Evaluation of Hanford Single-Shell Waste Tanks Suspected of Water Intrusion – 14196

Amie Feero *, Dennis Washenfelder *, Jeremy Johnson **, John Schofield *
* Washington River Protection Solutions
** US DOE

ABSTRACT

Intrusions evaluations for twelve single-shell tanks were completed in 2013. The evaluations consisted of remote visual inspections, data analysis, and calculations of estimated intrusion rates. The observation of an intrusion or the preponderance of evidence confirmed that six of the twelve tanks evaluated had intrusions. These tanks were tanks 241-A-103, BX-101, BX-103, BX-110, BY-102, and SX-106.

INTRODUCTION

Beginning in 1978, pumpable supernatant and interstitial liquids were removed from single-shell tanks (SSTs) at Hanford. This process was known as interim stabilization, and it was intended to limit the impact of waste leaks by leaving behind a primarily solid waste phase in the tanks. In addition to pumping, the process drain lines connected to the SSTs were capped, and the process pits were foamed in order to isolate the tanks and minimize rainwater or snowmelt intrusion. As the SSTs await retrieval into double-shell tanks, they are monitored by instruments that measure the interstitial liquid level (ILL) and/or the waste surface level (SL). Most of the SSTs have not been visually inspected since they were interim stabilized.

Water intrusion into SSTs is detrimental for several reasons. First, an increase in tank liquid presents an increase in the potential consequences of a waste leak. Second, per an agreement with the State of Washington Department of Ecology, a 23 m (75 ft.) diameter tank must have <18.9 m^3 (5,000 gallons) of supernatant liquid and <189 m^3 (50,000 gallons) of drainable interstitial liquid to meet interim stabilization requirements. With intrusion into tanks these quantities could be exceeded.

A few tanks in the 241-BX Farm experienced unexplained surface level increases from the 1980s up to the present time. The existence of intrusions in the BX Farm tanks led to the question of whether tanks in other tank farms were experiencing increasing surface level trends. After an informal review, it was discovered that a number of additional tanks had surface level behaviors indicating possible water intrusion. To determine the extent of the intrusion problem, a preliminary review of all 149 SSTs was performed in the summer of 2011.

A May 2012 report documented the review [1]. Approximately one-third of the tanks had SL or ILL data increase trends. An evaluation plan for the SSTs suspected of intrusion was issued in the fall of 2012. This plan recommended a minimum of 20 tanks for initial intrusion evaluation. The following actions were to be carried out to evaluate the 20 tanks for intrusion [2]:

- Increase tank waste level monitoring frequency where appropriate.
- Visually examine each tank by remote video camera inspection for signs of intrusion.

- If water intrusion is suspected of causing the level increase, perform an in-depth evaluation to identify the most probable intrusion pathways.
- Determine necessary intrusion mitigation.

Video inspections of 12 of the 20 tanks were completed in fiscal year 2013. Active intrusions were observed in three of the 12 tanks (tanks 241-BX-101, BY-102, and SX-106). An additional six tanks (tanks 241-A-103, BX-103, BX-110, BY-101, S-111, U-111) showed evidence of past intrusion, but no active intrusion droplets were observed at the time of video inspection. In three of these tanks (241-A-103, BX-103, BX-110) the intrusion was obvious and either wasn't observed due to foggy conditions in the tank headspace or was just missed. No evidence for intrusion was observed in the three remaining tanks (BY-111, S-109, TX-112). A report summarizing the findings was released in November 2013 [3].

METHODS

The intrusion evaluation process consists of analyzing the level change data of each SST selected for evaluation, conducting an in-tank video, and estimating a volumetric change rate. Videos are used to look for evidence of past or current intrusion into the tank. Data analysis is used to estimate the rate of an active intrusion observed in the video, or to assess the potential for an inactive intrusion to be present in a tank (and the rate) if an intrusion is not observed in the video.

Tank Level Data

The level data change rates are based upon linear regression trendlines drawn through the SL and ILL data points for each tank for as far back as a reasonable linear rate can be established. 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. 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 three to ten years.

The SL and ILL data change rates were estimated by downloading all the waste level data from the Tank Waste Information Network System database and calculating the regression line though the appropriate period.

The final SL and ILL level data change rates based upon the plot trendlines are given in Table II.

In-Tank Video Examination

In-tank videos were obtained in each tank selected for intrusion evaluation. In each tank, either a GE PTZ-70 or PTZ-140 camera was used for the inspections. The in-tank videos were reviewed for the following information:

- Observation of physical droplets coming from the tank dome, riser penetrations, or upper flashing
- Evidence of past intrusions on the tank dome or walls

- Evidence of past intrusions as indicated by pooling or water-caused depressions on the waste surface
- Fraction of the waste surface that is liquid
- Position of the Enraf surface level gauge plummet
- Nature of waste surrounding the liquid observation well (LOW), if present

Data Analysis

The level change rates were converted, to the extent practical, to a volumetric change rate. 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 does not track the ILL from the LOW, then the ILL increase rate is used to estimate a volumetric change rate for the tank. Tanks in this category are A-103, BY-101, BY-102, BY-111, S-109, S-111, SX-106, TX-112, and U-111.
- If the tank has an LOW, the ILL is near the waste surface, and the Enraf gauge plummet tracks the ILL from the LOW, then the average of the SL and ILL increase rates is used to estimate a volumetric change rate for the tank. The tank in this category is BX-110.
- If the tank does not have an LOW and the Enraf gauge plummet is known or believed to be measuring a liquid surface, then the SL increase rate is used to estimate a volumetric change rate for the tank. Tanks in this category are BX-101 and BX-103.

The estimated volumetric change rate for a 23 m (75 ft.) diameter tank is based upon the following equation:

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

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 the in-tank video. The extent of liquid over the waste surface is sketched on a plot of the tank and the area calculated using a planimeter.

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

TABLE I. 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 yet 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 tank volumetric change rate is a sum of the factors from Table I and is simplified to Equation 2.

$$volumetric\ change\ rate = intrusion\ rate + evaporation\ rate + leak\ rate + \sum other \quad \text{(Eq. 2)}$$

Intrusion rate is always positive, evaporation and leak rates are always negative, and [Σother] is equal to the net impact of Factors 1 through 5 in Table I and may be either positive or negative.

Factor 6 is a subjective assessment based upon review of the ILL data plot trend. There is no numerical value associated with Factor 6. Rather, it is a judgment as to whether the net level change rate estimate shows an actual change in the liquid level in the tank or results from a redistribution of liquid as it slowly seeks an equilibrium level after saltwell pumping.

Factor 7 is an assessment based upon review of the SL data plot trend and any data or videos 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, the data changes cannot be assumed to represent changes in the waste surface.

Rearranging Equation 2:

$$intrusion\ rate = volumetric\ change\ rate - evaporation\ rate - leak\ rate - \sum other \quad \text{(Eq. 3)}$$

The volumetric change rate and evaporation rate can be estimated from available data, and a value for [Σother] can be assumed following a review of the available information. There is no evidence that these tanks are actively leaking, so the leak rate is assumed to be zero.

RESULTS AND DISCUSSION

Tank Level Data

The level change rates were calculated from the trendlines and are provide below in Table II.

TABLE II. Level change rates

Tank	SL Rate		ILL Rate	
	mm/yr	in./yr	mm/yr	in./yr
A-103	-0.229	-0.009	2.62	0.103
BX-101	4.09	0.161	no LOW	no LOW
BX-103	-3.18	0.125	no LOW	no LOW
BX-110	1.75	0.069	2.26	0.089
BY-101	8.23	0.324	14.4	0.567
BY-102	2.79	0.110	8.89	0.350
BY-111	NA[a]	NA[a]	4.70	0.185
S-109	NA[b]	NA[b]	18.1	0.714
S-111	-6.68	-0.263	36.8	1.450
SX-106	-2.62	-0.103	55.7	2.191
TX-112	-1.91	-0.075	22.6	0.888
U-111	1.55	0.061	7.75	0.305

a. Value meaningless, as the Enraf wire was caught in the salt on the edge of a depression
b. Value meaningless, as the level data were erratic

In-Tank Video Examination

Tank A-103 had a liquid pool covering approximately 45% of the waste surface. An active intrusion was not observed during the inspection, but the liquid pool had grown in size since photographs were taken in 1988. The Enraf plummet was sitting in a small liquid pool, and the LOW was surrounded by solid surface.

In tank BX-101, an active intrusion was observed coming from Riser 4 at a rate of approximately 8 droplets in 20 seconds. A large liquid pool covered approximately 87% of the waste surface (Figure 1), and this was an increase in size since a 1994 inspection. The Enraf plummet was located on the surface of the tank’s liquid pool.

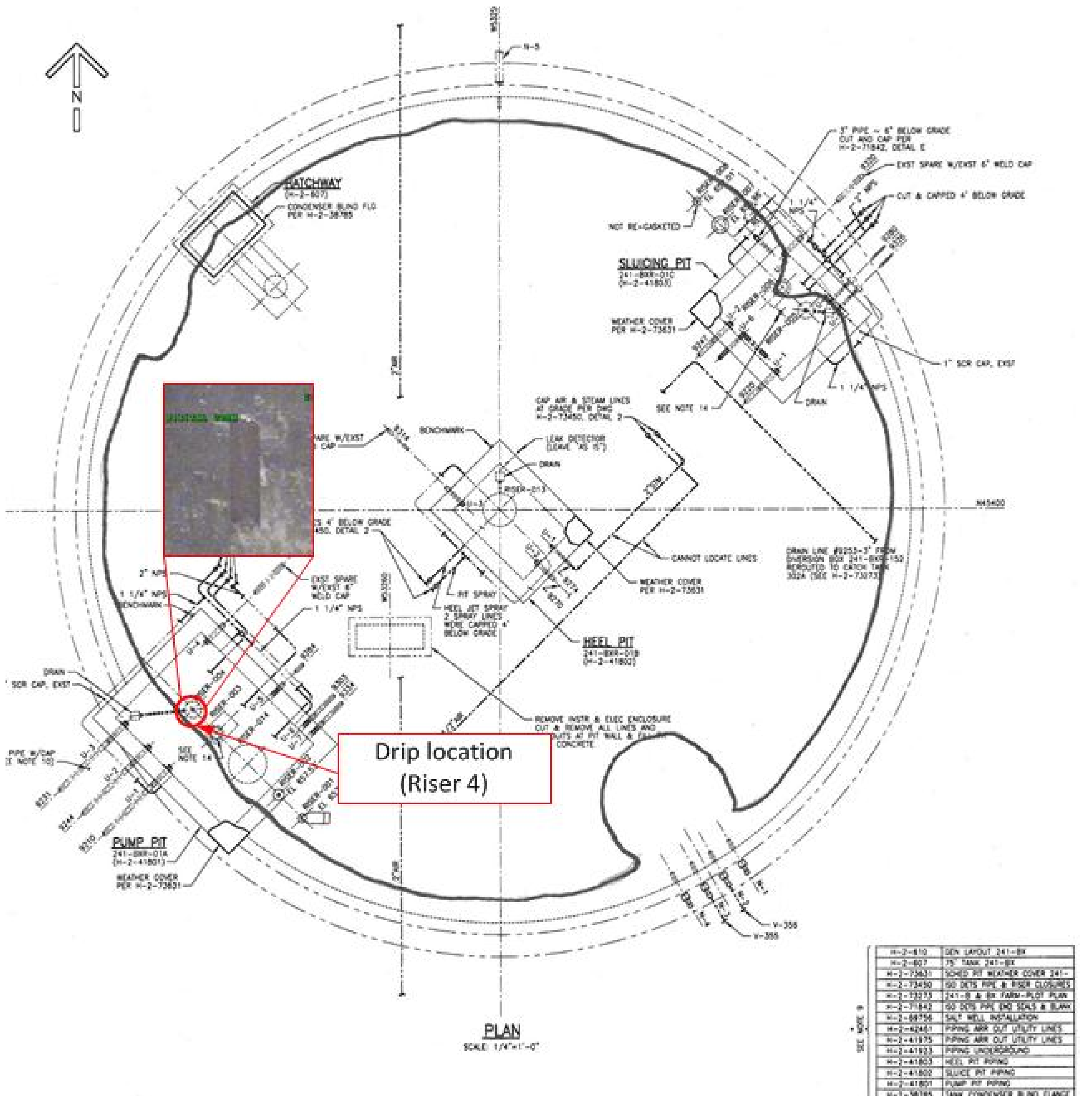

Fig. 1. Tank BX-101 liquid pool sketch and intrusion location.

Tank BX-103 had a waste surface that was approximately 92% liquid. The liquid pool had increased in size since a 1994 inspection. An active intrusion was not observed in the 2013 video inspection; however, a 2006 video showed the existence of droplets coming from the 42” manhole riser. The Enraf plummet was sitting on the liquid waste surface.

Tank BX-110 had a liquid pool covering approximately 71% of the waste surface. The size of the pool had increased since 1985 photographs. An active intrusion was not observed during the video. The Enraf plummet was located on the liquid surface, and the LOW was surrounded by liquid and fallen pipes.

Tank BY-101 had a very small liquid pool by the Riser 7 saltwell screen which wasn't there in 1989, and the pool covered less than 1% of the waste surface. An active intrusion was not seen on the video. The Enraf plummet was caught up on salt and debris in the tank, and its readings are not accurate. The LOW was surrounded by a salt mound.

Active intrusion droplets were observed in tank BY-102 originating from the Riser 3 pit drain. There was an average of 26.5 dropletss per minute observed during the video, and the droplets caused ripples in the liquid pool as shown in Figure 2. This liquid pool covered 2% of the total waste surface (Figure 3). The Enraf plummet was located on the salt surface; however, the Enraf plummet wire was lying over a broken piece of pipe that shows signs of wear caused by the wire rubbing against it. The LOW was surrounded by saltcake.

Fig. 2. Tank BY-102 ripples in liquid pool.

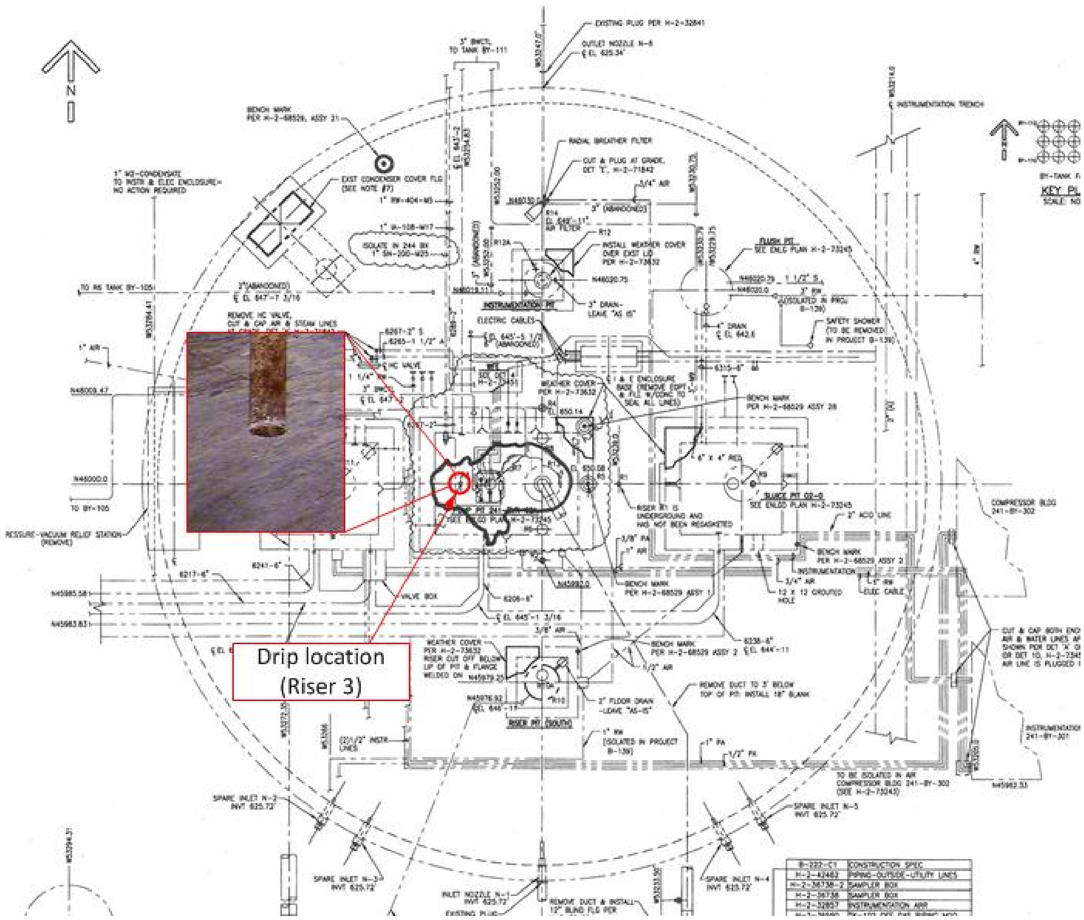

Fig. 3. Tank BY-102 liquid pool sketch and intrusion location.

Tank BY-111 waste surface was extremely dry and showed no visual indication of an intrusion. No liquid was observed on the waste surface. The Enraf plummet was not reading the waste surface because the wire was hung up on the salt waste. The LOW was surrounded by salt.

Tank S-109 also showed no strong visual basis to indicate an intrusion. No liquid pool was observed during the video inspection. The waste surface had not changed significantly from 2001. The Enraf plummet was resting on an uneven salt surface, and the LOW could not be seen from the video camera location.

Tank S-111 contained a liquid pool making up approximately 3% of the waste surface. An active intrusion was not observed, but there was some evidence of increased discoloration on the Riser 5 pump since the 2004 video. The Enraf plummet was resting on a dry and slanted waste surface, and the LOW was surrounded by salt in a very small depression.

In tank SX-106, an active intrusion was observed coming from the vapor header connection. The exhauster had been removed from the SX tank farm, but the buried vapor header connecting the 15 SX tanks drains to SX-106. During the video, water droplets fell from the header connection at a rate of approximately 57 droplets per minute, and the droplets created ripples in the liquid pool, as shown in Figure 4. The waste surface was a solid salt surface with a long liquid pool extending from the vapor header connection to the Riser 2 temperature probe as shown in Figure 5. The Enraf plummet was resting on an irregular surface, and the LOW could not be seen from the video camera location.

Fig. 4. Tank SX-106 liquid pool ripples.

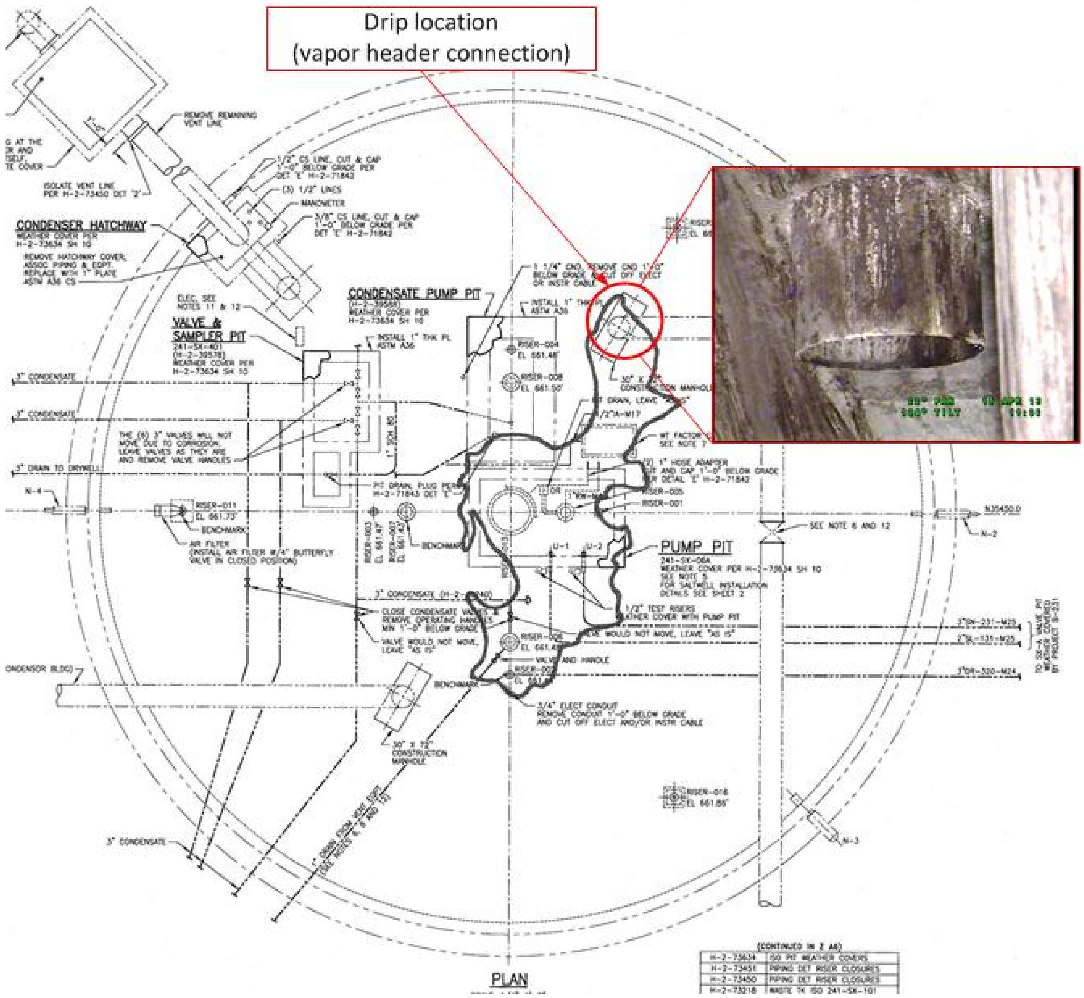

Fig. 5. Tank SX-106 liquid pool sketch and intrusion location.

The tank TX-112 video inspection showed no evidence of an intrusion. There was no liquid pool present on the surface. The Enraf plummet was sitting on solid waste surface near some fallen tape and tubing, and the LOW was surrounded by a relatively even, solid waste surface.

Tank U-111 contained a liquid pool making up approximately 1% of the waste surface. No standing water was apparent after interim stabilization [5]. No active intrusion was observed during the video, but there was evidence of discolorations on the dome penetrations on the side of the tank opposite the camera, and this could indicate intrusion. The Enraf plummet was resting in a small depression, and the LOW was surrounded by a solid surface.

Data Analysis

The volumetric change rates were estimated using Equation 1. The table below (Table III) provides the estimated volumetric change rate for each tank evaluated.

TABLE III. Estimated volumetric change rates

Tank	Liquid Change Rate		Basis	Fraction Surface Liquid	Assumed Porosity[a]	Volumetric Change Rate	
	mm/yr	in./yr				m^3/yr	gal/yr
A-103	2.62	0.103	ILL	0.45	0.15	0.572	151
BX-101	4.09	0.161	SL	0.87	0.15	1.49	394
BX-103	3.18	0.125	SL	0.92	0.15	1.21	320
BX-110	2.01	0.079	avg SL+ILL	0.71	0.25 salt	0.644	170
BY-101	14.4	0.567	ILL	0.003	0.10 salt	0.606	160
BY-102	8.89	0.35	ILL	0.02	0.26	1.00	265
BY-111	4.70	0.185	ILL	0	0.25	0.481	127
S-109	18.1	0.714	ILL	0	0.20	1.49	393
S-111	36.8	1.45	ILL	0.033	0.06	1.37	363
SX-106	55.7	2.191	ILL	0.07	0.06	2.87	758
TX-112	22.6	0.888	ILL	0	0.17	1.57	415
U-111	7.75	0.305	ILL	0.008	0.20	0.655	173

a. Basis for assumed porosity described in [3]

The atmospheric data, tank headspace temperature calculations, tank breathing rates, and tank headspace relative humidities were estimated and used to derive an evaporation rate for each tank. The process used to estimate an SST evaporation rate is described in-depth in Appendix A of RPP-RPT-54981, Rev. 0 [4].

A summary of the estimated evaporation rates is included in Table IV below.

TABLE IV. Estimated tank evaporation rates

Tank	Breathing Rate Used		Relative Humidity Assumed (%)	Evaporation Rate	
	m^3/hr	cfm		m^3/yr	gal/yr
A-103	17.45	10.27	74	1.779	470
BX-101	4.08	2.40	83	0.227	60
BX-103	4.06	2.39	83	0.204	54
BX-110	3.96	2.33	57	0.117	31
BY-101	3.98	2.34	50	0.117	31
BY-102	4.06	2.39	65	0.167	44
BY-111	3.96	2.33	31	0.000	0
S-109	3.86	2.27	45	0.057	15
S-111	3.96	2.33	50	0.121	32
SX-106	4.15	2.44	55	0.250	66
TX-112	3.79	2.23	60	0.144	38
U-111	3.23	1.90	50	0.102	27

The calculation of ∑other is described in RPP-RPT-50799, Rev. 1 [3].

Using Equation 3, the intrusion rates for the tanks were estimated and compiled in Table V.

TABLE V. Tank intrusion rates

Tank	Calculated Intrusion Rate Range[a]	
	m^3/yr	gal/yr
A-103	2.1 to 2.5	550 to 650
BX-101	1.5 to 1.9	400 to 500
BX-103	1.1 to 1.5	300 to 400
BX-110	0.57 to 0.95	150 to 250
BY-101	0.57 to 0.95[b]	150 to 250[b]
BY-102	0.95 to 1.3[b]	250 to 350[b]
BY-111	0.38 to 0.76	100 to 200
S-109	1.3 to 1.7[b]	350 to 450[b]
S-111	1.3 to 1.7[b]	350 to 450[b]
SX-106	2.8 to 3.2[b]	750 to 850[b]
TX-112	1.5 to 1.9[c]	400 to 500[c]
U-111	0.57 to 0.95	150 to 250

a. None of these tanks show evidence of active leaks; therefore, leak rate was assumed to be 0.
b. This tank has some evidence that retained gas growth may contribute to the level change
c. This tank has some evidence that retained gas growth and porosity change may contribute to the level change

CONCLUSIONS

The investigation into 12 tanks suspected of intrusions concluded that three of the tanks had visually confirmed intrusions: BX-101, BY-102, and SX-106, with calculated intrusion rates of approximately 1.5-1.9 m^3/yr (400-500 gal/yr), 0.95-1.3 m^3/yr (250-350 gal/yr), and 2.8-3.2 m^3/yr (750-850 gal/yr), respectively.

Another three tanks had confirmed intrusions based upon the preponderance of evidence, but an active intrusion was not observed during the video. Those tanks were A-103, BX-103, and BX-110. Tank A-103 showed a definite increase in surface liquid when comparing 1988 photos to the 2013 video, and the increasing ILL also shows evidence of an intrusion. The calculated intrusion rate for this tank was 2.1-2.5 m^3/yr (550-650 gal/yr). The tank BX-103 liquid pool has increased in size, and a 2006 video observed an active intrusion coming from the outside of a riser in the southwest pump pit. The calculated intrusion rate for this tank was 1.1-1.5 m^3/yr (300-400 gal/yr). Tank BX-110 showed an obvious increase in liquid level in the 2013 video when compared to past photos, and this tank also showed a steady increase in the level data going back to at least 1985. The calculated intrusion rate was 0.57-0.95 m^3/yr (150-250 gal/yr).

One tank had a probable intrusion based upon the increasing ILL and the presence of a liquid pool but cannot be confirmed: U-111. The intrusion rate for tank U-111 was estimated at 0.57-0.95 m^3/yr (150-250 gal/yr). Two tanks had possible intrusions based on the ILL trends and the presence of liquid pools: BY-101 and S-111. The estimated intrusion rates for these tanks were 0.57-0.95 m^3/yr (150-250 gal/yr) and 1.3-1.7 m^3/yr (350-450 gal/yr), respectively. Finally, three tanks had little evidence of intrusion: BY-111, S-109, and TX-112.

Intrusion investigation plans to identify the source of the intrusions, and eventually stop them, have been prepared for five of the six confirmed intrusion tanks.

Visual inspection of the remaining eight uninspected SSTs plus repeat video inspections of one or more of the fiscal year 2013 tanks will be conducted during fiscal year 2014.

REFERENCES

1. M. R. SAX, RPP-RPT-50799, “Suspect Water Intrusion in Single-Shell Tanks,” Revision 0, Washington River Protection Solutions LLC, Richland, Washington (2012).
2. C. A. SIMPSON, WRPS-1203139, “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,” Revision 1, Washington River Protection Solutions LLC, Richland, Washington (2012).
3. A. J. FEERO and J. S. SCHOFIELD, RPP-RPT-50799, “Suspect Water Intrusion in Single-Shell Tanks,” Revision 1, Washington River Protection Solutions LLC, Richland, Washington (2013).
4. J. S. SCHOFIELD, RPP-RPT-54981, “Evaluation of Fourteen Tanks with Decreasing Level Baselines Selected for Review in RPP-PLAN-55113, Revision 1,” Revision 0, Washington River Protection Solutions LLC, Richland, Washington (2013).

5. L. S. KROGSRUD, HNF-SD-RE-TI-178, “Single-Shell Tank Interim Stabilization Record,” Revision 9a, CH2M Hill Hanford Group, Inc., Richland, Washington (2007)