly present, then it represents contamination that is most likely localized to the borehole casing; therefore, this contamination was removed from the data set.

The Cs-137 detected at the surface of borehole 30-11-11 is most likely direct gamma rays from nearby contaminated equipment.

Isolated occurrences of Cs-137 were detected in the bottom of boreholes 30-11-01 and 30-11-06. This contamination is interpreted to be from particulate matter that has fallen into the bottom of the borehole."

RPP-8831, *Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm – 200 East Area*, provides the gross gamma logs for the drywells surrounding tank C-111 for the period 1975 – 1994. The time-sequenced gross gamma scans for drywells 30-11-01, 30-11-05, 30-11-06, 30-11-09, and 30-11-11 are presented below:

Figure A-6. Tank 241-C-111 Time-Sequenced Gross Gamma Scans 1975 – 1994

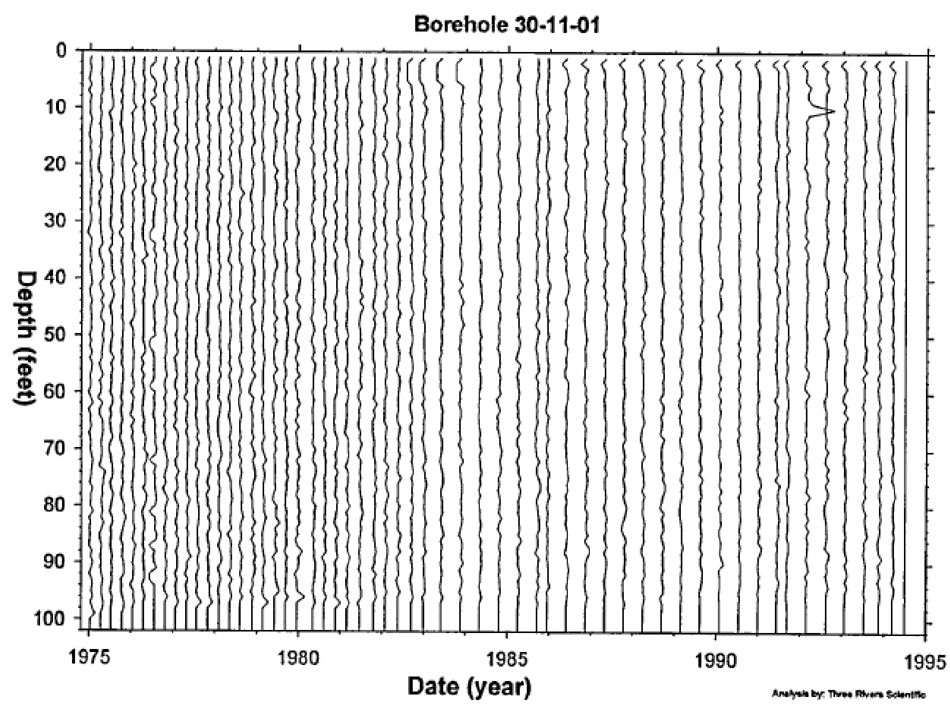
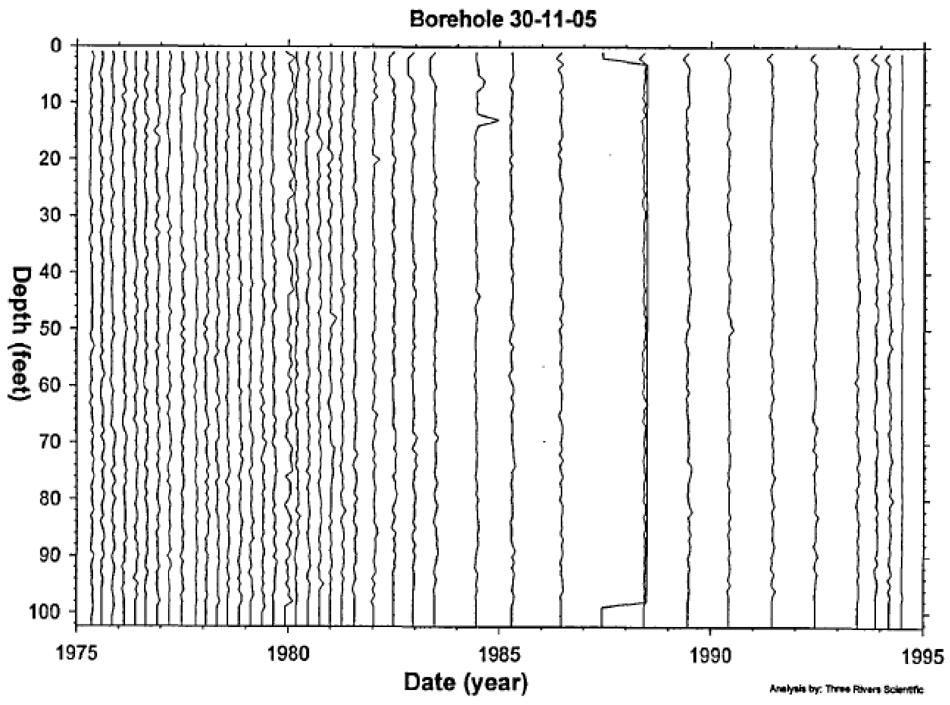


Figure A-6. Tank 241-C-111 Time-Sequenced Gross Gamma Scans 1975 – 1994 (cont'd)



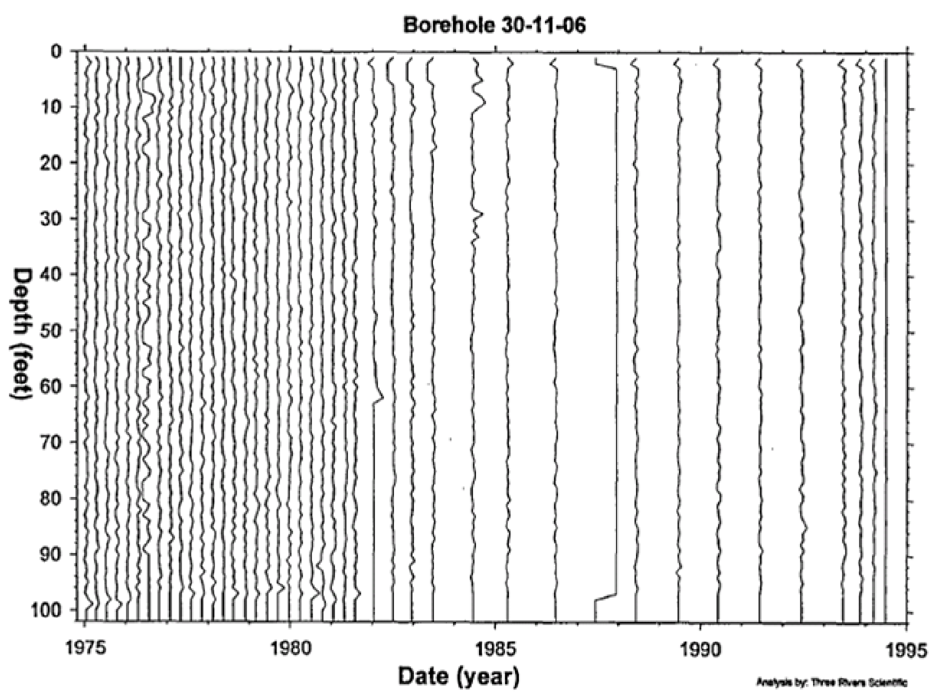
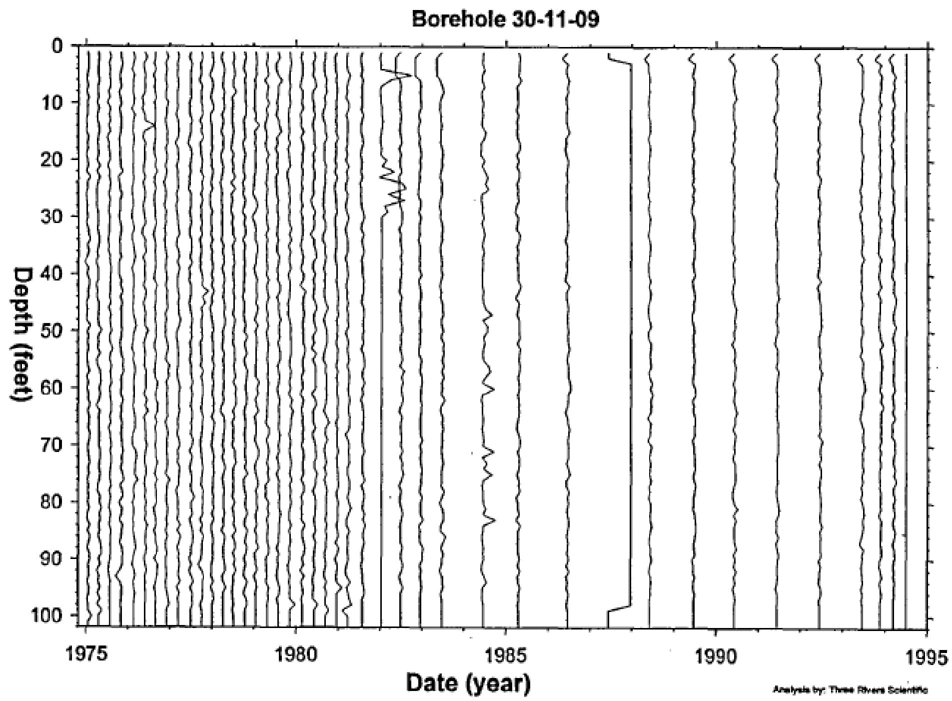
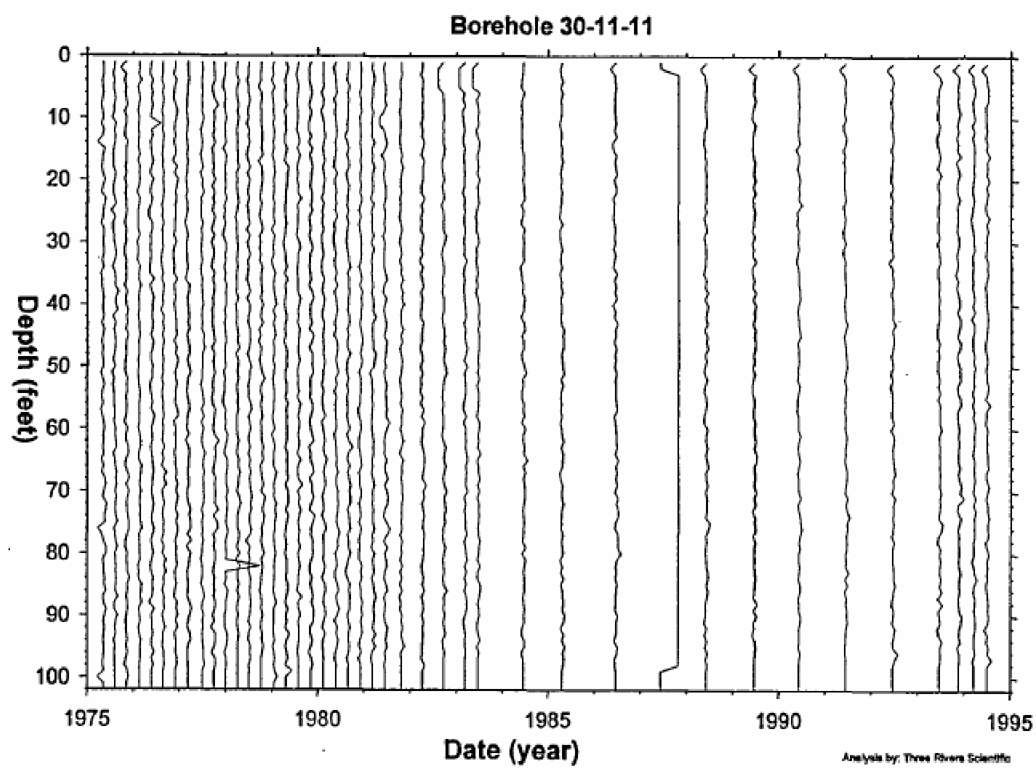


Figure A-6. Tank 241-C-111 Time-Sequenced Gross Gamma Scans 1975 – 1994 (cont'd)





Team Member Actions Status:

Leak assessment actions from the August 14th meeting are listed below:

	Member	Action
1.	DA Barnes	No further liquid level decreases were reported once the 350 kgal transfer was made, and the liquid level appears to have remained stable until tank C-111 received catch tank waste in the 2nd quarter of CY 1972. Plot the available post-transfer surface level data for the period 1969 – 1972 and examine for previously unreported changes. *Status: Complete. Chart incorporated into Meeting Minutes #3. Following the 1964 – 1969 loss there were extended periods of surface level stability: January 1972 – March 1973, when the tank contained 66 kgal of supernatant and 81 kgal of sludge; June 1972 – March 1974 following receipt of ~ 22 kgal of waste from catch tank 241-C-301 in the 2nd quarter of CY 1972; and June 1974 – December 1975 and June 1976 – present following further transfers from the tank.*
2.	DA Barnes	Obtain historical tank C-111 gross gamma drywell scans. *Status: Complete. Time-sequenced scans incorporated into Meeting Minutes #3. Review of the gross gamma scans of the drywells shows no hits during the monitoring period and no evidence of contamination from a tank C-111 leak.*
3.	DG Baide	Recover any tank C-111 passive ventilation headspace breathing rate measurements performed by PNNL. JL Huckaby was the principal investigator. *Status: Complete. Discussion incorporated into Meeting Minutes #3. RPP-5660 Collection and Analysis of Selected Tank Headspace Parameter Data Table 3-15 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics", and Table 3-16 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics from Monthly Reports" list the passive breathing rates for SSTs equipped with SHMS. The breathing rates ranged from 1.8 to 52.5 cfm, depending on bulk waste temperature. Tracer gas studies of ten SSTs using sulfur hexafluoride showed breathing rates larger than those measured with the SHMS.*

Leak assessment actions from the August 6th meeting are listed below:

	Member	Action
1.	ME Johnson	Prepare tank C-111 chart that simultaneously plots liquid level, decay BTUs, bulk supernatant temperature. *Status: Complete. Action modified to re-evaluate the required breathing rate for tank C-111 to have evaporated the 23,400 gal. This value was originally calculated to be about 5 cfm to exhaust ~5,460 gal of water per year with a bulk supernatant temperature of 190°F and 70% humidity. The rate was deemed to be at the high end of the observed natural breathing rate in single-shell tanks. The revised calculation using a psychrometric calculator at* http://www.natmus.dk/cons/tp/atmcalc/atmoclc1.htm *indicate a breathing rate of* 3.5 cfm at *190°F and 100% humidity or 10.9 cfm at 190°F and 70% humidity would be required.*

	Member	Action
2.	ME Johnson	Before the introduction of the Ce144 strontium purification waste, tank C-111 had received heat-producing ferrocyanide sludge waste. Determine whether the base heat load present in the tank at the onset of the strontium purification transfers would have measurably affected the evaporation rate. *Status: Not complete.*
3.	ME Johnson	Prepare similar tank C-109 chart. *Status: Cancelled.*
4.	DG Baide	Locate any available references that discuss the variation in passive breathing rate with single-shell tank bulk waste temperatures. *Status: Complete. See Item 3, August 14th actions.*
5.	ME Johnson	The 23,400 gallon liquid level drop in tank C-111 over a multiyear period did not cause an anomaly or deviation report to be issued. Do any of the records reviewed for preparation of the tank C-111 section in RPP-ENV-33418 Rev. 1 *Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Releases*, February 2008 [Accession #NA06755116] suggest this occurred? *Status: Complete. No evidence that either a UOR or deviation report was issued was recovered.*

References:

Briefings:

Date	Title
August 6, 2008	Tank C-111 Historical Leak Assessment Review, M. E. Johnson

Correspondence - Letters:

Number	Title
8901832B R1	*Single-Shell Tank Leak Volumes*, May 1989 [Accession #D3688064]

Documents:

Number	Title
GJ-HAN-93	*Vadose Zone Characterization Project at the Hanford Tank Farms*
	Tank Summary Data Report for Tank C-111, January 1998 [\\hanford\data\Sitedata\HLANPlan\Geophysical_Logs\index.html]
GJPO-HAN-18	*Vadose Zone Characterization Project at the Hanford Tank Farms C Tank Farm Report*, July 1998 [\\hanford\data\Sitedata\HLANPlan\Geophysical_Logs\index.html]
HNF-SD-WM-CN-116 Rev. 0A	*Calculation Note: Hydrogen Generation Rates at Steady-State Flammable Gas Concentrations for Single-Shell Tanks* September 1997 [Accession Number D197262773]
RHO-CD-1172 Rev. 0	*Survey of The Single-Shell Tank Thermal Histories*, December, 1981 [Accession #D196031179]
RHO-CD-1193 Rev. 0	*Review of Classification of Hanford Single-Shell Tanks 110-B, 111-C, 103-T, 107-TX, 104-TY, and 106-U* March 1981 [Accession #292-001007]
RPP-5660 Rev. 0	*Collection and Analysis of Selected Tank Headspace Parameter Data* April 2000 [D8285501]
RPP-8321 Rev. 0	*Analysis and Summary Report of Historical Dry Well Gamma Logs for the 241-C Tank Farm – 200 East Area* June 2001 (Accession #D6875724]
RPP-ENV-33418 Rev. 1	*Hanford C-Farm Leak Assessments Report: 241-C-101, 241-C-110, 241-C-111, 241-C-105, and Unplanned Releases*, February 2008 [Accession #NA06755116]
SD-WM-TI-356	*Waste Storage Tank Status and Leak Detection Criteria Volume 2* March 1990 [Accession #D197006846]
WHC-MR-0132	*A History of the 200 Area Tank Farms* June 1990 (Accession #D196015712)
	Measurements of the Passive Ventilation Rates of High-Level Radioactive Waste Tanks using Tracer Gases, 25th DOE/NRC Nuclear Air Cleaning and Treatment Conference [http://www.hss.energy.gov/CSA/CSP/hepa/Nureg_25th/waste4.pdf]

APPENDIX B
TANK SX-104 LEAK ASSESSMENT TEAM
EXPERT ELICITATION FORMS

B1. TABLE 2 IN TANK DATA

Tank 241-C-111 Leak Assessment In-Tank Data Form 2008-08-13
(from HNF-3747, Rev. 0)

SURFACE LEVEL MEASUREMENTS (SLM)	Observation		
ENRAF			
Unexplained, repeatable drop>tolerance ENRAFs were not deployed at the time of the 1968 Questionable Integrity (QI) declaration. The declaration was based on a 8.5 in decrease in the manual tape.	Yes	No	NA
Significant drop	Yes	No	NA
Significant trend change	Yes	No	NA
FIC			
Unexplained, repeatable drop>tolerance Earliest available record from PCSACS, dated January 12, 1981, indicates tank was monitored only with a manual tape.	Yes	No	NA
Significant drop	Yes	No	NA
Significant trend change	Yes	No	NA
MANUAL GAUGE			
Unexplained, repeatable drop>tolerance Between October 1, 1965 and December 26, 1969 there was an unexplained 8.5 in liquid level decrease in the tank. The tank was classified as a “Questionable Integrity” (QI) tank as a result of the unexplained decrease. Between July, 1962 through June, 1964, tank C-111 received about ~ 6.4 MCi of Ce^{144} from Hot Semiworks Sr^{90} purification waste, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964. Tank C-111 showed a decrease in waste volume from October, 1965 through June, 1969, of between 1 and 5 kgal per quarter, and a total loss of ~ 23.4 kgal. At the time, the bulk solution temperature was at least 190oF, driven by the radiolytic heat generation of the Ce^{144} [RPP-ENV-33418 and RHO-CD-1172 Rev. 0].	Yes	No	NA
Significant drop	Yes	No	NA
Significant trend change In the 4th quarter of CY 1969, about 350 kgal of supernatant was transferred from tank C-111 to tank C-104, leaving ~ 66 kgal of supernatant and ~ 84 kgal of sludge, ~ 54 in. No further liquid level decreases were reported once the transfer was made, and the liquid level appears to have remained stable until tank C-111 received catch tank waste in the 2nd quarter of CY 1972. Following the 1964 – 1969 loss tank C-111 experienced extended periods of surface level stability: January 1972 – March 1973, when the tank contained 66 kgal of supernatant and 81 kgal of sludge; June 1972 – March 1974 following receipt of ~ 22 kgal of waste from catch tank 241-C-301 in the 2nd quarter of CY 1972; and June 1974 – December 1975 and June 1976 – present following further transfers from the tank. Tank C-111 was declared interim stabilized March 9, 1984 (SD-WM-TI-356 D197006846).	Yes	No	NA

LIQUID OBSERVATION WELL (LOW) MEASUREMENTS	Observation		
Unexplained, repeatable drop>tolerance Tank C-111 was not equipped with a liquid observation well.	Yes	No	NA
Significant drop	Yes	No	NA
Significant trend change	Yes	No	NA

CORROBORATING EVIDENCE	Corroborates SLM or LOW Data Given		
Thermocouple	Leak	Alt. Hypoth.	NA
Salt well screen	Leak	Alt. Hypoth.	NA
Standard Hydrogen Monitoring System	Leak	Alt. Hypoth.	NA
Photos/Videos	Leak	Alt. Hypoth.	NA.
Weather conditions	Leak	Alt. Hypoth.	NA
Barometric pressure Calculations reviewed at the August 6th meeting demonstrated that the 23.4 kgal loss could be accounted for by a breathing rate of 3.5 cfm if the bulk waste supernatant temperature was 190°F (last recorded value). RPP-5660 *Collection and Analysis of Selected Tank Headspace Parameter Data* p68 indicates that tank C-111 had a passive breathing rate of 7 cfm. This value was based on a calculated average passive exchange rate of 0.45% of the headspace volume per day [D197262773] rather than a measured rate. If this calculation is correct, the breathing rate would have been well above the rate necessary to evaporate the 23.4 kgal during the 1964 – 1969 period. References that include measured SST passive breathing rates indicate that 3.5 cfm is toward the low end of the measured range, and realistic: • RPP-5660 Collection and Analysis of Selected Tank Headspace Parameter Data Table 3-15 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics", and Table 3-16 "Standard Hydrogen Monitoring System [H2] Monitoring Data Statistics from Monthly Reports" list the passive breathing rates for SSTs equipped with SHMS. The breathing rates ranged from 1.8 to 52.5 cfm, depending on bulk waste temperature. • Tracer gas studies of SSTs using sulfur hexafluoride showed breathing rates larger than those measured with the SHMS. For the nine passively ventilated SSTs (AX-102, AX-103, BY-105, TX-104, U-102, U-103, U-105, U-106, and U-111) reported in RPP-5660 Table 3-17 "Submitted Ventilation Rate References" and Table 4-1 "Tank Headspace Parameter Summary", measured breathing rates varied from a low of 2 cfm for low temperature tanks (U-102 [82°F], U-103 [83°F], and U-111 [77°F] to a high of 53 cfm (SX-103 [143°F]). • Further analysis of Table 4-1 indicates that for tanks <110°F, the breathing rate was generally 3 – 5 cfm, with a bounding flow of 7 cfm; for tanks >110°F, the rate was 7 – 9 cfm, with a bounding flow of about 10 cfm.	Leak	Alt. Hypoth.	NA
Precipitation	Leak	Alt. Hypoth.	NA
Temperature	Leak	Alt. Hypoth.	NA
Surface flooding	Leak	Alt. Hypoth.	NA
Process history During the period immediately before the liquid level decrease began, tank C-111 was not receiving low-level waste as the 1981 leak evaluation believed. Records show that from July, 1962 through June, 1964, tank C-111 received 194 kgal of Sr^{90} purification waste from the Hot Semiworks. Records show that the waste from the purification process would have contained ~ 6.4 MCi of Ce^{144}, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964. The transfers of the Sr90 purification waste from the Hot Semiworks in C-111 caused the tank bulk solution temperature to increase to at least 190°F according to a May 1963 - August 1964 temperature plot in RHO-CD-1172 Rev. 0, *Survey of The Single-Shell Tank Thermal Histories,* reflecting the high heat content of the Ce^{144} waste. The 1981 leak evaluation supposed that the tank bulk solution temperature was about 100°F and therefore discounted evaporation as a possible explanation for the observed liquid level decrease.	Leak	Alt. Hypoth.	NA
Occurrence reports No records could be located that either an unusual occurrence report or an environmental deviation report was generated at the time of the 8.5 in liquid level decrease. The 8901832B R1 *Single-Shell Tank Leak Volumes* , May 1989 [Accession #D3688064] indicates only that the tank was categorized as Questionable Integrity until 1984 when the QI and Confirmed Leaker categories were merged into a single "Assumed Leaker" category.	Leak	Alt. Hypoth.	NA

Construction history	Leak	Alt. Hypoth.	NA
Gas Release Events	Leak	Alt. Hypoth.	NA
Equipment maintenance calibration RPP-ENV-33418 Rev. 1 (p60) indicates that the apparent 20 kgal loss during the during the 01/01/65 - 06/30/65 period resulted from replacing the manual tape electrode. Discussion with the author indicates that the electrode was replaced twice during the period and that the apparent loss was the result of the maintenance activity rather than a leak.	Leak	Alt. Hypoth.	NA
Waste characteristics Between July, 1962 through June, 1964, tank C-111 received about ~ 6.4 MCi of Ce^{144} from Hot Semiworks Sr^{90} purification waste, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964. Tank C-111 showed a decrease in waste volume from October, 1965 through June, 1969, of between 1 and 5 kgal per quarter, and a total loss of ~ 23.4 kgal. At the time, the bulk solution temperature was at least 190^{o}F, driven by the radiolytic heat generation of the Ce^{144} [RPP-ENV-33418 and RHO-CD-1172 Rev. 0]. The half-life of Ce^{144} is 284.3 days; by the end of the October 1, 1965 – December 26, 1969 period of the unexplained 8.5 in liquid level decrease, the ~ 6.4 MCi of Ce^{144} would have decayed to 0.8% of it's original inventory, with a corresponding heat load of ~ 1,400 BTU/hr.	Leak	Alt. Hypoth.	NA
In-tank operations Between July, 1962 through June, 1964, tank C-111 received about ~ 6.4 MCi of Ce^{144} from Hot Semiworks Sr^{90} purification waste, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964.	Leak	Alt. Hypoth.	NA
Other (specify) - 1981 Leak Assessment In 2007 tank C-111 was again reviewed for purposes of retrieval technology selection and closure . Process history records that had not been reviewed during the 1981 evaluation identified exceptions to the earlier data set, that , if available during the earlier review, would possibly have altered the outcome: During the period immediately before the liquid level decrease began, tank C-111 was not receiving low-level waste as the 1981 evaluation believed. Records show that from July, 1962 through June, 1964, tank C-111 received 194 kgal of Sr^{90} purification waste from the Hot Semiworks. Records show that the waste from the purification process would have contained ~ 6.4 MCi of Ce^{144}, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964. The tank bulk solution temperature was not 100^{o}F as the 1981 evaluation supposed, but closer to 190^{o}F according to RHO-CD-1172 Rev. 0, *Survey of The Single-Shell Tank Thermal Histories* , reflecting the high heat content of the Ce^{144} waste.	Leak	Alt. Hypoth.	NA
Other (specify)	Leak	Alt. Hypoth.	NA
Other (specify)	Leak	Alt. Hypoth.	NA

Construction history	Leak	Alt. Hypoth.	NA
Gas Release Events	Leak	Alt. Hypoth.	NA
Equipment maintenance calibration RPP-ENV-33418 Rev. 1 (p60) indicates that the apparent 20 kgal loss during the during the 01/01/65 - 06/30/65 period resulted from replacing the manual tape electrode. Discussion with the author indicates that the electrode was replaced twice during the period and that the apparent loss was the result of the maintenance activity rather than a leak.	Leak	Alt. Hypoth.	NA
Waste characteristics Between July, 1962 through June, 1964, tank C-111 received about ~ 6.4 MCi of Ce^{144} from Hot Semiworks Sr^{90} purification waste, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964. Tank C-111 showed a decrease in waste volume from October, 1965 through June, 1969, of between 1 and 5 kgal per quarter, and a total loss of ~ 23.4 kgal. At the time, the bulk solution temperature was at least 190°F, driven by the radiolytic heat generation of the Ce^{144} [RPP-ENV-33418 and RHO-CD-1172 Rev. 0]. The half-life of Ce^{144} is 284.3 days; by the end of the October 1, 1965 – December 26, 1969 period of the unexplained 8.5 in liquid level decrease, the ~ 6.4 MCi of Ce^{144} would have decayed to 0.8% of it's original inventory, with a corresponding heat load of ~ 1,400 BTU/hr.	Leak	Alt. Hypoth.	NA
In-tank operations Between July, 1962 through June, 1964, tank C-111 received about ~ 6.4 MCi of Ce^{144} from Hot Semiworks Sr^{90} purification waste, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964.	Leak	Alt. Hypoth.	NA
Other (specify) - 1981 Leak Assessment In 2007 tank C-111 was again reviewed for purposes of retrieval technology selection and closure . Process history records that had not been reviewed during the 1981 evaluation identified exceptions to the earlier data set, that , if available during the earlier review, would possibly have altered the outcome: During the period immediately before the liquid level decrease began, tank C-111 was not receiving low-level waste as the 1981 evaluation believed. Records show that from July, 1962 through June, 1964, tank C-111 received 194 kgal of Sr^{90} purification waste from the Hot Semiworks. Records show that the waste from the purification process would have contained ~ 6.4 MCi of Ce^{144}, equivalent to ~ 175,000 BTU/hr when time decay-corrected to July, 1964. The tank bulk solution temperature was not 100°F as the 1981 evaluation supposed, but closer to 190°F according to RHO-CD-1172 Rev. 0, *Survey of The Single-Shell Tank Thermal Histories* , reflecting the high heat content of the Ce^{144} waste.	Leak	Alt. Hypoth.	NA
Other (specify)	Leak	Alt. Hypoth.	NA
Other (specify)	Leak	Alt. Hypoth.	NA

B2 TABLE 3 EX-TANK DATA

Tank 241-C-111 Leak Assessment Ex-Tank Data Form 2008-08-13
(from HNF-3747, Rev. 0)

SPECTRAL GAMMA LOGS (SGL)	Observation		
Radionuclides			
Man-made? The GJO report GJ-HAN-93 *Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-111* concluded the following with respect to the drywells surrounding tank C-111: "The characterization of the gamma-ray-emitting contamination in the vadose zone surrounding tank C-111 was completed using the SGLS. There is no indication in the data obtained from the SGLS, historical gross gamma-ray logs, and other available information of residual radionuclide contamination from a past or present leak from tank C-111. Data leading to the determination that this tank leaked in the past should be re-evaluated. However, the data considered in this report indicate that surface spills have occurred in the past and that minor leaks from pipelines or other service facilities may have also occurred. The contamination detected at and below the base of the tank farm excavation in boreholes 30-08-12 and 30-10-02 is indicative of a plume(s) that probably originated from tanks C-108 and C-110."	Yes	No	NA
Multiple?	Yes	No	NA
Distribution			
Peak at bottom of tank?	actual data		No or NA
Peak near surface? The GJO report GJ-HAN-93 Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-111 concluded the following with respect to the drywells surrounding tank C-111: "However, the data considered in this report indicate that surface spills have occurred in the past and that minor leaks from pipelines or other service facilities may have also occurred."	actual data		No or NA
Increased activity in between?	actual data		No or NA
Increased activity below tank? The GJO report GJ-HAN-93 Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-111 concluded the following with respect to the drywells surrounding tank C-111: "The contamination detected at and below the base of the tank farm excavation in boreholes 30-08-12 and 30-10-02 is indicative of a plume(s) that probably originated from tanks C-108 and C-110."	actual data		No or NA
Activity across boreholes			
Multiple boreholes? The GJO report GJ-HAN-93 Vadose Zone Characterization Project at the Hanford Tank Farms Tank Summary Data Report for Tank C-111 concluded the following with respect to the drywells surrounding tank C-111: "The contamination detected at and below the base of the tank farm excavation in boreholes 30-08-12 and 30-10-02 is indicative of a plume(s) that probably originated from tanks C-108 and C-110."	Yes	No	NA

Activity over time

Abrupt increase (bottom)?	Yes	No	NA
Abrupt increase (elsewhere)?	Yes	No	NA
Gradual increase (bottom)?	Yes	No	NA
Gradual increase (elsewhere)?	Yes	No	NA

CORROBORATING EVIDENCE	Corroborates SGL or GGL Data Given		
Moisture Probe	Leak	Alt. Hypoth.	NA
Psychrometrics	Leak	Alt. Hypoth.	NA
Bore hole core sample	Leak	Alt. Hypoth.	NA
Laterals	Leak	Alt. Hypoth.	NA
Weather conditions			
Barometric pressure	Leak	Alt. Hypoth.	NA
Precipitation	Leak	Alt. Hypoth.	NA
Temperature	Leak	Alt. Hypoth.	NA
Surface flooding	Leak	Alt. Hypoth.	NA
Process history	Leak	Alt. Hypoth.	NA
Drywell drilling logs	Leak	Alt. Hypoth.	NA
Occurrence reports	Leak	Alt. Hypoth.	NA
Surface spills	Leak	Alt. Hypoth.	NA
Transfer line leaks	Leak	Alt. Hypoth.	NA
Construction history	Leak	Alt. Hypoth.	NA
Equipment maintenance calibration	Leak	Alt. Hypoth.	NA
Waste characteristics	Leak	Alt. Hypoth.	NA
In-tank operations	Leak	Alt. Hypoth.	NA
Other (specify)	Leak	Alt. Hypoth.	NA
Other (specify)	Leak	Alt. Hypoth.	NA

B3. TABLE 6 ELICITATION FORMS

Expert Opinion: D. A. Barnes

Tank C-111 Leak Assessment Expert Elicitation Form 2008-08-27
From HNF-3747, Rev. 0)

Elicitation Date: 9/3/2008

Elicitation from: DA Barnes

Eliciation by: DJ Washenfelder

Hypotheses:

Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.50	0.50	1.00

0.50 was chosen so that no bias is introduced, either for or against a tank leak.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.10	0.90	0.11

I strongly support evaporation over leak. 1. Losses started immediately after introducing hot waste and seeing temperature increase, 2. Evaporation modelling supports evaporative loss, as long as 3-5 cfm breathing rate is realistic, 3. Most documented breathing rates in SSTs are >10 cfm, 4. Loss rate follows decay curve of radionuclides, 5. No further loss after pumpdown and short-lived radionuclides decay away.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent.

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.40	0.60	0.67

No contamination spikes noted in any drywells. Indicates sound tank, but small leak could be missed by drywells. A loss of 23000 gallons is less likely to be missed by a drywell.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.40	0.60	0.67

Spectral data confirms gross gamma data. No contamination present.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.50	0.50	1.00

I am treating the gross gamma and spectral data as independent measurements with no inherent interdependence, thus a valuse of 0.50

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.11	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.67	0.67	1.00	1.00

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio	L(SLM,LOW)
	0.11

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio	L(SGL,GGL)
	0.67

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis	L(in,ex)
	0.07

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.07	0.93	0.07

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. $\Omega_1 = L(in,ex) \times \Omega_O$
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Notes and Key:

Manual entries (Elicited probabilities)
Calculated entries

SLM: Surface Level Measurements
LOW: Liquid Observation Well
GGL: Gross Gamma Log
SGL: Spectral Gamma Log

For elicited probabilities, the ratio column is p(*|L)/p(*|NL).

Expert Opinion: D. G. Baide

Tank C-111 Leak Assessment Expert Elicitation Form 2008-08-27
From HNF-3747, Rev. 0)

Elicitation Date: 9/2/2008

Elicitation from: DG Baide

Eliciation by: DJ Washenfelder

Hypotheses:

Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

Prior Probability - Part 1

True State L	True State NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.10	0.90	0.11

C-110, -111, -112 part of three tank cascade. C-110 has been reassessed, and the conclusion is that the tank did not leak from a breach in the liner. Based on the available temperature data (1963 and later), C-110 was a low heat tank, without thermal cycling. The tank has a low probability that it was leaking before the 1964 - 1969 period when it stored the high-heat Ce-144 waste.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.40	0.60	0.67

The surface level drop equivalent to a loss of 23.4 kgal is a significant drop. Even with the Ce-144 waste probably contributing to evaporation, the calculations that all of the loss was due to evaporation would have to be convincing. It is possible that evaporation would mask a leak, for example.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent.

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.10	0.90	0.11

Most of the gamma peaks in the drywell scans were near the surface, indicative of surface spills. The five drywells' behavior over time show no change in peaks as would be expected for an active leak.

The 23.4 kgal leak would have been a substantial volume. With 5 drywells around the tank, the plume from a leak of this size should have been intercepted by a least one of the drywells.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.10	0.90	0.11

The SGL argument is similar to the GGL argument. For a leak of this size, the SGL scans should have identified a plume. They did not.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.50	0.50	1.00

The drywell scans made with SGLs add no additional information above and beyond the GGL scans. The GGL scans show not indication of a leak. The GGLs were taken between 1975 and 1994, shortly have the leak would have occurred.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.67	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.11	0.11	1.00	1.00

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio		L(SLM,LOW)
		0.67

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

The GGL scans were nearly contemporary with the C-111 liquid level drop (1975 - 1994 vs. 1964 - 1969), and occurred over a two decade period. The SGLs were completed in 1995, well after the suspected leak date, and done only once.

Ex-Tank Liklihood Ratio		L(SGL,GGL)
		0.11

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis		L(in,ex)
		0.07

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.01	0.99	0.01

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. $\Omega_1 = L(in,ex) \times \Omega_O$
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Notes and Key:

Manual entries (Elicited probabilities)
Calculated entries

SLM: Surface Level Measurements
LOW: Liquid Observation Well
GGL: Gross Gamma Log
SGL: Spectral Gamma Log

For elicited probabilities, the ratio column is p(*|L)/p(*|NL).

Expert Opinion: D. W. Brown

Tank C-111 Leak Assessment Expert Elicitation Form 2008-08-27
From HNF-3747, Rev. 0)

Elicitation Date: 9/3/2008

Elicitation from: DW Brown

Eliciation by: DA Barnes / DJ Washenfelder

Hypotheses:

Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

Prior Probability - Part 1

True State L	True State NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.50	0.50	1.00

No data prior to the loss suporting a leak integrity bias - either for a leak, or a non-leak condition.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.20	0.80	0.25

For the four year period after the addition of the Hot Semi-Works waste, the level dropped. This was most likely the result of evaporation based on the leak assessment team's review and the evaporation model prepared during the assessment.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent.

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.20	0.80	0.25

The 20 years' of drywell gross gamma scans show no leakage. At least one of the drywells should have shown contamination based on the 23.4 kgal leak size.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.40	0.60	0.67

There was only one set of SGL scans. The single set is not as reliable a prediction of leak integrity as the 20-year set of gross gamma scans.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.10	0.90	0.11

The gross gamma scans and the spectral gamma scan confirm each other, and support the 'no-leak' hypothesis.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.25	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.25	0.67	1.00	0.11

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio		L(SLM,LOW)
		0.25

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

There are more data available from gross gamma scans, for a longer period of time.

Ex-Tank Liklihood Ratio		L(SGL,GGL)
		0.03

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis		L(in,ex)
		0.01

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.01	0.99	0.01

Lack of documentation of the 1964 - 1969 surface level change suggests that the facility staff was aware of the circumstances and concluded that the loss was the result of evaporation. Probability is consistent with this explanation.

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. Ω_1= L(in,ex) x Ω_O
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Notes and Key:

Manual entries (Elicited probabilities)
Calculated entries

SLM: Surface Level Measurements
LOW: Liquid Observation Well
GGL: Gross Gamma Log
SGL: Spectral Gamma Log

For elicited probabilities, the ratio column is p(*|L)/p(*|NL).

Expert Opinion: L. S. Krogsrud

Tank C-111 Leak Assessment Expert Elicitation Form 2008-08-27
From HNF-3747, Rev. 0)

Elicitation Date: 8/29/2008

Elicitation from: LS Krogsrud

Eliciation by: DJ Washenfelder

Hypotheses:

Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

Prior Probability - Part 1

True State L	True State NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.20	0.80	0.25

Relatively low heat tank for most of its process life; the Ce-144 waste has a short half-life, and even though it raised the bulk waste temperature, the period of time would have been reasonably short compared to tanks that have been historically classified as "high heat" tanks.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.50	0.50	1.00

The asymptotic appearance of the surface level decrease could be accounted for by either a hydraulic-driven leak, or be the result of evaporation of the liquid being driven by the short-lived Ce-144 waste.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

No LOW present in C-111.

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent.

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.25	0.75	0.33

Dyrwell scans not consistent with ~ 23 kgal leak.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.25	0.75	0.33

GJPO report indicates SGLS hits were most likely from surface leaks, or from a nearby plume, or carried down during construction.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.50	0.50	1.00

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
1.00	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.33	0.33	1.00	1.00

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio		L(SLM,LOW)
		1.00

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio		L(SGL,GGL)
		0.33

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis		L(in,ex)
		0.33

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.08	0.92	0.08

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. $\Omega_1 = L(in,ex) \times \Omega_O$
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. $(L|in,ex) = \Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Notes and Key:

Manual entries (Elicited probabilities)
Calculated entries

SLM: Surface Level Measurements
LOW: Liquid Observation Well
GGL: Gross Gamma Log
SGL: Spectral Gamma Log

For elicited probabilities, the ratio column is p(*|L)/p(*|NL).

Expert Opinion: P. C. Miller

Tank C-111 Leak Assessment Expert Elicitation Form 2008-08-27
From HNF-3747, Rev. 0)

Elicitation Date: 9/3/2008

Elicitation from: PC Miller

Eliciation by: DA Barnes / DJ Washenfelder

Hypotheses:

Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio L:NL	
p(L)	p(NL)	Ω_0	No bias in favor of a leaking or sound tank prior to the 1964 - 1969 event.
0.50	0.50	1.00	

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)	Based on data and modeled evaporation, it is likely that the level drop was caused by evaporation.
	0.33	0.67	0.49	

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent.

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.25	0.75	0.33

Nothing in ex-tank gross gamma scan data supports a leak.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.15	0.85	0.18

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.40	0.60	0.67

Only 1 set of SGL scans. Number would have been lower if there had been multiple SGL scans to compare with GGL scans.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.49	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.33	0.18	1.00	0.67

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio	L(SLM,LOW)
	0.49

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio	L(SGL,GGL)
	0.22

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis	L(in,ex)
	0.11

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.10	0.90	0.11

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. $\Omega_1 = L(in,ex) \times \Omega_O$
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Notes and Key:

Manual entries (Elicited probabilities)
Calculated entries

SLM: Surface Level Measurements
LOW: Liquid Observation Well
GGL: Gross Gamma Log
SGL: Spectral Gamma Log

For elicited probabilities, the ratio column is p(*|L)/p(*|NL).

Expert Opinion: D. J. Washenfelder

**Tank C-111 Leak Assessment Expert Elicitation Form 2008-08-27
From HNF-3747, Rev. 0)**

Elicitation Date: 9/3/2008

Elicitation from: DJ Washenfelder

Eliciation by: DA Barnes

Hypotheses:

Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by a failure of the primary tank structure (leak)."

Non-Leaker: "The level decrease displayed by tank 241-C-111 from 1964 to 1969 was caused by evaporation. The evaporation was primarily driven by the introduction of high temperature waste in 1964, that raised the tank temperature to at least 190 deg. F."

Prior Probability - Part 1

True State: L	True State: NL	Liklihood Ratio L:NL
p(L)	p(NL)	Ω_0
0.20	0.80	0.25

Three of the 100-Series C Farm tanks have been classified as assumed leakers. One of the three, C-110 has been re-assessed, and determined to have most likely leaked from overfilling and waste loss through a spare inlet nozzle rather than from a breach in the tank liner. There is no history to indicate that C-111 was ever a high heat tank, or that it was thermally cycledd. In 1964 at the time of the 23.4 kgal loss, the tank was only ~ 20 years old.

p(L) = "prior" probability that an assumed sound tank has leaked given only two pieces of information: it is a single-shell tank, and it is either a high-heat tank or not. Any specific data on past surface level drops or ex-tank radioactivity measurements are ignored.

p(NL) = "prior" probability that an assumed sound tank has not leaked given the same data. p(NL) = 1- p(L)

Ω_0 = "prior" odds in favor of the leak hypothesis. Ω_0 = p(L)/p(NL)

Conditional Probabilities

In-Tank Data Surface Level Measurement - Part 2

Surface Level Measurement	p(SLM|L) (If no SLM, enter NA here and in Parts 4 and 5)	p(SLM|NL)	L(SLM)
	0.40	0.60	0.67

High-heat Ce-144 waste storage contributed to evaporation, but it is possible that the evaporation could have masked a leak. The 23.4 kgal loss experienced during the 1964 - 1969 period was equivalent to a passive breathing rate of ~ 3.5 cfm at 100 RH. He and SF_6 tracer gas measurements conducted on passively ventilated SSTs during the 1990's show that the 3.5 cfm rate is at the low end of the measured breathing rates, and therefore credible. The most recent photo, taken in 1972, shows the headspace completely fogged, indicating that the 100% RH is a reasonable assumption for the evaporation calculation.

When C-111 was reevaluated in 1981, and the Questionable Integrity designation retained, the four independent teams did not consider the evaporative impact of the Ce-144 waste. There is no indication from the review record that they were aware that the tank waste temperature had risen to 190F because of the high-heat waste inventory.

Considering the surface level measurement data reviewed for the leak assessment:

p(SLM|L) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a leaker.

p(SLM|NL) = ["posterior"] probability that the surface level measurement data would be observed, if the tank is a non - leaker. p(SLM|NL) = 1 - p(SLM|L)

L(SLM) = p(SLM|L)/p(SLM|NL). If surface level data are not available for the leak assessment, then L(SLM) = 1

If there are several essentially redundant surface level measurements (e.g., ENRAF, FIC, MT), the probabilities should be assessed only for the more diagnostic and reliable one.

In-Tank Data Liquid Observation Well - Part 3

Liquid Observation Well	p(LOW|L) (if no LOW, enter NA here and in Parts 4 and 5)	p(LOW|NL)	L(LOW)
	NA	NA	1.00

Considering the interstitial liquid level data reviewed for the leak assessment:

p(LOW|L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is a leaker.

p(LOW|NL)) = ["posterior"] probability that the LOW interstitial liquid level data would be observed, if the tank is not a leaker. p(LOW|NL) = 1 - p(LOW|L)

L(LOW) = p(LOW|L)/p(LOW|NL). If LOW intersititial liquid level data are not available for the leak assessment, then L(LOW) = 1

Surface Level Measurement - Liquid Observation Well Interdependence - Part 4

Surface Level Measurement - Liquid Observation Well Interdependence	p(SLM|LOW,L) (if no LOW, enter NA)	p(SLM|LOW,NL)	L(SLM|LOW)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(SLM|LOW,L) = ["posterior"] probability that the surface level measurement data would be observed if the LOW interstitial liquid level data are observed, and if the tank is a leaker.

p(SLM|LOW,NL) = ["posterior"] probability that a surface level measurement data would be observed if the LOW interstitial liquid level measurement data are observed, and if the tank is a non-leaker. p(SLM|LOW,NL) = 1 - p(SLM|LOW,L)

L(SLM|LOW) = p(SLM|LOW,L)/p(SLM|LOW,NL) . If either surface level measurement data or LOW intersititial liquid level data are not available for the leak assessment, then L(SLM|LOW) = 1.

If there is no LOW, skip to the next part.

Liquid Observation Well - Surface Level Measurement Interdependence - Part 5

Liquid Observation Well - Surface Level Measurement Interdependence	p(LOW|SLM,L) (if no SLM, enter NA)	p(LOW|SLM,NL)	L(LOW|SLM)
	NA	NA	1.00

Considering that in-tank data sources may be interdependent:

p(LOW|SLM,L) = ["posterior"] probability that the LOW interstitial liquid level data would be observed if a surface level measurement decrease is observed, and if the tank is a leaker.

p(LOW|SLM,NL) = ["posterior"] probability that a LOW interstitial liquid level measurement decrease would be observed if a surface level measurement decrease is observed, and if the tank is a non-leaker. p(LOW|SLM,NL) = 1 - pp(LOW|SLM,L)

L(LOW|SLM) = p(LOW|SLM,L)/p(LOW|SLM,NL) . If either surface level data or LOW intersititial liquid level data are not available for the leak assessment, then L(LOW|SLM) = 1.

Ex-Tank Data - Gross Gamma Drywell Logs - Part 6

Gross Gamma Drywell Logs	p(GGL|L) (if no GGL, enter NA here and in Parts 8 and 9)	p(GGL|NL)	L(GGL)
	0.30	0.70	0.43

20 years of gross gamma scan records show no peaks. A leak of this magnitude is likely to have shown up in at least one of the five drywells.

Considering the historical gross gamma drywell logs reviewed for the leak assessment:

p(GGL|L) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a leaker.

p(GGL|NL) = ["posterior"] probability that the gross gamma logs would be observed, if the tank is a non - leaker. p(GGL|NL) = 1 - p(GGL|L)

L(GGL) = p(GGL|L)/p(GGL|NL). If gross gamma logs are not available for the leak assessment, then L(GGL) = 1

Ex-Tank Data - Spectral Gamma Drywell Logs - Part 7

Spectral Gamma Drywell Logs	p(SGL|L) (if no SGL, enter NA here and in Parts 8 and 9)	p(SGL|NL)	L(SGL)
	0.40	0.60	0.67

A single set of SGLs was made in 1995. They confirm the data from 20 years of GGLs, but since they were not repeated over time, there has to be less confidence in their predict ion whether or not the tank was leaking.

Considering the spectral gamma drywell logs reviewed for the leak assessment:

p(SGL|L) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a leaker.

p(SGL|NL) = ["posterior"] probability that the spectral gamma drywell logs would be observed, if the tank is a non - leaker. p(SGL|NL) = 1 - p(SGL|L)

L(GGL) = p(SGL|L)/p(SGL|NL). If spectral gamma drywell logs are not available for the leak assessment, then L(SGL) = 1.

Gross Gamma Log - Spectral Gamma Log Interdependence - Part 8

Gross Gamma Log - Spectral Gamma Log Interdependence	p(GGL|SGL,L)	p(GGL|SGL,NL)	L(GGL|SGL)
	NA	NA	1.00

Considering that ex-tank data sources may be interdependent:

p(GGL|SGL,L) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are are observed, and if the tank is a leaker.

p(GGL|SGL,NL) = ["posterior"] probability that the gross gamma logs would be observed if the spectral gamma logs are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(GGL|SGL,L)

L(GGL|SGL) = p(GGL|SGL,L)/p(GGL|SGL,NL). If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(GGL|SGL) = 1.

Spectral Gamma Log - Gross Gamma Log Interdependence - Part 9

Spectral Gamma Log - Gross Gamma Log Interdependence	p(SGL|GGL,L)	p(SGL|GGL,NL)	L(SGL|GGL)
	0.50	0.50	1.00

Only one set of spectral gamma logs was made for the tank, and this occurred in 1995, 30 years after the apparent leak. The single set of SGLs was too distant from the event to impact the evaluation, and was only a single set of data.

Considering that ex-tank data sources may be interdependent:

p(SGL|GGL,L) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are observed, and if the tank is a leaker.

p(SGL|GGL,NL) = ["posterior"] probability that the spectral gamma logs would be observed if the gross gamma logs are are observed, and if the tank is a non-leaker. p(GGL|SGL,NL) = 1 - p(SGL|GGL,L)

L(SGL|GGL) = p(SGL|GGL,L) /p(SGL|GGL,NL) . If either gross gamma logs or spectral gamma logs are not available for the leak assessment, then L(SGL|GGL) = 1.

Combined Liklihood Ratios

L(SLM)	L(LOW)	L(SLM|LOW)	L(LOW|SLM)
0.67	1.00	1.00	1.00

L(GGL)	L(SGL)	L(GGL|SGL)	L(SGL|GGL)
0.43	0.67	1.00	1.00

Which In-Tank Condition Applies? (Mark X in Box)

SLM & No LOW?	X
LOW & No SLM?	
SLM & LOW; SLM most important? (Mark Part 4 NA)	
SLM & LOW; LOW most important? (Mark Part 5 NA)	

In-Tank Liklihood Ratio		L(SLM,LOW)
		0.67

If SLM and no LOW: L(SLM,LOW) = L(SLM)
if LOW and no SLM: L(SLM,LOW) = L(LOW)
If SLM and LOW and SLM most important: L(SLM,LOW) = L(LOW|SLM) x L(SLM)
If SLM and LOW and LOW most important: L(SLM,LOW) = L(SLM|LOW) x L(LOW)

Which Ex-Tank Condition Applies? (Mark X in Box)

GGL & No SGL?	
SGL & No GGL?	
GGL & SGL; GGL most important? (Mark Part 8 NA)	X
GGL & SGL; SGL most important? (Mark Part 9 NA)	

Ex-Tank Liklihood Ratio		L(SGL,GGL)
		0.43

If GGL and no SGL: L(SGL,GGL) = L(GGL)
if SGL and no GGL: L(SGL,GGL) = L(SGL)
If GGL and SGL and GGL most important: L(SGL, GGL) = L(SGL|GGL) x L(GGL)
If GGL and SGL and SGL most important: L(SGL, GGL) = L(GGL|SGL) x L(LSGL)

Combined Likelihood Ratio for Leak Hypothesis		L(in,ex)
		0.29

L(in,ex) = L(SLM,LOW) x L(SGL,GGL)

Posterior Probability for Leak Hypothesis

p(L|in,ex)	p(NL|in,ex)	Ω_1
0.07	0.93	0.07

Ω_1 = posterior (post-leak assessment) odds in favor of leak hypothesis. Ω_1= L(in,ex) x Ω_O
p(L|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. (L|in,ex) = $\Omega_1/(\Omega_1+1)$
p(NL|in,ex) = posterior probability (post-leak assessment) that the tank is a leaker. p(NL|in,ex) = 1- p(L|in,ex)

Notes and Key:

Manual entries (Elicited probabilities)
Calculated entries

SLM: Surface Level Measurements
LOW: Liquid Observation Well
GGL: Gross Gamma Log
SGL: Spectral Gamma Log

For elicited probabilities, the ratio column is p(*|L)/p(*|NL).

APPENDIX C
TANK C-111 EVAPORATION RATE ESTIMATED FOR OCTOBER 1965 – DECEMBER 1969

Tank C-111 Evaporation rate estimated for October 1965 - December 1969 - Message (HTML)

From: Johnson, Michael E
Sent: Mon 8/11/2008 8:47 AM
To: Washenfelder, Dennis J
Cc:
Subject: Tank C-111 Evaporation rate estimated for October 1965 - December 1969

Attachments: Tank C-111 Evaporation rates.xls (17 KB); C-111 waste level and heat load 1962-1969.ppt (73 KB)

Dennis,

I have recalculated the required exhaust airflow rates to account for evaporation of 23,400 gallons from tank C-111 (Oct 1965 - December 1969). As shown below and in the attached file, if the waste temperature was 190 oF (last recorded value) and the air existing the tank was 100% saturated, then the exhaust rate needed is only 3.5 cfm. Similarly, if the waste temperature was 200 oF and the air existing the tank was 100% saturated, then the exhaust rate needed is only 1.4 cfm.

I have also modified the waste level and heat load chart for tank C-111 to shown some events in the 1962 - 1969 time frame. I did not add any heat load for the ferrocyanide sludge in this tank. The evaporative waste loss calculation is based on the waste temperature and exhaust airflow rates and does not use the tank heat load. The tank heat load versus waste level is intended to show the waste level decline corresponds to the heat load in the tank caused from the Hot Semiworks waste.

Psychrometric Data from http://www.natmus.dk/cons/tp/atmcalc/atmoclc1.htm

oF	lbs water /lb dry air	lbs dry air /ft3	% Saturation
190	1.06	0.024	100
190	0.488	0.0167	70
200	2.17	0.029	100
200	0.742	0.020	70

Tank C-111 Liquid level decline occurred over	51	months	(Oct 1965 - December 1969)
	2203200	minutes	
Tank C-111 lost	23,400	gallons	
	8.34	lbs water per gallon	

Exhaust Airflow rates needed to account for amount of water lost from tank C-111

oF	% Saturation	Airflow (cfm)
190	100	3.5
190	70	10.9
200	100	1.4
200	70	5.9

Tank C-111 Evaporation Rates.xls

Psychrometric Data from http://www.natmus.dk/cons/tp/atmcalc/atmoclc1.htm

oF	lbs water /lb dry air	lbs dry air /ft3	% Saturation
190	1.06	0.024	100
190	0.488	0.0167	70
200	2.17	0.029	100
200	0.742	0.020	70

Tank C-111 Liquid level decline occurred over	51	months	(Oct 1965 - December 1969)
	2203200	minutes	
Tank C-111 lost	23,400	gallons	
	8.34	lbs water per gallon	

Exhaust Airflow rates needed to account for amount of water lost from tank C-111

oF	% Saturation	Airflow (cfm)
190	100	3.5
190	70	10.9
200	100	1.4
200	70	5.9

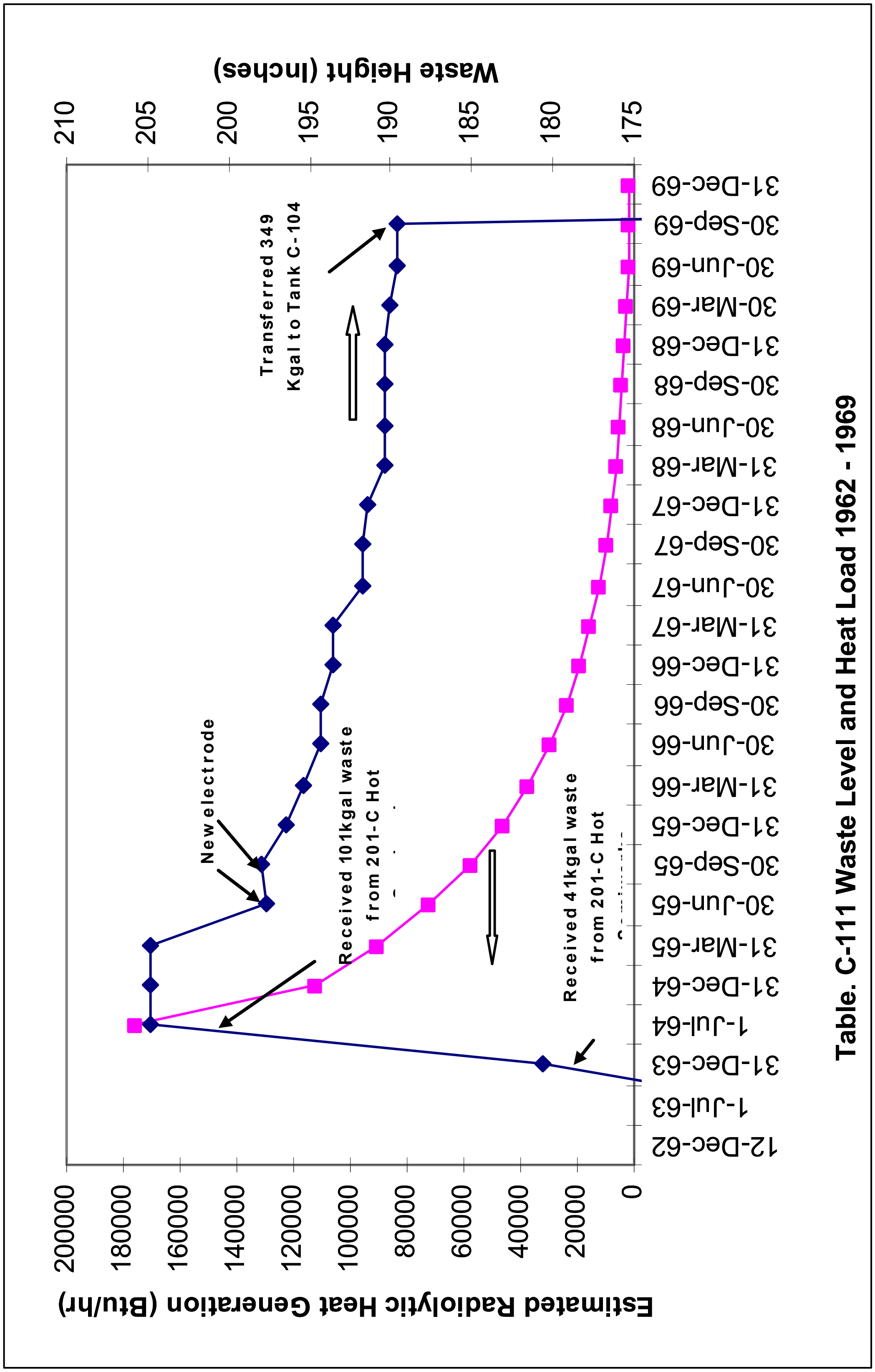
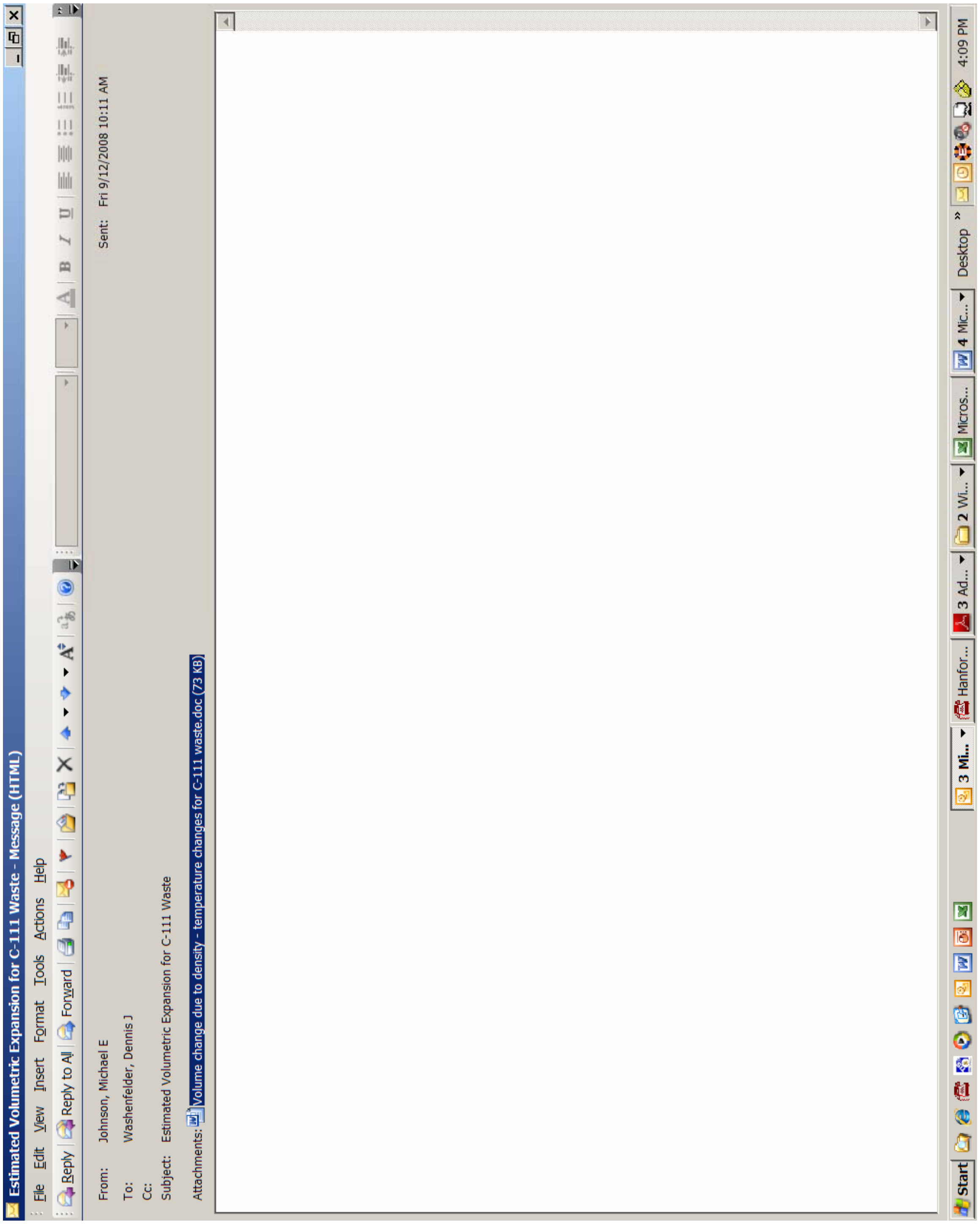


Table. C-111 Waste Level and Heat Load 1962 - 1969

APPENDIX D
TANK C-111 LEAK WASTE LOSS CORRECTION FOR THERMAL CONTRACTION


Estimated Volumetric Expansion for C-111 Waste - Message (HTML)
File Edit View Insert Format Tools Actions Help
Reply Reply to All Forward
From: Johnson, Michael E
To: Washenfelder, Dennis J
Cc:
Subject: Estimated Volumetric Expansion for C-111 Waste
Sent: Fri 9/12/2008 10:11 AM
Attachments: Volume change due to density - temperature changes for C-111 waste.doc (73 KB)
Start
Desktop
4:09 PM

Correction of Tank C-111 Waste Loss Due to Thermal Contraction

Strontium was separated from rare earth fission products in the 201-C Strontium Semi-Works facility using a solvent extraction process. Waste streams generated during the solvent extraction process included:

- high-activity waste (HAW) from the 1A solvent extraction column,
- organic wash waste (OWW)
- strontium carbonate cask filtrate waste

The HAW and OWW streams were separately evaporated to volatilize organic compounds, which were disposed to a crib nearby the 201-C building. The concentrated high activity waste streams were then mixed with the strontium carbonate cask filtrate waste and neutralized by addition of sodium hydroxide solution. The neutralized waste solution was then transferred to the 241-C Tank Farm. Table 1 lists the compositions for the concentrated high activity waste streams, the strontium carbonate cask filtrate waste, and the sodium hydroxide from the Strontium Semi-Works flowsheet (RL-SEP-20 pages 3.5-1 thru 3.5-5)[2]. The composition of the neutralized waste was calculated from the other three streams listed in Table 1.

Table D-1. Composition of Strontium Semiworks Wastes

	Cask Filtrate	Concentrated HAW and OWW	NaOH	Calculated Neutralized Waste
	M	**M**	**M**	**M**
$KHCO_3$	0.34			
NaOH	0.05		19	
KNO_3	1.6			
$SrCO_3$	0.0002			
Sr		0.0005		4.49E-04
Ce		0.0017		1.48E-03
Ca		0.0049		4.27E-03
Ba		0.0002		1.74E-04
Pb		0.034		0.030
Fe		0.03		0.026
Rare Earths		0.0069		6.02E-03
pH		8.5		
Flow[3]	3.2	41.6	2.9	47.7
Calculated				

[2] RL-SEP-20, 1965, *Specification and Standards Strontium Purification at the Strontium Semiworks*, General Electric Company, Richland Washington
[3] The units for the flow were not specified in RL-SEP-20.

Table D-1. Composition of Strontium Semiworks Wastes

	Cask Filtrate	Concentrated HAW and OWW	NaOH	Calculated Neutralized Waste
	M	**M**	**M**	**M**
Values				
Na	0.05			1.158
K	1.94			0.130
NO_3^-	1.6	0.2716		0.344
CO_3^{2-}	0.34			0.0228
OH^-	0.05			0.90

The Savannah River National Laboratory has developed a density correlation for the Waste Treatment and Immobilization Plant to use for pretreated (i.e. cesium removed) low-activity waste (LAW) Envelope A[4]. This correlation is accurate to +/- 6% for predicted versus measured densities for a 2 to 10M Na LAW Envelope A solutions.

Equation (1)

$$\text{Density (g/ml)} = 1.117 * x_{AlO2} + 1.110 * x_{CO3} + 1.075 * x_F + 1.072 * x_{NO2} + 1.096 * x_{NO3} + 0.9813 * x_{OH} + 1.141 * x_{PO4} - 1.119\text{E-}03 * \mathit{Temp} + 7.046\text{E-}03 * \mathit{SBS/Feed} + 0.03258 * [\mathit{Na}] - 4.438\text{E-}05 * (\mathit{SBS/Feed} - 1) * (\mathit{Temp} - 40.5) - 1.150\text{E-}04 * ([\mathit{Na}] - 8) * (\mathit{Temp} - 40.5)$$

Where

- x_{OH}, x_{AlO2}, $x_{CO}3$, x_{NO2}, $x_{NO}3$, x_F, and x_{PO4} are the relative mass fractions of OH^-, AlO_2^-, CO_3^{-2}, NO_2^-, NO_3^-, F^-, and PO_4^{-3} in the waste feed;
- *SBS/Feed* is the volume ratio of submerge bed scrubber (SBS) recycle to treated waste feed flow;
- [*Na*] is the Na molarity
- *Temp* is the temperature in degrees Celsius of the evaporator concentrate bottoms stream

Since the neutralized waste solution from the Strontium Semi-Works does not contain the SBS solution, NO_2^-, AlO_2^-, F^-, or PO_4^{-3} anions, the density correlation in equation (1) can be simplified to the following:

Equation 2:

$$\text{Density (g/ml)} = 1.110 * x_{CO3} + 1.096 * x_{NO3} + 0.9813 * x_{OH} - 1.119\text{E-}03 * \mathit{Temp} + 0.03258 * [\text{Na}] + 4.438\text{E-}05 * (\mathit{Temp} - 40.5) - 1.150\text{E-}04 * ([\text{Na}] - 8) * (\mathit{Temp} - 40.5)$$

[4] WSRC-TR-2003-00269, rev. 0, 2003, *Modeling Treated LAW Feed Evaporation*, Westinghouse Savannah River Company, Aiken South Carolina

For the neutralized waste solution from the Strontium Semi-Works, the mass fractions of the anions OH^-, CO_3^{-2}, and NO_3^- are 0.402, 0.036, and 0.562, respectively. The density correlation is reduced to equation (3) by substituting the relative mass fractions of these anions and the Na molarity into equation (2):

Equation 3:

Density (g/ml) = 1.110 * 0.036 + 1.096 * 0.562 + 0.9813 * 0.402 – 1.119E-03 * *Temp* + 0.03258 * [1.158] + 4.438E-05 * (*Temp* - 40.5) – 1.150E-04 * ([1.158] – 8) * (*Temp* – 40.5)

Density (g/ml) = 1.0881 – 1.119E-03 * *Temp* + 8.314E-04 * (*Temp* – 40.5)

Using equation (3), the estimated density of the neutralized Strontium Semi-Works waste at 80^{o}F (26.7^{o}C) and 190^{o}F (87.8^{o}C) is 1.047 and 1.029 gm/ml. The volumetric expansion of the waste solution can be determined from equation (4):

Equation (4)

Volumetric Expansion Factor = density at 80^{o}F (26.7^{o}C) / density at 190^{o}F (87.8^{o}C)

Volumetric Expansion Factor = 1.0175 (or ~1.75%)

The maximum fill level in tank C-111 after receiving the neutralized waste (containing the Ce^{144}) was 539,000 gallons recorded during the July, 1964 – December 1964 period (RPP-ENV-33418, Rev. 1). At that time the tank contained 81,000 gallons of sludge (WHC-MR-0132), so the height of the liquid column was:

Equation (5)

Height of Liquid Column = (539,000 gallons – 81,000 gallons)/2750 gallons/inch

Height of Liquid Column = 166.5 inches

As the liquid waste cooled from 190^{o}F to 80^{o}F, the liquid column would thermally contract by ~ 1.75%. The resulting decrease would be:

Equation (6)

Thermal Contraction = 166.5 inches * 0.0175

Thermal Contraction = 2.9 inches

Therefore the reported loss of 8.5 inches (RHO-CD-1193) should be reduced to 5.6 inches to account for the thermal contraction of the waste cooling to 80^{o}F, and the calculated loss reduced from 23,400 gallons to 15,400 gallons.

The impact of thermal contraction of the waste is to reduce the tank C-111 passive breathing rate necessary to evaporate the waste loss from 3.5 cfm to 2.3 cfm at 190^{o}F and 100% relative humidity during the October 1965 – December 1969 period.