Evaluation of Fourteen Tanks with Decreasing Level Baselines Selected for Review in RPP-PLAN-55113, Revision 1

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ACRONYMS

BBI	Best Basis Inventory
cfm	cubic feet per minute
Ci	curie
DE	diatomaceous earth
DST	double-shell tank
FIC	Food Instrument Corporation
FSL	fraction of surface that is liquid
ft	foot
HRR	high resolution resistivity
ILL	interstitial liquid level
in.	inch
IS	interim stabilization
LCR	level change rate
LLR	liquid loss rate
LOW	liquid observation well
PC-SACS	Personal Computer-Surveillance Analysis Computer System
PCE	porosity change effect
PUREX	Plutonium Uranium Extraction plant
REDOX	Reduction-Oxidation plant
RGG	retained gas growth
RH	relative humidity
SL	surface level
SST	single-shell tank
TBP	tri-butyl phosphate
TWINS	Tank Waste Information Network System
WCE	waste change effect

1. Summary

This report documents level decrease evaluations for 14 single-shell tanks (SSTs): A-102, A-106, AX-101, AX-103, BY-108, S-104, SX-102, SX-105, SX-114, TX-108, TY-101, TY-103, U-104, and U-108. It is the conclusion of this document that there is no evidence indicating any of these 14 tanks are actively leaking.

Twenty SSTs with decreasing surface level (SL) and/or interstitial liquid level (ILL) data trends were recommended for evaluation in Letter, WRPS-1301005, *Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Level Decrease Evaluation Plan to The U.S. Department of Energy, Office of River Protection*, March 18, 2013, C. A. Simpson, Washington River Protection Solutions LLC, to S. E. Bechtol, U.S. Department of Energy. Table 1-1 summarizes the evaluation results for the 14 tanks evaluated in this document and provides references for evaluations of the remaining six tanks.

Table 1-1 Summary of Results for The Single-Shell Tanks Recommended for Level Decrease Evaluation in WRPS-1301005

Tank	HNF-EP-0182 Rev 301 Leak Status	Basis for Level Decrease	Evaluation Summary
A-102	Sound	SL data	No evidence of a tank leak. Level decrease rate in WRPS-1301005 due to instrument problems.
A-106	Sound	ILL data	No evidence of a tank leak. Estimated liquid loss rate is less than the estimated tank evaporation rate.
AX-101	Sound	ILL data	No evidence of a tank leak. Estimated liquid loss rate is less than the estimated tank evaporation rate.
AX-103	Sound	ILL data	No evidence of a tank leak. Estimated liquid loss rate is less than the estimated tank evaporation rate.
B-203	Assumed Leaker	SL data	See RPP-RPT-55265 Rev 0
B-204	Assumed Leaker	SL data	See RPP-RPT-55265 Rev 0
BY-108	Assumed Leaker	ILL data	No evidence tank is actively leaking. Estimated liquid loss rate is less than the estimated tank evaporation rate.
S-104	Assumed Leaker	ILL data	No evidence tank is actively leaking. Estimated liquid loss rate is less than the estimated tank evaporation rate.
SX-102	Sound	ILL data	No evidence of a tank leak. Re-evaluation of ILL data indicates ILL increasing, ILL not yet stabilized following saltwell pumping. Level decrease rate in WRPS-1301005 due to selection of less than optimum characteristic of neutron scan data for ILL
SX-105	Sound	ILL data	No evidence of a tank leak. Estimated liquid loss rate is less than the estimated tank evaporation rate.
SX-114	Assumed Leaker	SL data	No evidence the tank is actively leaking. With only surface level data there is no reliable basis to calculate a liquid loss

Tank	HNF-EP-0182 Rev 301 Leak Status	Basis for Level Decrease	Evaluation Summary
			rate. No vapor sample data above detection limits are available to estimate a relative humidity to determine a tank evaporation rate, vapor sample data show less than detectable water vapor in headspace. Waste likely has little moisture with 160+°F waste temperature and 40,000 BTU/hr heat generation rate in the tank.
T-111	Assumed Leaker	ILL data	See RPP-RPT-54964 Rev 0 (RPP-RPT-54964 Rev 1 planned for release in fall of 2013)
T-203	Sound	SL data	See RPP-RPT-55264 Rev 0
T-204	Sound	SL data	See RPP-RPT-55264 Rev 0
TX-108	Sound	SL data	No evidence of a tank leak. With only surface level data there is no reliable basis to calculate a liquid loss rate. The estimated evaporation rate exceeds estimated minimum and rough approximate liquid loss rates.
TY-101	Assumed Leaker	SL data	No evidence the tank is actively leaking. With only surface level data there is no reliable basis to calculate a liquid loss rate. The estimated evaporation rate exceeds estimated minimum and rough approximate liquid loss rates.
TY-103	Assumed Leaker	ILL data	No evidence tank is actively leaking. Estimated liquid loss rate is less than the estimated tank evaporation rate.
TY-105	Assumed Leaker	ILL data	See RPP-RPT-55263 Rev 0
U-104	Assumed Leaker	SL data	No evidence the tank is actively leaking. With only surface level data there is no reliable basis to calculate a liquid loss rate. The estimated evaporation rate exceeds estimated minimum and rough approximate liquid loss rates.
U-108	Sound	ILL data	No evidence of a tank leak. Estimated liquid loss rate is less than the estimated tank evaporation rate.

2. Introduction

During the summer of 2012 SL and ILL plots were prepared for all 149 SSTs. Linear trendlines were drawn through the SL and ILL data points for each tank to provide an estimate of the SL or ILL long term change rates. Linear trendlines are of the form y = mx +b, with m being the slope of the line. Positive values of m mean the level is increasing and negative values mean it is decreasing.

An evaluation plan for SSTs with increasing SLs or ILLs was issued September 13, 2012 as an attachment to WRPS-1203139 R1, *Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Suspect Intrusion Evaluation Plan to The U.S. Department of Energy, Office of River Protection.* Concurrently with development and release of this plan, a second evaluation plan was drafted for SSTs with decreasing level data. This level decrease plan was issued on March 18, 2013 with WRPS-1301005.

Note: WRPS-1301005 has since been released as RPP-PLAN-55113, 2013, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan*, Revision 1, and is referred to by this number in the remainder of this document.

RPP-PLAN-55113, Rev 1, listed 83 SSTs with a decreasing ILL or SL. These tanks were screened down to a list of 20 tanks recommended in RPP-PLAN-55113, Rev 1, for further level decrease evaluation.

The level decrease plan in RPP-PLAN-55113, Rev 1, committed to perform an initial evaluation for each of the 20 tanks that includes:

- Review of tank conditions.
- Evaporation estimates.
- Analysis of other conditions [e.g., long term response to interim stabilization (IS) or liquid observation well (LOW) installations, equipment calibrations or repairs] that could explain level decreases.

Following initial evaluation the 20 tanks were to be sorted into:

- Tanks for which the level decrease can be readily explained without further investigation, and,
- Tanks for which field investigations are needed to better understand the cause of the level decrease:
    - In-tank videos
    - Drywell logging
    - Other (as applicable)

The following results were to be documented:

- Initial evaluations
- Field investigations
- Determine if results warrant evaluation of any of the additional SSTs with negative SL or ILL trends not included in the list of 20

An announcement was made on February 15, 2013 that tank 241-T-111 (T-111) was leaking. On February 22, 2013 an additional five tanks with level decreases were announced. The level decreases for all six tanks were interpreted as leaks. As a result of the February 22, 2013 announcement the planned 20 tank evaluation was divided into 5 reports:

- T-111 (RPP-RPT-54964)
- T-203 and T-204 (RPP-RPT-55264)
- B-203 and B-204 (RPP-RPT-55265)
- TY-105 (RPP-RPT-55263)
- Remaining 14 tanks (RPP-RPT-54981) – this report

Each of the first four evaluations will include, for each tank:

- Review of tank conditions
- Evaporation estimates
- Analysis of other conditions
- Results of in-tank videos
- Conclusions

The fifth evaluation includes:

- Review of tank conditions for each tank
- Evaporation estimates for each tank
- Analysis of other conditions for each tank
- Conclusions for each tank
- An appendix providing evaporation rate vs. relative humidity plots and estimated headspace relative humidity for all 20 tanks
- An appendix providing the estimated heat generation rates for all 20 tanks

The 14 tanks with level decrease evaluations in this report are: A-102, A-106, AX-101, AX-103, BY-108, S-104, SX-102, SX-105, SX-114, TX-108, TY-101, TY-103, U-104, and U-108.

Table 2-1 provides the ILL and SL trendline decrease rates for the 14 tanks selected for evaluation. Columns 2 and 3 provide the decrease rates given in RPP-PLAN-55113, Rev 1. These values were based upon ILL and SL plots with data current as of October-November 2012. Columns 4 and 5 provide updated ILL and SL decrease rates used in this document.

The tanks in RPP-PLAN-55113, Rev 1, were divided into 3 groups: Group 1 tanks showed both an ILL and SL decrease (14 tanks, 7 recommended for further evaluation); Group 2 tanks showed an ILL decrease but no SL decrease (11 tanks, four recommended for further evaluation); and Group 3 tanks which had an SL decrease and no ILL decrease or no LOW (58 tanks, nine recommended for further evaluation).

Table 2-1 Interstitial Liquid Level and Waste Surface Level Decrease Trends

1	2	3	4	5
Tank	**Values from RPP-PLAN-55113, Rev 1**		**Updated Values for RPP-RPT-54981**	
	ILL Change Rate (in./yr)	**SL Change Rate (in./yr)**	**ILL Change Rate (in./yr)**	**SL Change Rate (in./yr)**
A-102	No LOW	-0.112[2]	No LOW	0.008
A-106	-0.731	0	-0.736	no data since 2007[1]
AX-101	-0.312	0	-0.355	no data since 2009[1]
AX-103	-0.572	0	-0.596	no data since 2009[1]
BY-108	-0.287	0	-0.282	0[1]
S-104	-0.122	-0.071	-0.110	-0.072
SX-102	-0.664	-0.466	+0.459[3]	-0.144[1,4]
SX-105	-0.161	-0.128	-0.040[5]	-0.038[1]
SX-114	No LOW	-0.139	No LOW	-0.151
TX-108	No LOW	-0.070	No LOW	-0.033
TY-101	No LOW	-0.115	No LOW	-0.118
TY-103	-0.094	-0.022	-0.079	-0.016[1]
U-104	No LOW	-0.110	No LOW	-0.109
U-108	-0.136[6]	-0.043	-0.016	-0.055[1]

[1] Surface level change rates are current as of May-August 2013 but not used for level decrease estimation, ILL change is basis for level decrease evaluation.
[2] Value in WRPS-1301005 of -0.132 in./yr was an error, correct value should have been -0.112 in./yr, value is corrected in RPP-PLAN-55113, Rev 1.
[3] Value for SX-102 went from negative to positive when it was determined that ILL had been selected from incorrect characteristic of new LOW installed in January 2007.
[4] Value for SX-102 SL change is based upon 2nd degree polynomial trend line slope as of June 16, 2013.
[5] SX-105 ILL has been reinterpreted and change rate will be slightly positive when approved. Tank SX-105 data reinterpretation not approved at time this document released, so used ILL based upon previous interpretation method, but updated from RPP-PLAN-55113, Rev 1.
[6] Value in WRPS-1301005 of -0.135 in./yr was an error, correct value -0.136 in./yr, value is corrected in RPP-PLAN-55113, Rev 1.

3. Discussion

3.1 Selection of Tanks for Level Decrease Evaluation

Tanks were included on the list of 83 tanks in RPP-PLAN-55113, Rev 1 Appendix A, Table A-1, based upon their ILL and/or SL data change rate. All tanks with a change rate <0.001 in./yr were included. The basis for segregation into categories and screening of the tanks into the list of 20 tanks for evaluation is described in that document, as well as the basis for the level change values in Columns 2 and 3 of Table 2-1.

3.2 Updating of Tank Level Data Change Rates

The updated level data change rates in Columns 4 and 5 of Table 2-1 are based upon linear trendlines drawn through the SL and ILL data points for each tank for as far back as a reasonable linear rate can be established. For some tanks the SL or ILL change rate has been essentially constant for over 20 years; for other tanks, the change is relatively constant over only the past 3 to 10 years.

The SL and ILL data change rates in Columns 4 and 5 of Table 2-1 were estimated by:

- Downloading SL and ILL data from the TWINS, *Tank Waste Information Network System* (TWINS) database available on the Hanford Local Area Network (HLAN) at https://twins.labworks.org/twinsdata/Forms/About.aspx from 1/1/90 to the present. For a few tanks the data back to 1980 is included to show longer term trends.
- Plotting the results in Excel®. The following level data change plots were made for each tank:
  - A plot showing the ILL and SL raw data together, or just the SL if no LOW is present, for the tank. The raw data is exactly as retrieved from TWINS with no adjustments for data correction. The y-axis is shown as approximately the same height as the full depth of the tank, to give the reader an indication of the relative rate of change for the tank SL, and ILL if present.
  - A plot of the raw ILL data only, if the tank has an LOW, with the y-axis significantly expanded so that recent changes in the ILL with time can be discerned. The latest data date is stated on the plot.
  - A plot of the raw SL data only, with the y-axis significantly expanded so that recent changes in the SL with time can be discerned. The latest data date is given on the plot.
- The expanded raw data plots were then reviewed for problems which could result in incorrect data interpretation. These include:
  - Repair or replacement of level gauge (SL only).
  - Recalibration of level gauge resulting in different baseline depth value (SL only).
  - Changing zero value for tank reference level (i.e., changing from bottom of knuckle to tank centerline bottom) (SL only, ILLs always referenced to tank centerline bottom).
  - Not selecting a representative neutron count feature for ILL interpretation (ILL only).
  - Changing of method of interpretation for ILL data (i.e., neutron or gamma count data selected for indication of ILL) (ILL only).
- Following data review, adjusted data plots were prepared, if needed. Four of the 14 SSTs in this document needed adjusted SL data plots, no adjusted ILL data plots were prepared. Excel was used to calculate the linear regression line through the data for most

tanks for the rate of change in recent years, going back as far as to where it appeared the rate of change was reasonably consistent. For some data plots a polynomial regression line would provide a better fit to the data (i.e., the data change rate is not constant), but for the purpose of data evaluation in this document a linear regression line provides an acceptable data change rate. The trendline formula is shown on the expanded y-axis plots, with the conversion factor to convert the trendline slope to a level data change rate in inches per year.

The final SL and ILL level data change rates based upon the plot trendlines are given in Columns 4 and 5 of Table 2-1. The details of the process and the plots for each tank are given in the tank evaluation section for each tank.

3.3 Volumetric Change Rates

The level change rates in Columns 4 and 5 of Table 2-1 are converted, to the extent practical, to a volumetric change rate to assess the potential for a tank to be leaking. Estimation of a volumetric level change rate for each tank is based upon the following assumptions:

- If the tank has an LOW and the ENRAF gauge plummet is measuring a solid surface, or if the ENRAF plummet appears to be measuring a liquid surface but doesn't track the ILL from the LOW, only the ILL decrease rate is used to estimate a volumetric change rate for the tank. Tanks in this category are A-106, AX-101, AX-103, BY-108, SX-105, TY-103, and U-108.
- If the tank has an LOW and the ENRAF gauge plummet appears to be measuring a liquid surface and does track the ILL from the LOW, the average of the SL and ILL decrease rates is used to estimate a volumetric change rate for the tank. The tank in this category is S-104.
- If the tank does not have an LOW and the ENRAF gauge plummet is measuring a solid surface a reasonable estimate of the volumetric change rate cannot be made. Tanks in this category are A-102, SX-114, TX-108, TY-101, and U-104. For these tanks, excluding tank A-102, estimated liquid loss rates are derived based upon:
  - an estimated minimum rate assuming the ENRAF plummet is reading the ILL in a small depression, and,
  - a bounding maximum based upon a 100% liquid surface, and,
  - a rough approximation of a liquid decrease rate based upon the ratio of ILL volumetric decrease rate to SL level decrease rate for tanks with both decreasing ILLs and SLs.
- For tank A-102 the SL change rate in RPP-PLAN-55113, Rev 1 was caused by biased SL data from a poorly functioning gauge. Since gauge replacement, the surface level has shown a small increase. Although there is no longer an apparent decrease for this tank level, a volumetric change rate is calculated for the increase.
- No volumetric level change is estimated for tank SX-102. In March 2013 the neutron scan data for this tank were re-evaluated and a different characteristic in the neutron scan data selected for calculation of the ILL. The ILL data points in this tank have been recalculated using this different characteristic and the results show the ILL is increasing and not yet reached equilibrium.

The estimated volumetric change rate for a 75 ft. diameter tank is based upon the following equation:

$$volumetric\ change\ rate = LCR\ in./yr \times 2{,}750\ \frac{gal}{in.} \times (FSL + (1 - FSL) \times \sigma)$$

where:

LCR = level change rate in inches/yr
FSL = fraction of waste surface that is liquid
σ = waste porosity

The fraction of waste surface that is liquid is estimated from in-tank videos, photos, interim stabilization documentation, BBI information, or deduction based upon where the ILL is in relation to the SL.

The porosity assumed in RPP-5556, 2000, *Updated Drainable Interstitial Liquid Volume Estimates for 119 Single-Shell Tanks Declared Stabilized*, Rev. 0, is used for consistency with past calculations unless a different value is justified.

For tanks with an LOW the volumetric change rate calculation is straightforward. For the tanks without LOWs the volumetric change rate is bracketed with estimated minimum and bounding maximum rates, and a rough approximation of a possible liquid loss rate for the tank provided based upon the ratio of the ILL volumetric change rate to SL level change rate in tanks with both decreasing ILL and decreasing SLs.

An estimated minimum liquid loss rate for tanks with only SL data uses the volumetric change rate equation but assumes there is no surface liquid and the ENRAF plummet is sitting in a small depression reading a liquid level. The equation reduces to:

$$Bounding\ minimum\ liquid\ loss\ rate = LCR\ in./yr \times 2{,}750\ \frac{gal}{in.} \times \sigma$$

The estimated minimum liquid loss rate for tanks with only SL data may or may not be realistic. If the plummet is reading a liquid level below the waste surface then the estimated minimum represents a reasonable value. If the ILL is far enough below the waste surface that the plummet can only be resting on a hard surface the SL decrease may be due to waste subsidence or due to the plummet making a small depression in the surface. Five of the 14 tanks evaluated for level decrease in this document have only SL data, two of them (A-102 and TY-101) are believed to have ILLs close to the surface. The remaining three tanks (SX-114, TX-108, and U-104) probably do not have ILLs near the surface.

The bounding maximum liquid loss rate for tanks with only SL data uses the same volumetric change rate equation but assumes the surface is 100% liquid. The equation reduces to:

$$Bounding\ maximum\ liquid\ loss\ rate = LCR\ in./yr \times 2{,}750\ \frac{gal}{in.}$$

The bounding maximum is unrealistic for tanks with a solid surface, the surface decrease in such tanks is assumed due to the waste compressing. If a plummet is resting on a solid surface that is decreasing, the porosity in the tank is also decreasing, regardless of whether the tank is leaking or not.

The estimation of a rough approximation of a volumetric change rate for tanks with a decreasing SL and without an LOW is based upon data from tanks with both decreasing ILLs and SLs. RPP-PLAN-55113, Rev 1, Table A-1, lists 83 tanks with decreasing ILLs or SLs:

- 72 of the 83 have decreasing SLs
- 29 of the 72 (40.3%) have no LOWs
- 28 of the 72 (38.9%) have an increasing ILL
- 1 of the 72 (1.4%) has an ILL with no change
- 14 of the 72 (19.4%) have decreasing ILLs

Thus, over forty percent of the tanks with decreasing SLs have no liquid level decrease. For over 40 percent of the remaining tanks with decreasing SLs it is unknown what the ILL is doing. For the remaining 19% of the tanks with the decreasing SLs the ILL is also decreasing; the top nine tanks with the highest ILL decreases are being evaluated for level decrease, five in this document and the remaining four in separate documents. All 14 tanks with measurable ILL and SL level decreases form the basis for estimating a rough approximation of a volumetric change rate in the four SL decrease only tanks evaluated in this document.

Table 3-1 provides the level change rate, porosity, and fraction of surface that is liquid information for the 14 tanks with decreasing ILLs and SLs. Column 9 calculates the ILL based volumetric change rate for the tank and Column 10 calculates the ratio of the ILL based volumetric change rate to the SL level change rate.

The tanks are segregated into whether they have salt or sludge in the vicinity of the ILL in Columns 11 and 12. The ratios for B-107, S-101, and U-109 are not used because either the ILL or SL change rate is so low as to make the final result meaningless. The ratio for tank U-108 is applied in both columns because the waste is believed to be mixed in this tank (RPP-40545, Rev 2). An average ratio is calculated at the bottom of Columns 11 and 12 for tanks with salt around the ILL and sludge around the ILL respectively. The average value for a tank with salt in the vicinity of the ILL is 1,230 gal/yr per in./yr SL change. The average value for a tank with sludge in the vicinity of the ILL is 280 gal/yr per in./yr SL change.

Since there is no way of knowing where the ILL is in most tanks without an LOW, these factors are applied to tanks based upon whether the majority of the waste in the tank is salt or sludge. These ratios are used in the following equations to approximate a volumetric change for tanks without an LOW:

$$Rough\ approximation\ of\ volumetric\ change\ for\ tank\ without\ LOW = LCR \times 1{,}230\ for\ predominantly\ salt\ tanks$$

and

$$Rough\ approximation\ of\ volumetric\ change\ for\ tank\ without\ LOW = LCR \times 280\ for\ predominantly\ sludge\ tanks$$

Table 3-1 Estimation of ILL Volumetric Change Rate to SL Change Rate Ratios for Tanks with Decreasing ILL and SL Data

1	2	3	4	5	6	7	8	9	10	11	12
Tank	**ILL change rate in./yr**	**SL change rate in./yr**	**Basis**	**σ**	**σ Basis**	**FSL**	**FSL Basis**	**Volumetric Change Rate (gal/yr)**	**Ratio (ILL gal/yr per SL in./yr)**	**Ratio in Tanks with Salt @ ILL**	**Ratio in Tanks with Sludge @ ILL**
B-104	-0.056	-0.018	Footnote 1	0.25	Footnote 4	0.05	ILL just below SL	-44.3	2,459.7	2,460	-
B-107	-0.046	-0.003	Footnote 1	0.15	Footnote 5	0.05	ILL just below SL	-24.4	8,117.1	-	-
S-101	-0.021	-0.006	Footnote 1	0.20	Footnote 6	0	ILL 12 in. below SL	-11.6	1,925.0	-	-
S-104	-0.110	-0.072	Table 2-1	0.20	See 4.6.2	0.10	See 4.6.2	-84.7	1,176.4	1,175	-
SX-102	+0.473	-0.144	Table 2-1	NA	NA	NA	NA	NA	NA	-	-
SX-105	-0.040	-0.038	Table 2-1	0.2	See 4.8.2	0	See 4.8.2	-22.0	577.4	575	-
SX-112	-0.025	-0.022	Footnote 1	0.15	RPP-5556	0	ILL 15 in. below SL	-10.3	468.8		470
T-111	-0.611	-0.884	Footnote 2	0.105	Ref at right	0.08	RPP-RPT-54986, Rev 1	-296.7	335.7		335
TX-102	-0.038	-0.057	Footnote 1	0.36	RPP-5556	0.2	ILL is above SL	-51.0	894.7	895	-
TY-103	-0.079	-0.016	Table 2-1	0.15	See 4.12.2	0.05	See 4.12.2	-41.8	2,597.6	2,600	-
TY-105	-0.256	-0.284	Footnote 3	0.07	RPP-5556	0	ILL 15 in. below SL	-49.3	173.5		175
U-106	-0.031	-0.035	Footnote 1	0.20	Footnote 7	0.15	2 kgal supernate per BBI	-27.3	779.4	780	-
U-108	-0.016	-0.055	Table 2-1	0.18	See 4.14.2	0	See 4.14.2	-7.8	141.0	140	140
U-109	-0.002	-0.212	Footnote 1	0.20	Footnote 8	0	ILL 76 in. below SL	-1.1	5.2	-	-
									Average	1,230	280

[1] Values in RPP-PLAN-55113 Rev 1 updated to include latest data as of end of August, 2013.
[2] From RPP-PLAN-55113, Rev 1.
[3] Value in RPP-PLAN-55113 Rev 1 updated to include lasted data as of end of August, 2013, tank will be evaluated in separate document.
[4] Per BBI tank 17% salt, ILL just below SL, RPP-40545, Rev 2, shows salt on top so use RPP-5556 porosity for salt.
[5] Per BBI tank 53% sludge, ILL just below SL, RPP-40545, Rev 2, shows some sludge on top so use RPP-5556 porosity for sludge.
[6] Per BBI tank 33% salt, ILL 12. in below SL, RPP-40545, Rev 2, has salt on top, no RPP-5556 porosity, use RPP-40545, Rev 2 for salt.
[7] Per BBI tank all salt+2 kgal supernate, no RPP-5556 porosity, use RPP-40545, Rev 2 porosity for salt.
[8] Per BBI tank 92% salt, no RPP-5556 porosity, use RPP-40545, Rev 2 porosity for salt.

An example of why SL decreases from a solid surface are not valid for leak estimation or detection can be readily seen from Table A-1 in RPP-PLAN-55113, Rev 1. The last 6 tanks listed in Group 3 of Table A-1 in RPP-PLAN-55113, Rev 1, before the Category 3 "intrusion" tanks are shown in Table 3-2 along with the calculated SL decrease rate.

Table 3-2 Negative Surface Level Decrease Rates for C-Farm Tanks

Tank	SL Change (in./yr
C-110	-0.517
C-203	-0.455
C-104	-0.133
C-105	-0.063
C-112	-0.037
C-102	-0.013

Tank C-110 started retrieval on September 22, 2008 and began heel retrieval in the summer of 2013 with no indication of a tank leak evident from the high resolution resistivity (HRR) leak detection system used during active retrieval operations or the drywell logging done in the intervening years since retrieval was halted.

Tank C-203 completed retrieval on June 30, 2004 with no indication of leakage with the liquid mass balance done after the retrieval was completed. The 'large' level decrease shown above is from the ENRAF gauge resting on waste or the tank steel bottom.

Tank C-104 started retrieval on January 8, 2010 and completed retrieval in 2012. There was no indication of a tank leak evident from the HRR leak detection system used during active retrieval operations or the drywell logging done in the time when retrieval was halted.

Tank C-112 started retrieval in December 28, 2011 and is awaiting heel retrieval with no indication of a tank leak evident from the HRR leak detection system used during active retrieval operations or the drywell logging done in the intervening years since retrieval was halted.

Tanks C-105 and C-102 are awaiting retrieval operations.

The data from these C-Farm tanks provides evidence as to why an SL decrease is not valid for evaluating a tank for leak detection unless the plummet is sitting on a liquid surface.

Although the SL change rate for a solid surface is not useful for leak detection, there are negative SL decrease rates included in this document for completeness. RPP-PLAN-55113, Rev 1 listed all tanks with a negative ILL or SL change rate regardless of the method used for leak detection, and listed 20 tanks for evaluation. The 20 tanks included five 75 ft. diameter tanks without an LOW.

3.4 Data Analysis

Changes in the SL or ILL data do not necessarily mean the SL or ILL is changing. Analysis of the data is necessary to interpret what is occurring. Factors that could impact the SL or ILL data are listed in Table 3-3.

Table 3-3 Factors Impacting Surface Level or Interstitial Liquid Level Data

	Factor
1	ILL increase and/or SL decrease due to consolidation/slumping of waste into pores.
2	Gas generation and entrapment within the waste causing level increase.
3	Release of retained gas entrapped within the waste causing a level decrease.
4	Conscious liquid additions to the tanks such as core sampling drill string flushes, core sampling head fluid additions, level gauges flushes, water lancing of equipment during installation, grab sample flushes.
5	Chemical changes within the waste.
6	ILL not at equilibrium following LOW installation or saltwell pumping (ILL only).
7	Level gauge plummet resting on uneven solid surface, (plummet rests on different spot when raised and lowered, or surface resistance changes), gauge maintenance or calibration problems, changing of tank reference location for zero level (SL only).
8	Water intrusion for level data increase.
9	Evaporation for level data decrease.
10	Tank leak for level data decrease.

The volumetric change rate is the sum of:

- Liquid addition to and/or removal from the tank
- Retained gas growth in and/or release from the tank
- Loss of gas due to porosity decrease
- Waste density change due to chemical changes

The tank volumetric change rate is equal to the net effect of intrusion, evaporation, leaks, and all other factors:

$$volumetric\ change\ rate = intrusion\ rate + evaporation\ rate + leak\ rate + \Sigma\ other$$

The intrusion rate, Factor 8, is positive or zero, the evaporation rate and leak rate, Factors 9 and 10, are negative or zero, and [Σ other] is equal to the net impact of Factors 1 through 5 in Table 2-1 and may be either positive or negative.

Factor 6 is a subjective assessment based upon review of the ILL data plot trend and, if necessary, the raw neutron count data. There is no numerical value associated with Factor 6. Rather, it is a judgment as to whether the net level change rate estimate shows a change to the liquid level in the tank or a redistribution of the liquid as it slowly seeks an equilibrium level.

Factor 7 is an assessment based upon review of the SL data plot trend and any data available. If the plummet is resting on liquid or a reasonably flat solid surface, data changes can be assumed to represent changes in the waste surface. However, if the plummet is resting against debris in

the tank or is perched on the edge of a crack or clump of waste such that data will be inconsistent. In addition, some tanks had problems with the level gauge operation that resulted in misleading data trends, this became evident when the level gauge maintenance history was reviewed.

Rearranging the volumetric change rate equation:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

or:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

The volumetric change rate and the evaporation rate can be estimated from available data, and a value for [Σ other] assumed following a review of the available information. The net effect of the leak rate and intrusion rate can then be roughly estimated. It cannot be shown from SL and ILL data alone what a leak rate (or an intrusion rate) is for a tank without making assumptions as to the other variables in the equation. If the intrusion rate calculates to, e.g., (100 gal/yr + leak rate), this could mean there is a 100 gal/yr intrusion rate if the leak rate is zero, or a 300 gal/yr intrusion rate masking a -200 gal/yr leak rate, or any combination of intrusion plus leak rate that sums to a net 100 gal/yr. Data analysis cannot give separate values for a leak rate (or intrusion rate) but it can provide a degree of confidence as to what is probably occurring.

4. Tank Evaluations

Each of the evaluations is divided up into the following subsections:

Tank Summary - Provides a short summary of the tank history and lists the Best Basis Inventory (BBI) tank waste volumes from a TWINS query on September 25, 2012.

Liquid Volume Change Rate – Converts the in./yr level change rates in Columns 4 and/or 5 of Table 2-1 to gal/yr.

Data Analysis - Each tank data analysis uses the equation from Section 3.4:

$$volumetric\ change\ rate = intrusion\ rate + evaporation\ rate + leak\ rate + \Sigma\ other$$

where [Σ other] equals the net impact of:

- ILL increase and/or SL decrease due to consolidation/slumping of porous waste
- Gas generation, entrapment, and release within the waste causing level increase or decrease
- Conscious liquid additions to the tanks such as core sampling drill string or grab sample bottle flushes, core sampling head fluid additions, level gauges flushes, water lancing of equipment during installation
- Chemical changes within the waste

Data analysis passes through the following steps for each tank:

- Estimation of a value for [Σ other]
- Estimation of a value for a potential intrusion rate
- Evaluation of whether the ILL is at equilibrium and/or changes in the SL data represent actual movement of the waste surface.

The first part of [Σ other] concerns waste subsidence, or compression of the waste above the ILL onto the open pores. The potential for waste subsidence to be a factor in the level change rate is discussed for each tank.

The second part of [Σ other] is the effect of retained gas on the level change. The volume of retained gas in a tank is unknown, but the relative volume can be inferred from combined plots of the ILL and the inverse of atmospheric pressure vs. time. If retained gas is present an increase in the atmospheric pressure will result in a decrease in the ILL level as the gas bubbles are compressed, and a decrease in the pressure will result in an increase in the ILL level. Predominantly saltcake tanks have a more rigid waste matrix and thus the ILL can be seen to move up and down a small amount depending upon the volume of retained gas. Predominantly sludge tanks do not have a rigid waste matrix and show far less or no response to atmospheric pressure.

Retained gas plots were prepared using Excel file *BP Correlation with DB Connect*, SVF-1002, June 27, 2005. This file was developed to enable surveillance personnel to assess retained gas content of tanks. It downloads the hourly atmospheric data from the Hanford Site Weather Station (HWS) and the tank SL or ILL data from the Personal Computer Surveillance Analysis Computer System (PC-SACS) database, scales the data, adds a slope where helpful for display, and calculates an R^2 value for the two data files to show the degree of correlation. The higher the R^2 value (closer to 1.0) the better correlation between the ILL reading and barometric pressure and thus the more gas there is in the tank, the lower the R^2 value (closer to 0.0) the less correlation and thus less gas is present.

A limitation to the retained gas plots is the frequency of ILL data. The LOW scans used to be done weekly, which resulted in a nominal 50 data points per year. Since the 2003-2005 time frame LOW scan frequencies have been reduced to quarterly for most tanks, resulting in only four data points per year. Four data points in a year is inadequate for showing a correlation between retained gas and atmospheric pressure, so the retained gas plots in this document are mostly based upon data prior to 2003. If there is retained gas in a tank in 2013, some would also have been present in 2003. The retained gas volume may or may not be higher in 2013. Using retained gas plots from prior to 2003 is still useful for showing if there may be sufficient retained gas in a tank to impact the level or not.

The ILL data points are obtained from neutron scans taken periodically inside an LOW. Scans are obtained from near the top of the LOW riser to near the bottom of the tank. The ILL software interrogates the raw neutron count rate data and looks for a maximum change rate in a directed region of the data and calculates a value for the interstitial liquid level. While plots of the ILL data points are used to determine level trends, at times the plots of the raw neutron count data are also useful for estimating what is occurring in a tank above or below the ILL. Comparing past and present neutron scan data can show where liquid is moving either up or down in all levels of the tank, and a reduction in the liquid content below the ILL is evidence for

growth of retained gas in that region. The PC-SACS database includes all past neutron scan data for all past LOW scans as well as the calculated ILL data points. Neutron scan plots were prepared by downloading the neutron count data from the PC-SACS database and transferring it into Excel plots.

Conscious liquid additions make up the third part of [Σ other].

The last portion of [Σ other] is chemical change which may be occurring in the tanks over time. Since the waste has been in the SSTs for 40 to 70 years it is assumed that any chemical changes still occurring will have negligible impact on the level change for recent years.

A value is provided for [Σ other] consisting of four entries: The first entry is either 0 or PCE (for porosity change effect), the second is either 0 or RGG (for retained gas growth), the third is a numerical value to account for annual liquid addition to a tank, and the fourth is either 0 or WCE (for waste change effect).

Evaporation Estimate - Estimating a tank evaporation rate requires knowledge or estimation of:

- the temperature and water vapor content of the air entering a tank
- the temperature and water vapor content of the air leaving the tank
- the effective flow rate of air through the tank, and,
- accounting for condensation of water vapor from exiting air that returns to the tank.

The evaporation estimate methodology is described in Appendix A. A summary of the evaporation estimate results are provided in the Evaporation Estimate section of each evaluation.

Tank Heat Generation Rate - The energy to evaporate water from a tank comes from two sources:

- the latent heat of waste, surrounding soil, and air passing through the tank, and,
- heat generated within the waste by radioactive decay

Appendix B provides an estimated heat generation rate for each tank and compares that rate with the energy required to evaporate water to meet the liquid loss rate. The greater the heat generation rate in the tank the greater the likelihood evaporation is the cause of the liquid loss rate.

Tank Leak Potential This subsection summarizes the information from the previous subsections.

Each evaluation has a summary plot that provides evaporation, relative humidity, and liquid loss information (where applicable) to assess the potential for the tank to be leaking. Each of these plots contains:

- A blue line showing the estimated evaporation rate as a function of the relative humidity (RH) in the air leaving the tank headspace.
- A black vertical line for the estimated tank headspace RH for tanks excluding SX tanks. The basis for the estimate of the RH is provided in Section A.6 of Appendix A. SX tanks show green vertical dashed lines for the RHs when sampling was done and the tanks were actively exhausted. Two of the three SX tanks have red vertical dashed lines for estimates of where the RH may be today.

- A black horizontal dashed for the estimate of the liquid loss rate for tanks using ILL data (and ILL + SL data for S-104) for the level loss rate.
- Tanks without an LOW have estimated minimum and bounding maximum liquid loss rates based upon minimum/maximum liquid level change assumptions shown as tan horizontal dotted lines. These same tanks have a light blue dashed line showing a rough approximate loss rate calculated using the different basis of liquid loss rate to SL change rate ratio in tanks with an LOW.

Where the black line crosses the blue line is the estimated evaporation rate for a tank, based upon the conditions assumed for the tank conditions.

For tanks where the estimated liquid loss rate is based upon ILL data, or the average of ILL and SL data, if the loss rate is below the estimated tank evaporation rate it is assumed there is no evidence the tank is leaking.

For tanks with maximum, minimum, and rough approximate liquid loss rates based upon SL data only, where the liquid loss rate lines are located in relation to the estimated tank evaporation rate cannot provide evidence if the tank is or isn't leaking, but the location can be used to infer a degree of confidence in whether evaporation can account for the observed liquid loss rate.

The evaporation rate, liquid change rate, and headspace relative humidity values presented for each tank are used together to provide a basis to determine the potential for a tank to be actively leaking.

Conclusion The final subsection summarizes the information in the previous subsections and gives a conclusion as to whether there is evidence the tank is leaking or not.

4.1 Tank A-102

4.1.1 Tank Summary

Tank A-102 was put into service in 1956 and received waste from the PUREX plant until 1980. The tank also received supernatant waste from various SSTs, and B Plant. The tank was sluiced in 1964, 1972-1974, and 1976. It was declared inactive in 1980, intrusion prevention was completed in 1982 and interim stabilization completed in August 1989 (RPP-RPT-42740, Rev. 0, *2009 Auto TCR for 241-A-102*). Per a TWINS query on September 25, 2012 the tank contains 36.7 kgal salt and 3.2 kgal supernatant liquid.

Figure 4-1 shows the raw SL data for tank A-102 from January 1, 1990. There is no LOW in the tank. There is very little waste in the tank. Figure 4-2 is a plot of the same data with an expanded y-axis so the data changes can be seen. The data show an increase in the SL data when the ENRAF was installed and operated in automatic mode, but once monitoring changed to manual mode the data show a decrease. The slope of the decrease line was -0.112 in./yr.

Figure 4-3 is an updated plot showing the latest data included for this document. The problem with the decreasing waste surface level in the tank has been traced to ENRAF gauge problems. From the time of installation the ENRAF gauge showed a fairly steady increase rate, with periodic spike increases and decreases when calibrations were performed. In early 2009 when readings went from automatic to manual the gauge readings showed a decrease. The gauge failed in early 2011 and was replaced and calibrated in late June 2011. No data were obtained between December 15, 2010 and June 29, 2011. The change rate has been a +0.004 in./yr, or essentially flat since June 29, 2011.

4.1.2 Liquid Change Rate Estimation

The liquid change rate estimate is based upon the +0.004 in./yr SL change.

No in-tank video has been performed to evaluate whether an intrusion is occurring in the tank or whether the ENRAF plummet is sitting on solid waste or liquid. The tank A-102 interim stabilization documentation was based upon in-tank photos taken on July 20, 1989 when the waste level was about 15 in. The documentation states 15 to 20% of the waste surface was covered with liquid, with the liquid pools 7 to 8 in. deep. The supernatant liquid volume in the tank was estimated at 4,400 gal. In the 23 years since the photos were taken the waste level has shown slight decreases and increases, with the current waste level about 14.5 in. Since the level is not much less than it was 23 years ago it is assumed that the current fraction of liquid on the surface is 18%.

Assuming a saltcake porosity of 0.25 for consistency with RPP-5556, the estimate of the tank A-102 liquid change rate since June 29, 2011 is equal to:

$$Tank\ A - 102\ estimated\ liquid\ change\ rate\ since\ June\ 29, 2011$$
$$= 0.004 \times 2{,}750 \times (0.18 + (1 - 0.18) \times 0.25)) = \mathbf{+4\ gal/yr}$$

4.1.3 Data Analysis

Estimation of [Σ other] – Since liquid is at or near the waste surface there is no consolidation or slumping of the waste.

The BBI shows zero retained gas in tank A-102. Buildup and release of gases within the waste has been observed in double-shell tanks (DSTs) as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. Some SSTs may exhibit chronic release of gases at roughly the same rate gases are generated. With the low ~15 inch waste level in the tank it is very unlikely the waste matrix could retain and then release any gas.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1980. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for A-102 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

Potential for Intrusion – No in-tank video has been performed to evaluate whether an intrusion is occurring in the tank or whether the ENRAF plummet is sitting on solid waste or liquid. Prior to the ENRAF being switched to manual mode in late 2008 the ENRAF showed an increase rate of 0.112 in./yr. Assuming this increase was real and not due to ENRAF gauge problems, the intrusion rate from 2002 to 2009 is estimated below, using as:

$$Tank\ A - 102\ estimated\ liquid\ change\ rate\ 2002\ to\ 2009$$
$$= 0.112 \times 2{,}750 \times (0.18 + (1 - 0.18) \times 0.25)) = \mathbf{134\ gal/yr}$$

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = 134\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\ \frac{gal}{yr}$$
$$= 129\frac{gal}{yr} - leak\ rate - evaporation\ rate$$

Since both evaporation rate and leak rate are negative values, the minimum intrusion rate for the tank occurs when both evaporation and leak rate are zero. Therefore a minimum intrusion rate of about 130 gal/yr is implied for the tank based upon the ENRAF change from 2002 to 2009. While this intrusion rate is possible, it is more likely the change was a reflection of ENRAF gauge problems and not a real change in tank waste level.

Evaluation of ILL or SL Validity – There is no LOW in the tank, the volumetric change rate is based upon SL data.

The ENRAF plummet seating is unknown. The cause for the increase in waste surface level when the ENRAF was in auto mode and the subsequent decrease in manual mode appears to be due to internal gauge problems.

Table 4-1 lists all tank A-102 ENRAF work packages for the 2006 to 2013 time period. The last two columns list the as-found and as-left data from the work packages.

The data showed a steady increase since the gauge was installed in 2002, as long as it was in automatic mode. Shortly after switching to manual mode the raw data began to show a decrease. The actual gauge problem is unknown but it appears to have gotten steadily worse when operated continually in auto mode but upon switching to manual mode with only quarterly data taken the problem ceased. The gauge was replaced in 2011 and there has been one calibration work package since, in 2012. The calibration change in 2012 was negligible, only 0.02 inches.

Table 4-1 Tank A-102 ENRAF Gauge Work Packages Since January 1, 2006

Work Package No.	Title	Date	As Found (in.)	As Left (in.)
WFO-WO-06-2752	241-A, 102 ENRAF INSPECTION	February 6, 2007	14.92	14.62
WFO-WO-07-2477	241-A, 102 ENRAF INSPECTION	October 3, 2007	14.70	14.98
WFO-WO-08-1456	241-A, 102 ENRAF CALIBRATION	July 31, 2008	15.04	15.10
TFC-WO-09-0892	241-A, 102 ENRAF CALIBRATION	April 23, 2009	15.20	14.85
TFC-WO-09-3619	241-A, 102 ENRAF CALIBRATION	October 15, 2009	14.94	14.94
TFC-WO-10-2111	241-A, 102 ENRAF CALIBRATION	October 13, 2010	15.03	14.96
TFC-WO-11-2099	241-A-102 REPL ENRAF DRUM & WIRE	June 27, 2011	NA	NA
TFC-WO-11-3559	241-A, 102 ENRAF CALIBRATION	June 29, 2011	NA	14.67
TFC-WO-12-1556	241-A, 102 ENRAF CALIBRATION	May 17, 2012	14.65	14.65

There was no reference level change for tank A-102, the gauge readings have always been referenced to the tank centerline bottom for the tank.

It is assumed that the SL data since 2011 are valid.

4.1.4 Evaporation Estimate

Estimation of the evaporation rate from each tank is described in Appendix A. See Appendix A, Section A.5 for calculation estimate details. Figure 4-4 provides the evaporation estimate results for tank A-102.

The blue line in Figure 4-4 shows the estimated evaporation rate from tank A-102 as a function of the RH in the tank vapor space. The evaporation rate plots are of limited use without knowing the approximate RH in the tank. Appendix A, Section A.6 derives a RH value for the tank based upon past vapor sample data and interpretation of tank changes since the vapor sample was taken. The estimated average RH value for tank A-102 is indicated by the vertical black line.

Where the vertical black RH line crosses the blue evaporation line in Figure 4-4 is the best estimate for evaporation from tank A-102, assuming the parameters used in Appendix A are valid. Figure 4-4 indicates tank the A-102 evaporation rate is a nominal -500 gal/yr.

Appendix A describes the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank A-102 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank A-102, 10.4 cfm, is about a factor of 5 greater than that used for other 75 ft. diameter tanks, excluding A-106, AX-101 and AX-103. The high rate is based upon high rates calculated from tracer gas tests in A and AX farm tanks. The tracer gas test data used to calculate a breathing rate was the change in concentration of the gas in a tank headspace over time. Postulated reasons for the high breathing rates in the A/AX tanks include inleakage to the 702-AZ vent system via inadequately plugged seal loops in the buried A farm vent header, diffusion of the tracer gas into the large 20-24 inch buried exhaust header connecting the tanks in each farm, or a small unknown source of ventilation on the tank. If there is inleakage to an active vent system then the high breathing rates for A and AX tanks are likely valid. If the high rate results from diffusion into the vent header connecting the tanks the actual breathing rate is less since the calculated value actually measures the tracer gas depletion and the depletion rate for water vapor in the tank headspace would be less since water vapor would be brought back into A-102 from other A Farm tanks. The basis for the breathing rate assumed for tank A-102 is provided in Appendix A and is the best estimate when considering the information, but the actual rate could be lower than assumed. Changing the breathing rate would result in a proportional change in the evaporation rate.

The assumed tank A-102 headspace RH of 65% is based upon the 1995 vapor space sample showing water vapor present at 65.6% RH obtained when the headspace temperature was 91°F and there was assumed to be liquid on part of the waste surface. The headspace temperature is about the same in 2013 as it was in 1995, and the BBI indicates there is still supernatant present in the tank so it is reasonable to assume the RH should be about 65% still.

If liquid were really evaporating from tank A-102 at a rate of -500 gal/yr there should be no supernatant left unless there has been a corresponding intrusion. If there is no supernatant left in the tank the RH should be less than 65% now. Since Figure 4-3 does not show the level is decreasing in the tank the actual evaporation rate for the tank is a moot point.

An evaporation rate of -500 gal/yr for tank A-102 could be an overestimate, but it can more than account for any reasonable liquid loss rate assumed.

4.1.5 Tank Heat Generation Rate Impact

Appendix B, Table B-15 gives an estimated heat generation rate for the waste in tank A-102 as 2,293 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less.

The total waste depth in the tank is less than 15 in., which means that with capillary action there is little room for interstitial liquid to drain. There is sufficient heat generated in the tank to drive off water at any reasonable estimate of a liquid loss rate for the tank.

4.1.6 Tank A-102 Leak Potential

There is no basis to estimate any liquid loss for tank A-102.

The tank evaporation rate from Figure 4-4 shows evaporation can account for any reasonable estimated liquid loss rate.

There is sufficient heat generated in the tank to drive off water at any reasonable estimated liquid loss rate.

Using the equation from Section 3.4 and the volumetric change rate since 2011:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = 4\frac{gal}{yr} - intrusion\ rate - \left(-500\frac{gal}{yr}\right) = 504\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for A-102 is -500 gal/yr, the intrusion rate would have to exceed 504 gal/yr, for a leak to exist. This is unlikely.

4.1.7 Tank A-102 Conclusion

There is no basis to assume a leak from tank A-102.

Figure 4-1 Tank A-102 Full Depth Raw Data Plot

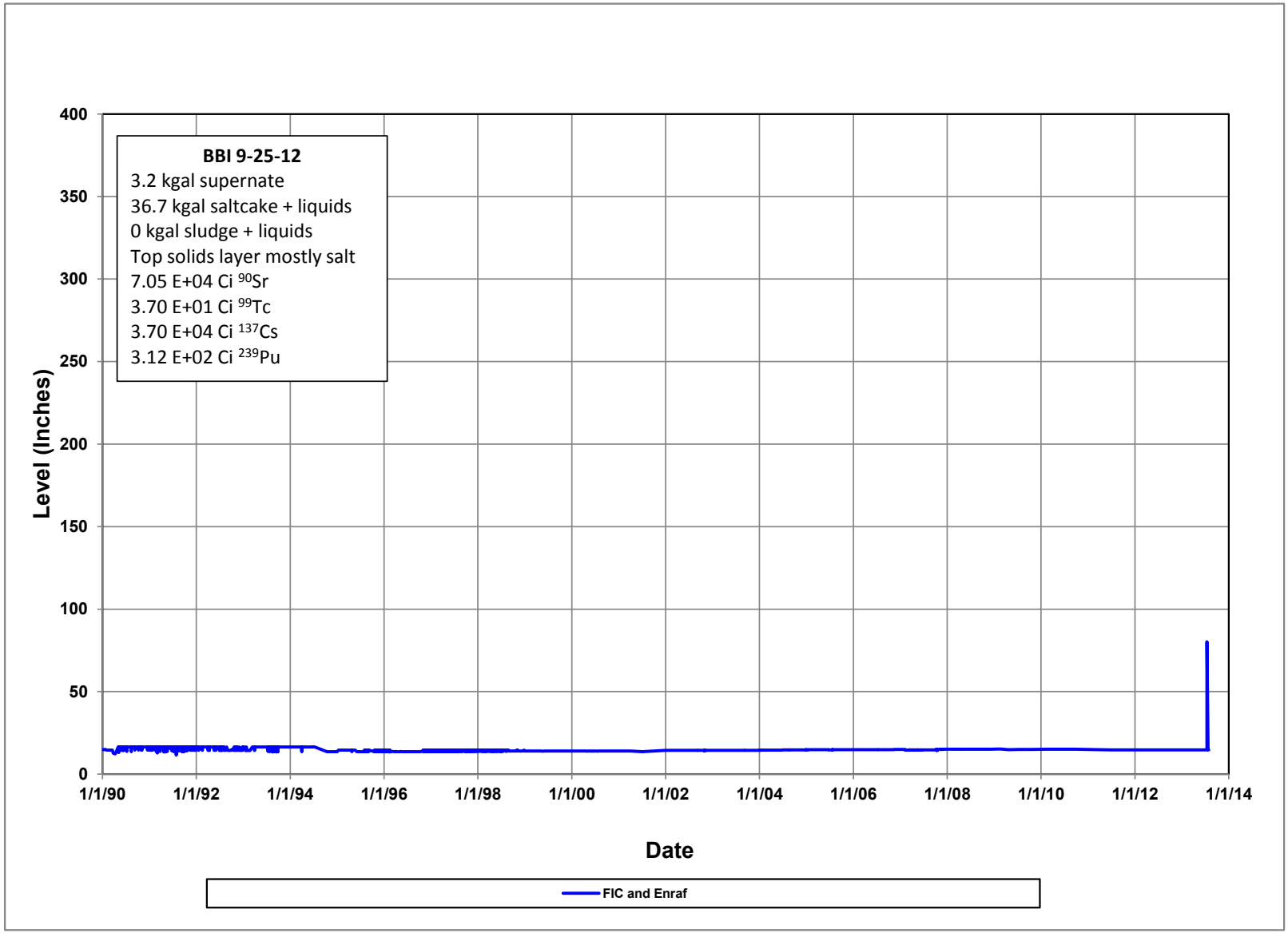


Figure 4-2 Tank A-102 Expanded SL Data Plot Used for RPP-PLAN-55113, Rev 1

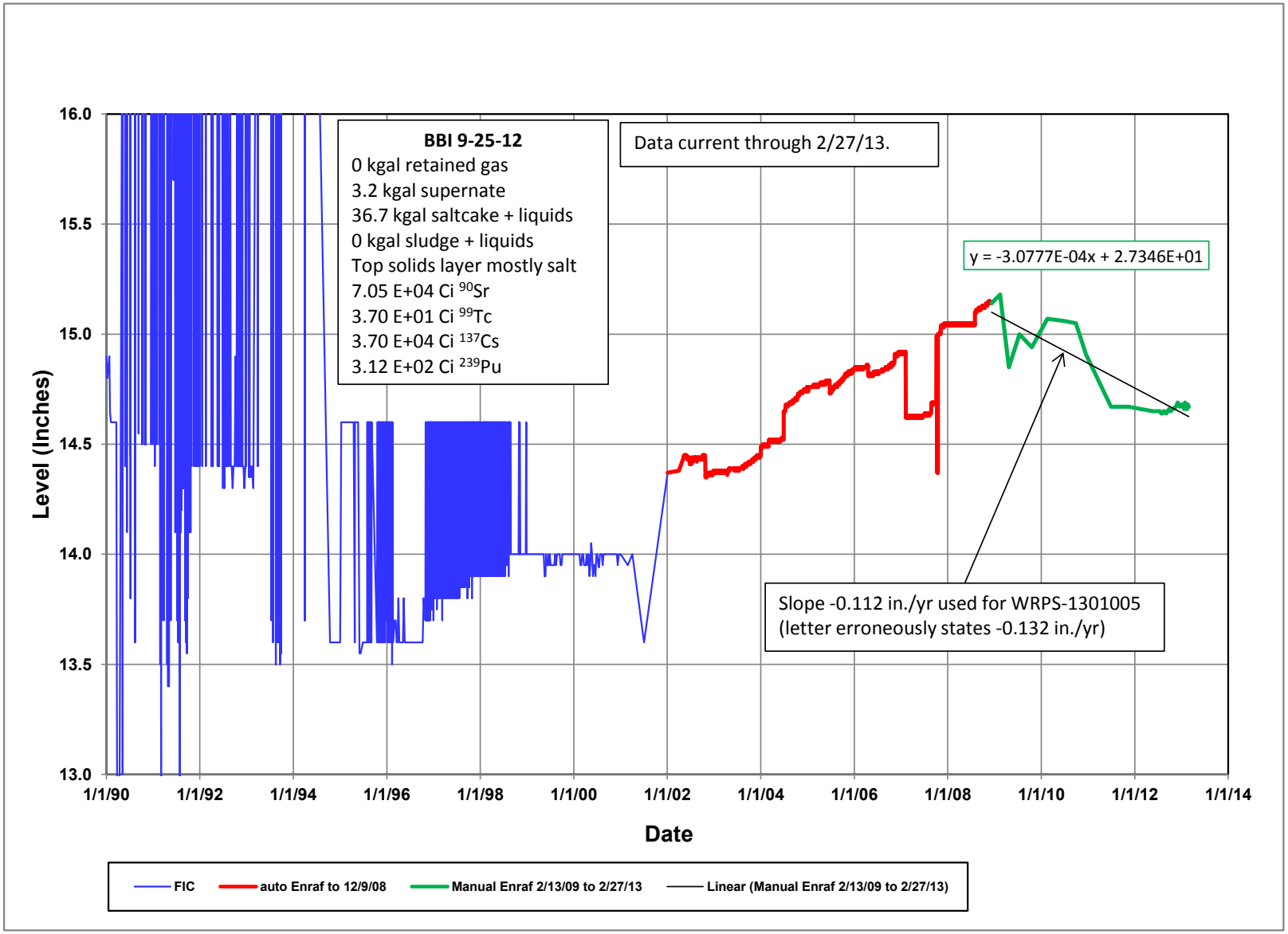


Figure 4-3 Tank A-102 Expanded SL Data Plot Used for RPP-RPT-54981

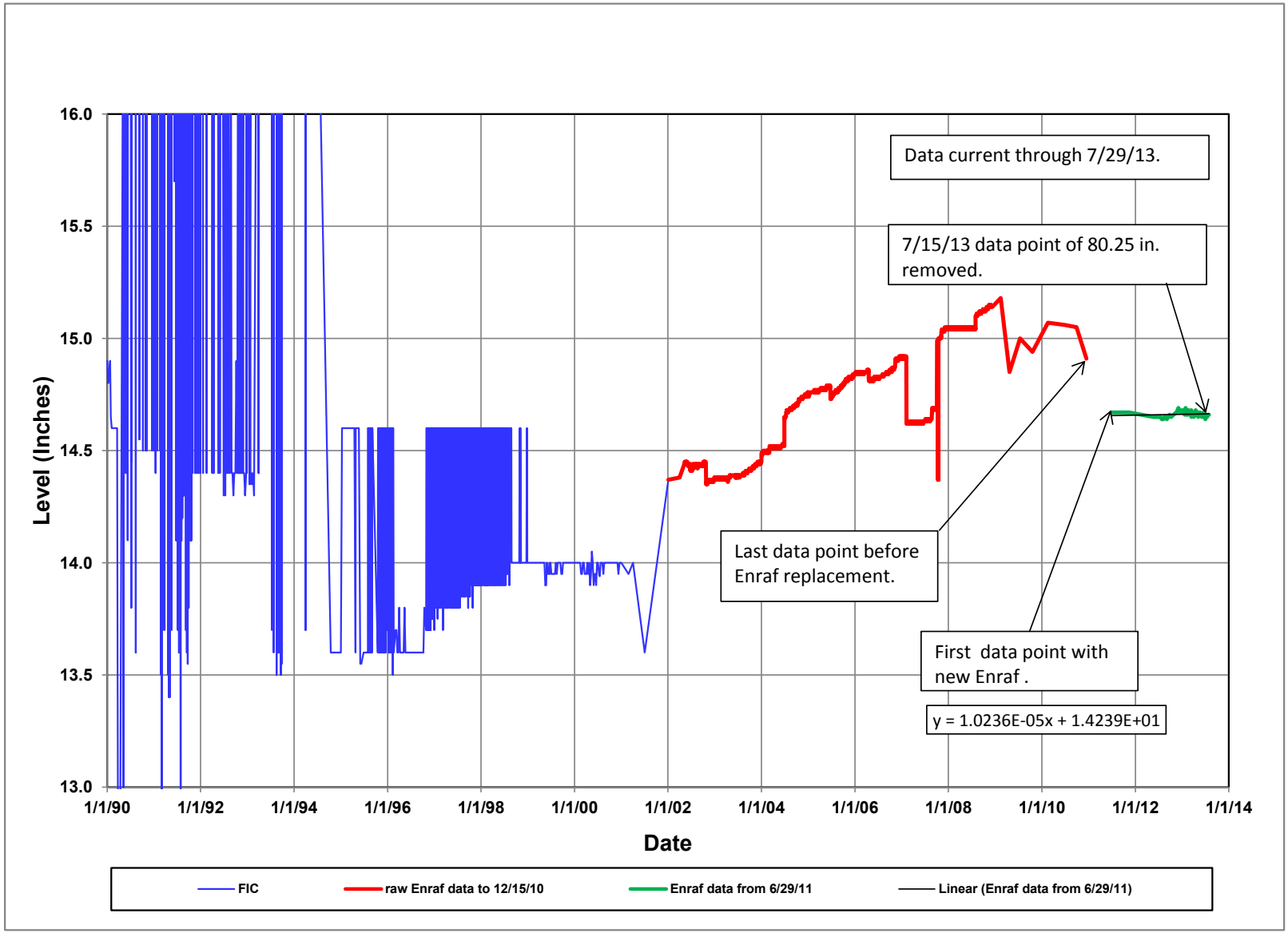
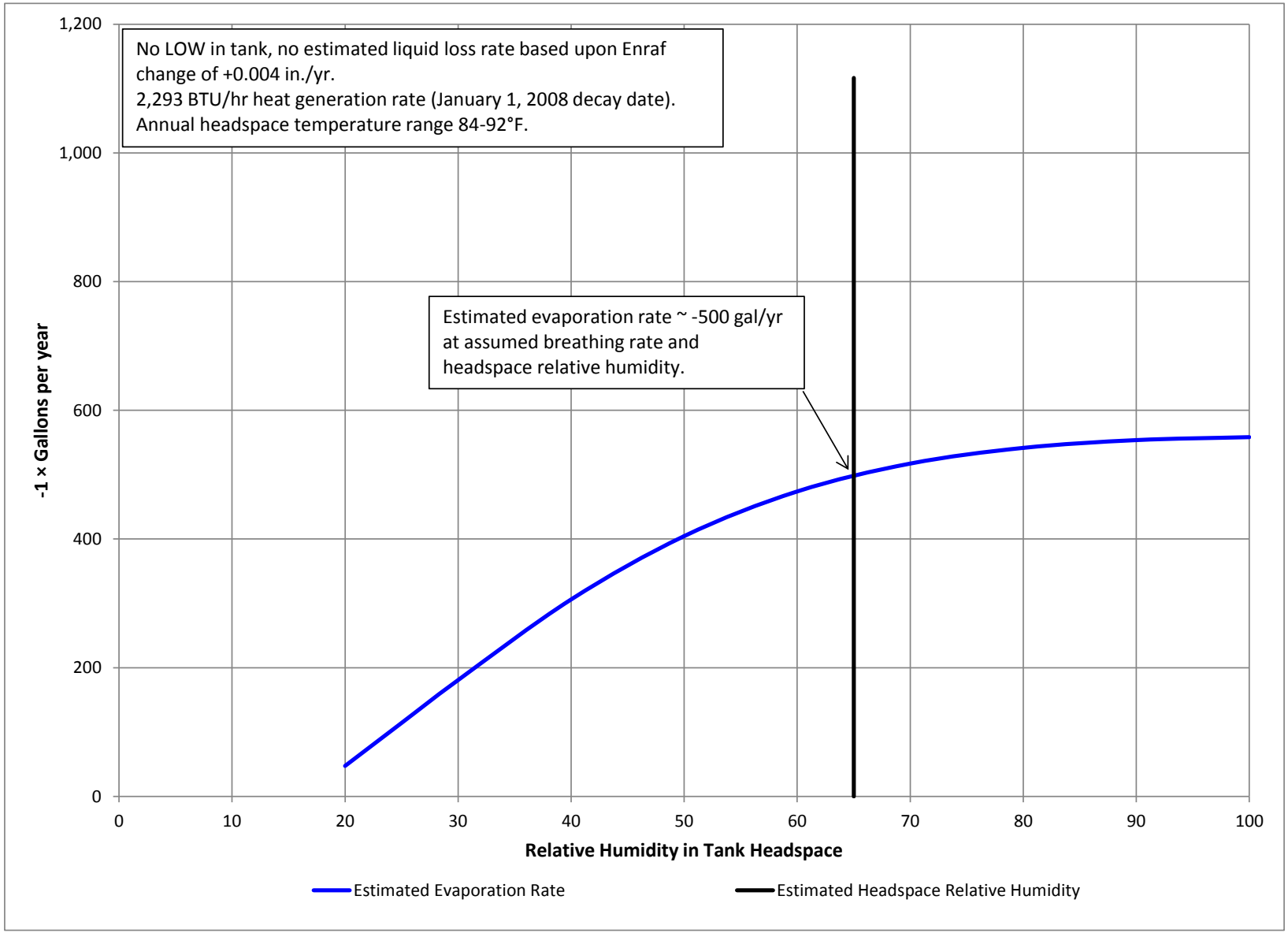


Figure 4-4 Tank A-102 Estimated Evaporation Loss Rate



4.2 Tank A-106

4.2.1 Tank Summary

Tank A-106 was put into service in 1957 and received PUREX waste through 1973. The tank was sluiced in the 1970's and received 242-A Evaporator bottoms saltcake from 1976 through 1978. The tank was labeled inactive in August 1980 and administratively interim stabilized in August 1982 (RPP-RPT-42744, Rev. 0, *2009 Auto TCR for 241-A-106*). Per a TWINS query on September 25, 2012 the tank contains about 29.1 kgal salt and 49.9 kgal of sludge.

Figure 4-5 shows the raw SL and ILL data for tank A-106 from January 1, 1990. Figure 4-6 is a plot of the same data with an expanded y-axis so the ILL data changes can be seen. The slope of the decrease line was -0.731 in./yr. Figure 4-7 is an updated plot showing the latest data included for this document. The slope changed only slightly to -0.736 in/yr as of April 3, 2013.

4.2.2 Liquid Change Rate Estimation

The estimate of liquid loss rate is based on the ILL change. There has been no waste surface level data since June of 2007 when the last surface level data point was at about 25 inches.

The sludge is assumed to be on the bottom, per RPP-40545, 2012, *Quantitative Assumptions for Single-Shell Tank Waste Retrieval Planning*, Rev 2, Appendix H. The top of the sludge, if there were no mixing with the salt and the sludge were in a flat layer, would be at about 17 inches, so the ILL which is currently about 13 inches is assumed to be in the sludge. Although the liquid level has presumably passed through the salt layer and is currently in the sludge, the RPP-5556 tank A-106 porosity of 0.15 assumed for the sludge is applied to all the waste solids above the ILL for simplicity and conservatism. This assumption is conservative since with the salt in the tank >2.0 anion mole % phosphate a salt porosity of 0.06 could be used per RPP-40545, Rev 2, Appendix H.

The interim stabilization documentation signed in 1982 was based upon in-tank photos when the waste level was about 46 inches. The documentation states there was no surface liquid, and lancing on July 15, 1982 showed the waste was wet but with no liquid zones apparent. With the ILL about a foot under the surface in 2013 it is assumed that the current fraction of liquid on the surface is zero.

The estimated tank A-106 liquid change rate is:

$$Tank\ A-106\ estimated\ liquid\ change\ rate = -0.736 \times 2{,}750 \times (0 + (1-0) \times 0.15)) = \mathbf{-304\ gal/yr}$$

4.2.3 Data Analysis

<u>Estimation of [Σ other]</u> – The level decrease is based upon the ILL decrease so subsidence is not applicable.

The BBI shows zero retained gas in tank A-106. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. Some SSTs may exhibit chronic release of gases at roughly the same rate gases are generated. With the low ~13 inch ILL in the tank it is very unlikely the waste matrix could retain and then release any gas.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1979. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for A-106 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

Potential for Intrusion – There is no evidence in Figure 4-7 for any intrusion in recent years.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -304\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= -309\frac{gal}{yr} - leak\ rate - evaporation\ rate$$

Since both evaporation rate and leak rate are negative values, the sum of the leak rate plus the evaporation rate would have to be <-309 gal/yr before an intrusion would be considered. Per Section 4.2.4 evaporation may be -650 gal/yr so an intrusion is possible if evaporation rate and volumetric change rate are accurate.

Evaluation of ILL or SL Validity – The ILL has been decreasing at the same steady rate since the first scan following LOW installation in August 2002. With the ILL a little over a foot above the tank bottom there is little reason to suspect the ILL would not be at equilibrium.

The ENRAF data are not used to estimate the tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

4.2.4 Evaporation Estimate

Figure 4-8 provides the evaporation estimate results for tank A-106. Figure 4-8 indicates tank A-106 evaporation rate could be a nominal -650 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank A-106 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank A-106, 10.4 cfm, is about a factor of 5 greater than that used for other 75 ft. diameter tanks, excluding A-102, AX-101 and AX-103. The high rate is based upon high rates calculated from tracer gas tests in A and AX farm tanks. The tracer gas test data used to calculate a breathing rate was the change in concentration of the gas in a tank headspace over time. Postulated reasons for the high breathing rates in the A/AX tanks include inleakage to the 702-AZ vent system via inadequately plugged seal loops in the buried A farm vent header,

diffusion of the tracer gas into the large 20-24 inch buried exhaust header connecting the tanks in each farm, or a small unknown source of ventilation on the tank. If there is inleakage to an active vent system then the high breathing rates for A and AX tanks are likely valid. If the high rate results from diffusion into the vent header connecting the tanks the actual breathing rate is much less since the calculated value actually measures the tracer gas depletion and the depletion rate for water vapor in the tank headspace would be less since water vapor would be brought back into A-106 from other A Farm tanks. The basis for the breathing rate assumed for tank A-106 is provided in Appendix A and is the best estimate when considering the information, but the actual rate could be lower than assumed. Changing the breathing rate would result in a proportional change in the evaporation rate. A breathing rate of approximately 4.9 cfm would result in an evaporation rate equaling the calculated liquid loss rate.

The assumed tank A-106 headspace RH of 50% is based upon the January 16, 1997 vapor space sample of 52.9% obtained when the headspace temperature was almost 105°F and there was no liquid on the waste surface. The calculated headspace temperature for January 16, 2013 is 101°F. The temperature is a little lower which could imply a higher RH, but the ILL is estimated to be greater than a foot lower, which could imply a lower RH. An RH of 50% was assumed in Appendix A, Section A.6. From Figure 4-8, assuming the tank breathing rate was correct an RH in the headspace of 27% would result in an evaporation rate equaling the calculated liquid loss rate.

An evaporation rate of -650 gal/yr for tank A-106 could be an overestimate, but it can more than account for the liquid loss rate assumed.

4.2.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank A-106 as 11,570 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. Only 2.6% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimated liquid change rate.

There is more than adequate heat to drive off water at the rate indicated despite the ILL being under the waste surface.

4.2.6 Tank A-106 Leak Potential

Based upon Figure 4-8 the tank A-106 estimated evaporation rate can account for the observed liquid loss rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = -304\frac{gal}{yr} - intrusion\ rate - (-650\frac{gal}{yr}) - (5\ gal/yr)$$
$$= 341\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for tank A-106 is -650 gal/yr, the intrusion rate would have to exceed 341 gal/yr, for a leak to exist. This is possible, but there has been no evidence of an intrusion to date, and such a rate is near the upper end of intrusions observed in tanks with known intrusions. A 341 gal/yr intrusion into A-106 is not likely.

In addition, the ILL is approximately 13 inches from the tank bottom, which is at or below the capillary height for the waste, and yet the ILL is still decreasing at a linear rate. Capillary action would prevent the ILL from continuing to drop, the fact that it is still decreasing at the same rate indicates the drop is due to evaporation.

4.2.7 Tank A-106 Conclusion

There is no basis to assume a leak from tank A-106.

Figure 4-5 Tank A-106 Full Depth Raw Data Plot

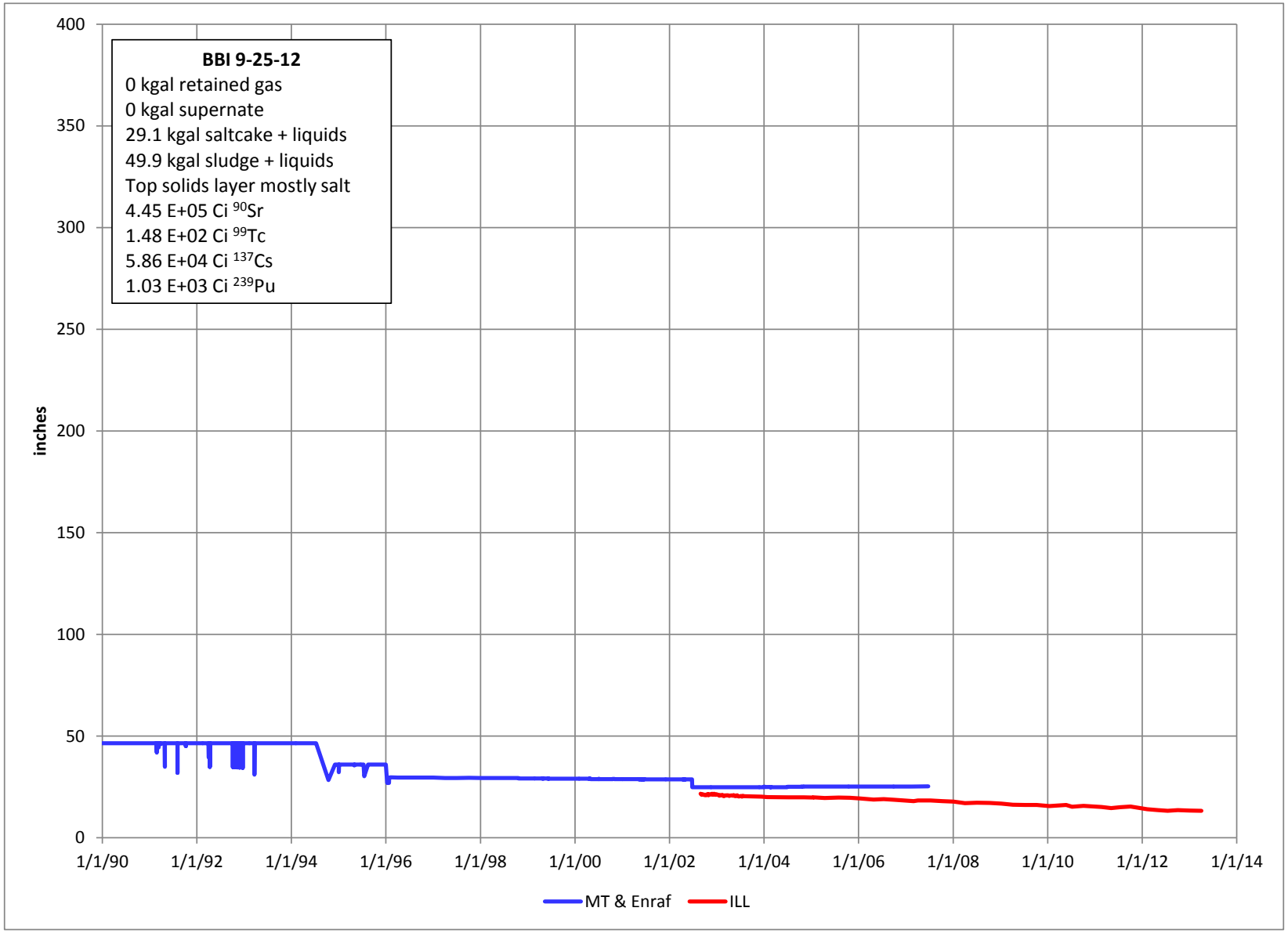


Figure 4-6 Tank A-106 Expanded ILL Data Plot Used for RPP-PLAN-55113, Rev 1

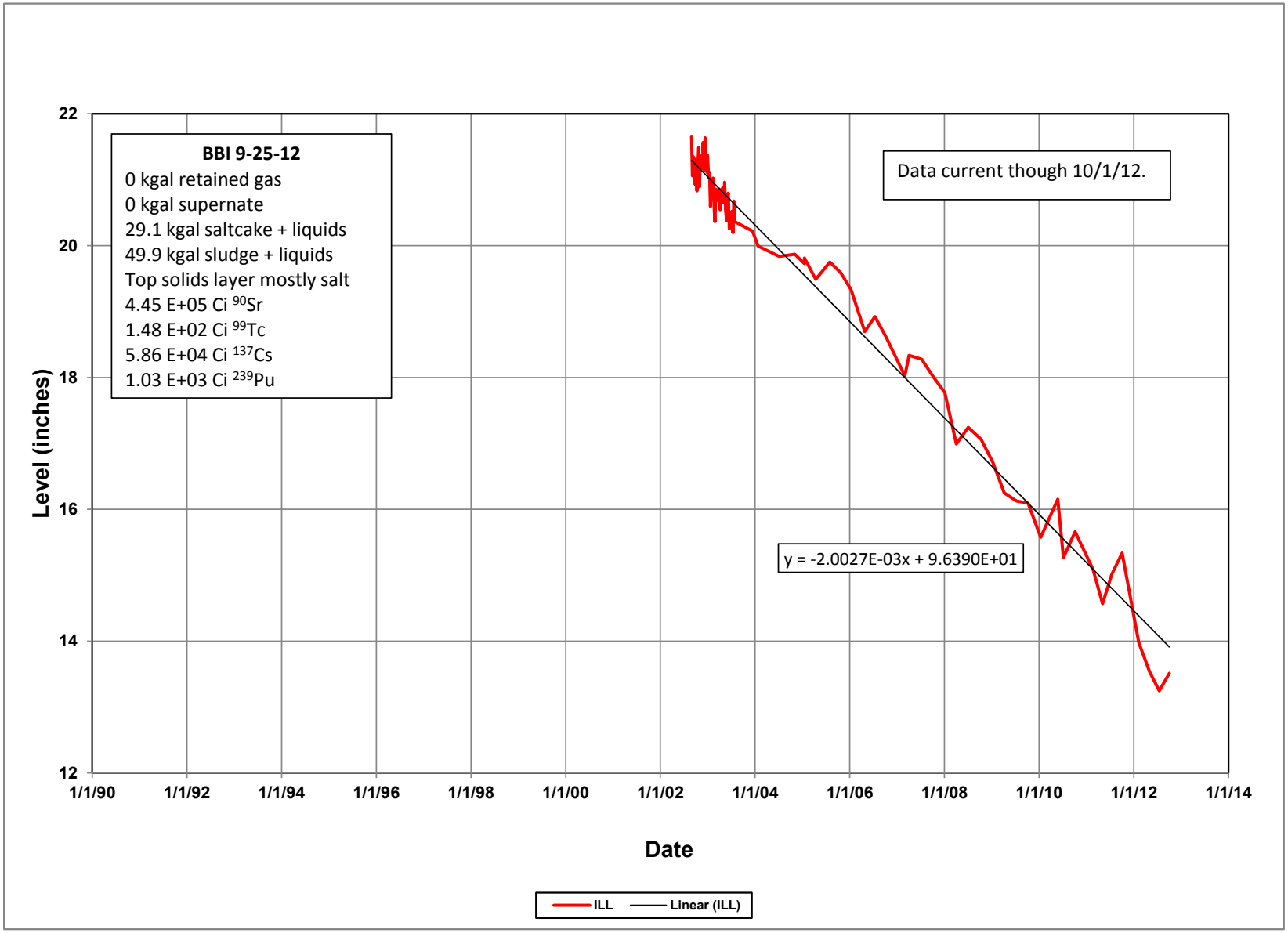


Figure 4-7 Tank A-106 Expanded ILL Data Plot Used for RPP-RPT-54981

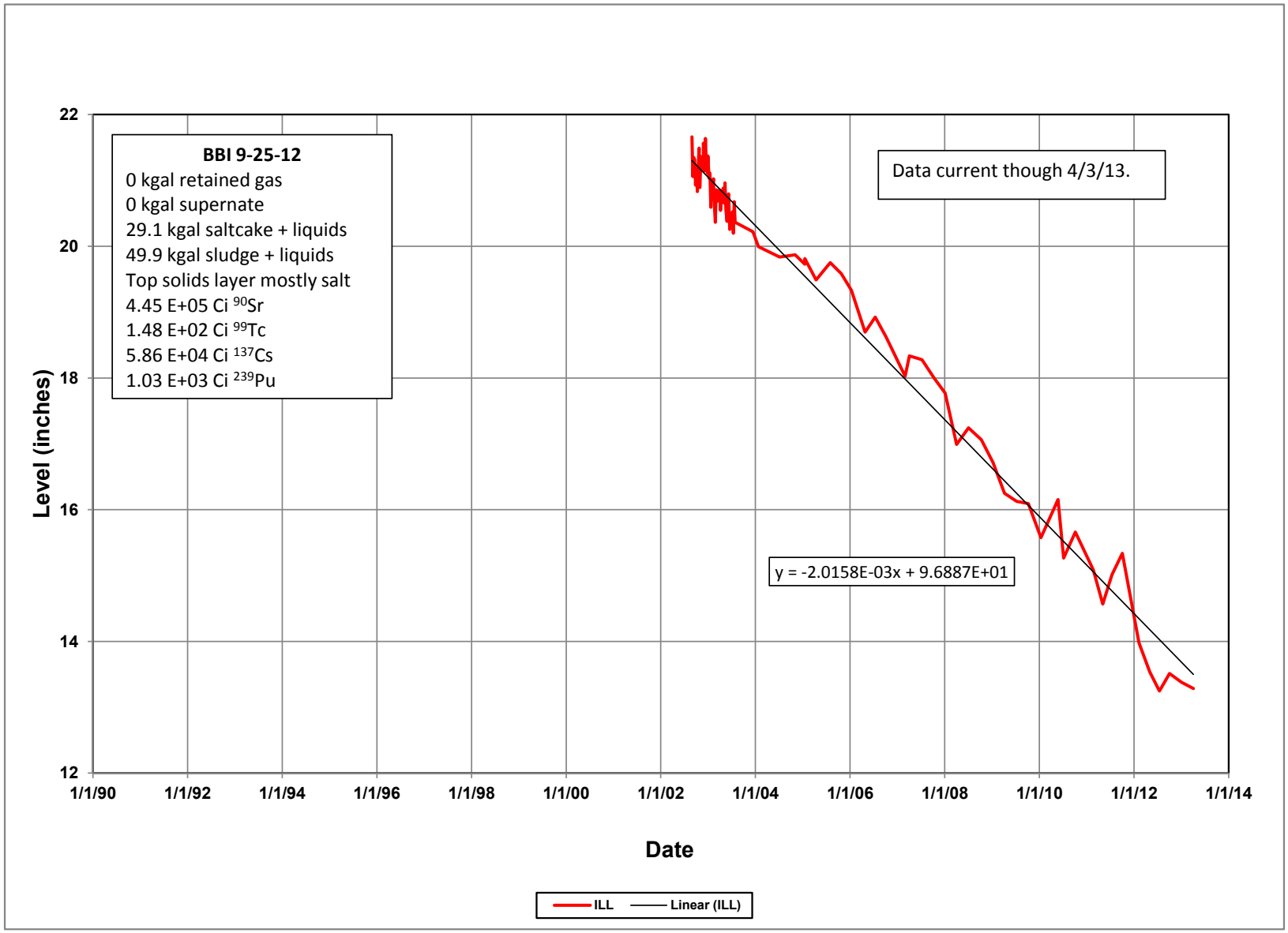
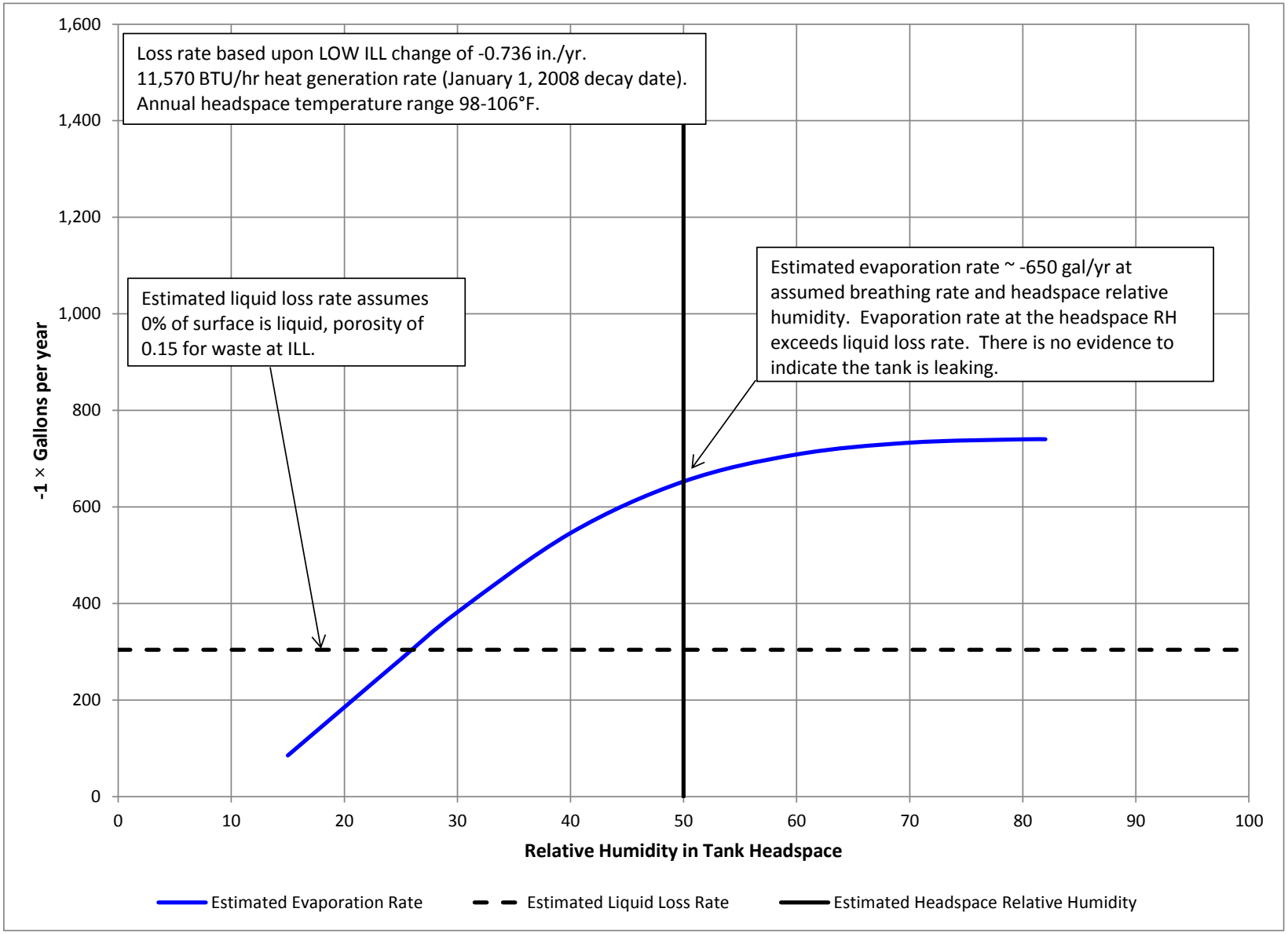


Figure 4-8 Tank A-106 Estimated Evaporation and Liquid Loss Rates



4.3 Tank AX-101

4.3.1 Tank Summary

Tank AX-101 entered service in the first quarter of 1965 receiving waste from the PUREX plant and other SSTs. The tank received waste from PUREX and other AX SSTs and boiled off liquid until 1968, when it began receiving fission product waste from B-Plant as well as PUREX waste. From 1972 through 1976 it received wastes from, and transferred wastes to, other SSTs. The tank was sluiced to remove the sludge in 1975 and 1976. In 1977 it became a salt slurry receiver. Supernatant was pumped from the tank in 1980 (WHC-MR-0132, *A History of The Hanford 200 Area Tank Farms*, Revision 0). The tank is categorized as sound, with intrusion prevention completed in 1982 and interim stabilization completed in August 1987 (RPP-RPT-42915 Rev. 0, *2009 Auto TCR for Tank 241-AX-101*). Per a TWINS query on September 25, 2012 the tank contains about 355 kgal salt and 3 kgal of sludge.

Figure 4-9 shows the raw SL and ILL data for tank AX-101 from January 1, 1990. The ILL data for tank AX-101 is based upon a gamma count rate, not a neutron count rate. It is the only tank which uses a gamma count rate for the ILL determination. Figure 4-10 is a plot of the data used for calculation of the -0.312 in./yr trendline slope used for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen. The plot shows an increase in the data for about three years after saltwell pumping was completed, then the ILL began to decrease. Figure 4-11 is an updated plot showing the latest data included for this document. The average slope of the decrease line is now slightly greater at -0.355 in./yr for the 7-year period before June 17, 2013, but appears to have settled out since late 2010 with little change since then.

4.3.2 Liquid Change Rate Estimation

The liquid change rate estimate is based on the ILL change rate of -0.355 in./yr. There has been no waste surface level data since October of 2009 when the last surface level data point was at about 132 inches.

The sludge is assumed to be on the bottom, per RPP-40545, Rev 2, Appendix H. Per RPP-40545, Rev 2, Appendix H, the salt in this tank is <2.0 anion mole % phosphate. A saltcake porosity of 0.20 is assumed per Appendix B of the same document because there is no RPP-5556 assumed porosity for tank AX-101.

With the ILL about 80 inches under the surface in 2010 it is assumed that the current fraction of liquid on the surface is zero.

The estimated tank AX-101 liquid change rate is:

$$Tank\ AX-101\ estimated\ liquid\ change\ rate = -0.355 \times 2{,}750 \times (0 + (1-0) \times 0.20)) = \mathbf{-195\ gal/yr}$$

4.3.3 Data Analysis

<u>Estimation of [Σ other]</u> – The level decrease is based upon the ILL decrease so subsidence is not applicable.

The BBI shows zero retained gas in tank AX-101. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. The decrease in the AX-101 ILL is not typical of an

episodic gas release. While it is theoretically possible the waste matrix could have been releasing retained gas since the time the ILL was installed, this is not realistic. No plot is provided of the reciprocal of the barometric pressure and the ILL for tank AX-101 since the Excel file (*BP Correlation with DB Connect*) used to prepare these plots only uses neutron scan data, and the predominant scans taken in the tank AX-101 LOW have been gamma scans.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1980. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for AX-101 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. Following the completion of interim stabilization in the tank the ILL did increase for about three years up to about 2006, but this appears to have been due to post-pumping stabilization of the ILL. There has been no increase in the ILL since 2006. From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -195\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= -200\frac{gal}{yr} - leak\ rate - evaporation\ rate$$

The sum of the leak rate plus the evaporation rate would have to be <-200 gal/yr before an intrusion would be considered. As described below, the estimated evaporation rate for tank AX-101 is -360 gal/yr so there could be an intrusion if the evaporation rate is accurate.

Evaluation of ILL or SL Validity – It is assumed the ILL was stabilized within three years of the completion of saltwell pumping, when the data plot changed slope in 2006.

The ENRAF data are not used to estimate the tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

The LOW ILL has always been referenced to the tank centerline bottom.

4.3.4 Evaporation Estimate

Figure 4-12 provides the evaporation estimate results for tank AX-101. Figure 4-12 indicates tank AX-101 would evaporate a nominal -360 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank AX-101 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank AX-101, 20.4 cfm, is about a factor of 10 greater than that used for other 75 ft. diameter tanks, excluding A-102, A-106 and AX-103. The high rate is based upon high rates calculated from tracer gas tests in A and AX farm tanks. The tracer gas test data used to calculate a breathing rate was the change in concentration of the gas in a tank headspace over time. Postulated reasons for the high breathing rates in the A/AX tanks include inleakage to the 702-AZ vent system via an inadequately plugged opening which can draw a negative pressure on AX tanks (there is currently a negative pressure on the 152-AX diversion box being investigated), diffusion of the tracer gas into the large 20-24 inch buried exhaust header connecting the tanks in each farm, or a small unknown source of ventilation on the tank. If there is inleakage to an active vent system then the high breathing rates for A and AX tanks are likely valid. If the high rate results from diffusion into the vent header connecting the tanks the actual breathing rate is much less since the calculated value actually measures the tracer gas depletion and the depletion rate for water vapor in the tank headspace would be less since water vapor would be brought back into AX-101 from other AX Farm tanks. The basis for the breathing rate assumed for tank AX-101 is provided in Appendix A and is the best estimate when considering the information, but the actual rate could possibly be lower than assumed. Changing the breathing rate would result in a proportional change in the evaporation rate. A breathing rate of approximately 11 cfm would result in an evaporation rate equaling the calculated liquid loss rate.

The assumed tank AX-101 headspace RH of 45% is based upon the June 15, 1995 vapor space sample of 37.2% obtained when the headspace temperature was almost 87°F and there was no liquid on the waste surface. The calculated headspace temperature for a June 15 annual date is 75°F. The temperature is lower than the temperature when sampled, which implies a higher RH. The ILL is nearer the waste surface also, being about 140 inches below the surface in 1995 and about 85 inches below now because of the waste surface decrease during saltwell pumping. An RH of 45% was assumed in Appendix A, Section A.6. From Figure 4-12, assuming the tank breathing rate was correct an RH in the headspace of 35% would result in an evaporation rate equaling the calculated liquid loss rate.

An evaporation rate of -360 gal/yr for tank AX-101 could be an overestimate, but it can more than account for the liquid loss rate assumed.

4.3.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank AX-101 as 10,773 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. Only 1.8% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimated liquid change rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated despite the ILL being about 85 in. below the waste surface.

4.3.6 Tank AX-101 Leak Potential

Based upon Figure 4-12 the tank AX-101 liquid loss rate can be explained by evaporation.

There is sufficient heat generated in the tank to evaporate water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = -195\frac{gal}{yr} - intrusion\ rate - (-360\frac{gal}{yr}) - (5\ gal/yr)$$
$$= 160\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for AX-101 is -360 gal/yr, the intrusion rate would have to exceed 160 gal/yr, for a leak to exist. This is possible, but there has been no evidence of an intrusion to date.

4.3.7 Tank AX-101 Conclusion

There is no basis to assume a leak from tank AX-101.

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Figure 4-9 Tank AX-101 Full Depth Raw Data Plot

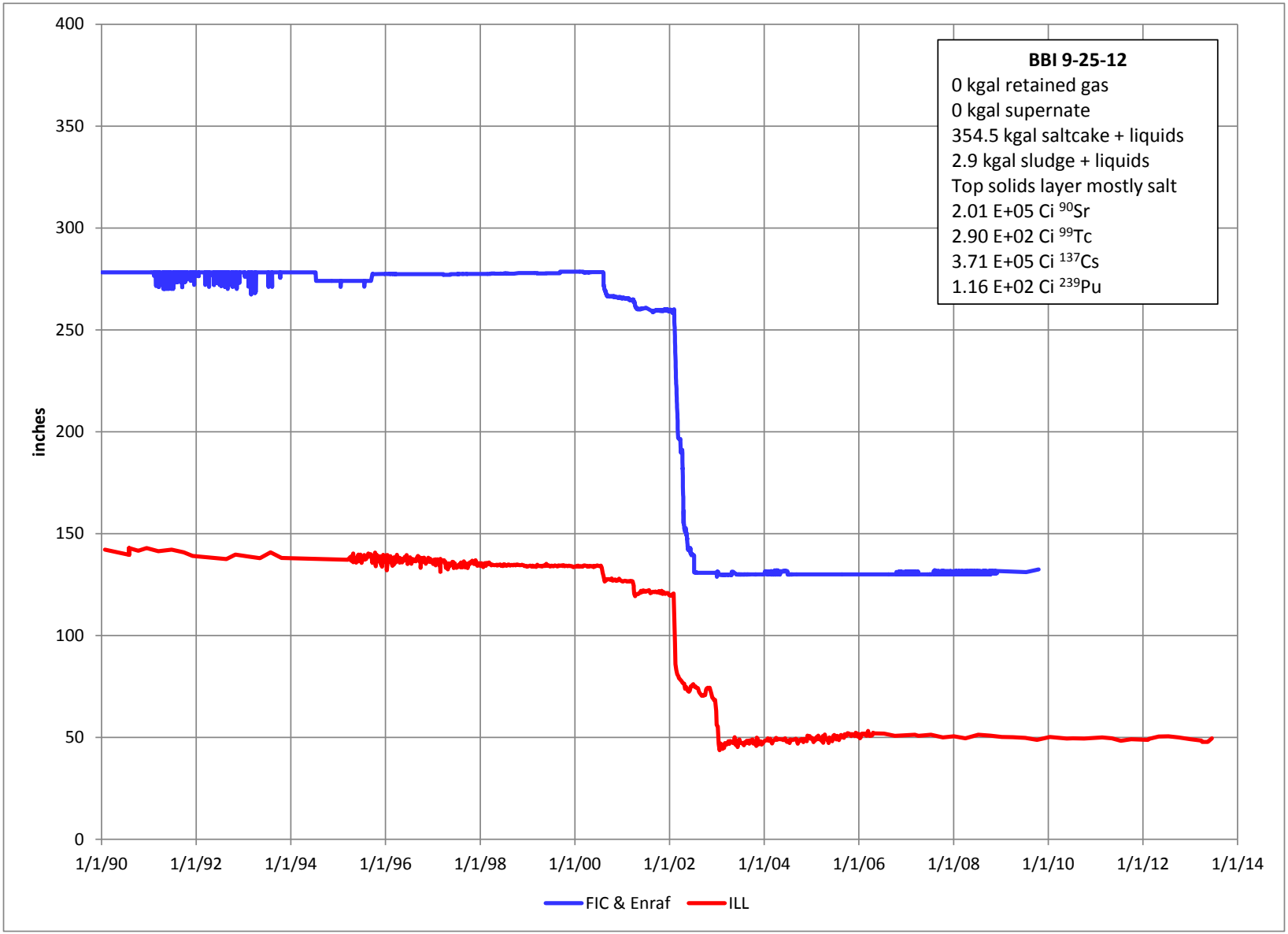


Figure 4-10 Tank AX-101 Expanded ILL Data Plot Used for RPP-PLAN-55113, Rev 1

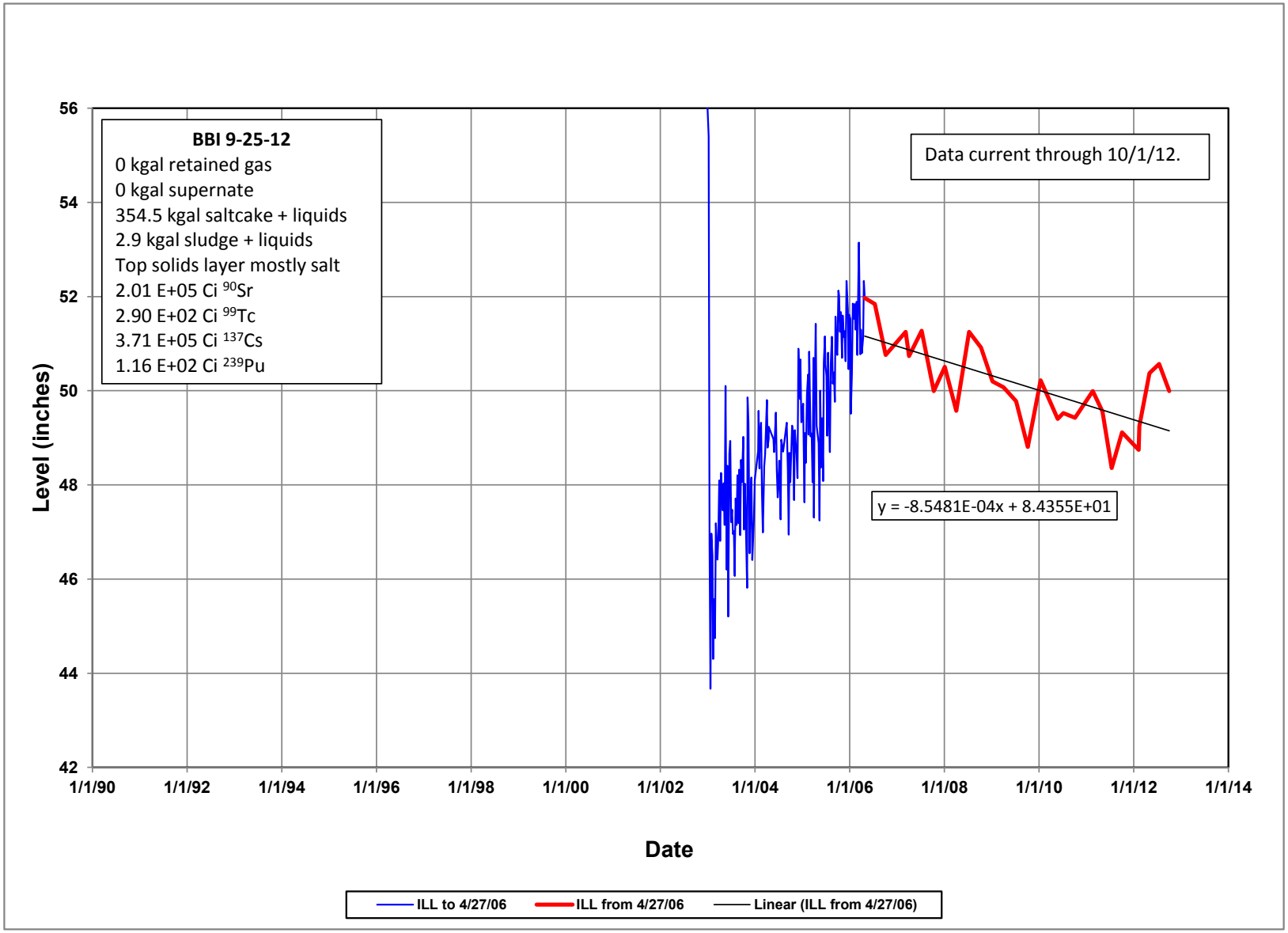


Figure 4-11 Tank AX-101 Expanded ILL Data Plot Used for RPP-RPT-54981

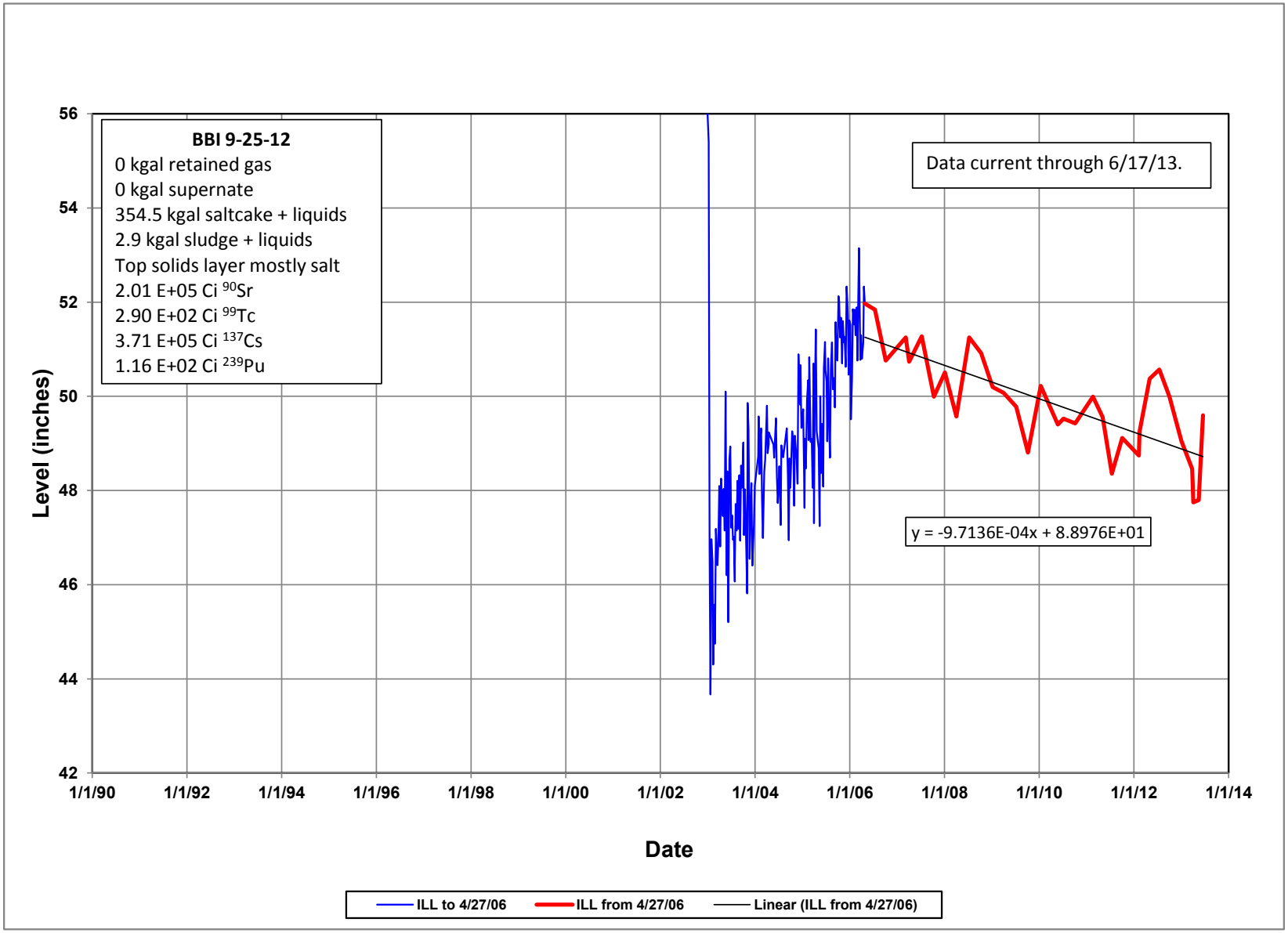
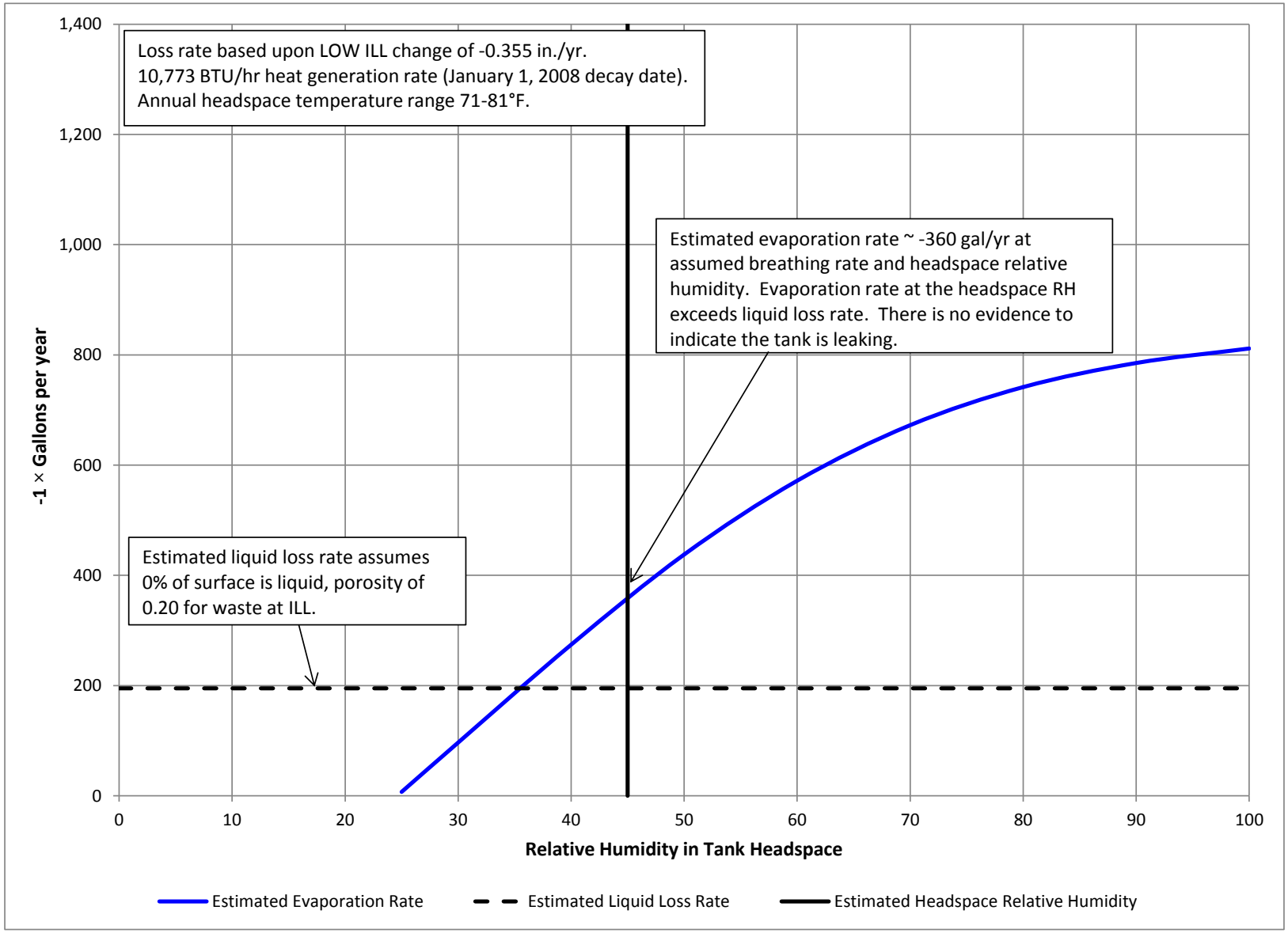


Figure 4-12 Tank AX-101 Estimated Evaporation and Liquid Loss Rates



4.4 Tank AX-103

4.4.1 Tank Summary

Tank AX-103 entered service in the first quarter of 1965 receiving waste from PUREX. The tank received waste from PUREX and other AX SSTs throughout the 1960s. In 1968, 1969, and 1972 the tank received B-Plant waste as well as other PUREX and AX tank liquids. In 1975, the tank received waste from the AR Vault. After the tank was sluiced, salt wastes were transferred into and out of the tank. Supernatant was pumped from the tank in 1980. The tank is categorized as sound, with intrusion prevention completed in 1982 and interim stabilization completed in August 1987 (RPP-RPT-42917, Rev. 0, *2009 Auto TCR for 241-AX-103*). Per a TWINS query on September 25, 2012 the tank contains about 98.5 kgal salt and 7.9 kgal of sludge.

Figure 4-13 shows the raw SL and ILL data for tank AX-103 from January 1, 1990. Figure 4-14 is a plot of the data used for calculation of the -0.572 in./yr trendline slope used for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen. The ILL shows a fairly constant decrease since the ILL appeared to stabilize after installation in early 2002. Figure 4-15 is an updated plot showing the latest data included for this document. The slope of the decrease line is now slightly greater at -0.596 in./yr as of April 3, 2013.

4.4.2 Liquid Change Rate Estimation

The best estimate of liquid loss rate is based on the ILL change rate of -0.596 in./yr. There has been no waste surface level data since October of 2009 when the last surface level data point was at about 38 inches.

The sludge is on the bottom, per RPP-40545, Rev 2, Appendix H. A saltcake porosity of 0.25 is used for consistency with RPP-5556.

With the ILL estimated at about 12 inches under the surface and there being zero supernatant liquid listed in the 1987 interim stabilization documentation (HNF-SD-RE-TI-178, 2007, *Single Shell Tank Interim Stabilization Record*, Rev 9a) it is assumed the fraction of liquid on the waste surface is zero.

The estimated tank AX-103 liquid change rate is:

$$Tank\ AX - 103\ best\ estimate\ liquid\ change\ rate$$
$$= -0.328 \times 2{,}750 \times (0 + (1 - 0) \times 0.25)) = \mathbf{-410\ gal/yr}$$

4.4.3 Data Analysis

<u>Estimation of [Σ other]</u> – The level decrease is based upon the ILL decrease so subsidence is not applicable.

Figure 4-16 is a plot of the inverse of the barometric pressure and the ILL data. The relatively high (0.714) R^2 value means there is a reasonable correlation between the ILL changes and the barometric pressure changes. This indicates there is sufficient retained gas in the tank to show a response to atmospheric pressure fluctuations.

Figure 4-17 is a comparison of tank AX-103 LOW neutron scan data from 2003 and 2013. There is no obvious gas volume decrease apparent. The liquid content has receded proportionately from the top of the waste rather than showing the expected liquid increase at

some level that would have occurred if a large volume of gas were released and replaced with liquid. The BBI shows zero retained gas in AX-103. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. Some SSTs may exhibit chronic release of gases at roughly the same rate gases are generated. But the continual release of retained gas from tank AX-103 for over 10 years is not realistic. Therefore, despite evidence for some retained gas in the tank there is no basis to assume any impact of retained gas on the level decrease rate.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1980. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for AX-103 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

<u>Potential for Intrusion</u> – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. There has been no evidence of intrusion based upon the ILL data since the LOW was installed in 2002, nor before that date based upon SL data.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -410\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= -415\frac{gal}{yr} - leak\ rate - evaporation\ rate$$

Since both evaporation rate and leak rate are negative values, the sum of the leak rate plus the evaporation rate would have to be <-415 gal/yr before an intrusion would be considered. As described below, the estimated evaporation rate for tank AX-103 is -510 gal/yr so there could be an intrusion if the evaporation rate is accurate.

<u>Evaluation of ILL or SL Validity</u> – The ILL appears from Figure 4-15 to have stabilized within less than a year of installation. Figure 4-17 shows an overall liquid decrease rate expected from a tank with an ILL at equilibrium across the tank.

The ENRAF data are not used to estimate the tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

The LOW ILL has always been referenced to the tank centerline bottom.

4.4.4 Evaporation Estimate

Figure 4-18 provides the evaporation estimate results for tank AX-103. Figure 4-18 indicates tank AX-103 would evaporate a nominal -510 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank AX-103 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank AX-103, 25 cfm, is about a factor of 12 greater than that used for other 75 ft. diameter tanks, excluding A-102, A-106 and AX-101. The high rate is the value from the tracer gas test in AX-103. The tracer gas test data used to calculate a breathing rate was the change in concentration of the gas in a tank headspace over time. Postulated reasons for the high breathing rates in the A/AX tanks include inleakage to the 702-AZ vent system via an inadequately plugged opening which can draw a negative pressure on AX tanks (there is currently a negative pressure on the 152-AX diversion box being investigated), diffusion of the tracer gas into the large 20-24 inch buried exhaust header connecting the tanks in each farm, or a small unknown source of ventilation on the tank. If there is inleakage to an active vent system then the high breathing rates for AX tanks are likely valid. If the high rate results from diffusion into the vent header connecting the tanks the actual breathing rate is less since the calculated value actually measures the tracer gas depletion. The depletion rate for water vapor in the tank headspace would be less since water vapor would be brought back into AX-103 from other tanks. The breathing rate assumed for tank AX-103 is the same as calculated from the tracer gas test data, and is the best estimate when considering the information, but the actual rate could possibly be lower than assumed. Changing the breathing rate would result in a proportional change in the evaporation rate. A breathing rate of approximately 20 cfm would result in an evaporation rate equaling the calculated liquid loss rate.

The assumed tank AX-103 headspace RH of 40% is based upon the June 21, 1995 vapor space sample of 38.4% obtained when the headspace temperature was 90°F and there was no liquid on the waste surface. The calculated headspace temperature for a June 21 annual date is 81°F. The temperature is a lower which implies a higher RH, while the ILL is estimated to be a foot below the surface. An RH of 40% was assumed in Appendix A, Section A.6. Per Figure 4-18, assuming the tank breathing rate was correct an RH in the headspace of 36% would result in an evaporation rate equaling the calculated liquid loss rate.

An evaporation rate of -510 gal/yr for tank AX-103 could be an overestimate, but it can more than account for the liquid loss rate assumed.

4.4.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank AX-103 as 11,105 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. Only 3.7% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimated liquid change rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated despite the ILL being about 11 in. below the waste surface.

4.4.6 Tank AX-103 Leak Potential

Based upon Figure 4-18 the tank AX-103 liquid loss rate can be explained by evaporation.

There is sufficient heat generated in the tank to evaporate water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = -410\frac{gal}{yr} - intrusion\ rate - (-510\frac{gal}{yr}) - (5\ gal/yr)$$
$$= 95\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for AX-103 is -510 gal/yr, the intrusion rate would have to exceed 95 gal/yr, for a leak to exist. This is possible, but there has been no evidence of an intrusion to date.

4.4.7 Tank AX-103 Conclusion

There is no basis to assume a leak from tank AX-103.

Figure 4-13 Tank AX-103 Full Depth Raw Data Plot

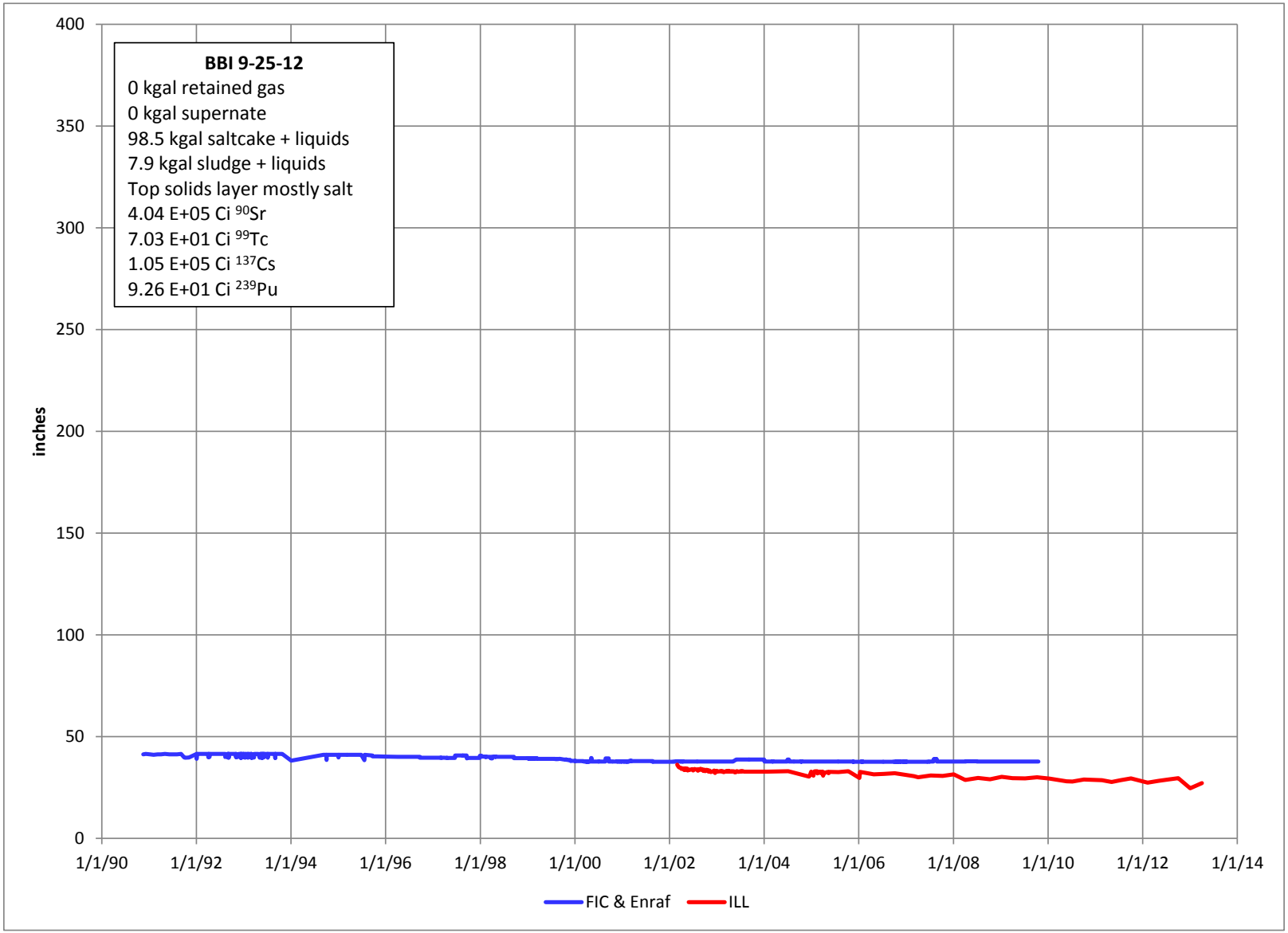


Figure 4-14 Tank AX-103 Expanded ILL Data Plot Used for RPP-PLAN-55113, Rev 1

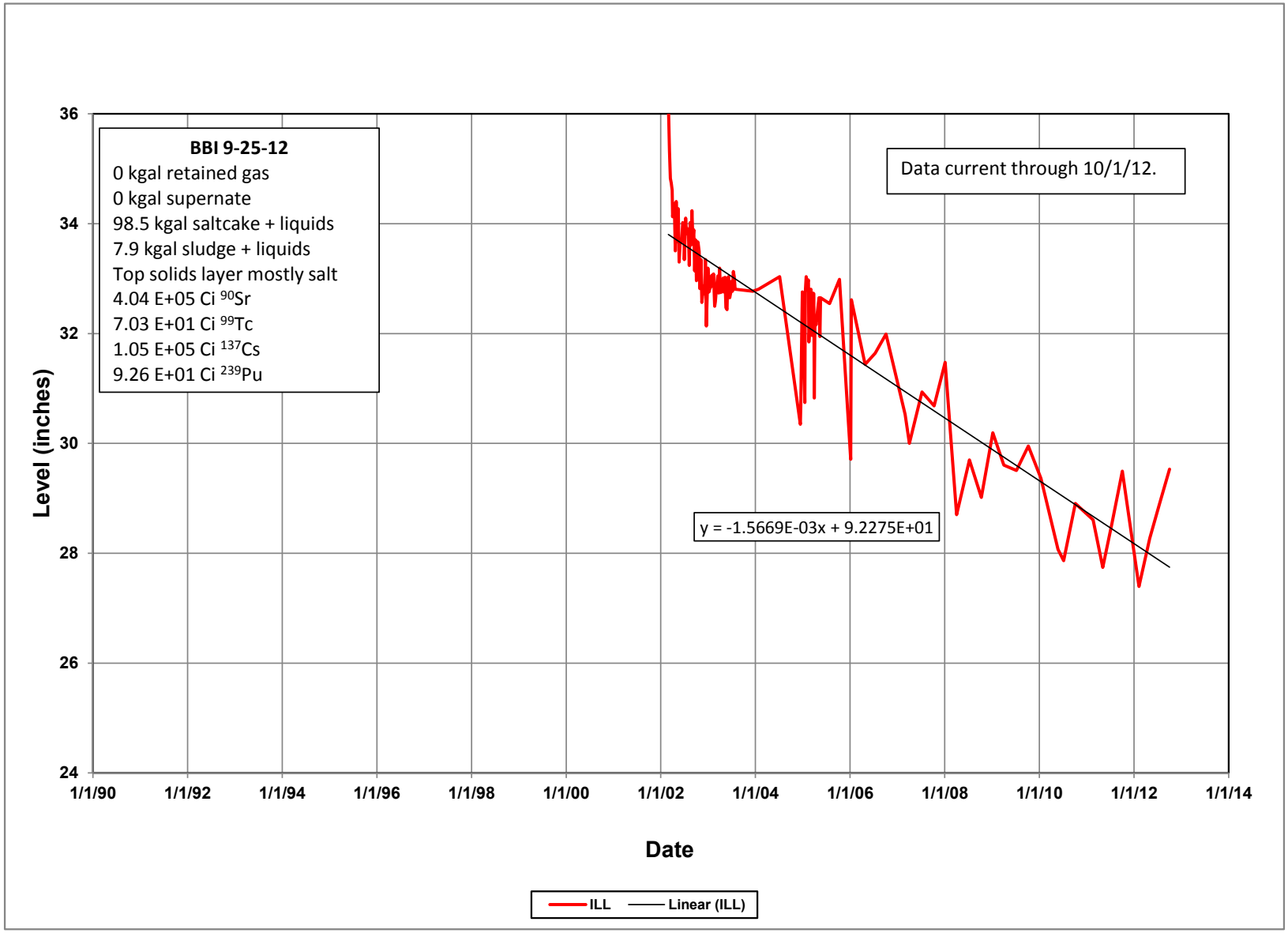


Figure 4-15 Tank AX-103 Expanded ILL Data Plot Used for RPP-RPT-54981

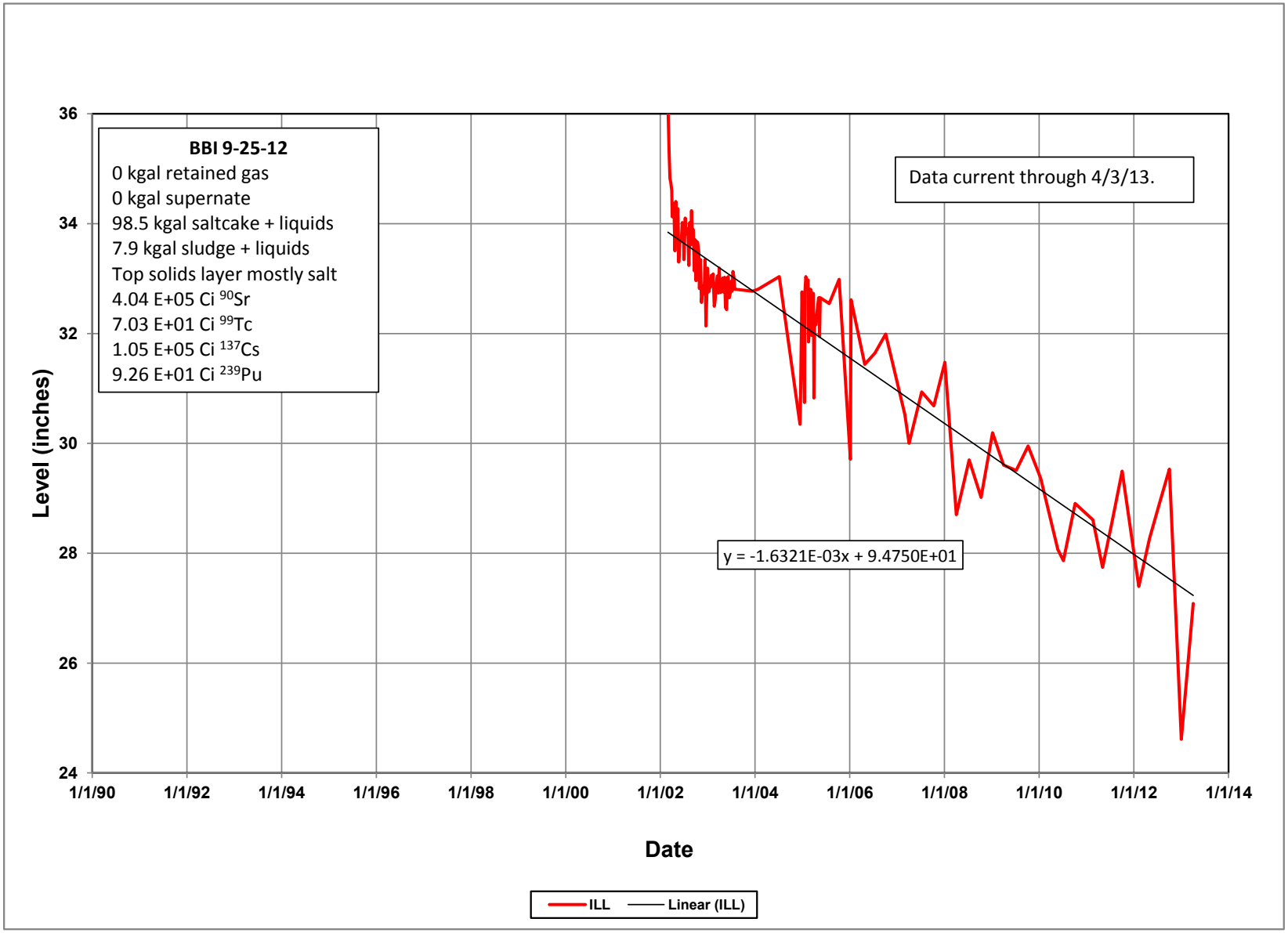


Figure 4-16 Tank AX-103 Raw Interstitial Liquid Level Data and Adjusted Inverse Barometric Pressure

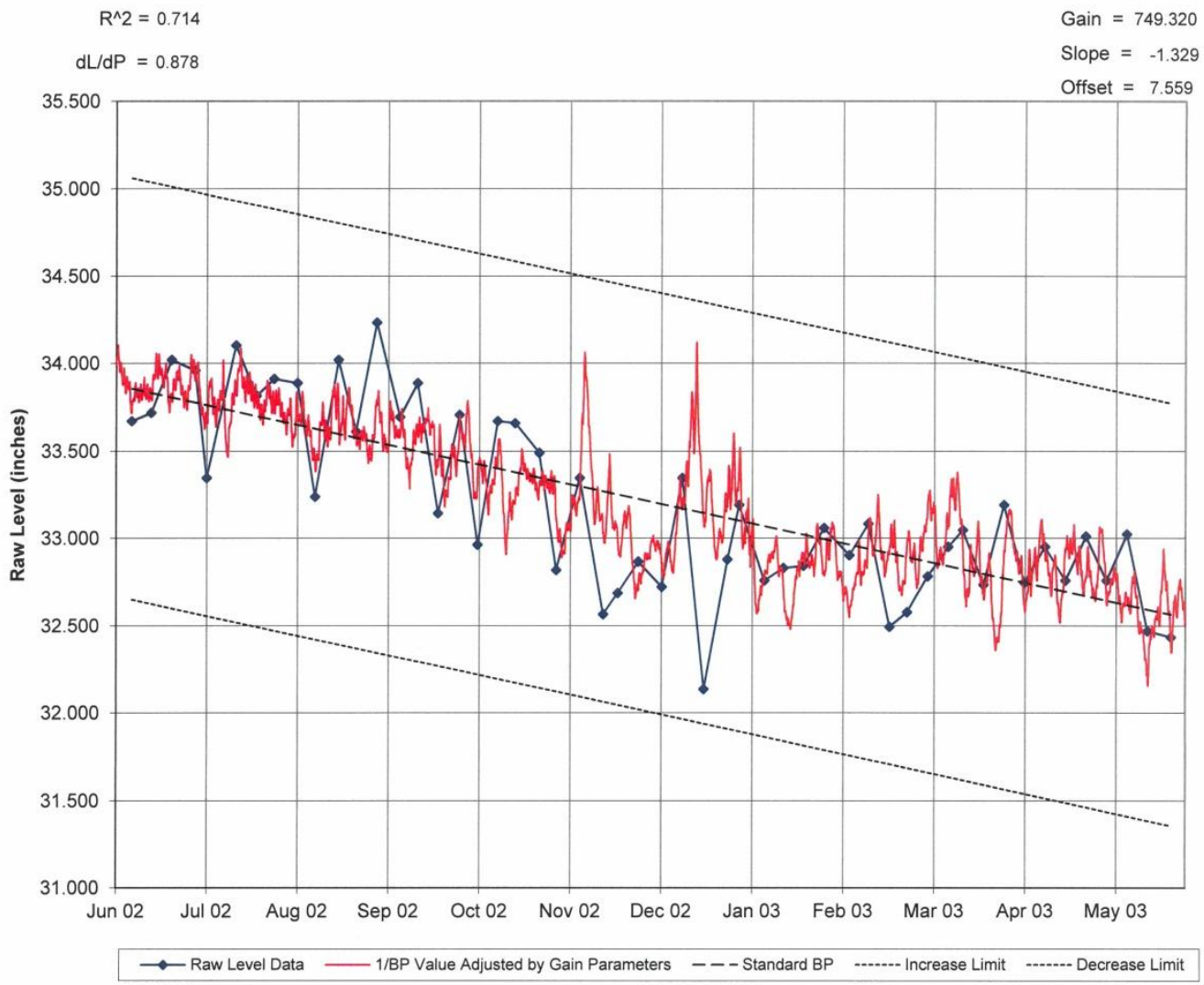


Figure 4-17 Comparison of Tank AX-103 2003 and 2013 Liquid Observation Well Neutron Scans

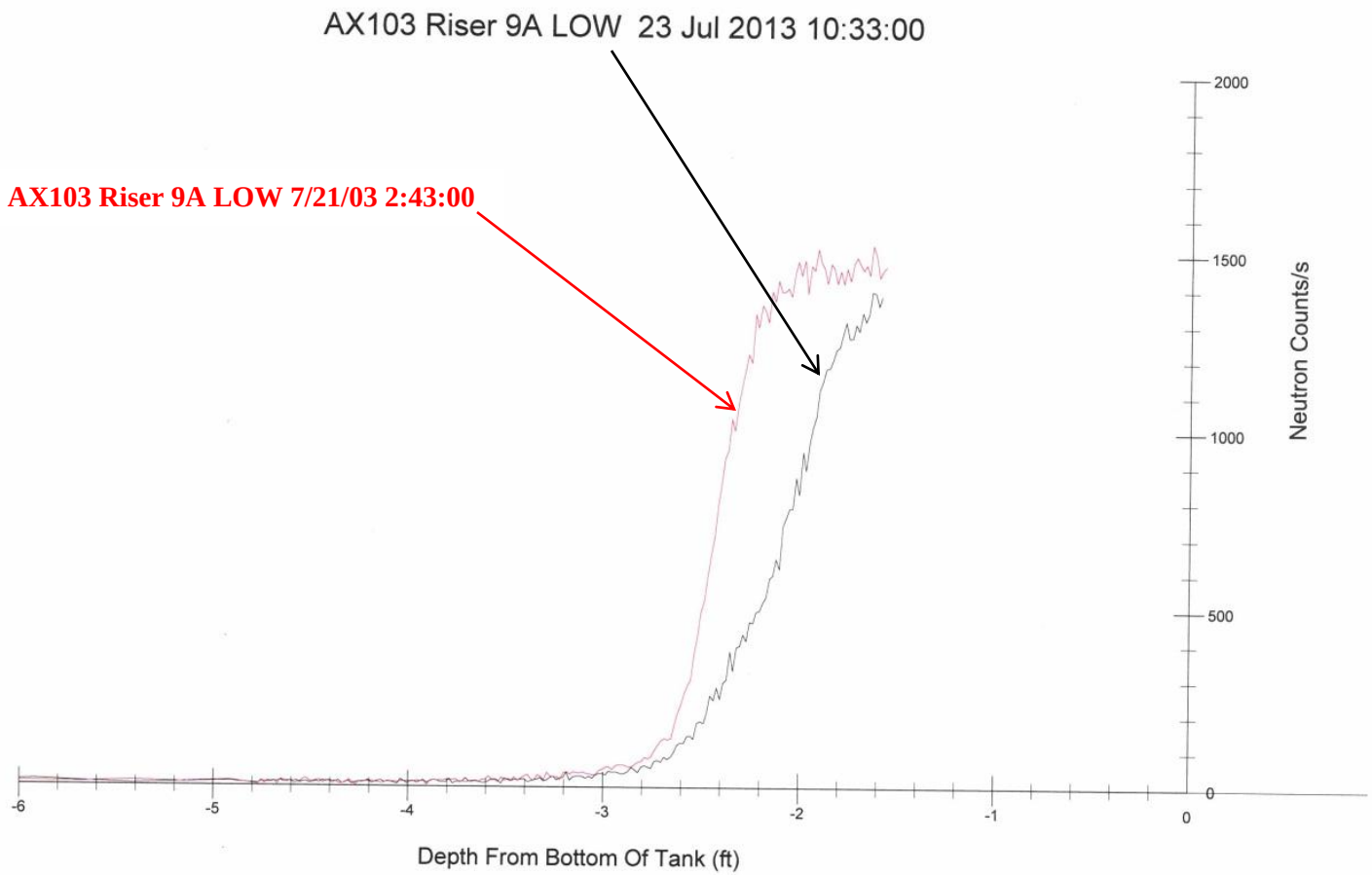
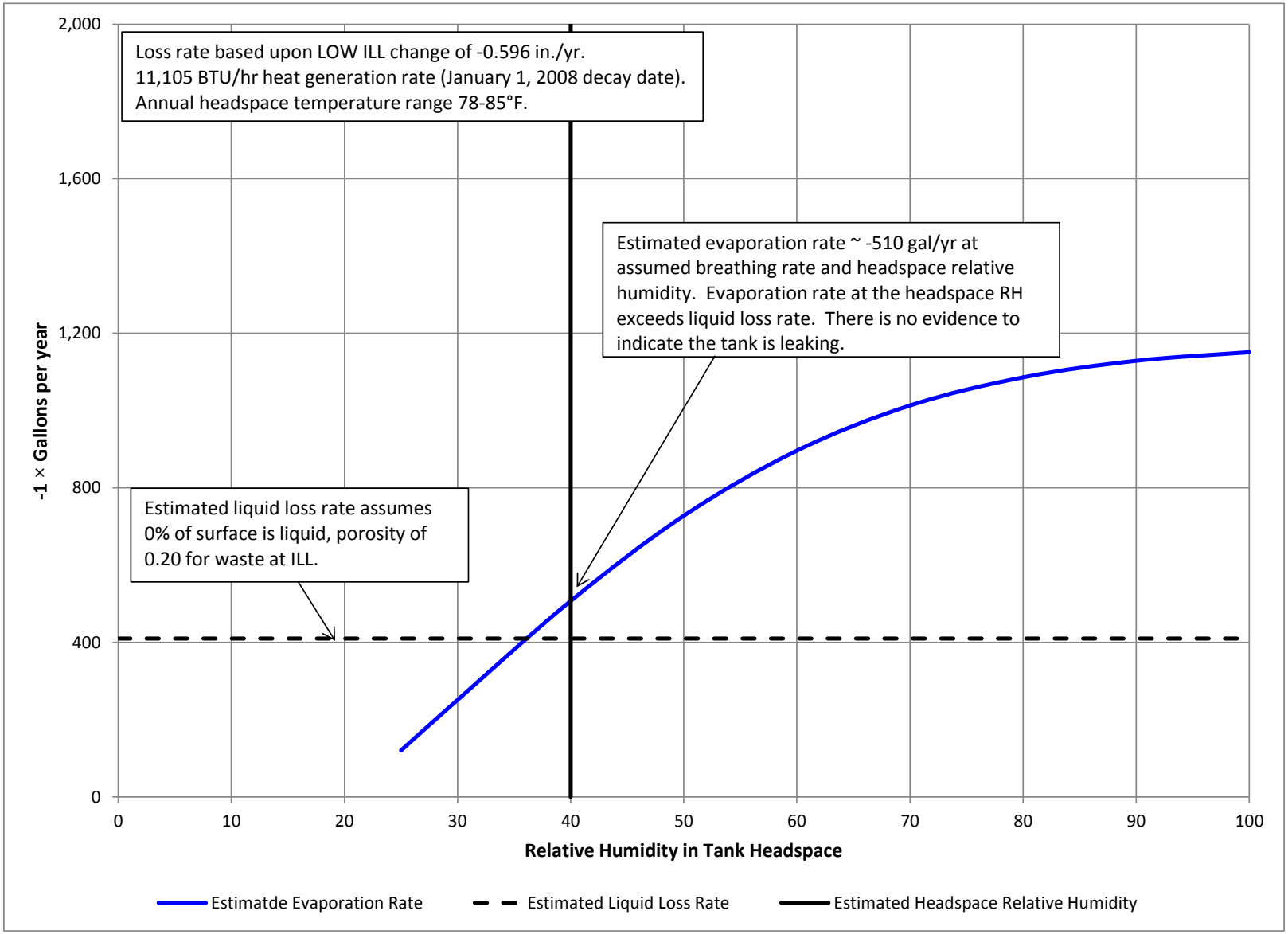


Figure 4-18 Tank AX-103 Estimated Evaporation and Liquid Loss Rates



4.5 Tank BY-108

4.5.1 Tank Summary

Tank BY-108 entered service in 1951 receiving $BiPO_4$ waste that cascaded from BY-107. It then served as a settling tank for ferrocyanide-scavenged uranium recovery waste. It sent waste to and received waste from other SSTs in the 1960s, and from 1969 until 1972 it was a receiver for in-tank solidification salt waste. Tank BY-108 was removed from service in late 1972 and is listed as an assumed leaker in HNF-EP-0182, Rev 301. The tank was interim stabilized in February 1985 and intrusion prevention was completed in 1991 (RPP-RPT-43002, Rev. 0, *2009 Auto TCR for 241-BY-108*). Per a TWINS query on September 25, 2012 the tank contains about 182.3 kgal salt and 39.9 kgal of sludge.

Figure 4-19 shows the raw ILL and SL data for tank BY-108 from January 1, 1990. Figure 4-20 is a plot of the ILL data used for calculation of the -0.287 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen. Figure 4-21 is an updated plot showing the latest data included for this document. The slope of the decrease line is essentially the same at -0.281 in./yr as of January 10, 2013.

The tank has shown no discernible waste surface level change since 1990. The ILL has shown a steady decrease since shortly after the LOW was installed in 2002. The ILL may be leveling off since early 2011. Since the waste surface appears to be rigid and dry it is reasonable to expect the SL drop to be zero even if the tank were leaking.

4.5.2 Liquid Change Rate Estimation

The liquid change rate estimate is based on the ILL change rate of -0.281 in./yr.

The sludge is on the bottom, per RPP-40545, Rev 2, Appendix H. Per RPP-5556 a porosity of 0.24 was assumed for both the sludge and saltcake in this tank. However, this document also indicated the saltcake volume was 74 kgal and the sludge volume was 154 kgal, when it is now shown in the BBI as being about 182 kgal saltcake and 40 kgal sludge. Per RPP-40545, Rev 2, Appendix H the salt in this tank is >2.0 anion mole % phosphate. A saltcake porosity of 0.06 is recommended for saltcake >2.0 anion mole % phosphate in Appendix B of the same document, based upon data obtained during waste retrieval operations in S-102. Since S-102 retrieval occurred 5 to 7 years after RPP-5556 was issued, a porosity of 0.06 is assumed for the BY-108 saltcake. The ILL is about 22 in. below the waste surface so only the porosity of the salt needs to be considered.

The IS documentation from 1985 did not indicate any surface liquid. Based upon the ILL location and the IS documentation it is assumed that the fraction of liquid on the surface is zero.

The best estimate of the tank BY-108 volumetric change rate is equal to:

$$Tank\ BY-108\ estimated\ liquid\ change\ rate = -0.281 \times 2{,}750 \times (0 + (1-0) \times 0.06)) = \mathbf{-46\ gal/yr}$$

4.5.3 Data Analysis

Estimation of [Σ other] – The level decrease is based upon the ILL decrease rather than the surface level change so subsidence is not applicable.

Figure 4-22 is a plot of the inverse of the barometric pressure and the ILL data. There is some correlation between the ILL change and the atmospheric pressure as indicated by the moderate (0.454) R^2 value. Observation of the plot shows considerable matching of 'peaks and valleys' indicating there is probably some retained gas in the tank. Figure 4-23 is a comparison of tank BY-108 LOW neutron scan data from 2003 and 2013. There is no obvious gas volume decrease apparent. The liquid content has receded proportionately from the top of the waste rather than showing the expected liquid decrease at some level that would have occurred if a large volume of gas were replaced with liquid. The BBI shows zero retained gas in BY-108. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. Some SSTs may exhibit chronic release of gases at roughly the same rate gases are generated. But, the continual release of retained gas from tank BY-108 for over 10 years is not realistic. Therefore, despite evidence for some retained gas in the tank there is no basis to assume any impact of retained gas on the level decrease rate.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1969. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for BY-108 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. The decreasing ILL could mask an intrusion, but there has been no decrease in the SL data since 1990, and an intrusion would be expected to dissolve up salt in this tank and thus cause some SL decrease if there were an intrusion.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -46\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= -51\frac{gal}{yr} - leak\ rate - evaporation\ rate$$

Since both evaporation rate and leak rate are negative values, the sum of the leak rate plus the evaporation rate would have to be <-51 gal/yr before an intrusion would be considered. As described below, the estimated evaporation rate for tank BY-108 is -60 gal/yr so there could be a very small intrusion if the evaporation rate is accurate.

Evaluation of ILL or SL Validity – The ILL appears from Figure 4-21 to have stabilized within less than a year of installation. Figure 4-23 also shows the steady liquid decrease expected of a tank with the ILL at equilibrium.

The ENRAF data are not used to estimate the tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

The LOW ILL has always been referenced to the tank centerline bottom.

4.5.4 Evaporation Estimate

Figure 4-24 provides the evaporation estimate results for tank BY-108. Figure 4-24 indicates tank BY-108 would evaporate about -60 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank BY-108 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank BY-108, 2.4 cfm, is similar to the rates for other 75 ft. diameter tanks excluding A and AX tank farms, and is within the range of breathing rate data for the non-A/AX tanks with tracer gas tests in 1996 to 1998. The basis for the breathing rate assumed for tank BY-108 is provided in Appendix A and is the best estimate when considering the information. The breathing rate results in an evaporation rate that exceeds the calculated liquid change rate.

The assumed tank BY-108 headspace RH of 53% is based upon the nine vapor space samples taken between January 10, 1994 and January 30, 1997 which averaged 50% when the headspace temperature was almost 77°F to 87°F and there was no liquid on the waste surface. Per Table A-9 in Appendix A the temperature now averages 73°F to 81°F. With the temperature lower this implies a slightly higher RH. The ILL is about 4 inches farther below the surface now than in 1994-1997. An RH of 53% was assumed in Appendix A, Section A.6. From Figure 4-24, assuming the tank breathing rate was correct an RH in the headspace of 45% would result in an evaporation rate equaling the calculated liquid loss rate.

An evaporation rate of -60 gal/yr for tank BY-108 can account for the liquid loss rate assumed.

4.5.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank BY-108 as 3,480 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. Only 1.4% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimated liquid change rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated despite the ILL being about 21 in. below the waste surface.

4.5.6 Tank BY-108 Leak Potential

Based upon Figure 4-24 the tank BY-108 liquid loss rate can be explained by evaporation.

There is sufficient heat generated in the tank to evaporate water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = -46\frac{gal}{yr} - intrusion\ rate - (-60\frac{gal}{yr}) - (5\ gal/yr)$$
$$= 9\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for BY-108 is -60 gal/yr, the intrusion rate would have to exceed 9 gal/yr, for a leak to exist. This is possible, but there has been no evidence of an intrusion to date.

4.5.7 Tank BY-108 Conclusion

There is no basis to assume a leak from tank BY-108.

Figure 4-19 Tank BY-108 Full Depth Raw Data Plot

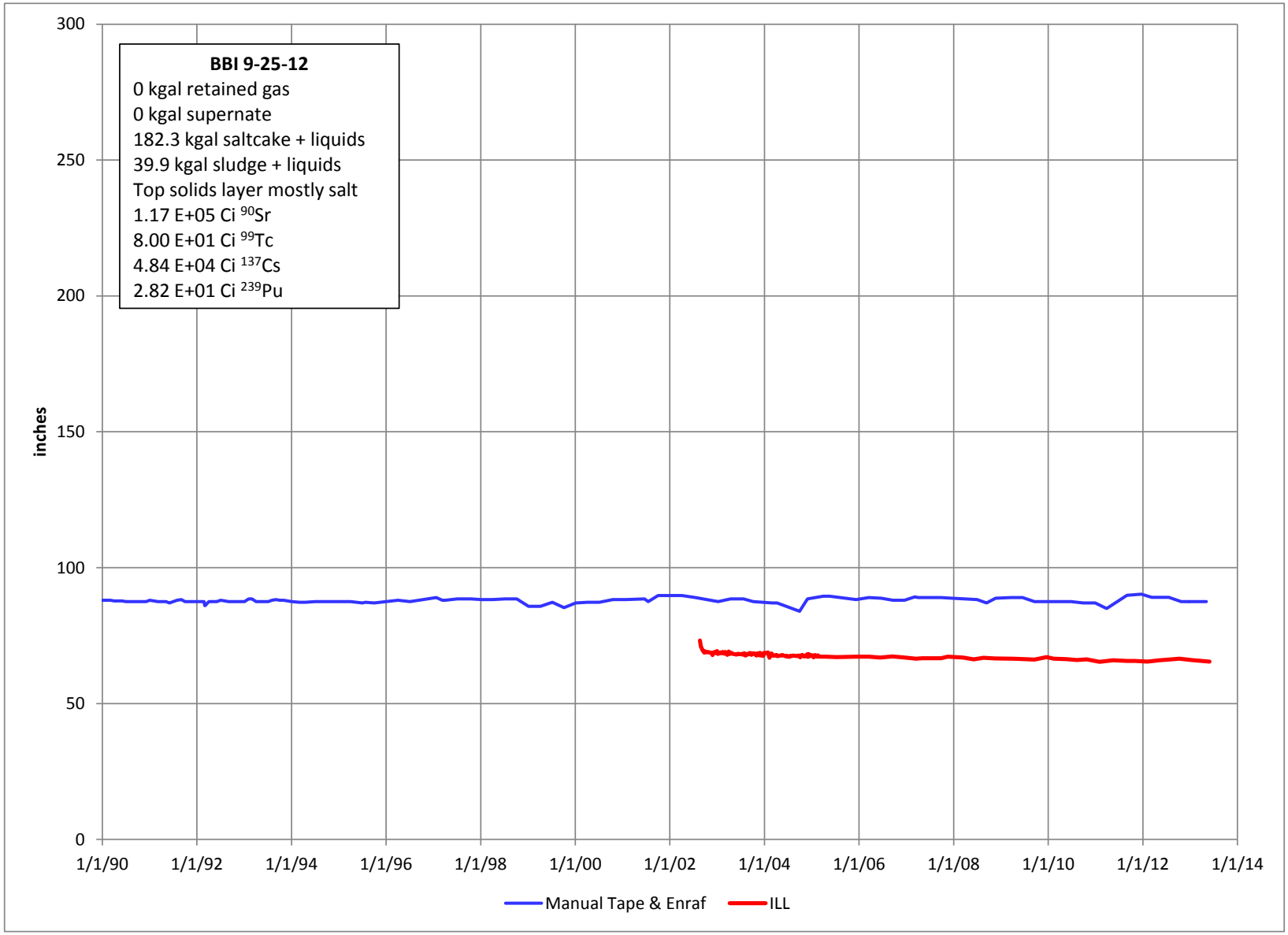


Figure 4-20 Tank BY-108 Expanded ILL Data Plot Used for RPP-PLAN-55113, Rev 1

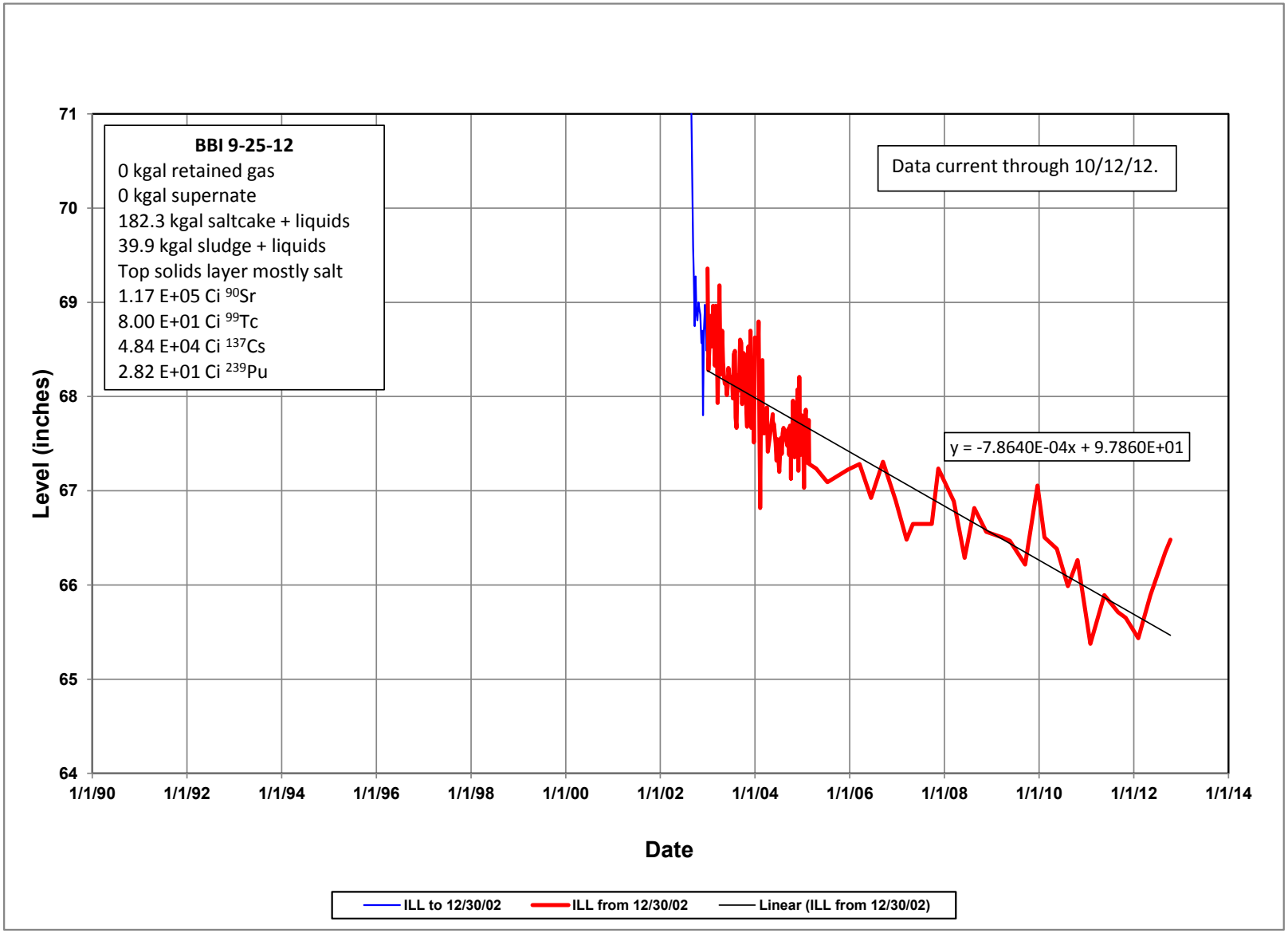


Figure 4-21 Tank BY-108 Expanded ILL Data Plot Used for RPP-RPT-54981

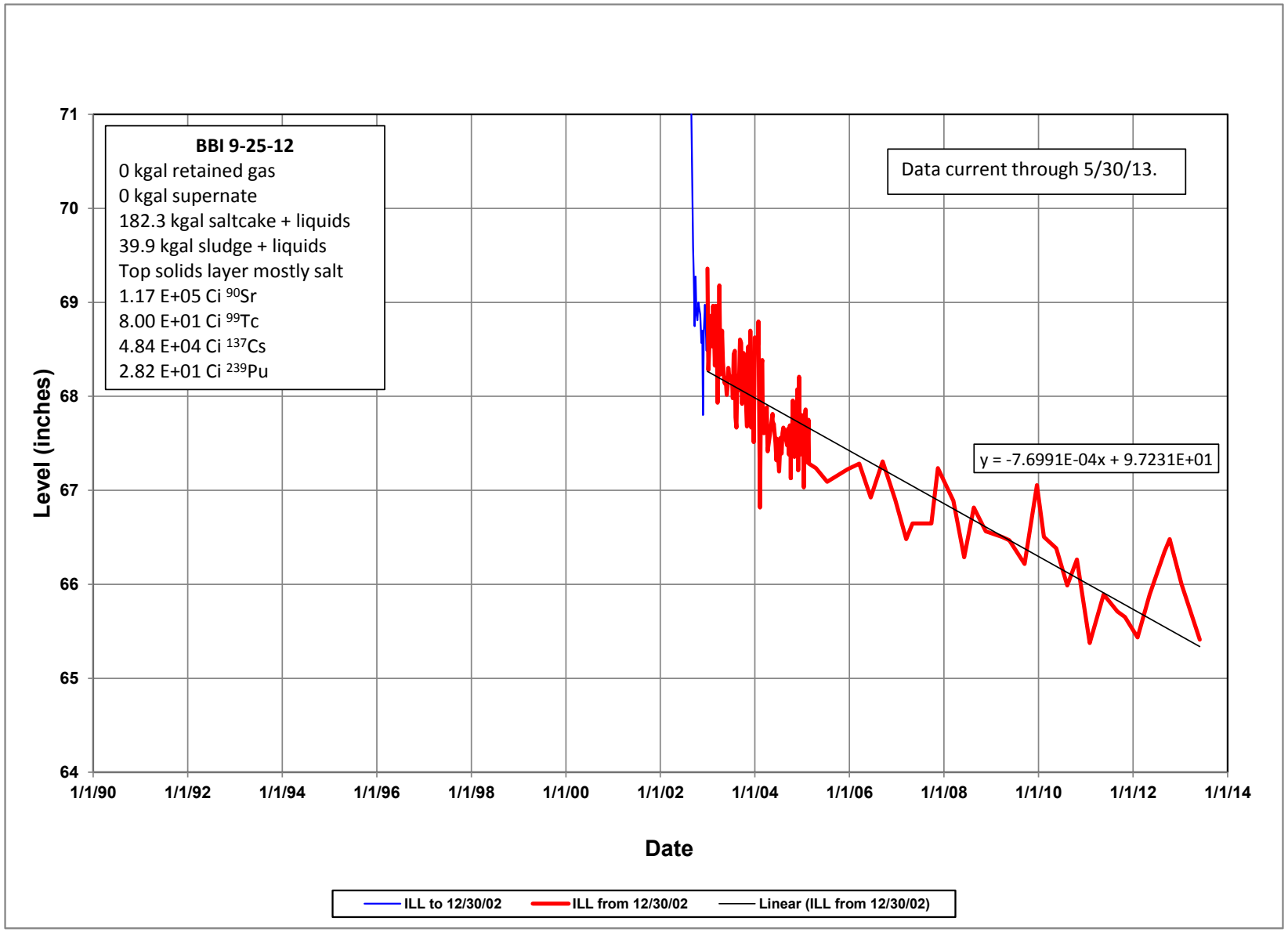


Figure 4-22 Tank BY-108 Raw Interstitial Liquid Level Data and Adjusted Inverse Barometric Pressure

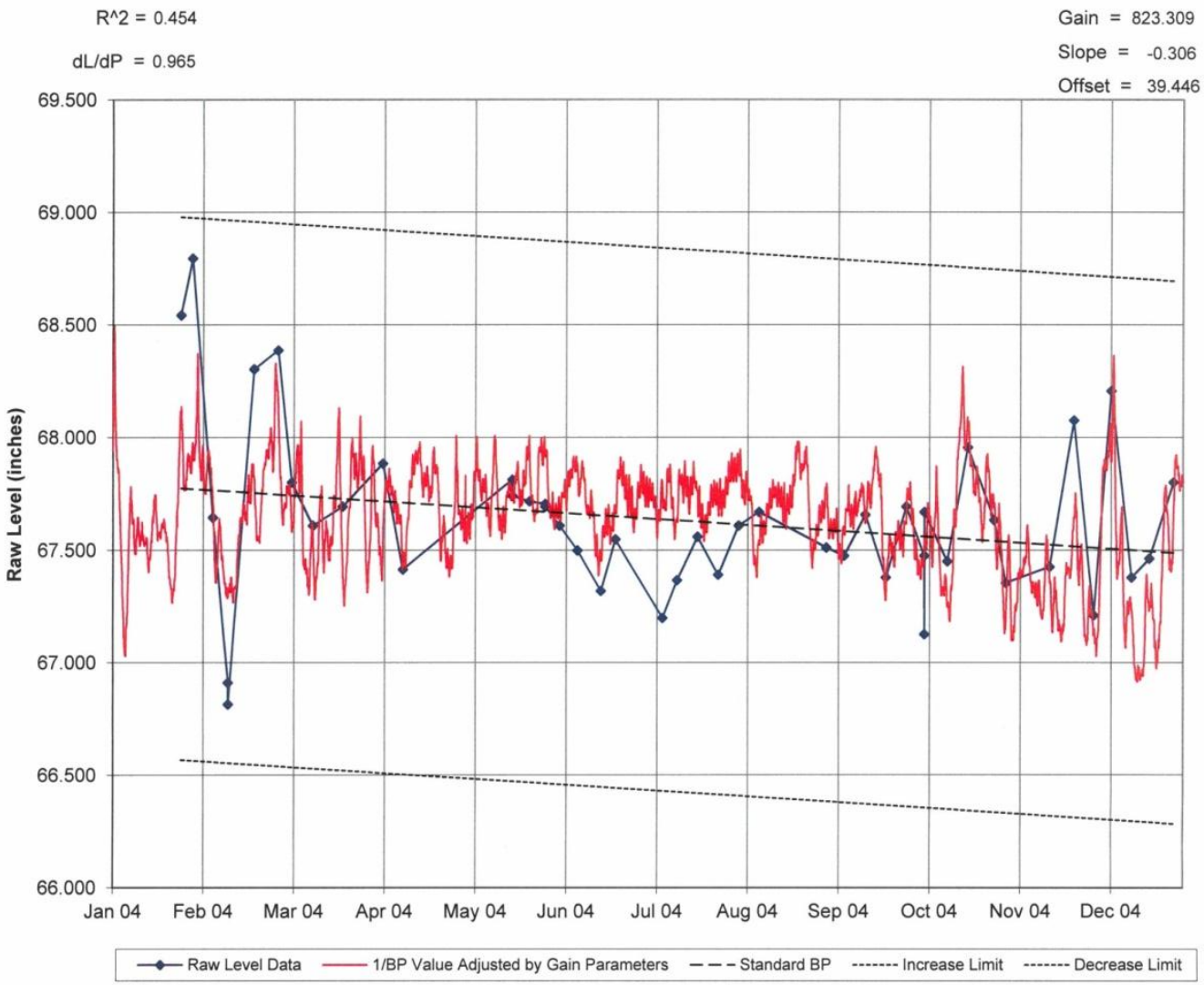


Figure 4-23 Comparison of Tank BY-108 2003 and 2013 Liquid Observation Well Neutron Scans

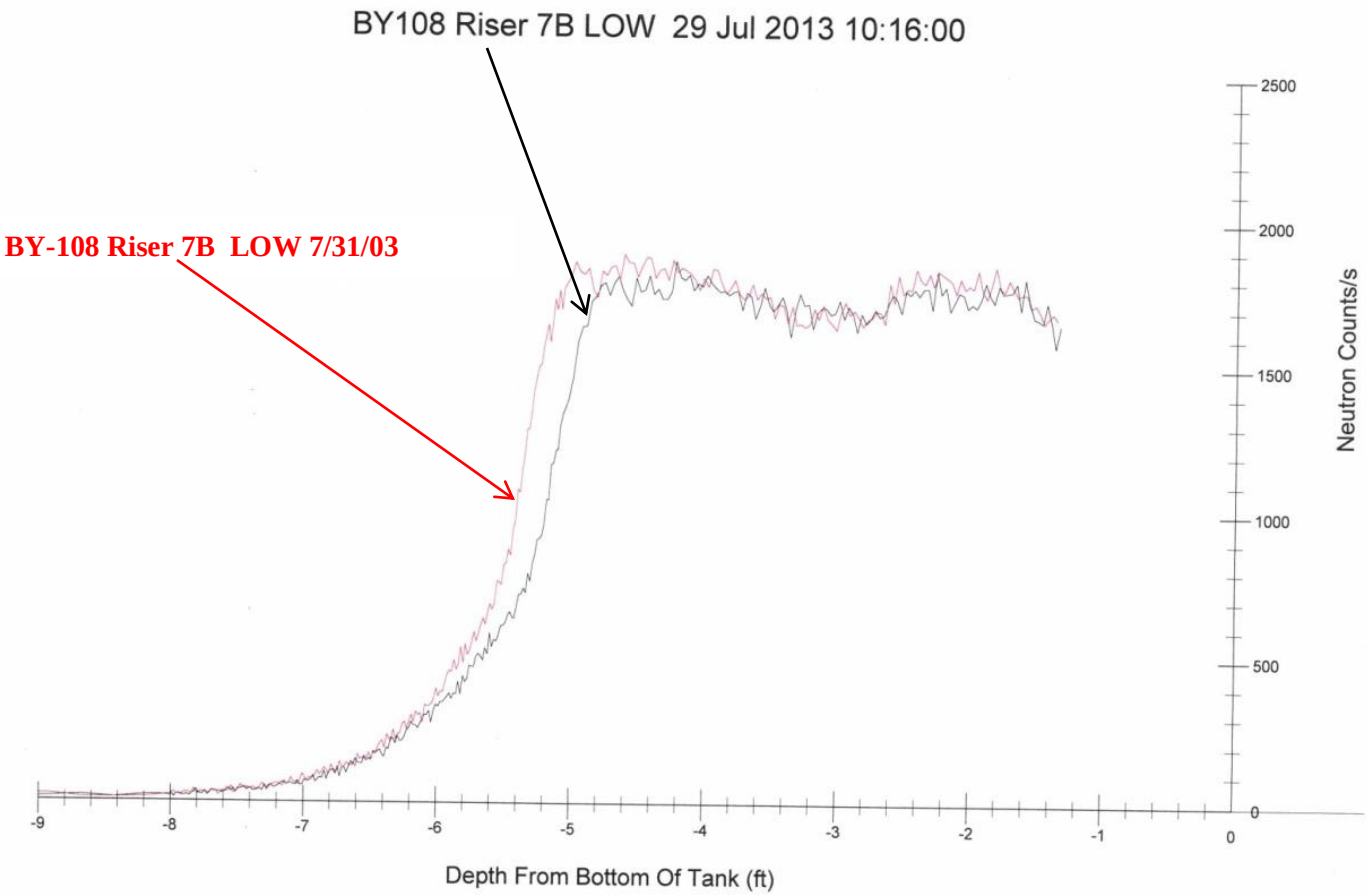
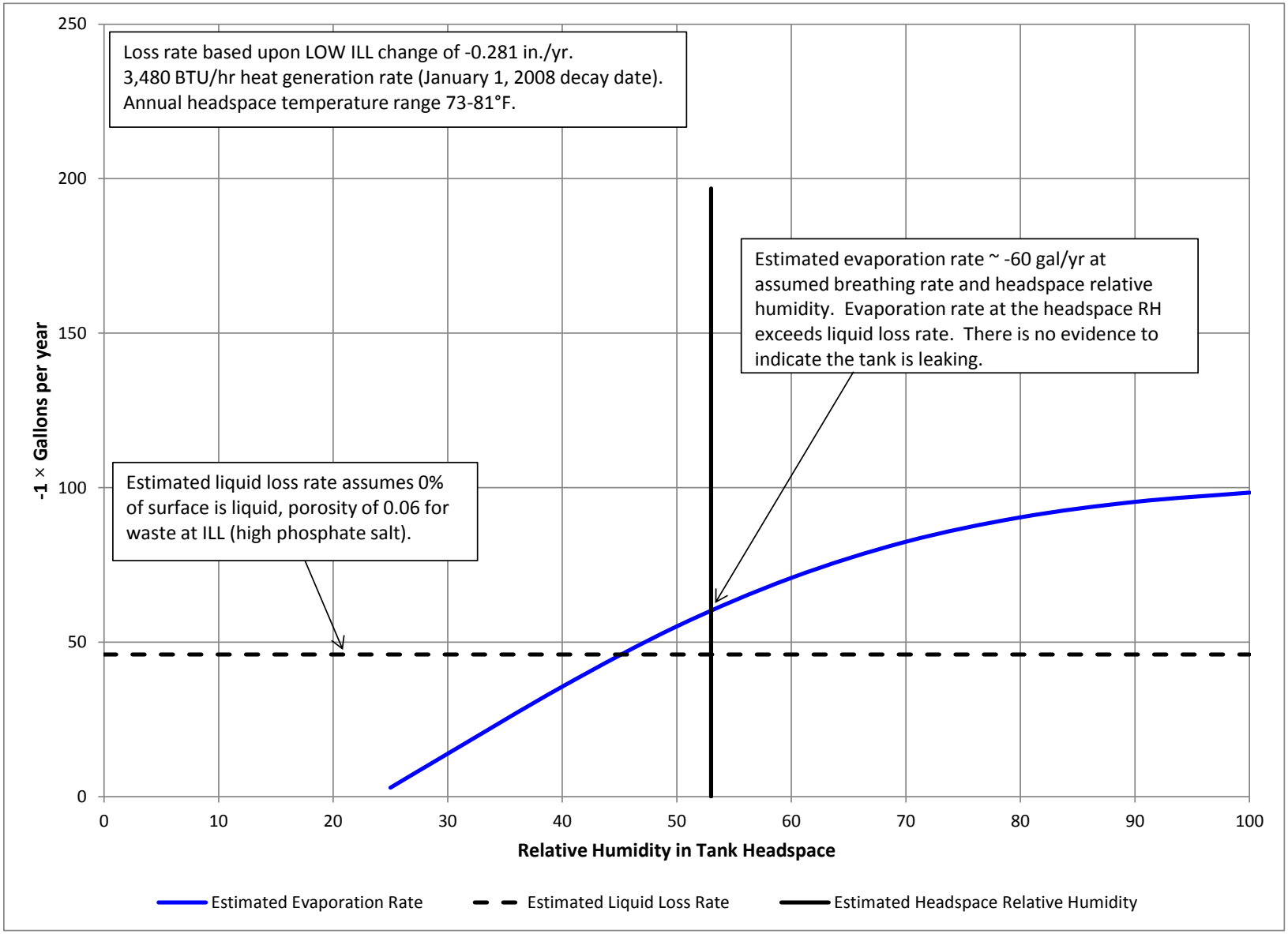


Figure 4-24 Tank BY-108 Estimated Evaporation and Liquid Loss Rates



4.6 Tank S-104

4.6.1 Tank Summary

Tank S-104 went into service in 1953 when it received REDOX process waste. The REDOX waste cascaded to tank S-105. This cascade line was not used after 1956. Tank S-104 received its last waste in 1965. The tank was later declared an assumed leaker and was taken out of service. Most of the supernatant was removed in 1970, and saltwell turbine pumping was completed in 1976. The tank was interim stabilized in 1984. Intrusion prevention was completed in 1988 (RPP-RPT-43047, Rev. 0, *2009 Auto TCR for 241-S-104*). The tank is listed as an assumed leaker in HNF-EP-0182, Rev 301. Per a TWINS query on September 25, 2012 the tank contains about 155.9 kgal salt and 132.1 kgal of sludge.

Figure 4-25 shows the raw ILL and SL data for tank S-104 from January 1, 1990. Figure 4-26 is a plot of the ILL data used for calculation of the -0.122 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen. Figure 4-27 is an updated plot showing the latest data included for this document. The slope of the ILL decrease line is somewhat less than before, it is at -0.110 in./yr as of June 12, 2013, and may have almost leveled out the past four years. The ILL appeared to become stabilized about two years after installation in 1995, was fairly level despite annual temperature cycling until about 2005 when it began to show a very slight decrease.

Figure 4-28 is an expanded plot of the SL data showing the latest date included for this document. Comparing Figure 4-27 and Figure 4-28 the ILL and SL data trends appear similar. The slope of the SL decrease line is at -0.051 in./yr as of July 10, 2013.

4.6.2 Liquid Change Rate Estimation

The liquid level appears to be at the waste surface level, and the ILL and SL plots track each other, so the estimated liquid change rate is based upon the average of the values derived from each decease rate.

RPP-5556 assumed this tank had 0 kgal saltcake and 293 kgal sludge, and used a porosity of 0.15 for the sludge. The most recent BBI information shows 156 kgal saltcake and 132 kgal sludge in the tank. The sludge is on the bottom, per RPP-40545, Rev 2, Appendix H. With the salt assumed to be on the top and the liquid level essentially even with the waste surface, only the porosity of the salt needs to be considered. Per RPP-40545, Rev 2, Appendix H the salt in this tank is <2.0 anion mole % phosphate so a saltcake porosity of 0.20 is assumed for conservatism per Appendix B of the same document instead of the sludge value of 0.15 from RPP-5556.

The IS documentation from 1984 stated the surface had a small liquid pool of about 500 gal around the saltwell screen. Photos from that time show the waste is saturated with liquid. The current ILL is about even with the surface level measurement so it is reasonable to assume there is still substantial liquid present. A 2010 video was obtained in the tank but there was no clear look at the waste surface. It is assumed that the current fraction of liquid on the surface is about 10%.

The estimate of the tank S-104 liquid change rate based upon the ILL change rate is equal to:

$$Tank\ S-104\ estimated\ liquid\ change\ rate\ based\ on\ ILL = -0.110 \times 2{,}750 \times (0.1 + (1-0.1) \times 0.20)) = \mathbf{-85\ gal/yr}$$

The estimate of the tank S-104 liquid change rate based upon the SL change rate is equal to:

$$Tank\ S-104\ estimated\ liquid\ change\ rate\ based\ on\ SL = -0.051 \times 2{,}750 \times (0.1 + (1-0.1) \times 0.20)) = \mathbf{-39\ gal/yr}$$

$$S-104\ estimated\ liquid\ change\ rate = (-85-39) \div 2 = \mathbf{-62\ gal/yr}$$

4.6.3 Data Analysis

<u>Estimation of [Σ other]</u> – Waste subsidence is not a factor since the liquid level is essentially at the waste surface.

Figure 4-29 is a plot of the inverse of the barometric pressure and the ILL data. There is negligible correlation between the ILL and barometric pressure changes. Figure 4-30 is a comparison of tank S-104 LOW neutron scan data from 2003 and 2013. There is no obvious gas volume decrease apparent. The liquid content has receded slightly the depth of the tank, which could be interpreted as gas retention, but is likely just due to instrumentation response. The BBI shows zero retained gas in S-104. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. Some SSTs may exhibit chronic release of gases at roughly the same rate gases are generated. But, the continual release of retained gas from tank S-104 for over eight years is not realistic. There is no basis to assume any impact of retained gas on the level decrease rate.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1966. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for S-104 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

<u>Potential for Intrusion</u> – An in-tank video was obtained in 2010 with no intrusion evidence noted. There has been no evidence of intrusion based upon the ILL data going back to 1995 or SL data going back to 1990, other than the annual fluctuations seen in tanks with a liquid or semi-liquid surface.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -62\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= -\frac{67gal}{yr} - leak\ rate - intrusion\ rate$$

Since both evaporation rate and leak rate are negative values, the sum of the leak rate plus the evaporation rate would have to be <-67 gal/yr before an intrusion would be considered. As described below, the estimated evaporation rate for tank S-104 is -82 gal/yr so there could be an intrusion if the evaporation rate is accurate.

Evaluation of ILL and SL Validity – The ILL appears from Figure 4-27 to have been equilibrated since 1998.

The ENRAF plummet seating is unknown, but it appears the plummet is reading the liquid level in a pool since it tracks the ILL data.

Table 4-2 lists all tank S-104 ENRAF work packages for the 2006 to 2013 time period. The last two columns list the as-found and as-left data from the work packages. The data show the only change of any note is the decrease of 0.31 in. following the December 28, 2010 calibration adjustment, which is evident on Figure 4-28. Figure 4-28 indicates there may have been calibration or other data spikes prior to 2006.

Table 4-2 Tank S-104 ENRAF Gauge Work Packages Since January 1, 2006

Work Package No.	Title	Date	As Found (in.)	As Left (in.)
CLO-WO-07-0773	241-S, 104 ENRAF INSPECTION	No date	No data	No data
CLO-WO-07-2014	241-S, 104 ENRAF INSPECTION	March 11, 2008	112.03	111.98
WFO-WO-09-4686	241-S, 104 ENRAF INSPECTION	December 28, 2010	111.9	111.59
WFO-WO-12-5572	241-S, 104 ENRAF INSPECTION	March 7, 2013	111.5	111.51

The ILL has always been referenced to the tank centerline bottom. The SL data in TWINS shows the tank surface level as referenced to the tank centerline since before 1980.

4.6.4 Evaporation Estimate

Figure 4-31 provides the evaporation estimate results for tank S-104. Figure 4-31 indicates tank S-104 would evaporate about -82 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank S-104 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank S-104, 2.4 cfm, is similar to the rates for other 75 ft. diameter tanks excluding A and AX tanks, and is within the range of breathing rate data for the non-A/AX tanks with tracer gas tests in 1996 to 1998. The basis for the breathing rate assumed for tank S-104 is provided in Appendix A and is the best estimate when considering the information. The breathing rate results in an evaporation rate that exceeds the calculated liquid change rate.

The assumed tank S-104 headspace RH of 52% is based upon the average for tanks S-101 and S-102 since no vapor sample was taken from tank S-104. Tank S-104 has a waste surface level of about 112 in., an ILL of about the same, and headspace temperatures ranging from 74 to 83°F

the past three years. Tank S-101 had a waste surface level of about 161 in. in 1996 when sampled, an ILL of about the same, and a headspace temperature of 87°F. Tank S-102 had a waste surface level of about 205 in. in the 1995 to 1997 period when multiple samples were taken, an ILL of about the same, and headspace temperatures ranging from 76 to 87°F. From Figure 4-31, assuming the tank breathing rate was correct an RH in the headspace of 42% would result in an evaporation rate equaling the calculated liquid loss rate.

An evaporation rate of -82 gal/yr for tank S-104 can account for the liquid loss rate assumed.

4.6.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank S-104 as 9,303 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. Only 0.7% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimated liquid change rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated, plus the liquid level is right at the waste surface.

4.6.6 Tank S-104 Leak Potential

Based upon Figure 4-31 the tank S-104 liquid loss rate can be explained by evaporation.

There is sufficient heat generated in the tank to evaporate water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$\begin{aligned} leak\ rate &= -65\frac{gal}{yr} - intrusion\ rate - (-82\frac{gal}{yr}) - (5\ gal/yr) \\ &= 12\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

If the evaporation rate for S-104 is -82 gal/yr, the intrusion rate would have to exceed 12 gal/yr, for a leak to exist. This is possible, but Figure 4-27 and Figure 4-28 show no evidence of intrusion in the tank going back to the early 1990s. It is highly unlikely that intrusion and a leak would have approximately balanced each other since then.

4.6.7 Tank S-104 Conclusion

There is no basis to assume a leak from tank S-104.

Figure 4-25 Tank S-104 Full Depth Raw Data Plot

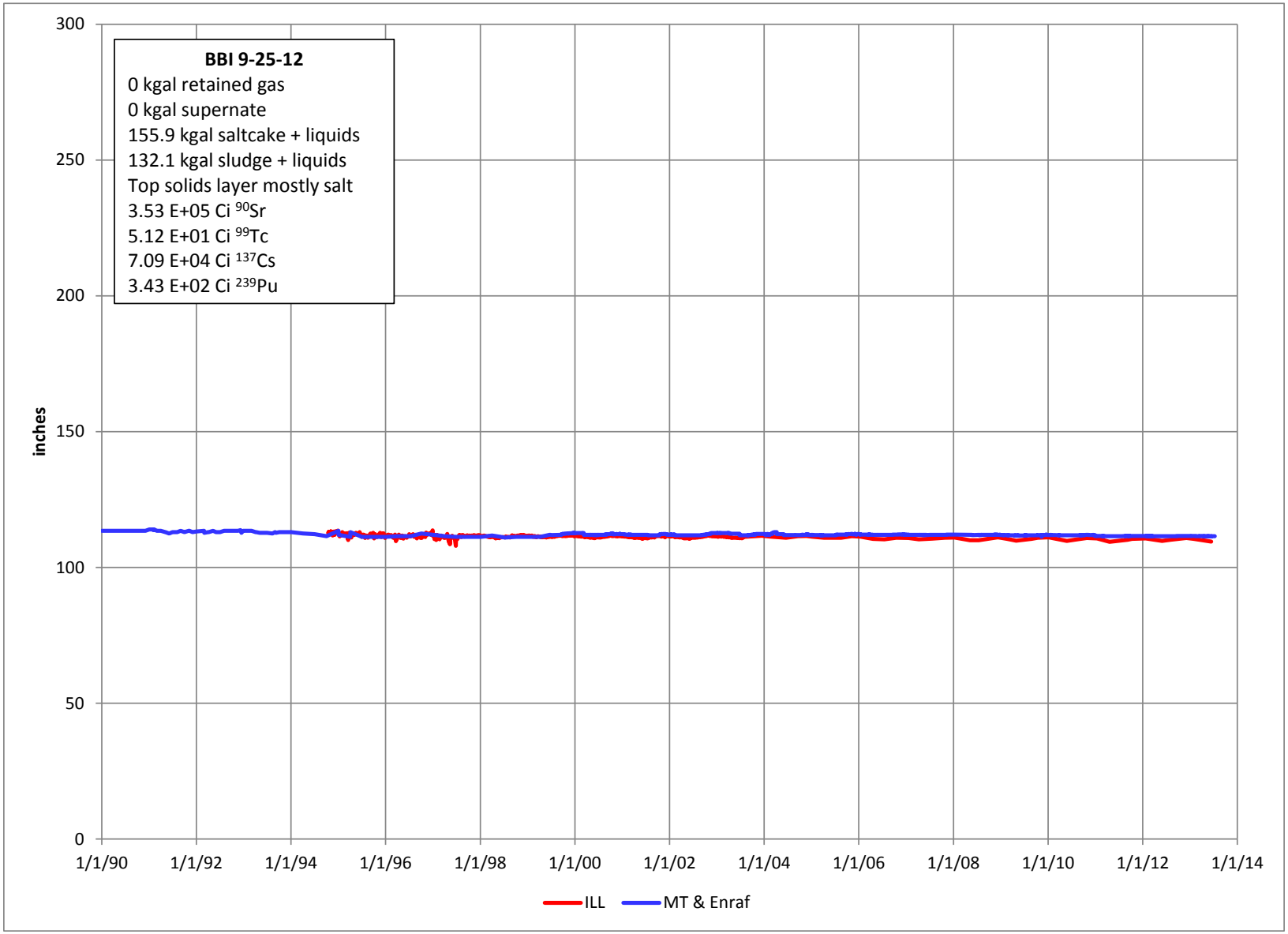


Figure 4-26 Tank S-104 Expanded ILL Data Plot Used for RPP-PLAN-55113, Rev 1

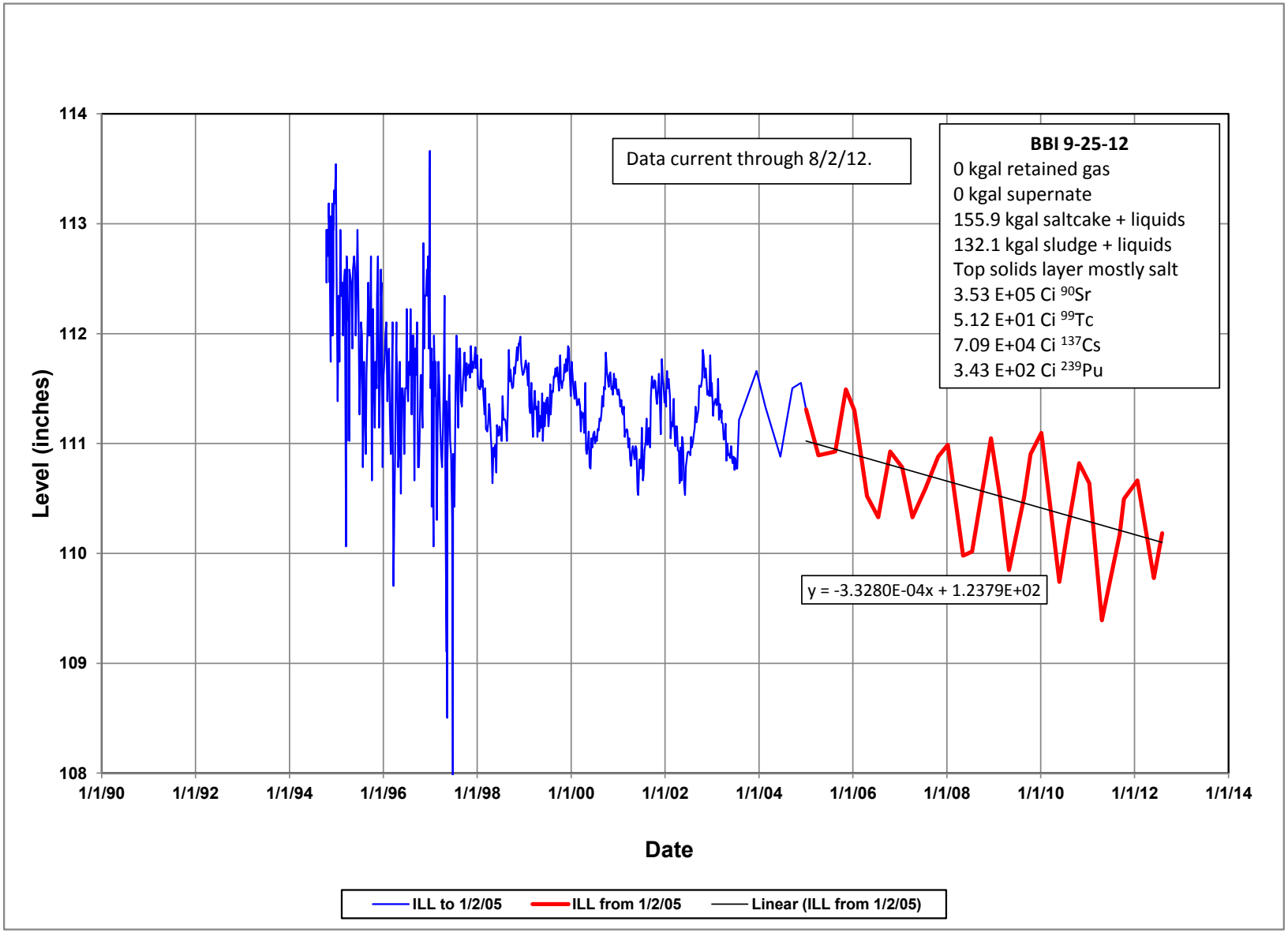


Figure 4-27 Tank S-104 Expanded ILL Data Plot Used for RPP-RPT-54981

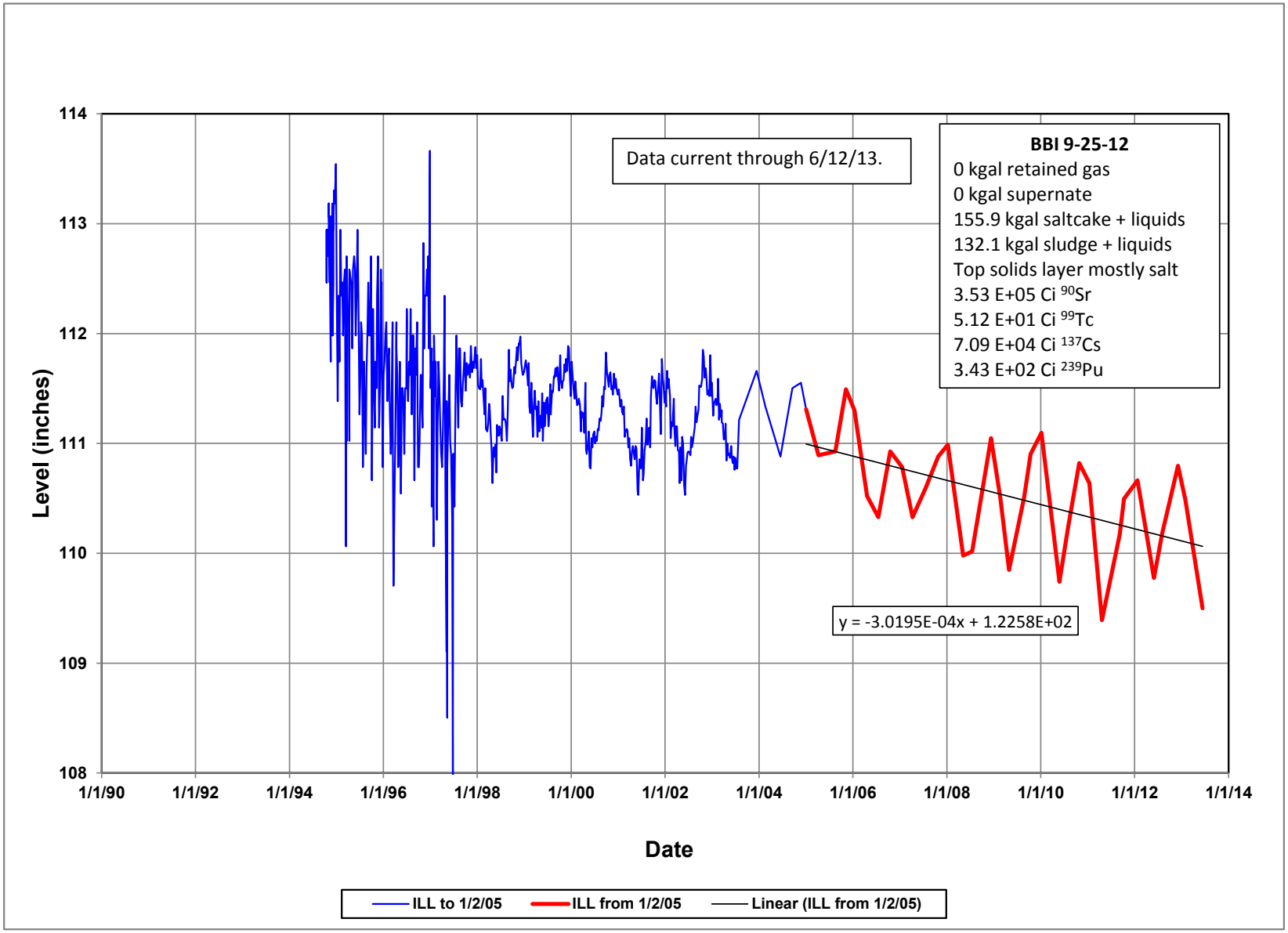


Figure 4-28 Tank S-104 Expanded SL Data Plot Used for RPP-RPT-54981

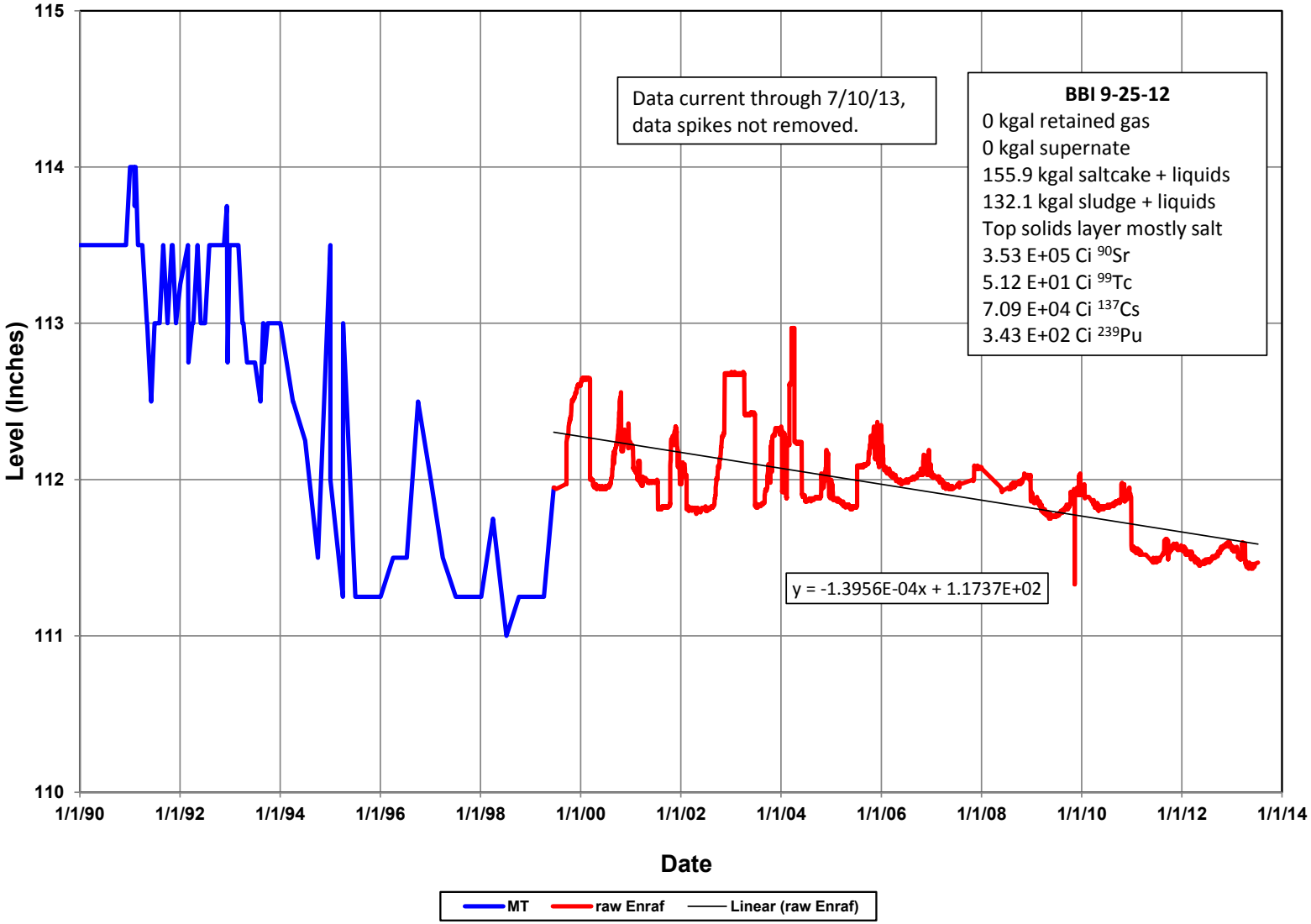


Figure 4-29 Tank S-104 Raw Interstitial Liquid Level Data and Adjusted Inverse Barometric Pressure

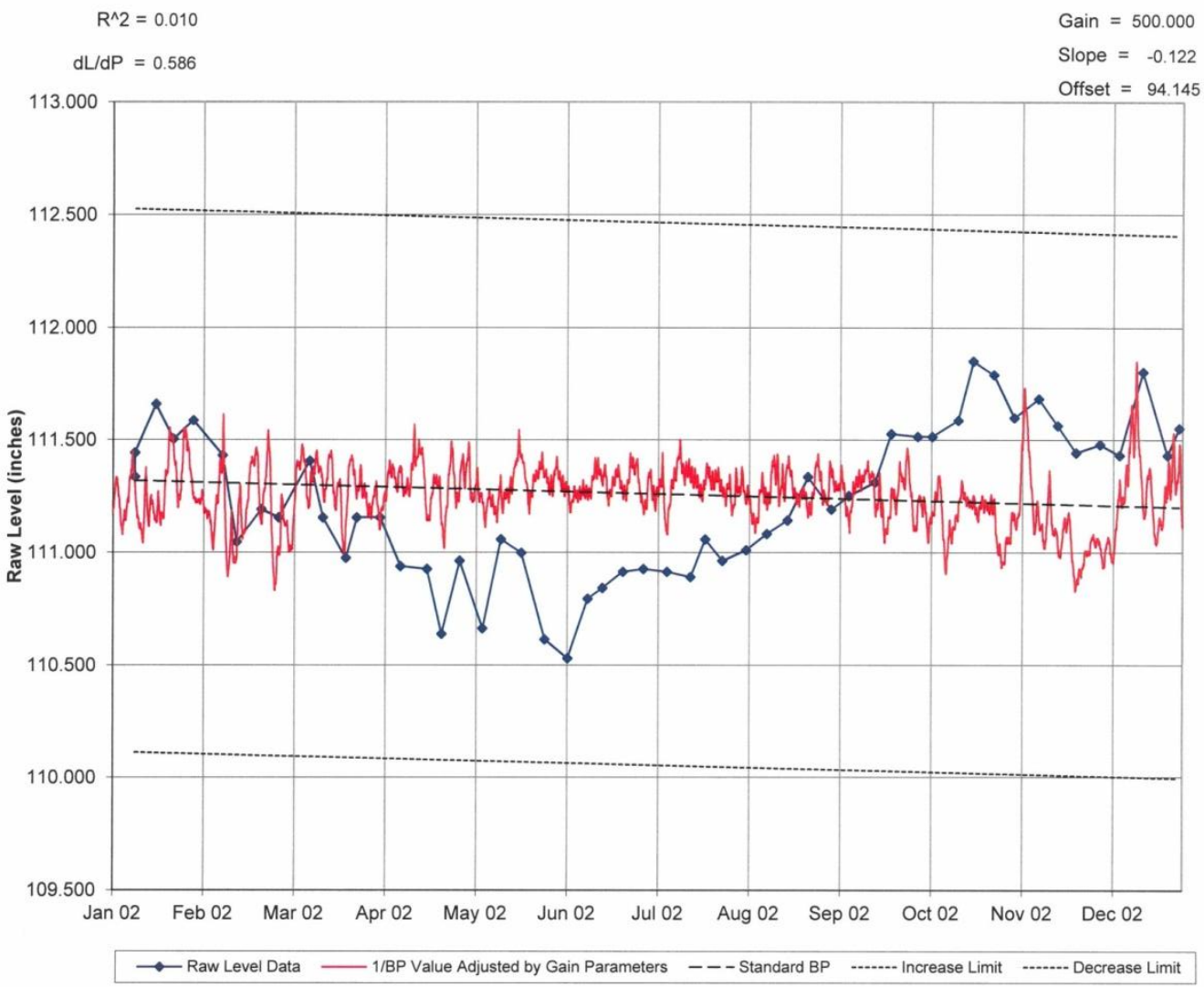


Figure 4-30 Comparison of Tank S-104 2003 and 2013 Liquid Observation Well Neutron Scans

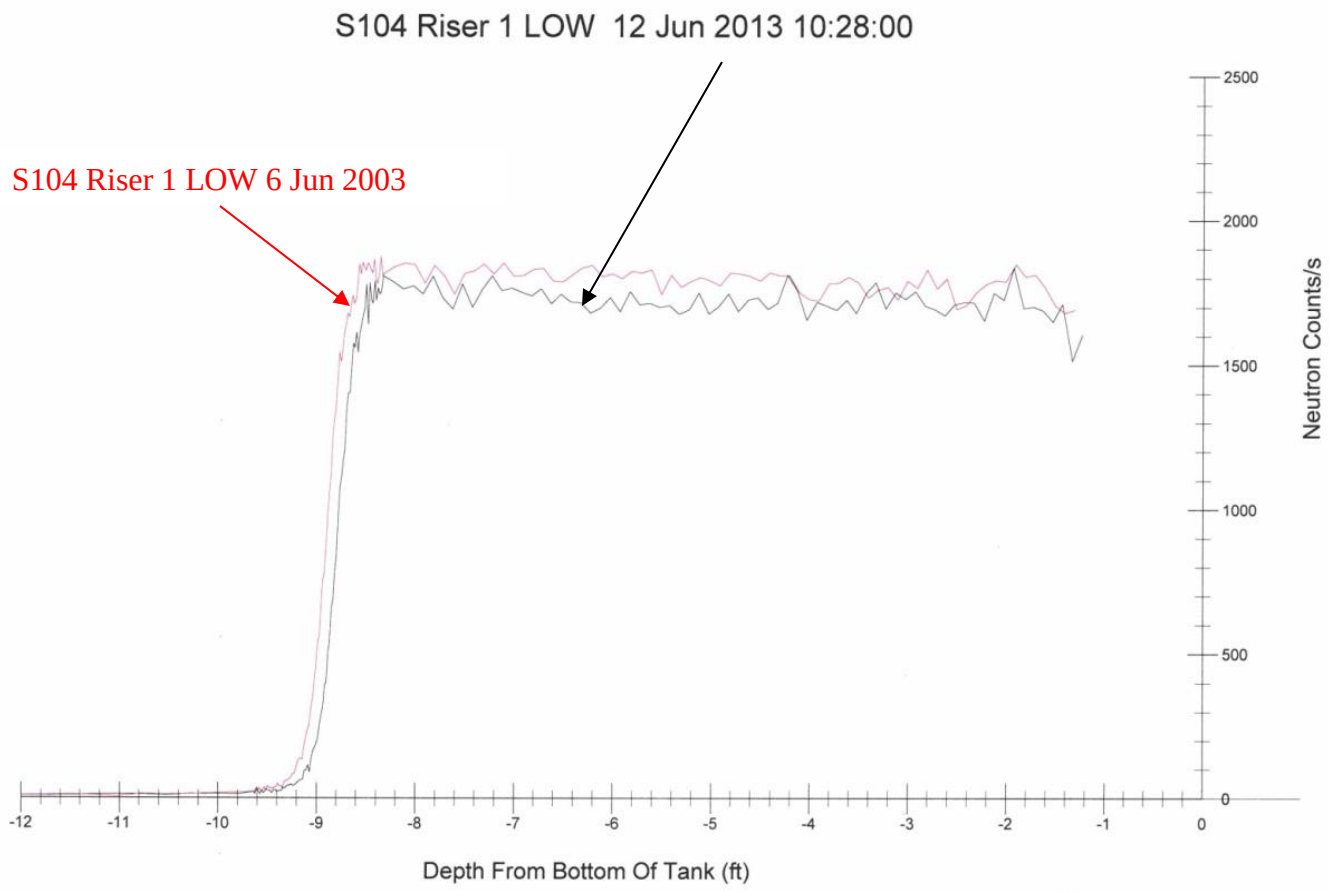
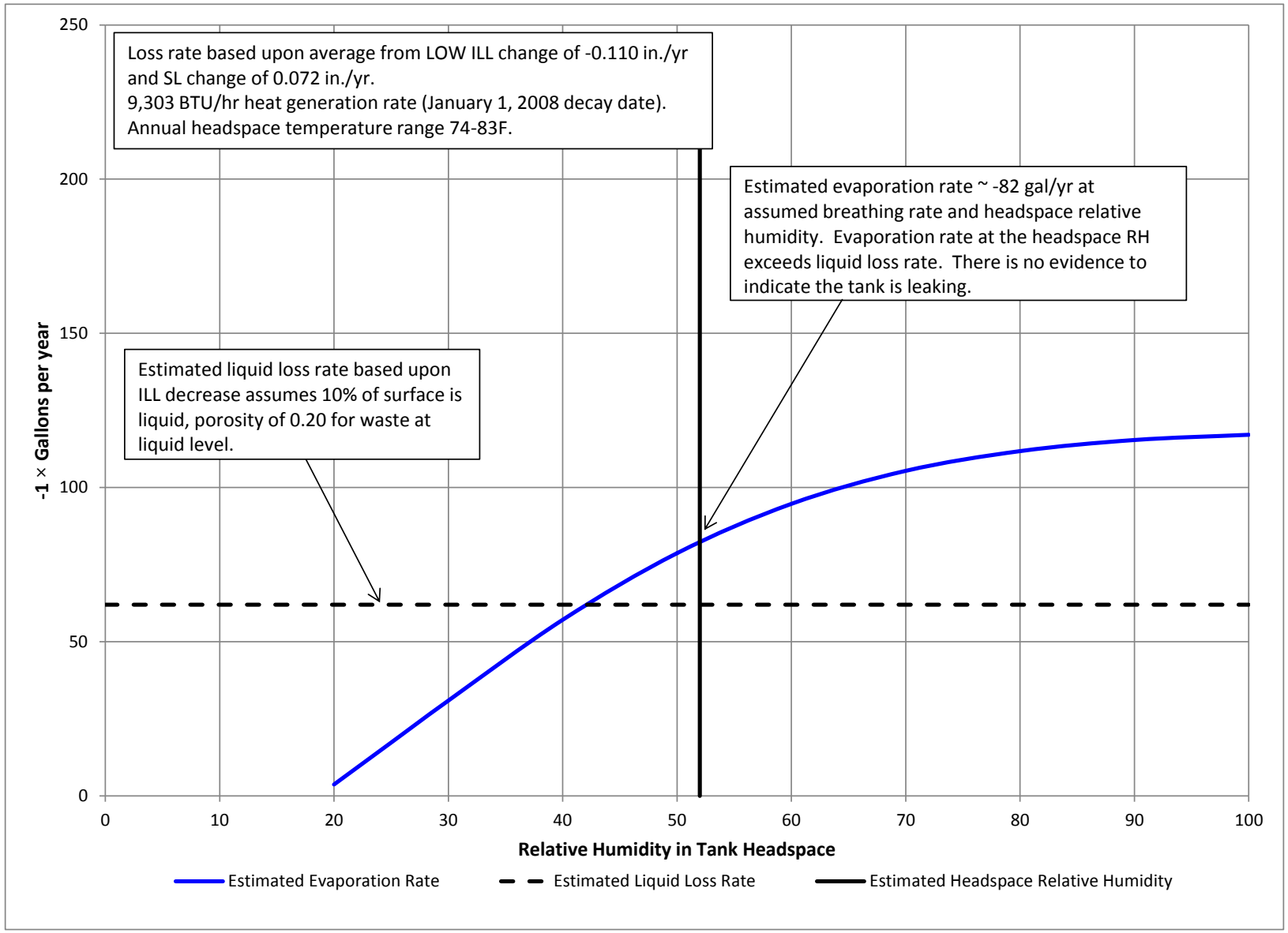


Figure 4-31 Tank S-104 Estimated Evaporation and Liquid Loss Rates



4.7 Tank SX-102

4.7.1 Tank Summary

Tank SX-102 entered service in 1954 when it received high-level waste from REDOX. Between 1954 and 1973 the tank transferred to and received waste from other SX tanks and other tank farms. In 1974 it began receiving evaporator bottoms from 242-S. The tank was removed from service and labeled inactive in 1980. The tank was partially isolated in June 1985 and had interim stabilization completed in 2004 (RPP-RPT-43057, Rev. 0, *2009 Auto TCR for 241-SX-102*). Per a TWINS query on September 25, 2012 the tank contains about 286.1 kgal salt and 55.2 kgal of sludge.

Figure 4-32 shows the raw ILL and SL data for tank SX-102 from January 1, 1990. The figure shows both the old ILL data interpretation results and the new post-2008 ILL data interpretation results implemented in March 2013. The original LOW in the tank failed in 2002, a new one was installed in Riser 8 in 2007. Figure 4-33 is a plot of the ILL data used for calculation of the -0.664 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen.

In 2013 the ILL neutron scans for tank SX-102 were re-evaluated and it was determined that a non-representative characteristic was being used as the ILL. What had been assumed to be the ILL was a location above the ILL which was slowly draining down to where the ILL actually was. Figure 4-34 is a plot of a tank SX-102 neutron scan showing the neutron scan feature used before March 2013 to determine the ILL and the neutron scan feature used since March 2013 to determine the ILL. All the SX-102 neutron scan data since 2007 have been recalculated and the ILL data points based upon the revised scan feature stored in the PC-SACS database. Figure 4-35 is an updated plot comparing the old and updated data and showing the new ILL data trendline. The slope of the trendline is now at +0.459 in./yr as of August 1, 2013. The trendline increase is due to liquid draining down from above to the ILL, the ILL in the tank is not yet stabilized.

Figure 4-36 is an expanded SL plot. Little meaningful loss rate information can be obtained from this, the level is either still settling from saltwell pumping or the surface level is acting like a RPP-PLAN-55113, Rev 1, Category 3 level increase tank with the SL decreasing and the ILL increasing. The numerous data fluctuations indicate there may be ENRAF gauge instrumentation problems, or, more likely, due to the 10+ years of fluctuations the plummet is not resting on a flat surface. Figure 4-37 is an expanded plot of the same SL data with the post-2005 data spikes removed. The slope change for the adjusted SL data calculates to a -0.144 in./yr rate as of June 16, 2013. If the polynomial regression line formula for the SX-102 surface level data trend in Figure 4-37 is maintained, the surface could level out towards the end of 2015.

4.7.2 Liquid Change Rate Estimation

Not estimated.

4.7.3 Data Analysis

Estimation of [Σ other] – Information not provided since liquid change rate not estimated.

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. There has been no evidence of intrusion based upon the SL or ILL data going back to 1990. The ILL is increasing since 2008 based upon the revised neutron scan characteristic selected, but this is believed to be the ILL equilibrating following saltwell pumping and not due to evidence of an intrusion that began at that time. No intrusion rate is estimated since a liquid loss rate was not estimated.

Evaluation of ILL or SL Validity – The ILL appears to not yet be equilibrated.

The ENRAF data are not used to estimate a tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

The LOW ILL has always been referenced to the tank centerline bottom.

4.7.4 Evaporation Estimate

Figure 4-38 provides the evaporation estimate results for tank SX-102. The headspace RH is unknown since the 1995 vapor sample was obtained when the tank was being exhausted. The green dashed RH line is what was determined from the vapor sample in 1995. Although the value was very low at 17.2% and would result in about 8 gal/yr being evaporated in 2013 at the assumed tank breathing rate of 2.5 cfm, the RH was measured when the tank was being exhausted at a nominal 100 cubic feet per minute (cfm). The tank headspace temperature is about the same in 2013 as in 1995 when the tank was exhausted, and if all other conditions are assumed to be the same the evaporation rate at 17.2% RH would have been about -325 gal/yr at 100 cfm. Per Appendix A, Table A-9, comparing tank SX-102 with tank S-101, the non-exhausted salt-containing tank with the closest headspace temperature to tank SX-102 the tank SX-102 RH could be around 50%. The red dashed line in Figure 4-38 indicates a possible current tank SX-102 RH of 50%. Per Figure 4-38 the evaporation rate at a 50% RH and 2.5 cfm would be about -110 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank SX-102 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank SX-102, 2.5 cfm, is similar to the rates for other 75 ft. diameter tanks excluding A and AX tank farms, and is within the range of breathing rate data for the non-A/AX tanks with tracer gas tests in 1996 to 1998. The basis for the breathing rate assumed for tank SX-102 is provided in Appendix A and is the best estimate when considering the information.

4.7.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank SX-102 as 8,384 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less.

There is sufficient heat generated in the tank to drive off a significant amount of water despite the ILL being about 80 in. below the waste surface.

4.7.6 Tank SX-102 Leak Potential

The tank ILL is currently increasing slowly, as can be seen in Figure 4-35. The decrease prior to saltwell pumping seen in Figure 4-32 is assumed due to evaporation. Evaporation is still occurring in the tank due to the heat generation rate but is being masked by the ILL not yet being stabilized. Once the ILL is stabilized it should begin to decrease slowly as a result of evaporation. The SL decrease since saltwell pumping is assumed due to waste subsidence.

With the tank no longer evincing a decreasing ILL and the SL appearing in the process of equalizing, a leak rate range for SX-102 is not estimated because the net liquid change rate is positive.

4.7.7 Tank SX-102 Conclusion

There is no basis to assume a leak from tank SX-102.

Figure 4-32 Tank SX-102 Full Depth Raw Data Plots

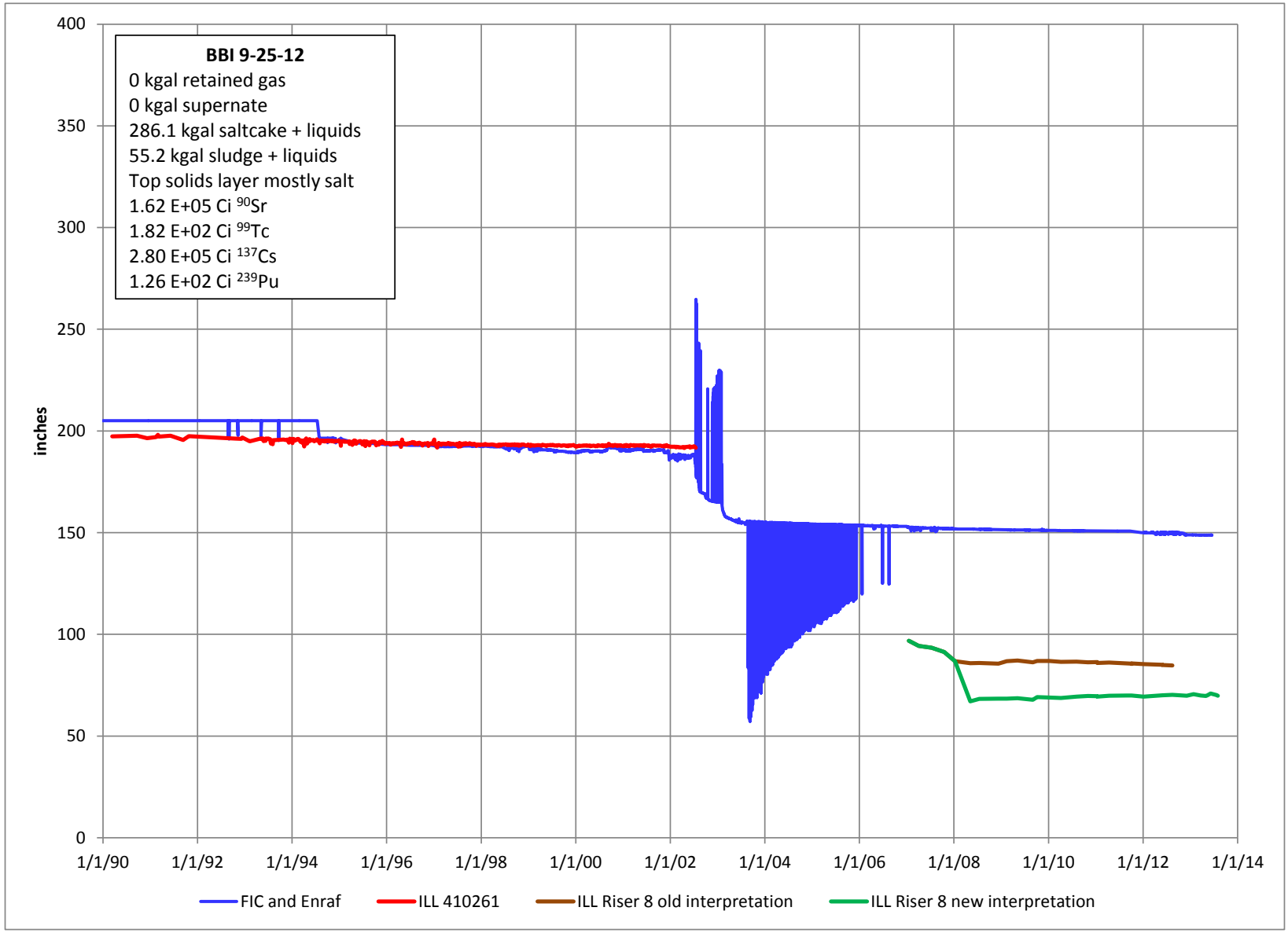


Figure 4-33 Tank SX-102 Expanded ILL Data Plot for RPP-PLAN-55113, Rev 1 with Old Data Interpretation

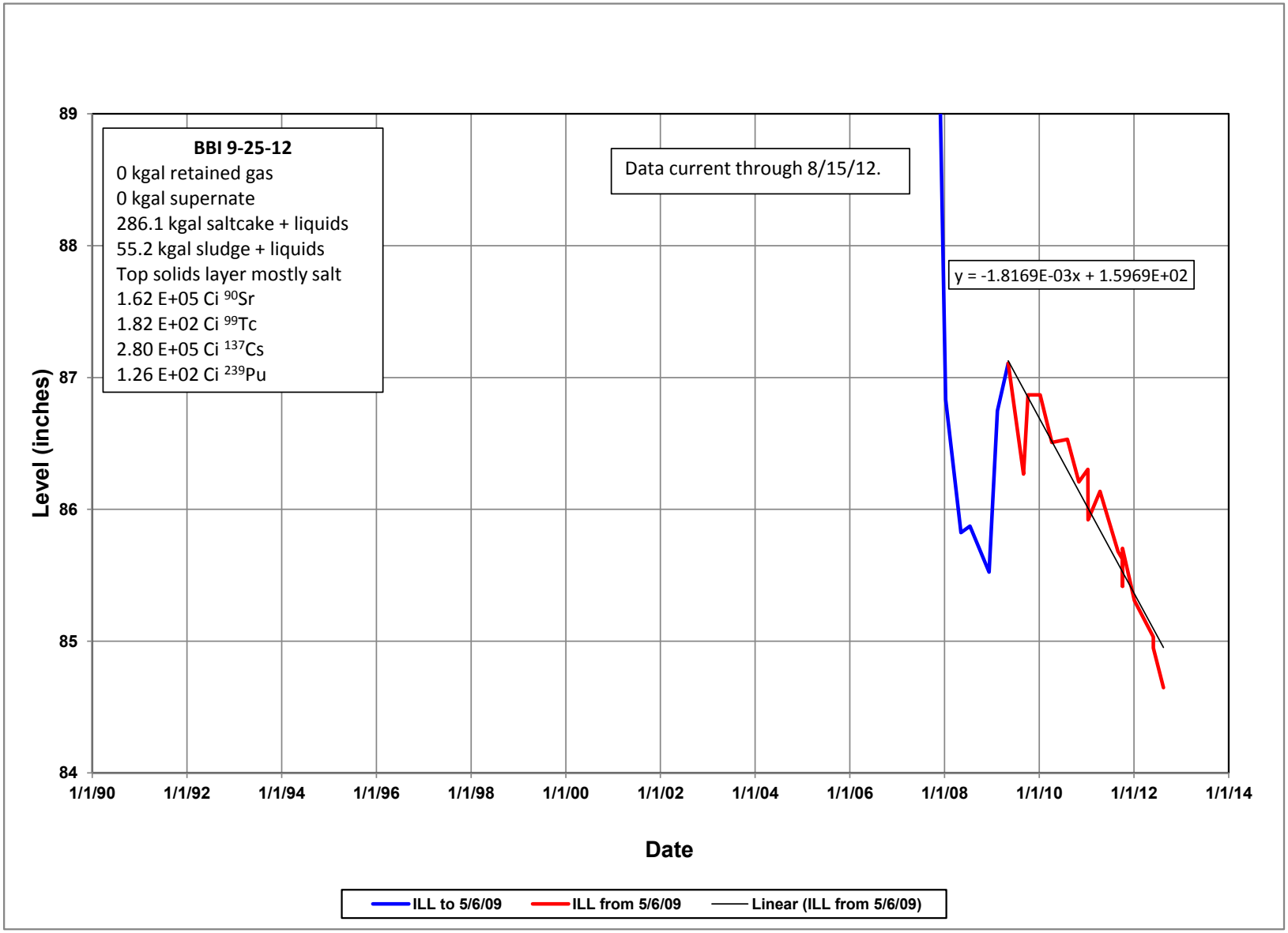


Figure 4-34 Tank SX-102 Selected Neutron Scan Data

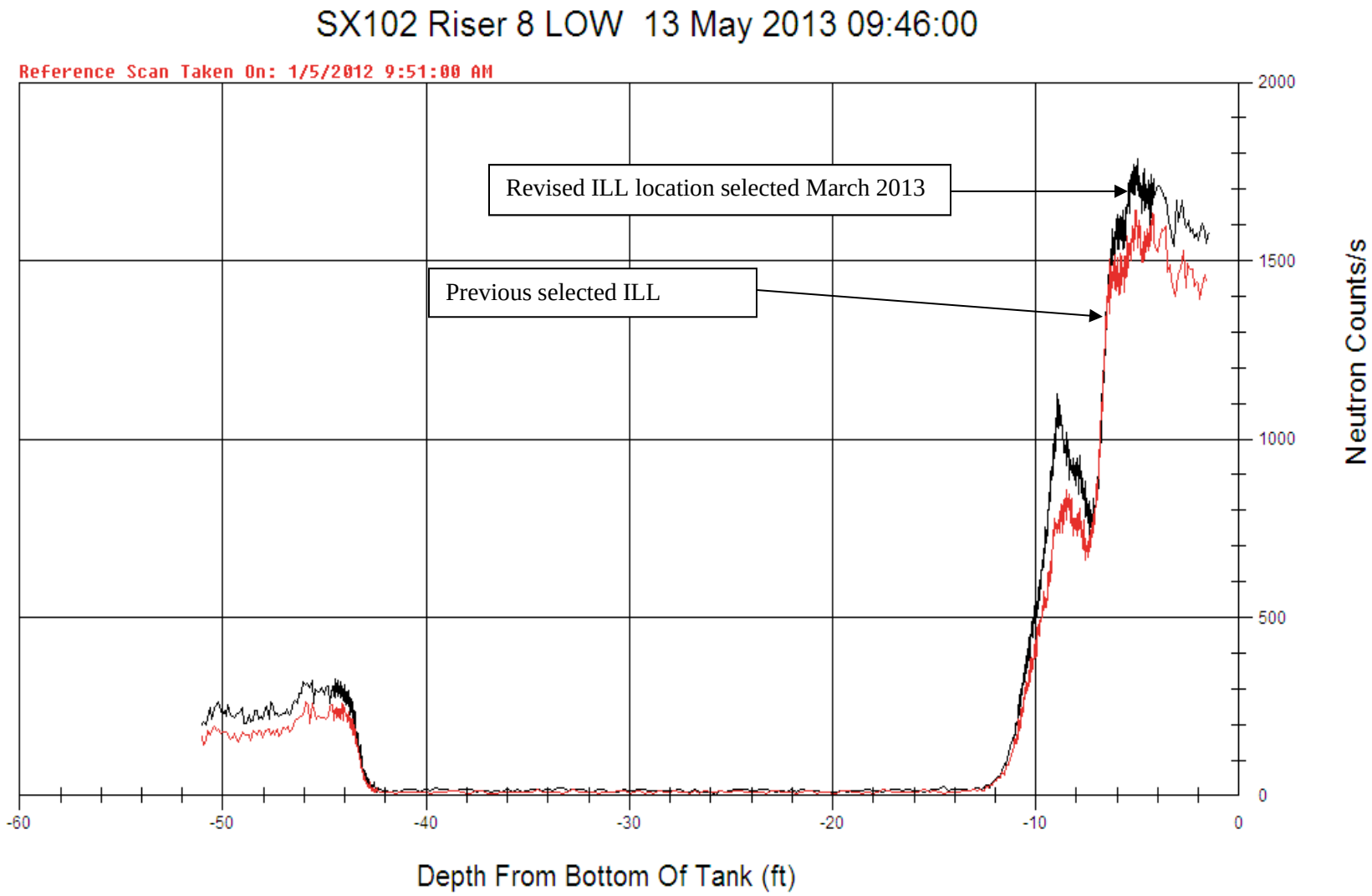


Figure 4-35 Tank SX-102 Expanded ILL Data Plot Used for RPP-RPT-54981

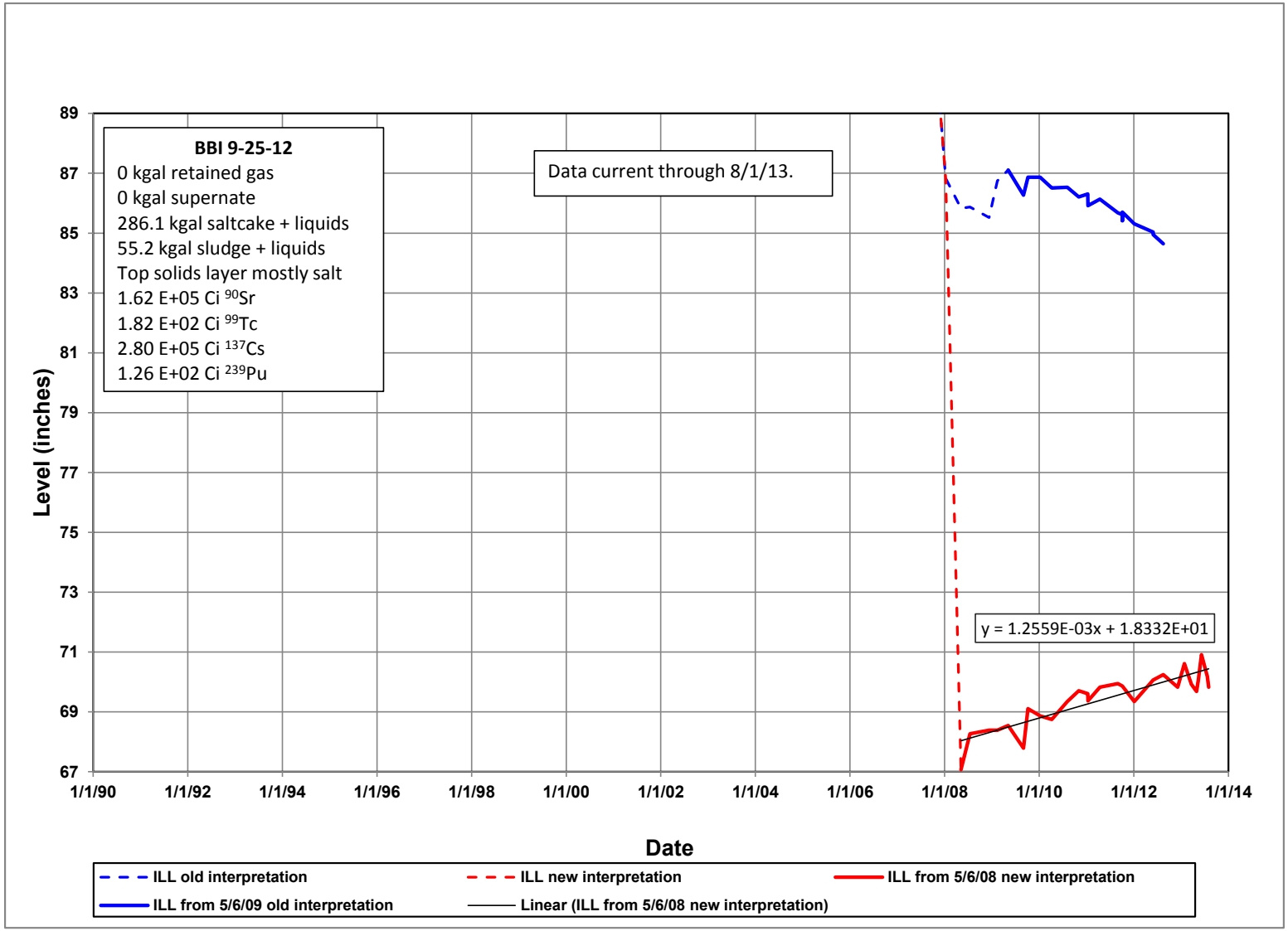


Figure 4-36 Tank SX-102 Expanded Surface Level Data Plot

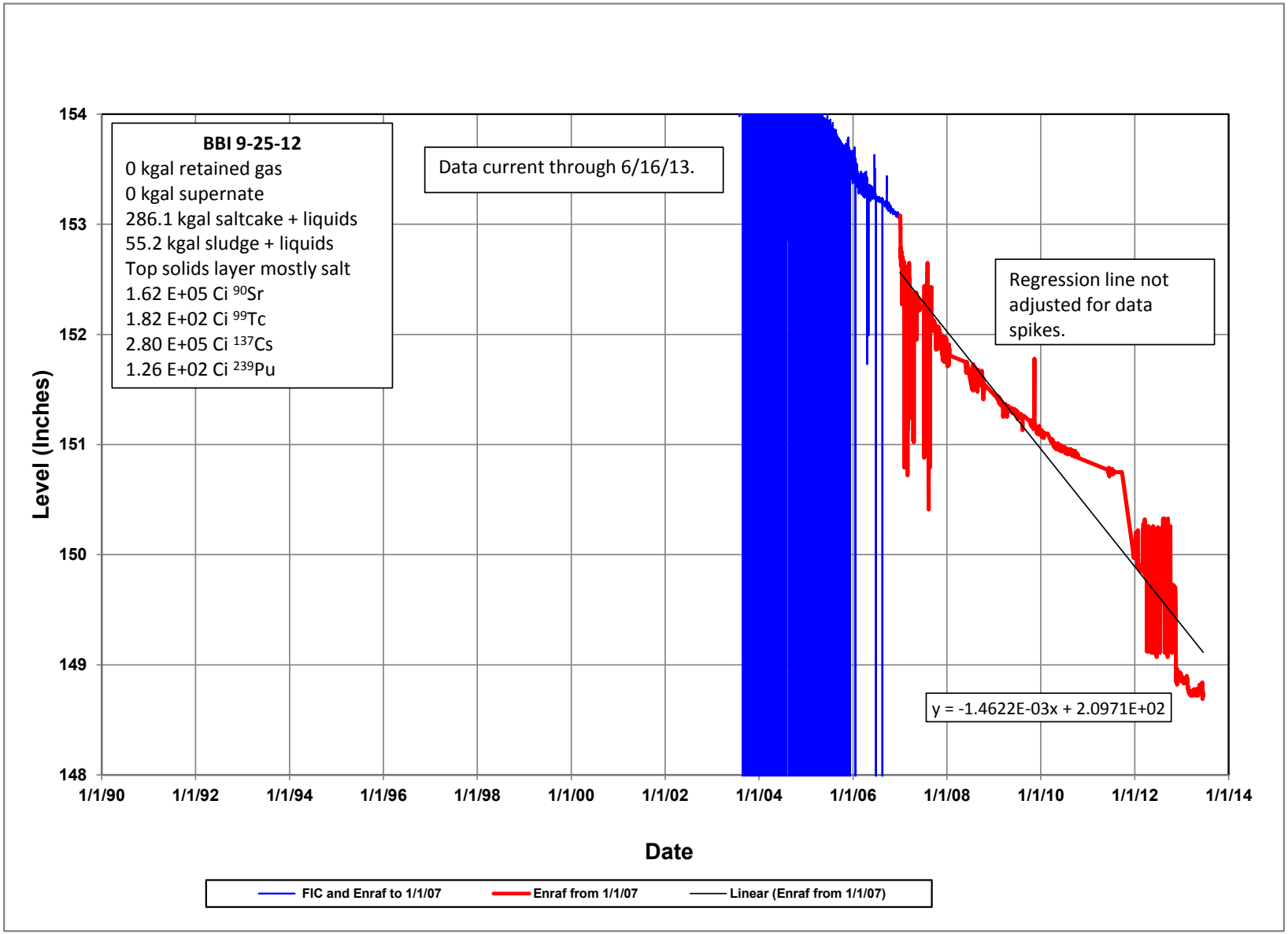


Figure 4-37 Tank SX-102 With Adjusted Surface Level Data From January 1, 2006

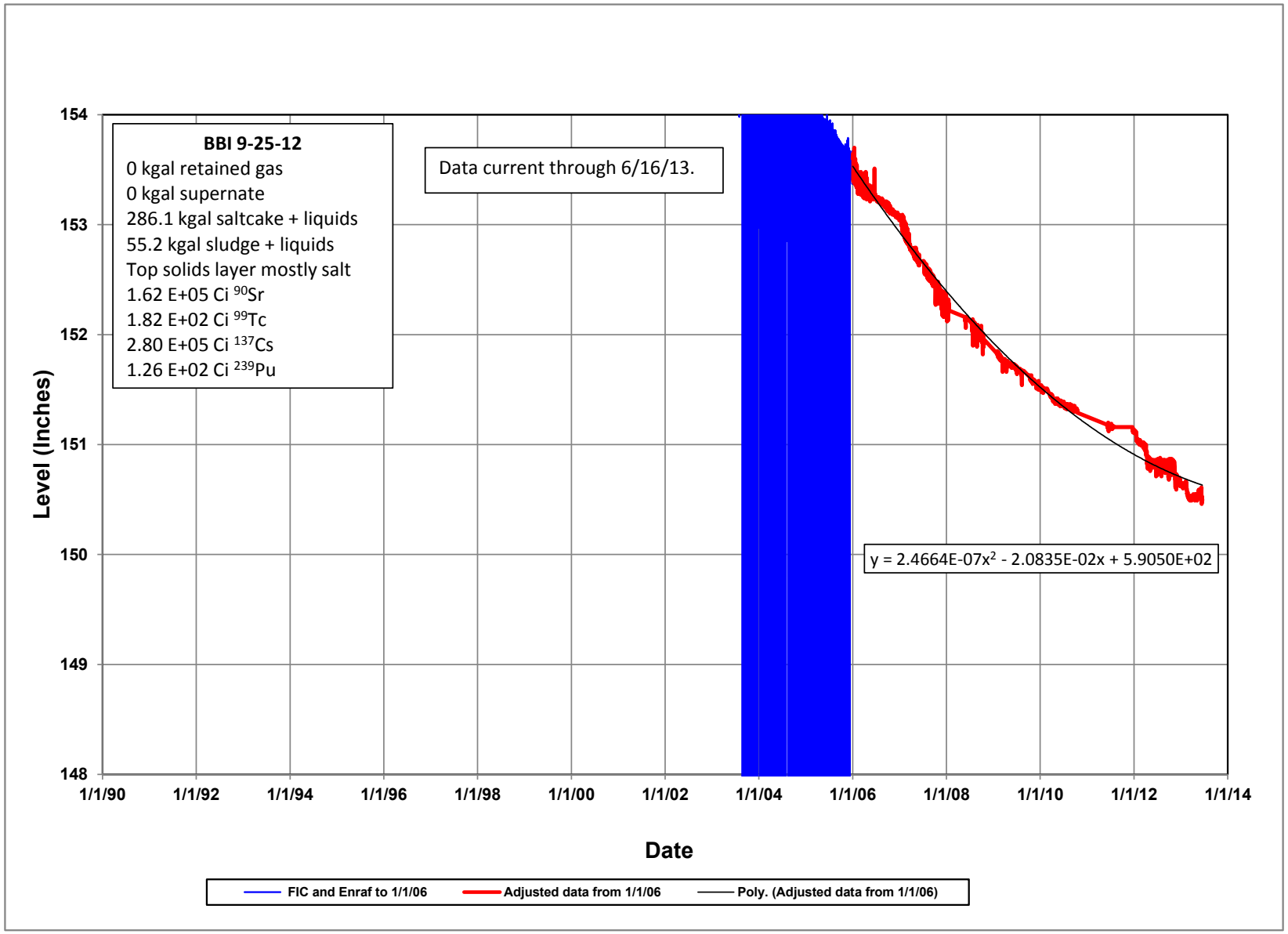
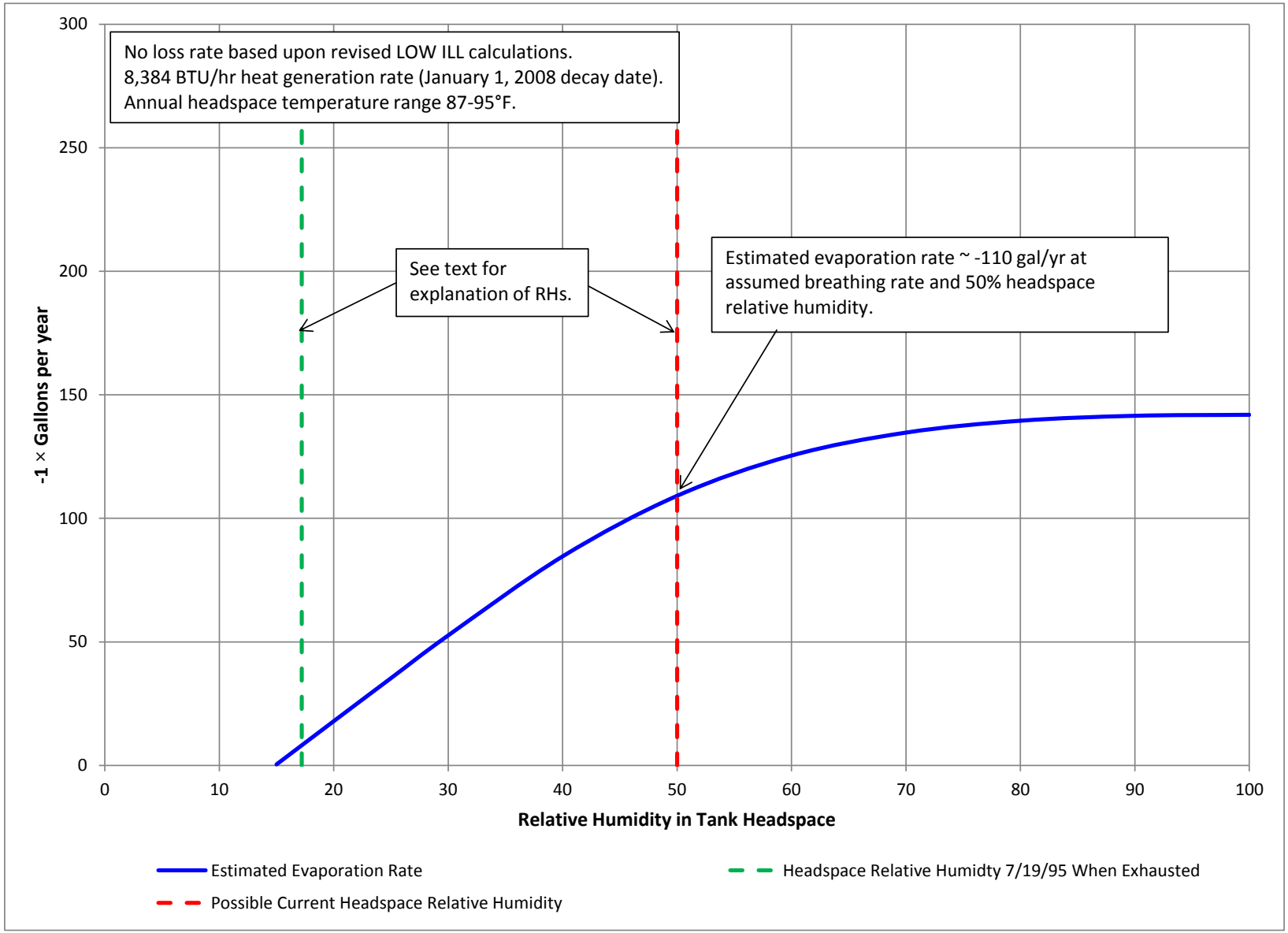


Figure 4-38 Tank SX-102 Estimated Evaporation Loss Rate



4.8 Tank SX-105

4.8.1 Tank Summary

Tank SX-105 entered service in 1955 when it received high-level waste from REDOX. From then through 1967 the tank received wastes from REDOX or other SX tanks. During 1967, the tank received small amounts of laboratory waste. From 1968 through 1980 the tank received and transferred supernatant and evaporator bottoms, and some wastes from other SSTs and DSTs. The tank was removed from service in 1980 and partially isolated in 1985 (RPP-RPT-43060, Rev. 0, *2009 Auto TCR for 241-SX-105*). Interim stabilization was completed in 2002. Per a TWINS query on September 25, 2012 the tank contains about 312.8 kgal salt and 62.9 kgal of sludge.

Figure 4-39 shows the raw ILL and SL data for tank SX-105 from January 1, 1990. Figure 4-40 is a plot of the ILL data used for calculation of the -0.161 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen.

From Figure 4-39 it can be seen the ILL was decreasing at a steady rate all through the 1990s, presumably due to evaporation in the thermally hot tank. The tank was saltwell pumped from 2000 to 2001. Figure 4-40 showed the ILL had an increasing level change following completion of saltwell pumping until 2007 when it appears to stabilize, then had a downward trend until about 2010 when it appeared to level off. The SL has also decreased asymptotically since completion of IS.

In 2013 the ILL neutron scans for tank SX-105 were re-evaluated and a more consistent data interpretation method has been proposed the ILL. Figure 4-41 is an updated ILL data plot comparing the old and revised ILL data. The revised trend line is essentially level based upon the re-evaluation, with a nominal increase of 0.006 in./yr as opposed to the previous decrease. This data reinterpretation has not been approved as of the release date of RPP-RPT-54981, Rev 0, so for conservatism the old data interpretation with decreasing ILL data is used in this document.

Figure 4-42 is the updated plot showing the additional ILL data included for this document but with the old data interpretation method. The slope of the decrease line is less than before, at -0.040 in./yr as of 4/30/13. The decrease is due to shortening the trendline duration to the past 3.5 years to better reflect what the data show is occurring in the tank.

Figure 4-43 compares the August 2013 LOW neutron scan data with the July 2001 scan taken just after the LOW was installed. The decrease in liquid level below ~8 ft and the increase below it is obvious indication of liquid in the tank equilibrating. However, the decrease in liquid below ~6.3 ft is more difficult to explain, the decrease below 6.3 ft. is what might be expected if the tank were leaking, or if there were a gas buildup.

The basis for the selection of the ILL location in SX-105 is not obvious from Figure 4-43. The chosen ILL point is towards the bottom of the neutron count rate scan after it begins to rise, not near the maximum count rate where the water content is higher. The ILL location was selected after reviewing many scans and observing the changing patterns in successive scans over an extended time period. The ILL location in a tank is not usually a sharp demarcation unless the waste porosity is high, the point selected as the ILL for a tank is a point that can be consistently measured and relied upon to be an indicator of change in a given region.

Figure 4-44 shows the same information as Figure 4-43, but with the July 2001 gamma scan added. There has been no gamma scan performed since July 2001. The lower ^{137}Cs content of the waste above ~100 inches is an indicator of a low porosity in this region, which in turn explains why the neutron scans begin to rise below ~100 inches.

The decrease in liquid below 6.3 ft, and increase above 6.3 ft, could be explainable by retained gas buildup. Figure 4-45 is a plot of the ILL and reciprocal of the barometric pressure. The correlation is low as evidenced by the 0.261 R^2 value, but the time period selected for the plot was July 2003 to January 2004. This time period was the only useful post-saltwell pumping period for the plot because the subsequent quarterly LOW monitoring provides too few data points to give useful correlation, and before July 2003 the ILL was changing too rapidly following saltwell pumping to give a useful correlation. Saltwell pumping is known to release retained gas from a tank, which could explain the low R^2 value in Figure 4-45. Figure 4-46 is a pre-saltwell pumping plot from January 1999 to July 2000. The correlation here is high, with an R^2 value of 0.869. This indicates the presence of retained gas at that time. In the years between the completion of saltwell pumping in 2001 and 2013 gas could have again built up as the liquid level in the tank equilibrated.

4.8.2 Liquid Change Rate Estimation

The liquid change rate estimate is conservatively based on the ILL change rate of -0.040 in./yr using the old data interpretation method.

The sludge is on the bottom, per RPP-40545, Rev 2, Appendix H. With the salt assumed to be on the top and with the ILL approximately 46 inches below the surface the ILL is in the salt layer so only the porosity of the salt needs to be considered. RPP-5556 does not list a porosity for tank SX-105 and per RPP-40545, Rev 2, Appendix H the salt in this tank is <2.0 anion mole % phosphate, so a saltcake porosity of 0.20 is assumed per Appendix B of the same document.

With the ILL about 46 inches below the surface it is assumed that the fraction of liquid on the surface is zero.

The estimated tank SX-105 liquid change rate is:

$$Tank\ SX - 105\ estimated\ liquid\ change\ rate = -0.040 \times 2{,}750 \times (0 + (1 - 0) \times 0.20)) = \mathbf{-22\ gal/yr}$$

<u>Estimation of [Σ other]</u> – The level decrease is based upon the ILL decrease so subsidence is not applicable.

Based upon Figure 4-45 there may not have been much gas in SX-105 in 2003. But, based upon Figure 4-46 the tank has the capability for building up a quantity of retained gas and in the ten years since the data were taken for Figure 4-45 there has been sufficient time for retained gas to again build up in the tank. Neutron scans in Figure 4-43 and Figure 4-44 also show the possible buildup of retained gas in the level below ~80 in. in the tank.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1977. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for BY-108 is assumed to be = RGG + 0 + 5 + 0 = 5 gal/yr + RGG

where RGG = retained gas growth

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. The SL was decreasing prior to saltwell pumping, probably from evaporation, and has been decreasing asymptotically since completion of saltwell pumping, with the change rate almost leveled out. An intrusion would be expected to dissolve up salt in this tank and thus cause some SL decrease if there were an intrusion.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -22\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= -27\frac{gal}{yr} - leak\ rate - evaporation\ rate$$

The sum of the leak rate plus the evaporation rate would have to be <-27 gal/yr before an intrusion would be considered. As described below, the estimated evaporation rate for tank SX-105 is between -31 to -92 gal/yr so there could be an intrusion if the evaporation rate is accurate.

Evaluation of ILL or SL Validity – The ILL appears from Figure 4-42 to be at or near equilibrium.

The ENRAF data are not used to estimate the tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

The LOW ILL has always been referenced to the tank centerline bottom.

4.8.3 Evaporation Estimate

Figure 4-47 provides the evaporation estimate results for tank SX-105. The headspace RH is unknown since the 1995 vapor sample was obtained when the tank was being exhausted. The green dashed RH line is the 27.3% RH calculated from the 1995 vapor sample when the tank was being exhausted at a nominal 100 cubic feet per minute (cfm). The tank headspace temperature is about the same in 2013 as in 1995 when the tank was exhausted. Per Appendix A, Table A-9, comparing tank SX-105 with tank S-101, the non-exhausted salt-containing tank with the closest headspace temperature to tank SX-105, the tank SX-105 RH could be around 50%. The red dashed line indicates this possible current tank SX-105 RH. Per Figure 4-47 the evaporation rate at 27% RH would be about -31 gal/yr and at 50% RH would be about -92 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank SX-105 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank SX-105, 2.5 cfm, is similar to the rates for other 75 ft. diameter tanks excluding A and AX tank farms, and is within the range of breathing rate data for the non-A/AX tanks with tracer gas tests in 1996 to 1998. The basis for the breathing rate assumed for tank SX-105 is provided in Appendix A and is the best estimate when considering the information.

4.8.4 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank SX-105 as 15,617 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. Only 0.1% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimated liquid change rate.

There is sufficient heat generated in the tank to drive off water despite the ILL being about 45 in. below the waste surface.

4.8.5 Tank SX-105 Leak Potential

Based upon Figure 4-47 the tank SX-105 liquid loss rate can be explained by evaporation regardless of whether a 27.3% RH or 50% RH is assumed for the tank headspace.

There is sufficient heat generated in the tank to evaporate water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = -22\frac{gal}{yr} - intrusion\ rate - \left(-31\ to - 92\frac{gal}{yr}\right) - \left(5\frac{gal}{yr}\right)$$
$$= 4\ to\ 65\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for SX-105 is -92 gal/yr, the intrusion rate would have to exceed 65 gal/yr for a leak to exist. If the evaporation rate is only -31 gal/yr, any intrusion over 4 gal/yr could mask a leak.

The decrease rate for SX-105 is based upon the previous characteristic selected for ILL interpretation. The revised, but not yet approved, method of ILL interpretation for SX-105 will result in the ILL change rate going from a slight decrease to a slight increase if approved.

4.8.6 Tank SX-105 Conclusion

There is no basis to assume a leak from tank SX-105.

Figure 4-39 Tank SX-105 Full Depth Raw Data Plot

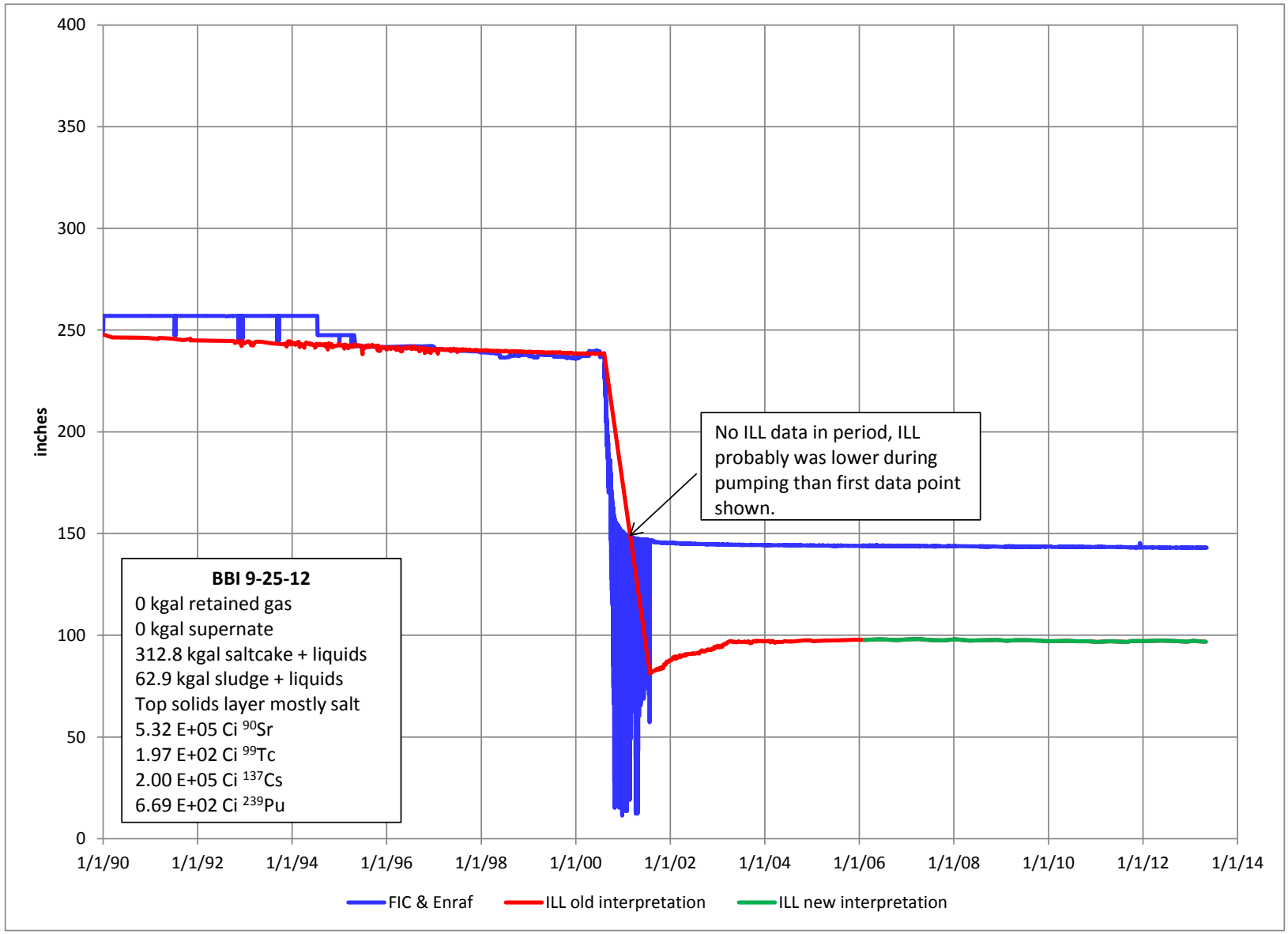


Figure 4-40 Tank SX-105 Expanded ILL Data Plot Used for RPP-PLAN-55113, Rev 1

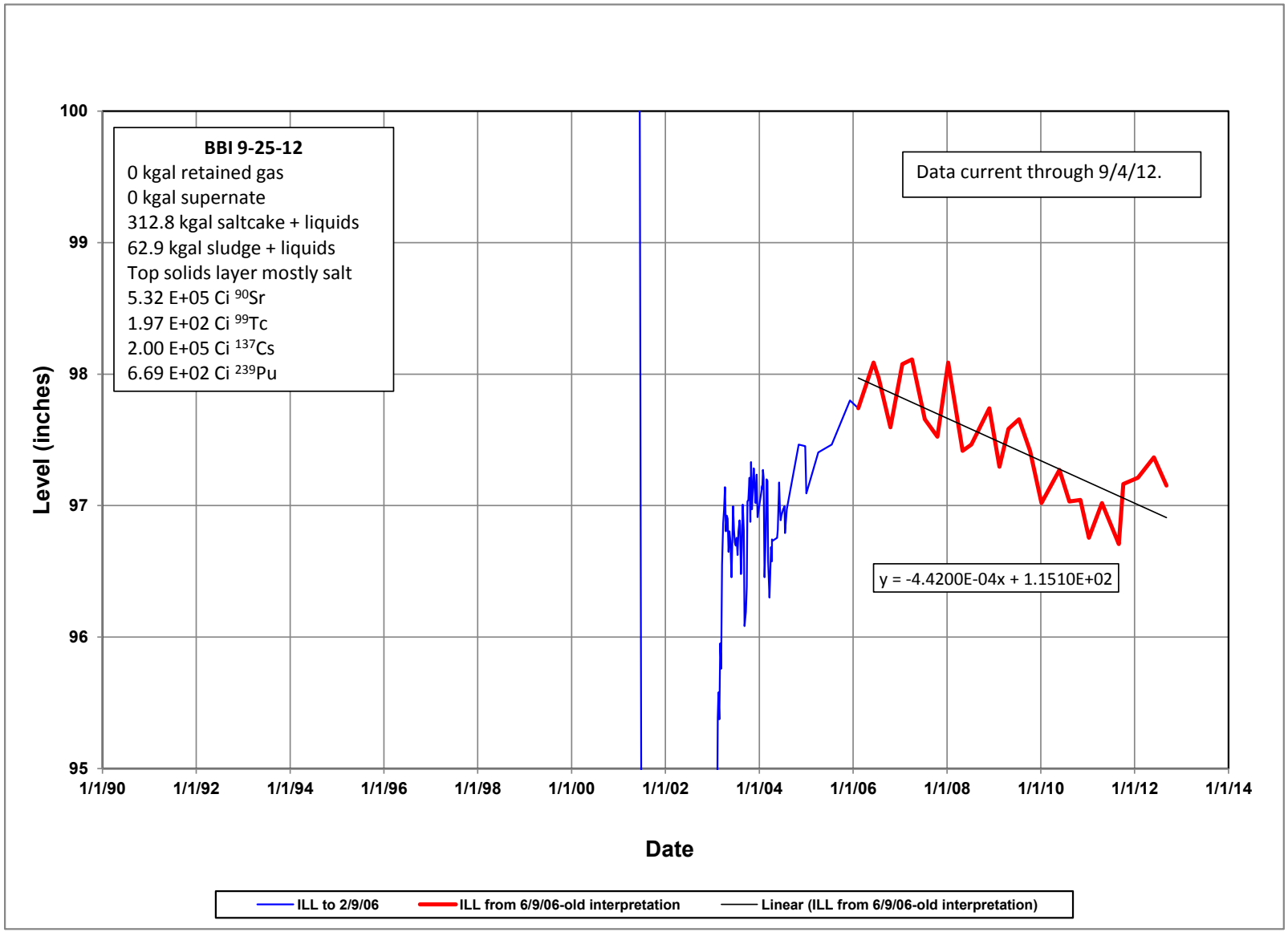


Figure 4-41 Tank SX-105 Expanded ILL Data Plot with Planned Data Reinterpretation

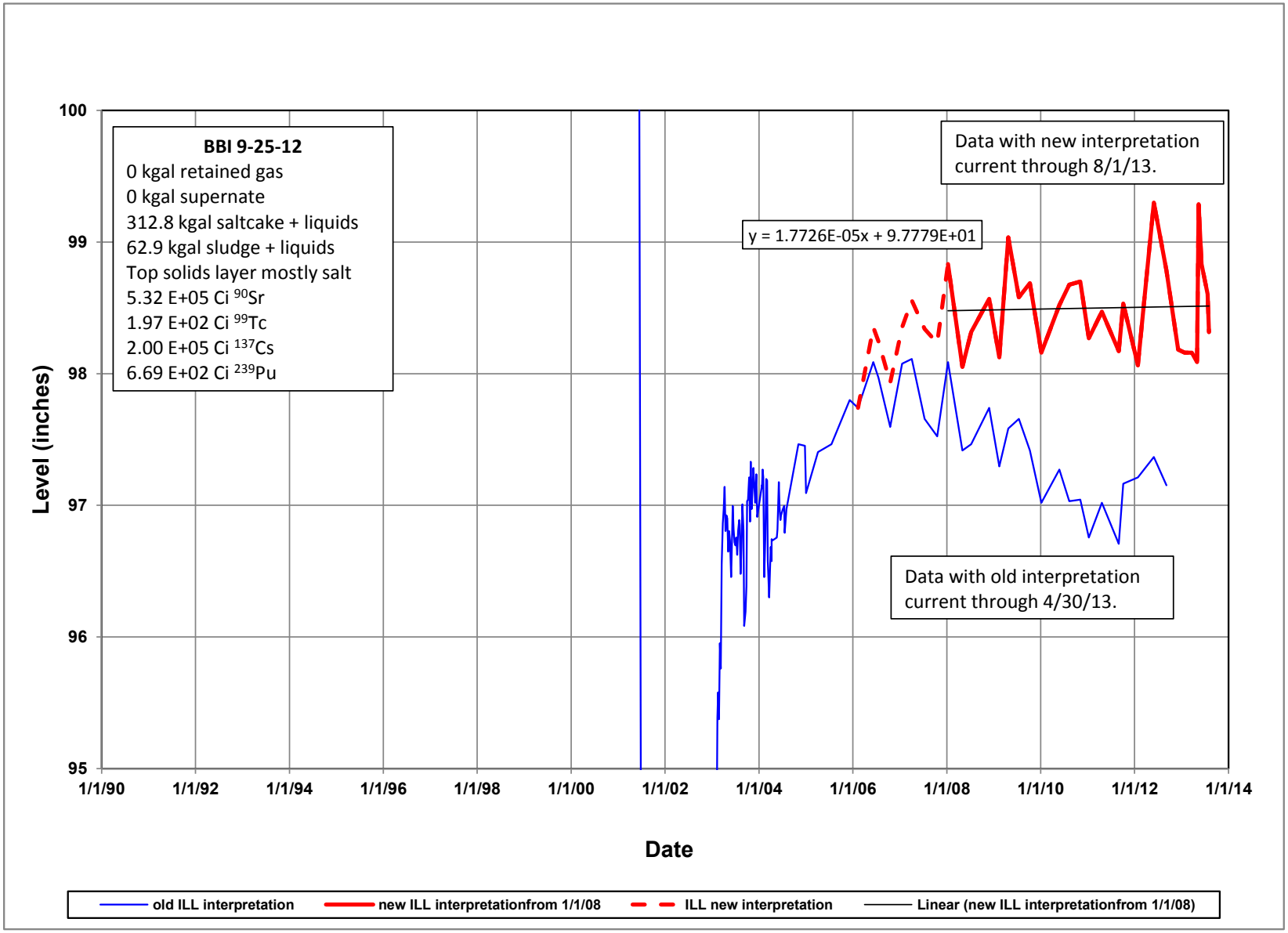


Figure 4-42 Tank SX-105 Expanded ILL Data Plot Used for RPP-RPT-54981

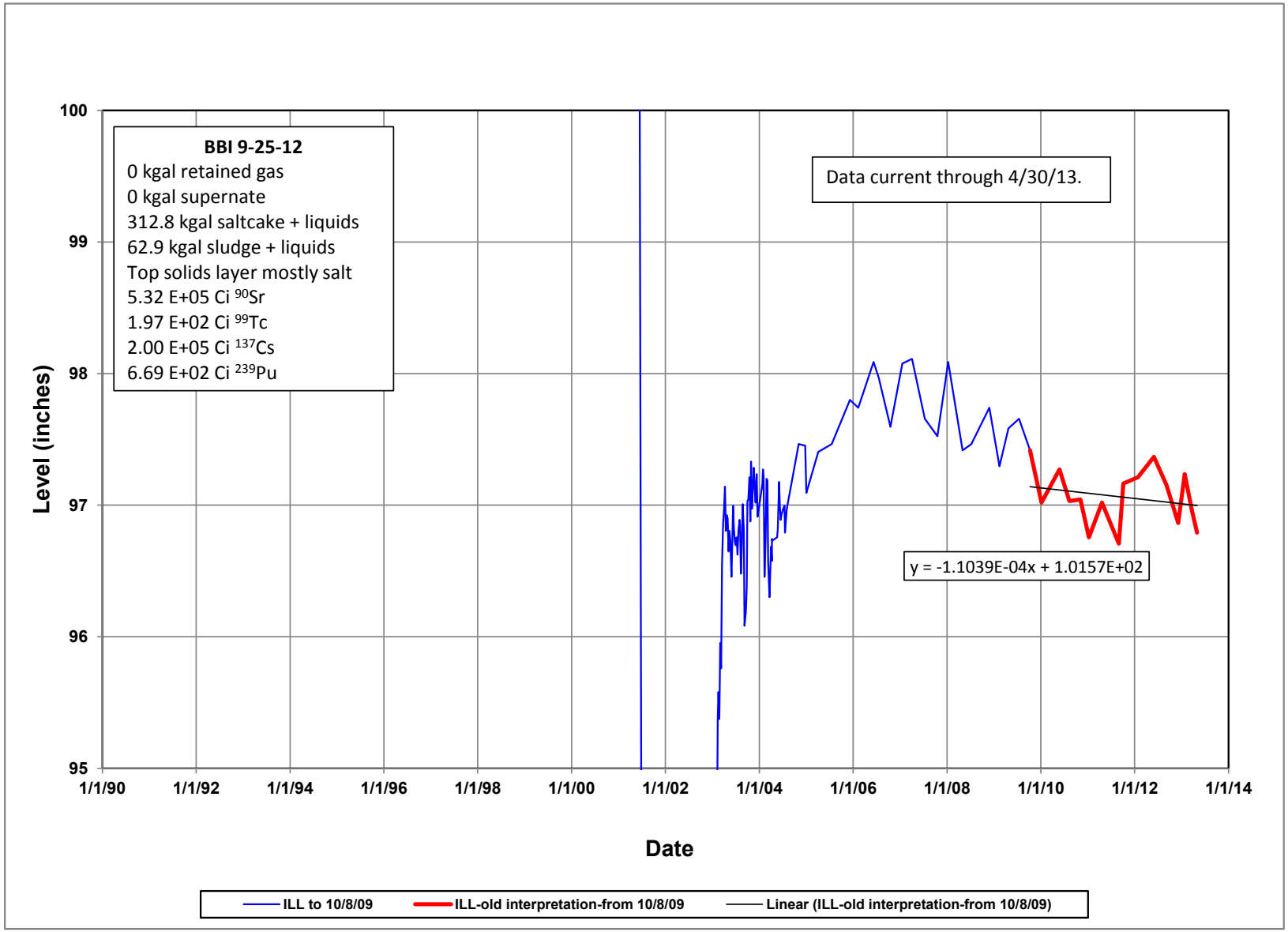


Figure 4-43 Comparison of Tank SX-105 July 2001 and August 2013 Liquid Observation Well Neutron Scans

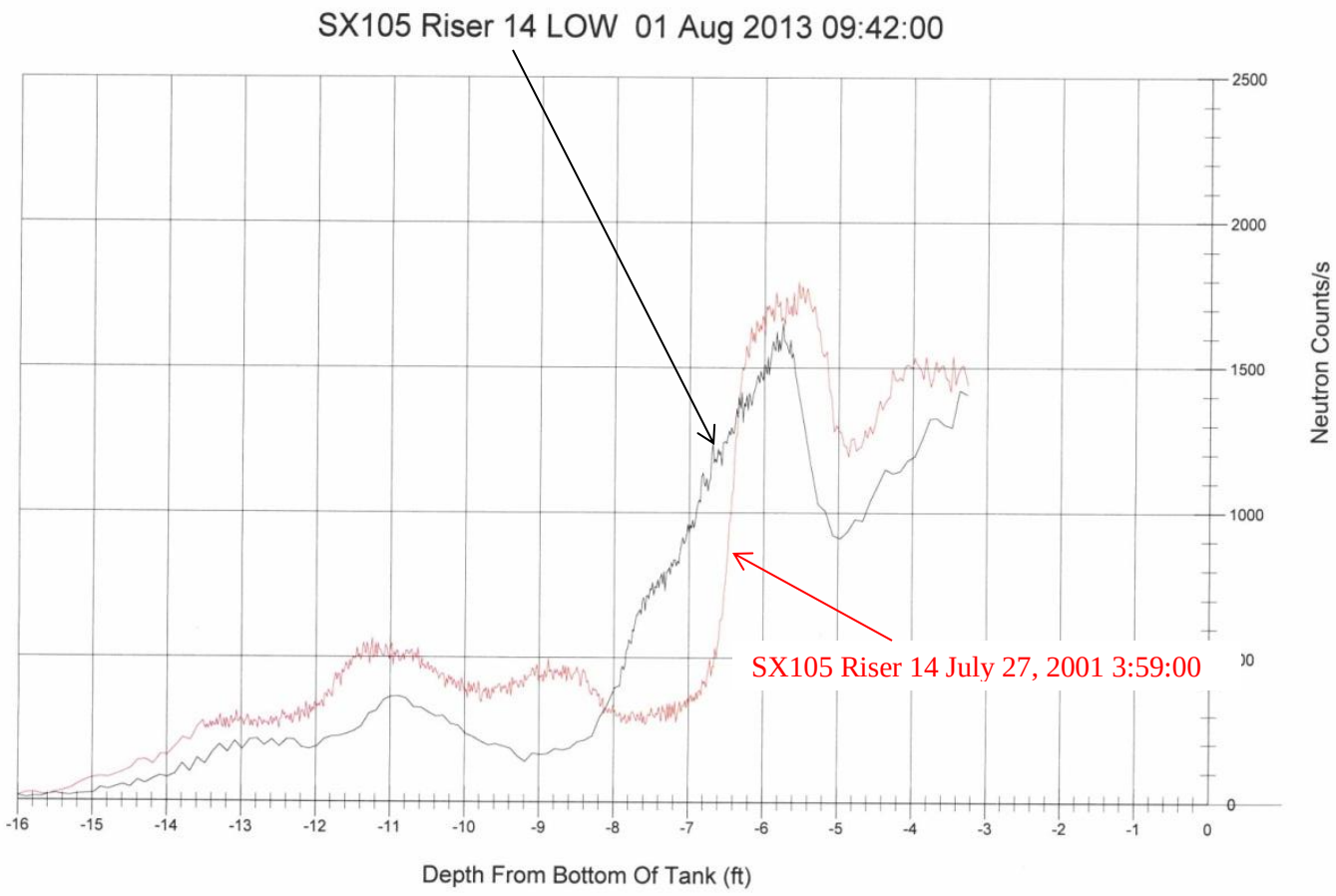


Figure 4-44 Comparison of Tank SX-105 July 2001 Neutron and Gamma Scans with August 2013 Liquid Observation Well Neutron Scan

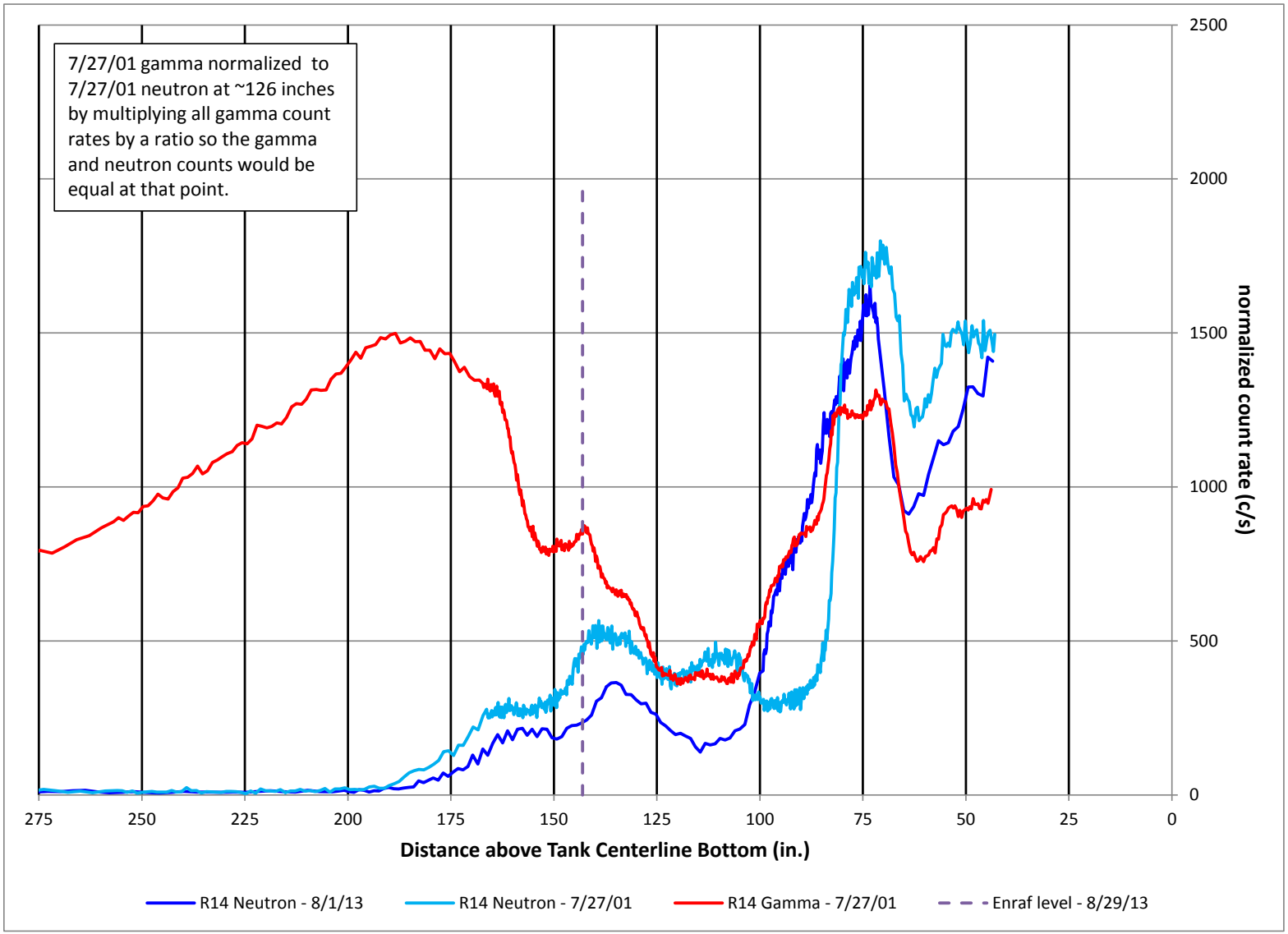


Figure 4-45 Tank SX-105 2003 – 2004 Raw Interstitial Liquid Level Data and Adjusted Inverse Barometric Pressure

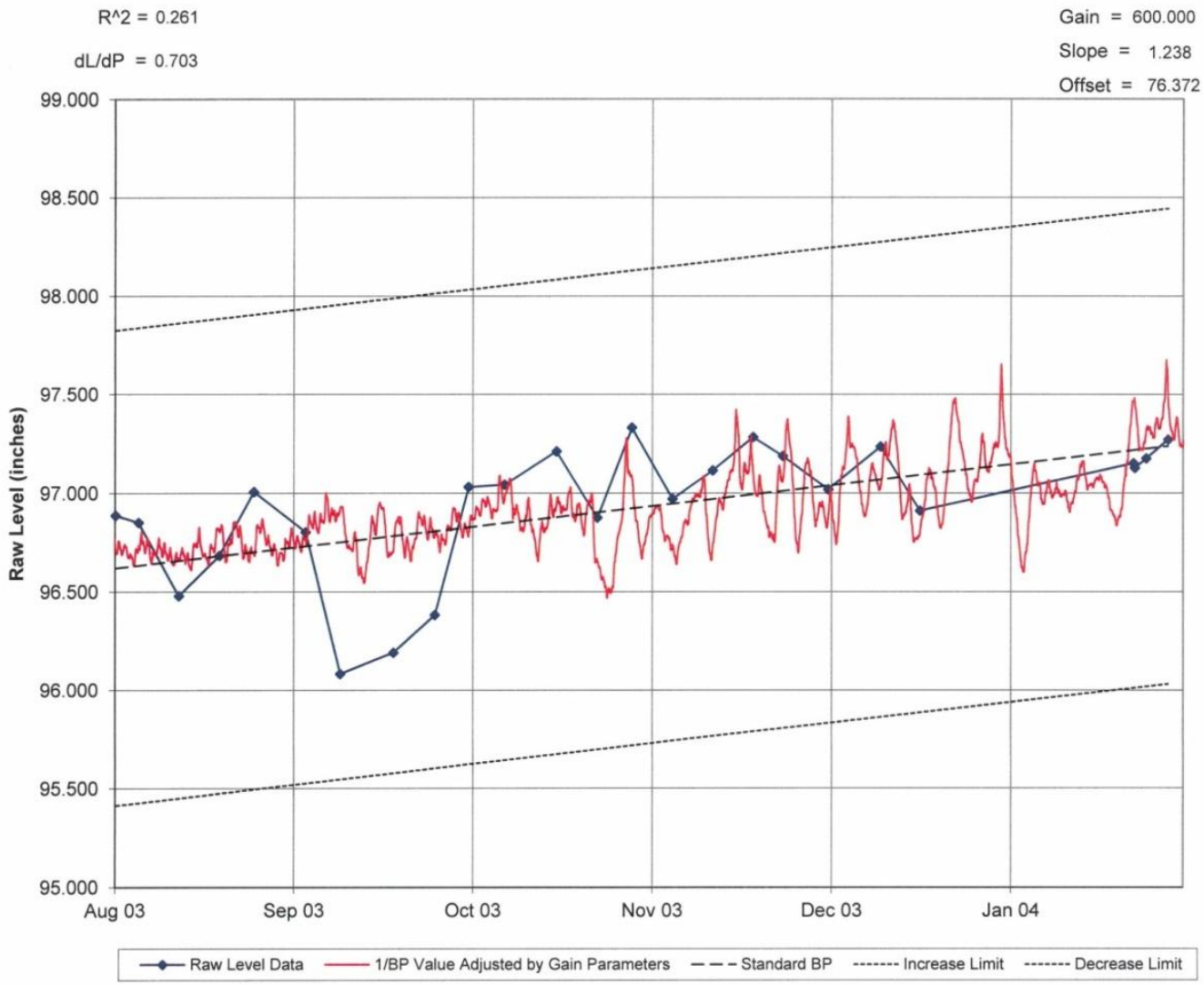


Figure 4-46 Tank SX-105 1999 -2000 Raw Interstitial Liquid Level Data and Adjusted Inverse Barometric Pressure

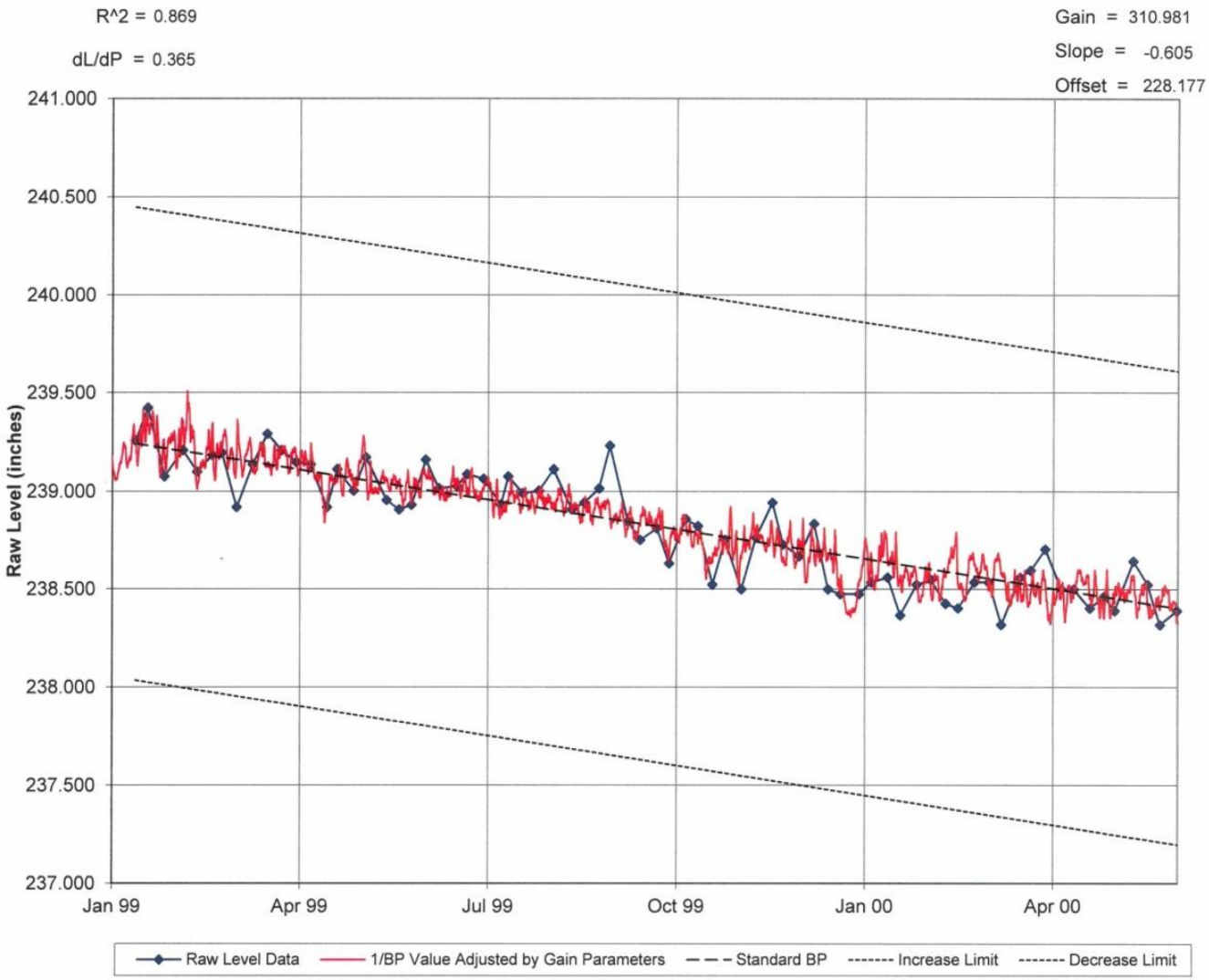
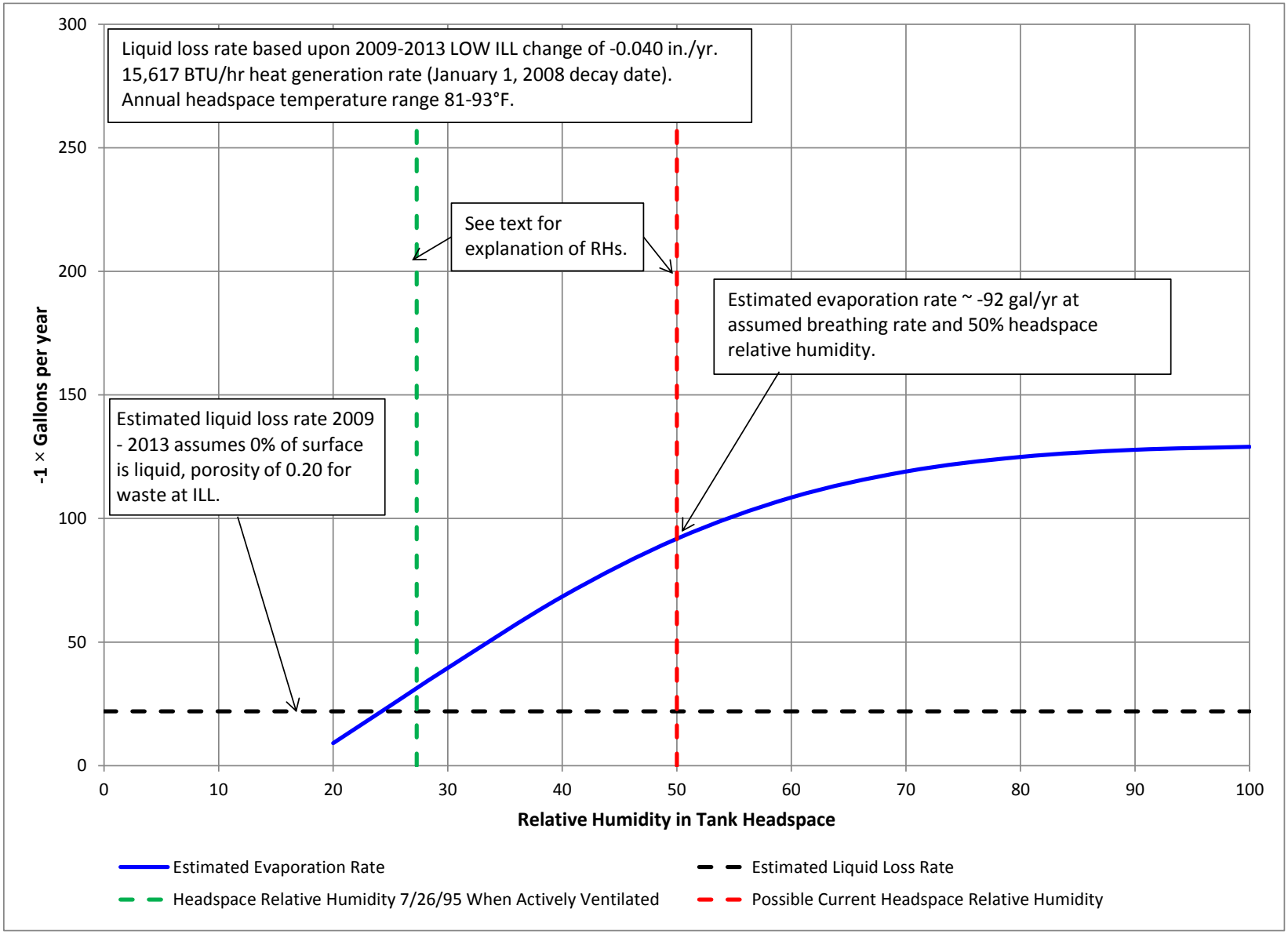


Figure 4-47 Tank SX-105 Estimated Evaporation Loss Rate



4.9 Tank SX-114

4.9.1 Tank Summary

Tank SX-114 entered service in 1956 when it received high-level waste from REDOX. It continued to receiver REDOX wastes from the plant and other SX tanks through 1965. It then received and transferred mostly dilute wastes from and to other tanks. The tank was suspected of leaking in 1974 and removed from service in 1975 (RPP-RPT-43069, Rev. 0, *2009 Auto TCR for 241-SX-114*). The tank was declared interim stabilized in 1979 (HNF-SD-RE-TI-178, 2007, *Single-Shell Tank Interim Stabilization Record*, Rev 9a). Per a TWINS query on September 25, 2012 the tank contains about 29.1 kgal saltcake and 126.3 kgal sludge.

Figure 4-48 shows the raw SL data for tank SX-114 from January 1, 1990. Figure 4-49 is a plot of the SL data used for calculation of the -0.139 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen. The surface level decrease trendline of -0.139 in./yr for this tank was only measured for the period February 1, 2001 to July 31, 2003, as it was the most consistent period of change since 1990, with there being many up and down spikes between 1990 and 2013. Figure 4-50 is an updated plot showing the latest data included for this document. The data have been adjusted to remove the numerous spikes. The slope of the decrease line is at -0.151 in./yr as of June 16, 2013. Note that removal of the spike in mid-2003 makes the red line used for calculating a regression line slope below the general level for the remaining data. The red line is the representation of the Enraf data change, the actual value of a data point is not of concern.

There is no LOW in the tank.

4.9.2 Liquid Change Rate Estimation

Photos from 1989 (last images available for the tank) show the waste surface dry and quite smooth, with cracking around the edge. The waste looks like sludge. Per RPP-40545, Rev 2, Appendix H, the sludge is on the bottom in the tank but based upon the photos it appears that the sludge, which is over 80% of the waste in the tank per the BBI, is on the top.

A manual tape in riser 2 was used to obtain SL data until mid-1999. An ENRAF was installed in the same riser at that time and has been used to obtain the data since. A photo from 1989 shows the pile of old tapes usually seen underneath a surface level measurement riser. Although the waste surface is smooth in the photos it is possible that the spikes seen in the level are due to the manual tape and ENRAF plummets occasionally resting on old tapes sitting on the waste surface.

The tank waste solids height is currently about 63 inches. The liquid level, if any, in the tank is unknown. The IS documentation for the tank from 1979 states the entire surface is solids, with some areas of wet solids at the base of the air lift circulators. The same documentation states the liquid level was about 71.25 inches at riser 2 and the solids about 78 inches at a different riser (number not stated). If there are only 10-11 inches of salt and 52-53 inches of sludge (in 2013) it is difficult to see how the waste surface could have dropped by 15 inches the past 33 years unless most of the sludge has dried out and the sludge has all collapsed on itself. This would in turn mean that the sludge originally had a very high porosity.

Overall, since 1981 the tank waste surface level data reading has dropped by about 10 percent. It is not realistic to assume that 10 percent of the tank sludge has leaked to the environment, so the assumption is made that either the waste surface is subsiding near the level gauge(s) due to

porosity change or the level gauge(s) aren't providing a valid indication due to where the plummet is contacting the waste.

For this document the assumption is made that the waste is all sludge with a porosity of 0.15 for consistency with RPP-5556.

At a heat generation rate of over 40,000 BTU/hr it is by far the highest heat generating tank evaluated in this document and has the highest tank headspace temperature. The maximum waste temperature is over 160°F. With the tank as hot as it is and very little liquid being present in the 1979 IS evaluation, and none present in the 1989 photos, that the fraction of liquid on the surface is zero. The minimum estimated liquid loss rate assumes the plummet is resting in a small depression on liquid.

The minimum estimate of the tank SX-114 liquid change rate is equal to:

$$Tank\ SX - 114\ min\ estimate\ liquid\ change\ rate = -0.151 \times 2{,}750 \times (0 + (1 - 0) \times 0.15)) = \mathbf{-62\ gal/yr}$$

A rough approximation to the liquid loss rate, using a ratio of 280 gal/yr per in./yr SL change is, since SX-114 is a predominantly sludge tank:

$$Tank\ SX - 114\ rough\ approximate\ liquid\ change\ rate = -0.151 \times 280 = \mathbf{-42\ gal/yr}$$

A maximum estimate of the liquid loss rate assumes the surface level drop is equal over the waste surface:

$$Tank\ SX - 114\ max\ estimate\ liquid\ change\ rate = -0.151 \times 2{,}750 = \mathbf{-416\ gal/yr}$$

4.9.3 Data Analysis

Estimation of [Σ other] – The level decrease is based upon the SL change. It is probable that the waste is subsiding on itself.

The BBI shows zero retained gas in SX-114. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. The decrease in the SL is not typical of an episodic gas release. While it is theoretically possible the waste matrix could have retained gas for a long time and then released it slowly at a constant rate for over 30 years, this is not realistic.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1971. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for SX-114 is assumed to be = PCE + 0 + 5 + 0 = 5 gal/yr + PCE.

where PCE = porosity change effect

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. There has been no evidence of intrusion based upon the SL or ILL data going back to 1980, and it is doubtful that any would be noticed with the temperature and heat generation rate in the tank.

No rough estimate is made for an intrusion into tank SX-114 as it would be of negligible value for this document, there is no basis for either a usable volumetric change rate or a usable evaporation rate.

Evaluation of ILL and SL Validity – The level change information is based upon surface level change, there is no LOW in the tank.

How the ENRAF plummet is resting is unknown, but it is possible some of the data spikes are due to the plummet resting on old manual tapes lying on the waste surface or cracks in the waste. The spike pattern is roughly the same for both manual tape and ENRAF data going back to before 1990. Based upon the pattern observed with both manual tape data and ENRAF data it is assumed that the long term data decrease trend is real.

Table 4-3 lists all tank SX-114 ENRAF work packages for the 2006 to 2013 time period. The last two columns list the as-found and as-left data from the work packages. The calibrations on January 23, 2007 (0.31 in. differential), July 16, 2009 (1.17 in. differential), July 14, 2010 (0.38 in. differential), and June 20, 2012 (1.66 in. differential) are significant changes. Looking at Figure 4-50 however it can be seen that there are a number of additional data spikes beside the calibration changes. There may be some minor problems with the ENRAF gauge that causes the sudden jumps or calibration changes, but based upon the pattern observed with both manual tape data and ENRAF data it is still assumed that the long term data decrease trend is real.

Table 4-3 Tank SX-114 ENRAF Gauge Work Packages Since January 1, 2006

Work Package No.	Title	Date	As Found (in.)	As Left (in.)
CLO-WO-06-00220	241-SX, 114 ENRAF INSPECTION	January 23, 2007	65.48	64.17
CLO-WO-07-1449	241-SX, 114 ENRAF INSPECTION	October 16, 2007	64.11	64.04
TFC-WO-08-0612	241-SX, 114 ENRAF CAL	September 23, 2008	65.13	65.06
TFC-WO-09-0902	241-SX, 114 ENRAF CAL	July 16, 2009	64.88	63.71
TFC-WO-10-0425	241-SX, 114 ENRAF CAL	July 14, 2010	63.57	63.19
TFC-WO-11-2013	241-SX, 114 ENRAF CAL	October 23, 2011	63.47	63.46
TFC-WO-12-1945	241-SX, 114 ENRAF CAL	June 20, 2012	64.63	62.97

All the data shown are referenced to the tank centerline bottom.

4.9.4 Evaporation Estimate

Figure 4-51 provides the evaporation estimate results for tank SX-114. The dashed vertical RH line is the result from the vapor sample in 1995. This value, shown as 5.5%, is actually <5.5% as it was based upon a vapor sample result of <5.89 mg/L. The water content in the headspace air was below detection limits.

The current tank SX-114 headspace temperature is about 7°F higher than when the tank was being exhausted and the vapor sample was taken. At 5.5% RH in the tank headspace at the current headspace temperature it can be seen from Figure 4-51 that essentially zero water would be evaporated.

It is difficult to infer much information from Figure 4-51 due to the non-detectable water vapor in the 1997 sample. This leads to several assumptions:

- The vapor sample was not a valid sample
- There was/is negligible water left in the tank waste, it all having been evaporated
- There was a high exhaust rate through the tank, the water vapor content in the headspace was low and diluted out by the high air flow

The vapor samples for SX-107, SX-108, SX-109, SX-110, SX-111, SX-112 and SX-114 all showed less than detectable water vapor in the headspace air. One of the samples from these seven tanks was obtained in 1995, the remaining six were obtained over a 2.5 month period in 1997. The RH was measured when the tanks were being exhausted. This means that there was either a systematic error associated with sampling of these thermally hot tanks that didn't impact sampling of other tanks, or the water vapor content of these SX tanks was less than detectable. With the samples taken and analyzed over an extended period it is assumed not likely that a systematic lab error was involved with the less than detectable values. Since high RHs were obtained in thermally warm C-Farm tanks which were not exhausted it is assumed the sampling methodology was acceptable and that these SX tanks really did have low water vapor content.

The annual tank headspace temperature in tank SX-114 is 125°F to 135°F. For comparison purposes, air with 100% RH at 70°F would be only 16% RH when heated to 130°F.

There is no basis to estimate what the tank SX-114 headspace RH is, but from looking at Figure 4-51 it is apparent an RH of about 10% would evaporate water at the minimum liquid loss rate, an RH of about 8% would evaporate water at the rough approximate liquid change rate.

4.9.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank SX-114 as 40,836 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. Only 0.2% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the minimum estimated or rough approximate liquid change rate, and only 1.0% would be needed to evaporate water at the maximum estimated liquid change rate.

There is more than sufficient heat generated in the tank to drive off water at the estimated bounding maximum rate. The location of the liquid level in the tank, if there is any liquid present, is unknown but the heat generation rate is adequate to evaporate the liquid whatever depth it is at.

4.9.6 Tank SX-114 Leak Potential

The tank SX-114 liquid loss rate can be readily explained by evaporation, less than 1% of the heat generated in the waste is necessary to evaporate water at the maximum rate shown in Figure 4-51. The 1997 vapor sample, if accurate, indicate little free water is left to evaporate.

A good estimate of a liquid loss rate for SX-114 is not possible in the tank since only the surface level change is being measured. There is no comparison basis to indicate whether the tank is leaking or not. The tank is an assumed leaking tank.

The tank SX-114 estimated minimum liquid loss rate is easily explainable by evaporation due to the tank heat load, but the maximum possible loss rate is far above the estimated evaporation plot in Figure 4-51. The maximum possible rate is not realistic however, because it assumes a liquid surface in the tank. The rough approximation for a tank SX-114 liquid loss rate based upon the ILL gal/yr loss rate per in./yr SL change rate from tanks with both decreasing ILLs and SLs is similar to the estimated minimum loss rate.

There is more than sufficient heat generated in the tank to evaporate water at a significant rate from tank SX-114, if water is present.

Estimating a leak rate for tank SX-114 has little value. With the large heat load and high temperatures in the tank, water will be evaporated at a rate higher than in any of the other tanks, assuming the tank is breathing. If there is no liquid present, there is no liquid to leak.

It is noted that in Figure 4-50, the adjusted ENRAF data for SX-114, a subtle annual level cycle can be detected. Such a cycle is usually seen in tanks with a moist or liquid surface, not in one that is assumed to be very dry like SX-114. No explanation is postulated for this cycle.

4.9.7 Tank SX-114 Conclusion

Surface level data obtained from solid surfaces are inadequate to accurately estimate liquid change rates, and the evaporation rate can’t be estimated without a reasonable relative humidity basis. The heat load in SX-114 and the waste temperature are high enough to drive off water at a sufficient rate such that there may not be much liquid left in the tank. There is no basis to assume a leak from tank SX-114.

Figure 4-48 Tank SX-114 Full Depth Raw Data Plot

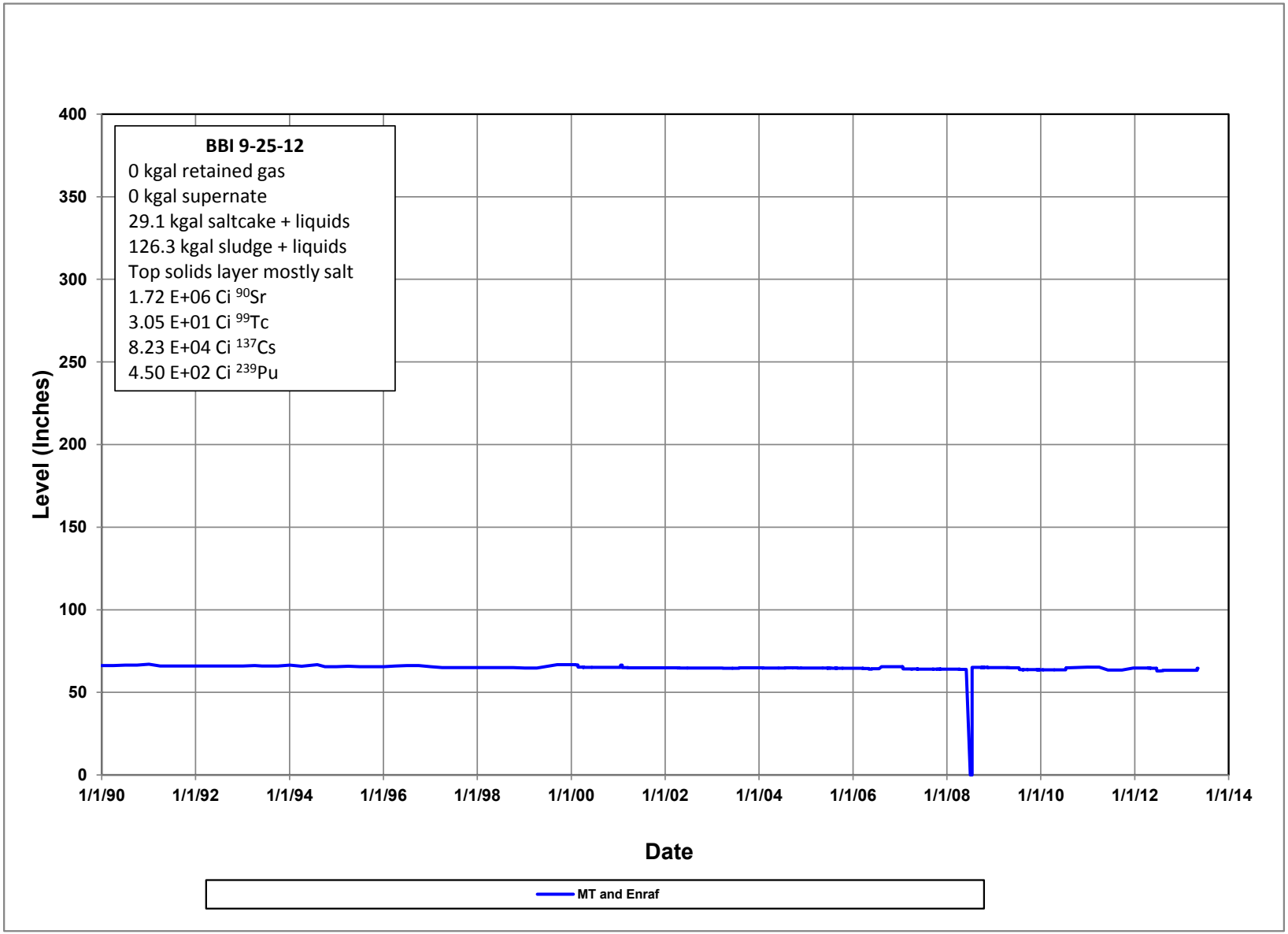


Figure 4-49 Tank SX-114 Expanded SL Data Plot Used for RPP-PLAN-55113, Rev 1

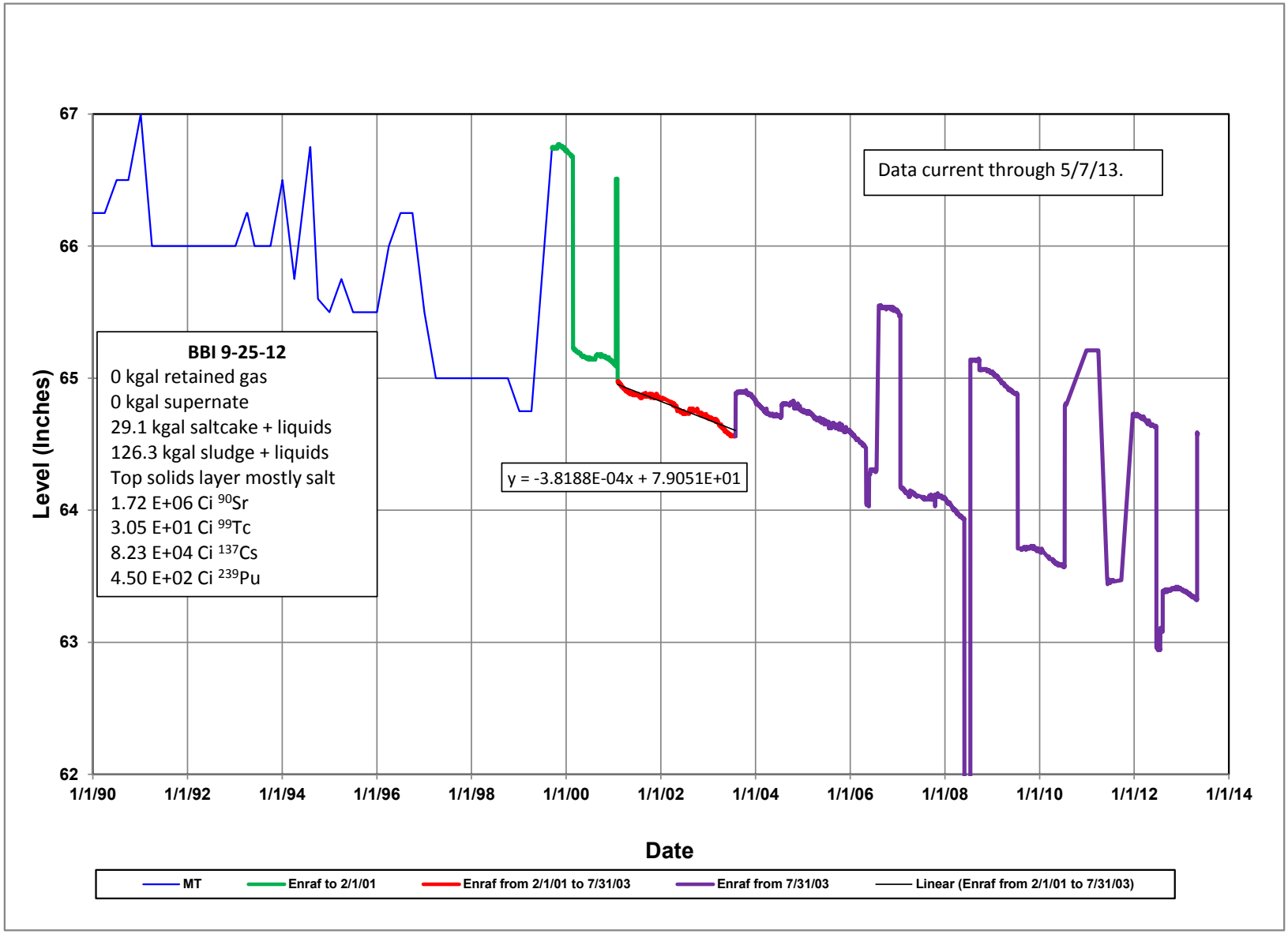


Figure 4-50 Tank SX-114 Expanded Adjusted Surface Level Data Plot Used for RPP-RPT-54981

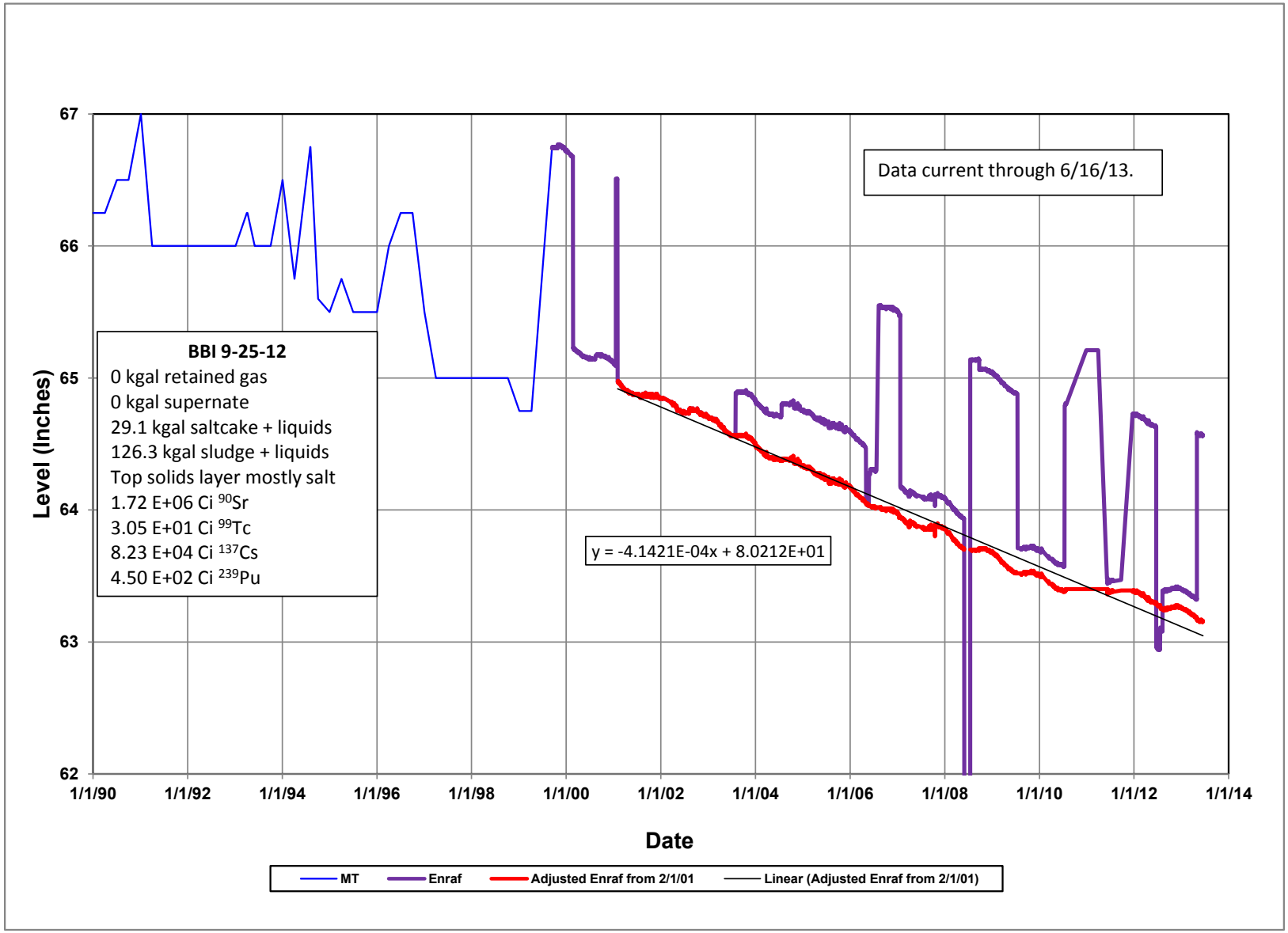
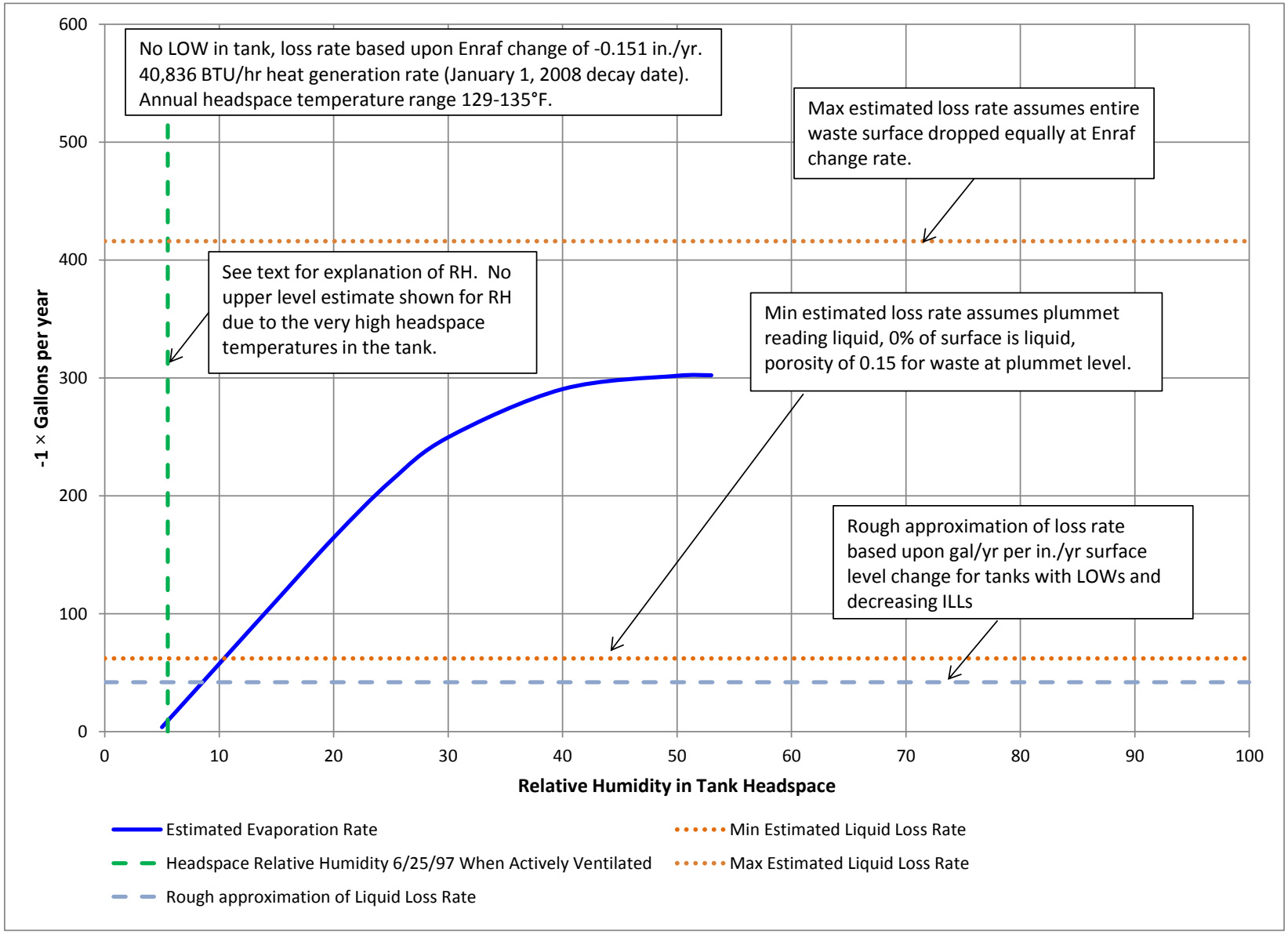


Figure 4-51 Tank SX-114 Estimated Evaporation and Max/Min/Rough Approximate Liquid Loss Rates



4.10 Tank TX-108

4.10.1 Tank Summary

Tank TX-108 entered service in 1952 when $BiPO_4$ process waste was transferred in from other SSTs. It occasionally received other tank wastes and TBP process wastes through 1966. From 1974 through 1977 it received evaporator bottoms. The tank was declared inactive in 1977 and was interim stabilized in 1983. Intrusion prevention was completed in 1984 (RPP-RPT-43182, Rev. 0, *2009 Auto TCR for 241-TX-108*). Per a TWINS query on September 25, 2012 the tank contains about 120.2 kgal salt and 6.1 kgal of sludge.

Figure 4-52 shows the raw SL data for tank TX-108 from January 1, 1990. Figure 4-53 is a plot of the data used for calculation of the -0.070 in./yr trendline slope for the ENRAF data going back to 2003 used for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the SL data changes can be seen. The tank level was essentially constant when the Food Instrument Corporation (FIC) gauge was in place (primarily in intrusion mode) but when the ENRAF was installed in 1996 the level showed a decreasing trend which came close to leveling off by 2004. Figure 4-54 is an updated plot showing the latest data included for this document, with the trendline going back to 2008. The slope of the decrease line is at -0.033 in./yr as of July 21, 2013. There is no working LOW in the tank, the LOW failed in 1994 and was not replaced.

Figure 4-55 shows the same raw data as Figure 4-53 and Figure 4-54, but going back to 1980. The tank showed a decrease from 57 to 55 inches from 1983 to 1984 with the FIC gauge, but the FIC was then put in intrusion mode until the ENRAF was installed in 1996. Part of this decrease was due to saltwell pumping but it is unknown why the level kept decreasing following pumping, there was negligible drainable liquid in the tank based upon HNF-SD-WM-TI-378, Rev 9a. Periodic FIC readings (downward spikes in blue line) showed about a 53.5 inch level for a number of years. There was a 1.33 inch rise in the SL data between the last FIC reading on January 1, 1996 and the first ENRAF reading (manual mode) on May 15, 1996. There was an additional 1.67 inch increase in the reading when the ENRAF was put in auto mode on June 27, 1996. Shortly after the ENRAF was installed the level began to decrease asymptotically.

4.10.2 Liquid Change Rate Estimation

The minimum level decrease rate is based upon the SL change rate of -0.033 in./yr.

The last ILL data in 1994 showed the ILL at ~30 inches, about 25 inches below the waste surface. Based upon 0 kgal supernatant liquid in the 1983 IS calculations and the approximate ILL location there is zero liquid on the waste surface. With the salt assumed to be on the top and the ILL 25 inches below the waste surface, only the porosity of the salt needs to be considered.

The sludge is on the bottom, per RPP-40545, Rev 2, Appendix H. A saltcake porosity of 0.25 is assumed for consistency with RPP-5556.

The minimum estimated liquid loss rate assumes the plummet is reading a liquid pool in a small depression. The minimum estimate of the tank TX-108 liquid change rate is equal to:

$$Tank\ TX-108\ min\ estimate\ liquid\ change\ rate = -0.033 \times 2{,}750 \times (0 + (1-0) \times 0.25)) = \mathbf{-23\ gal/yr}$$

A rough approximation to the liquid loss rate, using a ratio of 1,230 gal/yr per in./yr SL change, since TX-108 is a predominantly sludge tank:

$$Tank\ TX-108\ rough\ approximate\ liquid\ change\ rate = -0.033 \times 1{,}230 = \mathbf{-41\ gal/yr}$$

A maximum estimate of the liquid loss rate assumes the surface level drop is equal over the waste surface, porosity is not considered:

$$Tank\ TX-108\ max\ estimate\ liquid\ change\ rate = -0.033 \times 2{,}750 = \mathbf{-90\ gal/yr}$$

4.10.3 Data Analysis

Estimation of [Σ other] – There appears to be a subtle relationship between an increase in the tank temperature and a corresponding decrease in the waste surface level for tank TX-108. Figure 4-56 is a plot of the same level data as in Figure 4-55, with the tank headspace temperature overlaid. Figure 4-57 is a plot of the same level data but with the tank thermocouple #4 waste temperature overlaid on the same plot. The SL decrease starting about 1996 corresponds with a subtle, but real, increase in the waste and the headspace temperatures. The reason for the increase in temperatures beginning around 1996 has not been determined, but there were no operating TX exhausters which were shut off at that time.

Since the tank contents are primarily salt, and the last known position of the ILL in 1994 was about 25 inches below the waste surface it is possible the waste surface is subsiding, or there is an intrusion in the tank dissolving up salt. Adjacent tanks TX-107 and TX-112 both show asymptotically decreasing surface levels and subtly increasing waste temperatures during the same period as TX-108, but with smaller surface level and temperature changes. Tank TX-112 has an increasing ILL (it has been increasing steadily since before 1990) while TX-107 has no ILL for comparison. Figure 4-58 is a plot of the TX-108 ILL data from installation in 1985 through LOW failure in 1994. The data show a steady increase for the nine year period, except for the one large drop in 1990 between the reading taken in March of that year and the next reading in September. The reason for the drop is unknown, but at the time the method for calculating the ILL, and the equipment, were not as sophisticated as the methods and equipment developed later in the 1990s, the level change could also be due to selecting a different characteristic in the neutron data plot as the ILL. Based upon Figure 4-58 it appears TX-108 had an increasing ILL like TX-112 and nine of the other TX tanks which put them on the list of the Category 3 intrusion evaluation tanks in RPP-PLAN-55112, Rev 1.

The BBI shows zero retained gas in tank TX-108. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. The decrease in the tank TX-108 SL is not typical of an episodic gas release. While it is theoretically possible the waste matrix could have retained gas for a long time and then released it slowly for a number of years, this is not realistic. No liquid level vs. reciprocal of the barometric pressure plot is provided for tank TX-108 because the only level data available are from the solid surface.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1974. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for tank TX-108 is assumed to be = PCE + 0 + 5 + 0 = 5 gal/yr.

where PCE = porosity change effect

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. There has been no evidence of intrusion based upon the SL or ILL data going back to 1990.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -22\ to - 90\frac{gal}{yr} - leak\ rate - evaporation\ rate - \left(PCE + \frac{5gal}{yr}\right)$$

$$= -27\ to - 93\frac{gal}{yr} - leak\ rate - evaportion\ rate - PCE$$

The estimated minimum liquid change rate ignores any change ascribed to 'PCE' since it assumes the plummet is reading an interstitial liquid near the surface. The bounding maximum liquid change rate assumes a liquid surface in the tank, and so it includes any change ascribed to ‘PCE’. The rough approximate liquid change rate ignores any change ascribed to ‘PCE’ since it is based upon an average change observed in other tanks. As described below, the estimated evaporation rate for tank TX-108 is -60 gal/yr. Therefore, an intrusion up to 27 gal/yr could occur before a leak would exist based upon the minimum change rate. The existence of an intrusion is irrelevant compared to the bounding maximum change rate.

Evaluation of ILL and SL Validity –There is no working LOW in the tank. It is unknown what the surface condition is underneath the ENRAF plummet. The frequent spikes indicate it may be sitting on a rough salt surface.

Table 4-4 lists all tank TX-108 ENRAF work packages for the 2006 to 2013 time period. The last two columns list the as-found and as-left data from the work packages. The calibrations on May 11, 2006 (0.92 in. differential) and June 20, 2012 (0.61 in. differential) show significant changes. Looking at Figure 4-54, however, it can be seen that there are a number of additional data spikes beside the calibration changes. Work packages were not reviewed back to the 2000 to 2004 period where there were a significant number of data spikes on a routine basis. There may be some minor problems with the ENRAF gauge that causes the sudden jumps or calibration changes, but based upon the pattern observed with both manual tape data and ENRAF data it is assumed that the long term data decrease trend is real.

Table 4-4 Tank TX-108 ENRAF Gauge Work Packages Since January 1, 2006

Work Package No.	Title	Date	As Found (in.)	As Left (in.)
CLO-WO-06-000616	241-TX, 108 ENRAF INSPECTION	May 11, 2006	52.94	52.02
CLO-WO-06-002212	241-TX, 108 ENRAF INSPECTION	January 8, 2007	51.95	51.68
CLO-WO-07-1767	241-TX, 108 ENRAF INSPECTION	November 8, 2007	None	49.08
TFC-WO-08-0411	241-TX, 108 ENRAF CAL	September 30, 2008	52.80	52.80
TFC-WO-09-1369	241-TX, 108 ENRAF CAL	August 6, 2009	52.77	52.76
TFC-WO-10-0958	241-TX, 108 ENRAF CAL	July 29, 2010	52.72	52.89
TFC-WO-11-2020	241-TX, 108 ENRAF CAL	July 21, 2011	52.82	52.83
TFC-WO-12-2012	241-TX, 108 ENRAF CAL	July 16, 2012	52.75	52.14

There has been no change to the SL reference value during the time period used for this document.

4.10.4 Evaporation Estimate

Figure 4-59 provides the evaporation estimate results for tank TX-108. Figure 4-59 indicates tank TX-108 would evaporate a nominal -60 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank TX-108 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank TX-108, 2.5 cfm, is about the same as that used for other 75 ft. diameter tanks, excluding A-102, A-106, AX-101 and AX-103. The basis for the breathing rate assumed for tank TX-108 is provided in Appendix A and is the best estimate when considering the information.

The assumed tank TX-108 headspace RH of 80% is based upon the December 5, 1997 vapor space sample of 90.1% obtained when the headspace temperature was about 63°F and there was no liquid on the waste surface. The calculated headspace temperature for a December 5 annual date is about 7°F higher, which implies a lower RH. An RH of 80% was assumed in Appendix A, Section A.6. From Figure 4-59, assuming the tank breathing rate was correct an RH in the headspace of 45% would result in an evaporation rate equaling the estimated minimum calculated liquid loss rate. The conservatively estimated bounding maximum liquid loss rate exceeds the estimated evaporation rate.

An evaporation rate of -60 gal/yr for tank TX-108 exceeds the minimum estimated liquid loss rate.

4.10.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank TY-108 as 982 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. About 1.9% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the minimum estimated liquid change rate, and 7.9% would be needed to evaporate water at the maximum estimated liquid change rate.

While this amount of heat in the tank may be adequate to evaporate water at the estimated evaporation rate, the tank headspace temperatures, excluding 3 flyers from 2012, are all in the 63-71°F range (see Figure A-16 in Appendix A). These temperatures are indicative of a tank with a low heat generation rate, so the 982 BTU/hr estimate (equivalent to slightly less than the power usage of a 300 watt light bulb) may be high. Some of the energy for evaporation likely comes from the incoming air and the latent heat in the top of the waste.

4.10.6 Tank TX-108 Leak Potential

Based upon Figure 4-59 the tank TX-108 estimated minimum and rough approximate liquid loss rate can be explained by evaporation, but evaporation is inadequate to explain the unrealistic bounding maximum liquid loss rate.

There is sufficient heat generated in the tank to evaporate water at the bounding maximum rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$\begin{aligned} &leak\ rate\ compared\ to\ estimated\ minimum\ liquid\ loss\ rate \\ &\quad = -23\frac{gal}{yr} - intrusion\ rate - (-60\frac{gal}{yr}) - (5\ gal/yr) \\ &\quad = 32\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

$$\begin{aligned} &leak\ rate\ compared\ to\ rough\ approximate\ liquid\ loss\ rate \\ &\quad = -41\frac{gal}{yr} - intrusion\ rate - (-60\frac{gal}{yr}) - (5\ gal/yr) \\ &\quad = 14\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

$$\begin{aligned} &leak\ rate\ compared\ to\ bounding\ maximum\ liquid\ loss\ rate \\ &\quad = -90\frac{gal}{yr} - intrusion\ rate - \left(-60\frac{gal}{yr}\right) - \left(5\frac{gal}{yr}\right) \\ &\quad = -35\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

If the evaporation rate for TX-108 is -60 gal/yr, an intrusion rate would have to exceed 27 gal/yr for there to be a leak, if the minimum estimated liquid loss rate is valid. The rough approximation for a tank TX-108 liquid loss rate based upon the ILL gal/yr loss rate per in./yr SL

change rate from tanks with both decreasing ILLs and SLs is still below the estimated evaporation rate.

Figure 4-56 and Figure 4-57 show there is appears to be a relationship between temperature changes and waste surface level. The relationship is unknown.

4.10.7 Tank TX-108 Conclusion

Surface level data obtained from solid surfaces are inadequate to accurately estimate liquid change rates. The evaporation rate is above the bare minimum and rough approximate liquid loss rates. There is no basis to assume a leak from tank TX-108.

Figure 4-52 Tank TX-108 Full Depth Raw Data Plot

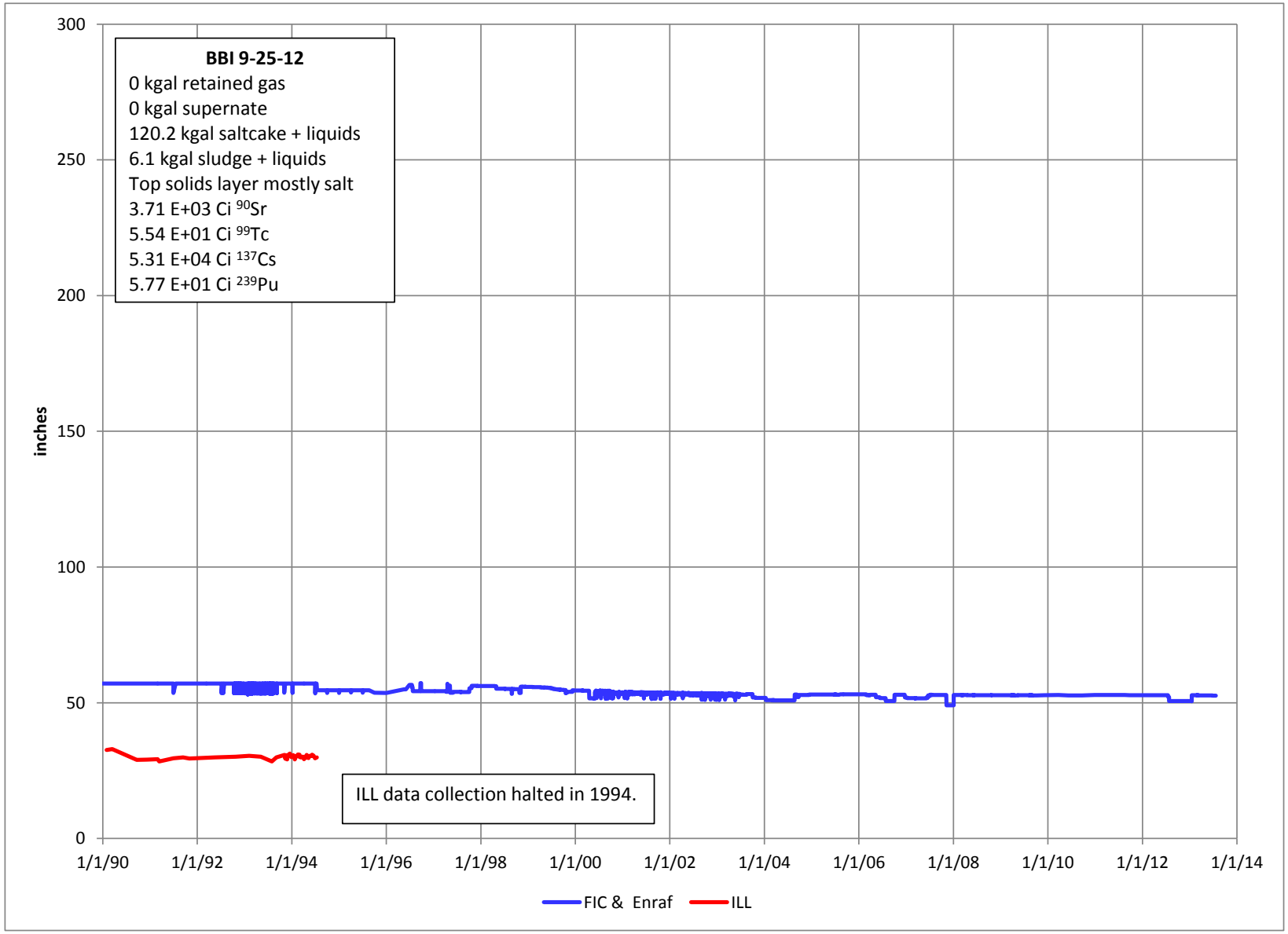


Figure 4-53 Tank TX-108 Expanded SL Data Plot Used for RPP-PLAN-55113, Rev 1

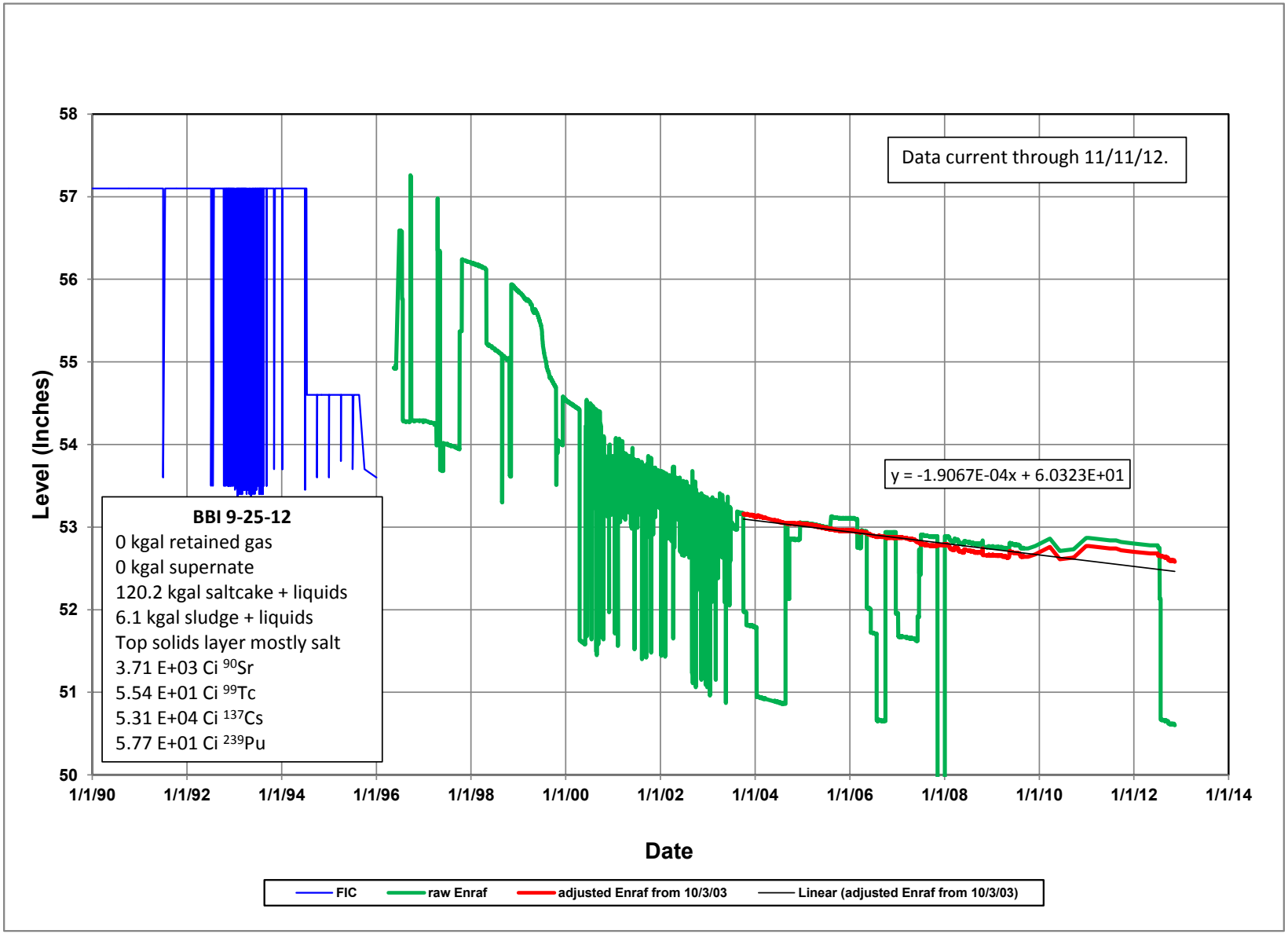


Figure 4-54 Tank TX-108 Expanded SL Data Plot Used for RPP-RPT-54981

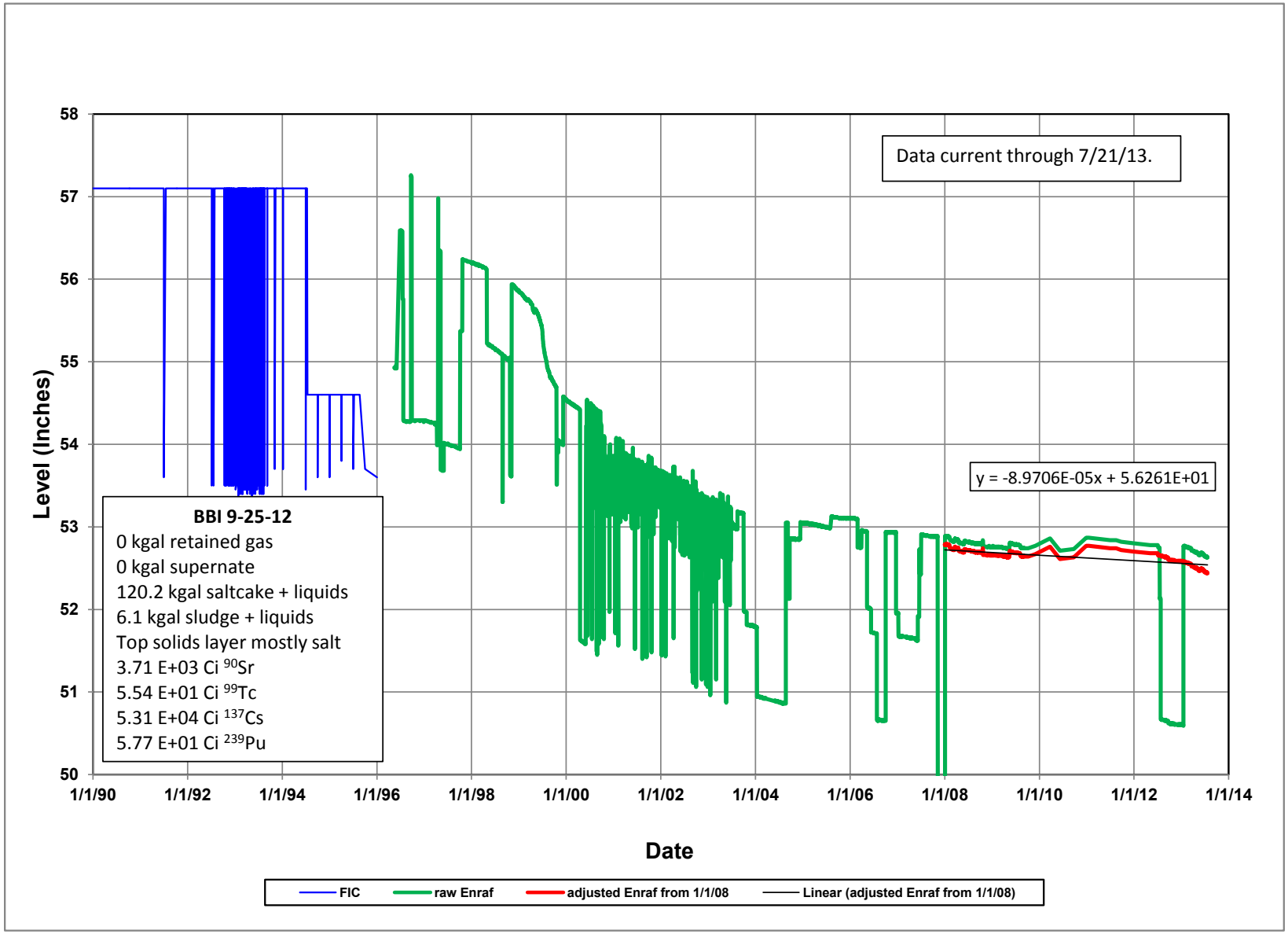


Figure 4-55 Tank TX-108 Expanded SL Data Plot from 1980

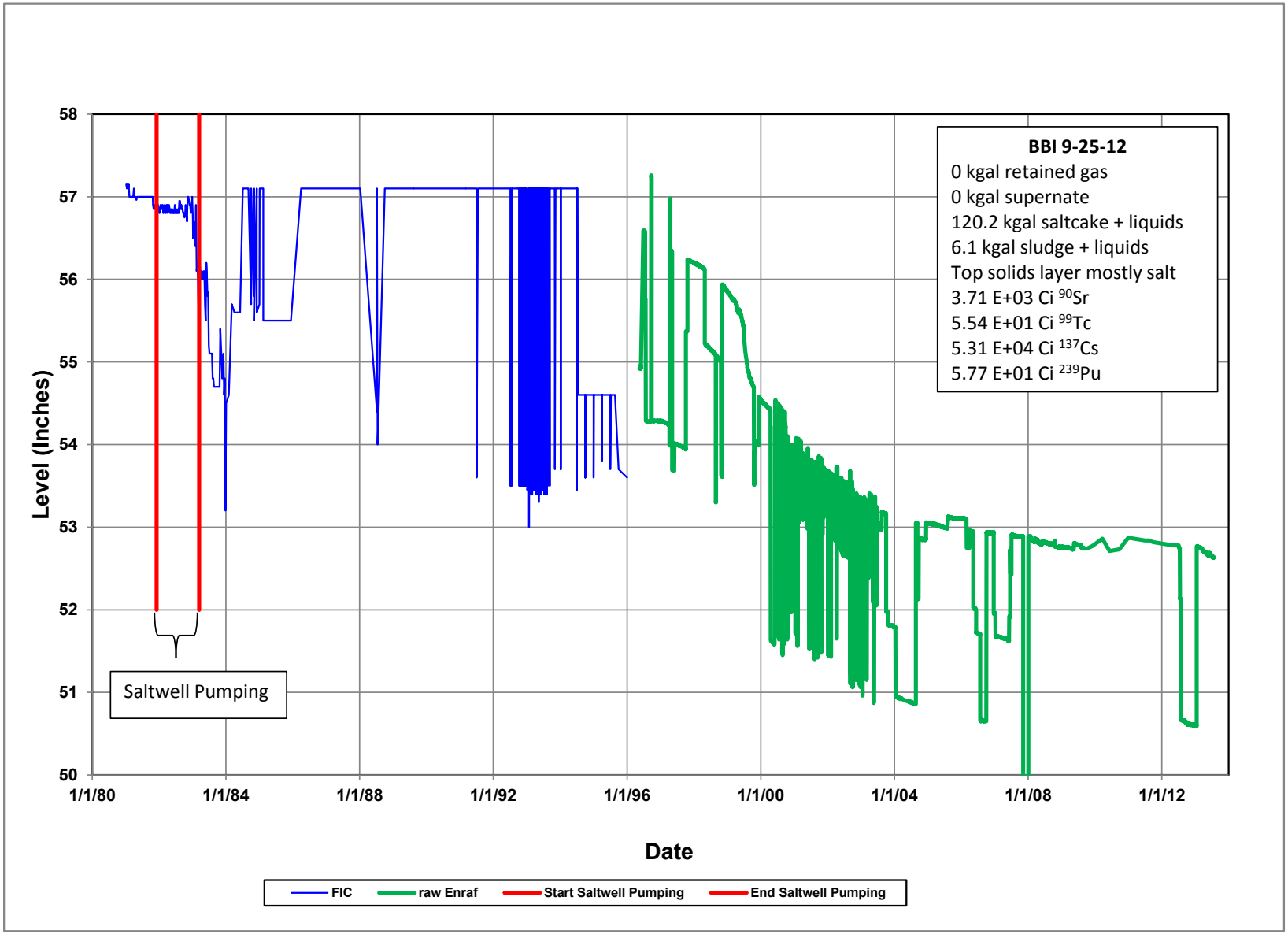


Figure 4-56 Tank TX-108 Combined Surface Level and Headspace Temperature Data Plot from 1980

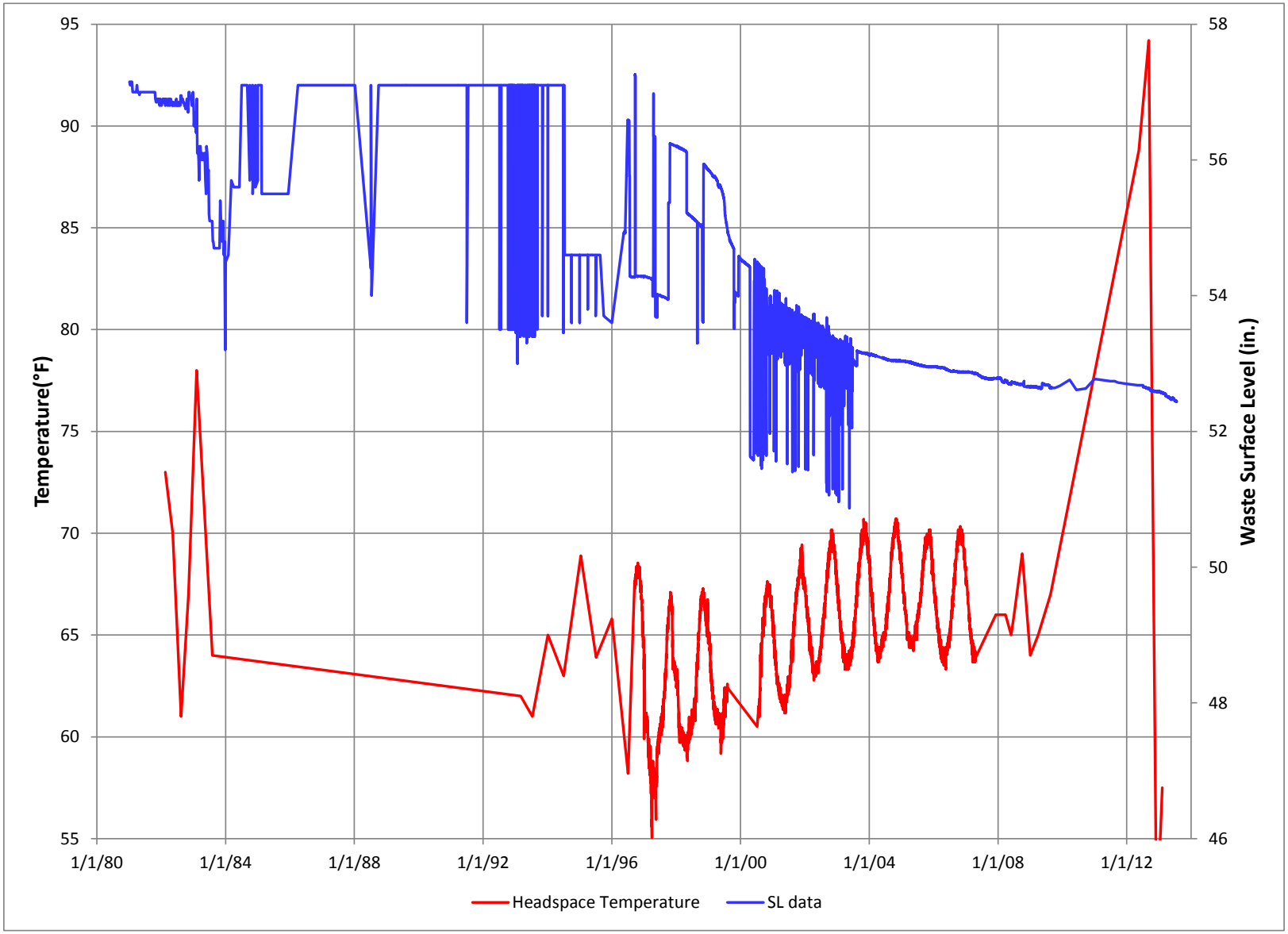


Figure 4-57 Tank TX-108 Combined Surface Level and Thermocouple #4 Waste Temperature Data Plot from 1980

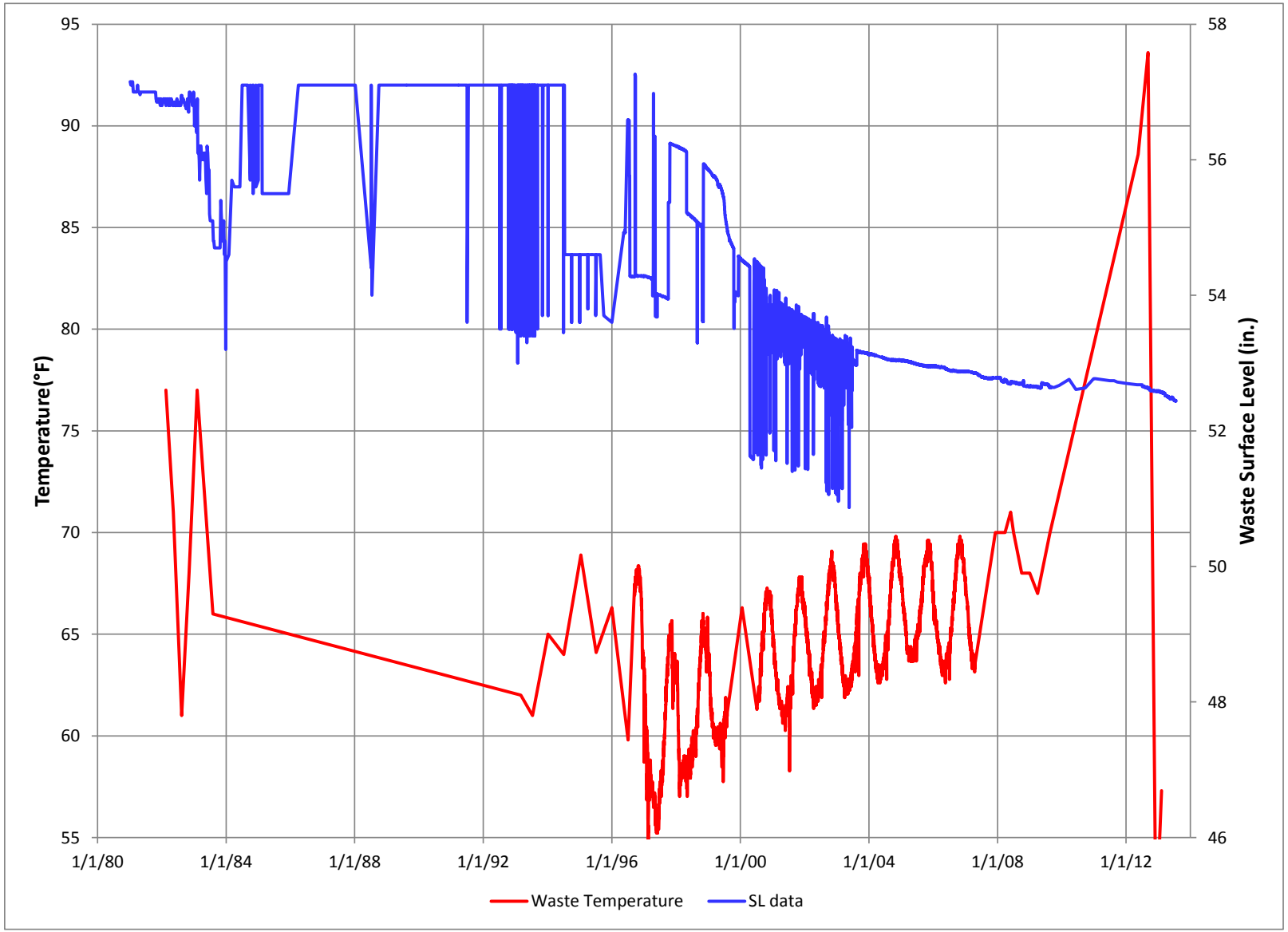


Figure 4-58 Tank TX-108 ILL Data from 1985 LOW Installation to 1994 LOW Failure

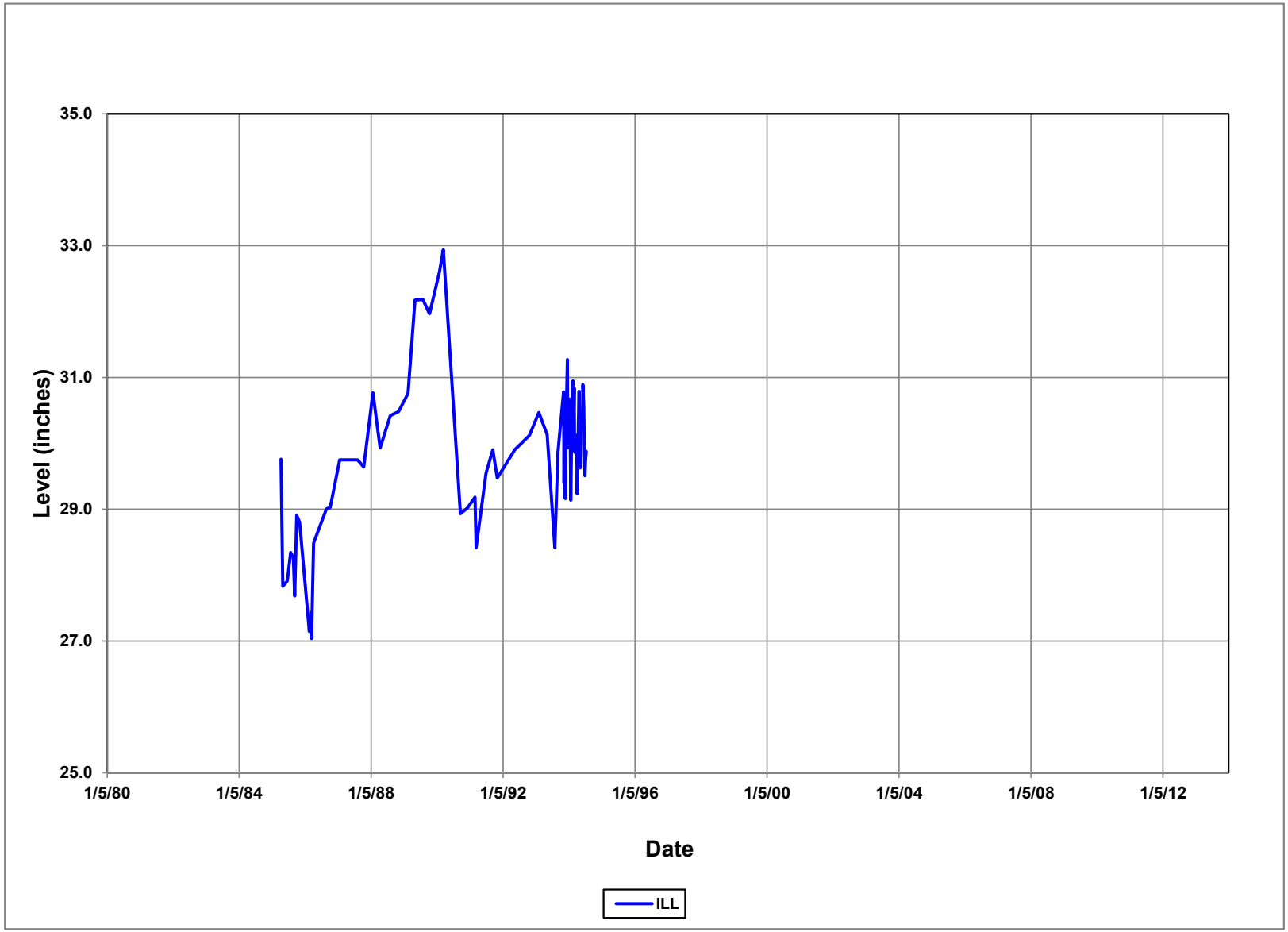
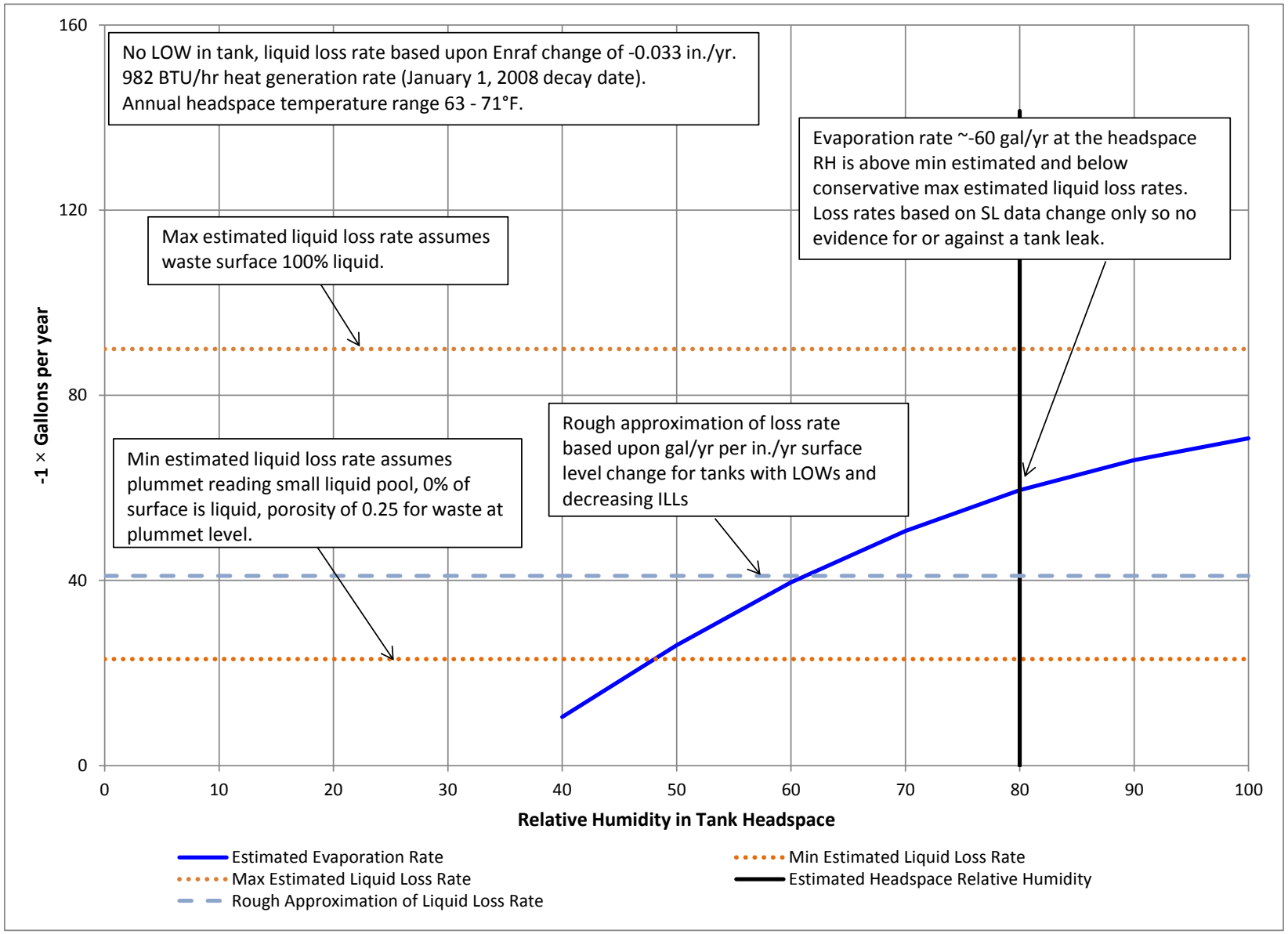


Figure 4-59 Tank TX-108 Estimated Evaporation and Max/Min/Rough Approximate Liquid Loss Rates



4.11 Tank TY-101

4.11.1 Tank Summary

Tank TY-101 entered service in 1953 with the receipt of waste evaporator bottoms from other SSTs. It subsequently received ferrocyanide treated waste, supernatant, and evaporator bottoms through 1955. It subsequently received TBP process and REDOX wastes from other SSTs through 1957. The tank was assumed to be leaking in 1974 and removed from service in 1975. Interim stabilization was complete in 1983 (RPP-RPT-43193, Rev. 0, *2009 Auto TCR for 241-TY-101*). Per a TWINS query on September 25, 2012 the tank contains about 46.0 kgal salt and 72.1 kgal of sludge.

Figure 4-60 shows the raw SL data for tank TY-101 from January 1, 1990. Figure 4-61 is a plot of the data used for calculation of the -0.115 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the SL data changes can be seen. There were a number of spikes in the data that were not removed. Figure 4-62 is an updated plot showing the latest data included for this document with the data adjusted to remove the spikes. The trendline slope is almost the same at -0.118 in./yr as of July 22, 2013. There is no LOW in the tank.

4.11.2 Liquid Change Rate Estimation

The sludge is assumed to be on the top, per RPP-40545, Rev 2, Appendix H. A sludge porosity of 0.08 is assumed for consistency with RPP-5556.

Photos from 1989 show liquid in cracks in the waste surface. Based upon this and the two to three inch drop in waste surface level since, it is assumed the current waste surface is 1% liquid.

The minimum estimate liquid loss rate assumes the ENRAF plummet is sitting in a small pool of liquid, and equal to:

$$Tank\ TY-101\ min\ estimate\ liquid\ change\ rate = -0.118 \times 2{,}750 \times (0.01 + (1-0.01) \times 0.08)) = \mathbf{-29\ gal/yr}$$

A rough approximation to the liquid loss rate, using a ratio of 280 gal/yr per in./yr SL change since TY-101 is a predominantly sludge tank:

$$Tank\ TY-101\ rough\ approximate\ liquid\ change\ rate = -0.118 \times 280 = \mathbf{-33\ gal/yr}$$

A maximum estimate to the liquid loss rate assumes the surface level drop is equal over the waste surface:

$$Tank\ TY-101\ max\ estimate\ liquid\ change\ rate = -0.118 \times 2{,}750 = \mathbf{-325\ gal/yr}$$

4.11.3 Data Analysis

<u>Estimation of [Σ other]</u> – The tank contents are about 60% sludge and 40% salt. It is possible that the sludge, which is presumed on top per RPP-40545, Rev 2, is slowly subsiding as it dries out.

The BBI shows zero retained gas in TY-101. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. The decrease in the TY-101 SL is not typical of an episodic gas release. While it is theoretically possible the waste matrix could have retained gas for a long time and then released it constantly for a number of years, this is not realistic. There is no basis

to assume any impact of retained gas on the level decrease rate. No liquid level vs. reciprocal of the barometric pressure plot is provided for tank TY-101 because the only level data available are from the solid surface. .

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1967. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for TY-101 is assumed to be = PCE + 0 + 5 + 0 = 5 gal/yr.

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. There has been no evidence of intrusion based upon the SL data going back to 1990.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -29\ to - 325\frac{gal}{yr} - leak\ rate - evaporation\ rate - \left(PCE + 5\frac{gal}{yr}\right)$$

$$= -34\ to - 330\frac{gal}{yr} - leak\ rate - evaportion\ rate - PCE$$

The bounding maximum liquid change rate assumes a liquid surface in the tank, and so it includes any change ascribed to 'PCE'. The estimated minimum liquid change rate ignores any change ascribed to 'PCE' since it assumes the plummet is reading an interstitial liquid near the surface. As described below, the estimated evaporation rate for tank TY-101 is -45 gal/yr. Therefore, an intrusion up to 11 gal/yr could occur before a leak would exist based upon the estimated minimum change rate. The existence of an intrusion is irrelevant compared to the bounding maximum change rate.

Evaluation of ILL and SL Validity – There is no LOW in the tank.

It is unknown what the surface condition is underneath the ENRAF plummet. The frequent spikes indicate it may be sitting on or near a crack in the surface.

Table 4-5 lists all tank TY-101 ENRAF work packages for the 2006 to 2013 time period. The last two columns list the as-found and as-left data from the work packages. The calibration on August 7, 2007 (1.93 in. differential) was the only significant change, but this data point is not in PC-SACS or TWINS. The next data point after August 7, 2007 is on December 4, 2007. There are cryptic statements about data on August 8, 2007 being suspect but no explanation. Whatever the problem was, it was resolved by December 4, 2007. There are numerous spikes in the data but the overall downward trend is still apparent.

Table 4-5 Tank TY-101 ENRAF Gauge Work Packages Since January 1, 2006

Work Package No.	Title	Date	As Found (in.)	As Left (in.)
CLO-WO-06-001744	241-TY, 101 ENRAF INSPECTION	November 2, 2006	50.80	50.66
CLO-WO-07-1108	241-TY, 101 ENRAF INSPECTION	August 7, 2007	50.85	48.92
CLO-WO-08-0557	241-TY, 101 ENRAF CAL	May 28, 2008	50.44	50.50
TFC-WO-08-1575	241-TY, 101 ENRAF CAL	February 12, 2009	50.39	50.21
TFC-WO-09-1372	241-TY, 101 ENRAF CAL	August 10, 2009	50.21	50.24
TFC-WO-10-0959	241-TY, 101 ENRAF CAL	August 5, 2010	50.21	50.21
TFC-WO-10-4381	241-TY, 101 ENRAF CAL	June 28, 2011	None	50.23

There has been no change to the SL reference value during the time period used for this document.

4.11.4 Evaporation Estimate

Figure 4-63 provides the evaporation estimate results for tank TY-101. Figure 4-63 indicates tank TY-101 would evaporate a nominal -45 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank TY-101 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank TY-101, 2.5 cfm, is about the same as that used for other 75 ft. diameter tanks, excluding A-102, A-106, AX-101 and AX-103. The basis for the breathing rate assumed for tank TY-101 is provided in Appendix A and is the best estimate when considering the information.

The assumed tank TY-101 headspace RH of 70% is based upon the April 6, 1995 vapor space sample of 72.8% obtained when the headspace temperature was about 62°F and there was no liquid on the waste surface, although there may have been some still remaining in surface cracks as shown in 1989 photos. The calculated headspace temperature for April 6, 2012 is about 60°F, which implies a similar RH. An RH of 70% was assumed in Appendix A, Section A.6. From Figure 4-63, assuming the tank breathing rate was correct an RH in the headspace of 57% would result in an evaporation rate equaling the minimum calculated liquid loss rate. The conservatively estimated maximum calculated liquid loss rate exceeds the estimated liquid loss rate significantly.

An evaporation rate of -45 gal/yr for tank TY-101 exceeds the minimum estimated liquid loss rate.

4.11.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank TY-101 as 164 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. This is a negligible rate and would require from 18 to >100% of the January 1, 2008 heat generation rate to evaporate water at the min and max estimate liquid change rates respectively. Much or all of the heat for evaporation has to come from the incoming air and the latent heat in the top of the waste.

4.11.6 Tank TY-101 Leak Potential

Based upon Figure 4-63 the tank TY-101 minimum liquid loss rate can be explained by evaporation. The rough approximation for a tank TY-101 liquid loss rate based upon the ILL gal/yr loss rate per in./yr SL change rate from tanks with both decreasing ILLs and SLs is almost identical to the estimated minimum loss rate.

The maximum liquid loss rate is considerably above the estimated evaporation rate. The maximum estimated change rate is not realistic however, it assumes the whole waste surface drops at 0.118 in./yr. It is possible that only a fraction of the waste surface is decreasing closer to the center of the tank. The tank has shown a very consistent decrease rate since 1995, with the data spikes removed.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$\begin{aligned} &leak\ rate\ compared\ to\ estimated\ minimum\ liquid\ loss\ rate \\ &\quad = -29\frac{gal}{yr} - intrusion\ rate - (-45\frac{gal}{yr}) - \left(5\frac{gal}{yr}\right) \\ &\quad = 11\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

$$\begin{aligned} &leak\ rate\ compared\ to\ rough\ approximate\ liquid\ loss\ rate \\ &\quad = -33\frac{gal}{yr} - intrusion\ rate - (-45\frac{gal}{yr}) - \left(5\ \frac{gal}{yr}\right) \\ &\quad = 7\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

$$\begin{aligned} &leak\ rate\ compared\ to\ bounding\ maximum\ liquid\ loss\ rate \\ &\quad = -325\frac{gal}{yr} - intrusion\ rate - \left(-45\frac{gal}{yr}\right) - \left(5\frac{gal}{yr}\right) \\ &\quad = -285\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

If the evaporation rate for TY-101 is -45 gal/yr, an intrusion rate would have to exceed 11 gal/yr for there to be a leak, if the minimum estimated liquid loss rate (and rough approximation loss rate) is valid. The maximum estimated liquid loss rate is far above the estimated evaporation rate, but is not realistic.

4.11.7 Tank TY-101 Conclusion

Surface level data obtained from solid surfaces are inadequate to accurately estimate liquid change rates. The evaporation rate is above the bare minimum and rough approximate liquid loss rates. There is no basis to assume a leak from tank TY-101.

Figure 4-60 Tank TY-101 Full Depth Raw Data Plot

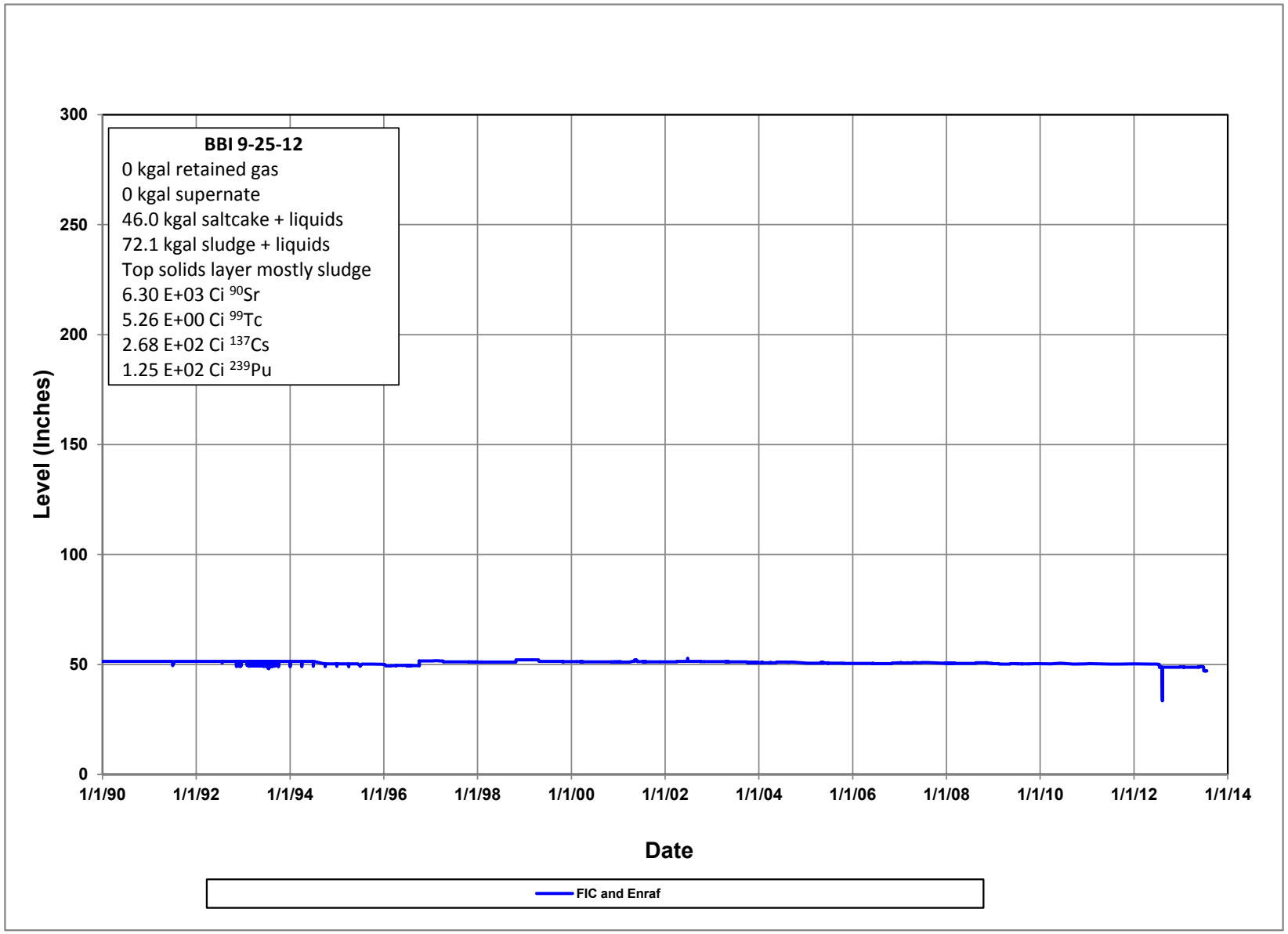


Figure 4-61 Tank TY-101 Expanded SL Data Plot Used for RPP-PLAN-55113, Rev 1

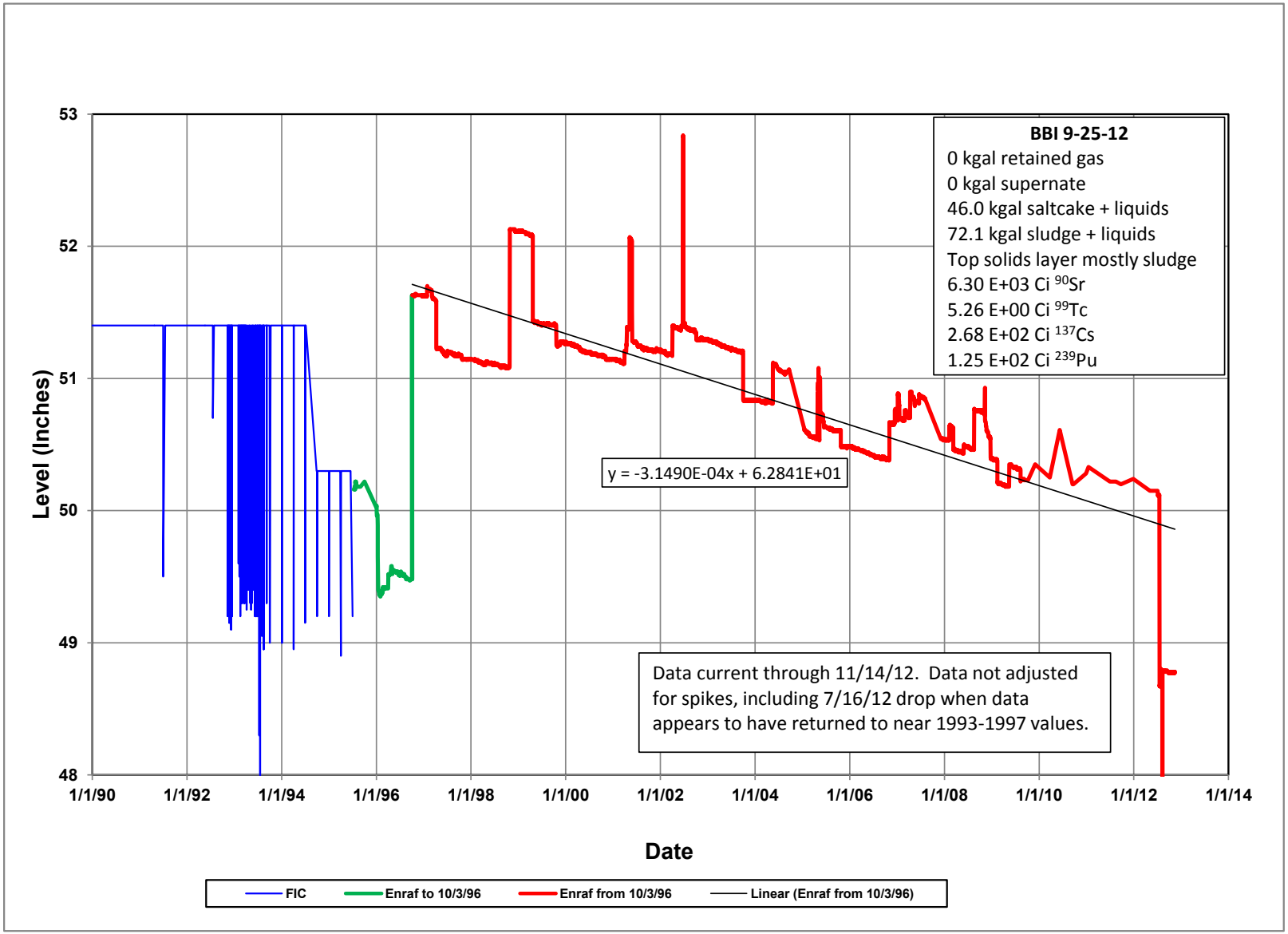


Figure 4-62 Tank TY-101 Expanded and Adjusted SL Data Plot Used for RPP-RPT-54981

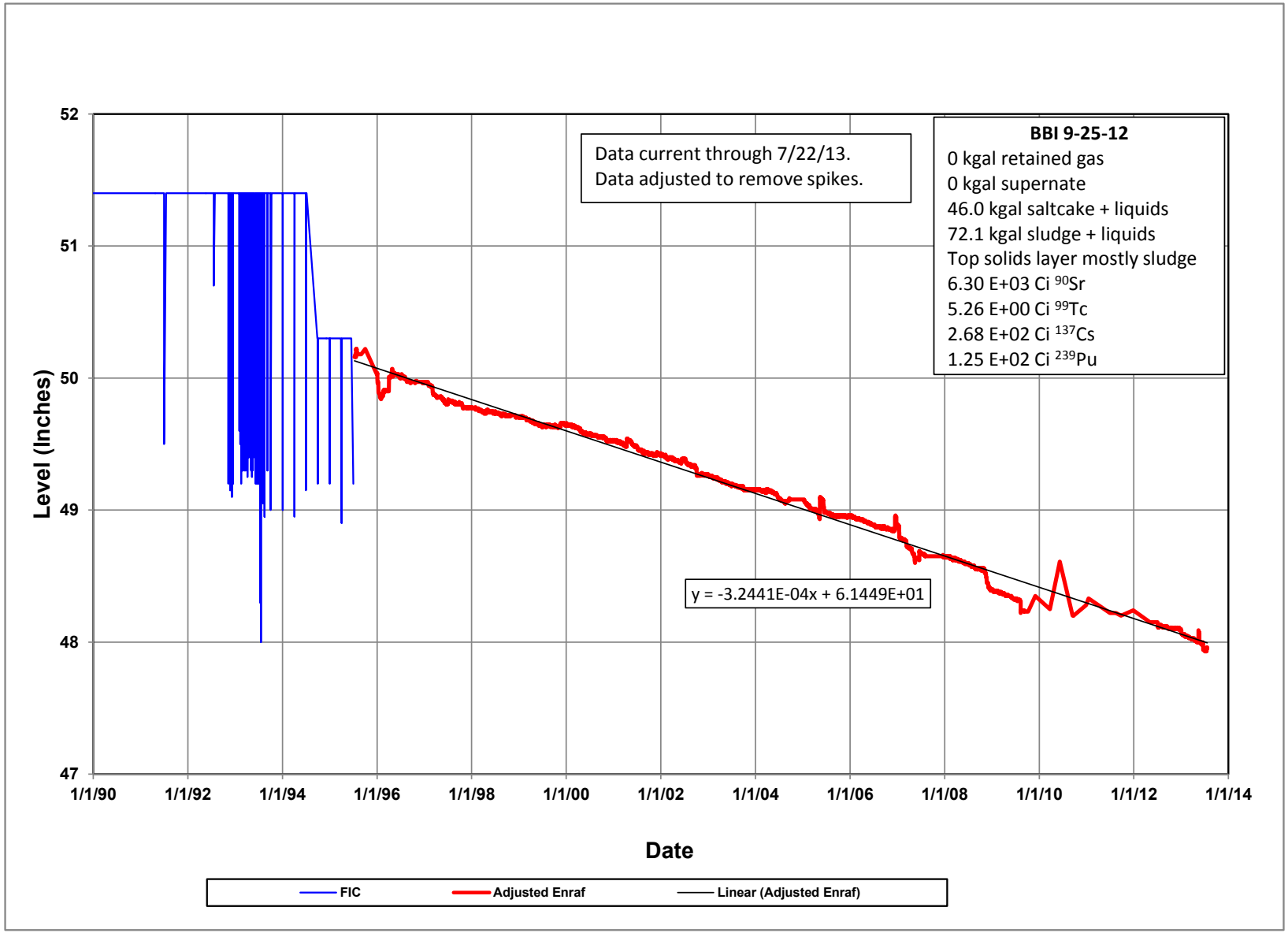
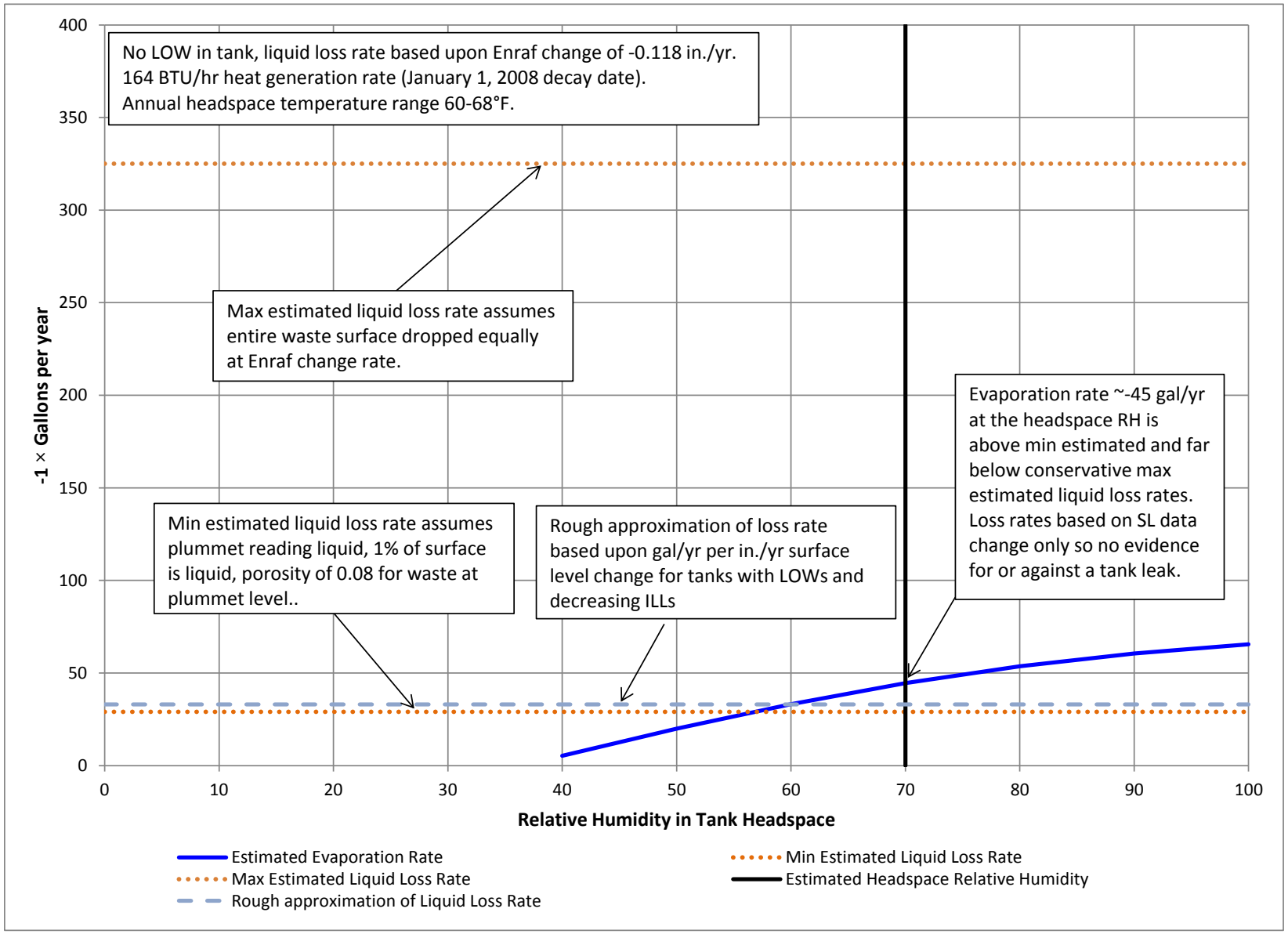


Figure 4-63 Tank TY-101 Estimated Evaporation and Max/Min/Rough Approximate Liquid Loss Rates



4.12 Tank TY-103

4.12.1 Tank Summary

Tank TY-103 entered service in 1953 with the receipt of uranium recovery waste from other SSTs. From 1955 through 1961 it received ferrocyanide treated waste, supernatant, and evaporator bottoms. Starting in 1967 it was used for evaporator feed and receipt of dilute evaporator bottoms. The tank was assumed to be leaking in 1973. Interim stabilization was complete in 1983 (RPP-RPT-43195, Rev. 0, *2009 Auto TCR for 241-TY-103*). Per a TWINS query on September 25, 2012 the tank contains about 51.5 kgal of saltcake and 103.1 kgal sludge.

Figure 4-64 shows the raw ILL and SL data for tank TY-103 from January 1, 1990. Figure 4-65 is a plot of the ILL data used for calculation of the -0.094 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with the x-axis expanded back to 1980 and an expanded y-axis so the ILL data changes can be seen. Figure 4-66 is an updated plot going back to 1990 showing the latest data included for this document. The slope of the ILL decrease line is less than before, at -0.079 in./yr. The decrease is due to shortening the trendline duration to the past five years to more accurately reflect what appears to be occurring in the tank.

The ILL showed a decrease from about 70 inches in 1982 to about 62.5 inches in 1998, a small rise from then to 2003, then began to decrease again, although the decrease rate is slowing down considerably the past few years the ILL is about equal to what it was in 1998.

Figure 4-67 is an updated plot of the SL data included for this document. The liquid level is right at the waste surface but the slope of the SL and the ILL data do not track each other too well, the SL data has a far lower trendline slope, so for conservatism only the ILL data are used for the volumetric change rate calculation. Averaging the ILL and SL change rates would result in a significantly lower liquid loss rate.

4.12.2 Liquid Change Rate Estimation

The liquid change rate is based upon the ILL change.

The BBI does not indicate any supernatant liquid is present but 1983 IS documentation indicated 200 gal liquid was present and the ILL and SL are essentially reading the same at ~63 inches so it is reasonable to assume the surface has some liquid. It is assumed the surface is 5% liquid.

The saltcake is assumed to be on the top, per RPP-40545, Rev 2, Appendix H. Per RPP-40545, Rev 2, Appendix H the salt in this tank is >2.0 anion mole % phosphate so a saltcake porosity of 0.06 could be used, but a porosity of 0.15 is assumed for consistency with RPP-5556.

The estimated tank TY-103 liquid change rate is equal to:

$$Tank\ TY-103\ estimated\ liquid\ change\ rate = -0.079 \times 2{,}750 \times (0.05 + (1 - 0.05) \times 0.15)) = \mathbf{-42\ gal/yr}$$

If a porosity of 0.06 was used the estimated liquid change rate would be -23 gal/yr.

4.12.3 Data Analysis

Estimation of [Σ other] – Waste subsidence is not a factor since the liquid level is essentially at the waste surface.

Figure 4-68 is a plot of the inverse of the barometric pressure and the ILL data. The R^2 value is low, 0.031, showing negligible correlation between the ILL and atmospheric pressure changes. Figure 4-69 is a comparison of tank TY-103 LOW neutron scan data from 2003 and 2013. There is no obvious gas volume decrease apparent. The liquid content has receded slightly the depth of the tank, which could be interpreted as gas retention, but is likely just due to instrumentation response. The BBI shows zero retained gas in TY-103. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. Some SSTs may exhibit chronic release of gases at roughly the same rate gases are generated. But, the buildup of retained gas during the 1998 to 2004 period followed by continual release of the gas from 2004 to 2013 is not realistic. There is no basis to assume any impact of retained gas on the level decrease rate.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1971. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for S-104 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

Potential for Intrusion – No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. There has been no evidence of intrusion based upon the SL data going back to 1990. The ILL data did show a small increase of about 1 in. between 1998 and 2004, but the increase either halted in 2004 or has continued but been exceeded by a corresponding leak since. Whether this ILL change was due to an intrusion or just liquid in the tank rearranging is unknown.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -42\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= -47\frac{gal}{yr} - leak\ rate - evaporation\ rate$$

Since both evaporation rate and leak rate are negative values, the sum of the leak rate plus the evaporation rate would have to be <-47 gal/yr before an intrusion would be considered. As described below, the estimated evaporation rate for tank TY-103 is -60 gal/yr so there could be an intrusion if the evaporation rate is accurate.

The estimated tank TY-103 liquid change rate from 1998 to 2004 was equal to:

$$Tank\ TY - 103\ estimated\ liquid\ change\ rate\ 1998\ to\ 2004 = 0.143 \times 2{,}750 \times (0.05 + (1 - 0.05) \times 0.15)) = \mathbf{+76\ gal/yr}$$

If a porosity of 0.06 was used the estimated liquid change rate from 1998 to 2004 would be +42 gal/yr.

Evaluation of ILL and SL Validity – The LOW was installed in 1982 and the tank was saltwell pumped in 1983, the ILL is assumed to be at equilibrium by now. The reason for the ILL increase from 1998 to 2004 is unknown, but from the shape of the ILL plots in Figure 4-66 it appears the ILL is back to where it was in 1998.

The ILL has always been referenced to the tank centerline bottom.

The ENRAF data are not used to estimate the tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

4.12.4 Evaporation Estimate

Figure 4-70 provides the evaporation estimate results for tank TY-103. Figure 4-70 indicates tank TY-103 would evaporate a nominal -60 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank TY-103 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank TY-103, 2.5 cfm, is about the same as that used for other 75 ft. diameter tanks, excluding A-102, A-106, AX-101 and AX-103. The basis for the breathing rate assumed for tank TY-101 is provided in Appendix A and is the best estimate when considering the information.

The assumed tank TY-103 headspace RH of 82% is based upon the average of the April 11, 1995 and November 22, 1996 vapor space samples of 83.1% and 81% respectively. The headspace temperatures are about the same and the ILL is still right at the waste surface.

The evaporation rate exceeds the calculated liquid loss rate by about 18 gal/yr.

An evaporation rate of -60 gal/yr for tank TY-103 exceeds the estimated liquid loss rate.

4.12.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank TY-103 as 1,864 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. About 2.3% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimate liquid change rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated. The ILL is at or near the waste surface.

4.12.6 Tank TY-103 Leak Potential

Based upon Figure 4-70 the estimated evaporation rate from the tank exceeds the estimated liquid loss rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = -42\frac{gal}{yr} - intrusion\ rate - (-60\frac{gal}{yr}) - \left(5\ \frac{gal}{yr}\right) = 13\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for TY-103 is -60 gal/yr, the intrusion rate would have to exceed 13 gal/yr for a leak to exist.

If a waste porosity of 0.06 is used a intrusion rate would have to exceed 37 gal/yr for there to be a leak.

The change rate of +76 gal/yr from 1998 to 2004 is the sum of the intrusion, evaporation, leak rate and other impacts during that period. If there was an intrusion during that period and it has stopped, there is no basis to assume a current leak from TY-103. If there was an intrusion during that period and it is still continuing there is a possibility the tank is currently leaking.

4.12.7 Tank TY-103 Conclusion

There is no basis to assume a leak from tank TY-103 if there is no intrusion in the tank.

Figure 4-64 Tank TY-103 Full Depth Raw Data Plot

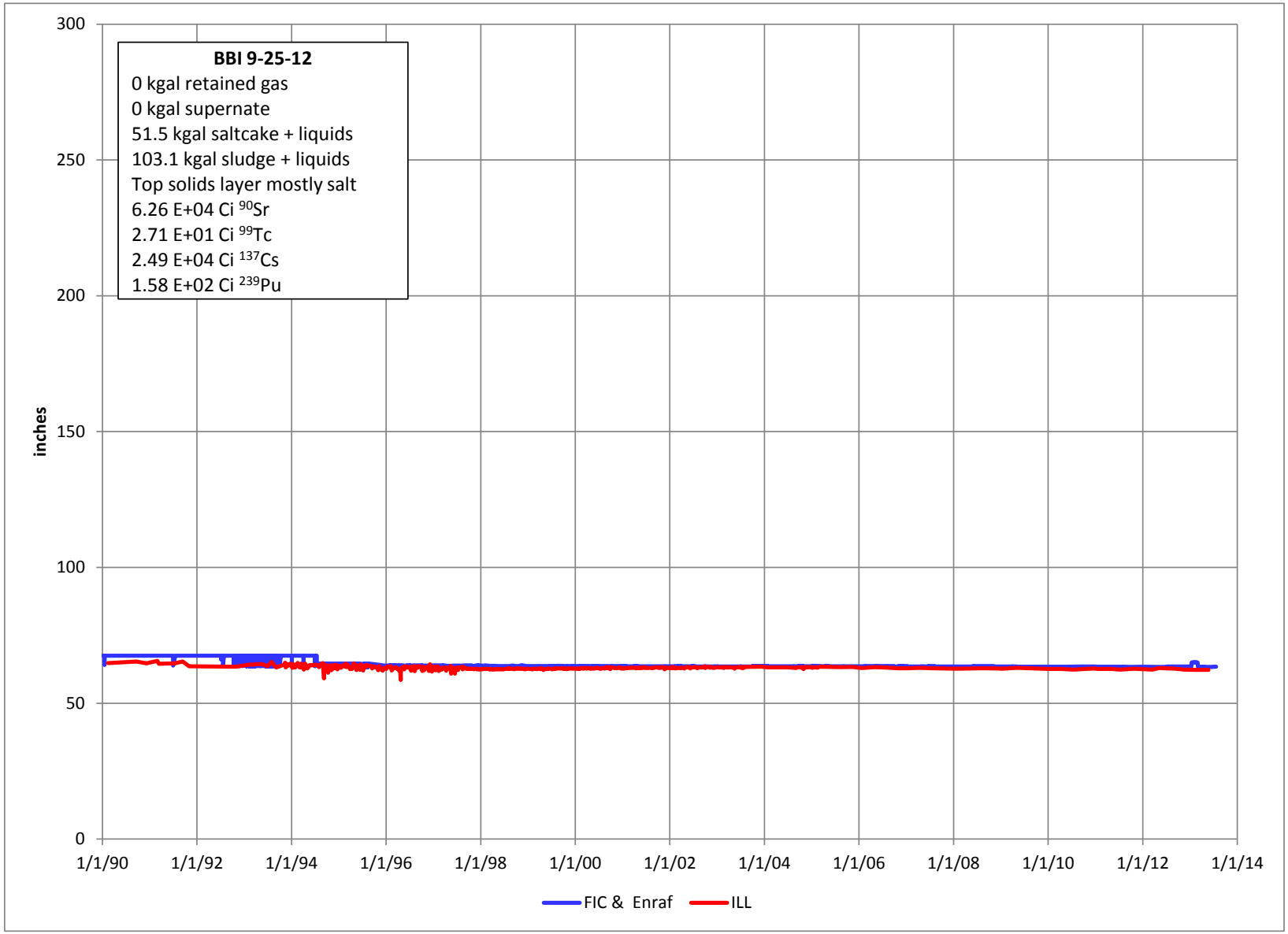


Figure 4-65 Tank TY-103 Expanded ILL Data Plot from 1980 Used for RPP-PLAN-55113, Rev 1

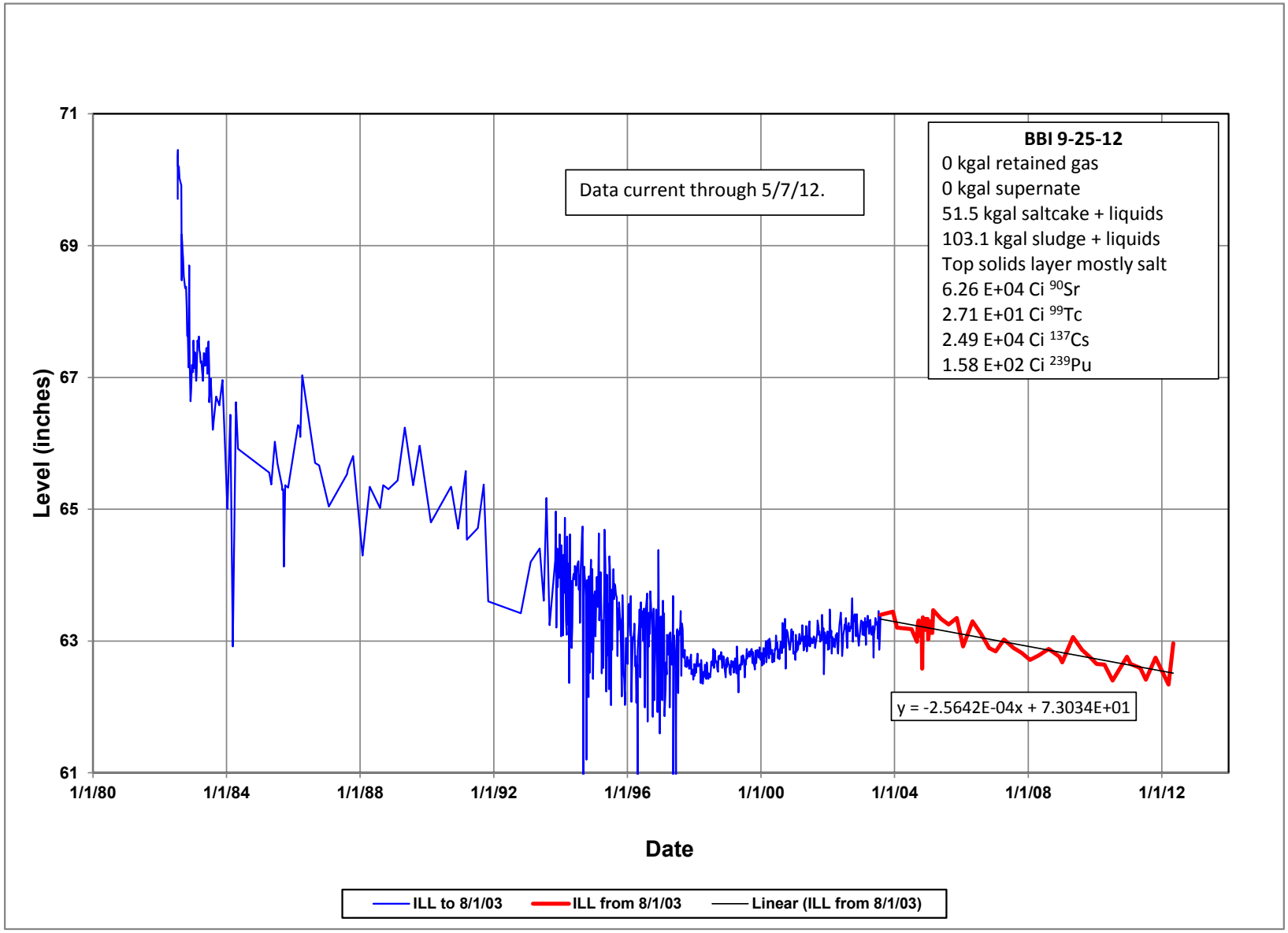


Figure 4-66 Tank TY-103 Expanded ILL Data Plot Used for RPP-RPT-54981

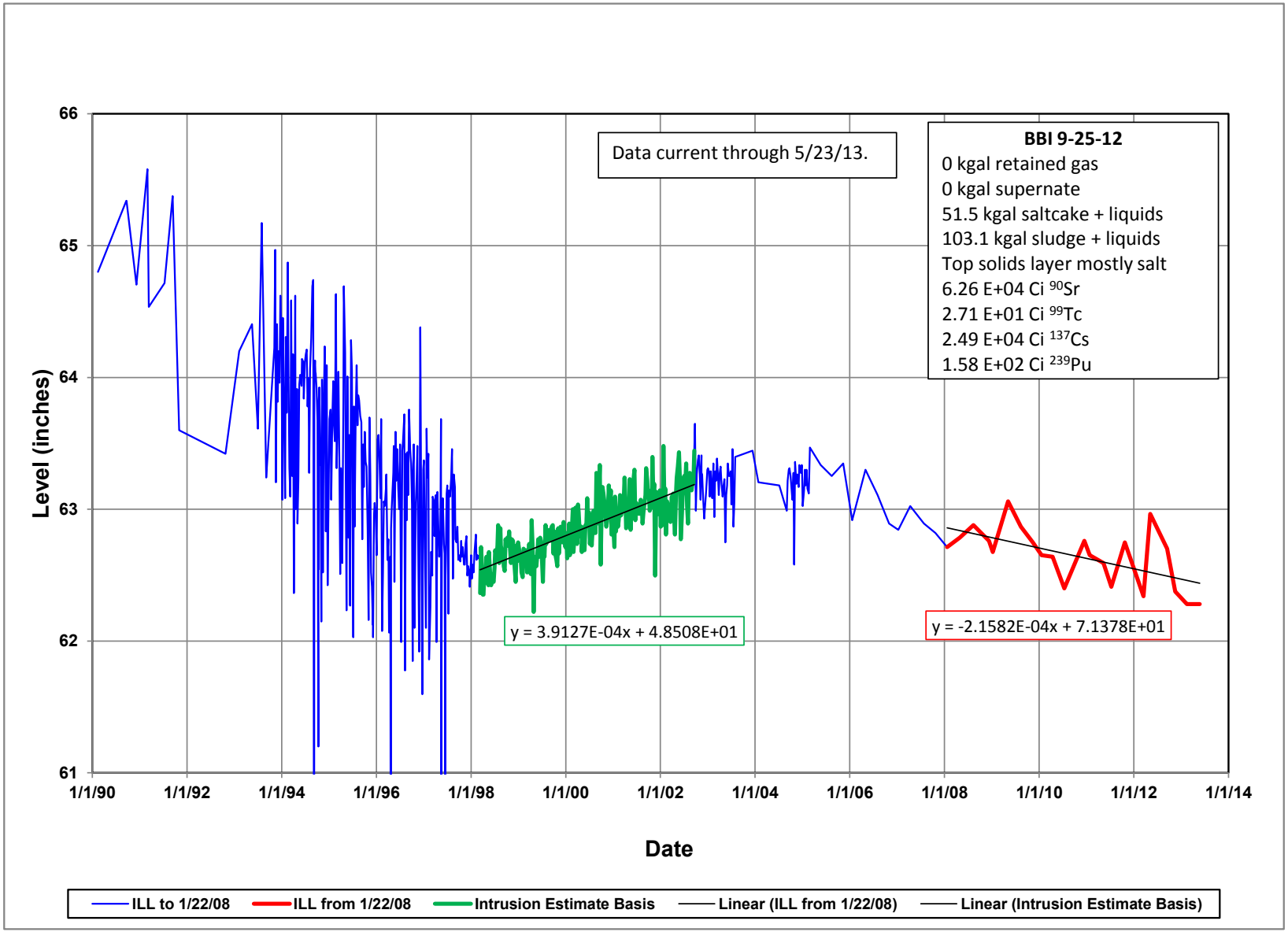


Figure 4-67 Tank TY-103 Expanded SL Data Plot Used for RPP-RPT-54981

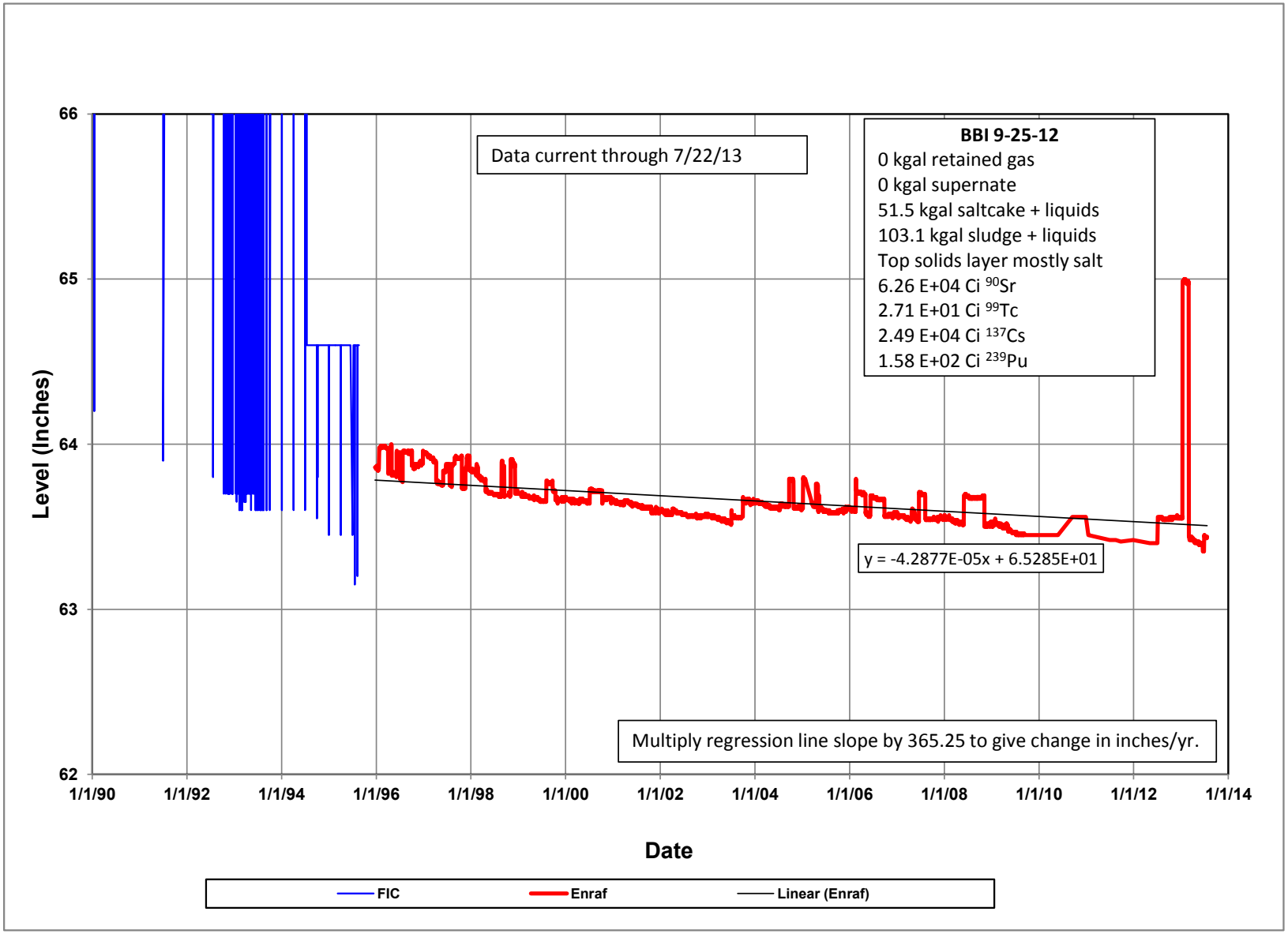


Figure 4-68 Tank TY-103 Raw Interstitial Liquid Level Data and Adjusted Inverse Barometric Pressure

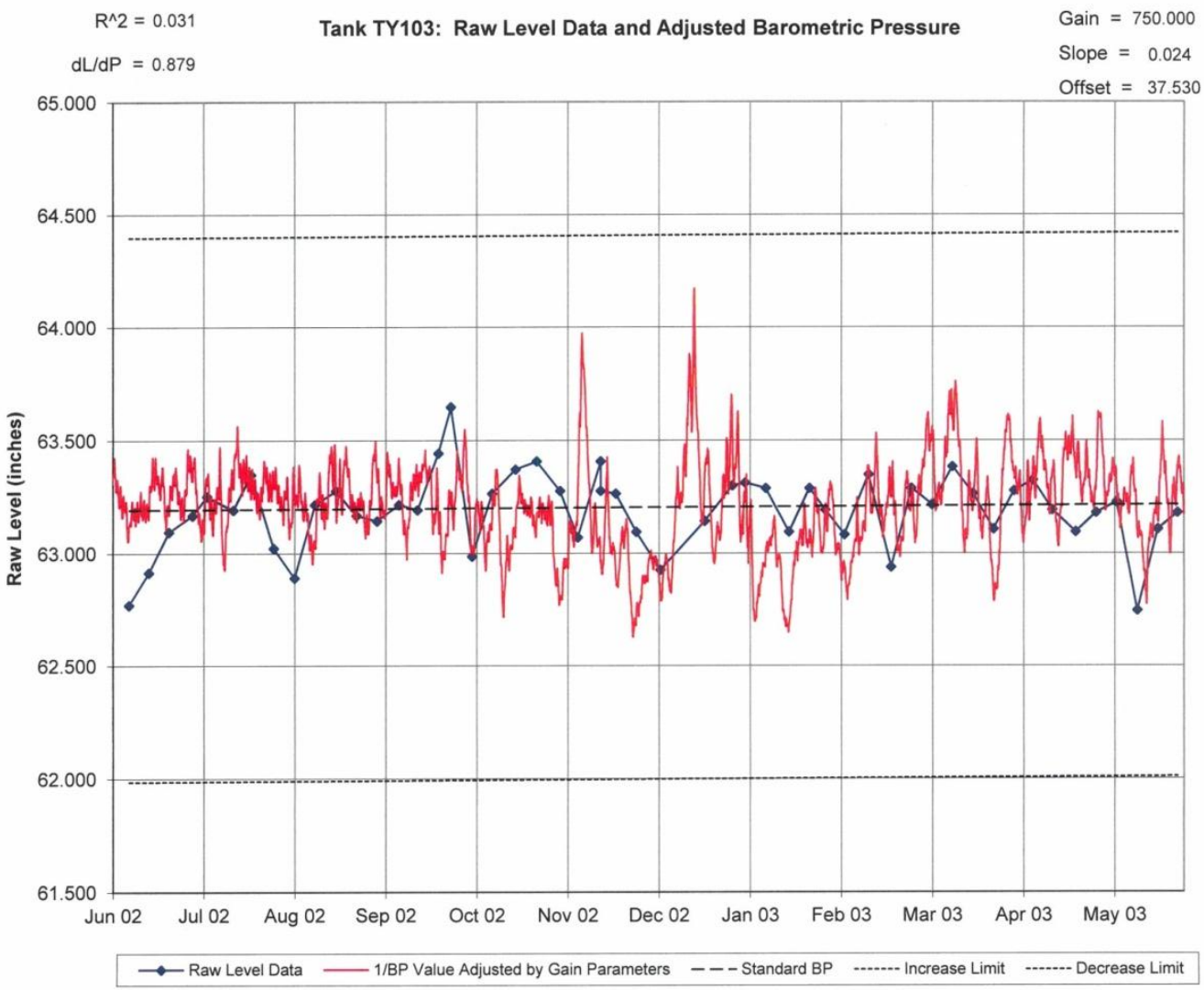


Figure 4-69 Comparison of Tank TY-103 2003 and 2013 Liquid Observation Well Neutron Scans

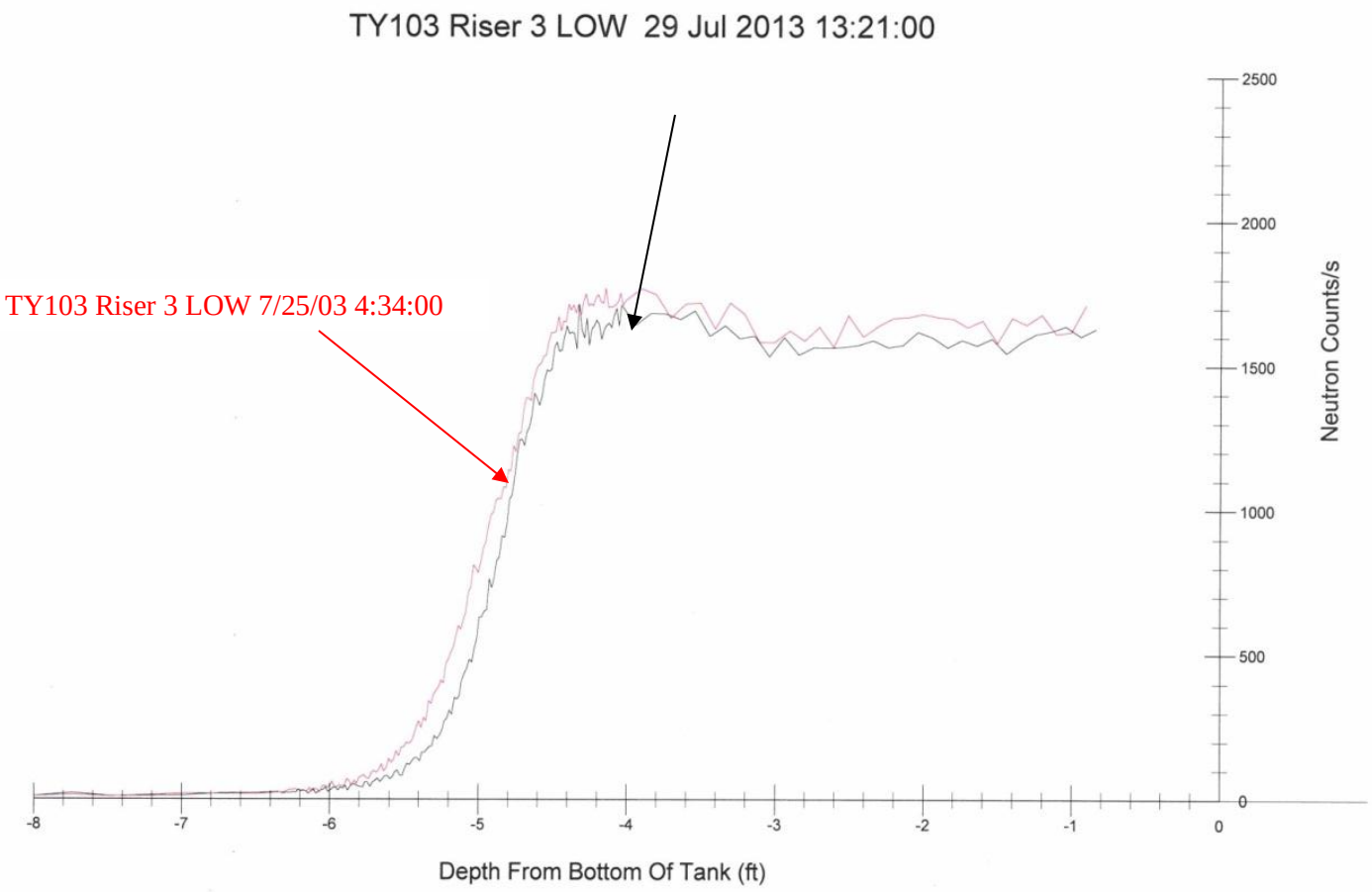
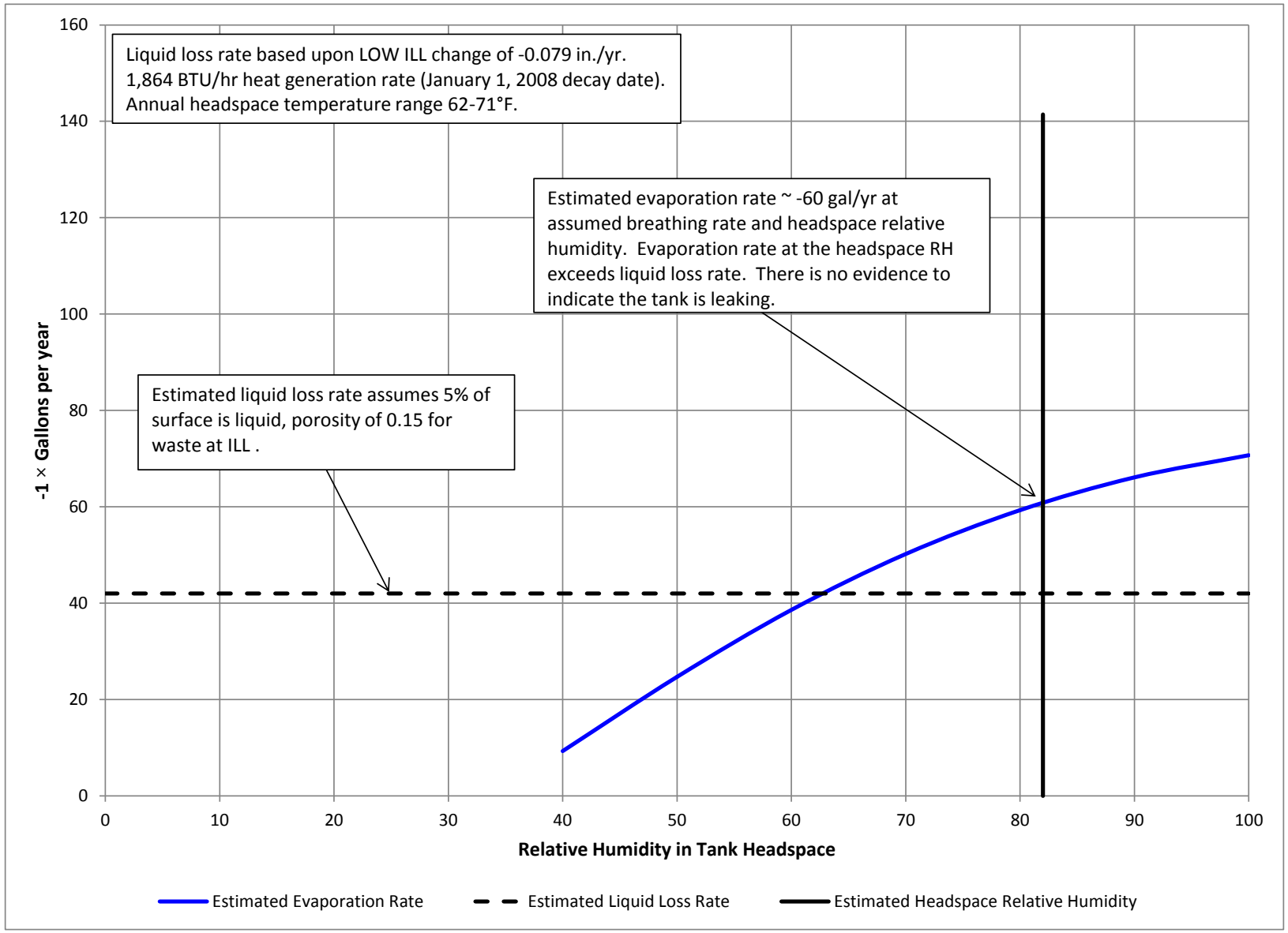


Figure 4-70 Tank TY-103 Estimated Evaporation and Liquid Loss Rates



4.13 Tank U-104

4.13.1 Tank Summary

Tank U-104 entered service in 1947 with the receipt of $BiPO_4$ process waste. The tank was full to the cascade line before the end of the year. Some waste was removed in 1952 and 1953, and more waste added in 1954. The waste was sluiced out in 1956 and water added to determine if the tank was leaking after a bulged bottom was noted during sluicing operations. The water was removed in 1961. Sixty tons of diatomaceous earth (DE) were added to the tank in 1972 to absorb supernatant liquid. The tank was declared interim stabilized in 1978 (RPP-RPT-43238, Rev. 0, *2009 Auto TCR for 241-U-104*). Per a TWINS query on September 25, 2012 the tank contains about 54.2 kgal of sludge and no supernatant liquid or saltcake.

Figure 4-71 shows the raw SL data for tank U-104 from January 1, 1990. Figure 4-72 is a plot of the data used for calculation of the -0.110 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the SL data changes can be seen. There were a number of spikes in the ENRAF data that were removed in order to give a better trendline slope estimate. Figure 4-73 is an updated plot showing the latest data included for this document. Tank U-104 is an assumed leaking tank and has no LOW. The SL has shown a relatively consistent decrease rate of -0.109 in./yr since 2003 when the ENRAF was installed, and a decrease rate somewhat higher before 2003 when the manual tape was used for surface level measurement.

Tank U-104 has a rather unique surface. It is one of six tanks which had diatomaceous earth (DE) added on top of the waste in the early 1970s to absorb supernatant liquid. Approximately 60 tons of DE were added in May of 1972. The surface in the tank is extremely cracked and dry looking, with the level somewhat higher near the tank wall. Figure 4-74 is a photo from February 7, 1974 showing the manual tape in Riser 7 appearing to be sitting in a small depression with moist waste around it. The ENRAF gauge used since February 2003 to measure the U-104 waste surface is installed in Riser 8, where the pipe is pictured next to the manual tape in Figure 3-70. Figure 4-75 is a photo from August 10, 1989 showing an expanded view of the area around the manual tape and the pipe/future ENRAF location. Figure 4-76 is an August 10, 1989 close-up of the cracked DE on the waste surface.

Tank U-104 is one of the oldest assumed leaking tanks at Hanford. It was first suspected of leaking in the 1950s, and the pumpable liquid was removed by 1960. The addition of DE in 1972 absorbed most of the remaining supernatant liquid. Photographs taken between 1974 and 1989 show the residual liquid in several pools slowly disappearing. The last photos taken in 1989 show negligible supernatant liquid remaining, but several locations nearer the center of the tank where pools previously existed appear moist.

4.13.2 Liquid Change Rate Estimation

The tank contains about 54.2 kgal of sludge and no supernatant liquid or saltcake, per the BBI. A sludge porosity of 0.12 is assumed for estimating a minimum liquid loss rate since RPP-5556 does not list a porosity for the tank.

From looking at Figure 4-74 through Figure 4-76 it is reasonable to assume the ENRAF plummet is either sitting on an irregular-shaped pile of DE, in a crack between several piles, or in a small depression. It is assumed there is negligible supernatant liquid remaining on the waste surface.

The minimum estimated liquid loss rate assumes the ENRAF plummet is sitting in a depression of moist waste and that the plummet goes down as the moisture leaves.

The minimum estimate of the tank U-104 liquid change rate is equal to:

$$Tank\ U-104\ minimum\ estimated\ liquid\ change\ rate = -0.109 \times 2{,}750 \times (0 + (1-0) \times 0.12)) = \mathbf{-36\ gal/yr}$$

A rough approximation to the liquid loss rate, using a ratio of 280 gal/yr per in./yr SL change since U-104 is a predominantly sludge tank:

$$Tank\ U-104\ rough\ approximate\ liquid\ change\ rate = -0.109 \times 280 = \mathbf{-31\ gal/yr}$$

A maximum estimated liquid loss rate assumes the entire waste surface drops at the level change rate:

$$Tank\ U-104\ max\ estimated\ liquid\ change\ rate = -0.109 \times 2{,}750 = \mathbf{-299\ gal/yr}$$

4.13.3 Data Analysis

Estimation of [Σ other] The tank contents are all sludge, mostly DE with the DE on top. It is possible that the sludge and/or DE, is slowly subsiding as it dries out. Subsidence can be seen in the 1974 and 1989 photos where the liquid has been absorbed, but is not evident around the outer edge in Figure 4-73.

The BBI shows zero retained gas in U-104. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. The decrease in the U-104 SL is not typical of an episodic gas release. While it is theoretically possible the waste matrix could have retained gas for a long time and then released it constantly for a number of years, this is not realistic. There is no basis to assume any impact of retained gas on the level decrease rate. No liquid level vs. reciprocal of the barometric pressure plot is provided for tank U-104 because the only level data available are from the solid surface. .

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1956, and diatomaceous earth in 1972. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for U-104 is assumed to be = PCE + 0 + 5 + 0 = 5 gal/yr.

Estimation of A Value for Intrusion Rate – An in-tank video was performed in 2010 and no intrusion was observed. There has been no evidence of intrusion based upon the SL data going back to 1990.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -31\ to - 299\frac{gal}{yr} - leak\ rate - evaporation\ rate - \left(PCE + 5\frac{gal}{yr}\right)$$

$$= -36\ to - 304\frac{gal}{yr} - leak\ rate - evaporation\ rate - PCE$$

The bounding maximum liquid change rate assumes a liquid surface in the tank, and so it includes any change ascribed to 'PCE'. The estimated minimum liquid change rate ignores any change ascribed to 'PCE' since it assumes the plummet is reading an interstitial liquid near the surface. As described below, the estimated evaporation rate for tank U-104 is -62 gal/yr. Therefore, an intrusion up to 26 gal/yr could occur before a leak would exist based upon the estimated lowest volumetric change rate. The existence of an intrusion is irrelevant compared to the bounding maximum volumetric change rate.

Evaluation of ILL and SL Validity – There is no LOW in the tank.

It is unknown what the surface condition is underneath the ENRAF plummet. The spikes and the old photos showing the cracked DE surface indicate it is possibly sitting in a crack or a depression.

Table 4-6 lists all tank U-104 ENRAF work packages for the 2006 to 2013 time period. The last two columns list the as-found and as-left data from the work packages. The calibration on November 19, 2007 (0.62 in. differential) was the only significant change, the remaining calibration differentials were all small. All readings from January 2003 through September 2011 were quarterly readings (except a few additional ones in March 2003) taken in manual mode. All readings since September 23, 2011 have been daily readings in auto mode.

Table 4-6 Tank U-104 ENRAF Gauge Work Packages Since January 1, 2006

Work Package No.	Title	Date	As Found (in.)	As Left (in.)
CLO-WO-06-001862	241-U, 104 ENRAF INSPECTION	January 25, 2007	35.59	35.85
CLO-WO-07-1760	241-U, 104 ENRAF INSPECTION	November 19, 2007	36.07	35.45
TFC-WO-08-0418	241-U, 104 ENRAF CAL	August 21, 2008	35.36	35.36
TFC-WO-09-1359	241-U, 104 ENRAF CAL	May 19, 2009	35.18	35.17
TFC-WO-10-0243	241-U, 104 ENRAF CAL	February 16, 2010	35.29	35.09
TFC-WO-11-0160	241-U, 104 ENRAF CAL	February 23, 2011	34.91	34.90
TFC-WO-12-0069	241-U, 104 ENRAF CAL	February 13, /2012	34.71	34.89
TFC-WO-13-0255	241-U, 104 ENRAF CAL	February 5, 2013	34.74	34.74

The SL reference was changed on February 27, 2003 when the manual tape was removed and an ENRAF installed. Twelve inches have been added to the manual tape readings in Figure 4-72 and Figure 4-73, but this has no impact on the ENRAF data trendline slope.

4.13.4 Evaporation Estimate

Figure 4-77 provides the evaporation estimate results for tank U-104. Figure 4-77 indicates tank U-104 would evaporate a nominal -62 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank U-104 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank U-104, 2.4 cfm, is about the same as that used for other 75 ft. diameter tanks, excluding A-102, A-106, AX-101 and AX-103. The basis for the breathing rate assumed for tank U-104 is provided in Appendix A and is the best estimate when considering the information.

The assumed tank U-104 headspace RH of 95% is based upon the July 16, 1996 vapor space sample of 97.3%. The headspace temperature is unknown since there is no thermocouple in the tank, but the heat generation rate is negligible so the tank headspace should change little on an annual basis. A slightly lower value of 95% was assumed since some water has to have evaporated over the years from the waste.

The evaporation rate exceeds the estimated minimum liquid loss rate by about 26 gal/yr and the rough approximate liquid loss rate by slightly more.

4.13.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank U-104 as 13 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. The heat generation rate is negligible. Essentially all heat for evaporation comes from the incoming air and the latent heat in the top of the waste.

4.13.6 Tank U-104 Leak Potential

Based upon Figure 4-77 the tank U-104 minimum liquid loss rate can be explained by evaporation. The rough approximation for a tank U-104 liquid loss rate based upon the ILL gal/yr loss rate per in./yr SL change rate from tanks with both decreasing ILLs and SLs is almost identical to the estimated minimum loss rate.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$\begin{aligned} leak\ rate\ compared\ to\ estimated\ minimum\ liquid\ loss\ rate \\ &= -36\frac{gal}{yr} - intrusion\ rate - (-62\frac{gal}{yr}) - \left(5\frac{gal}{yr}\right) \\ &= 21\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

$$\begin{aligned} leak\ rate\ compared\ to\ rough\ approximate\ liquid\ loss\ rate \\ &= -31\frac{gal}{yr} - intrusion\ rate - (-62\frac{gal}{yr}) - (5\ gal/yr) \\ &= 26\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

$$\begin{aligned} leak\ rate\ compared\ to\ bounding\ maximum\ liquid\ loss\ rate \\ &= -299\frac{gal}{yr} - intrusion\ rate - \left(-62\frac{gal}{yr}\right) - \left(5\frac{gal}{yr}\right) \\ &= -242\frac{gal}{yr} - intrusion\ rate \end{aligned}$$

If the evaporation rate for U-104 is -62 gal/yr, an intrusion rate would have to exceed 21 gal/yr for there to be a leak, if the minimum estimated liquid loss rate is valid. The maximum estimated liquid loss rate is far above the estimated evaporation rate, but is not realistic.

4.13.7 Tank U-104 Conclusion

Surface level data obtained from solid surfaces are inadequate to accurately estimate liquid change rates. The evaporation rate is above both the minimum and rough approximation liquid loss rates. There is no basis to assume a leak from tank U-104.

Figure 4-71 Tank U-104 Full Depth Raw Data Plot

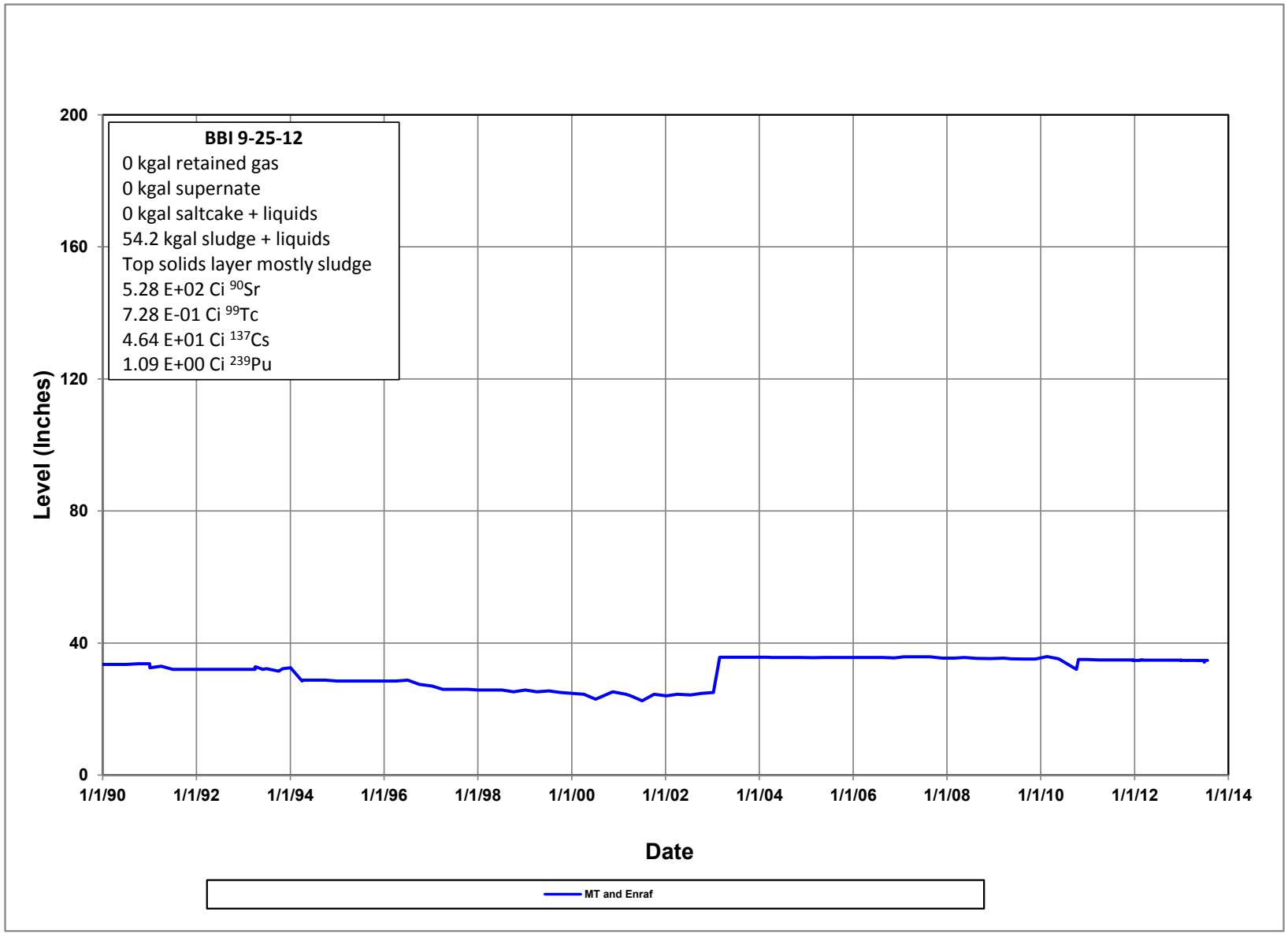


Figure 4-72 Tank U-104 Expanded Surface Level Adjusted Data Plot Used for RPP-PLAN-55113, Rev 1

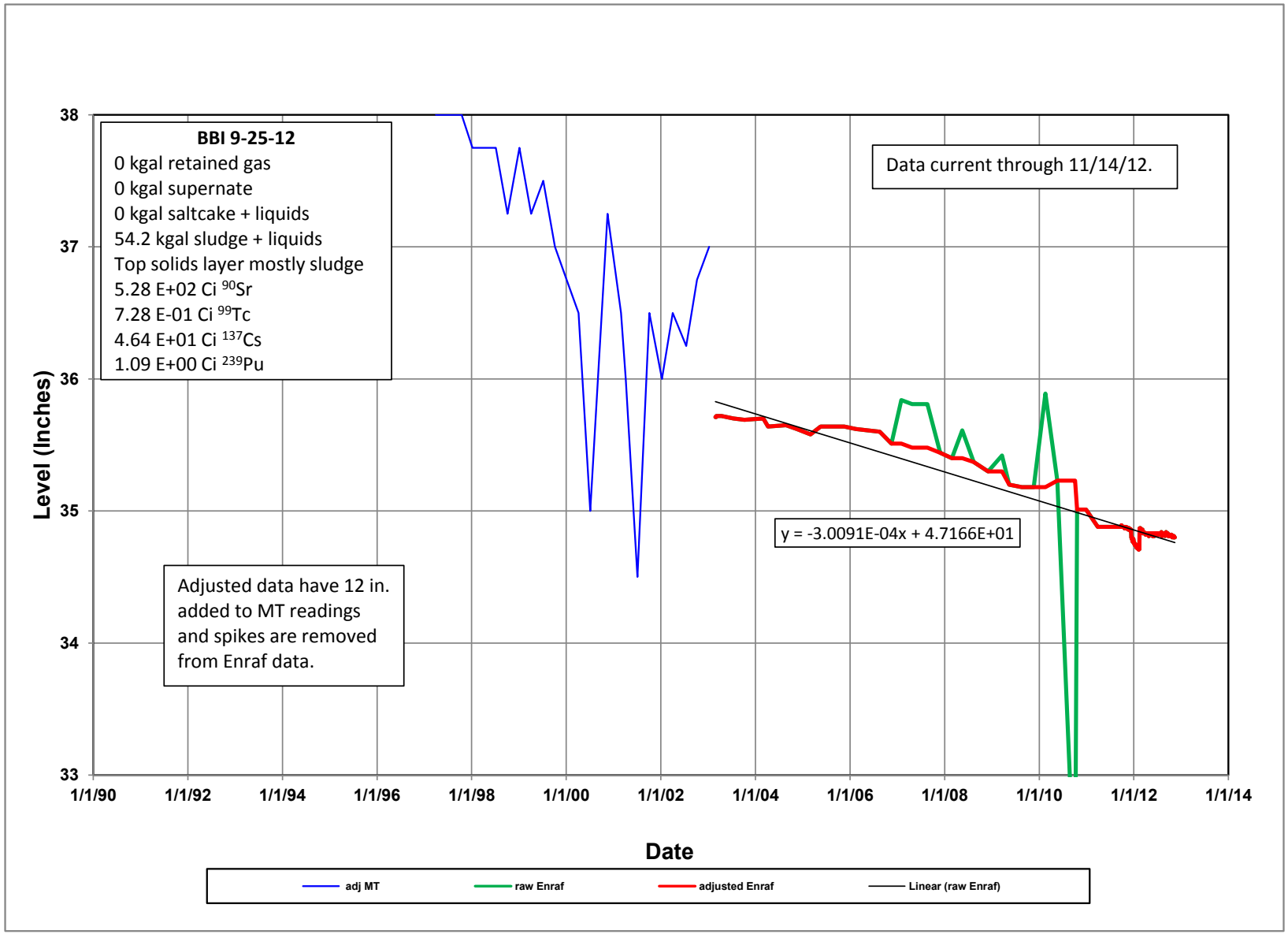


Figure 4-73 Tank U-104 Expanded Surface Level Adjusted Data Plot Used for RPP-RPT-54981

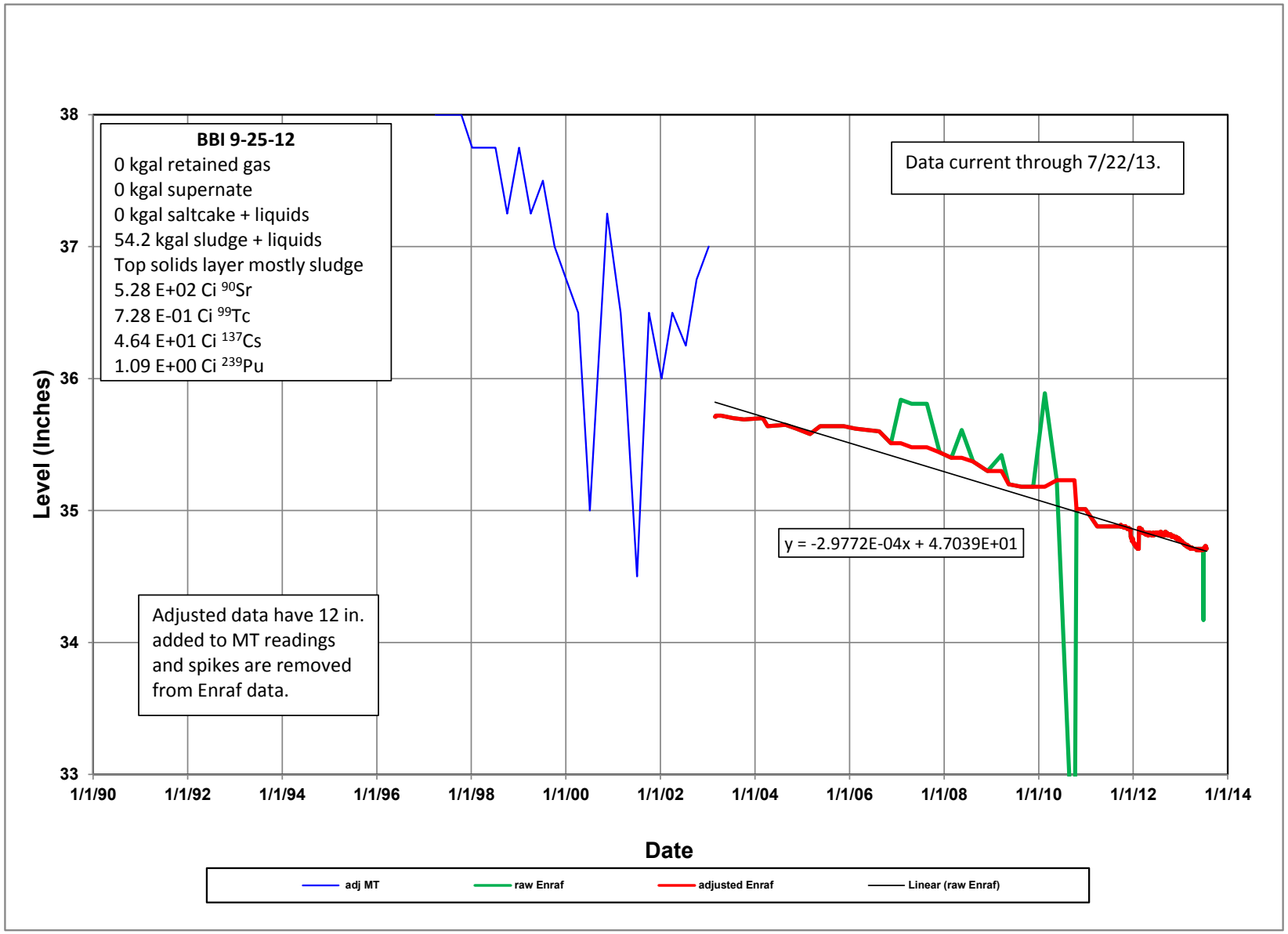


Figure 4-74 February 7, 1974 Photograph of Tank U-104 Manual Tape and Future ENRAF Location

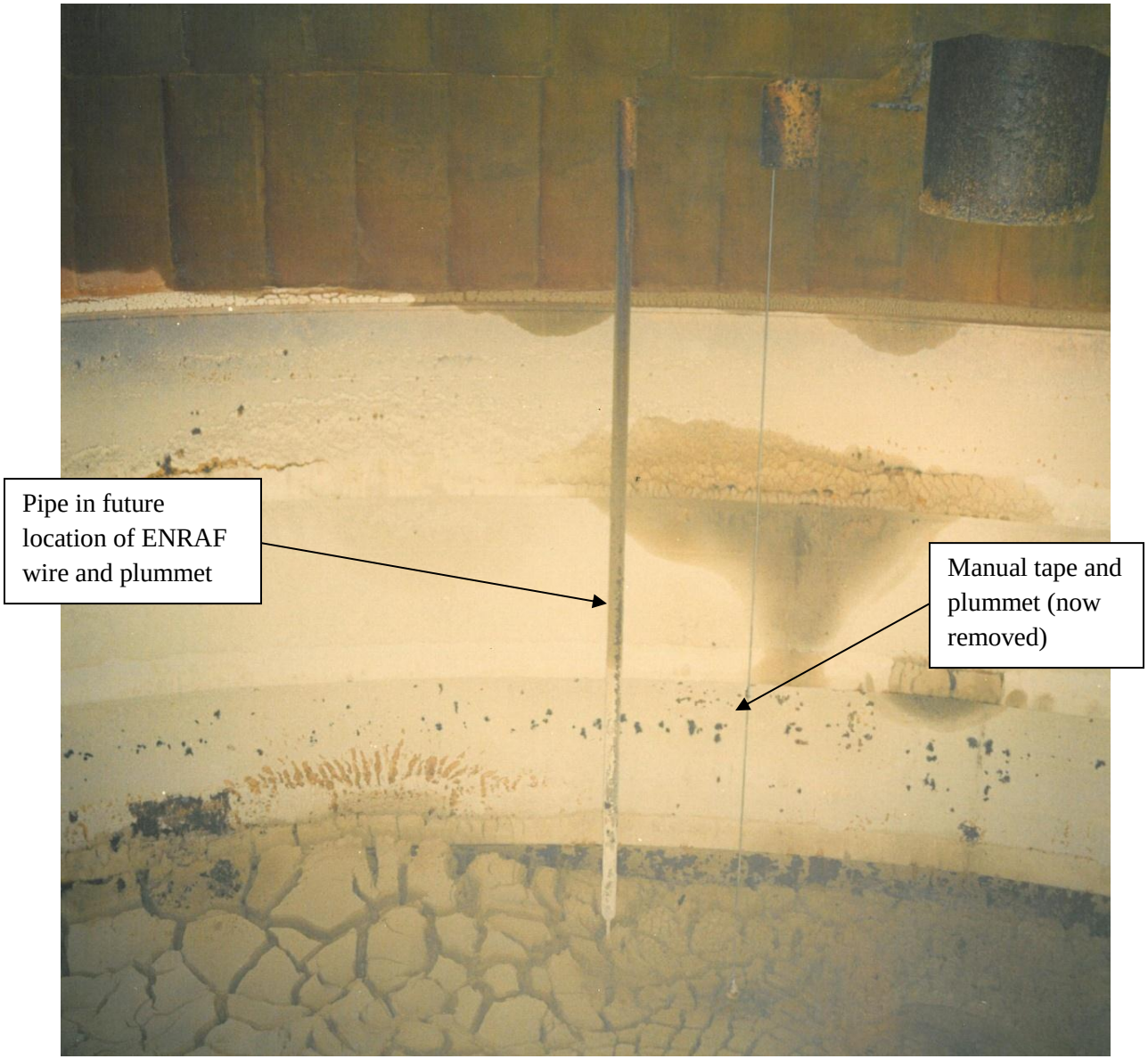


Figure 4-75 August 10, 1989 Photograph Showing Area around Tank U-104 Manual Tape and Future ENRAF Location

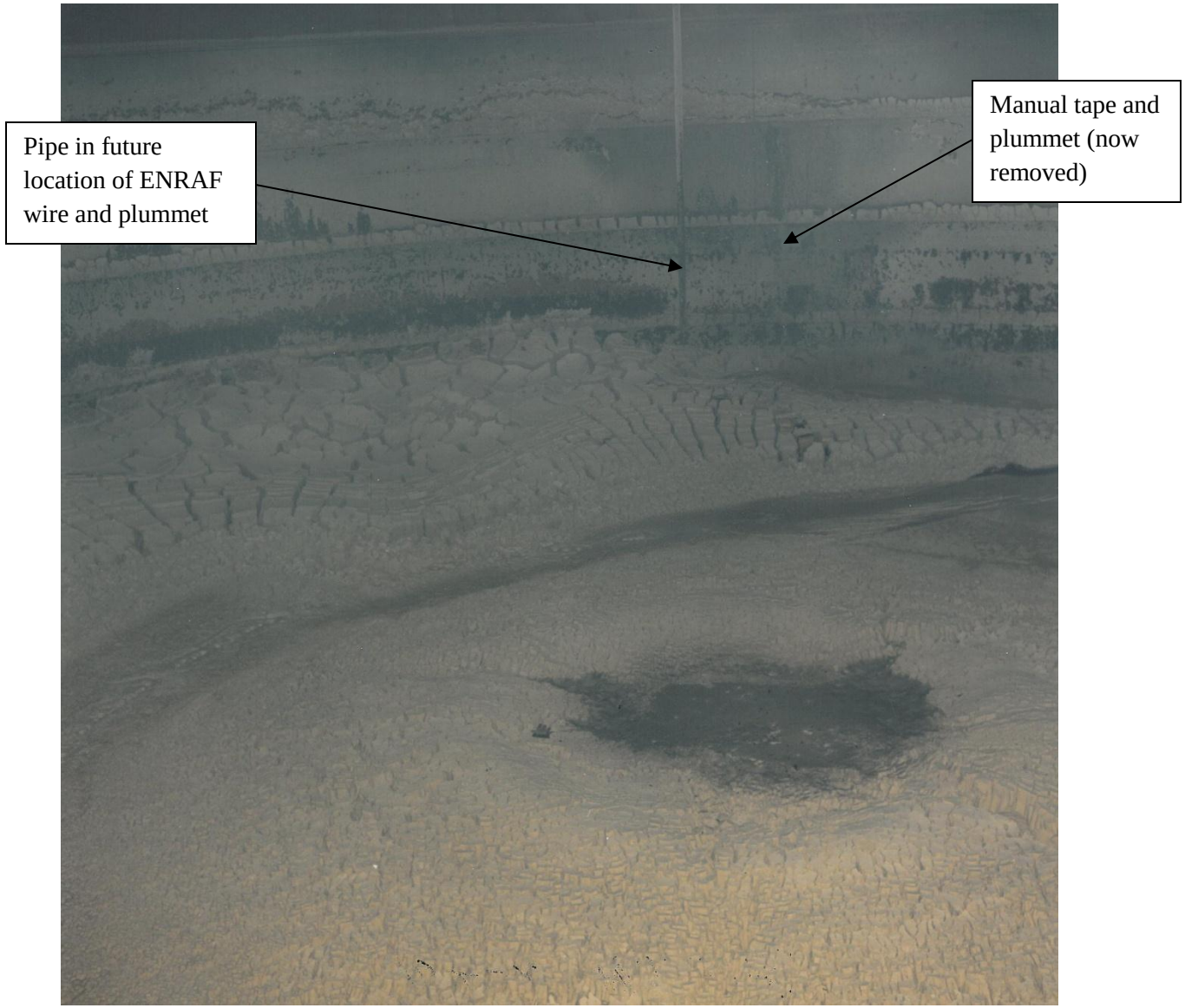
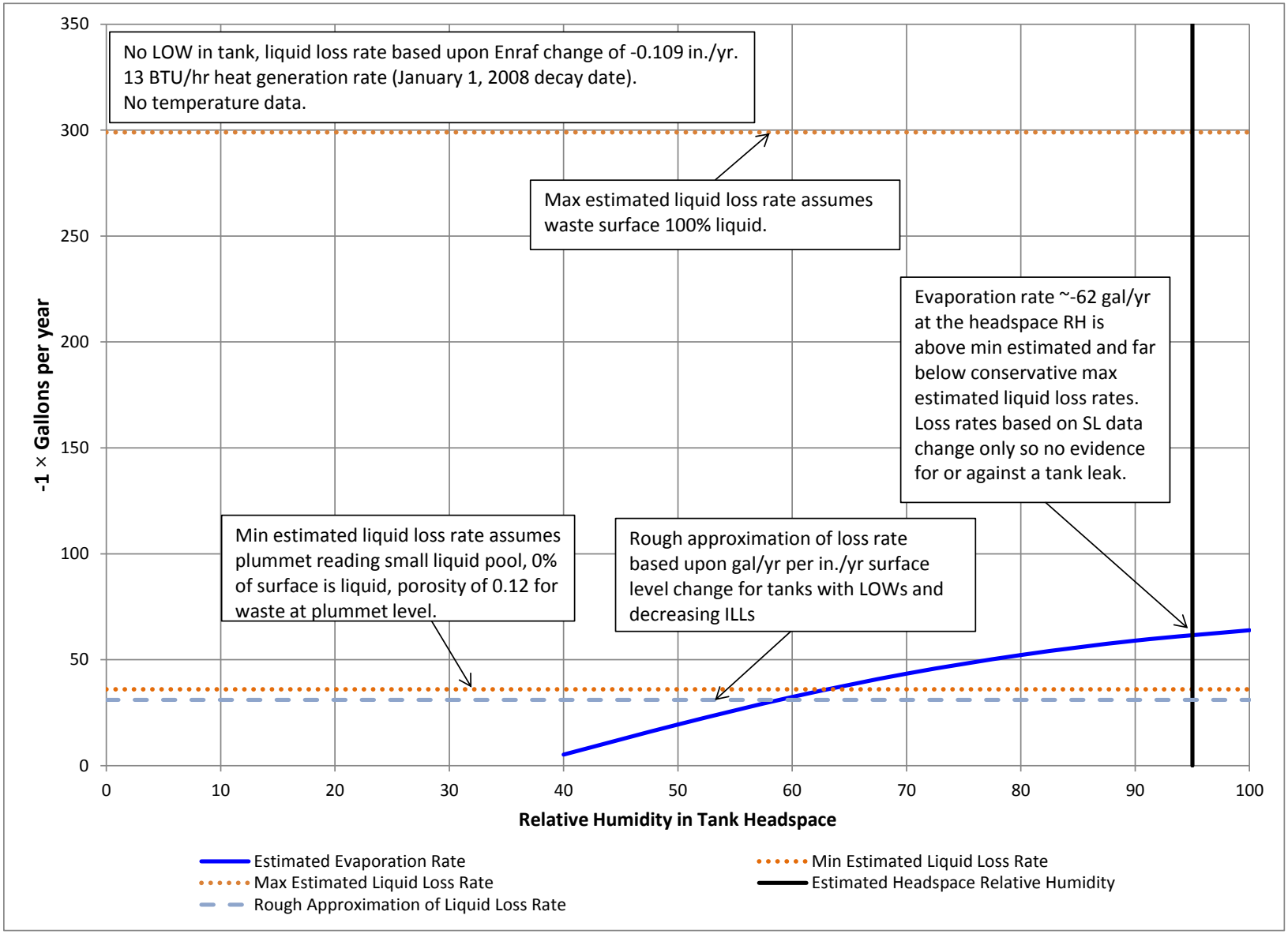


Figure 4-76 August 10, 1989 Photograph Showing Close-Up of Tank U-104 Waste Surface

Figure 4-77 Tank U-104 Estimated Evaporation and Max/Min/Rough Approximate Liquid Loss Rates



4.14 Tank U-108

4.14.1 Tank Summary

Tank U-108 entered service in 1949 with the receipt of $BiPO_4$ process waste. The tank was full to the cascade line before the end of the year. Some waste was removed in 1953 and more waste added in 1954. The waste was sluiced out in 1956. Wastes were sent to and from other SSTs from 1959 to 1969, and again from 1972 to 1975. During the latter period the tank also received N-Reactor decontamination waste, and laboratory/other wastes. In 1975 and 1976 it was used to recycle evaporator bottoms (RPP-RPT-43242, Rev. 0, *2009 Auto TCR for 241-U-108*). The tank was interim stabilized in 2004. Per a TWINS query on September 25, 2012 the tank contains about 404.1 kgal of saltcake and 29.1 kgal of sludge with no supernatant liquid.

Figure 4-78 shows the raw ILL and SL data for tank U-108 from January 1, 1990. Figure 4-79 is a plot of the ILL data used for calculation of the -0.136 in./yr trendline slope for RPP-PLAN-55113, Rev 1, with an expanded y-axis so the ILL data changes can be seen. Figure 4-80 is an updated plot showing the latest data included for this document. The slope of the ILL decrease line is much less than before, at -0.016 in./yr. The decrease is due to shortening the trendline duration to the past four years to better reflect stabilization of the ILL. The ILL has shown a decrease since IS was completed in 2005, and appears to be nearly stabilized.

4.14.2 Liquid Change Rate Estimation

The liquid change rate estimation is based upon the ILL change rate of -0.016 in./yr.

The saltcake and sludge are assumed mixed in this tank, per RPP-40545, Rev 2, Appendix H. No porosity is listed for tank U-108 in RPP-5556. RPP-40545, Rev 2, Appendix H indicates the salt in this tank is <2.0 anion mole % phosphate so the saltcake porosity is assumed to be 0.20. Since the salt and sludge are assumed mixed but mostly salt, a porosity of 0.18 is assumed.

With the ILL about 34 in. below the waste surface it is assumed there is no supernatant present.

The best estimate of the tank U-108 volumetric change rate is equal to:

$$Tank\ U-108\ best\ estimate\ liquid\ change\ rate = -0.016 \times 2{,}750 \times (0 + (1-0) \times 0.18)) = \mathbf{-8\ gal/yr}$$

4.14.3 Data Analysis

<u>Estimation of [Σ other]</u> – The level decrease is based upon the ILL decrease rather than the surface level change so subsidence is not applicable.

Figure 4-81 is a plot of the inverse of the barometric pressure and the ILL data. There is little correlation as indicated by the low (0.128) R^2 value. Figure 4-82 is a comparison of tank U-108 LOW neutron scan data from 2003 and 2013. There is no obvious gas volume decrease apparent. The liquid content has receded proportionately the depth of the tank rather than showing the expected liquid increase at some level that would have occurred if a large volume of gas were replaced with liquid. The BBI shows zero retained gas in U-108. Buildup and release of gases within the waste has been observed in DSTs as evidenced by a slow increase in the waste level followed by a sudden decrease when the gas is released. Some SSTs may exhibit chronic release of gases at roughly the same rate gases are generated. But, the continual release

of retained gas from tank U-108 for over 10 years is not realistic. There is no basis to assume any impact of retained gas on the level decrease rate.

No large items of equipment are known to have been lanced into the tank in the past 10 years and the TWINS database indicates no samples have been taken from the tank in that time. The water usage data sheets were not reviewed, but making the assumption that a level gauge is flushed with a nominal 10 gal of water every two years results in a nominal 5 gal/yr conscious liquid addition.

The last waste was put into the tank in ~1975. The assumption is made that any significant chemical changes that may occur within the waste would have already occurred so the potential for chemical reactions to be causing changes that would affect the level data is very small.

Therefore, the value [Σ other] for U-108 is assumed to be = 0 + 0 + 5 + 0 = 5 gal/yr.

Potential for Intrusion No in-tank video has been done to evaluate whether an intrusion is occurring in the tank. There has been negligible evidence of intrusion based upon the SL or ILL data going back to 1990.

From Section 3.4:

$$intrusion\ rate = volumetric\ change\ rate - leak\ rate - evaporation\ rate - \Sigma\ other$$

$$intrusion\ rate = -8\frac{gal}{yr} - leak\ rate - evaporation\ rate - 5\frac{gal}{yr}$$
$$= \frac{13gal}{yr} - leak\ rate - evaporation\ rate$$

Since both evaporation rate and leak rate are negative values, the sum of the leak rate plus the evaporation rate would have to be <-13 gal/yr before an intrusion would be considered. As described below, the estimated evaporation rate for tank U-108 is -38 gal/yr so there could be an intrusion up to 25 gal/yr masking a leak if the evaporation rate is accurate.

Evaluation of ILL or SL Validity – – The LOW was installed in 1985 and the tank saltwell pumping was completed in 2004. It can be seen from Figure 4-80 that the ILL is still in the process of stabilizing. The ILL stabilizing is the reason the ILL is decreasing.

The ENRAF data are not used to estimate the tank liquid loss rate so the maintenance history was not reviewed, and the ENRAF plummet seating is not considered.

The LOW ILL has always been referenced to the tank centerline bottom.

4.14.4 Evaporation Estimate

Figure 4-83 provides the evaporation estimate results for tank U-108. Figure 4-83 indicates tank U-108 would evaporate a nominal 38 gal/yr.

Appendix A describes all the variables involved with the evaporation rate estimate and provides a basis for the value selected. The ambient air conditions and tank headspace temperatures are obtained from recorded data. The primary variables in Appendix A that will impact the tank U-108 evaporation rate are the assumed breathing rate and the assumed tank headspace relative humidity.

The breathing rate used for tank U-108, 2.2 cfm, is about the same as that used for other 75 ft. diameter tanks, excluding A-102, A-106, AX-101 and AX-103. The basis for the breathing rate assumed for tank U-108 is provided in Appendix A.

The assumed tank U-108 headspace RH of 45% is based upon the August 29, 1995 vapor space sample of 50.5%. The headspace temperature was 82°F when sampled. The temperature for an August 29 annual date from Appendix A, Figure A-21, is slightly less than 80°F. A slightly lower value of 45% was assumed since some water has to have evaporated over the years from the waste.

The evaporation rate exceeds the estimated liquid loss rate by about 30 gal/yr.

4.14.5 Tank Heat Generation Rate Impact

Table B-15 in Appendix B gives an estimated heat generation rate for the waste in tank U-108 as 5,558 BTU/hr. This is based upon a radionuclide decay date of January 1, 2008, so the heat generation rate as of mid-summer 2013 is about 12% less. About 0.14% of the January 1, 2008 heat generation rate would need to be needed to evaporate water at the estimated liquid change rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated despite the ILL being about 35 in. below the waste surface.

4.14.6 Tank U-108 Leak Potential

Based upon Figure 4-83 the estimated evaporation rate from the tank exceeds the estimated liquid loss rate.

There is sufficient heat generated in the tank to drive off water at the rate estimated.

Using the equation from Section 3.4:

$$leak\ rate = volumetric\ change\ rate - intrusion\ rate - evaporation\ rate - \Sigma\ other$$

$$leak\ rate = -8\frac{gal}{yr} - intrusion\ rate - (-38\frac{gal}{yr}) - \left(5\ \frac{gal}{yr}\right) = 25\frac{gal}{yr} - intrusion\ rate$$

If the evaporation rate for U-108 is -38 gal/yr, the intrusion rate would have to exceed 25 gal/yr, for a leak to exist.

4.14.7 Tank U-108 Conclusion

There is no evidence for a leak from tank U-108.

Figure 4-78 Tank U-108 Full Depth Raw Data Plot

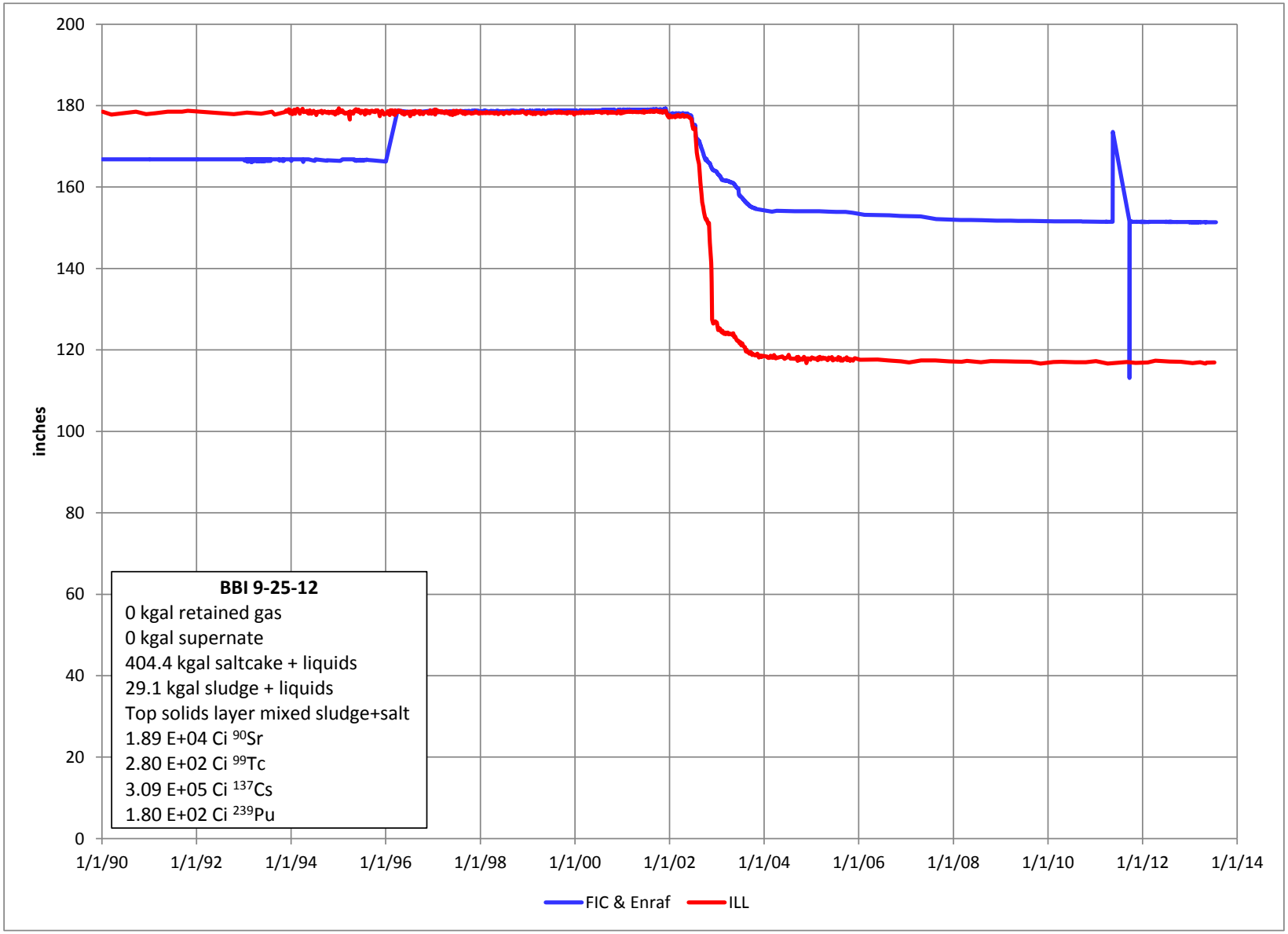


Figure 4-79 Tank U-108 Expanded ILL Data Plot Used for RPP-PLAN-55113, Rev 1

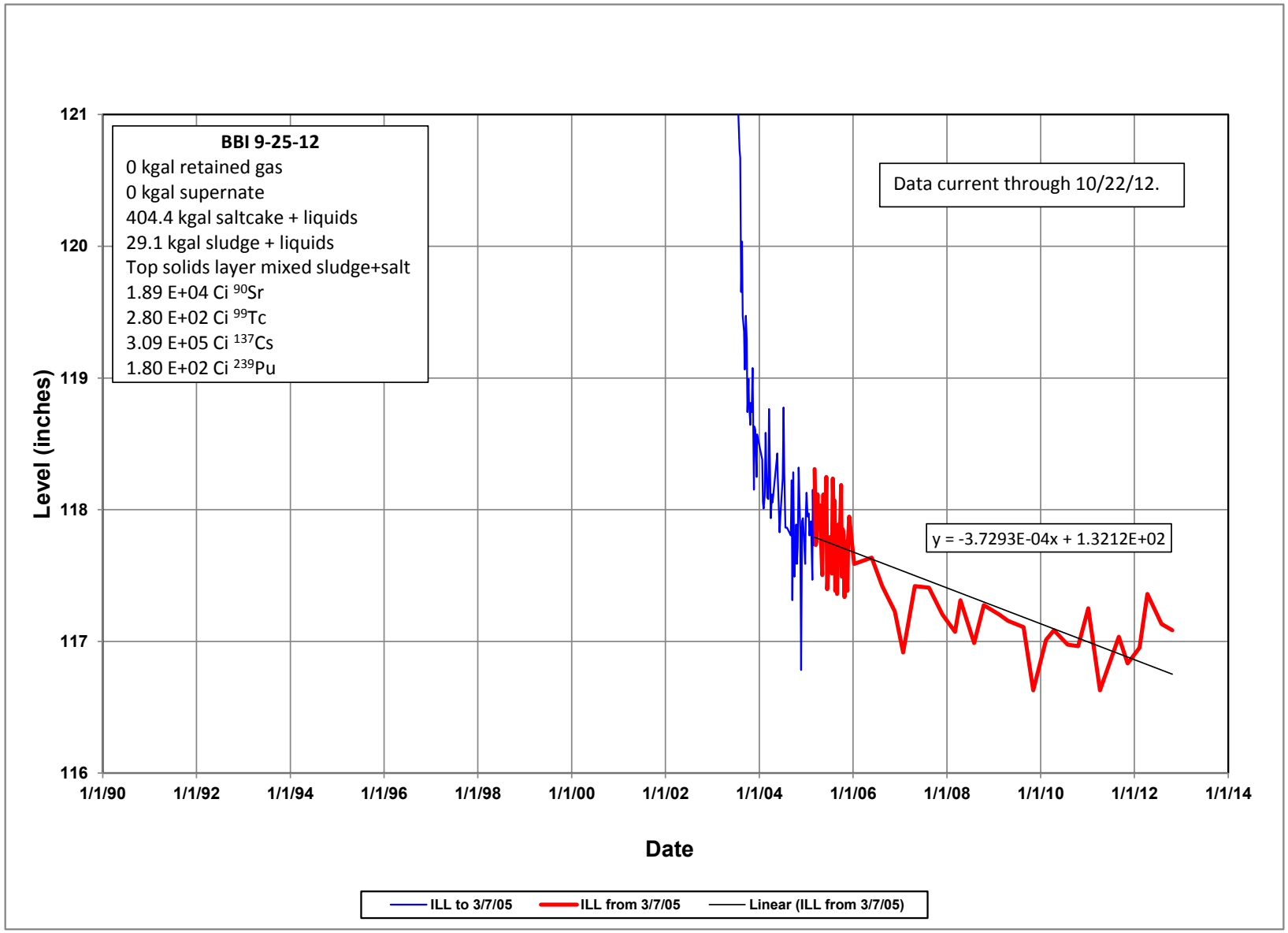


Figure 4-80 Tank U-108 Expanded ILL Data Plot Used for RPP-RPT-54981

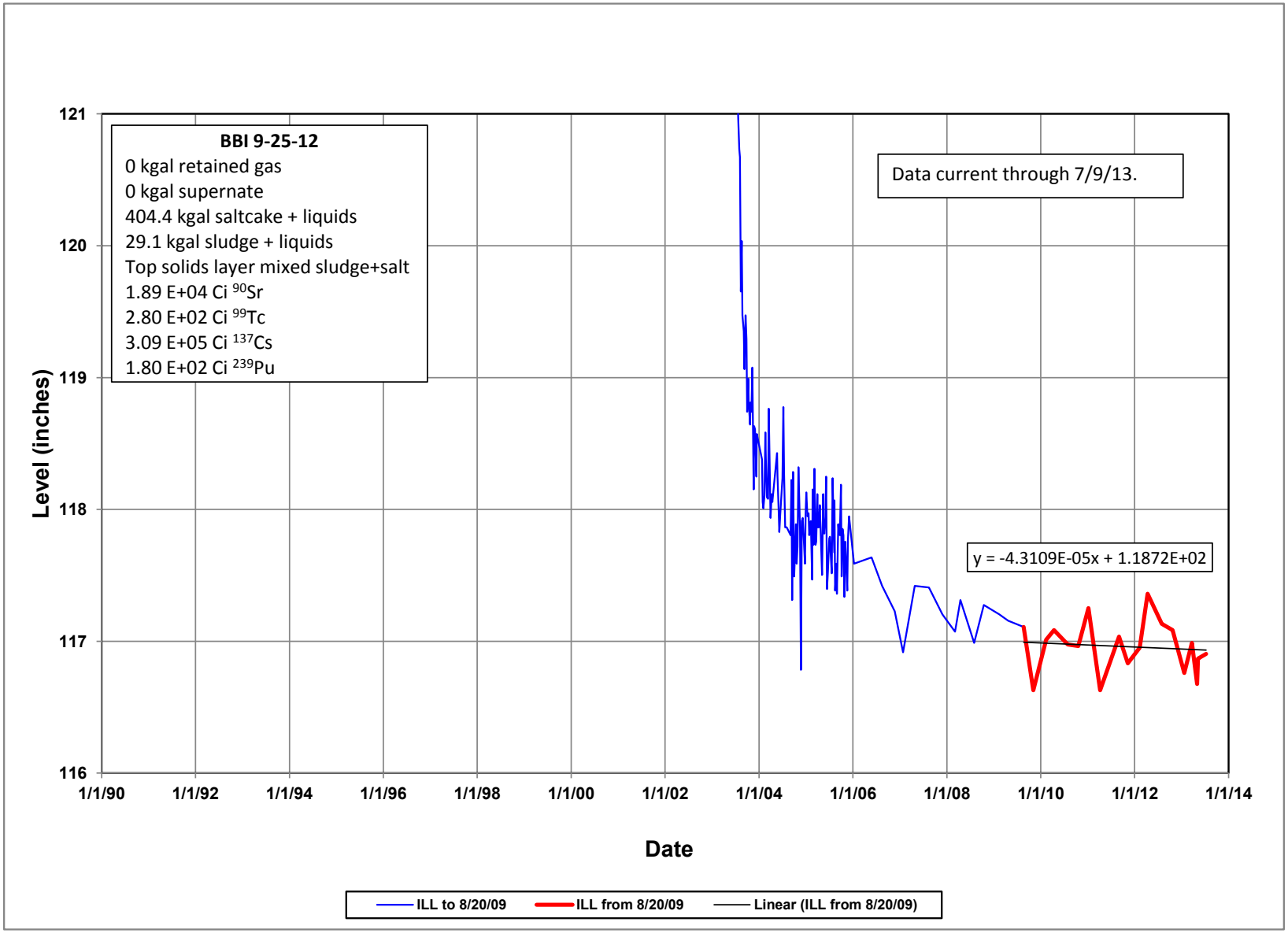


Figure 4-81 Tank U-108 Raw Interstitial Liquid Level Data and Adjusted Inverse Barometric Pressure

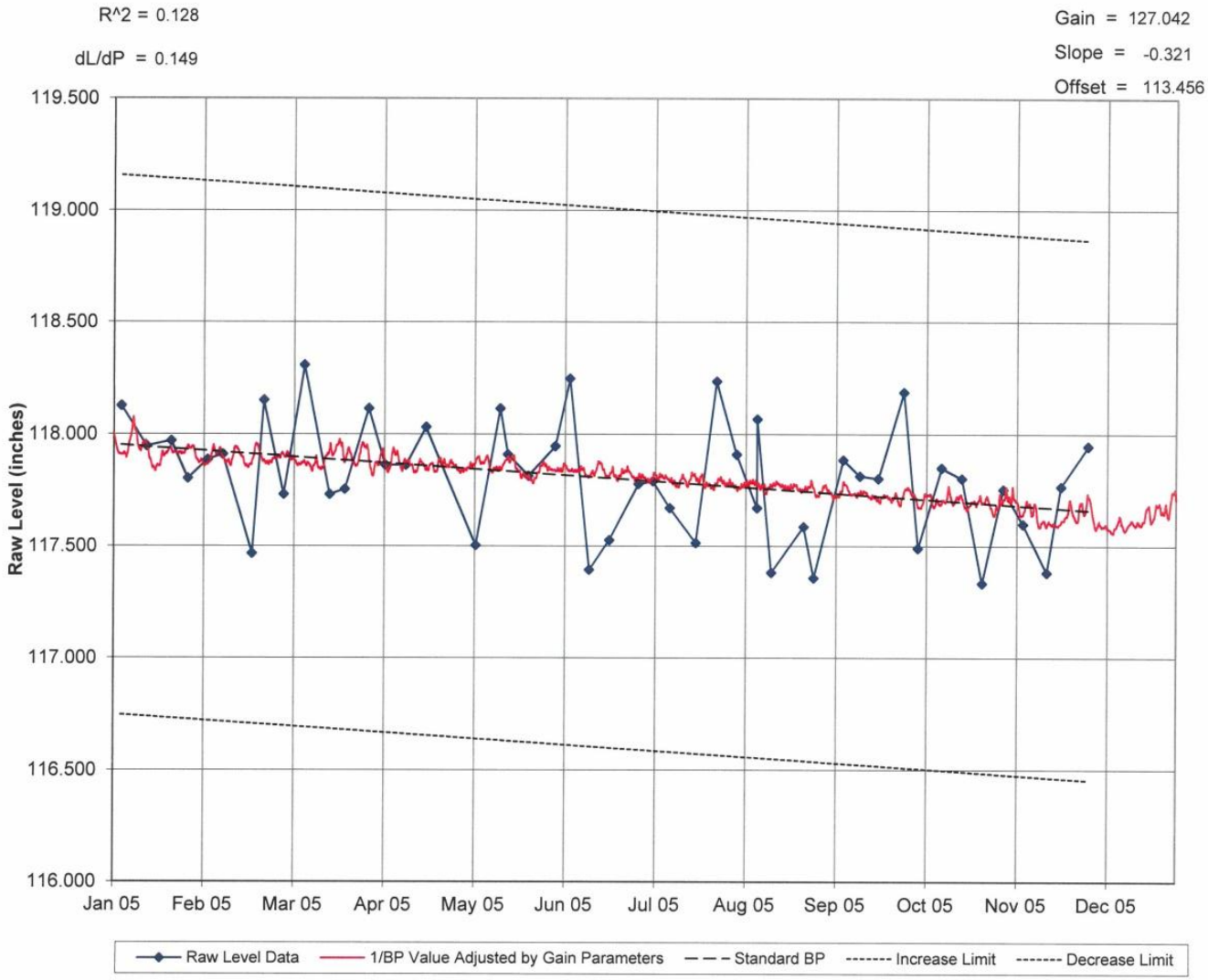


Figure 4-82 Comparison of Tank U-108 2003 and 2013 Liquid Observation Well Neutron Scans

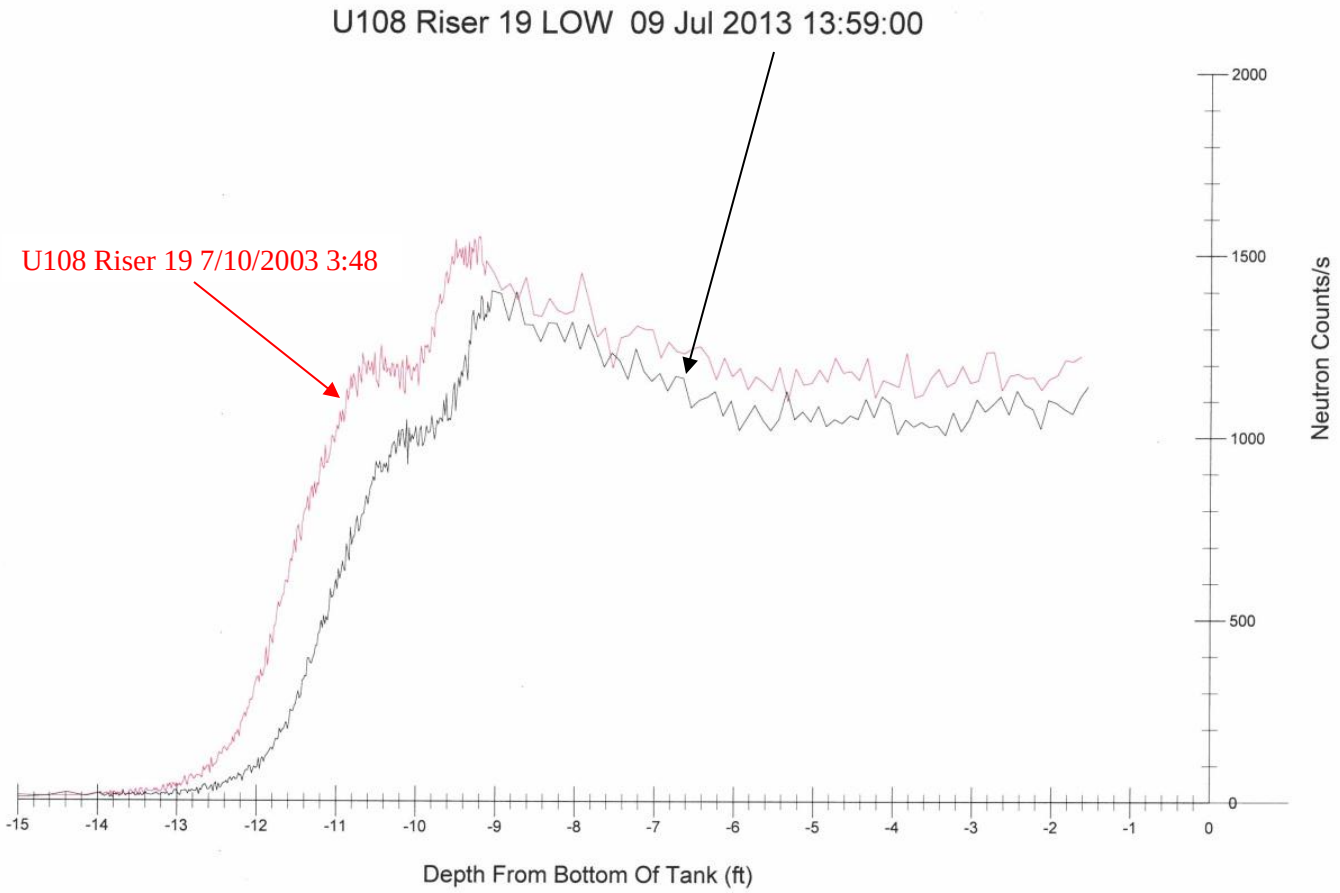
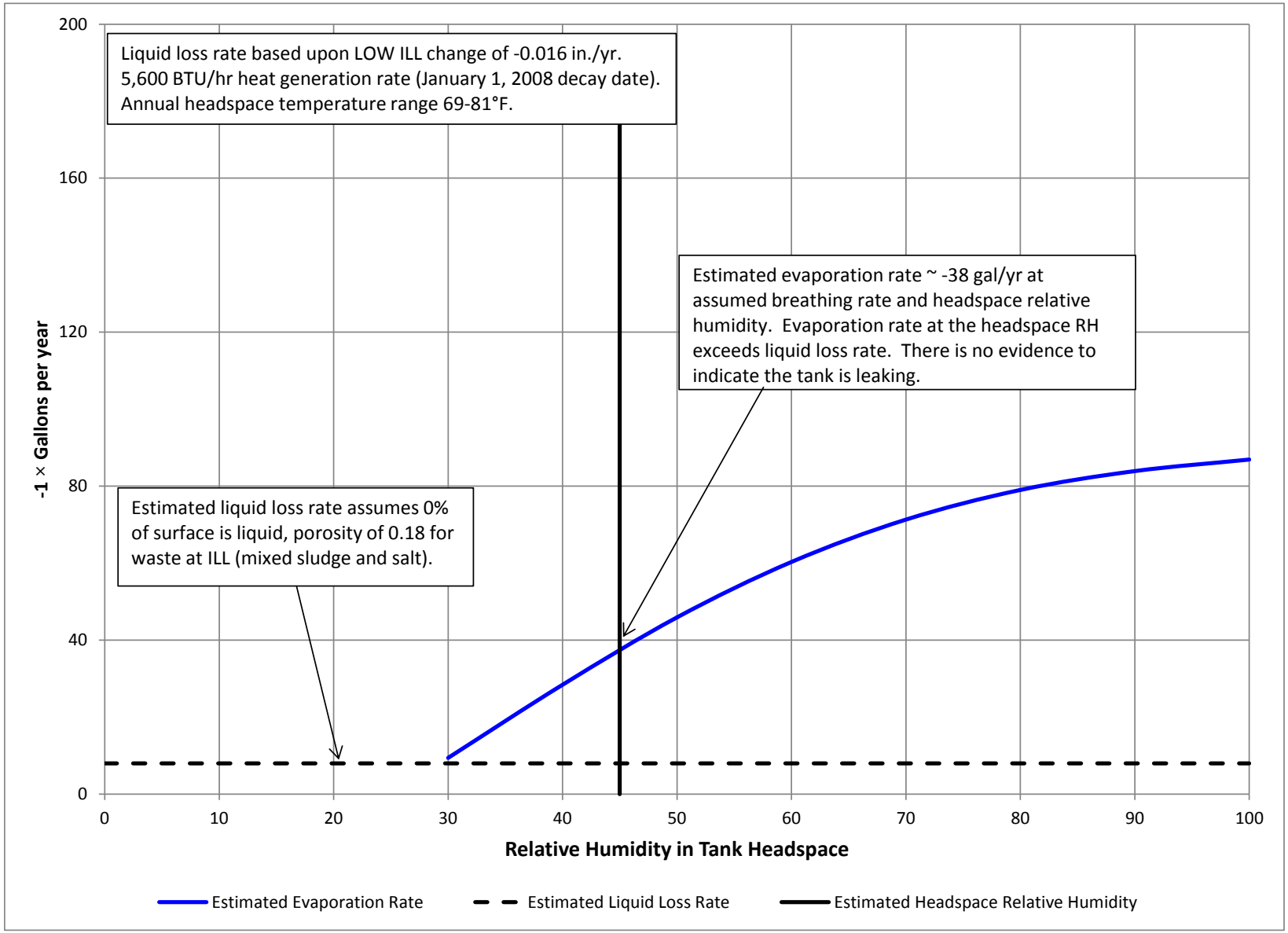


Figure 4-83 Tank U-108 Estimated Evaporation and Liquid Loss Rates



5. Discussion of Results

The tank evaluations for 12 of the 14 tanks (tanks A-102 and SX-102 are excluded) are dependent upon the validity of three separate estimates: evaporation rate, volumetric change rate, and tank headspace relative humidity. The tank evaluations show the tank A-102 SL decrease rate in RPP-PLAN-55113, Rev 1, was due to a faulty level gauge and the tank SX-102 ILL decrease rate in RPP-PLAN-55113, Rev 1, was also incorrect. The tank SX-102 ILL is actually increasing due to not yet being stabilized. The apparent tank SX-102 decrease rate was due to using a less than optimum neutron scan characteristic for selection of the ILL.

The possible variation in the evaporation rate, volumetric change rate, and tank headspace relative humidity for the remaining 12 tanks is addressed in the following subsections.

5.1 Evaporation Rate Variation

The tank evaporation rate depends upon the following variables:

- Ambient temperature, pressure, and relative humidity
- Tank headspace air temperature
- Tank headspace relative humidity
- Tank breathing rate
- How a tank breathing rate differs from a once-through active ventilation process with its effect on water vapor condensing out of headspace air before the air reaches the atmosphere.

Ambient conditions are assumed the same as measured at the HWS. While local conditions at each tank can vary slightly from at the HWS, and the HWS data used is hourly not continuous, any errors in using the HWS are assumed to be minor and should cancel each other out over three years' worth of data.

The tank headspace air temperature is based upon a regression line formula for each tank, which is in turn dependent upon the accuracy of the tank thermocouple used and the degree of variation of the data over the years used for the regression line. The tank thermocouples themselves cannot be calibrated since they are located inside pipes inserted into the waste, but it is assumed that the tank thermocouple data is reasonably accurate as the data points read about as expected and show the same nominal 60 to 70°F temperature range for tanks with low heat generation rate. It is also assumed that variations in the headspace temperature in comparison to the regression line formula will cancel out over the period of evaporation calculations.

Appendix A, Section A.4 explains the derivation of breathing rate estimates. The breathing rate estimates are based upon extrapolation of results from 13 tracer gas tests made in the 1990s. There was a significant difference between the results from A and AX tank farms and the results from other tanks, and no breathing rate tests were performed in 20 ft. diameter tanks. Information presented in Appendix A indicates atmospheric pressure variation may not have a major impact on tank breathing rate. See Appendix A for further discussion of tank breathing rates.

How condensation during a tank breathing process differs from a once-through active ventilation system was estimated conservatively. In an active ventilation system there should be minimal condensation until the ventilated air leaves the tank and is above ground. For a breathing tank it is conservatively assumed that the air leaving the tank headspace and entering the bottom of the

breather filter (in the process of leaving the tank), and the ambient air entering the top of the breather filter (in the process of entering the tank) are mixed, and any water vapor remaining at 100% relative humidity for the air mixture is returned to the tank. This assumption should overestimate the quantity of water returned to the tank at higher tank headspace relative humidities, resulting in an underestimation of the tank evaporation rate.

5.2 Liquid Change Rate Variation

The tank liquid loss rate depends upon the following variables:

- Accuracy of ILL or SL data used
- Assumed fraction of a tank surface that is liquid
- Assumed tank waste porosity

The tank ILL and SL data are assumed accurate since the instruments used are routinely calibrated. The most important data attribute is repeatability so that trends can be observed. It is assumed the data are acceptable for this purpose. For several tanks (A-102, SX-102, and potentially SX-105) the fact that the data were not acceptable for use in estimating level change rates was determined during preparation of this document. It is assumed that for the remaining tanks if there were any significant accuracy problems they would have been noted.

The assumed fraction of a tank surface that is liquid is based upon engineering judgment after evaluating photos or video images, interpreting data and reviewing interim stabilization documentation and BBI information. Only four of the 14 tanks were assumed to have a fraction of the surface being liquid. If the fraction of the waste surface that is assumed to be liquid is underestimated the liquid change rate from the tank is underestimated. The basis for the assumed liquid surface fraction is provided in each section. For the tanks assumed to have a zero percent liquid surface the basis is defensible for each tank, e.g., the ILL is significantly below the SL or an image shows zero liquid present. For the four tanks with fraction of surface level being liquid it is believed the assumed liquid fractions are reasonable.

Variation in the waste porosity represents the largest source of error in estimation of the liquid change rate. The actual waste porosity values are unknown, but waste porosity was calculated for each tank which underwent saltwell pumping. These values were revised and updated in RPP-5556. The porosity values in RPP-5556 were used in this document where available for consistency with other documentation. Where justified, or where RPP-5556 did not provide a porosity for the waste in a tank, an alternate value was used as stated in the evaluation.

It is assumed that the porosity is constant, but it is not. The porosity is higher near the top of the waste and lower near the bottom. There is no formula for a variable porosity with depth, an average value is used. The porosities used are primarily from interim stabilization data. The higher the porosity value used the more conservative the liquid change rate estimate is.

5.3 Headspace Relative Humidity Variation

The assumed current tank headspace relative humidity is based upon water vapor data from headspace samples taken in the 1994 to 1998 time period, with allowance made for changes in tank headspace temperature and tank conditions (e.g., if the tank was saltwell pumped in the intervening period to remove supernatant liquid). These allowances are discussed in Appendix A, Section A.6. The impact that a change in the relative humidity can have on the evaporation rate for each tank is readily seen on the evaporation rate plot for each tank, e.g.,

Figure 4-8 shows the assumed current tank headspace relative humidity for tank A-106 of 50%, it can be seen from the plot that the relative humidity could decrease to 27% before the evaporation rate would meet the estimated liquid change rate.

6. Conclusions

The conclusions of this report are:

1. For seven tanks with LOWs, A-106, AX-101, AX-103, BY-108, S-104, SX-105, and U-108, there is no evidence for a tank leak, assuming the parameters and assumptions used for estimating the liquid loss and evaporation rates reflect tank conditions.
2. Tank TY-103 appears to have a stabilized ILL, but there was an apparent intrusion into this tank in the 1998 to 2003 period. Based upon the intrusion stopping, there is no evidence for a tank leak.
3. There is no evidence for a leak from tank SX-102. The ILL in SX-102 is not yet stabilized. A re-evaluation of the neutron scan data showed the ILL in this tank is not decreasing, it is increasing due to downward liquid movement within the tank.
4. For three of the five tanks with no LOWs, TX-108, TY-101, and U-104, the estimated evaporation rate exceeds the minimum estimated liquid loss rate and the rough approximated loss rate. There is no basis to assume a leak from any of these tanks.
5. For one of the five tanks without an LOW, A-102, the SL decrease rate for this tank in RPP-PLAN-55113, Rev 1 was inaccurate. A review of the calibration work packages for this tank showed the decrease was due to ENRAF gauge problems. There is no evidence for a leak from tank A-102.
6. The last tank without an LOW is SX-114. The relative humidity (RH) measurement obtained in the tank in 1997 showed the water vapor concentration was less than detectable in the tank headspace. Tank SX-114 is by far the hottest tank in this evaluation, at approximately 40,000 BTU/hr, with this heat load and the ~160+ºF waste temperature there is likely little liquid left in the tank to leak. There is no basis to assume a leak from tank SX-114.

7. References

CLO-WO-06-00220, 241-SX, 114 ENRAF INSPECTION, completed January 23/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-06-000616, 241-TX, 108 ENRAF INSPECTION, completed 5/11/2006, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-06-001744, 241-TY, 101 ENRAF INSPECTION, completed 11/2/2006, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-06-001862, 241-U, 104 ENRAF INSPECTION, completed January 25/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-06-002212, 241-TX, 108 ENRAF INSPECTION, completed January 8/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-07-1108, 241-TY, 101 ENRAF INSPECTION, completed 8/7/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-07-1449, 241-SX, 114 ENRAF INSPECTION, completed 10/16/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-07-1760, 241-U, 104 ENRAF INSPECTION, completed 11/19/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-07-1767, 241-TX, 108 ENRAF INSPECTION, completed 11/8/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

CLO-WO-08-0557, 241-TY, 101 ENRAF CAL, completed 5/28/2008, CH2M Hill Hanford Group, Inc., Richland, Washington.

Excel file *BP Correlation with DB Connect*, SVF-1002, June 27, 2005, CH2M HILL Hanford Group Inc. and Lockheed Martin Services Inc., Richland Washington.

HNF-EP-0182, 2013, *Waste Status Summary for Month Ending April 30, 2013*, Revision 301, Washington River Protection Solutions LLC, Richland, Washington.

HNF-SD-RE-TI-178, 2007, *Single Shell Tank Interim Stabilization Record*, Rev 9a, CH2M Hill Hanford Group, Inc., Richland, Washington.

RPP-5556, 2000, *Updated Drainable Interstitial Liquid Volume Estimates for 119 Single-Shell Tanks Declared Stabilized*, Rev 0, CH2M Hill Hanford Group, Inc., Richland, Washington.

RPP-40545, 2012, *Quantitative Assumptions for Waste Retrieval Planning*, Revision 2, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-42740, *2009 Auto TCR for Tank 241-A-102*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-42744, *2009 Auto TCR for Tank 241-A-106*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-42915, *2009 Auto TCR for Tank 241-AX-101*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-42917, *2009 Auto TCR for Tank 241-AX-103*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-42003, *2009 Auto TCR for Tank 241-BY-108*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43047, *2009 Auto TCR for Tank 241-S-104*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43057, *2009 Auto TCR for Tank 241-SX-102*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43060, *2009 Auto TCR for Tank 241-SX-105*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43069, *2009 Auto TCR for Tank 241-SX-114*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43182, *2009 Auto TCR for Tank 241-TX-108*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43193, *2009 Auto TCR for Tank 241-TY-101*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43195, *2009 Auto TCR for Tank 241-TY-103*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43238, *2009 Auto TCR for Tank 241-U-104*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-43242, *2009 Auto TCR for Tank 241-U-108*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-54964, 2013, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-PLAN-55112, 2013, *September 2012 Single-Shell Tank Waste Level Increase Evaluation Plan*, Revision 1, Washington River Protection Solutions LLC, Richland, Washington.

RPP-PLAN-55113, 2013, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan*, Revision 1, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-55265, 2013, *Evaluation of Tanks 241-B-203 and 241-B-204 Level Data and In-Tank Video Inspections*, Rev 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-55264, 2013, *Evaluation of Tanks 241-T-203 and 241-T-204 Level Data and In-Tank Video Inspections*, Rev 0, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-55263, *Evaluation of Tank TY-105 Level Data and In-Tank Video Inspection*, Rev 0, Washington River Protection Solutions LLC, Richland, Washington

TFC-WO-08-0411, *241-TX, 108 ENRAF CAL*, completed 9/30/2008, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-08-0418, *241-U, 104 ENRAF CAL*, completed 8/21/2008, CH2M Hill Hanford Group, Inc., Richland, Washington.

TFC-WO-08-0612, *241-SX, 114 ENRAF CAL*, completed 9/23/2008, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-08-1575, *241-TY, 101 ENRAF CAL*, completed 2/12/2009, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-09-0892, *241-A, 102 ENRAF CALIBRATION*, completed 4/23/2009, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-09-0902, *241-SX, 114 ENRAF CAL*, completed 7/16/2009, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-09-1359, *241-U, 104 ENRAF CAL*, completed 5/19/2009, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-09-1369, *241-TX, 108 ENRAF CAL*, completed 8/6/2009, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-09-1372, *241-TY, 101 ENRAF CAL*, completed 8/10/2009, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-09-3619, *241-A, 102 ENRAF CALIBRATION*, completed 10/15/09, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-10-0243, *241-U, 104 ENRAF CAL*, completed February 16/2010, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-10-0425, *241-SX, 114 ENRAF CAL*, completed 7/14/2010, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-10-0958, *241-TX, 108 ENRAF CAL*, completed 7/29/2010, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-10-0959, *241-TY, 101 ENRAF CAL*, completed 8/5/2010, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-10-2111, *241-A, 102 ENRAF CALIBRATION*, completed 10/13/2010, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-10-4381, *241-TY, 101 ENRAF CAL*, completed 6/28/2011, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-11-0160, *241-U, 104 ENRAF CA*L, completed 2/23/2011, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-11-2013, *241-SX, 114 ENRAF CAL*, completed 10/23/2011, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-11-2020, *241-TX, 108 ENRAF CAL*, completed 7/21/2011, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-11-2099, *241-A-102 REPL ENRAF DRUM & WIRE*, completed 6/27/2011, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-11-3559, *241-A, 102 ENRAF CALIBRATION*, completed 6/29/2011, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-12-0069, *241-U, 104 ENRAF CAL*, completed 2/13/2012, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-12-1556, *241-A, 102 ENRAF CALIBRATION*, completed 5/17/2012, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-12-1945, *241-SX, 114 ENRAF CAL*, completed 6/20/2012, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-12-2012, *241-TX, 108 ENRAF CAL*, completed 7/16/2012, Washington River Protection Solutions LLC, Richland, Washington.

TFC-WO-13-0255, *241-U, 104 ENRAF CAL*, completed 2/5/2013, Washington River Protection Solutions LLC, Richland, Washington.

TWINS, *Tank Waste Information Network System*, database available on the Hanford Local Area Network at https://twins.labworks.org/twinsdata/Forms/About.aspx

WFO-WO-06-2752, *241-A, 102 ENRAF INSPECTION*, completed 2/6/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

WFO-WO-07-2477, *241-A, 102 ENRAF INSPECTION*, completed 10/3/2007, CH2M Hill Hanford Group, Inc., Richland, Washington.

WFO-WO-08-1456, *241-A, 102 ENRAF CALIBRATION*, completed 7/31/2008, CH2M Hill Hanford Group, Inc., Richland, Washington.

WHC-MR-0132, 1990, *A History of The Hanford 200 Area Tank Farms*, Revision 0, Westinghouse Hanford Company, Inc., Richland, Washington.

WHC-SD-WM-TI-689, 1996, *Waste Status and Transaction Record Summary for the Southeast Quadrant of the Hanford 200 Area*, Revision 1, Westinghouse Hanford Company, Inc., Richland, Washington.

WRPS-1203139 R1, *Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Suspect Intrusion Evaluation Plan to The U.S. Department of Energy, Office of River Protection*, Letter, September 13, 2012, C. A. Simpson, Washington River Protection Solutions LLC, to S. E. Bechtol, U.S. Department of Energy, Richland, Washington.

WRPS-1301005, *Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Level Decrease Evaluation Plan to The U.S. Department of Energy, Office of River Protection*, Letter, March 18, 2013, C. A. Simpson, Washington River Protection Solutions LLC, to S. E. Bechtol, U.S. Department of Energy, Richland, Washington.

APPENDIX A

ESTIMATION OF SELECTED SINGLE-SHELL TANK EVAPORATION RATES

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ACRONYMS

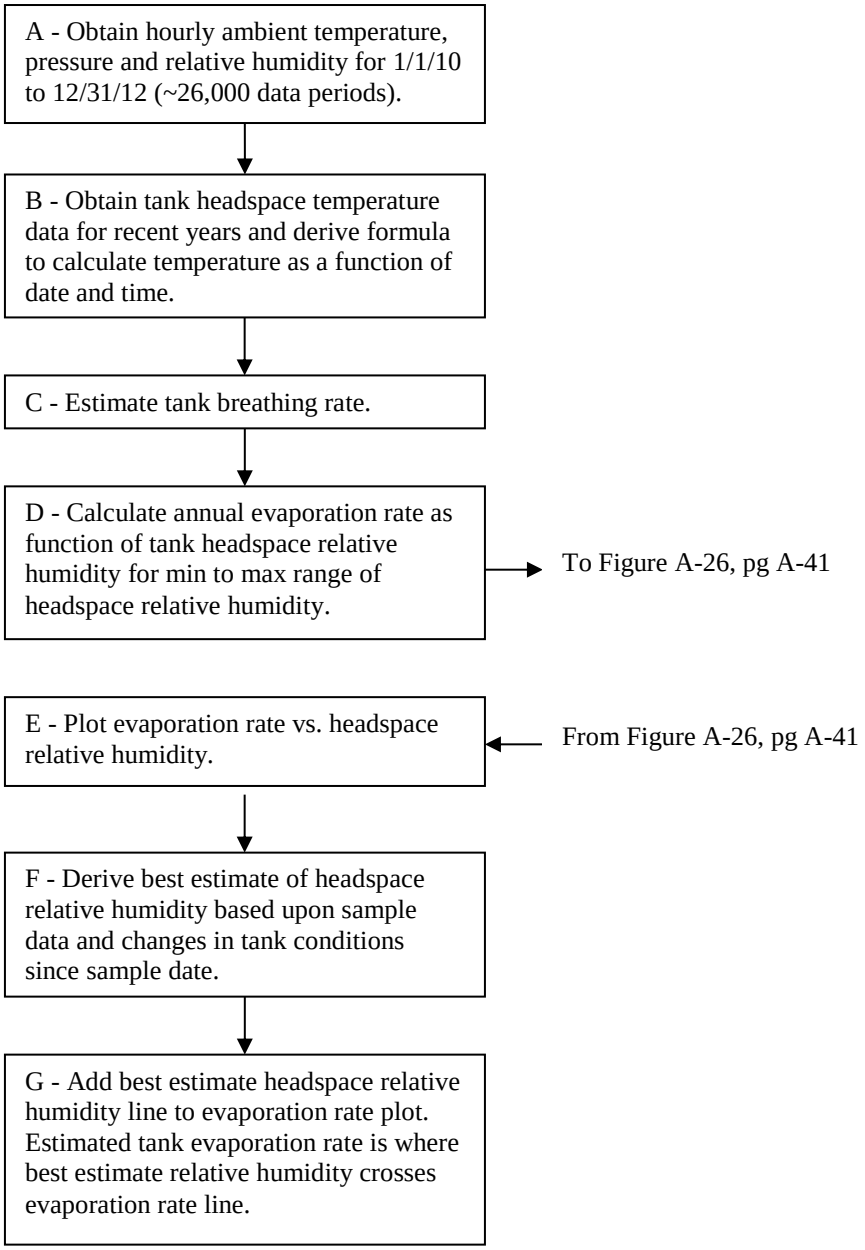
cfm	cubic feet per minute
HRR	High Resolution Resistivity
HWS	Hanford Weather Station
HS	headspace
ILL	interstitial liquid level
RH	relative humidity
SST	single-shell tank
TWINS	Tank Waste Information Network System
VP	vapor pressure

A.1 Introduction

The main body of this document provides an evaluation of the level decrease data in 14 of the 20 tanks recommended for evaluation in RPP-RPT-55113, 2013, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan*, Revision 1 (WRPS-1301005). Level decrease evaluations for the remaining six tanks are provided in separate documents. Appendix A provides the evaporation rate estimates for all 20 tanks.

Figure A-1 is a flowchart for calculating the estimated annual evaporation rate for each tank.

Figure A-1 Flowchart for Evaporation Rate Estimates



The rationale for each of these steps is explained below.

A – (Section A.2) Ambient air conditions are required to calculate the concentration of water vapor in the air coming into each tank. While there can be small variations in atmospheric conditions between tanks and tank farms, it is reasonable to use the site Hanford Site Weather Station data as indicative of the air entering each tank. Data were selected for the 3-year period 2010 through 2012 (and the evaporation mass results divided by 3) to minimize the impact of off-normal conditions occurring in any single year.

B – (Section A.3) Tank headspace air conditions are required to calculate the concentration of water vapor in the air leaving each tank and entering the breather filter riser (or other openings to the atmosphere). Tank headspace pressure is assumed equal to the ambient air pressure, and tank headspace relative humidity is one of the variables used in the calculations. Hourly tank headspace temperatures are not available, but periodic data are for 19 of the 20 tanks. The highest elevation thermocouple reading for each tank was assumed to represent the temperature of the headspace air entering the breather filter riser, or other opening to the atmosphere. The periodic data were plotted for each of the 19 tanks and a best-fit polynomial regression line through the data calculated to provide an equation to estimate a tank headspace temperature at any specific date and time.

C – (Section A.4) The concentration of water vapor in the air times the air flow rate gives the mass of water coming into or out of the tank. The single-shell tanks (SST) are ventilated to the atmosphere through breather filters (and some other openings for selected tanks). Gas injection tests were conducted for a number of tanks in the 1996 to 1998 time period and the results used to calculate breathing rates for those tanks. Only one of the tanks with a gas injection test was among the 20 tanks needing an evaporation rate estimate for this document, but the 1996 to 1998 results from all the tanks were sufficient to enable breathing rates to be estimated for the 20 tanks.

D – (Section A.5) Evaporation rates were calculated for the entire practical range of relative humidity for each tank. The calculations are described in detail in Section A.5, and include the following general steps:

1. A value is assumed for the relative humidity in a tank headspace.
2. The mass of water leaving the headspace at that relative humidity and entering the breather filter riser (or other opening) is calculated for the data period. There are approximately 26,300 data periods.
3. The mass of dry air in the gas leaving the headspace is calculated. This value is required as it is subsequently set equal to the mass of dry air entering the tank headspace.
4. The mass of water entering the tank headspace from the atmosphere is calculated.
5. Since the tanks are breathing rather than being exhausted the incoming and outgoing air is mixed at times. When mixed, water vapor can condense out of the air leaving the headspace if the headspace temperature is greater than the ambient air temperature. This is accounted for by:
    a. Calculating the maximum possible water vapor content of air leaving the tank at an average temperature equal to the average of the tank headspace air and the ambient air, and,

   b. If the maximum possible value is greater than the mass of water calculated to exit the headspace, the amount of water assumed to return to the tank as condensate is zero, or,
   c. If the maximum possible value is less than the mass of water calculated to exit the headspace, the difference between the two is assumed to return to the tank as condensate.
6. The net water evaporated from an SST in the period is:

$$\begin{aligned} &net\ mass\ of\ water\ evaporated\ in\ period \\ &\qquad = mass\ of\ water\ leaving\ headspace\ to\ breather\ filter\ riser \\ &\qquad - mass\ of\ water\ entering\ headspace\ from\ atmosphere \\ &\qquad - mass\ of\ water\ returned\ to\ tank\ as\ condensate \end{aligned}$$

7. The calculations are repeated for all data periods, the net mass of water evaporated on an annual basis is equal to the sum of all individual data periods divided by three. This value is the calculated annual evaporation rate for the tank headspace relative humidity assumed in the first step.
8. These calculations are repeated for different headspace relative humidities until evaporation rate values are available to cover the practical range of relative humidity for each tank.

E – (Section A.5) A plot of evaporation rate vs. tank headspace relative humidity is prepared for each tank.

F – (Section A.6) An estimated average tank headspace relative humidity value is derived for each tank. Tank headspace samples were obtained in 107 of the 149 SSTs during the 1994 to 1997 time period using heated vapor probes or in-tank sampling cartridges. Relative humidities were calculated for each tank from the sample water vapor concentrations. Vapor samples were obtained from 15 of the 20 tanks for which evaporation calculations are required. Tank temperature and liquid levels were compared between when the samples were taken and the present, and a current tank headspace relative humidity estimated for the 15 tanks. Data are available from tanks with similar conditions to the five unsampled tanks so that a current relative humidity could be estimated for each tank.

G – (Main body, Section 3.1.5, 3.2.5, etc.) A line showing the estimated average tank headspace relative humidity for the tank is added to the evaporation rate vs. relative humidity plot from E above. The estimated average tank headspace relative humidity line crosses the evaporation rate line at the estimated evaporation rate for that tank.

Energy is required to evaporate water to a vapor, the more energy from radioactive decay within the waste the greater the evaporation rate will be, providing all other factors are equal. For tanks with negligible heat generation rate the energy for evaporation comes solely from the latent heat of the waste, surroundings, and incoming air. Estimating an evaporation range from an SST for this document requires the following:

- Temperature of ambient air into the tank
- Relative humidity (RH) of ambient air into the tank
- Ambient air pressure
- Temperature of tank headspace air leaving the tank
- RH of tank headspace air leaving the tank

- Tank headspace air pressure
- Air flow rate into and out of the tank
- Accounting for return of condensation from air leaving the tank headspace

If there were an exhauster on an SST with the same capacity as the effective tank breathing rate the estimation of an evaporation rate would be straightforward – with air entering one (or more) locations and leaving by another location evaporation is equal to water vapor out minus water vapor in. However, the tanks are not exhausted and thus do not have separate air in and out locations, but do 'breathe' to the atmosphere. The effective breathing rates for selected SSTs were measured in the mid to late 1990s using gas injection tests.

The term 'breathing rate' or 'effective breathing rate' is undefined. A tank may have an effective breathing rate of 2 cubic feet per minute (cfm), but it is unknown if the tank breathes out for half the time at 4 cfm and then breathes in at 4 cfm, or the tank breathes in and out at different rates but is also stagnant for a time, or if the air exchange is a constant mixing process. Regardless of how the breathing process works, wherever the incoming and outgoing air mixes there is the potential for the mixture to become saturated and excess water vapor condense and return to the tank or be removed as a mist. For this document the assumption was made that all the incoming and outgoing air mixes and that if the calculated relative humidity of the mixture reaches 100% all additional water vapor in the mixture condenses and is sent to the tank as condensate. This should underestimate the evaporation rate for a tank and thus be conservative, especially for A and AX farm tanks - see Section A.5.

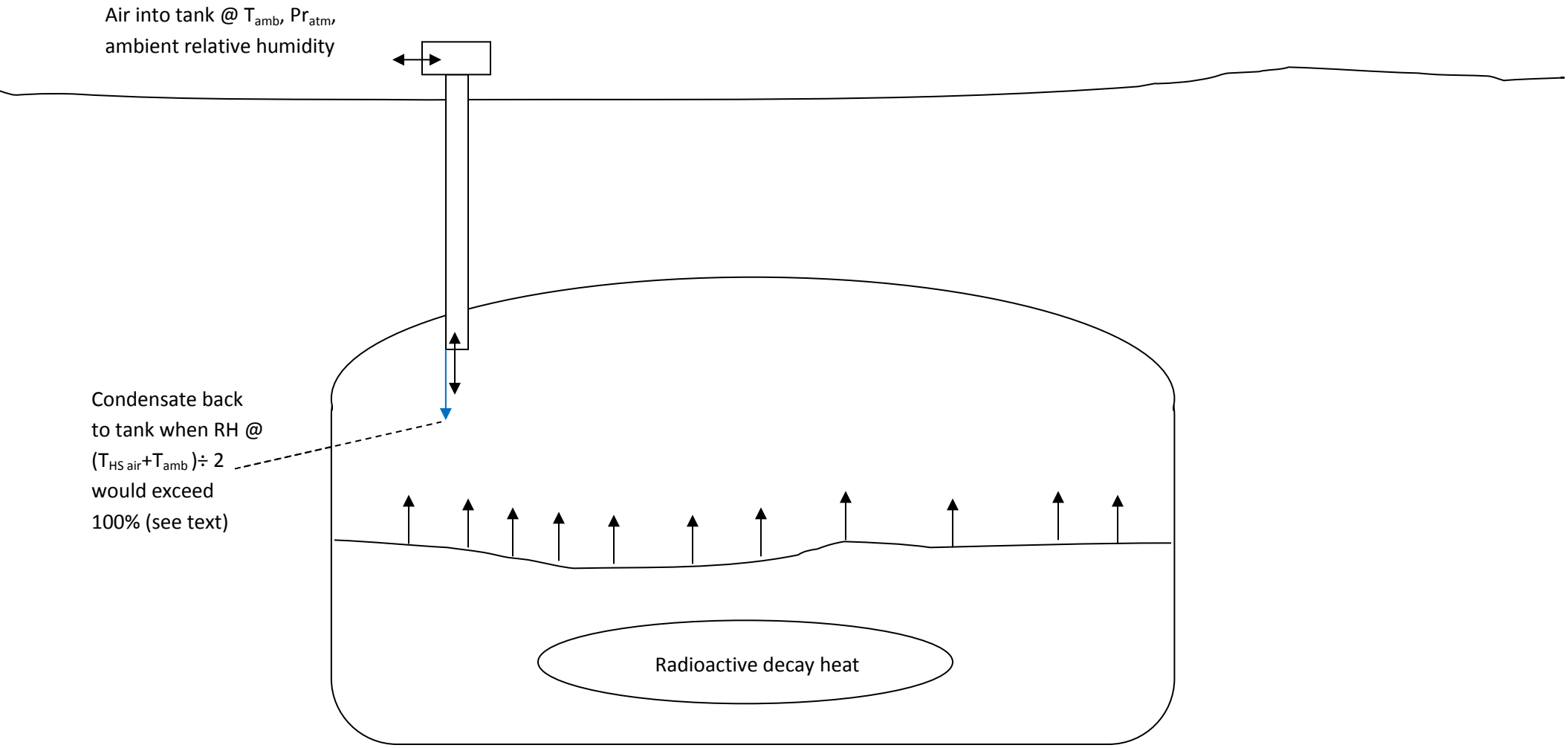
Figure A-2 is a sketch of the methodology for estimating SST evaporation rates in this document. For simplicity the mixing or incoming and outgoing air is shown in Figure A-2 as occurring in the breather filter riser, but it can occur in any opening where the incoming and outgoing air can mix.

The evaporation methodology makes the following assumptions:

1. The concentration of water vapor entering the tank is equal to that present in ambient air at the ambient air temperature, pressure, and relative humidity.
2. The concentration of water vapor leaving the tank headspace and entering the breather filter riser (or other opening) is equal to that present in the tank headspace air at the tank headspace air temperature, pressure, and relative humidity.
3. The tank breathes at the effective breathing air rates derived in Section A.4.
4. All incoming and outgoing air mixes equally in the breather filter riser (and in any other paths) and if the relative humidity of the air mixture exceeds 100% all water in excess of what would exist at 100% relative humidity in the mixture returns to the tank as condensate.
5. The mass of water evaporated is equal to the mass of water vapor leaving the tank minus the mass of water vapor entering the tank minus the mass of water vapor returned to the tank as condensate.
6. No transient conditions exist in a tank. The breathing and evaporation process is at equilibrium except for that caused by seasonal changes.
7. The breathing rates derived in Section A.4 are valid for estimating water vapor removal.

This process eliminates estimation of energy balances and mass transfer rates.

Figure A-2 Schematic of Assumed Evaporation Process



The tank breathing rates derived in Section A.4 are based upon 14 tracer gas injection tests conducted in 1996 to 1998 that measured the change in He or SF_6 gas concentrations in a tank headspace after measured quantities were injected into the tank headspace. Most air exchange for a tank is assumed to be with the atmosphere via the breather filter but some exchange can occur with tanks connected via cascade lines. While He or SF_6 would not be expected to exist in an adjacent tank, water vapor would. So, using breathing rates based upon He or SF_6 concentration change to estimate evaporation rates could overestimate the actual removal of H_2O from a tank since the rates would not account for H_2O added to a headspace from an adjacent tank.

Tank breathing is postulated to result from atmospheric pressure changes, gas temperature differences, gas diffusion, and the Bernoulli effect when wind passes by the breather filter opening. Using tracer gas based breathing rates for tank evaporation rate calculations, excluding the impact of connecting vent lines in A and AX tank farms on the high breathing rates for those tanks, is assumed to not be a significant source of error for this document for several reasons:

- Tank breathing caused by atmospheric pressure changes would affect connected tanks the same, there would be no driving force to cause air to go from one tank to another by atmospheric pressure changes.
- Tank breathing via cascade lines due to gas temperature differences between adjacent tanks should be low because the cascade lines are horizontal and about 28 ft. long, so there wouldn't be as much driving force present as for a vertical connection. Some air exchange could occur with interconnected tanks if a cascade line was not plugged (a number of them are partially or fully plugged) but should not have a major impact on the tank breathing rate calculation. Table A-1 lists the maximum tank headspace temperatures during the gas injection tests for each of the test tanks and the tanks to which they are connected via a cascade line. Only one tank, C-107, had a temperature difference greater than 10°F from a cascade connected tank, C-108. The temperature difference here was 38°F, yet the breathing rate from Table A-5 for C-107 was the lowest of any of the test tanks.
- Tank breathing caused by a Bernoulli effect from wind passing by a breather filter should affect connected tanks in a similar fashion. There should be little driving force to cause air to go from one tank to another unless breather filter orientation to the wind flow direction was significantly different for adjacent tanks.
- Tank breathing via diffusion between adjacent tanks, excluding those connected by underground ducting in A and AX farms, should not be significant because the cascade lines are horizontal and about 28 ft. long. Some air exchange could occur with interconnected tanks via non-plugged cascade lines but this is expected to have a minor impact on the breathing rate calculation compared to diffusion via a nominal 10 ft. long vertical breather filter riser.

The impact of connecting vent lines in A and AX tank farms on the A and AX tank breathing rates is discussed in Section A.4.

Table A-1 Headspace Temperatures for Interconnected Tanks during Tracer Gas Tests[1,2]

Tank	Max Headspace Temperature (°F)	Cascade Inlet Line from Tank	Max Headspace Temperature (°F)	Cascade Outlet Line to Tank	Max Headspace Temperature (°F)
A-101	97	none	NA	A-102 (seal loop filled?)	90
AX-102	NA	none	NA	none	NA
AX-103	NA	none	NA	none	NA
BY-105	72	BY-104	72	BY-106	71
C-107	101	none	NA	C-108	63
S-102	85	S-101	87	S-103	79
TX-104	65	TX-103	67	none	NA
U-102	74	U-101	64	U-103	74
U-103 97-1	77	U-102	76	none	NA
U-103 97-2	79	U-102	77	none	NA
U-103 97-98	79	U-102	78	none	NA
U-105	79	U-104	no temp data	U-106	76
U-106	73	U-105	75	none	NA
U-111	71	U-110	73	U-112	62

[1] See Table A-5 for test dates.

[2] Temperatures from *Tank Waste Information Network System*, (TWINS) download, database available on the Hanford Local Area Network at https://twins.labworks.org/twinsdata/Forms/About.aspx.

The method of calculation for tank evaporation rates is described in Section A.5. Sections A.2 through A.4 provide the basis for the values used in the calculations.

A.2 Ambient Air Temperature, Pressure, and Relative Humidity

The hourly ambient air temperature, pressure, and relative humidity data for the calendar years 2010, 2011 and 2012 were obtained from the Hanford Weather Station (HWS) and saved as an Excel® file. Table A-2 is an excerpt for the first few entries to show the information.

Table A-2 Excerpt from 2010 to 2012 Hourly Hanford Weather Station Data Files[1]

Date	(PST)	T	RH	Press
1/1/2010	1	30	98	29.24
1/1/2010	2	30	97	29.23
1/1/2010	3	30	98	29.22
……				
12/31/2012	24	29	88	29.70

[1] From Excel files for selected 2010, 2011, and 2012 hourly weather data provided by HWS personnel, April 3, 2013 (HWS-2013)

There are 26,303 hourly entries from 1/1/2010 @0:00 to 12/31/2012 @23:00. The data were used as described in Section A.5 to calculate an evaporation quantity for each of the 26,303 periods.

A.3 Tank Headspace Temperatures

SST headspace temperature data were obtained from a TWINS download on November 30, 2012 for 19 of the 20 SSTs. Tank U-104 has no temperature data in TWINS going back to 1980. Per Appendix B, Table B-1, tank TY-101 is the 100 series tank with the closest calculated heat generation rate to U-104 so the tank TY-101 temperature data were used for U-104.

The highest elevation thermocouple in each of the 19 tanks was assumed representative of the headspace air leaving the tank. There is a paucity of SST headspace temperature data in recent years so for all tanks the temperature data from a number of years were assembled to get a quantity of data sufficient to establish an annual temperature cycle pattern. For some tanks the data were so sparse that the temperatures for several of the highest vapor space thermocouple points were averaged together. Table A-3 provides the date range and the number of thermocouple locations used for the tank temperatures for each tank.

Table A-3 Dates and Thermocouple Points Used for Tank Headspace Temperatures[1]

Tank	Date Range	Thermocouple Points Used	Data Points
A-102	2002 - 2012	12, 13, 14, 15, 16, 17, 18	137
A-106	1990 - 2006	16, 17, 18	95
AX-101	2007-2012	16	407
AX-103	2007-2010	6	405
B-203	2002 - 2012	10, 11	66
B-204	2002 - 2012	10, 11	66
BY-108	2002 - 2012	10	1,415
S-104	2002 - 2012	11	690
SX-102	2002 - 2012	6	1,916
SX-105	2002 - 2012	6	667
SX-114	2007 - 2012	8	903
T-111	2002 - 2012	11	1,797
T-203	2004 - 2012	11	1,148
T-204	2004 - 2010	11	1,147
TX-108	2002 - 2012	10	1,811
TY-101	2004 - 2012	14	1,807
TY-103	2004 - 2012	14	304
TY-105	2004 - 2012	11	1,807
U-104	no data available, assumed headspace temperature same as TY-101		
U-108	2002 - 2012	10	756

[1] From TWINS download on November 30, 2012.

The year date for each data point was then changed to 2012 to prepare a composite annual temperature history for the tank, and the temperature data plotted against the month and the day. Figures A-2 through A-20 provide the temperature plots. While it is logical to assume the temperatures in the warmer tanks will decline with time due to radioactive decay, the impacts were small for the date ranges used in this document. A 3rd degree polynomial regression line was calculated through the data points for each tank. This formula was subsequently used to calculate a tank headspace temperature for the tank for each of the 26,303 hourly data periods from 1/1/2010 @0:00 to 12/31/2012 @23:00.

Notes:

1. The temperature data for two tanks, SX-102 and SX-105, show some inconsistencies which are due to periodic operation of the SX tank farm exhauster, which last operated in 2005.
2. The regression line formulas for most tanks do not quite match between January 1 on the left side of the plots and December 31 on the right side. This is to be expected with the lack of complete data for every day of the year, the errors involved are not significant.
3. The constants in the regression line formulas are shown to 10 significant figures. The data behind the formula are obviously not known or accurate to this many decimal places; the number of digits is required for the Excel plot formulas to provide meaningful calculated temperature values because in Excel the x-axis dates are in the five digit range.

Figure A-3 Tank A-102 Annual Temperature Cycle

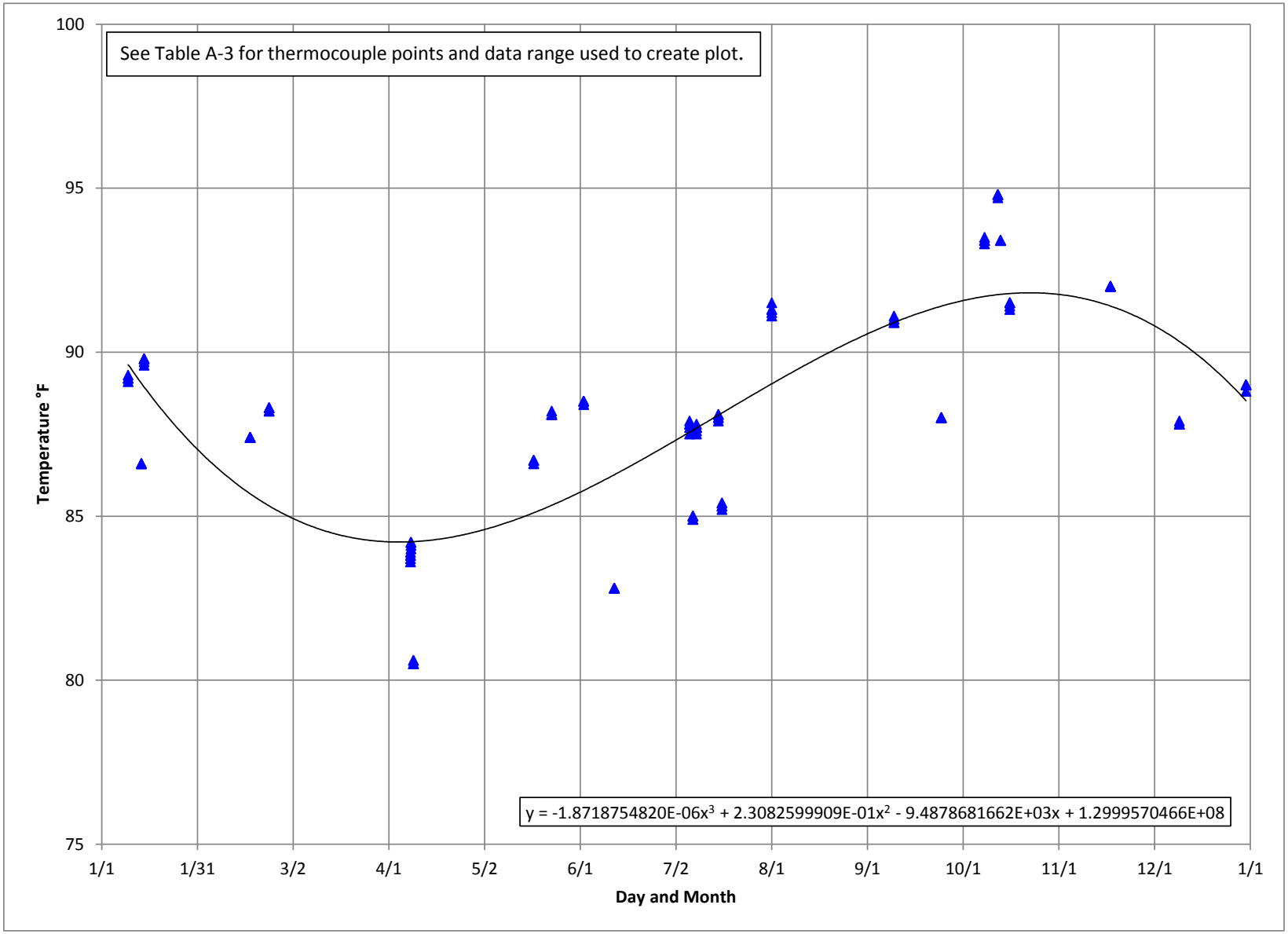


Figure A-4 Tank A-106 Annual Temperature Cycle

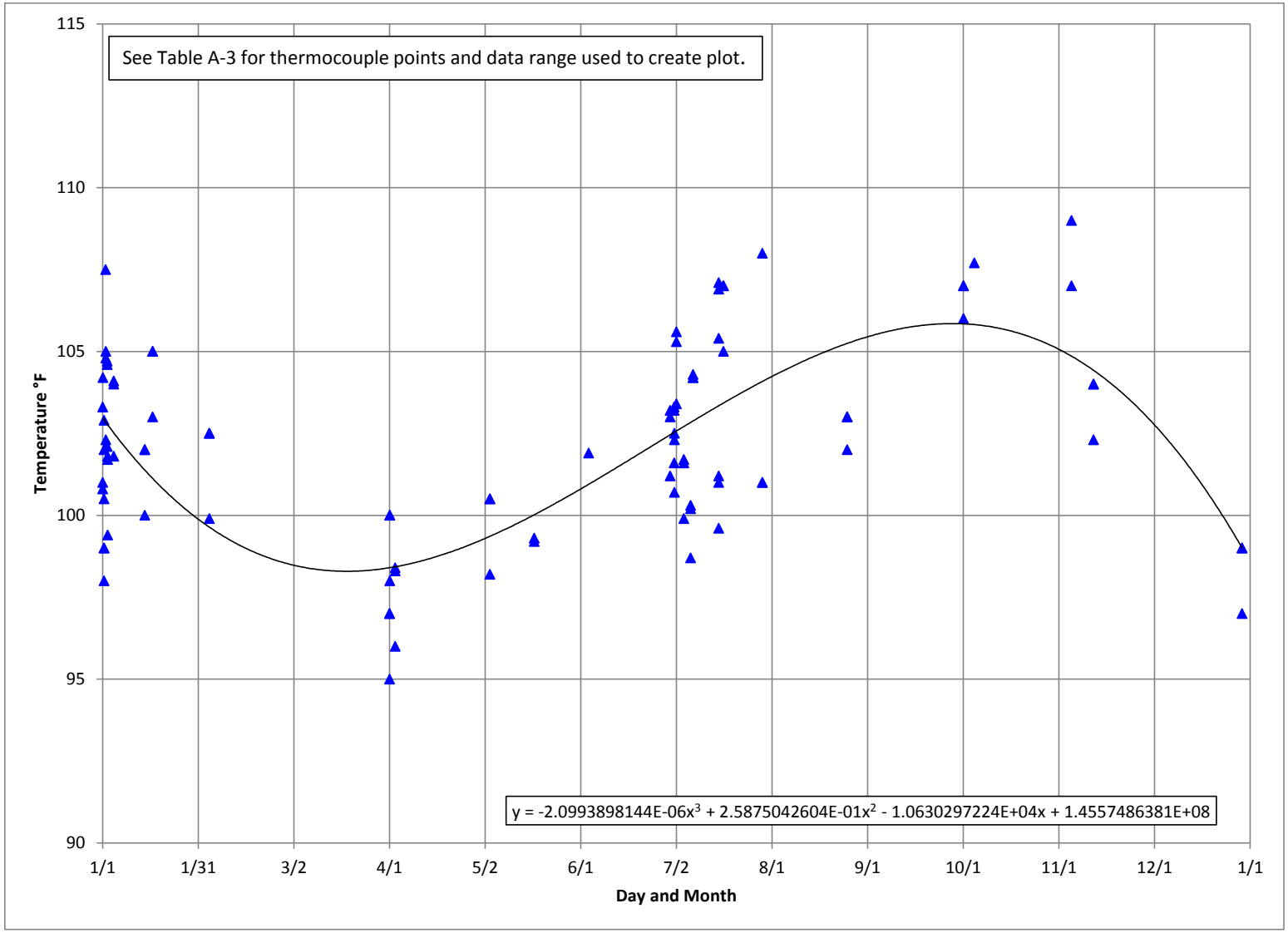


Figure A-5 Tank AX-101 Annual Temperature Cycle

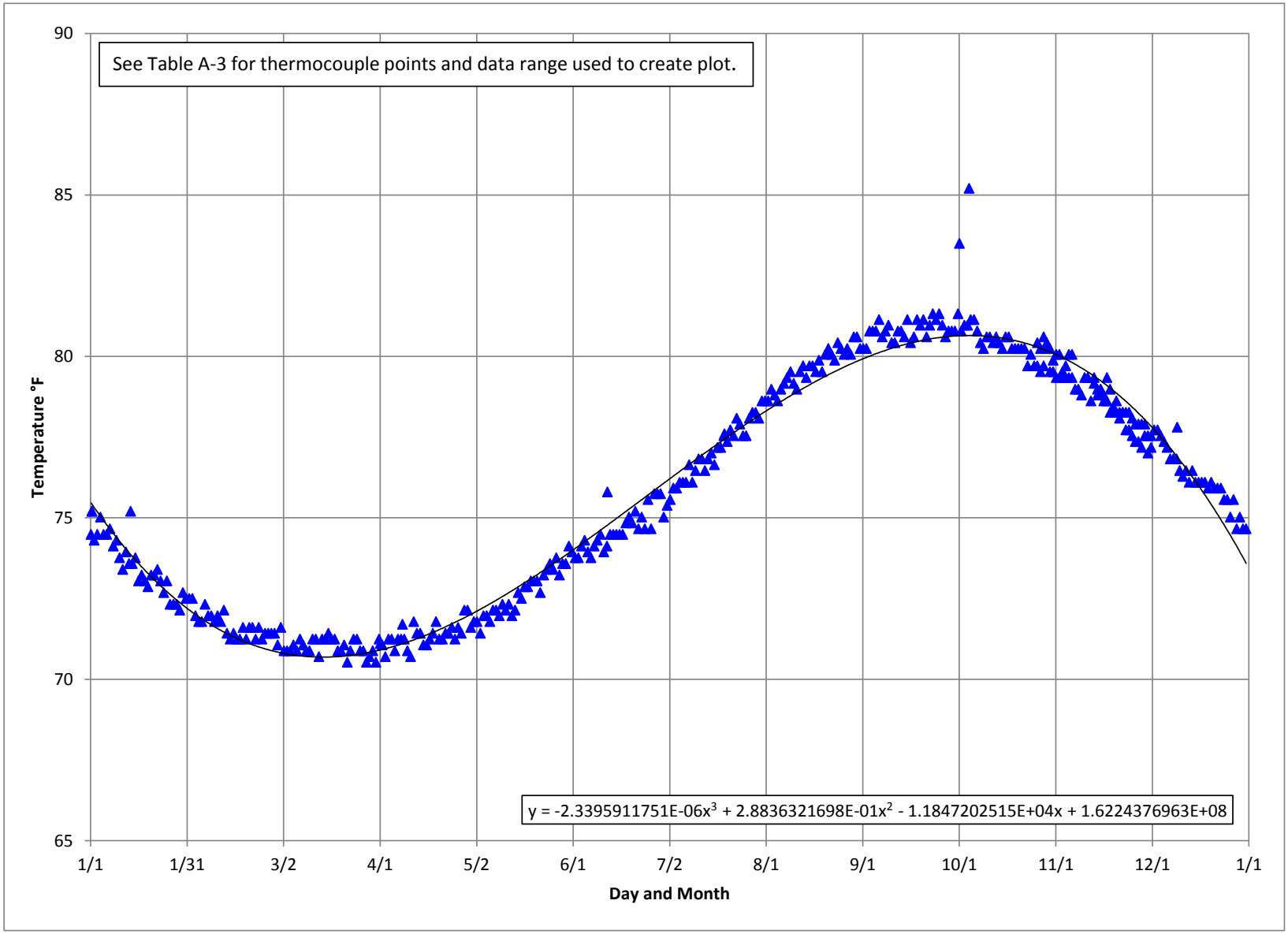


Figure A-6 Tank AX-103 Annual Temperature Cycle

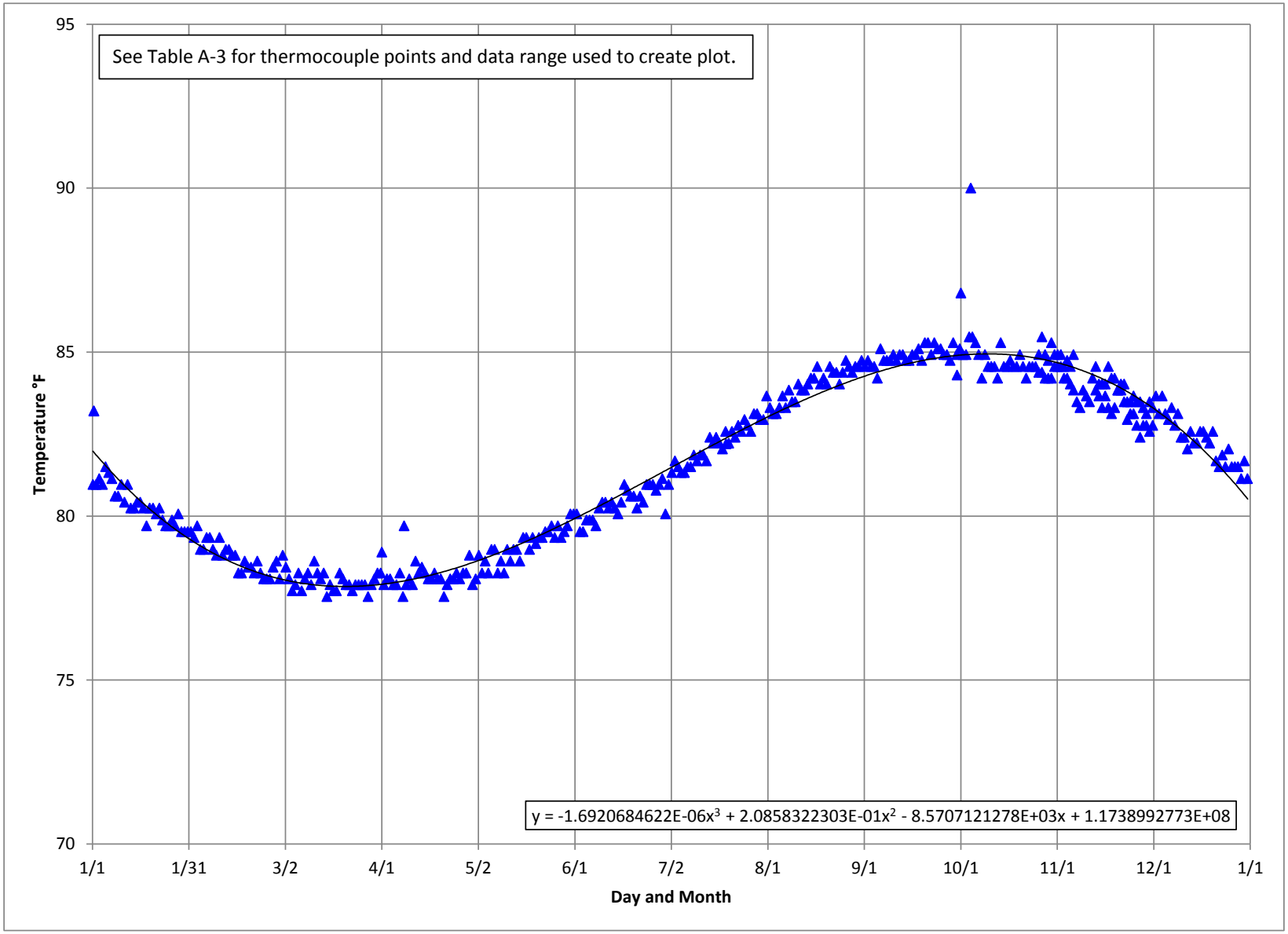


Figure A-7 Tank B-203 Annual Temperature Cycle

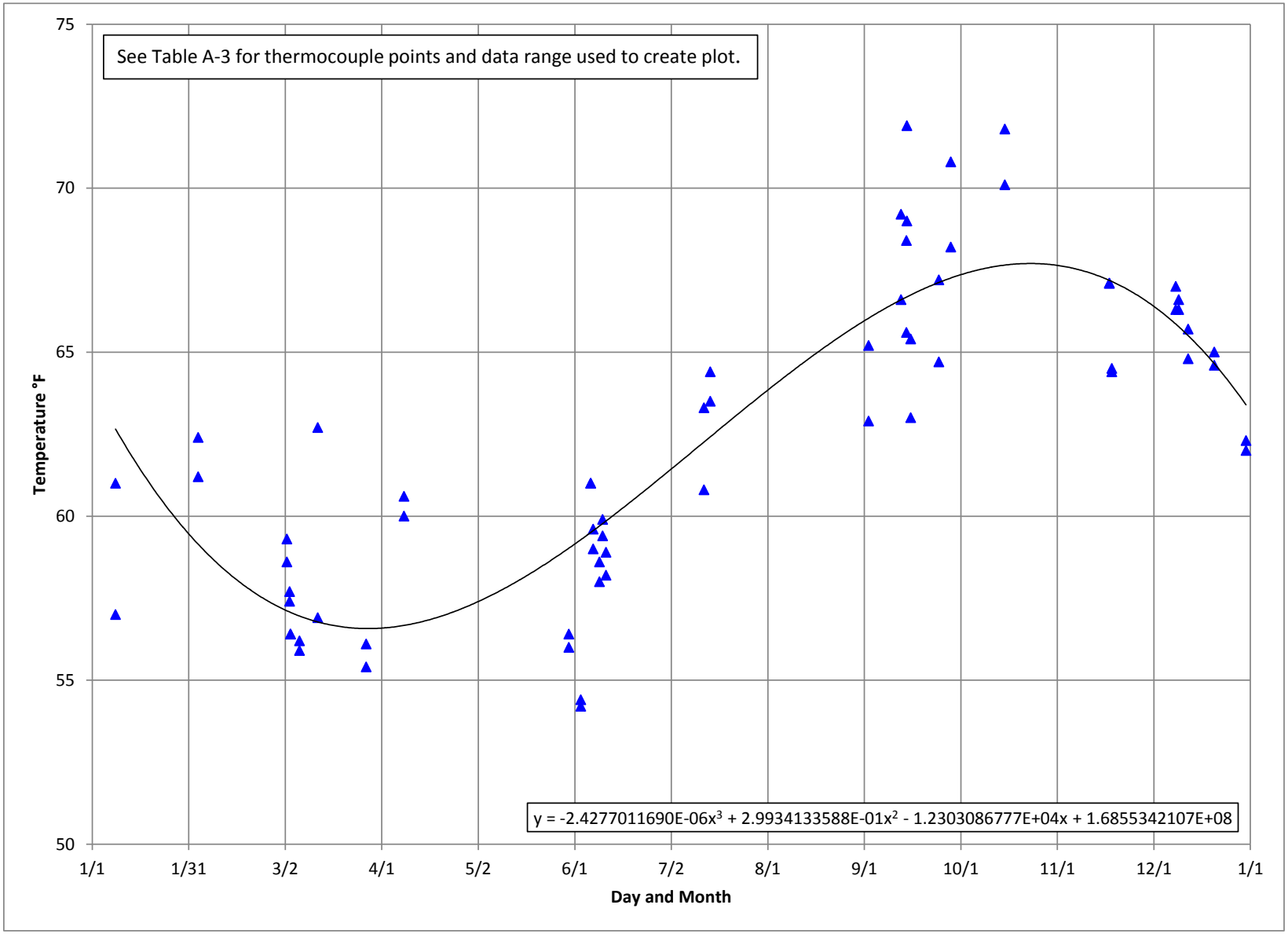


Figure A-8 Tank B-204 Annual Temperature Cycle

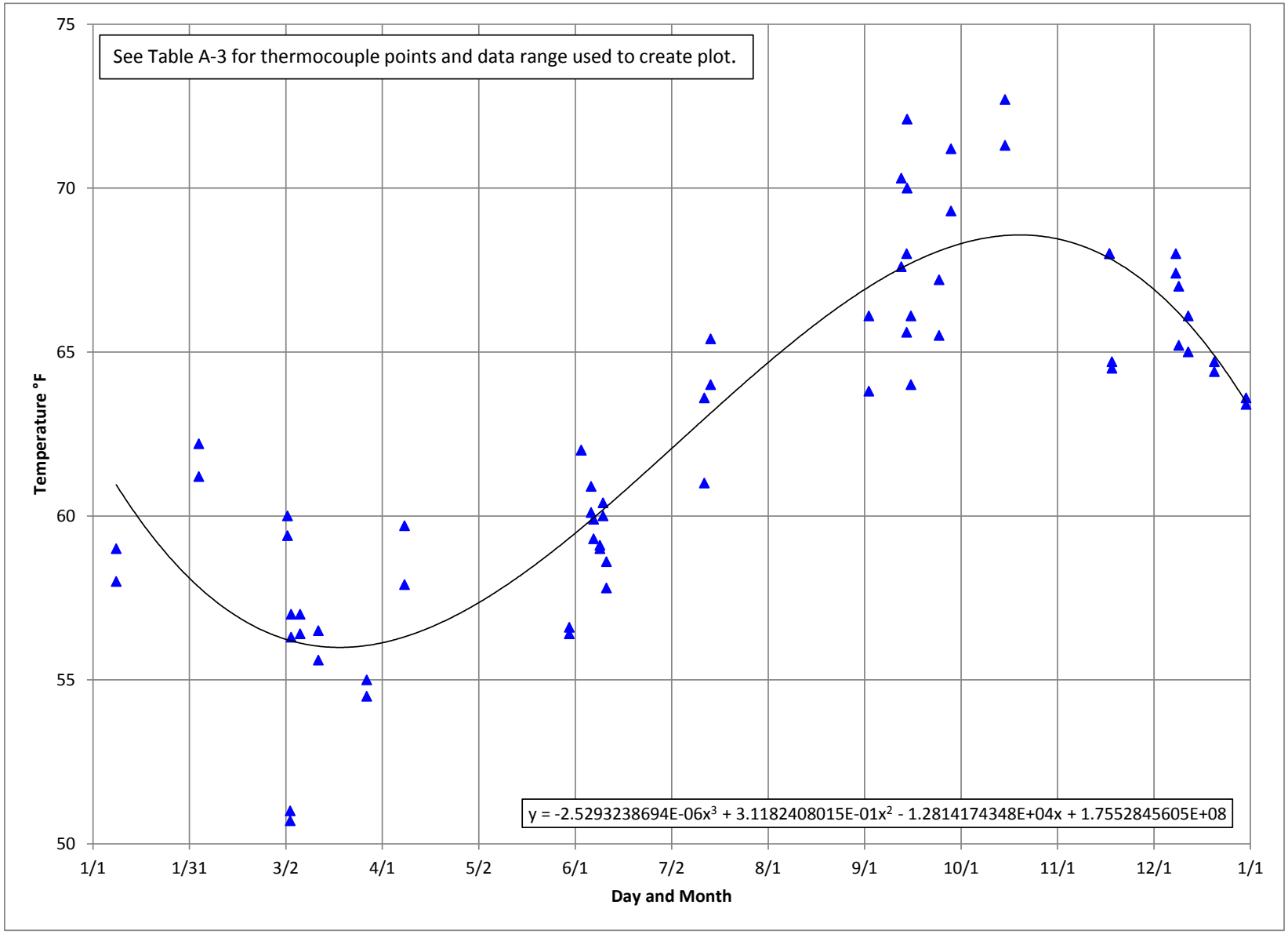


Figure A-9 Tank BY-108 Annual Temperature Cycle

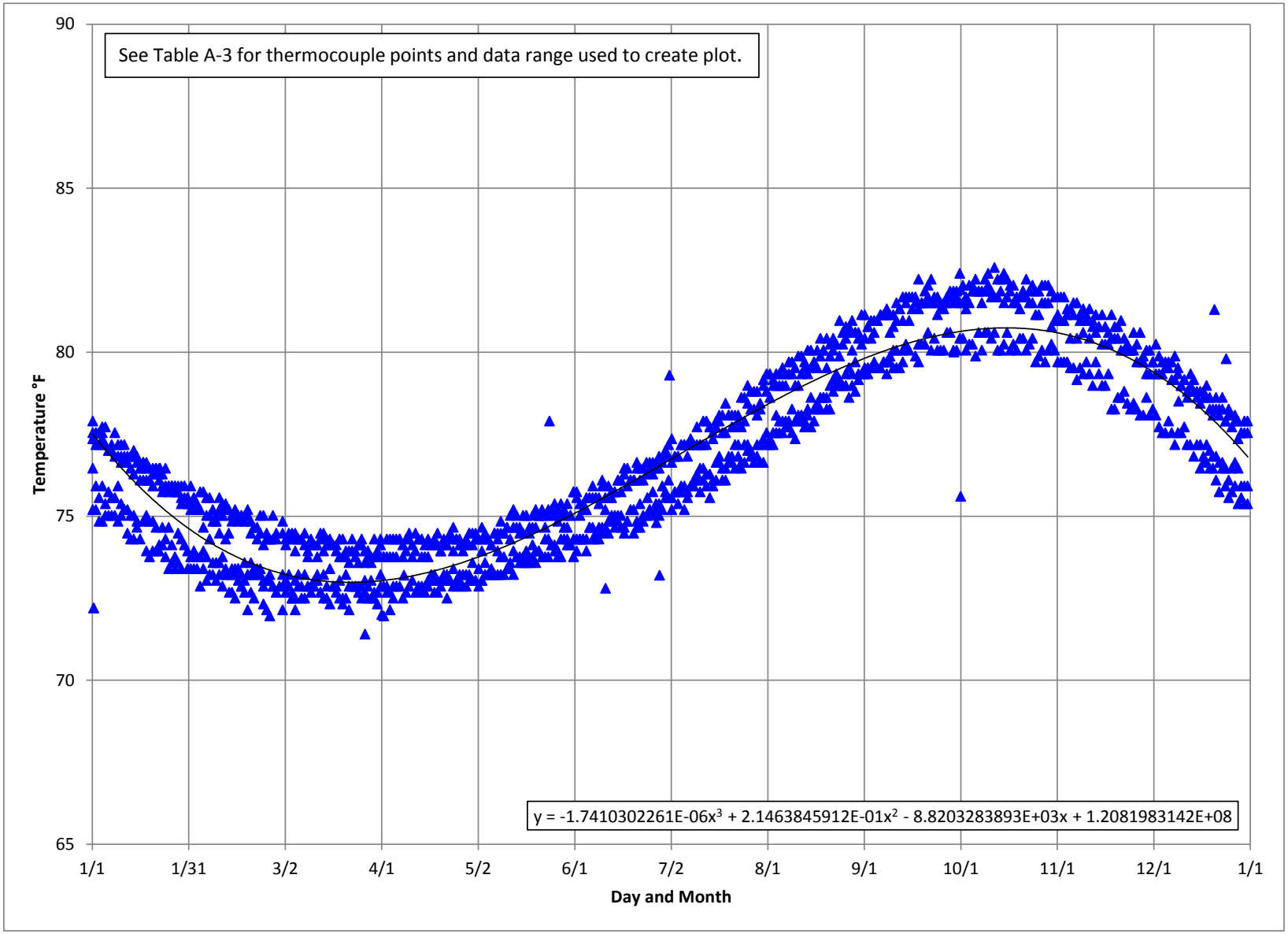


Figure A-10 Tank S-104 Annual Temperature Cycle

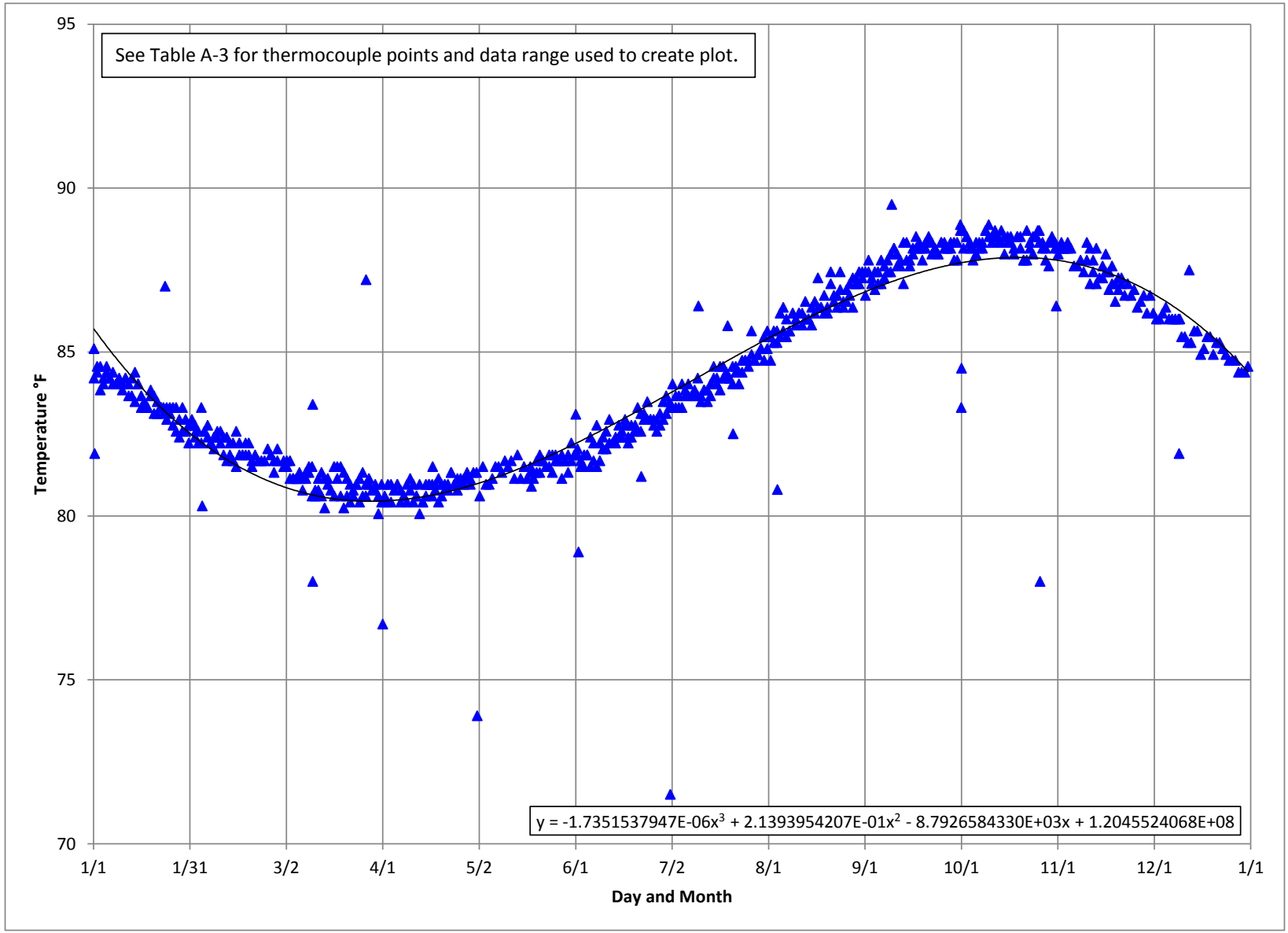


Figure A-11 Tank SX-102 Annual Temperature Cycle

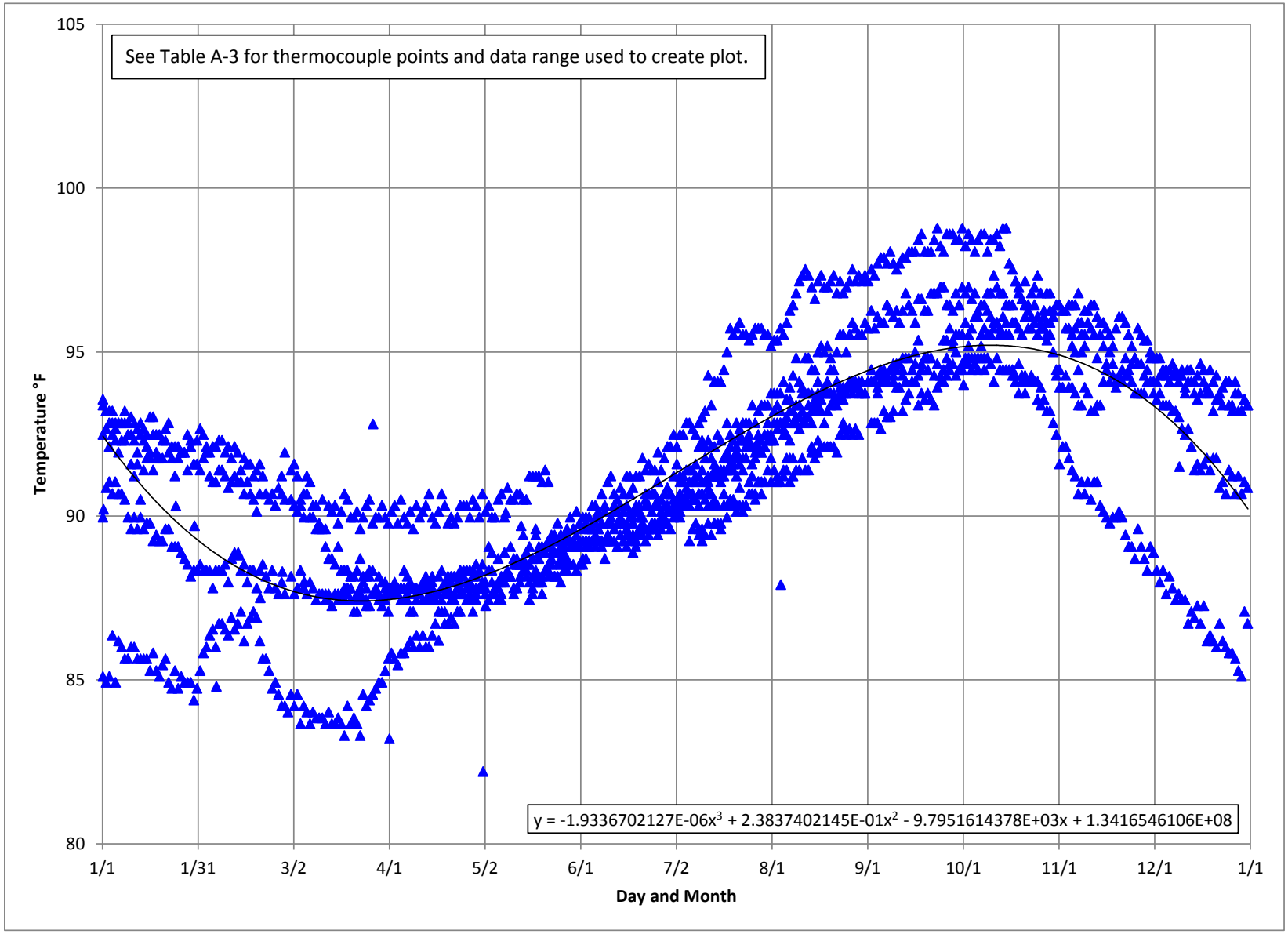


Figure A-12 Tank SX-105 Annual Temperature Cycle

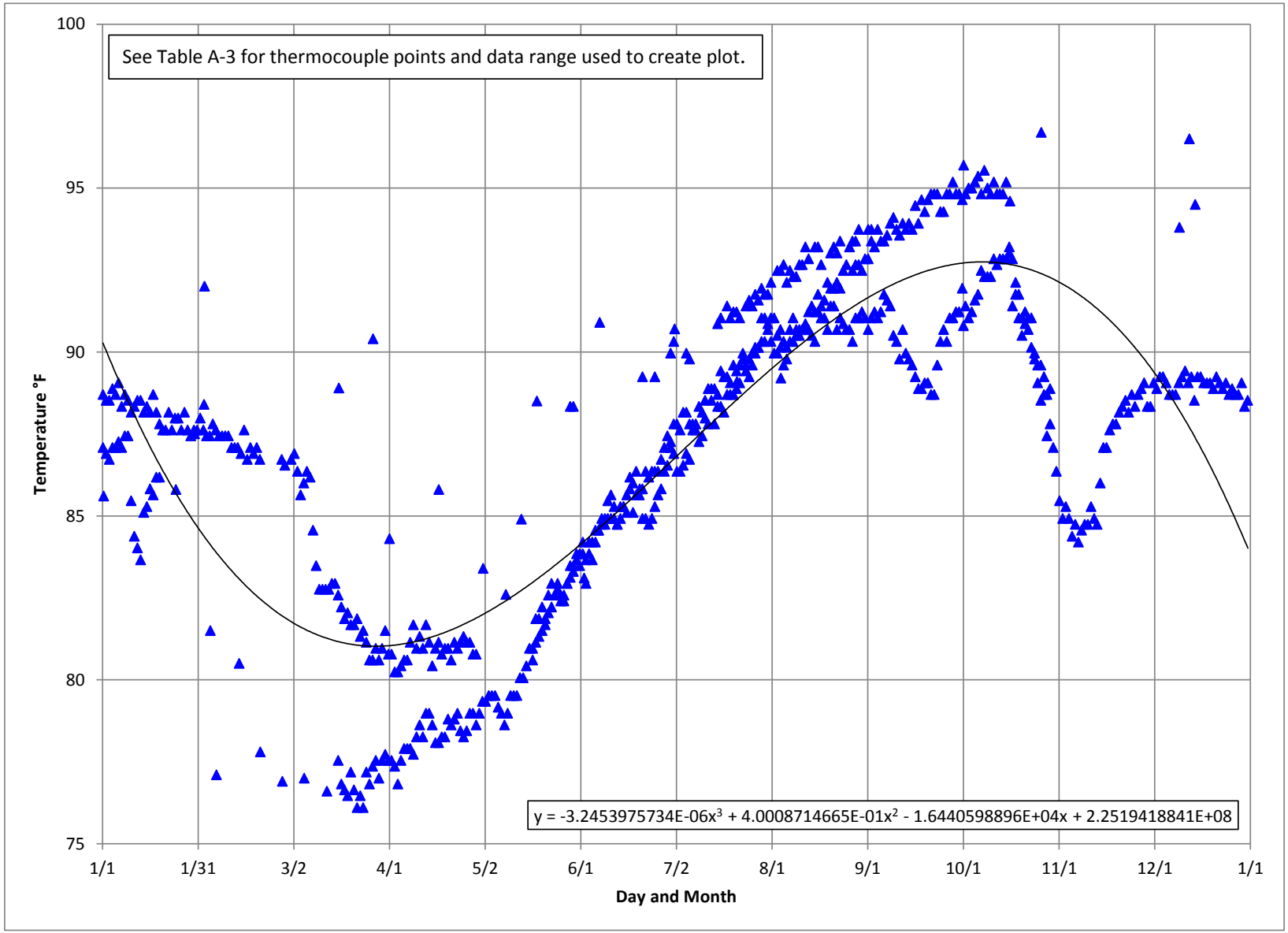


Figure A-13 Tank SX-114 Annual Temperature Cycle

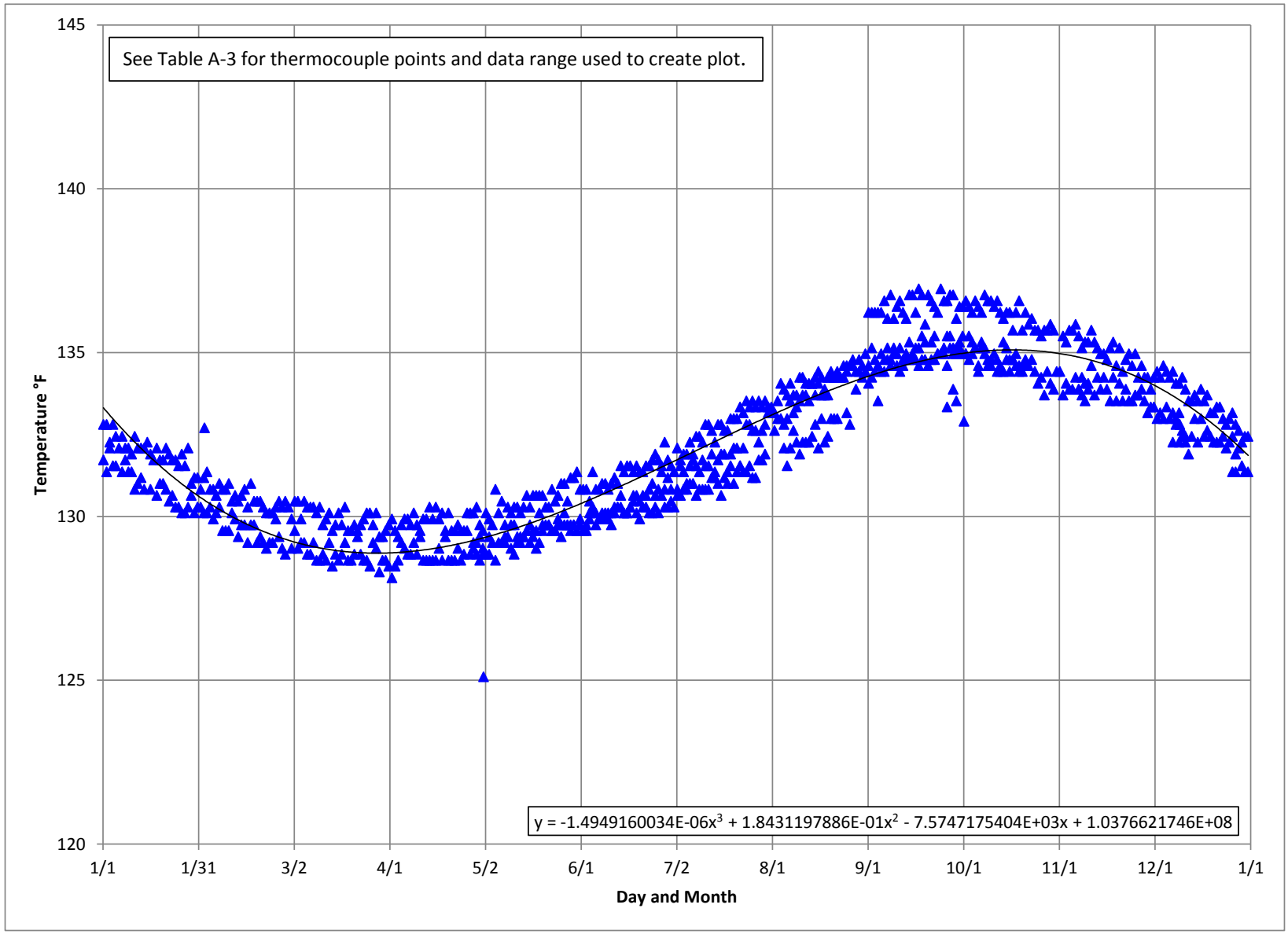


Figure A-14 Tank T-111 Annual Temperature Cycle

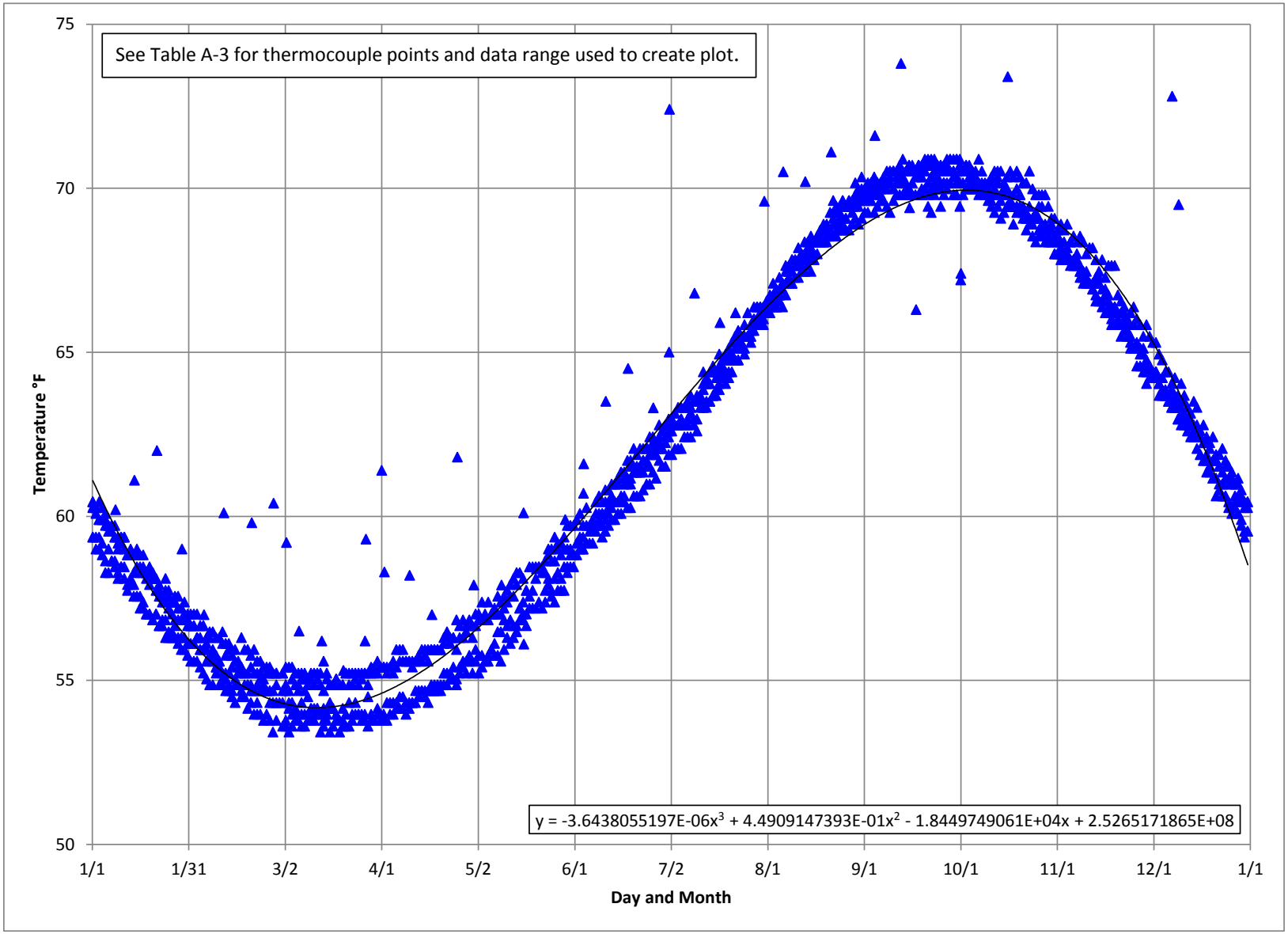


Figure A-15 Tank T-203 Annual Temperature Cycle

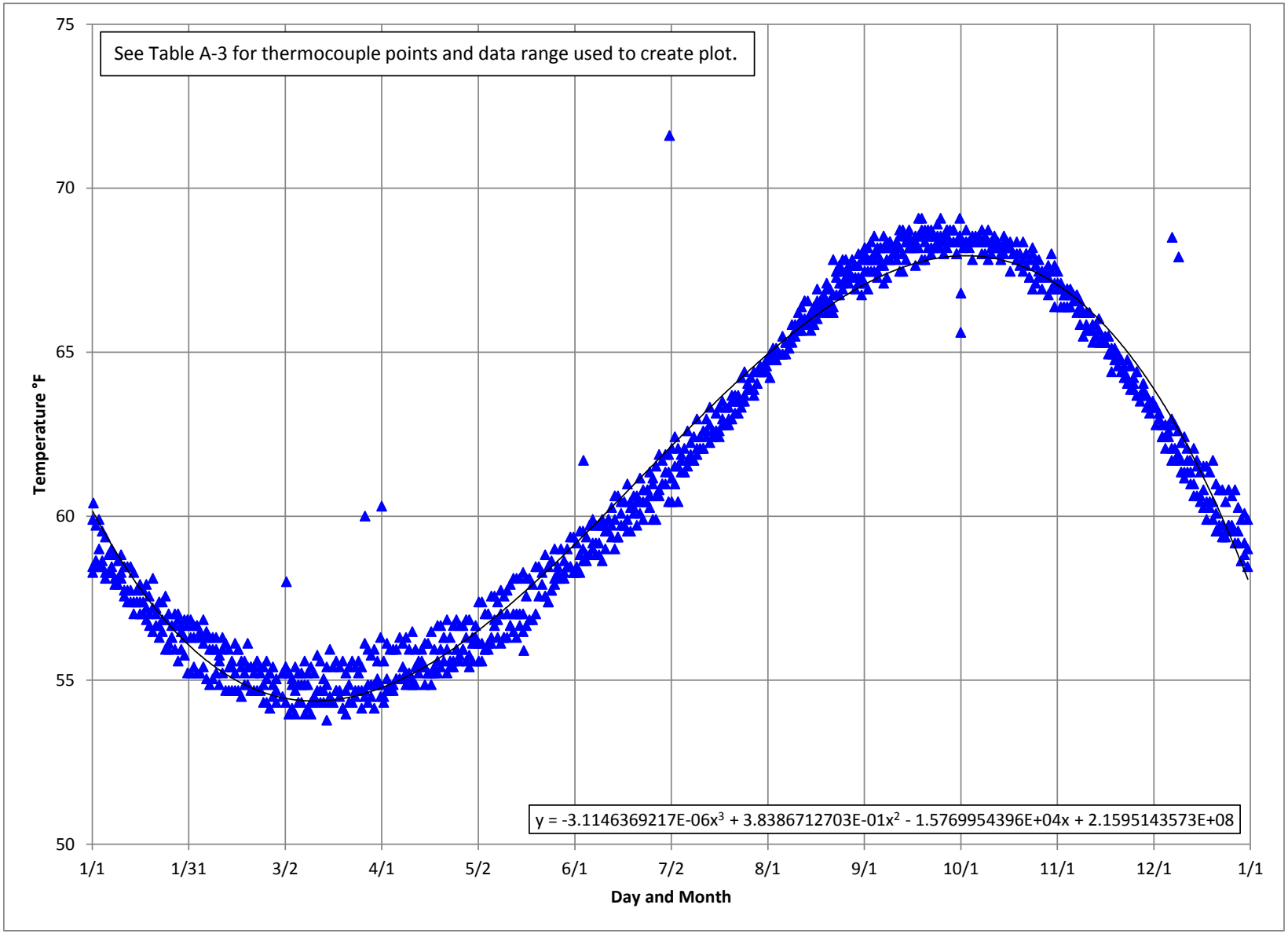


Figure A-16 Tank T-204 Annual Temperature Cycle

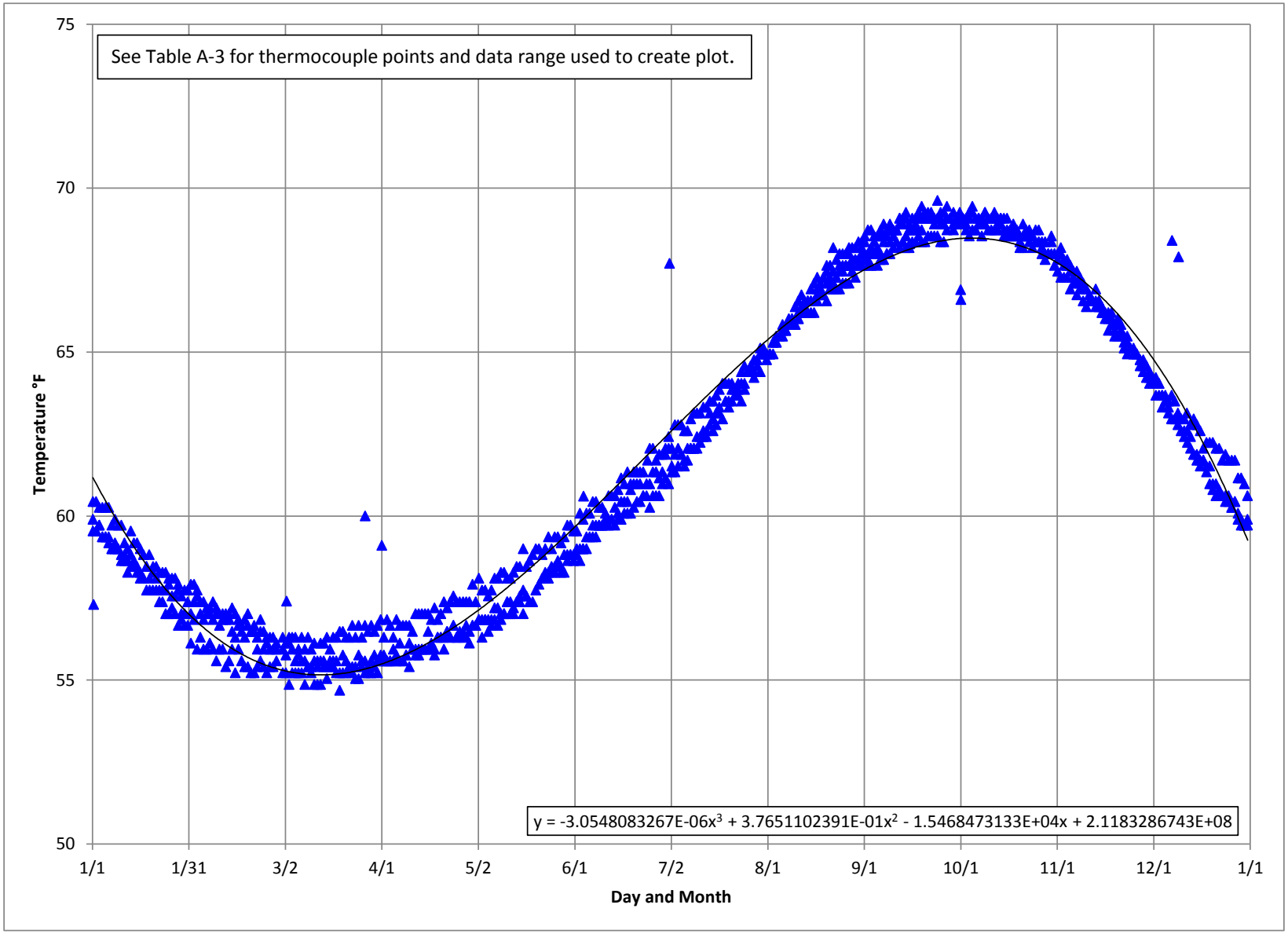


Figure A-17 Tank TX-108 Annual Temperature Cycle

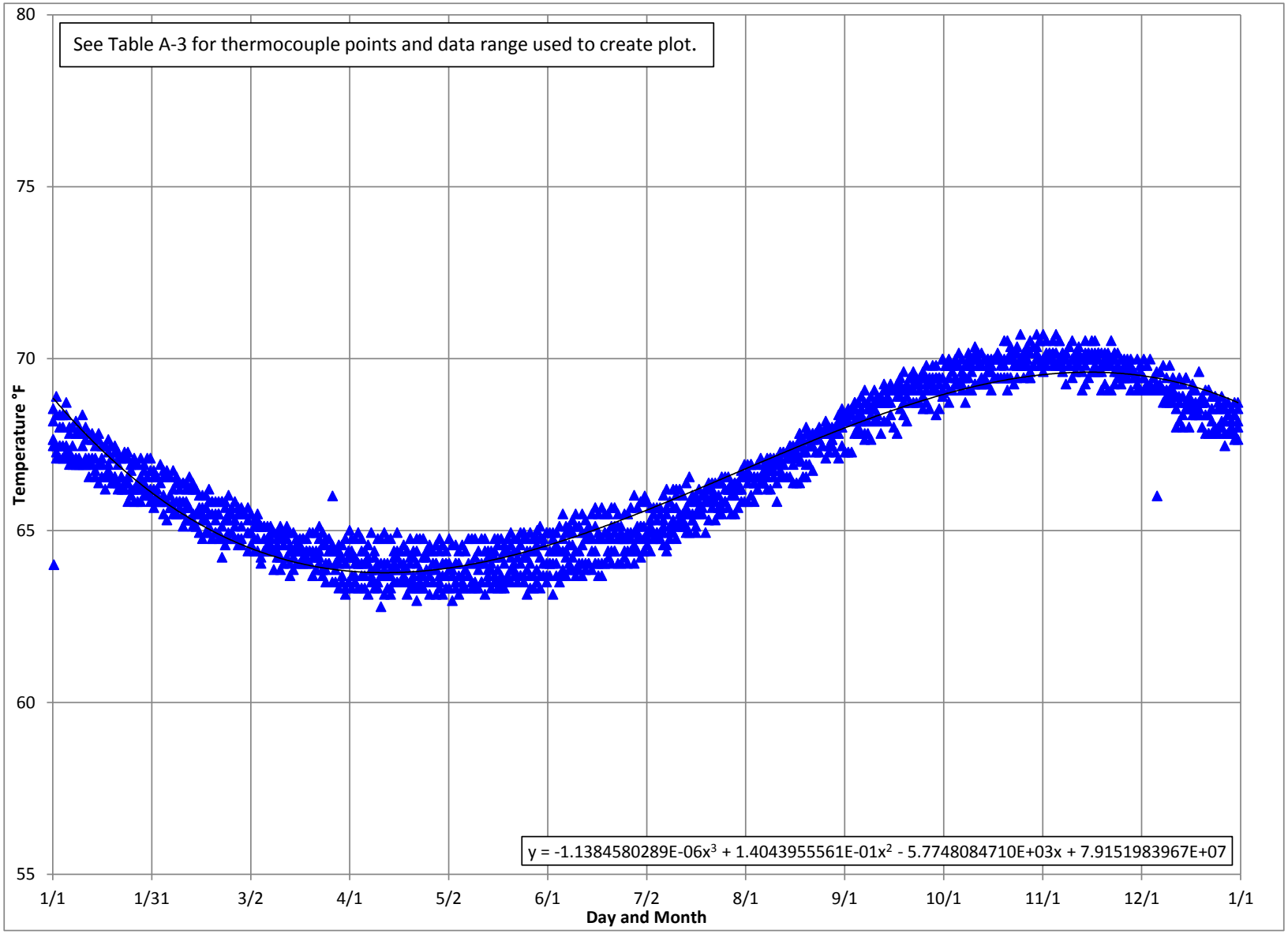


Figure A-18 Tank TY-101 and Assumed Tank U-104 Annual Temperature Cycle

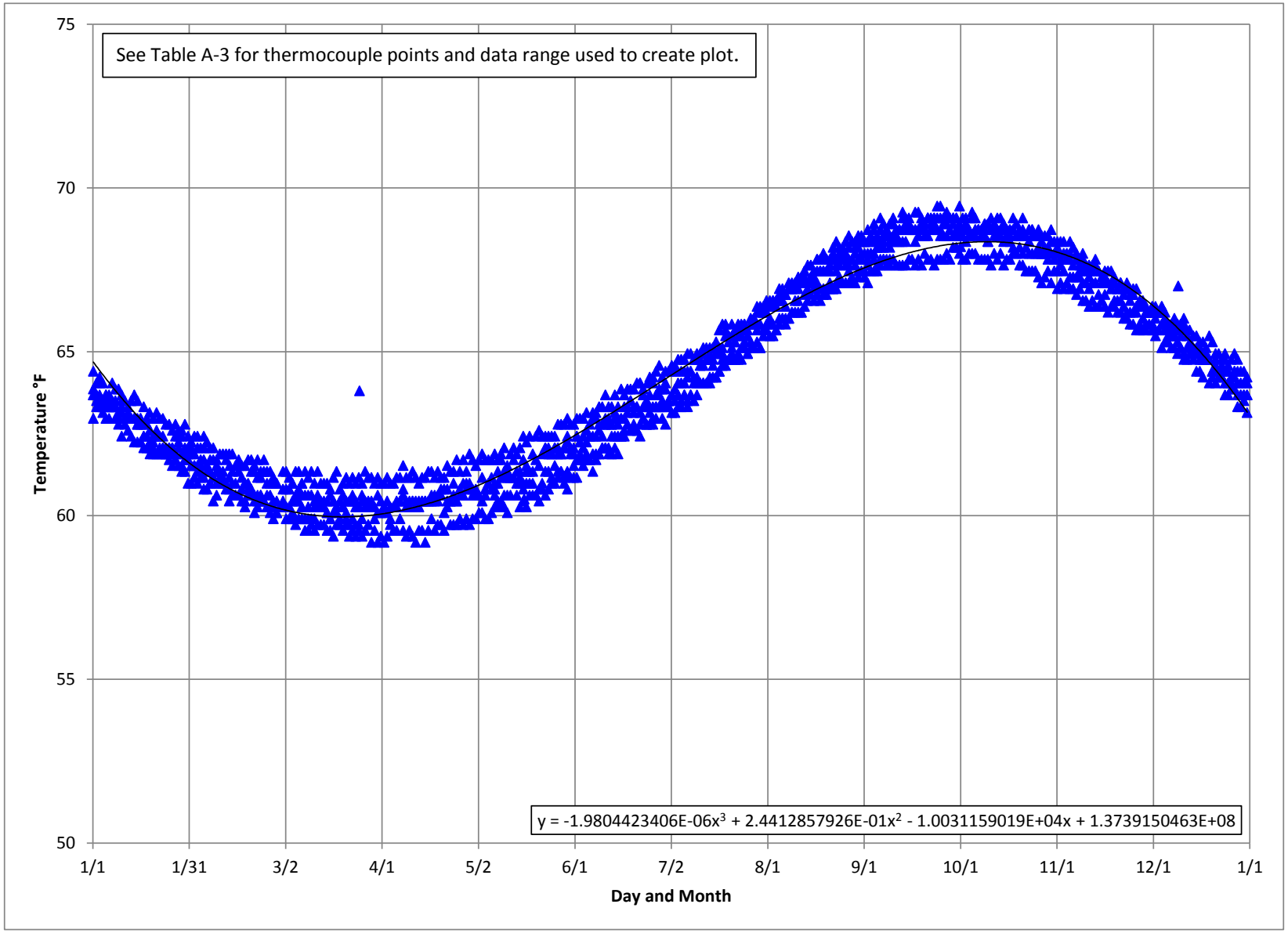


Figure A-19 Tank TY-103 Annual Temperature Cycle

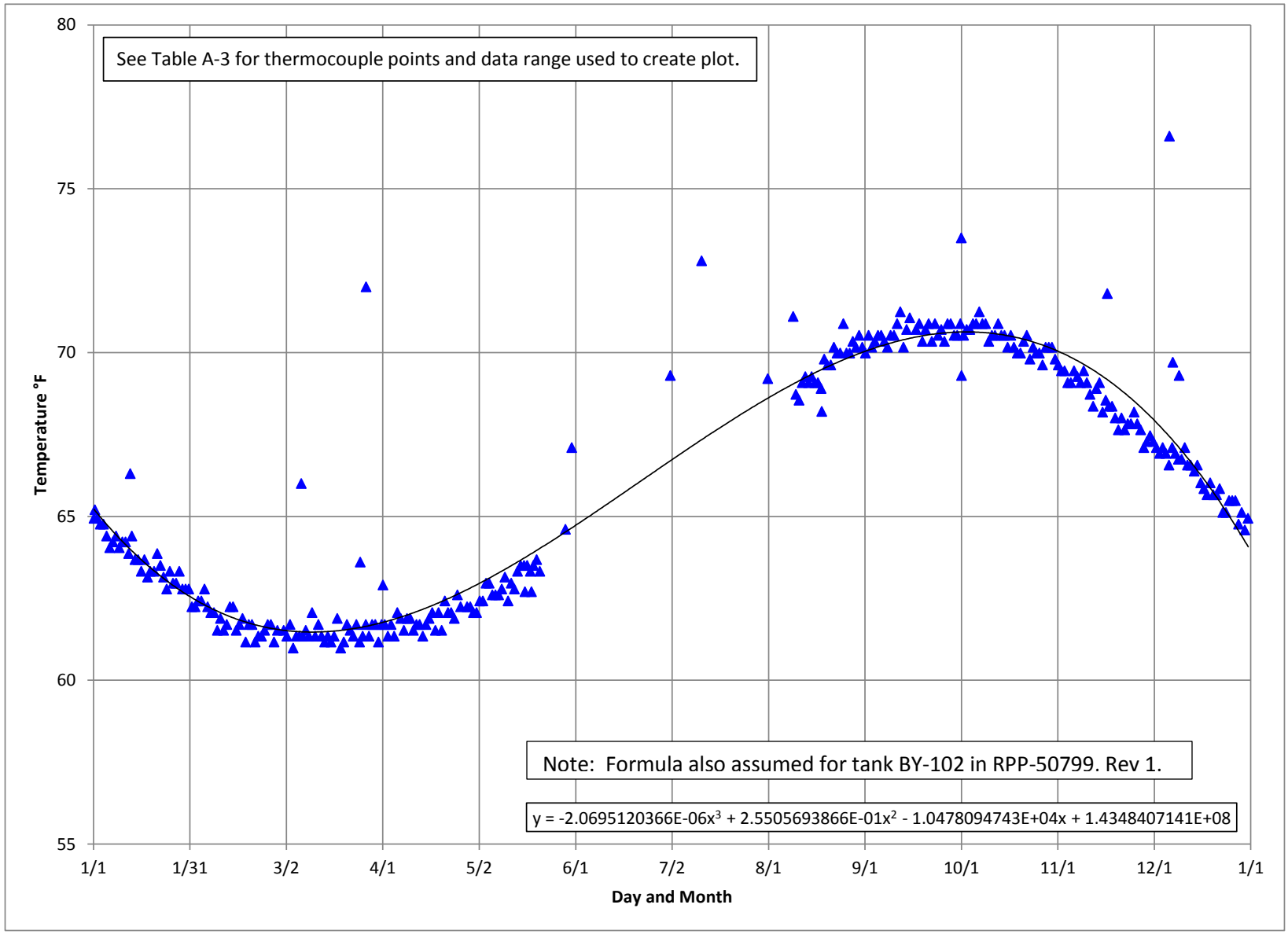


Figure A-20 Tank TY-105 Annual Temperature Cycle

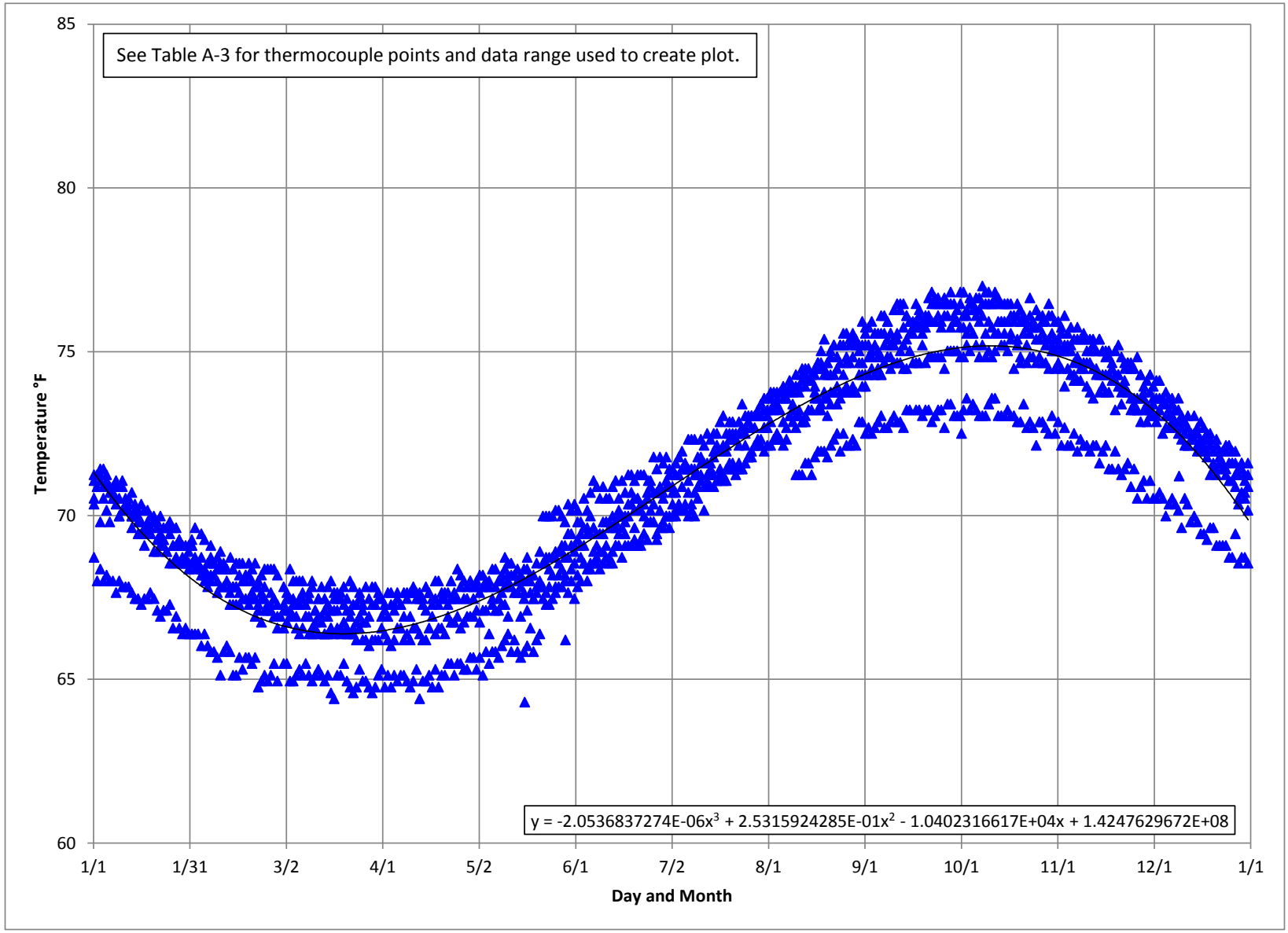
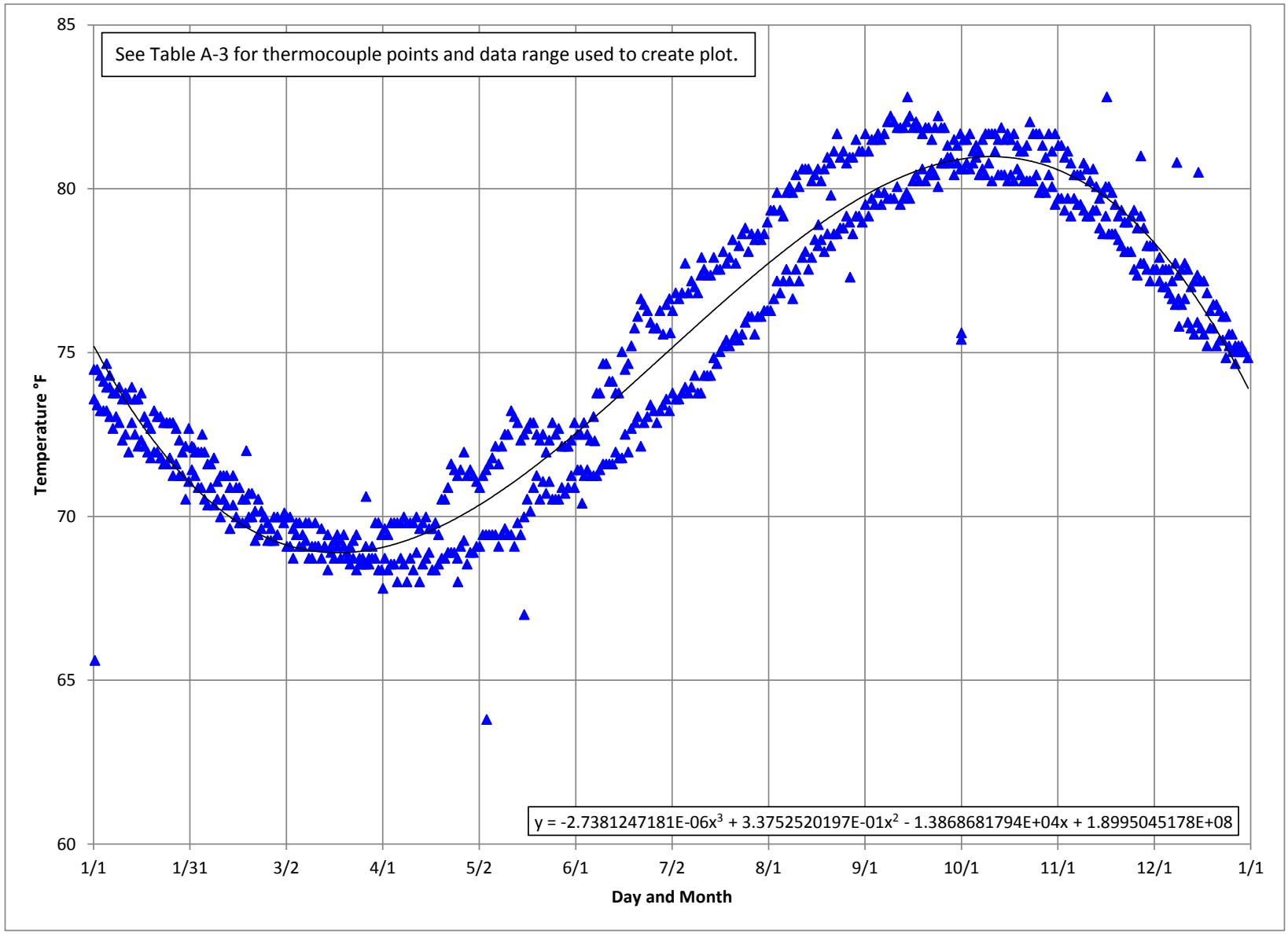


Figure A-21 Tank U-108 Annual Temperature Cycle



A.4 Tank Breathing Rates

The SSTs are no longer actively ventilated. The last SST exhauster, excluding portables used for selected activities such as retrieval operations, was the SX tank farm exhauster that was shut down in 2005. The SSTs are not sealed and breathe to the atmosphere through filters, pit drains, buried out of service ducting, or random openings. Many of the SSTs can also breathe to each other via cascade lines, if the lines aren't plugged. In the process of breathing the tanks can evaporate water, largely during the winter months, or add condensate, largely during the summer months.

The breathing rate for a tank is assumed to be the flow rate out of the tank. Since the air flow out of a tank will include the incoming air plus any water evaporated, the incoming air flow rate is slightly less. The difference in flow rates between incoming and outgoing air is negligible.

The tanks are postulated to breathe due to combined effects of atmospheric pressure changes, temperature difference between the tank headspace and ambient air, diffusion, and/or Bernoulli's principle (when the wind is blowing across openings with access to the tank headspace). Tank breathing rates were measured in 16 leak injection tracer gas tests covering 14 SSTs in 1996 to 1998. Results for 14 of these tests were used for estimating SST breathing rates for this document. Test results for a 15th tank, tank C-104, were not used because they were affected by operation of the C-106 exhauster through cascade lines to and from tank C-105. Test results for a 16th tank, tank AX-101, were not used as the test was aborted. Table A-4 summarizes the applicable data for the 14 tests.

Table A-4 Single-Shell Tank Measured Breathing Rates and Related Data

Tank	Test Date	Breathing Rate (ft^3/min)	Tank Headspace Volume (ft^3)
A-101	7/9/97 – 7/15/97	10[1]	43,083[1]
AX-102	8/28/97 – 9/8/97	16[1]	163,751[1]
AX-103	2/28/97 – 3/3/97	25[1]	153,863[1]
BY-105	4/17/97 – 5/8/97	16[1]	82,034[1]
C-107	2/21/97 – 3/21/97	1.1[1]	82,705[1]
S-102	9/24/96 – 2/11/97	2.2[1]	67,838[1]
TX-104	1/14/98 - 2/12/98	3.5[2]	131,900[2]
U-102	1/9/98 - 3/24/98	2.1[2]	63,619[3]
U-103 97-1	2/27/97 – 7/22/97	1.8[1]	51,241[1]
U-103 97-2	7/15/97 – 8/13/97	1.6[1]	51,241[1]
U-103 97-98	11/18/97 – 1/8/98	2.3[2]	51,241[4]
U-105	7/18/97 – 8/15/97	5.0[1]	57,385[1]
U-106	1/14/98 - 2/12/98	1.3[2]	83,772[3]
U-111	1/14/98 - 2/12/98	1.9[2]	69,514[3]

[1] From PNNL-11683, 1997, *Measurements of Waste Tank Passive Ventilation Rates Using Tracer Gases*, Rev 0.
[2] From PNNL-11925, 1998 *Waste Tank Ventilation Rates Measured with a Tracer Gas Method*, Rev 0.
[3] From SVF-1770, 2009, *Tank Waste Volume Calculator*, Revision 0 empty tank volume minus waste volume from HNF-EP-0182-120 *Waste Status Summary for Month Ending March 31, 1998.*
[4] Used same value documented for previous two tank U-103 tests.

Only one of the tanks requiring an evaporation estimate in this appendix, tank AX-103, is listed in Table A-4. A methodology thus had to be developed to permit extrapolation of the data in Table A-4 to estimation of breathing rates for other SSTs.

The first attempt was to plot the breathing rates against likely influences, the tank headspace volume and the tank headspace temperature. It seems intuitive that the breathing rate for a tank should be somewhat proportional to the tank headspace volume, since the larger the headspace volume the more air will be drawn in or out of the tank for a given atmospheric pressure fluctuation. It also seems logical that higher temperatures in a tank headspace should cause air to rise in the breather filter riser due to the lower density of the warmer air and exit the tank.

Figure A-22 shows the Table A-4 measured breathing rates plotted against tank headspace volumes. Figure A-22 appears to show a moderate correlation between headspace volume and breathing rate.

Figure A-23 shows the Table A-4 measured breathing rates plotted against the tank headspace temperatures. Figure A-23 appears to show a smaller correlation between headspace temperature and breathing rate. PNNL-11683 states:

> *It is currently thought that passive ventilation is partially driven by the buoyancy* [sic] *difference between warm air in the headspace and cool ambient air. If that is correct, the ventilation rate is more appropriately correlated with the difference between ambient and headspace temperatures…… Comparison of the temperature differences with the ventilation rates suggests that while ventilation rate does decrease as the temperature difference decreases, it approaches and fluctuates about a minimum value, and is not decreased by further decreases in the temperature difference.*

Four of these breathing rates may be biased high. The gas injection test that was aborted in tank AX-101 was stopped because the tracer gas concentration reduced so quickly that the test results were unexplainable other than by a significant dilution. For tanks A-101, AX-102 and AX-103 the breathing rates may be biased high due to either:

- a slight negative pressure being drawn on the A/AX tanks via inadequately isolated seal loops in one or more old ventilation ducts, or,
- tracer gas diffusion via the 20 to 24 inch buried ventilation ducts connecting the tanks in A and AX tank farms, or,
- an unknown source of ventilation on the tanks.

If the high breathing rates are due to a slight negative pressure then the tank ventilation rates are as high as indicated and evaporation estimates should reflect tank conditions. If the high breathing rates are due to tracer gas diffusion through the vent ducts, evaporation estimates based upon the tank ventilation rates could be overstated because the ventilation rates would not account for water vapor coming in from other tanks connected to the vent duct.

The reason for the high breathing rate value for tank BY-105 is unknown. During the test period saltwell pumping was occurring in two BY tanks, BY-103 and BY-109. These tanks are adjacent to tank BY-105 and had active ventilation during some of the saltwell pumping activities, but there are no cascade lines between BY-105 and BY-103 or BY-109 and no obvious other connections. The rotary mode core sampling exhauster was not in operation in BY farm during the BY-105 test and no other portable exhauster is known to have been used at that time in the BY farm area. The BY-105 data point is based upon SF_6 tracer gas data. Only a few

breathing rate data points were based upon SF_6 due to problems encountered with some tanks. The BY-105 test appeared to be acceptable but PNNL-11683 states that literature indicates SF_6 may not be stable under high radiation fields. Degradation of SF_6 would result in the calculated breathing air rate being higher than actual.

Figures A-24 and A-25 are the same plots as Figures A-22 and A-23, but with the potentially biased A/AX data points shown in red and the unexplained BY-105 data point shown in green. Based upon Figures A-24 and A-25 there is not much correlation of the tank breathing rate with either headspace volume or temperature when excluding data points that may be biased.

Figure A-22 Breathing Rate vs. Tank Headspace Volume

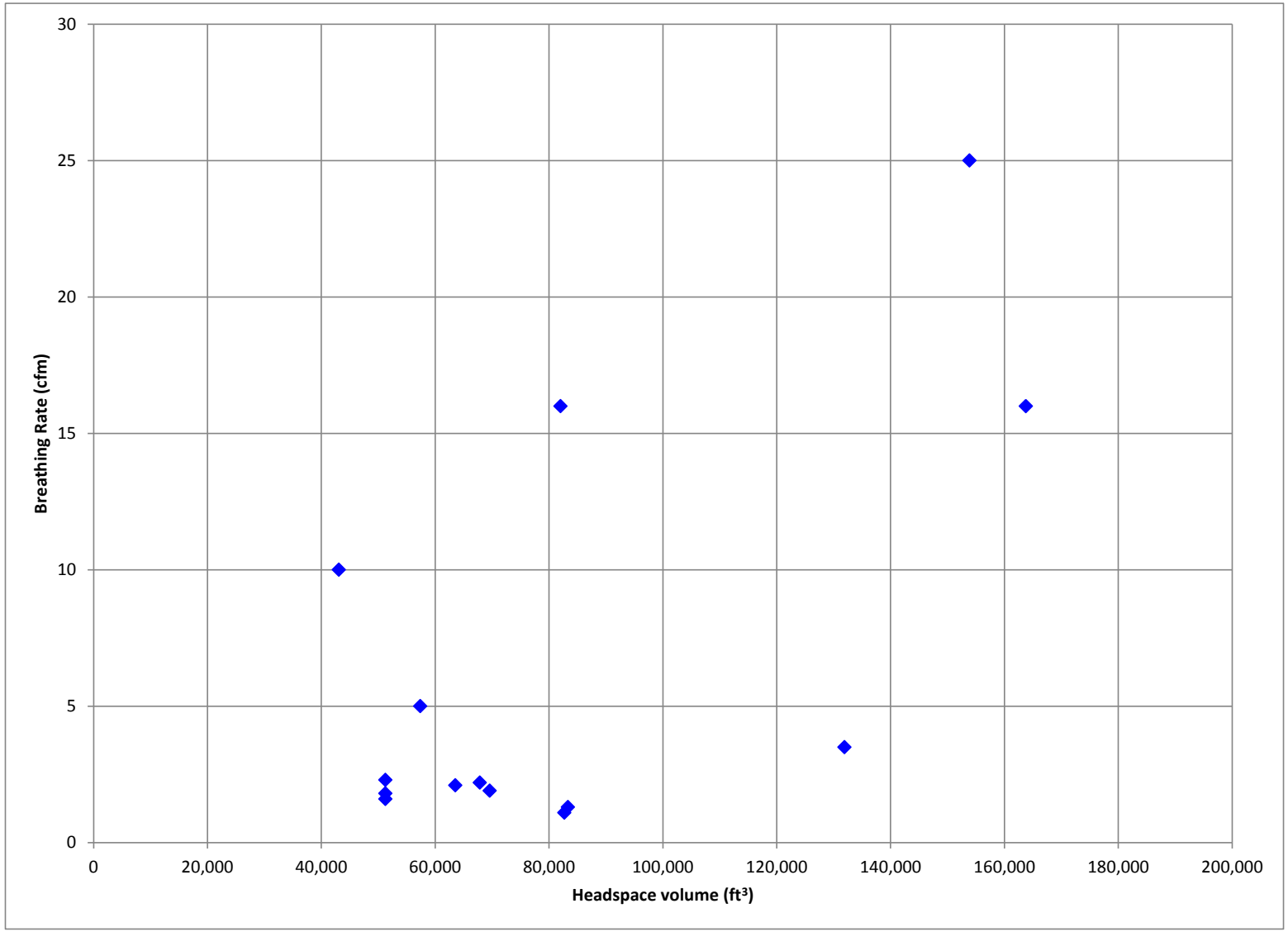


Figure A-23 Breathing Rate vs. Tank Headspace Temperature

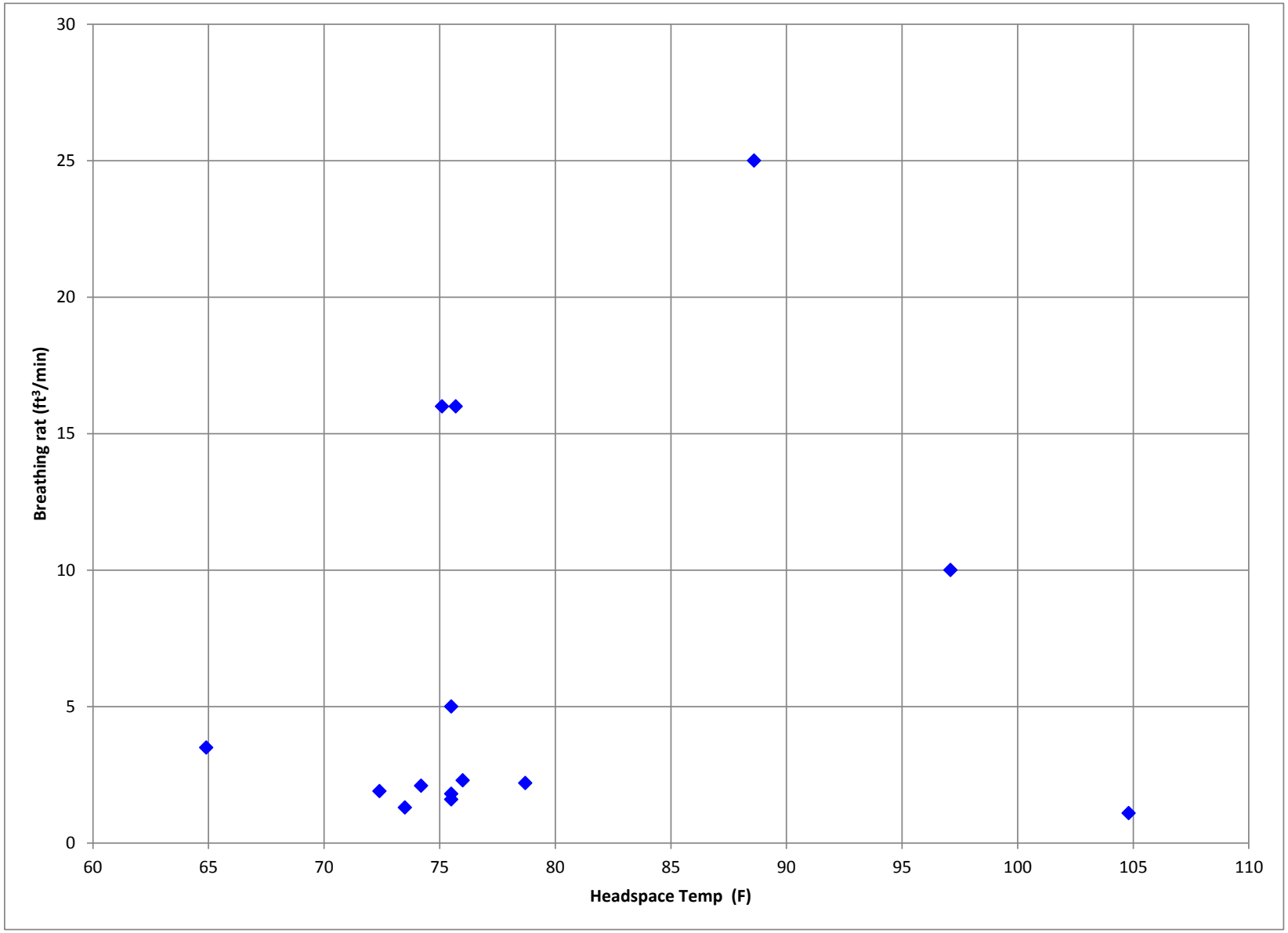


Figure A-24 Breathing Rate vs. Tank Headspace Volume with Potentially Biased Rates Highlighted

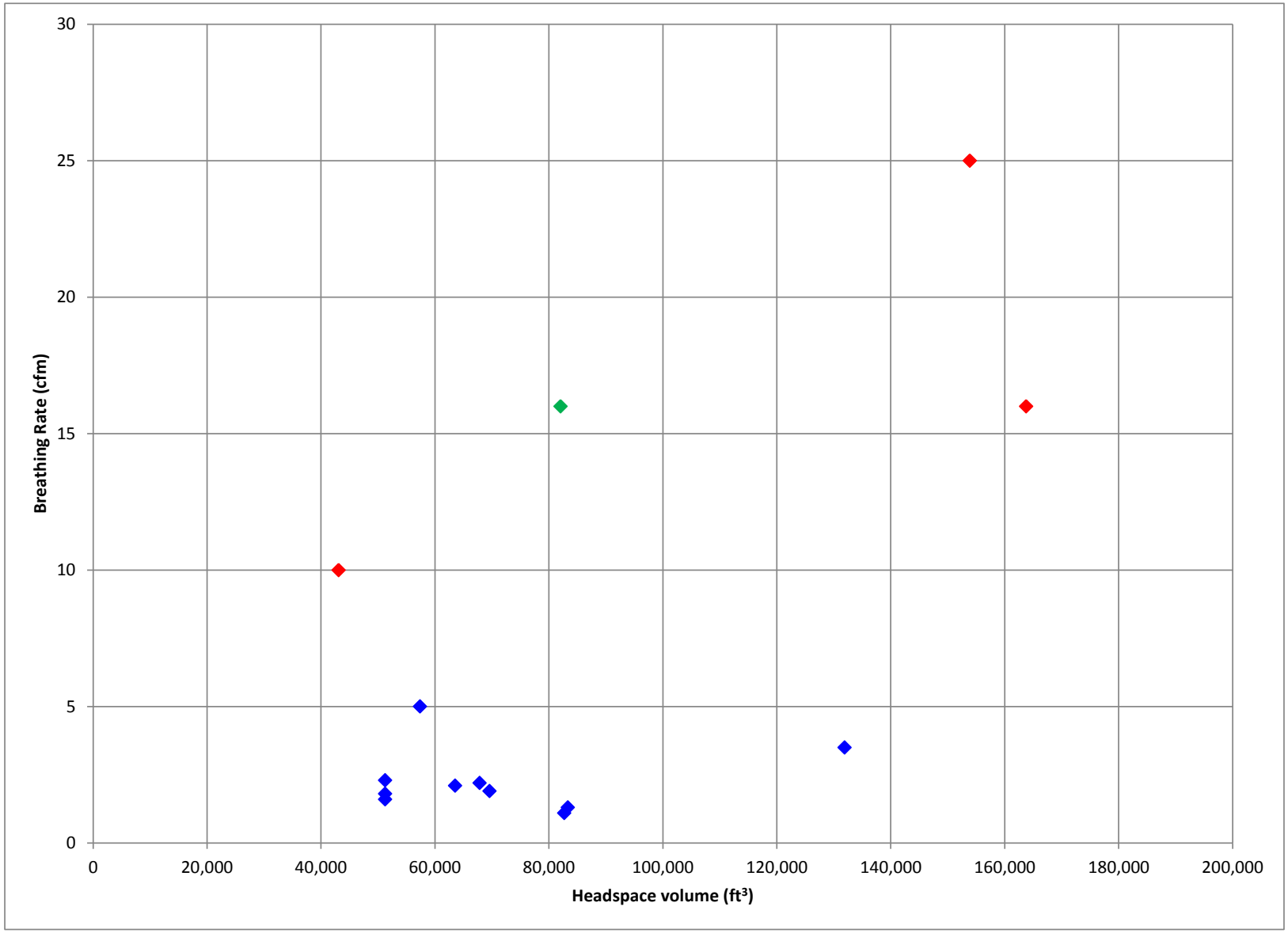
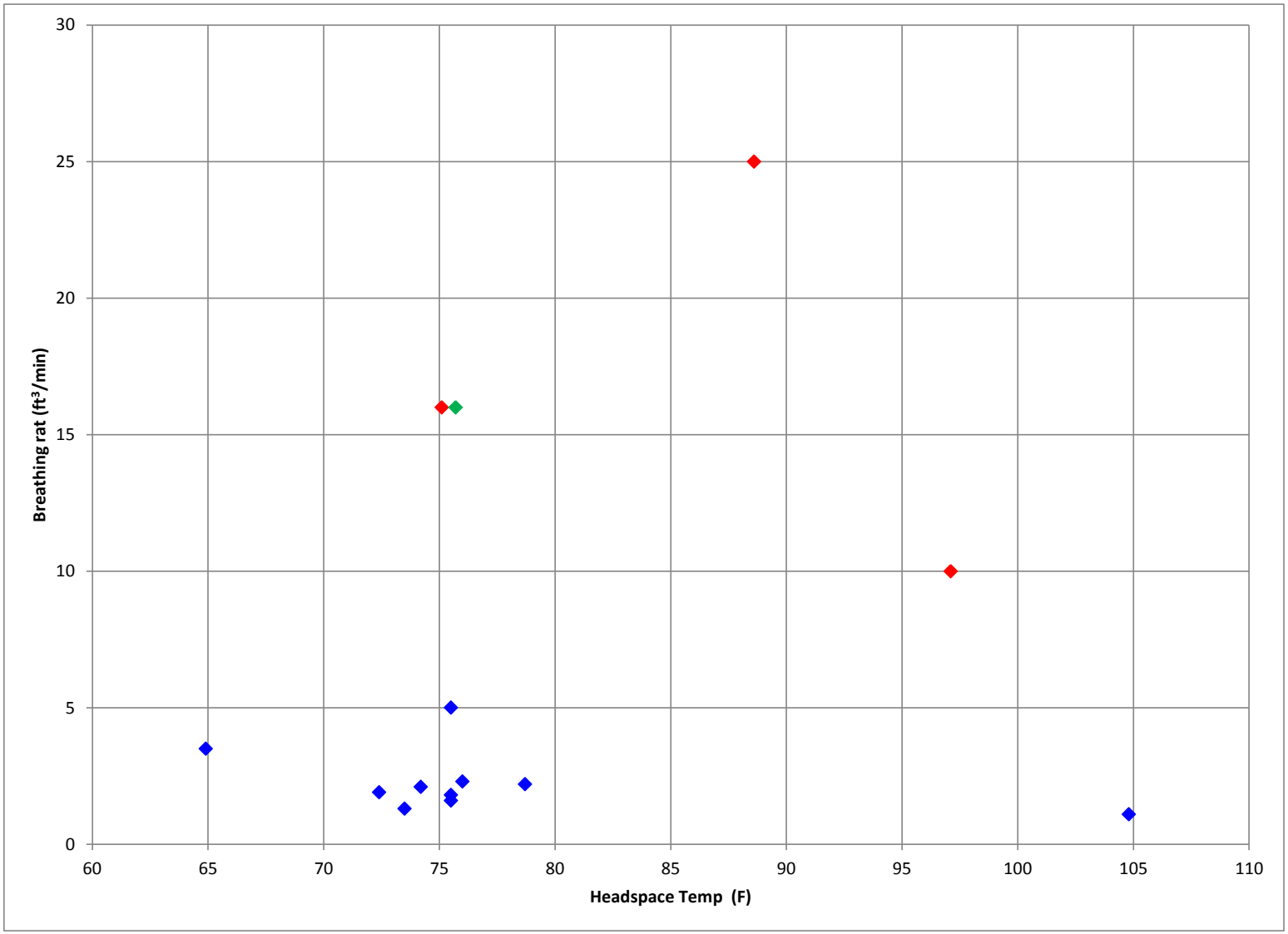


Figure A-25 Breathing Rate vs. Tank Headspace Temperature with Potentially Biased Rates Highlighted



To see how atmospheric pressure changes alone will affect the tank breathing rate the hourly atmospheric pressure data from the HWS for 2010 through 2012 was evaluated for the volume change that atmospheric pressure fluctuations alone would cause in a year. All positive pressure changes (i.e. the pressure from one period was greater than the pressure an hour earlier) and all negative pressure changes (i.e. the pressure from one period was less than the pressure an hour earlier) were calculated for the three year period and totaled. The results are provided in Columns 2 and 3 of Table A-5. Column 4 gives the annual average of the changes in Columns 2 and 3, and Column 5 gives the 3-year average for the atmospheric pressure at Hanford. The number of tank headspace changeouts in Column 6 that would result from the total pressure change in Column 4 is calculated by:

$$Total\ headspace\ volumes\ of\ gas = (annual\Delta P + P_{atm}) \div P_{atm}$$
$$= (50.70 + 29.19) \div 29.19 = 2.74\ headspace\ volumes$$

$$Tank\ headspace\ changeouts = total - start = 2.74 - 1 = 1.74$$

For comparison purposes the 15 minute atmospheric pressure data was obtained from the weather station located atop the C-Farm High Resolution Resistivity (HRR) leak detection electronics trailer. These are provided below the HWS data in Table A-5. The C-Farm HRR weather station is uncalibrated but past use shown it to reasonably match the HWS data. The main item to note from Table A-5 is that the 15 minute data show a greater annual pressure change, which is expected since the data are obtained four times as frequently as from the HWS.

Table A-5 Hanford Atmospheric Pressure Changes

1	2	3	4	5	6
	Σ Positive Pressure Changes (in. Hg)	**Σ Negative Pressure Changes (in. Hg)**	**Annual Average Pressure Change (in. Hg)**	**Annual Average Pressure (in. Hg)**	**Tank Headspace Changeouts per Year Due to Atmospheric ΔP Only**
HWS Hourly Data 1/1/10 to 12/31/12	152.33	-151.87	50.70	29.19[1]	1.74
C-Farm HRR Weather Station 15 Minute Data 8/1/11 to 7/31/12[2]	76.809	-76.729	76.769	29.981[1]	2.53

[1] HWS pressure is based upon pressure measured at the weather station elevation, C-Farm HRR weather station data are normalized to sea level.

[2] C-Farm HRR weather station data downloaded from data files stored on HRR system computer in 2704-HV, Rm B-224, September 12, 2012

A tank headspace change out of 1.74 times per year is essentially the same as the 1.69 times per year given in WHC-EP-0651, *Barometric Pressure Variations*, 1993.

The breathing rate of a tank due solely to pressure fluctuations was calculated by:

$$Tank\ breathing\ rate\ due\ to\ \Delta P\ only = 1.74 \times headspace\ volume\ ft^3 \div 525{,}960\ min/yr$$

Table A-6 gives the calculated breathing rate due to atmospheric pressure fluctuations only in Column 4, using 1.74 changeouts per year based upon the HWS atmospheric pressure data. Column 5 gives the breathing rate independent of atmospheric pressure changes when subtracting the breathing rate due to atmospheric pressure fluctuations in Column 4 from the measured breathing rate in Column 2.

Table A-6 Single-Shell Tank Air Exchange Data from Atmospheric Pressure Change Only

1	2	3	4	5	6
Tank	**Breathing Rate (ft^3/min)**	**Tank Headspace Volume @ Time of Test (ft^3)**	**Breathing Rate Due to Atmospheric ΔP Changes Only[1] (ft^3/min)**	**Breathing Rate Due to Non-ΔP Factors (ft^3/min)**	**Percent of Breathing Rate due to Atmospheric ΔP Changes**
A-101	10	43,083	0.14	9.86	1.4
AX-102	16	163,751	0.54	15.46	3.4
AX-103	25	153,863	0.51	24.49	2.0
BY-105	16	82,034	0.27	15.73	1.7
C-107	1.1	82,705	0.27	0.83	24.8
S-102	2.2	67,838	0.22	1.98	10.2
TX-104	3.5	131,900	0.44	3.06	12.4
U-102	2.1	63,619	0.21	1.89	10.0
U-103 97-1	1.8	51,241	0.17	1.63	9.4
U-103 97-2	1.6	51,241	0.17	1.43	10.6
U-103 97-98	2.3	51,241	0.17	2.13	7.4
U-105	5.0	57,385	0.19	4.81	3.8
U-106	1.3	83,772	0.28	1.02	21.2
U-111	1.9	69,514	0.23	1.67	12.1

[1] Based upon 1.74 tank headspace changeouts per year.

It is apparent from looking at Column 6 that the air exchange due to atmospheric pressure fluctuations is a minor constituent of most tank breathing rates, ranging from 1.4 to 25% of the total rate and averaging 9.3%. If the value of 2.53 changeouts per year in Table A-5 calculated from the C-Farm HRR weather station is used the atmospheric pressure fluctuations would account for 2.1 to 37% of the total rate and average 14%.

The purpose of this document is not to provide an in-depth evaluation of tank breathing rate mechanisms; the purpose is to provide a reasonable estimate of the breathing rate from a tank to use in evaporation calculations. After reviewing the values in Table A-6 the assumption was made that, for this document, the breathing rate for SSTs was due to the following factors:

- air exchange due to atmospheric pressure change, and,
- air exchange independent of atmospheric pressure change, and,
- in-leakage for selected tanks from adjacent active ventilation systems.

As used here, air exchange independent of atmospheric pressure change refers to such factors as:

- gas diffusion
- temperature (and thus density) induced air movement
- negative pressure due to wind across openings (Bernoulli's principle)
- other unrecognized mechanisms which will result in headspace gas transfer in and out of a tank unrelated to atmospheric pressure changes.

The main outlet for air exchange independent of atmospheric breathing on a tank is probably the breather filter, but other openings such as pit drains, cascade lines, open transfer lines, interconnecting encasements in pre-2005 waste transfer piping, unsealed ventilation ducts, unsealed condenser pits, or other unaccounted for openings also contribute. An in-depth evaluation of each SST was not made for this document. Instead, the air exchange independent of atmospheric breathing portion of a tank breathing rate was calculated for all 75 ft. diameter SSTs by averaging the values in Column 5 of Table A-6, excluding A-101, AX-102, AX-103, and BY-105. The average is 2.05 cfm.

An air exchange independent of atmospheric breathing value of 2.05 cfm should be applicable to 20 ft. diameter tanks in B, C, T, and U farms since these tanks have as many openings to the atmosphere as the 75 ft. diameter tanks in these farms, and the openings are essentially the same size. The tanks have similar numbers of waste addition lines and spares, the only difference in horizontal liquid addition/removal lines between the tanks being the 20 ft. diameter tanks do not have cascade lines from/to another tank. While it seems reasonable that a 2.05 cfm value could be applied for the 20 ft. diameter tanks, to be conservative a value of half 2.05, or 1.02 cfm was assumed. HNF-3588, *Organic Complexant Topical Report*, Rev 1 assumed a breathing rate of 1 cfm for 20 ft. diameter tanks. Using 1.02 cfm for an air exchange independent of atmospheric breathing for these tanks results in calculated breathing rates of 1.02 to 1.05 cfm for them, which is essentially consistent with the rates used in HNF-3588.

The air exchange due to atmospheric pressure change for a tank was calculated using 1.74 tank headspace volume changeouts per year, with the tank headspace volume calculated from the SVF-1770 tank volume calculator.

An air exchange rate independent of atmospheric pressure change of 2.05 cfm was assumed for all 75 ft. diameter tanks. A value of 1.02 cfm was assumed for all 20 ft. diameter tanks.

Only the A and AX tanks are assumed to have inleakage to an active ventilation system. An inleakage rate of 9.86 – 2.05 = 7.81 cfm was assumed for tanks A-102 and A-106 based upon the A-101 data point. An inleakage rate of ((15.46 – 2.05) + (24.49 – 2.05))/2 = 17.9 cfm was assumed for AX-101 as this is the average for AX-102 and AX-103.

The effective breathing rate for each SST is assumed to be the sum of the atmospheric pressure changes plus the non-pressure related changes plus inleakage from other systems. Table A-7 provides the estimated breathing rates used for evaporation estimates for all 20 SSTs in Column 8.

Notes:

1. Although estimated breathing rates are shown to three significant figures there is no accuracy claimed to this level, the significant figures are shown only because the values are calculated in Excel and used directly to calculate evaporation rates. The estimated breathing rates were not rounded off in order to provide consistency in the calculated evaporation rates.

   Included for comparison in Table A-7 are the SST ventilation rates provided in RPP-5660, *Collection and Analysis of Selected Tank Headspace Parameter Data* (Column 9) and HNF-3588, Rev 1 (Column 10). The breathing rates in Column 8 for most tanks are similar to or less than the Column 9 ventilation rates from RPP-5660, so the evaporation rates for most tanks will be lower than if calculated using RPP-5660 breathing rates, with three exceptions germane to this document. The exceptions are for tanks B-203, B-204, and T-203. RPP-5660 gives a 0 cfm ventilation rate for these three tanks and a 7 cfm ventilation rate for the five other B-200 and T-200 tanks. Table 3-17 in RPP-5660 gives the reference for the B-203, B-204, and T-203 ventilation rates as WHC-SD-WM-ER-526, 1998, *Evaluation of Hanford Tanks for Trapped Gases*, Revision 1D. Table 4-2 in RPP-5660 gives the same reference but says the methodology is based upon WHC-SD-WM-TI-724, Rev 1. Both WHC-SD-WM-ER-526, Rev 1D and WHC-SD-WM-TI-724, Rev 1 were reviewed and no reference to the 0 cfm ventilation rate for these tanks was found, nor was basis for the difference between 0 cfm for three of the eight B/T 200-series tanks and the 7 cfm for the remaining five. The C/U 200-series tanks in RPP-5660 show ventilation rates between 2 and 10 cfm. HNF-3588, Rev 1 lists six B/C/T/U 200-series tanks in Table D-4 of that document, with an estimated 1 cfm breathing rate shown for each. The 0 cfm breathing rates for tanks B-203, B-204, and T-203 in RPP-5560 are ignored for this document.

Table A-7 Single-Shell Tank Breathing Rates Used for Evaporation Estimates

1	2	3	4	5	6	7	8	9	10
Tank	**Empty Tank Volume (ft^3)**	**Waste Volume (ft^3)**	**Headspace Volume (ft^3)**	**Air Change due to Atmospheric ΔP (cfm)**	**Air Change Independent of Atmospheric ΔP (cfm)**	**Air Change from Inleakage to Active Vent System (cfm)**	**Breathing Rate Used (cfm)**	**RPP-5660 Rev 0 Breathing Rate (cfm)**	**HNF-3588 Rev 1 Breathing Rate (cfm)**
A-102	176,158	5,333	170,825	0.56	2.05	7.81	**10.4**	8	10
A-106	176,158	10,560	165,598	0.55	2.05	7.81	**10.4**	10	10
AX-101	178,184	47,784	130,400	0.43	2.05	17.93	**20.4**	28	20
AX-103	178,184	14,233	163,951	NA, used measured breathing rate			**25.0**	25	25
B-203	7,918	6,710	1,208	0.00	1.02	0	**1.03**	0[1]	1.0[2]
B-204	7,918	6,604	1,314	0.00	1.02	0	**1.03**	0[1]	1.0[2]
BY-108	140,086	29,702	110,384	0.36	2.05	0	**2.41**	7	16
S-104	140,362	38,496	101,866	0.34	2.05	0	**2.38**	6	Not listed
SX-102	173,139	45,630	127,509	0.42	2.05	0	**2.47**	40	100
SX-105	173,139	50,221	122,918	0.41	2.05	0	**2.45**	40	100
SX-114	173,139	20,767	152,372	0.50	2.05	0	**2.55**	325	100
T-111	113,552	59,721	53,831	0.18	2.05	0	**2.22**	6	5
T-203	7,918	4,803	3,115	0.01	1.02	0	**1.03**	0[1]	1.0[2]
T-204	7,918	4,803	3,115	0.01	1.02	0	**1.03**	7	1.0[2]
TX-108	140,086	16,882	123,204	0.41	2.05	0	**2.45**	9	5
TY-101	140,362	15,787	124,575	0.41	2.05	0	**2.46**	3	5
TY-103	140,362	20,661	119,701	0.40	2.05	0	**2.44**	8	5
TY-105	140,362	30,867	109,495	0.36	2.05	0	**2.41**	7	5
U-104	113,552	7,240	106,312	0.35	2.05	0	**2.40**	7	5
U-108	113,552	57,956	55,596	0.18	2.05	0	**2.23**	4	5

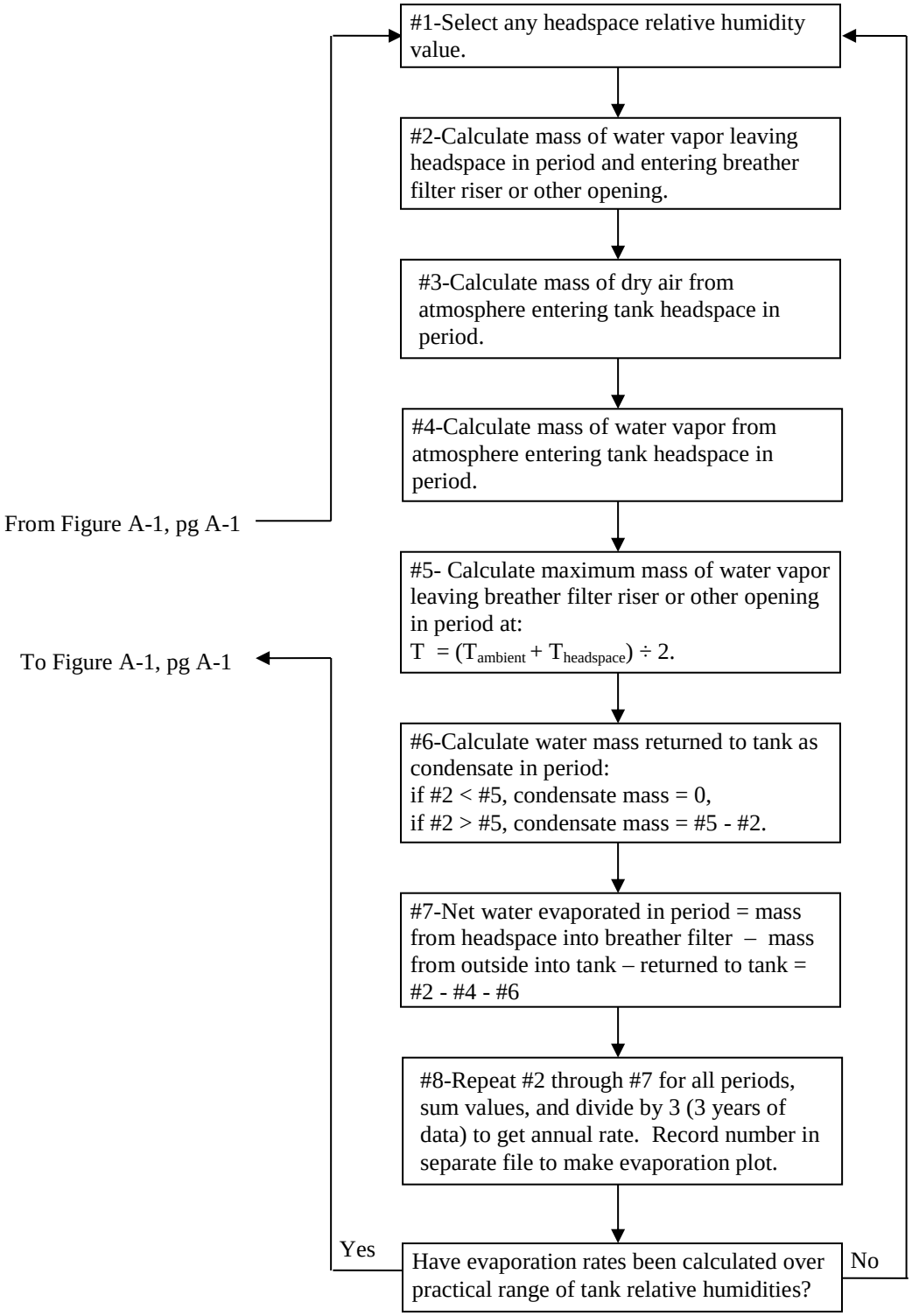
1 No rate listed for tank in Table D-4 of HNF-3588 Rev 1, but text states to assume 1.0 cfm for 200 Series tanks, and 1.0 cfm is given for the six 200 Series tanks listed in Table D-4 of HNF-3588 Rev 1.

2 No basis for 0 cfm rate in RPP-5660, or referenced documents WHC-SD-WM-ER-526 or WHC-SD-WM-TI-724.

A.5 Estimation of Tank Evaporation Rates

Figure A-26 provides a flowchart for how the evaporation calculations were done.

Figure A-26 Flowchart for Evaporation Calculations



The following assumptions are used for estimation of SST evaporation rates as a function of tank headspace relative humidity in this document:

- Calculations based upon the 2010 to 2012 atmospheric data are applicable to earlier years.
- The ambient air temperature and relative humidity used are applicable to the temperature and relative humidity of the air entering the breather filter riser (and other breathing locations).
- The methodology used to derive a tank headspace temperature vs. date formula for each tank is reasonable even though the data for the tanks spans several (or more) recent years.
- The tank headspace air temperatures used are applicable to the temperature of the headspace air entering the breather filter riser (and other air exchange locations).
- The breathing rates measured in the mid- to late-1990s provide a realistic value for the air exchange rate between a tank headspace and the atmosphere with respect to water vapor. See Section 4 in main body of this document for discussion of this assumption.

Notes:

1. All calculations were done in an Excel file set up to perform the same calculations for any tank, then 20 copies were made, one for each tank with the specific parameters for that tank entered into the appropriate cells. Each file consisted of 26,303 rows, one for each hourly atmospheric data entry from 2010 through 2012.
2. The breathing rate for a tank is assumed to be the flow rate out of the tank. Since the air flow out of a tank will include the incoming air plus any water evaporated, the incoming air flow rate is slightly less. The difference in flow rates between incoming and outgoing air is negligible, but this basis needs to be stated to ensure accuracy and consistency in the calculations.
3. Estimating condensate recycle quantities for A and AX tanks is conservative since it assumes all incoming and outgoing air is mixed, while if the air exchange rate for these tanks is due to inleakage from an existing ventilation system there will be little condensate return.

Table A-8 shows the calculation results for the first two and last data periods for tank A-102. This table is used as an example to explain the calculations performed. The paragraphs following the table explain the data entries or calculations in each column, and give the math for calculations in the first data period of Table A-8.

In Table A-8, the green colored headings for Columns J through T calculate the quantity of water vapor leaving the tank headspace and entering the breather filter riser. The yellow colored headings for Columns U through AD calculate the quantity of water vapor entering the tank headspace from the atmosphere. The magenta colored headings for Columns AE through AJ calculate the quantity of water that entered the breather filter riser from the tank headspace that is returned to the tank as condensate after mixing with air from the atmosphere. The blue colored headings AL and AM calculate the net volume of water evaporated in the period, and the cumulative water evaporated.

Table A-8 Example of Evaporation Calculations[1] - Tank A-102

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Data Period	HWS Date			HWS Date & Time	Temp °F	RH %	Press in. Hg	Date for A-102 HS Temperature	A-102 Calculated HS Temperature °F	Breathing Rate (cfm)	VP H_2O @ 100% RH in Headspace (mm Hg)	Assumed Tank Headspace RH %	VP H_2O in Headspace (mm Hg)	Ambient Pressure (in. Hg)
1	1/1/2010	1	0:00	1/1/10 0:00	30	98	29.24	1/1/12 0:00	90.9	10.4	37.10	40.0	14.84	29.24
2	1/1/2010	2	1:00	1/1/10 1:00	30	97	29.23	1/1/12 1:00	90.9	10.4	37.09	40.0	14.84	29.23
	……..													
26303	12/31/2012	24	23:00	12/31/12 23:00	29	88	29.70	12/31/12 23:00	88.4	10.4	34.30	40.0	13.72	29.7

	O	P	Q	R	S	T	U	V	W	X	Y
	Water Vapor & Dry Air to BF Riser (g-moles)	Mole Fraction H_2O in HS Air	Moles H_2O to BF Riser in Headspace Air (g-moles)	Moles Air to BF Riser in Headspace Air (g-moles)	Mass H_2O to BF Riser in Headspace Air (lbs)	Volume Water to BF Riser as Liquid (gal)	Ambient Temp (°F)	Ambient RH %	VP H_2O @ 100% RH in Ambient Air (mm Hg)	VP H_2O in Ambient Air (mm Hg)	Dry Air into Tank (g-moles)
1	689.03	0.0200	13.766	675.266	0.547	0.06557	30	98	4.22	4.14	675.266
2	688.80	0.0200	13.764	675.041	0.547	0.0656	30	97	4.22	4.10	675.041
……	.										
26303	703.05	0.0182	12.785	690.267	0.508	0.0609	29	88	4.05	3.57	690.267

	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
	Mole Fraction Water in Ambient Air	Mole Fraction Dry Air in Ambient Air	H_2O into Tank (g-moles)	Mass H_2O into Tank (lbs)	Volume Water into Tank as Liquid (gal)	Tavg of T_{amb} +T_{hs} °F	VP H2O @ 100% RH @ Tavg (mm Hg)	Ambient Pressure (mm Hg)	Max g-moles H_2O out	Condensate Returned (g-moles)	Volume Condensate Returned in Period (gal)	Volume Evaporated (gal)	Cumulative Volume Evaporated (gal)
1	0.0056	0.9944	3.7849	0.150	0.01803	60.4	13.46	742.73	12.463	1.303	0.00621	0.04134	0.0413
2	0.0055	0.9945	3.7461	0.149	0.0178	60.4	13.46	742.47	12.46	1.30	0.0062	0.0415	0.0829
……													
26303	0.0047	0.9953	3.2778	0.130	0.0156	58.7	12.65	754.41	11.77	1.01	0.0048	0.0405	918.2008

[1] HWS=Hanford Weather Station, HS=headspace, VP=vapor pressure, BF=breather filter, RH=relative humidity

Columns A through G – The input data for date, data time period, ambient temperature (°F), RH (%), and pressure (in. Hg) from the HWS is copied directly in Columns A, B, E, F, and G respectively. Column C changes the 1,2,3, etc. data period given by the HWS into a 0:00, 1:00, 2:00, etc., time. Column D adds the date in Column A and the time in Column C to give a combined date + time for subsequent use.

Column H – Column H adjusts the date and time in Column D to a 2012 year basis. This is done because the tank headspace temperature formula used in the next column is based upon a 2012 date, as explained in Section A.3.

Column I – This calculates a tank headspace temperature in °F for each time period using the polynomial equation shown on Figures A-2 to A-20. The formula for tank A-102 from Figure A-2 is:

$$y = -1.8718754820E-06x^3 + 2.3082599909E-01x^2 - 9.4878681662E+03(x) + 1.2999570466E+08$$

where y = temperature in °F

x = date/time in Excel format, 1/1/12 @0:00 = 40909.00, 1/1/12 @1:00 = 40909.0417,…

12/31/12 @23:00 = 41274.9583

The tank A-102 tank headspace temperature for the first date and time shown in Column I is thus:

$$T = -1.8718754820E-06(40909)^3 + 2.3082599909E-01(40909)^2 - 9.4878681662E+03(40909) + 1.2999570466E+08$$

$$= 90.9°F$$

Column J – This is the estimated breathing rate of 10.4 cfm from Table A-7.

Column K – Figure A-27 is a plot of the vapor pressure (VP) of water using data from Weast, et al, 1988, *Handbook of Chemistry and Physics*, 68th edition. An Excel polynomial regression line through the data was used to calculate the vapor pressure of water at 100% RH in the tank headspace in Column K. The vapor pressure is calculated using the regression line formula:

$$VP = 0.0000003617T^4 - 0.000017643T^3 + 0.002712T^2 + 0.021578T + 1.3196$$

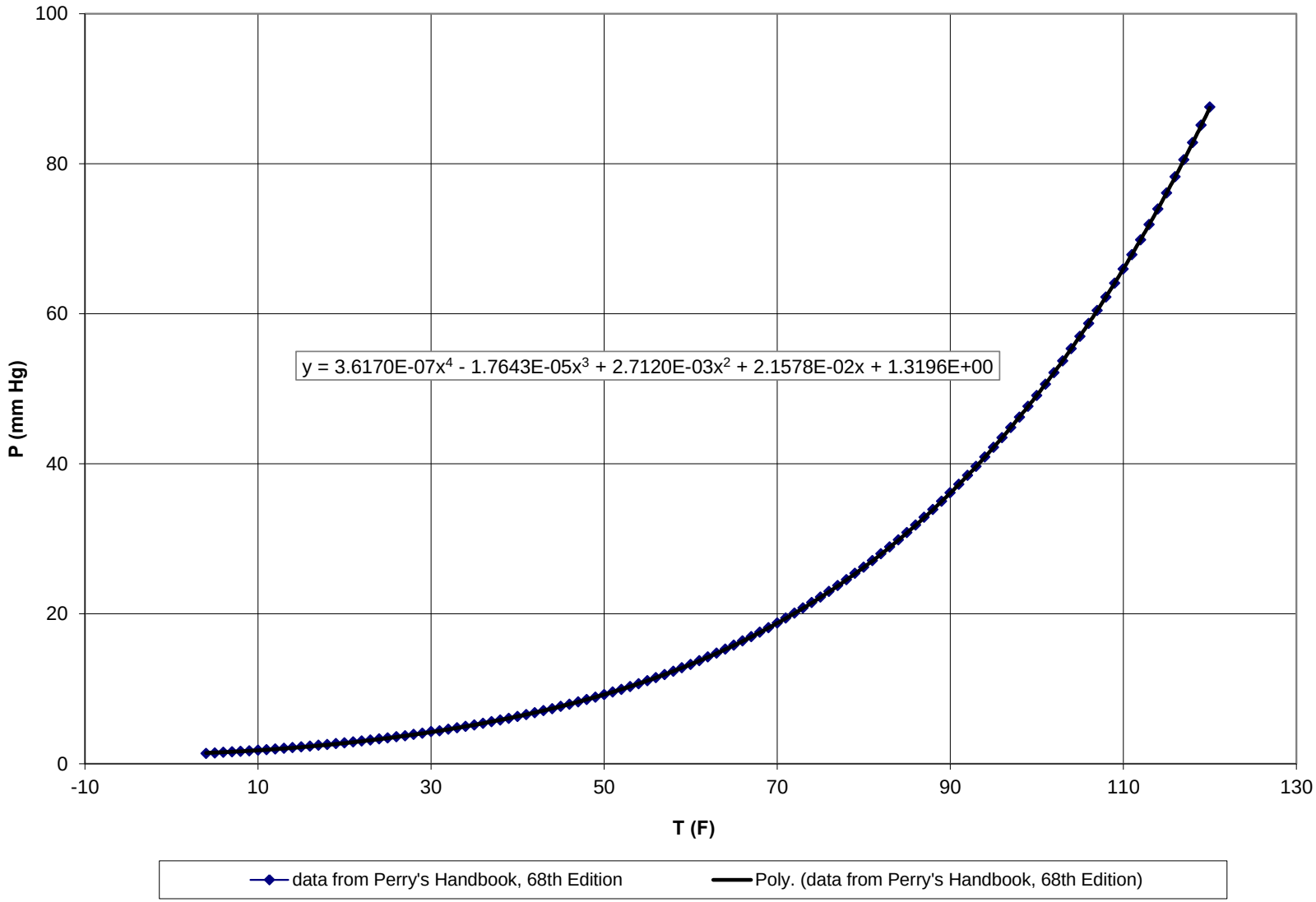
Where VP is in mm Hg and T is in °F

The tank vapor pressure of water for 90.9°F calculates to:

$$VP = 0.0000003617(90.9)^4 - 0.000017643(90.9)^3 + 0.002712(90.9)^2 + 0.021578(90.9) + 1.3196$$

$$= 37.1 \text{ mm Hg}$$

Figure A-27 Vapor Pressure of Water



Column L – Any desired value for a tank headspace relative humidity is entered in Column L. The practical range for each tank becomes apparent after a few entries. Most tanks will need a minimum headspace relative humidity of about 25% to show a positive evaporation rate, but a few thermally hot tanks will show a positive rate at less than 10%. Most tanks can have a maximum practical RH of 100%, with a few maxing out at a lower number. A practical range of values for a specific tank are entered and the evaporation rate sum below Row 26,303 at the bottom of Column AL is recorded in a separate file subsequently used to make the evaporation plot for the tank. e.g., Table A-8 shows a value of 40 entered for tank A-102 and a value of 918.2 gal below Cell AL 26303 (this is the calculated 3-year evaporation rate from 2010 through 2012). The RH input numbers used for tank A-102 ranged from 20% to 100%.

Column M – Column M calculates the vapor pressure of water in the tank headspace air entering the breather filter riser by multiplying the vapor pressure at 100% RH from Column K by the RH from Column L:

$$Vapor\ pressure\ in\ tank\ headspace = 37.1\ \times 40 \div 100 = 14.84\ mm\ Hg$$

Column N – This column repeats the ambient atmospheric pressure from Column G.

Column O – Column O uses the natural gas law to calculate the gram moles of water vapor plus air out of the tank in the period:

$$PV = nRT$$

Rearranging:

$$n = PV \div RT$$

Where:

n = g-moles
V= ft^3
T = temperature in °R = temperature in °F + 459.67
R = natural gas constant = 0.0482 (in. Hg)(ft^3)/(g-moles)(°R) from Weast, et al, 1988, pg F-185

The volume V is the breathing rate in cfm times the period duration of 60 minutes. Thus, for the first period of Table A-8 the moles of gas out of the tank headspace to the breather filer riser is:

$$gmoles\ of\ gas\ out\ of\ tank = (29.24 \times 10.4 \times 60) \div (0.0482 \times (90.9 + 459.67))$$
$$= 689.03 \text{ gmoles}$$

Column P – Column P calculates a mole fraction of water vapor molecules in the gas leaving the tank. This is equal to the vapor pressure of water vapor in the tank headspace gas leaving the tank from Column M divided by the atmospheric pressure from Column N:

$$mole\ fraction\ water\ vapor\ in\ gas\ leaving\ tank$$
$$= 14.84\ mm\ Hg \div (29.24\ in.Hg \times 760\ mm\ Hg \div 29.92\ in.Hg)$$
$$= 0.0200$$

where: 29.24 in. Hg is the ambient pressure from Column N and 760 mm Hg and 29.92 in. Hg are equivalent sea level pressures.

Column Q – Column Q calculates the gmoles of water vapor leaving the tank in the headspace air by multiplying the total moles of gas out by the mole fraction of water vapor:

$$gmoles\ of\ water\ vapor\ leaving\ tank = 689.03\ gmoles \times 0.0200 = 13.766\ gmoles$$

Column R – Column R calculates the moles of dry air leaving the tank in the headspace gas by subtracting the moles of water vapor from the total moles of air:

$$gmoles\ dry\ air\ leaving\ tank = 689.03\ gmoles\ gas - 13.766\ gmoles\ water\ vapor = 675.266\ gmoles$$

Column S – Column S calculates the mass of water vapor leaving the tank:

$$mass\ of\ water\ vapor\ leaving\ tank = 13.766\ gmoles \times \frac{18.02g}{gmole} \times \frac{lb}{453.6}g = 0.547\ lbs$$

Column T – Column T changes the mass of water vapor out of the tank to a liquid volume:

$$volume\ of\ water\ leaving\ tank\ (as\ liquid) = 0.547\ lbs \div 8.34\frac{lb}{gal} = 0.06557\ gal$$

Columns U and V – These repeat the ambient temperature and RH from Columns E and F.

Column W – Column W calculates the vapor pressure of water at 100% RH for the ambient air temperature. The same formula as in Column K is used. The tank vapor pressure of water for 30°F calculates to:

$$VP = 0.0000003617(30)^4 - 0.000017643(30)^3 + 0.002712(30)^2 + 0.021578(30) + 1.3196 = 4.22\ mm\ Hg$$

Column X – The ambient air water vapor pressure is equal to the ambient air RH times the ambient air water vapor pressure at 100% RH:

$$Vapor\ pressure\ of\ ambient\ air = 98 \times 4.22 \div 100 = 4.14\ mm\ Hg$$

Column Y – The gmoles of dry air assumed entering the tank is assumed equal to the gmoles of dry air leaving the tank in Column R, 675.266 gmoles.

Column Z - Column Z calculates a mole fraction of water vapor molecules in the gas entering the tank. This is equal to the vapor pressure of water vapor in the ambient air divided by the atmospheric pressure:

$$mole\ fraction\ water\ vapor\ in\ gas\ entering\ tank = 4.14\ mm\ Hg \div (29.24\ in.Hg \times 760\ mm\ Hg \div 29.92\ in.Hg)$$

= 0.0056

Column AA – The mole fraction of dry air in the incoming gas is the mole fraction in the ambient air, or:

$$mole\ fraction\ of\ dry\ air\ in\ incoming\ gas = 1 - 0.0056 = 0.9944$$

Column AB – The gmoles of water coming into the tank is equal to the moles of dry air times the ratio of the mole fraction of water vapor to the mole fraction of dry air in the incoming gas (ambient air):

$$moles\ water\ vapor\ in\ incoming\ gas = 675.266 \times 0.0056 \div 0.9944 = 3.7849\ gmoles$$

Column AC - Column AC calculates the mass of water vapor entering the tank:

$$mass\ of\ water\ vapor\ entering\ tank = 3.7849\ gmoles \times \frac{18.02g}{gmole} \times \frac{lb}{453.6}g = 0.150\ lbs$$

Column AD – Column AD changes the mass of water vapor into the tank to a liquid volume:

$$volume\ of\ water\ entering\ tank\ (as\ liquid) = 0.150\ lbs \div 8.34\frac{lb}{gal} = 0.01803\ gal$$

<u>Summary explanation for Columns AE through AJ</u>

Columns AE through AJ calculate a volume of water returned to the tank due to mixing of headspace air and atmospheric air in the tank breather filter riser (or any other air pathway between the tank and the atmosphere). If each SST had a small exhauster which drew air through the tank at the same rate as an estimated tank breathing rate the calculation of an evaporation rate from the tank would be trivial, the water evaporated equals the water out of the tank to the exhauster minus the water into the tank from the atmosphere. With a tank that breathes instead of being exhausted the incoming and outgoing air will mix at times. The atmospheric air and tank headspace air will rarely be at the same temperature, so the temperature change on mixing could result in water vapor condensing out of either the atmospheric air or the headspace air. Water condensing out of the atmospheric air is immaterial to these calculations since all the atmospheric air is assumed to enter the tank anyway. But, water condensing out of the tank headspace air that has entered the riser needs to be accounted for since a simple 'water out minus water in' calculation like for an exhausted tank will overestimate the tank evaporation rate. It is unknown what fraction of the tank headspace air entering the breather filter riser mixes with atmospheric air, so it is conservatively assumed that all incoming and outgoing air is mixed and that an equilibrium temperature is reached that is the average of the ambient air temperature and the headspace temperature. Equal mixing is assumed. There may not be equal mixing very often, there will be periods when the breather filter riser is filled with ambient air and other times when the breather filter riser is filled with headspace air, but conservatively the mixing is assumed to occur all the time. The maximum water vapor that can exist at 100% RH in the tank headspace air in the riser at this average temperature is calculated, and if it is less than the quantity of water vapor entering the riser from the headspace the excess is assumed returned to the tank as condensate.

Column AE – Column AE calculates the average temperature for mixing of the tank headspace air and the ambient air in the breather filter riser, or any other opening through which the tank breathes:

$$Tavg = (T_{amb} + T_{HS}) \div 2 = (30 + 90.9) \div 2 = 60.4°\text{F}$$

Column AF – This column calculates the vapor pressure of water at 100% RH at the average temperature in the riser. The same vapor pressure formula as in Column K is used. The tank vapor pressure of water for 60.4°F calculates to:

$$VP = 0.0000003617(60.4)^4 - 0.000017643(60.4)^3 + 0.002712(60.4)^2 + 0.021578(60.4) + 1.3196 = 13.46\ mm\ Hg$$

Column AG – Column AG converts the atmospheric pressure in Column N to mm Hg.

$$Atm\ \text{Pr} = 29.24 \times 760 \div 29.92 = 742.73\ mm\ Hg$$

Column AH – Column AH calculates the maximum gmoles of water that could exist in the air mixture in the riser at 100% RH.

The number of moles of a constituent in a gas mixture is proportional to the vapor pressure:

$$\frac{moles_{H2O@100\%RH}}{moles_{total}} = \frac{VP_{H2O@100\%RH}}{VP_{total}}$$

The number of moles total in a mixture is equal to the sum of the constituent moles:

$$moles_{total} = moles_{H2O@100\%RH} + moles_{dry\ air}$$

Substituting and rearranging:

$$moles_{H2O@100\%RH} \times VP_{total} = VP_{H2O@100\%RH} \times (moles_{H2O@100\%RH} + moles_{dry\ air})$$

$$moles_{H2O@100\%RH} \times VP_{total} - moles_{H2O@100\%RH} \times VP_{H2O@100\%RH} = moles_{dry\ air} \times VP_{H2O@100\%RH}$$

$$moles_{H2O@100\%RH} \times (VP_{total} - VP_{H2O@100\%RH}) = moles_{dry\ air} \times VP_{H2O@100\%RH}$$

$$moles_{H2O@100\%RH} = moles_{dry\ air} \times \frac{VP_{H2O@100\%RH}}{VP_{total} - VP_{H2O@100\%RH}}$$

From Column R the number of moles of air is 675.266 gmoles, from Column AF the vapor pressure of water at 100% RH at the average temperature in the breather filter riser is 13.46 mm Hg, and from Column AG the total pressure is 742.73 mm Hg. Therefore, the maximum number of moles of water vapor suspended in the air mixture is:

$$moles_{H2O@100\%RH} = 675.266 \times 13.46 \div (742.72 - 13.46) = 12.463\ gmoles$$

Column AI – Column AI calculates the gmoles of water that is returned to the tank as condensate if the gmoles of water at the average temperature of the air mixture and 100% RH is greater than that in Column Q. If Column Q is greater than Column AH, the excess is sent back as condensate. If Column Q is less than or equal to Column AH, zero is entered in Column AI:

$$13.766\ gmoles\ H_2O out\ of\ headspace\ to\ breather\ filter\ riser - 12.463\ gmoles\ H_2O\ max = 1.303\ gmoles\ H_2O\ returned\ as\ condensate$$

Column AJ – Column AJ converts the gmoles of condensate returned to gallons:

$$1.303\ gmoles \times \frac{18.02g}{gmole} \times lb/453.6g \times gal/8.34lb = 0.00621gal$$

Column AK – The net volume of water evaporated (as liquid) is calculated by subtracting the volume of water vapor into the tank in Column AD and the condensate returned from Column AJ from the water vapor out of the tank in Column T:

$$net\ volume\ of\ water\ evaporated\ in\ period = 0.06557 - 0.01803 - 0.00621 = 0.04134\ gal$$

Column AL – This column sums the cumulative volume evaporated as liquid, 0.0413 gal after period 1, 0.0829 gal after period 2, and the total in data period 26,303 is 918.2008 gal for the 3 years 2010 to 2012. The average volume evaporated from tank A-102 for this example is therefore:

$$average\ annual\ evaporation\ rate\ from\ tank\ A - 102\ if\ 40\%\ RH\ in\ headspace$$
$$= 918.2008 \div 3 = 306.1\ gal\ per\ year$$

The tank A-102 plot in Figure A-28 was made by calculating the tank A-102 evaporation rate with the tank headspace RH ranging from 20 to 100%. The line in Figure A-28 is the same as the blue line in Figure 3-4 in the main body of this document.

Calculations were done in a similar manner and plots made for all 20 tanks. The plots are provided in Figures A-28 through A-31.

NOTE: RPP-RPT-54964, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection*, Rev 1, used a simplified method for estimating tank evaporation, resulting in a slightly higher evaporation rate for the preliminary evaporation estimates in that document. The lower evaporation rate in this document thus has no impact on the conclusions in RPP-RPT-54964, Rev 1.

Figure A-28 Estimate of Evaporation Rate for Tanks A-102, A-106, AX-101, AX-103 and SX-114

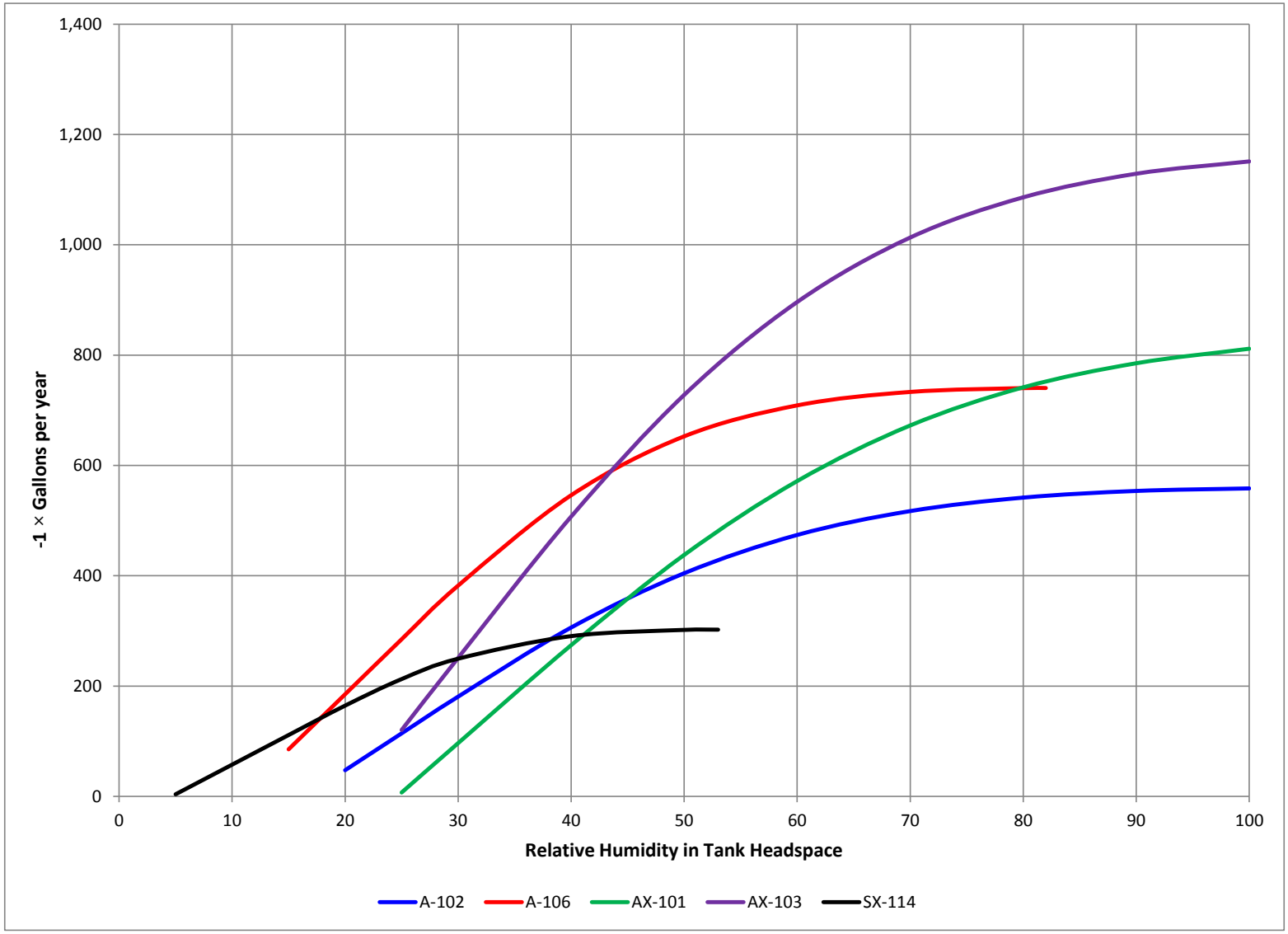


Figure A-29 Estimate of Evaporation Rate for Tanks BY-108, S-104, SX-102, SX-105 and U-108

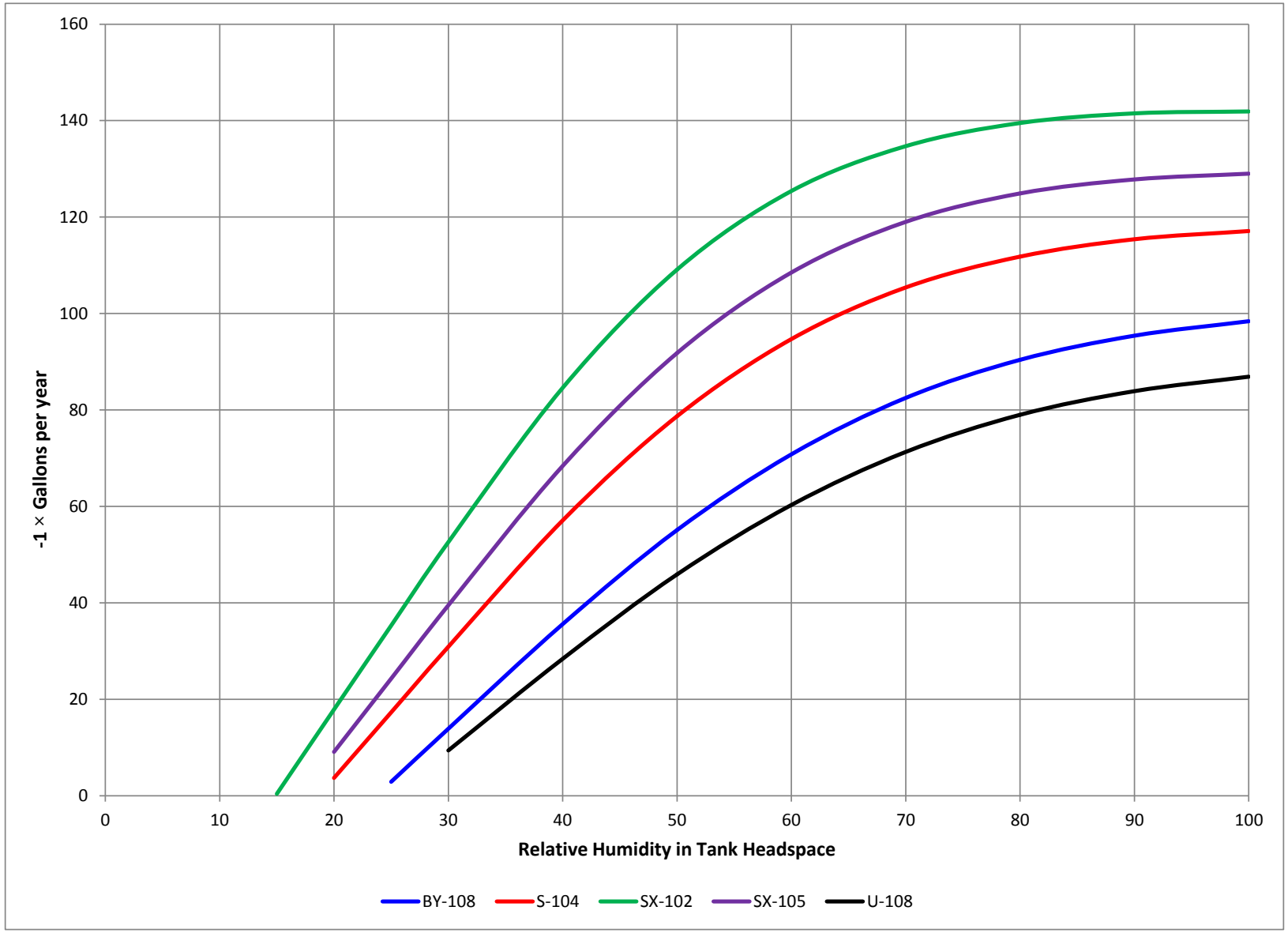


Figure A-30 Estimate of Evaporation Rate for Tanks TX-108, TY-101, TY-103, TY-105 and U-104

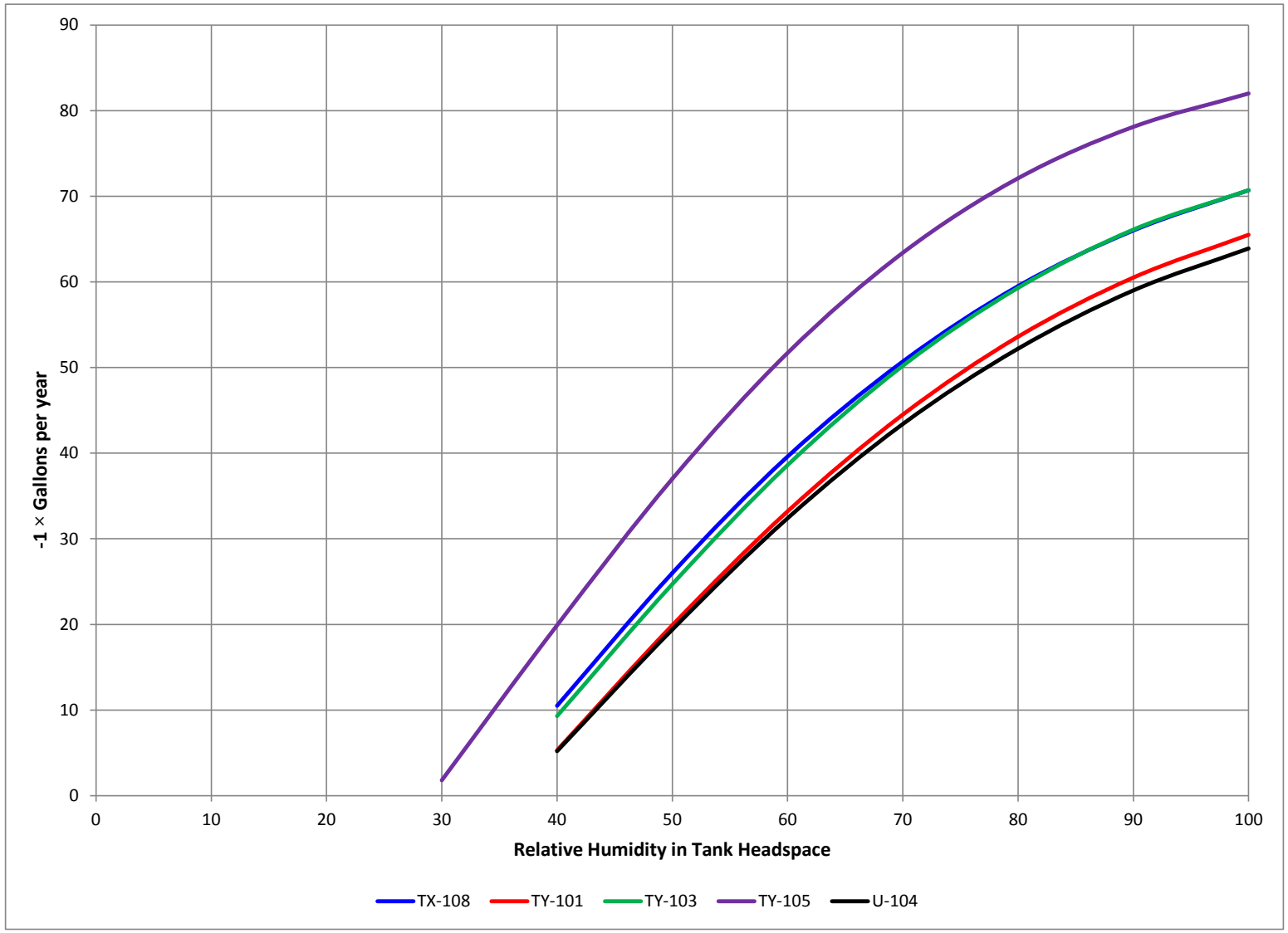
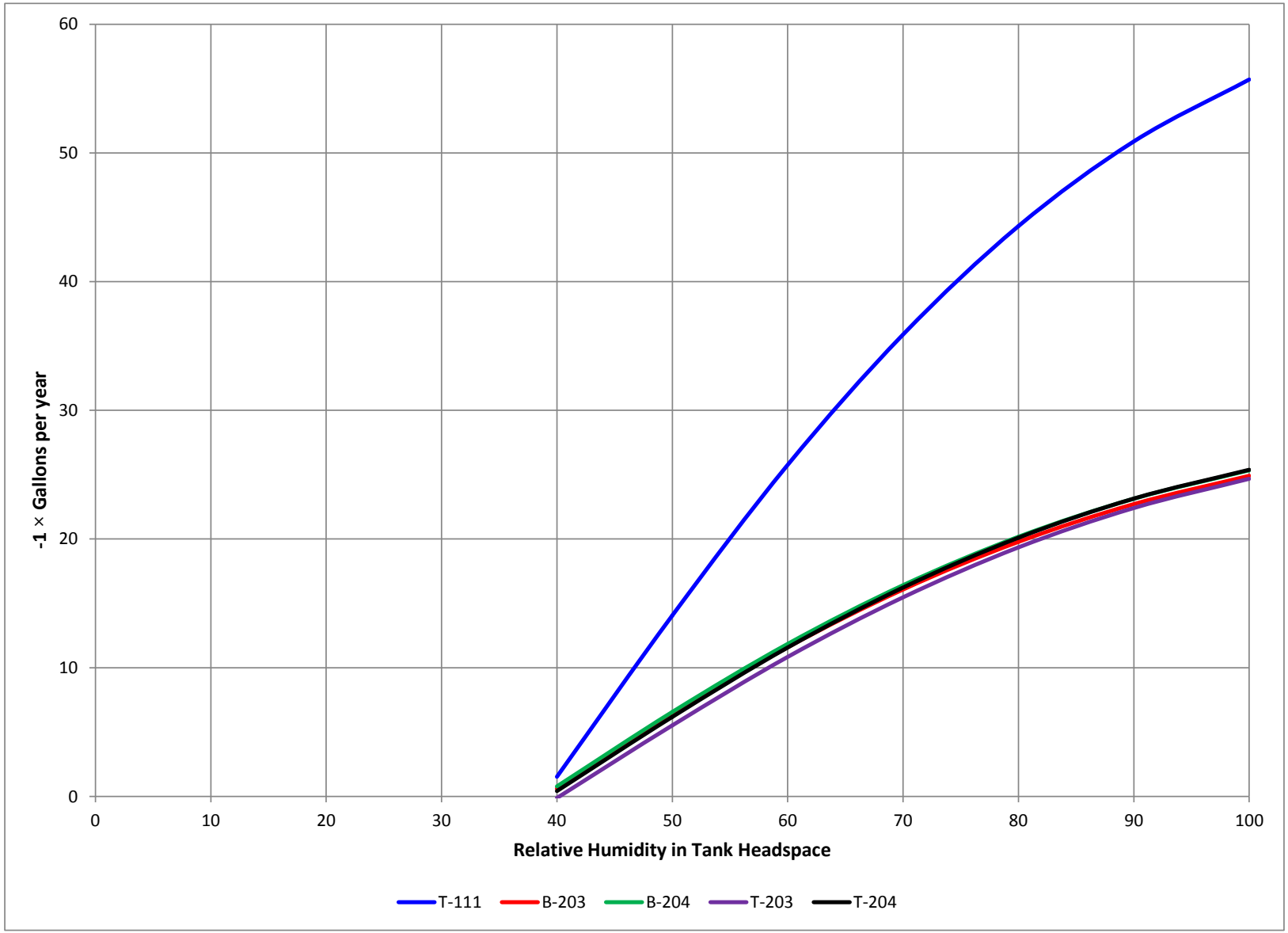


Figure A-31 Estimate of Evaporation Rate for Tanks T-111, B-203, B-204, T-203 and T-204



A.6 Tank Headspace Relative Humidity

Figures A-28 through A-31 give the estimated evaporation rates for the 20 tanks vs. the relative humidity in the outgoing headspace air. The relative humidity in each tank is shown as varying from the minimum practical to result in a positive evaporation rate from the tank up to a maximum of 100%. In this section a specific value is derived for the best estimate of the average annual headspace relative humidity in each of the 20 tanks.

Vapor samples were taken from 1994 to 1998 with heated vapor probes or in-tank sampling equipment to get samples which were analyzed for water vapor (and other analytes). The relative humidities calculated from the water vapor content were taken from HNF-3588, Rev 1. Vapor samples were obtained for 15 of the 20 tanks being analyzed for level decreases. The five tanks without vapor samples were S-104, B-203, B-204, T-203 and T-204. For these latter five tanks, data are available from other tanks with similar tank conditions to enable estimation of average annual relative humidities for the tanks. Table A-9 Columns 2, 3 and 4 list the sample date, relative humidity and tank headspace temperature for all the tanks used to estimated annual average relative humidities for the 20 tanks.

Column 6 of Table A-9 provides the average tank headspace relative humidity assumed for each of the 20 tanks, with a basis for the assumed relative humidity in Column 7. For B-203, B-204, T-203 and T-204 the relative humidity was based upon a sample taken from B-202. Tank B-202 has a waste level in the approximate range of the other four tanks, has ambient temperatures, and is believed to have the same or less surface liquid. For tank S-104 the relative humidity was based upon the average for tanks S-101 and S-102, nearby tanks with similar temperatures and similar interstitial liquid level (ILL) levels with respect to the waste surface. There is no relative humidity estimated for the tank SX-114 headspace air due to the high temperature in this tank and the 1997 vapor sample which showed a less than detectable quantity of water vapor in the headspace at that time.

The assumed relative humidity for each tank in Table A-9 is shown as a black vertical line on the estimated evaporation loss rate plots (e.g., Figure 3-4 for tank A-102) in the main body of this document.

Table A-9 Relative Humidity Sample Data, Assumed Relative Humidity, and Basis

1	2	3	4	5	6	7
Tank	**Vapor Sample Date**	**Relative Humidity from HNF-3588 Rev 1**	**Tank Headspace Temperature When Sampled (°F)**	**Supernate Volume (gal)**	**Relative Humidity Assumed for RPP-RPT-54981 (%)**	**Basis for Assumed Relative Humidity**
A-102	11/10/95	65.6	91.0	3.2	**65**	Calculated temperature for November 10 annual date per formula on Figure A-3 is about same as on sample date. Assume have same or more liquid because level is higher and may have had intrusion, still have supernate, assume RH essentially the same at 65%.
A-106	1/16/97	52.9	104.7	0	**50**	Calculated temperature for January 16 annual date per formula on Figure A-4 is a few degrees less than on sample date, so RH may be higher, but ILL is lower in the tank by estimated >12 in. so evaporation may give less water vapor in head space, assume RH slightly lower at 50%
AX-101	6/15/95	37.2	86.7	0	**45**	Calculated temperature for June 15 annual date per formula on Figure A-5 is about 12°F less than on sample date. ILL also closer to the waste surface (~85 inches vs. ~140 inches in 1995), so RH should be higher. Assume RH of 45%
AX-103	6/21/95	38.4	90.0	0	**40**	Calculated temperature for June 21 annual date per formula on Figure A-6 is about 10°F less than on sample date, so RH should be higher, but ILL is an estimated 12 in. lower under the waste surface, assume RH at 40%
B-202	7/18/96	91.7	60.8	NR	**NR**	NA, value used to estimate B-203, B-204, T-203, T-204 RH
B-203	None	NA	NA	1.5	**92**	Tank has 100% liquid surface, small headspace, assume same RH as B-202.
B-204	None	NA	NA	1.6	**92**	Tank has 100% liquid surface, small headspace, assume same RH as B-202.
BY-108	10/27/94	42.3	86.9	0	**53**	Average RH of all BY-108 samples was 50%. Calculated

Table A-9 Relative Humidity Sample Data, Assumed Relative Humidity, and Basis

1	2	3	4	5	6	7
Tank	**Vapor Sample Date**	**Relative Humidity from HNF-3588 Rev 1**	**Tank Headspace Temperature When Sampled (°F)**	**Supernate Volume (gal)**	**Relative Humidity Assumed for RPP-RPT-54981 (%)**	**Basis for Assumed Relative Humidity**
	1/23/96	50.1	79.9			temperature for same month/day annual date per formula on Figure A-9 are about 4-5°F less than on sample dates so RH should be slightly higher. ILL lower by estimated 3-4 in. so likely not much impact on water vapor in headspace, so assume 53%
	1/23/96	49.0	79.9			
	1/23/96	47.6	79.9			
	3/28/96	52.4	77.0			
	3/28/96	54.4	77.0			
	9/10/96	52.0	82.2			
	11/14/96	57.6	82.4			
	1/30/97	46.2	82.4			
S-101	6/6/96	51.2	87.8	0	**NR**	NA, value used to estimate S-104 RH.
S-102	3/14/95	63.9	75.2	2.4		NA, value used to estimate S-104 RH.
	1/26/96	47.7	78.8			
	1/26/96	51.9	78.8			
	1/26/96	48.4	78.8			
	4/4/96	50.2	75.2			
	4/4/96	52.2	75.2			
	9/19/96	49.7	84.2			
	12/19/96	49.6	80.6			
	2/11/97	54.6	75.2		**NR**	

Table A-9 Relative Humidity Sample Data, Assumed Relative Humidity, and Basis

1	2	3	4	5	6	7
Tank	**Vapor Sample Date**	**Relative Humidity from HNF-3588 Rev 1**	**Tank Headspace Temperature When Sampled (°F)**	**Supernate Volume (gal)**	**Relative Humidity Assumed for RPP-RPT-54981 (%)**	**Basis for Assumed Relative Humidity**
S-104	None	NA	NA	0	**52**	No vapor sample water vapor data available. Temp range now is about same as for S-101 and S-102 in 1996-1997. S-104 ILL is at surface, same as S-101 and S-102 in 1996-1997. Average of S-101 and S-102 RHs is 52%, so assume 52% for S-104.
SX-102	7/19/95	17.2	94.8	0	**~50**	The 1995 tank SX-102 headspace RH of 17.2% was based upon a vapor space sample when the tank was being exhausted at a nominal 100 cfm. The mid July temperature for tank SX-102 with the exhauster off calculates to about 93°F per Figure A-11. A slightly lower temperature and a 40-fold reduction in the air change rate implies a higher RH. The only non-exhausted salt containing tank with a headspace temperature approaching tank SX-102 that had a vapor sample taken was tank S-101, which was about 88°F. Tank S-101 had a RH of 51.2%. The only non-exhausted sludge containing tanks with headspace temperatures approaching tank SX-102 that had a vapor sample taken were tanks C-101 (95°F & 75.4% RH), C-103 (102°F & 87% RH), and C-107 (101 to 116°F & 67.8 to 90.3% RH).
SX-105	7/26/95	27.3	94.5	0	**~50**	The 1995 tank SX-105 headspace RH of 27.3% was based upon a vapor space sample when the tank was being exhausted at a nominal 100 cfm. The tank headspace temperature is about the same in 2013 as in 1995 when the tank was exhausted. Tank SX-105 had almost the same headspace temperature as tank SX-102 when sampled. See discussion for tank SX-102 for a nominal RH of about 50% based upon the tank S-101 RH, the same reasoning is used for the tank SX-105 RH.

Table A-9 Relative Humidity Sample Data, Assumed Relative Humidity, and Basis

1	2	3	4	5	6	7
Tank	**Vapor Sample Date**	**Relative Humidity from HNF-3588 Rev 1**	**Tank Headspace Temperature When Sampled (°F)**	**Supernate Volume (gal)**	**Relative Humidity Assumed for RPP-RPT-54981 (%)**	**Basis for Assumed Relative Humidity**
SX-114	6/25/97	5.5	124.0	0	**Not estimated**	Current headspace temperature is about 7ºF higher that in 1997 because tank is no longer exhausted. The 5.5% RH in 1997 was based upon the water vapor content in the sample, which was actually a 'less than' number, the water vapor content was below the detectable limit. This in turn either means the sample was in error or the liquid was essentially al evaporated from the tank by that time. See Section 3.9.5 in main body of report for discussion of the SX-114 RH.
T-111	1/20/95	85.9	61.0	0	**86**	Calculated temperature for January 20 annual date per formula on Figure A-14 is about same as when sampled, liquid pool in tank about the same, assume no change in RH at 86%. **NOTE:** RPP-RPT-54964, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection*, Rev 0, used a slightly different tank headspace relative humidity for the preliminary evaporation estimates in that document. The lower evaporation rate in this document thus has no impact on the conclusions in RPP-RPT-54964.
T-203	None	NA	NA	0.1	**85**	Tank has about a 18% liquid surface per video, the tank is also about 2/3 full. Tank has more waste in it than B-202 and about the same temperature. B-202 may have a higher fraction of the waste surface that is liquid though, since it appears to have an intrusion. Assume 85% vs. the 91.7% measured in B-202.

Table A-9 Relative Humidity Sample Data, Assumed Relative Humidity, and Basis

1	2	3	4	5	6	7
Tank	**Vapor Sample Date**	**Relative Humidity from HNF-3588 Rev 1**	**Tank Headspace Temperature When Sampled (°F)**	**Supernate Volume (gal)**	**Relative Humidity Assumed for RPP-RPT-54981 (%)**	**Basis for Assumed Relative Humidity**
T-204	None	NA	NA	0.2	**85**	Tank has about a 34% liquid surface per video, the tank is also about 2/3 full. Tank has more waste in it than B-202 and about the same temperature. B-202 may have a higher fraction of the waste surface that is liquid though, since it appears to have an intrusion. Assume 85% vs. the 91.7% measured in B-202.
TX-108	12/5/97	90.1	62.8	0	**80**	Calculated temperature for December 5 annual date per formula on Figure A-17 about 7°F higher than sample date, but temperature is still low. ILL should be slightly lower in tank if no intrusion. Assume RH lower at 80% vs. 90% measured value.
TY-101	4/6/95	72.8	61.9	0	**70**	Calculated temperature for April 6 annual date per formula on Figure A-18, waste surface slightly less, ILL should be little lower, assume RH slightly lower at 70% vs. measured 72.8%.
TY-103	4/11/95	83.1	61.5	0	**82**	Calculated temperatures for April 11 and November 22 annual dates per formula on Figure A-19 within a degree or two of temperature when sampled, ILL right at waste surface, assume RH the same, use 82%, average of two sample values.
	11/22/96	81.0	66.4			
TY-105	10/20/97	82.1	71.6	0	**80**	Calculated temperature for October 20 annual date per formula on Figure A-20 is a few degrees higher and ILL slightly lower, but ILL is about same depth below waste surface since waste surface also is going down. Assume RH down slightly at 80% vs. 82% measured.
U-104	7/16/96	97.3	65.7	0	**95**	Temperatures unknown but should be about the same with negligible heat in tank. Assume RH down slightly at 95% vs. measured 97% since some water has to have evaporated.

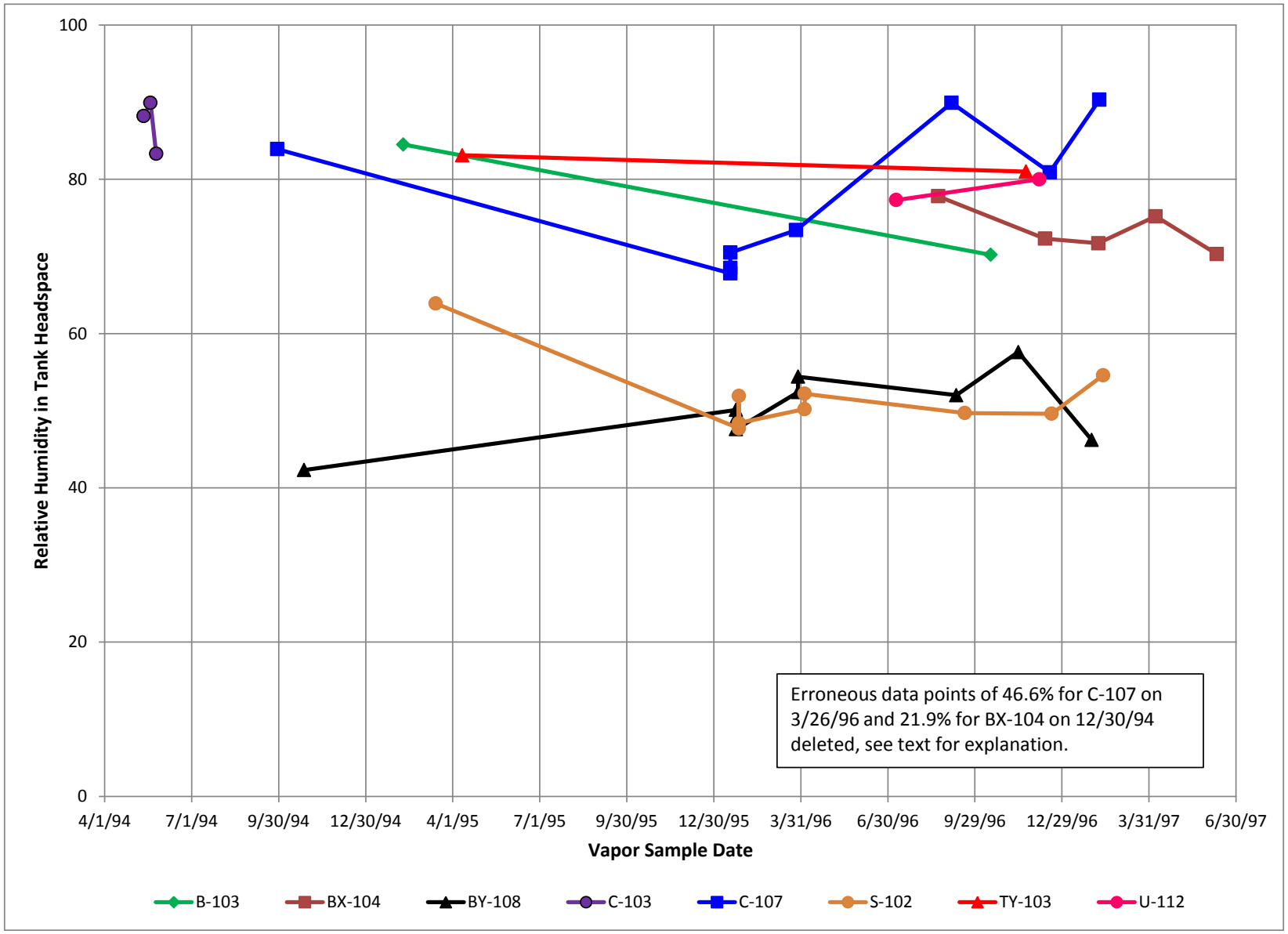
Table A-9 Relative Humidity Sample Data, Assumed Relative Humidity, and Basis

1	2	3	4	5	6	7
Tank	**Vapor Sample Date**	**Relative Humidity from HNF-3588 Rev 1**	**Tank Headspace Temperature When Sampled (°F)**	**Supernate Volume (gal)**	**Relative Humidity Assumed for RPP-RPT-54981 (%)**	**Basis for Assumed Relative Humidity**
U-108	8/29/95	50.5	81.9	0	**45**	Calculated temperature for August 29 annual date per formula on Figure A-21 is a few degrees less but ILL is below waste surface now, it was above in 1995. Assume RH down some at 45% vs. measured 50%.

The assumption of a constant headspace RH does not mean the water vapor concentration in mass per unit volume of headspace air is constant. The headspace temperature varies as shown in Figures A-3 through A-21. Assuming a constant RH means the water vapor concentration is a constant fraction of the maximum possible water vapor concentration for the tank headspace temperature. The water vapor concentration varies with the temperature in accordance with Figure A-27.

It is assumed that the tank headspace RH is constant throughout the year. This is not an accurate assumption on an absolute scale, but is reasonable and the errors involved should not cause any significant error in the evaporation rate results because a number of tanks had multiple samples taken at different times and the relative humidities in the samples were reasonably consistent for each tank. There were eight tanks (C-103, B-103, BX-104, BY-108, C-107, S-102, TY-103, and U-112) which had more than one vapor sample taken on different days in the 1990s. The C-103 samples were taken within a two week period but for the remaining seven tanks the samples stretched out over periods from 5 to 28 months. Figure A-32 shows the results. Omitted from Figure A-32 is one low value of 47% for C-107 believed to be an error since there is another sample on the same date with a RH of 73% (similar to all other C-107 samples) and one off-the-chart result for BX-104 of 22% RH that is assumed to be an error. From Figure A-32 it can be seen that the RH for the tanks sampled didn't vary significantly over time, and thus assuming a constant RH all year is a reasonable assumption for this document.

Figure A-32 Relative Humidities in Single-Shell Tanks with More Than One Vapor Sample



A.7 References

HNF-3588, 2003, *Organic Complexant Topical Report*, Revision 1, CH2M Hill Hanford Group Inc., Richland, Washington.

HNF-EP-0182, 1998, *Waste Status Summary for Month Ending March 31, 1998*, Revision 120, Lockheed Martin Hanford Company, Richland, Washington.

HWS-2013, *Hourly Ambient Temperature, Pressure, and Relative Humidity Data* obtained from Hanford Weather Station personnel via e-mail, April 3, 2013

PNNL-11683, 1997, *Measurements of Waste Tank Passive Ventilation Rates Using Tracer Gases*, J. L. Huckaby, et al, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11925, 1998, *Waste Tank Ventilation Rates Measured with a Tracer Gas Method*, J. L. Huckaby, et al, Pacific Northwest National Laboratory, Richland, Washington.

RPP-5660, 2000, *Collection and Analysis of Selected Tank Headspace Parameter Data*, Revision 0, CH2M Hill Hanford Group, Inc., Richland, Washington.

RPP-PLAN-55113, 2013, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan*, Revision 1, Washington River Protection Solutions LLC, Richland, Washington.

RPP-RPT-54964, 2013, *Evaluation of Tank 241-T-111 Level Data and In-Tank Video Inspection*, Revision 1, Washington River Protection Solutions LLC, Richland, Washington.

SVF-1770, 2009, *Tank Waste Volume Calculator*, Revision 0, Washington River Protection Solutions LLC, Richland, Washington.

TWINS, *Tank Waste Information Network System*, database available on the Hanford Local Area Network at https://twins.labworks.org/twinsdata/Forms/About.aspx

Weast, et al, 1988, CRC *Handbook of Chemistry and Physics*, 68th edition, CRC Press, Boca Raton, Florida.

WHC-EP-0651, 1993, *Barometric Pressure Variations*, Revision 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-ER-526, 1998, *Evaluation of Hanford Tanks for Trapped Gases*, Revision 1D, Lockheed Martin Hanford Company, Richland, Washington.

WHC-SD-WM-TI-724, 1996, Methodology for Flammable Gas Evaluations, Revision 1, Westinghouse Hanford Company, Richland, Washington.

APPENDIX B

ESTIMATION OF SELECTED SINGLE-SHELL TANK HEAT GENERATION RATES

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Best Basis Inventory	BBI
single-shell tank	SST
TWINS	Tank Waste Information Network System

B.1 Introduction

A heat generation rate is calculated for each of the 14 tanks being evaluated for level decreases in the main body of this document. The heat generation rate is based upon the Best Basis Inventory (BBI) values for the tank radionuclides. The BBI radionuclide curie values are multiplied by the watts per Ci value for each radionuclide and summed to give an estimated waste heat generation rate for the waste in the tank.

While the BBI radionuclide values are the official numbers to use for tank constituents, they are still only estimates. Tank waste and headspace temperatures are also an indication of the waste heat generation rate. Higher temperatures in general indicate higher heat generation rates, although waste thermal conductivity, waste volume, soil conditions and tank ventilation rates are also factors. Tank waste and headspace temperatures are thus also provided for each of the 14 tanks.

Evaporation of water requires energy. For evaporation from single-shell tank (SST) waste this energy comes from both radioactive decay of constituents in the waste and from the incoming air and soil surrounding the tank. In tanks with low heat generation rates the energy to evaporate water has to come from the air and waste surroundings. With a water vapor concentration in the tank headspace of less than 100% water there exists a driving force to evaporate water from a liquid or moist surface. As evaporation occurs, the liquid level decreases. When the liquid level recedes below the waste surface the evaporation rate due to latent heat exchange from the soil and incoming air will decrease until it reaches a level at which mass transfer to the tank headspace air is negligible due to this heat source. However, in tanks with sufficient radiolytic heat generation to increase the waste temperature above that for the surrounding soil the heat will continue to evaporate liquid and ensure mass transfer to the headspace air despite having the interstitial liquid below the waste surface. The greater the heat generation rate the hotter the waste will become, assuming other conditions don't change. The greater the radioactive decay energy released within the waste the greater the driving force is for evaporation.

B.2 Tank Waste Heat Generation Rates

The BBI tracks 46 radionuclides for each waste tank. Tank radionuclide content is obtained from the *Tank Waste Information Network System*, (TWINS) database available on the Hanford Local Area Network at https://twins.labworks.org/twinsdata/Forms/About.aspx. A TWINS download was made on September 28, 2012 for all the constituents in the tanks being evaluated. The decay heats in for each BBI listed radionuclide were extracted from HNF-EP-0063, 2008, *Hanford Site Solid Waste Acceptance Criteria*, Revision 14 (reissue), and multiplied by the curies of each radionuclide to derive an estimated heat generation rate for each of the tanks. The results are provided in Tables B-1 through B-14, and summarized in Table B-15. The TWINS data decay date is January 1, 2008, so the heat generation rates are about 12% less in mid-summer 2013 for all tanks except low heat tanks with heat largely from actinide decay.

Maximum waste temperatures for the 13 tanks with temperature data evaluated in the main body of this document were taken from a BBI download on November 30, 2012 and are also included in Table B-15. Maximum headspace temperatures calculated for each of these tanks from the regression line formulas in Appendix A, Figures A-3 through A-21 are also included in Table B-15.

The heat of vaporization of water at 70°F is 1,054 BTU/lb (Weast, et al, 1988, CRC Handbook of Chemistry and Physics, 68th Edition). Column 5 of Table B-15 lists the percentage of the decay heat in a tank needed to evaporate water at the estimated liquid loss rates for the tanks evaluated in the main body of this document. For the four tanks with only surface level data, the percentage range of decay heat needed for the minimum and maximum estimated liquid loss rates is listed.

Figure B-1 shows the relationship between estimated waste heat generation rate and tank waste and headspace temperatures for 19 of the 20 tanks (tank U-104 has no temperature data) recommended for evaluation in RPP-RPT-55113 (WRPS-1301005). A plot showing the relationship between estimated waste heat density (BTU/hr/ft^3 waste) provides a similar graph but with slightly more data scatter. Figure B-1 is included in this document to show there is a reasonable correlation between the tank temperatures and the estimated heat generation rates calculated from the BBI constituents.

B.3 Discussion

The lower the percentage of the decay heat in a tank needed to meet the liquid loss rate the higher the potential is that the liquid loss is due to evaporation.

For 10 of the 14 tanks (A-106, AX-101, AX-103, BY-108, S-104, SX-105, SX-114, TX-108, TY-103, and U-108) less than 8% of the available heat is needed for evaporation at the estimated liquid loss rates. This enforces a conclusion that evaporation is probably causing the estimated liquid loss in these tanks since there is easily enough heat generation to drive off water at the loss rate observed.

Two of the tanks have negligible heat generation (TY-101, U-104) and require essentially all the energy for evaporation to come from the air or waste surroundings.

For tanks A-102 and SX-102 the level decrease values in WRPS-1301005, *Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Level Decrease Evaluation Plan to The U.S. Department of Energy, Office of River Protection*, were erroneous. For A-102 the surface level decrease was due to a faulty ENRAF gauge, the level has shown a slight increase since the gauge was replaced. For SX-102 the ILL is actually increasing as the ILL has not yet stabilized. With the temperatures and heat generation rate in this tank there should be considerable evaporation, so the ILL in tank SX-102 should decrease again when the ILL does stabilize.

Table B-1 Radionuclides Contributing Greater Than 0.01% to the Tank A-102 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	1.08E+01	1.54E-02	1.67E-01
90Sr	7.05E+04	6.70E-03	4.72E+02
90Y	7.05E+04	0.00E+00 (with parent)	0.00E+00
93Zr	5.84E+00	1.13E-04	6.60E-04
137Cs	3.70E+04	4.82E-03	1.78E+02
137mBa	3.50E+04	0.00E+00 (with parent)	0.00E+00
151Sm	1.47E+03	1.17E-04	1.72E-01
154Eu	1.29E+01	9.01E-03	1.16E-01
155Eu	3.71E+00	7.75E-04	2.87E-03
233U	1.35E+01	2.91E-02	3.93E-01
234U	2.36E+00	2.88E-02	6.80E-02
238Pu	1.24E+01	3.32E-02	4.11E-01
238U	2.12E+00	2.53E-02	5.37E-02
239Pu	3.12E+02	3.11E-02	9.70E+00
240Pu	7.24E+01	3.12E-02	2.26E+00
241Am	2.50E+02	3.34E-02	8.36E+00
Sum			672 (2,293 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-2 Radionuclides Contributing Greater Than 0.01% to the Tank A-106 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	2.91E+01	1.54E-02	4.49E-01
90Sr	4.45E+05	6.70E-03	2.98E+03
90Y	4.45E+05	0.00E+00 (with parent)	0.00E+00
137Cs	5.86E+04	4.82E-03	2.82E+02
137mBa	5.53E+04	0.00E+00 (with parent)	0.00E+00
151Sm	3.10E+05	1.17E-04	3.63E+01
152Eu	5.48E+01	7.67E-03	4.20E-01
154Eu	3.42E+03	9.01E-03	3.08E+01
155Eu	1.07E+03	7.75E-04	8.29E-01
238Pu	3.90E+01	3.32E-02	1.29E+00
239Pu	1.03E+03	3.11E-02	3.20E+01
240Pu	2.36E+02	3.12E-02	7.35E+00
241Am	5.86E+02	3.34E-02	1.96E+01
Sum			3,391 (11,570 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-3 Radionuclides Contributing Greater Than 0.01% to the Tank AX-101 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	2.64E+01	1.54E-02	4.07E-01
90Sr	2.01E+05	6.70E-03	1.35E+03
90Y	2.01E+05	0.00E+00 (with parent)	0.00E+00
99Tc	2.90E+02	5.99E-04	1.74E-01
137Cs	3.71E+05	4.82E-03	1.79E+03
137mBa	3.50E+05	0.00E+00 (with parent)	0.00E+00
151Sm	2.90E+04	1.17E-04	3.39E+00
154Eu	2.95E+02	9.01E-03	2.66E+00
239Pu	1.16E+02	3.11E-02	3.61E+00
240Pu	2.68E+01	3.12E-02	8.35E-01
241Am	3.92E+02	3.34E-02	1.31E+01
Sum			3,157 (10,773 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-4 Radionuclides Contributing Greater Than 0.01% to the Tank AX-103 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	4.16E+01	1.54E-02	6.41E-01
90Sr	4.04E+05	6.70E-03	2.70E+03
90Y	4.04E+05	0.00E+00 (with parent)	0.00E+00
137Cs	1.05E+05	4.82E-03	5.06E+02
137mBa	9.95E+04	0.00E+00 (with parent)	0.00E+00
151Sm	2.06E+04	1.17E-04	2.41E+00
154Eu	1.39E+03	9.01E-03	1.25E+01
155Eu	3.00E+02	7.75E-04	2.32E-01
239Pu	9.26E+01	3.11E-02	2.88E+00
240Pu	2.34E+01	3.12E-02	7.29E-01
241Am	7.24E+02	3.34E-02	2.42E+01
Sum			3,255 (11,105 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-5 Radionuclides Contributing Greater Than 0.01% to the Tank BY-108 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	3.29E+01	1.54E-02	5.07E-01
63Ni	2.17E+03	1.02E-04	2.20E-01
90Sr	1.17E+05	6.70E-03	7.83E+02
90Y	1.17E+05	0.00E+00 (with parent)	0.00E+00
137Cs	4.80E+04	4.82E-03	2.31E+02
137mBa	4.53E+04	0.00E+00 (with parent)	0.00E+00
151Sm	9.81E+03	1.17E-04	1.15E+00
154Eu	8.71E+01	9.01E-03	7.85E-01
233U	2.79E+00	2.91E-02	8.12E-02
234U	3.77E+00	2.88E-02	1.09E-01
238U	3.81E+00	2.53E-02	9.65E-02
239Pu	2.82E+01	3.11E-02	8.77E-01
240Pu	4.28E+00	3.12E-02	1.33E-01
241Am	3.79E+01	3.34E-02	1.27E+00
Sum			1,020 (3,480 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-6 Radionuclides Contributing Greater Than 0.01% to the Tank S-104 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
3H	8.33E+00	3.38E-05	2.82E-04
90Sr	3.53E+05	6.70E-03	2.36E+03
90Y	3.53E+05	0.00E+00 (with parent)	0.00E+00
137Cs	7.09E+04	4.82E-03	3.41E+02
137mBa	6.69E+04	0.00E+00 (with parent)	0.00E+00
151Sm	8.83E+03	1.17E-04	1.03E+00
154Eu	5.92E+01	9.01E-03	5.33E-01
238Pu	9.47E+00	3.32E-02	3.14E-01
239Pu	3.43E+02	3.11E-02	1.07E+01
240Pu	6.97E+01	3.12E-02	2.17E+00
241Am	1.95E+02	3.34E-02	6.52E+00
Sum			2,726 (9,303 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-7 Radionuclides Contributing Greater Than 0.01% to the Tank SX-102 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	8.74E+00	1.54E-02	1.35E-01
63Ni	5.76E+02	1.02E-04	5.85E-02
79Se	1.15E+00	6.02E-04	6.92E-04
90Sr	1.63E+05	6.70E-03	1.09E+03
90Y	1.63E+05	0.00E+00 (with parent)	0.00E+00
137Cs	2.80E+05	4.82E-03	1.35E+03
137mBa	2.64E+05	0.00E+00 (with parent)	0.00E+00
151Sm	2.14E+04	1.17E-04	2.50E+00
154Eu	6.94E+01	9.01E-03	6.25E-01
239Pu	1.26E+02	3.11E-02	3.92E+00
240Pu	2.65E+01	3.12E-02	8.25E-01
241Am	2.67E+02	3.34E-02	8.93E+00
Sum			2,457 (8,384 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-8 Radionuclides Contributing Greater Than 0.01% to the Tank SX-105 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
90Sr	5.32E+05	6.70E-03	3.56E+03
90Y	5.32E+05	0.00E+00 (with parent)	0.00E+00
137Cs	2.00E+05	4.82E-03	9.63E+02
137mBa	1.89E+05	0.00E+00 (with parent)	0.00E+00
151Sm	3.65E+04	1.17E-04	4.2705
154Eu	1.83E+02	9.01E-03	1.65E+00
238Pu	1.49E+01	3.32E-02	4.94E-01
239Pu	6.69E+02	3.11E-02	2.08E+01
240Pu	1.33E+02	3.12E-02	4.14E+00
241Am	5.95E+02	3.34E-02	1.99E+01
Sum			4,577 (15,617 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-9 Radionuclides Contributing Greater Than 0.01% to the Tank SX-114 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
90Sr	1.72E+06	6.70E-03	1.15E+04
90Y	1.72E+06	0.00E+00 (with parent)	0.00E+00
137Cs	8.23E+04	4.82E-03	3.96E+02
137mBa	7.77E+04	0.00E+00 (with parent)	0.00E+00
151Sm	4.82E+04	1.17E-04	5.64E+00
154Eu	5.09E+02	9.01E-03	4.59E+00
239Pu	4.50E+02	3.11E-02	1.40E+01
240Pu	9.47E+01	3.12E-02	2.95E+00
241Am	8.35E+02	3.34E-02	2.79E+01
Sum			11,968 (40,836 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-10 Radionuclides Contributing Greater Than 0.01% to the Tank TX-108 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	8.86E+00	1.54E-02	1.37E-01
63Ni	5.63E+02	1.02E-04	5.72E-02
90Sr	3.71E+03	6.70E-03	2.48E+01
90Y	3.71E+03	0.00E+00 (with parent)	0.00E+00
99Tc	5.54E+01	5.99E-04	3.32E-02
137Cs	5.31E+04	4.82E-03	2.56E+02
137mBa	5.01E+04	0.00E+00 (with parent)	0.00E+00
151Sm	4.66E+03	1.17E-04	5.45E-01
154Eu	3.74E+01	9.01E-03	3.37E-01
233U	6.21E-01	2.91E-02	1.81E-02
234U	1.52E+00	2.88E-02	4.38E-02
238Pu	1.96E+00	3.32E-02	6.50E-02
238U	1.53E+00	2.53E-02	3.87E-02
239Pu	5.77E+01	3.11E-02	1.79E+00
240Pu	1.21E+01	3.12E-02	3.77E-01
241Am	1.16E+02	3.34E-02	3.88E+00
Sum			288 (982 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-11 Radionuclides Contributing Greater Than 0.01% to the Tank TY-101 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
63Ni	2.53E+01	1.02E-04	2.57E-03
90Sr	6.30E+03	6.70E-03	4.22E+01
90Y	6.30E+03	0.00E+00 (with parent)	0.00E+00
93Zr	2.19E+01	1.13E-04	2.47E-03
93mNb	1.97E+01	1.83E-04	3.61E-03
99Tc	5.26E+00	5.99E-04	3.15E-03
137Cs	2.68E+02	4.82E-03	1.29E+00
137mBa	2.53E+02	0.00E+00 (with parent)	0.00E+00
151Sm	1.22E+02	1.17E-04	1.43E-02
234U	5.41E-01	2.88E-02	1.56E-02
238Pu	5.97E-01	3.32E-02	1.98E-02
238U	5.51E-01	2.53E-02	1.40E-02
239Pu	1.25E+02	3.11E-02	3.89E+00
240Pu	1.05E+01	3.12E-02	3.27E-01
241Am	9.21E+00	3.34E-02	3.08E-01
Sum			48 (164 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-12 Radionuclides Contributing Greater Than 0.01% to the Tank TY-103 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
90Sr	6.26E+04	6.70E-03	4.19E+02
90Y	6.26E+04	0.00E+00 (with parent)	0.00E+00
137Cs	2.49E+04	4.82E-03	1.20E+02
137mBa	2.35E+04	0.00E+00 (with parent)	0.00E+00
151Sm	1.51E+03	1.17E-04	1.77E-01
154Eu	1.09E+01	9.01E-03	9.82E-02
233U	5.29E+00	2.91E-02	1.54E-01
234U	5.79E+00	2.88E-02	1.67E-01
238Pu	2.00E+00	3.32E-02	6.63E-02
238U	5.70E+00	2.53E-02	1.44E-01
239Pu	1.58E+02	3.11E-02	4.91E+00
240Pu	1.90E+01	3.12E-02	5.92E-01
241Am	2.41E+01	3.34E-02	8.06E-01
Sum			546 (1,864 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-13 Radionuclides Contributing Greater Than 0.01% to the Tank U-104 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
90Sr	5.28E+02	6.70E-03	3.53E+00
90Y	5.28E+02	0.00E+00 (with parent)	0.00E+00
99Tc	7.28E-01	5.99E-04	4.36E-04
137Cs	4.64E+01	4.82E-03	2.23E-01
137mBa	4.38E+01	0.00E+00 (with parent)	0.00E+00
151Sm	5.25E+01	1.17E-04	6.14E-03
154Eu	1.10E-01	9.01E-03	9.91E-04
155Eu	3.85E-02	7.75E-04	2.98E-05
234U	8.69E-01	2.88E-02	2.50E-02
235U	3.85E-02	2.77E-02	1.07E-03
236U	1.18E-02	2.71E-02	3.20E-04
238Pu	9.16E-03	3.32E-02	3.04E-04
238U	8.88E-01	2.53E-02	2.25E-02
239Pu	1.09E+00	3.11E-02	3.39E-02
240Pu	1.38E-01	3.12E-02	4.30E-03
241Am	2.93E-01	3.34E-02	9.79E-03
Sum			4 (13 BTU/hr)

[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-14 Radionuclides Contributing Greater Than 0.01% to the Tank U-108 Waste Heat Generation Rate

Radionuclide	Ci[1]	Heat Generation Rate (watts/Ci)[2]	Heat Generation Rate (watts)
60Co	2.36E+01	1.54E-02	3.64E-01
90Sr	1.89E+04	6.70E-03	1.27E+02
90Y	1.89E+04	0.00E+00 (with parent)	0.00E+00
99Tc	2.80E+02	5.99E-04	1.68E-01
137Cs	3.09E+05	4.82E-03	1.49E+03
137mBa	2.92E+05	0.00E+00 (with parent)	0.00E+00
151Sm	2.21E+04	1.17E-04	2.59E+00
154Eu	7.41E+01	9.01E-03	6.68E-01
238Pu	4.71E+00	3.32E-02	1.56E-01
239Pu	1.80E+02	3.11E-02	5.60E+00
240Pu	3.94E+01	3.12E-02	1.23E+00
241Am	9.52E+01	3.34E-02	3.18E+00
Sum			1,629 (5,558 BTU/hr)

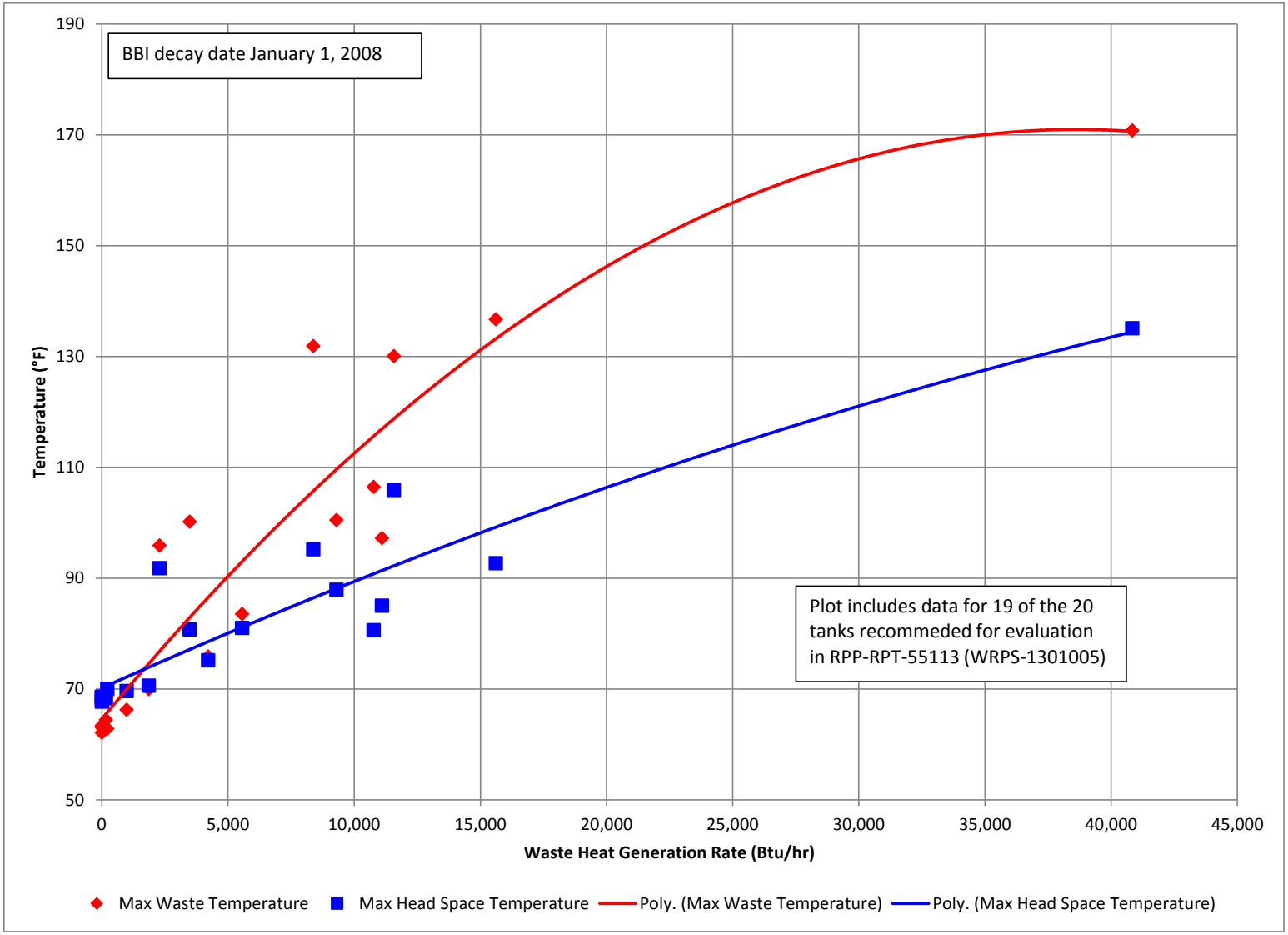
[1] From TWINS download September 28, 2012, decay date January 1, 2008
[2] From HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, Rev 14 (reissue), August 11, 2008

Table B-15 Summary of Tank Heat Generation Rates and Temperatures

Tank	Heat Generation Rate[1] (BTU/hr)	Maximum Observed Waste Temperature (°F)	Maximum Calculated Headspace Temperature (°F)	Liquid Loss Rate Estimate Basis				Percent of Heat Generation Needed for Liquid Loss Rate
				ILL	Min	Rough Approx.	Max	
A-102	2,293	95.9	91.8					NA
A-106	11,570	130.1	105.9	X				2.6
AX-101	10,773	106.5	80.6	X				1.8
AX-103	11,105	97.2	85.0	X				3.7
BY-108	3,480	100.2	80.7	X				1.4
S-104	9,303	100.5	87.9	X[2]				0.7
SX-102	8,384	131.9	95.2					NA
SX-105	15,617	136.7	92.7	X				0.1
SX-114	40,836	170.8	135.1		X	X	X	0.2 to 1.0
TX-108	982	66.2	69.6		X	X	X	1.9 to 7.9
TY-101	164	64.4	68.3		X	X	X	18 to >100
TY-103	1,864	70.0	70.6	X				2.3
U-104	13	none	none		X	X	X	>100
U-108	5,558	83.5	81.0	X				0.14

[1] Decay date for radionuclides January 1, 2008
[2] Average of ILL and SL

Figure B-1 Maximum Tank Waste and Headspace Temperatures vs. Heat Generation Rate



B.4 References

TWINS, *Tank Waste Information Network System*, database available on the Hanford Local Area Network at https://twins.labworks.org/twinsdata/Forms/About.aspx

HNF-EP-0063, 2008, *Hanford Site Solid Waste Acceptance Criteria*, Revision 14 (reissue), Fluor, Richland, Washington.

RPP-PLAN-55113, 2013, *March 2013 Single-Shell Tank Waste Level Decrease Evaluation Plan*, Revision 1, Washington River Protection Solutions LLC, Richland, Washington.

WRPS-1301005, *Contract Number DE-AC27-08RV14800 – Washington River Protection Solutions LLC Submittal of Single-Shell Tank Level Decrease Evaluation Plan to The U.S. Department of Energy, Office of River Protection*, Letter, March 18, 2013, C. A. Simpson, Washington River Protection Solutions LLC, to S. E. Bechtol, U.S. Department of Energy, Richland, Washington.