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TANK S-102 WASTE RETRIEVAL LEAK DETECTION, MONITORING, AND MITIGATION STRATEGY

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Abstract: This paper presents a proactive and mitigative strategy for the identification and management of potential S-102 waste leaks during the S-102 Waste Retrieval and the basis for this approach. The strategy is based on preventing leakage, minimizing leak volumes if a leak should occur, and providing the best available leak detection and monitoring technologies. Ex-tank leak detection will use the baseline borehole gamma and neutron drywell logging trucks, supplemented with manually deployed neutron moisture measurements. Waste mitigation includes management of the retrieval fluids in a manner that limits the risk for a potential leak.

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TANK S-102 WASTE RETRIEVAL LEAK DETECTION, MONITORING, AND MITIGATION STRATEGY

May 2003

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EXECUTIVE SUMMARY

The purpose of this document is to describe a proactive and mitigative strategy for the identification and management of potential S-102 tank waste leaks during the S-102 Waste Retrieval campaign and the basis for this approach. The strategy is based on preventing leakage, minimizing leak volumes if a leak should occur, and providing the best available leak detection and monitoring technologies. Tank S-102 is categorized as a nonleaking tank. However, given the age of the tank and the planned retrieval method, there is a need to address tank leakage and to deploy means for detecting and monitoring potential leak events.

The leak detection and monitoring systems along with the leak mitigation strategy described meets the functions and requirements and conditional approvals defined for this project. This is accomplished through a combination of innovative, first-of-a-kind operational improvements in retrieval strategy with best available leak detection and leak monitoring technology.

Leak mitigation is accomplished through design features and the operational strategy developed for the waste retrieval system. Mitigation includes actions that reduce the likelihood of a leak and the environmental impact of a leak, should one occur. Potential leaks are proactively and responsively prevented and/or minimized throughout the retrieval demonstration operations. A summary of the mitigative operational approach is as follows:

- Control in-tank liquid inventory during retrieval to less than previous nonleaking interstitial liquid level. Years of static level monitoring have shown the tank to have not leaked below this level.

- Retrieve waste from the center of the tank out to minimize liquid contact with the tank wall, the location of most historical single-shell tank leaks.

- Design the retrieval system and operational retrieval strategy to minimize the "time at risk" (time when tank leakage could occur). By minimizing the time at risk, potential leak volumes are limited in size. For slow leaks (less than 2 gal/hr), the resulting leak volume incurred during the retrieval campaign would be more than an order of magnitude smaller than the detection limit of current leak detection equipment.

- Use the retrieval pump to minimize tank S-102 liquid inventory between retrieval campaigns (e.g., while waiting for cross-site transfers) to further reduce any leak driving head and exposure of the tank wall.

- Minimize potential leak volume by providing a (nominal 90 gal/min) pump, located as close to tank bottom as possible, to rapidly pump down liquids if a leak were to be detected.

Leak detection is accomplished through deployment of best available technology. A summary of the leak detection approach is as follows:

- Use existing drywells that surround tank S-102 to watch for potential leakage plumes. The drywells will be monitored for soil gamma levels (cesium-137 leakage from the tank) and changes in soil moisture content. Existing truck-mounted gamma detectors will

be used to perform soil gamma surveys before and after waste retrieval, and truck-mounted neutron moisture probes will be used to perform soil moisture surveys at intervals during waste retrieval operations.

- Use manually deployed neutron moisture probes to frequently monitor the moisture of the most likely plume depths (up to three times per week).

- Monitor the tank S-102 liquid level between retrieval campaigns and during significant interruptions to detect possible tank bottom leakage. Between retrieval campaigns the liquid will be pumped down and drainable liquid in the saltcake will drain to the center of the tank until hydraulic equilibrium is reached. It is expected that during the static test the liquid level will rise asymptotically toward an equilibrium level. Any drop in the liquid level during this time might indicate a leakage event.

- Augment primary leak detection systems with alternate methods to develop a "defense-in-depth" approach. This will be accomplished by monitoring process measurements and observations to assess tank S-102 and transfer system integrity.

Leak monitoring, the determination of the waste volume leaked (if any), will be accomplished through collection and evaluation of data from the leak detection systems. Gamma and neutron moisture detector surveys will be used to assess the magnitude, shape or direction of a leak plume, should one occur.

The LDMM Strategy for S-102 retrieval is based on the previous work for the S-112 Waste Retrieval Project which assembled a multi-disciplinary project team composed of CH2M HILL Hanford Group, Inc. Process Control engineers; the Vadose Zone Program, S-112 Project technical support; the tank S-112 design architect/engineer; and the Pacific Northwest National Laboratory and determined the best available leak detection technologies to support SST waste retrieval activities. Detailed analyses were performed to assess the expected performance capability of both in-tank mass balance and ex-tank drywell leak detection methods. These analyses included development of numerical models with system equations, reduction of the equations to measurable variables, determination of variable distributions, and performance and interpretation of Monte Carlo statistical analyses completed with these equations. These leak detection system assessments can be found in RPP-10413, *Tank S-112 Saltcake Waste Retreival demonstration Project leak Detection, monitoring, and Mitigation Strategy.*

These analyses determined that in-tank mass balance methods have a performance uncertainty of at least 80,000 gallons. Although uncertainties are not additive, insight into the large uncertainty associated with material balance methods can be gained by considering the large uncertainties associated with the initial waste volume and mass. This is further compounded by uncertainties associated with the distribution of waste within the tank (i.e., heterogeneities in waste composition and physical properties) and waste behavior during retrieval. Consequently, in-tank mass balance methods do not represent best available technology in Hanford saltcake tanks and would only be used to corroborate data gathered by the ex-tank surveys.

Ex-tank drywell methods were found to have uncertainties that vary with leak rate and the travel distance from a leak site to a drywell. Based on the conceptual model and leak parameters

evaluated, a slow leak corresponding to historical Hanford tank leak rates (less than 2 gal/hr), drywell logging techniques have a 95th percentile volume of 300 gallons for the cases with a drywell located 10 feet from the leak site. The 95th percentile volume increases to 18,000 gallons if the drywell is located 45 feet from the leak site (this is the distance from the center of the tank to a typical tank drywell). The travel times associated with leaks from the side of the tank range from 1 to 70 days and the travel times from the center of the tank floor range from 4 days to 12 years depending on the leak rate. This means that a leak from the tank floor is unlikely to be consistently detected by drywells during waste retrieval operations. To monitor for high rate leaks near the center of the tank floor, periodic verification of static liquid level will be used. This combination of drywell monitoring and static liquid level monitoring covers the full range of potential leak cases.

Ex-tank resistivity technologies, currently under evaluation by CH2M HILL Hanford Group, Inc., are being considered for future deployment at SSTs (RPP-14606). In an initial SST resistivity system deployment, the system would be operated in a test mode and would not be used as primary leak detection methods. The resistivity methods under development are not yet mature enough to replace the baseline drywell monitoring methods.

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LIST OF TERMS

ALARA	As low as reasonable achievable
CH2M HILL	CH2M HILL Hanford Group, Inc.
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
HFFACO	Hanford Federal Facility Agreement and Consent Order
LDMM	leak detection, monitoring, and mitigation
SST	single-shell tank

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this document is to describe the tank S-102 Waste Retrieval Project (S-102 Project) strategy for leak detection, monitoring, and mitigation (LDMM). The bases for the selected LDMM methodology are presented, as well as the bases for not including an in-tank material balance as a primary leak detection method. Specific topics addressed in this document include the following:

- S-102 Project response to identified requirements, expectations and conditions
- S-102 Project leak mitigation strategy
- S-102 Project leak detection and monitoring system
- Limitations of the S-102 Project leak management approach.

1.2 BACKGROUND

The mission of the River Protection Project includes the retrieval, immobilization, storage, and disposal of Hanford Site tank waste. In support of the River Protection Project mission, and to achieve compliance with federal and state hazardous waste requirements as enforced by the *Hanford Federal Facility Agreement and Consent Order* (HFFACO; Ecology et al. 1989), CH2M HILL Hanford Group, Inc. has identified several initiatives to implement the recently renegotiated HFFACO strategy defined in Change Number M-045-02-03 for near-term waste retrieval activities. The new strategy places an emphasis on acceleration of waste retrieval from selected single-shell tanks (SSTs) and closure of a tank farm. Milestone M-045-05B provides the criteria for the completion of the S-102 retrieval project design for all physical systems that includes the design and operating strategies necessary for LDMM.

The waste retrieval strategy for Tank S-102 focuses on the deployment of the S-112 modified sluicing waste retrieval technology to recover as much waste as technically practical. A process that controls liquid inventories during waste retrieval has been selected for this waste retrieval demonstration. The water used by the modified sluicing system acts as a solvent to dissolve and mobilize the soluble waste constituents and carry insoluble solids. The resulting slurry can then be pumped to a safe storage in a more reliable double-shell tank. Goals established in HFFACO Milestone M-45-05A for the S-102 retrieval include the recovery and safe storage of approximately 490 curies of mobile, long-lived radioisotopes and 99% of tank contents by volume, based on the best-basis inventory of August 8, 2000 (BBI 2001). HFFACO Milestone M-45-05B requires that the design will be considered complete by May 31, 2003 when 90% of the design has been approved for fabrication or construction.

1.3 OVERVIEW

The leak detection and leak monitoring system was selected based upon best available technology. An analysis of in-tank mass balance leak detection methods are presented in RPP-10413 Appendix A, and an analysis of ex-tank drywell monitoring methods is presented in RPP-

10413 Appendix B to support selection of the best available technology. The analyses illustrate that there are:

- large uncertainties associated with material balance leak detection methods when all elements of the system are considered
- limitations associated with both in-tank and ex-tank leak detection methods.

LDMM capabilities and actions have been agreed upon by U.S. Department of Energy, Washington State Department of Ecology (Ecology), and U.S. Environmental Protection Agency in the HFFACO. LDMM definitions as accepted by the U.S. Department of Energy, Office of River Protection, and Ecology are as follows:

- **Leak Mitigation**: Technologies, waste retrieval methods, or systems that can reduce the potential for a leak to occur, the volume of a leak if it were to occur, actions taken to minimize leak volumes in the event a leak is detected during waste retrieval.
- **Leak Detection**: Technologies, methods, or systems used to detect a leak.
- **Leak Monitoring**: Technologies, methods, or systems used to quantify liquid waste release volumes from a SST if a release is detected during waste retrieval operations. Leak monitoring also includes assessment of leak monitoring data in an effort to estimate the rate and direction of movement through the soil.

Details regarding the specific functions and requirements were proposed in *S-102 Initial Waste Retrieval Technology Functions and Requirements* (RPP-10901, Rev. 0). RPP-10901 is a primary document prepared in response to HFFACO Milestone M-45-05-T16. Since the S-112 waste retrieval system will be also used in S-102, the S-102 functions and requirements are being revised to align it with the S-112 functions and requirements document (RPP-7825). The drivers for this S-102 LDMM strategy are based on these revised S-102 functions and requirements. The S-102 functions and requirements document is pending approval by Ecology.

2.0 LEAK DETECTION, LEAK MONITORING, AND LEAK MITIGATION REQUIREMENTS

This section gives the requirements that drive the S-102 retrieval LDMM approach, and how the proposed strategy responsibly meets those requirements. Requirements, expectations, and conditions are found in three sources:

1. The HFFACO identifies key programmatic expectations for the deployment and use of advanced retrieval and leak detection technologies.

2. RPP-10901 identifies the state and federal regulations that apply to the tank S-102 LDMM program. These regulatory requirements are imposed on the design of the tank S-102 LDMM system via the requirement statements in Section 4.0 of RPP-10901.

3. The conditional approval (Schepens 2003) of the tank S-102 functions and requirements document (RPP-7825) by ORP/DOE.

Table 2.1 identifies the specific LDMM-related requirements, expectations, and conditions for the S-102 Project. The source documents are also identified in the table, as well as the S-102 Project response action to fulfill the requirement or expectation. Cross-references to sections within this document are provided for further detail.

Table 2.1. Tank S-102 Requirements (4 Sheets)

No.	Leak Mitigation, Leak Detection, or Leak Monitoring, or Related Requirement, Condition, or Expectation	Project Approach, Action, or Response	Source Document
1.	Seek to improve on past-practice sluicing in the areas of retrieval efficiency, leak loss potential during retrieval, and leak detection mitigation and monitoring (LDMM).	The waste retrieval system has been designed around the requirement that tank S-102 liquid inventory be kept to a practical minimum at all times. This will significantly reduce the likelihood of tank wall leaks and the potential volume of a leak, should one occur.	Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Milestone M-45-00-B.
2.	The design will include physical systems including design and operating strategies necessary for leak detection monitoring and mitigation (LDMM)	The leak mitigation strategy along with the leak detection and monitoring strategy defined in Section 3.1 and the system described in Section 4.0 provide for full-scale leak mitigation coupled with leak detection and monitoring during waste retrieval operations.	Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, as amended, Milestone M-45-05-B.
3.	The system shall be designed to detect a cumulative leak loss during the retrieval campaign of 8,000 gallons or the system shall be designed using the BATEA to detect tank leaks during retrieval to ALARA.	The S-102 retrieval system represents the best available technology, gamma and neutron moisture detection surveys in the drywells near tank S-102 (see Section 3.0). This approach is augmented with in-tank methods to provide defense-in-depth leak detection and monitoring.	RPP-10901, Section 4.6.1, *S-102 Waste Retrieval Functions And Requirements*, Rev. 1.
4.	The tank S-102 waste retrieval system shall have a probability of leak detection of greater than 95% and a probability of false alarm less than or equal to 5%.	The uncertainties associated with leak detection capability using both in-tank dynamic material balance and ex-tank drywell monitoring techniques are described in Section 5.0 and are evaluated based on conceptual models and parameter distributions developed for both methods. 95th percentile leak volumes are presented for both methods. There is insufficient data to define a minimum detectable leak volumes tied to a probability of false alarm. In lieu of this, the project will use an investigative approach to leak detection that will be defined in the process control plan.	RPP-10901, Section 4.6.1, *S-102 Waste Retrieval Functions And Requirements*, Rev. 1.
5.	The tank S-102 waste retrieval system shall quantify liquid waste release volumes from tank S-102 if a release is detected during waste retrieval operations. The data shall be collected, in the event of a leak, to help respond to the leak and to support a post-retrieval RPE. Data collected will be used to address estimates of the volume and composition of leaked material, as well as the residual waste in the tank.	The leak detection system will be used to quantify leak volumes from tank S-102 in the event that a leak is detected (see Section 3.0). Following detection of a leak, if one should occur, response actions will be taken to estimate the volume and potential characteristics of the waste released from the tank, including additional drywell monitoring.	RPP-10901, Section 4.6.2, *S-102 Waste Retrieval Functions And Requirements*, Rev. 1.

Table 2.1. Tank S-102 Requirements (4 Sheets)

No.	Leak Mitigation, Leak Detection, or Leak Monitoring, or Related Requirement, Condition, or Expectation	Project Approach, Action, or Response	Source Document
6.	The tank S-102 waste retrieval system shall minimize waste generation to the greatest extent practical, including water introduced into the tanks and solid waste.	Water is the only process chemical currently planned for addition during the tank S-102 retrieval. Process controls described in the process control plan (e.g., the ability to recycle pumped fluids) prevent excessive water usage.	RPP-10901, Section 4.8, *S-102 Waste Retrieval Functions And Requirements*, Rev. 1.
7.	The S-102 integrated retrieval and leak detection and monitoring system shall be designed and operated to mitigate leak volumes ranging from 8,000 gallons to 40,000 gallons for the duration of the retrieval demonstration. The tank S-102 waste retrieval system shall mitigate leaks as the primary means of minimizing environmental impact caused by releases during retrieval of SST waste. If a leak occurs, the release shall be evaluated and appropriate actions implemented (e.g., continue or discontinue retrieval). As the primary mitigation means, the retrieval pump shall be designed to allow continuous pumping for a sufficient amount of time (to be determined during design) to remove all pumpable liquids. An operational approach that minimizes the free liquid in the tank shall be employed for waste retrieval, ensuring that the interstitial liquid level remains below its starting level. The current interstitial liquid level is approximately 10.3 feet (124 inches). Mitigation activities will be consistent with the intent of HNF-SD-WM-AP-005, *SST Leak Emergency Pumping Guide*.	The operational strategy designed for the waste retrieval was developed to mitigate the potential for leaks. The addition of liquids will be controlled to maintain the interstitial liquid level at or below the pre-saltwell pumping level (see Section 3.1). Additionally, waste will be retrieved from the center out to minimize liquid contact with the tank walls. Based on evaluations of currently available leak detection and monitoring technologies, it was determined that the best available leak detection and monitoring technology for tank S-102 involves monitoring the existing drywells surrounding the tank for gamma radiation and moisture. With this technology the ability of the system to detect leaks from the center of the tank is unlikely in the time frame of this retrieval activity. Such leak will be detected by level monitoring of the liquid pool. Tank wall leaks would be detectable by drywell monitoring at smaller volumes (see Sections 3.0 and 5.0).	RPP-10901, Section 4.9, *S-102 Waste Retrieval Functions And Requirements*, Rev. 1.

Table 2.1. Tank S-102 Requirements (4 Sheets)

No.	Leak Mitigation, Leak Detection, or Leak Monitoring, or Related Requirement, Condition, or Expectation	Project Approach, Action, or Response	Source Document
8.	CA #1. Resolve all non-RPE-specific RCR comments.	CH2M Hill will support the resolution of RCR comments to the satisfaction of ORP and Ecology.	Schepens, 2003, Letter from R.J. Schepens (DOE/ORP) to E.S. Aromi (CH2M HILL). Re: Conditional Approval of the S-102 Functions and Requirements (F&R) Documents RPP-10901, Rev. 0, Deliverables of Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-45-05-T116, December 16, 2002.
9.	CA #2. (paraphrased) Ecology requires all RPE-related corrections, requested changes and additional information be incorporated into future RPE and SST closure documentation.	CH2M Hill will continue to support ORP's on going effort to develop agreements with Ecology concerning level of risk analysis needed for retrieval actions, level of risk analysis needed for individual tank closure/HFFAC Appendix H determinations, and level of risk analysis needed for tank farm Waste Management Area closure.	Schepens, 2003, Letter from R.J. Schepens (DOE/ORP) to E.S. Aromi (CH2M HILL). Re: Conditional Approval of the S-102 Functions and Requirements (F&R) Documents RPP-10901, Rev. 0, Deliverables of Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-45-05-T116, December 16, 2002.
10.	CA #3. Ecology requires that ORP maintain design flexibility to incorporate at least one viable ex-tank LDMM technology for each retrieval. Ecology expects that ORP will continue to seek out and invest in technology to improve the capability to detect and mitigate leaks during retrieval.	CH2M HILL has recently completed the evaluation of field tests with new ex-tank LDM technologies and will provide a briefing of test results to DOE/ORP and Ecology. Current plans involve developing cost and schedule estimates for deployment in a tank farm. If the new technologies prove to add value, a decision will be made regarding additional testing within a tank farm. At present, these technologies are not sufficiently mature to rely on for leak detection in the absence of sufficient demonstration testing in the farms (see Section 3.0).	Schepens, 2003, Letter from R.J. Schepens (DOE/ORP) to E.S. Aromi (CH2M HILL). Re: Conditional Approval of the S-102 Functions and Requirements (F&R) Documents RPP-10901, Rev. 0, Deliverables of Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-45-05-T116, December 16, 2002.

Table 2.1. Tank S-102 Requirements (4 Sheets)

No.	Leak Mitigation, Leak Detection, or Leak Monitoring, or Related Requirement, Condition, or Expectation	Project Approach, Action, or Response	Source Document
11.	CA #4. DOE will include Ecology in the process control program, including the development of process controls and review of documentation.	CHG2M Hill will support ORP/DOE in their effort to involve and include Ecology in document reviews, briefings on process controls, and process control documentation.	Schepens, 2003, Letter from R.J. Schepens (DOE/ORP) to E.S. Aromi (CH2M HILL). Re: Conditional Approval of the S-102 Functions and Requirements (F&R) Documents RPP-10901, Rev. 0, Deliverables of Hanford Federal Facility Agreement and Consent Order (HFFACO) Milestone M-45-05-T116, December 16, 2002.

ALARA = as low as reasonably achievable.
BATEA = best available technology economically achievable.
CA = Conditional Approval.
CH2M HILL = CH2M HILL Hanford Group, Inc.
DOE = U.S. Department of Energy.
Ecology = Washington State Department of Ecology.
HFFACO = *Hanford Federal Facility Agreement and Consent Order.*
LDMM = leak detection, monitoring, and mitigation.
ORP = Office of River Protection.
RCR = review comment record.
RPE = retrieval performance evaluation.
SST = single-shell tank.

3.0 LEAK DETECTION, MONITORING, AND MITIGATION STRATEGY

The tank S-102 retrieval system and retrieval strategy are based on the S-112 waste retrieval system and strategy with the primary LDMM strategy goal being leak mitigation. The S-102 waste retrieval system will be deployed and operated in a manner that will reduce the possibility of a leak and to reduce the potential environmental impact of a leak, should one occur. The leak detection strategy places emphasis on using the best available technology. The Office of River Protection is developing new leak detection technologies with improved leak detection sensitivities for the Hanford tanks (RPP-10604) but these technologies won't be ready for an S-102 deployment.

Existing in-tank and ex-tank options have been evaluated, and it was determined that tank wall leaks would be most quickly and reliably detected by monitoring the soil around the tank via existing drywells. It was also determined that leaks from the center of the tank floor would be most reliably detected using static liquid level tests at appropriate times during the retrieval. The leak monitoring strategy for S-102 is to use data from the leak detection systems to locate and quantify the leak. The following subsections provide further descriptions of the LDMM system and strategy, along with summaries of the analyses that have been conducted to select the LDMM baseline system.

3.1 LEAK MITIGATION

The leak mitigation strategy (i.e., reduction of leak loss potential) is twofold. The operational strategy involves taking actions to minimize leakage potential from the onset of retrieval and, if a leak is detected, involves responding to minimize the overall environmental impact.

The operational strategy to minimize the leak potential (initiation of a leak and leak volume) during retrieval in the absence of any indication of a leak involves the following:

- Control in-tank liquid inventory during retrieval to less than previous nonleaking interstitial liquid level. Years of static level monitoring have shown the tank to have not leaked below this level.

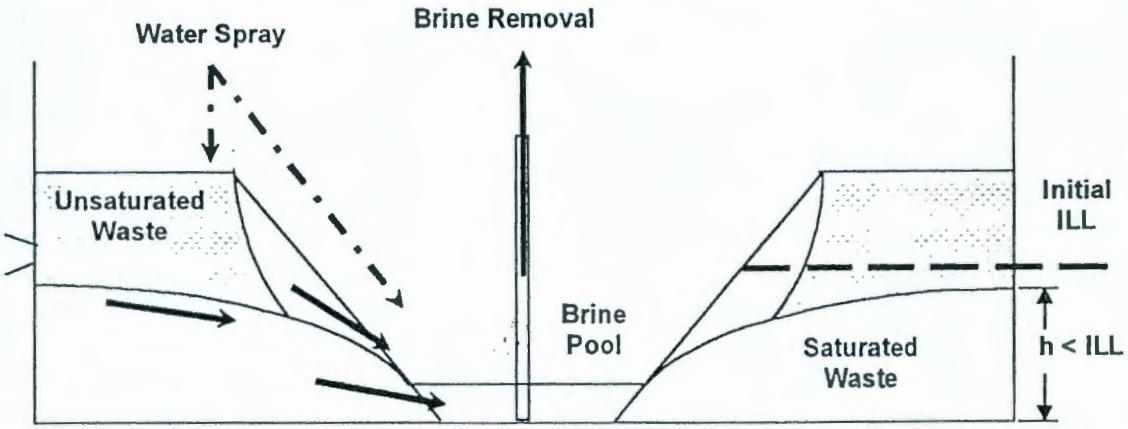
- Retrieve waste from the center of the tank out to minimize liquid contact with the tank wall, the location of most historical SST leaks (see Figure 3.1). In the center-out retrieval strategy, dissolved waste and released interstitial liquids drain quickly into a central pool, and can be rapidly pumped from the tank if a leak is detected.

- Design the retrieval system and operational strategy to minimize "time at risk." By minimizing the time at risk, potential leak volumes are limited in size. The relatively short retrieval duration (2 to 4 weeks) limits the overall leakage volume from a leak, should it go undetected. Table 3.1 provides leakage volumes as a function of leak rate and leak duration. A conservative leak rate based on historical data of 1.8 gal/hr is provided along with the highest historical leak rate of 100 gal/hr.

- Use the retrieval pump to minimize tank S-102 liquid inventory at the end of each retrieval campaign (e.g., while waiting for cross-site transfers) to further reduce any leak driving head and exposure of the tank wall.

- Minimize potential leak volume by providing a (nominal 90 gal/min) pump, with the inlet located as close to tank bottom as possible, to rapidly pump down liquids if a leak were to be detected.

Figure 3.1. Illustration of Leak Mitigative, Center-Out Retrieval Strategy



ILL = interstitial liquid level.

Table 3.1. Leakage Volumes

Leak Rate (gal/hr)	Duration (weeks)					
	1	2	3	4	8	12
0.5	84	168	252	336	672	1,008
1	168	336	504	672	1,344	2,016
1.8	302	604	907	1,209	2,419	3,628
5	840	1,680	2,520	3,360	6,720	10,080
10	1,680	3,360	5,040	6,720	13,440	20,160
50	8,400	16,800	25,200	33,600	67,200	100,800
100	16,800	33,600	50,400	67,200	134,400	201,600

In the event a leak is detected, sluicing operations will be stopped and the tank quickly pumped down to a minimum liquid level using the retrieval pump. Waste retrieval operations may

resume after assessing tank conditions, if warranted, and further leakage can be mitigated. Details of the operational response to a leak will be defined in the process control plan.

3.2 LEAK DETECTION

Both in-tank and ex-tank methods that have been used historically for leak detection will be used in an S-102 waste retrieval. The following subsections discuss the evaluations performed, the conclusions drawn, and the leak detection strategy that will be used for the S-102 waste retrieval. A detailed assessment of currently available and deployable in-tank and ex-tank LDMM methods are presented in RPP-10413.

The tank S-102 waste retrieval functions and requirements identified a limited number of leak detection and monitoring technologies that have been proven in the tank farm environment (RPP-10901). To be a suitable candidate for full-scale deployment, leak detection and monitoring technologies must be technically mature and capable of being deployed in the tank farm in a manner that supports waste retrieval schedule and operational performance and reliability requirements. Based on evaluating the uncertainties associated with available leak detection and monitoring technologies, the LDMM strategy to be implemented for the S-102 Project will:

- use drywell monitoring techniques to detect leaks that originate on the sidewalls of the tank or near the tank edge and
- use static liquid level monitoring to detect leaks originating from the center portion of the tank floor.

This will be supplemented with the observation of in-tank process control data as a defense-in-depth approach to monitor for catastrophic leaks.

3.2.1 In-Tank Leak Detection

In-tank leak detection methods include dynamic mass balance and static liquid level monitoring. SST retrieval activities have historically relied on material balance methods, and leak detection in quiescent SSTs has been based on level monitoring. This method historically applied to tank C-106 is the basis of the 8,000-gallon C-106 leak detection requirement. The dynamic mass balance method works well if the tank being retrieved and the receiver tank both have a free liquid surface over the entire diameter of the tank that can be accurately measured and used to estimate waste inventory in both tanks and the tank waste property uncertainties are small. As described in Section 5.0, the uncertainties associated with dynamic mass balance are large and are not suited for leak detection and monitoring in tanks containing saltcake waste without a free liquid surface over the entire diameter. The static liquid level leak detection method is also expected to work well when there is a free liquid surface across the entire tank, and the transitory effects of water addition, salt dissolution, seepage, and pumping have subsided. However, the tank S-102 retrieval strategy, to reduce leak potential, will not allow a free liquid surface across the entire tank diameter until late in the retrieval process. Static liquid level methods will have large uncertainties during operations because the liquid level is subject to oscillations associated with variable water application, drainage, pumping rates, etc. After liquid additions are stopped

it is expected that a number of weeks will be required for the liquid level to equilibrate for a valid static level check to be performed using historical liquid level monitoring methods.

A modified form of static leak detection for S-102 retrieval will be used to check for large leaks from the tank floor where drywell monitoring is least timely. In this case, any decrease in liquid level would indicate a possible leak, but sensitivity will be low until equilibrium is reached.

3.2.1.1 In-Tank Static Level Observation

Volumetric methods measure the liquid surface in a static tank and convert the level data to volume data from the known tank parameters. Historically static level measurements were performed on a free-liquid surface that covered the waste and were available for level monitoring. In the case of tank S-102, interim stabilization has removed the surface liquid. While the tank S-102 retrieval strategy will create a center pool that can be accessed for level measurement it will not be stable enough for a static measurement of historical accuracy for several weeks due to plans to pump the liquid down between waste retrieval campaigns. The causes of this instability are listed in Section 5.0.

As drywell monitoring is not very sensitive to leakage originating from the center of the tank, static level observation will be adapted to fill this need. Before level monitoring the liquid will be pumped down to approximately 12 inches in depth as part of the leak mitigation strategy. Following removal of liquid from the central pool, liquid from the surrounding waste will seep into the central pool over a period of time (see Figure 3.1). Under these conditions it is expected that the liquid level would slowly rise to an equilibrium level, any lowering of the liquid level (using the standard 0.5-inch criteria) will indicate a leak. A leak will initially be masked by the level rise, but a large leak will soon become evident. Detection of small leaks will not be possible until the liquid level reaches equilibrium, which could take several weeks. Static-level observations will be done near the end of scheduled down times associated with transferring waste out of the receiver tank, as well as unscheduled delays, to improve the chances of detecting a leak.

3.2.1.2 In-Tank Dynamic Mass Balance

Mass balance observations using process control data involves monitoring the volumetric inventory balance using level instruments in the waste retrieval tank along with flow meters and inventory estimates to balance the flow in and out of the waste retrieval tank. This method provides a rough indication of gross leaks. The driving disadvantage of this method is that the minimum discernable leakage volumes are large, limiting this method to monitoring for catastrophic leaks.

Dynamic mass balance leak detection, not selected for use in tank S-102 based on performance uncertainty, is sensitive to a number of environmental and operational interferences. Limitations in the ability to accurately measure the physical and chemical conditions (e.g., uncondensed evaporation, dynamic changes in the waste properties, homogeneity, layering) significantly affect the accuracy of available dynamic leak detection technologies. These uncertainties will result in a dynamic leak detection system that will be required to decipher the discrepancies between what is added to tank S-102, how much is removed from the tank, and how much remains at any point during the waste retrieval.

3.2.2 Ex-Tank Leak Detection

Available ex-tank leak detection methods involve indirect measurement of subsurface conditions in the drywells surrounding the tank. Drywell monitoring has been used extensively in the past for leak detection and monitoring. Drywell monitoring methods have inherent limitations and uncertainty depending on the proximity of a leak site to a drywell, how a drywell intercepts the leak plume, leak rate, and soil properties.

There are 8 monitoring wells, ranging in depth from 100 to 145 feet below ground surface near tank S-102 (see Section 4.1). Four of the drywells are within 11 to 12 feet from the tank, with the four other drywells at 8, 14, 18 and 25 ft locations from the tank wall. The baseline leak detection methodology involves deployment of an existing truck mounted geophysical logging systems using both gamma and neutron moisture monitoring tools. Measurements will be taken before waste retrieval operations begin, to establish a moisture baseline, and at the end of waste retrieval operations to assess potential moisture changes. The initial baseline will be established by deploying calibrated gamma and neutron moisture probes over the full depth of each drywell. During waste retrieval operations, the truck-mounted systems will be supplemented by the use of manually deployed moisture gauges on a frequency to be established in the process control plan at depths corresponding to moist layers. Moist layers should be the first affected by a new leak plume and may decrease detection times. In the event of an unexplained increase in soil moisture content, additional monitoring with the truck-mounted system will be used to determine if there have been any changes in gamma-emitting radionuclide concentration surrounding the drywells.

The use of manually deployed moisture monitors represents an enhancement to the truck-mounted system by providing more frequent moisture measurements in areas of interest without having to continually deploy the trucks into the farm.

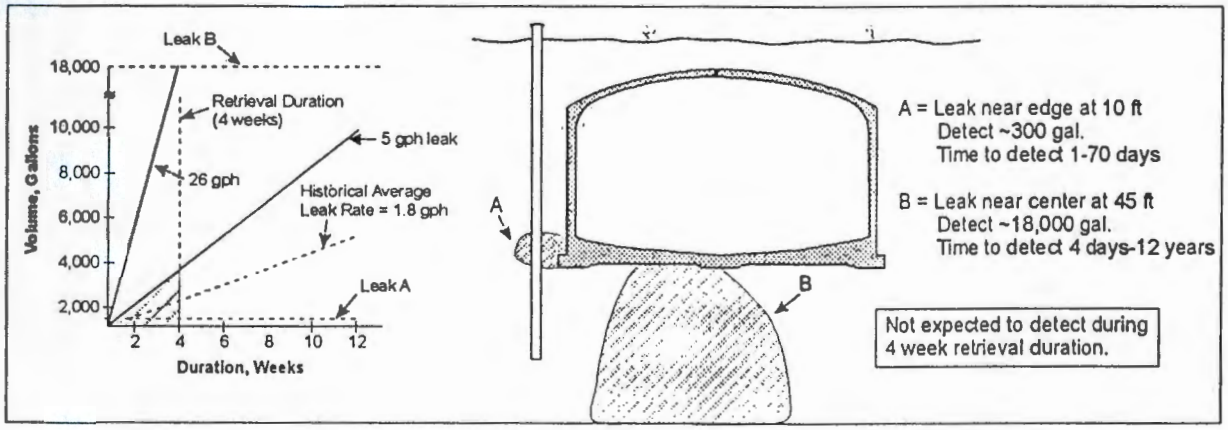
Water has utility as a leak indicator over other potential waste constituents for the following reasons:

- Neutron moisture monitors are sensitive to small changes in moisture content in soil surrounding drywells.
- Water will be added to the tanks during the planned waste retrieval demonstrations.
- Gamma-emitting radionuclides that remain in the tanks have decayed to the point where cesium-137 is the primary radionuclide remaining. Cesium-137 in dilute tank waste is only slightly mobile and its retardation may be sufficient to inhibit timely detection of changes to the area surrounding the drywells.
- Manually deployed neutron moisture monitors are readily available, can be more easily deployed by waste retrieval personnel, and can be deployed on a more frequent basis than truck mounted systems.
- Data from the neutron moisture monitors can be readily analyzed to determine if changes have taken place.

- Neutron moisture monitors are fully capable of detecting increases in soil moisture content as low as 2%.

Based on the results of uncertainty analyses, it was determined that drywell monitoring is best suited to detecting leaks originating near the tank sidewall (RPP-7825). Different potential leak locations of interest to drywell monitoring are illustrated in Figure 3.2. Figure 3.2 shows two potential leak locations, at or near the tank sidewall and near the center of the tank floor. As shown in the upper portion of the figure leaks on the order of 300 gallons can be detected for slow leaks that originate near the edge of the tank (A) within 10 feet of a drywell. Leaks on the order of 18,000 gallons originating near the center of the tank floor can be detected in a drywell (B) but not in the 4-week timeframe of waste retrieval activity. Based on the S-102 drywell configuration, the one drywell that is 25 feet from the tank wall will have a minimum detectable leak on the order of 8,000 gallons.

Figure 3.2. Schematics of Potential Tank Leak Conditions During Retrieval



3.2.3 Summary of Leak Detection Strategy

The overall strategy for leak detection is as follows:

- Survey the existing drywells using both truck-mounted gamma and neutron moisture probes. The existing wells will be monitored before and after retrieval using the truck mounted logging system to establish a baseline. This will be supplemented by the deployment of a manually deployed neutron moisture detector. This probe will be deployed more frequently at depths corresponding to moist layers under the tank during retrieval to shorten the deployment time. In the event of an unexplained increase in soil moisture content, the truck-mounted logging systems using both gamma and moisture logging tools will be deployed to monitor for changes in the baseline concentration of isotopes and moisture levels in the soil around the tank.

- Conduct modified static level monitoring during periods between retrieval campaigns for evidence of any leakage from the tank center floor. This is the potential leak location that is least likely to be detectable by drywell. This approach provides the opportunity to

detect leaks and minimize the leak duration. It allows for static level monitoring at times when the waste retrieval system is shut down and the liquid level pumped down.

- Observation and measurement of the receiver tank to assess transfer integrity. Static observation periods shall occur during double-shell tank cross-site transfer operations and during maintenance outages.

- Diligently observe process control data concerning mass balance for the possibility of a catastrophic release while waste is actively being retrieved as a defense-in-depth approach.

This approach represents deployment of the best available technology, meets the functions and requirements identified in RPP-10901, and the conditional approvals for similar retrieval activities. This S-102 LDMM strategy will be completed using a combination of operational improvements in retrieval strategy with best available, leak detection and leak monitoring technology. The requirements identified in Section 2.0 serve to provide a basis for the strategy described in this section and the system description provided in Section 4.0.

3.3 LEAK MONITORING STRATEGY

If a leak is detected during waste retrieval operations, the leak will be monitored using the same drywell logging / static level measuring equipment to estimate the total volume or leak rate. Gamma surveys and neutron moisture logging will be used to determine the extent of a contamination plume by understanding the changes and rate of change associated with measurements at the drywell locations. A leak volume estimate must be performed to quantify the environmental impact resulting from a leak (RPP-10901). The data collected through monitoring, in addition to being used to estimate leakage volumes, will be evaluated in an attempt to estimate the rate and direction of movement through the soil. Estimated leak volumes will be used to assess the potential need for corrective action, consideration of retrieval leakage criteria for future retrievals in the S tank farm, and characterization needs for tank farm closure.

4.0 BASELINE SYSTEM DESCRIPTIONS

The waste retrieval and leak detection and monitoring systems summarized in this section represent the systems to be used in tank S-102. Potential uncertainties related to the leak detection and leak-monitoring systems are summarized in Section 5.0.

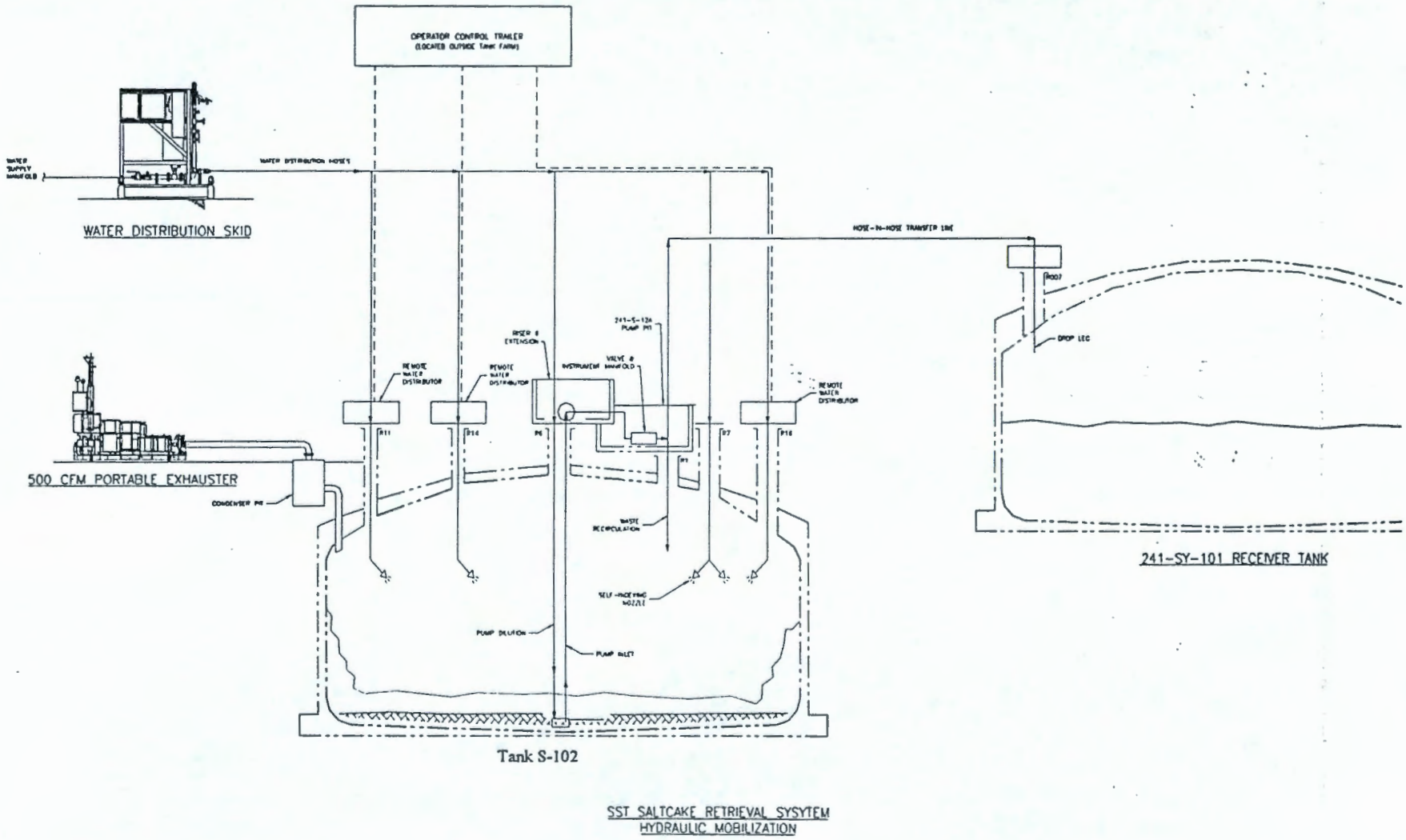
4.1 TANK S-102 WASTE RETRIEVAL SYSTEM DESCRIPTION

The S-102 Project will utilize two separate systems to dissolve and mobilize waste and remove it from the tank:

- **Water distribution system**: Water is introduced to the tank through four water distribution devices. The water distribution system has three directable nozzles in the three outer risers. The fourth distribution device is a modified tank washer nozzle (oscillating spray nozzle) that will be located 6 feet off center. The stream of the fourth nozzle is not directable once installed, but will be used to carve out a well around the central pump to ensure flow away from the tank wall and toward the pump. The flow rate through the water distribution system can be varied and the flow monitored and recorded. The water is applied in a manner that will retrieve the waste from the "inside-out"; that is, the waste is first removed from the center of the tank to create a well or pit around the central pump (see Figure 4.1). This central well will then be gradually enlarged until the tank wall is reached. At this point, the remaining waste is undermined to fall away from the wall. Finally, the remaining heel will be removed.

- **Waste solution removal system**: Waste will be removed by a centrally located pump and pumped via a hose-in-hose transfer line to the SY tank farm. The pump has a capacity of approximately 90 gal/min to quickly pump down liquid inventory. Pump operation will be integrated with water addition to manage liquid level in the tank. The pump inlet is located as close to the tank bottom as possible to maximize retrieval recovery. The hose-in-hose transfer line utilizes leak detectors to ensure line integrity. The pumping system can, if necessary, recirculate waste back to the tank through a pipe routed through an open riser in the dirtributor pit to reduce the total amount of water added by increasing contact time of the water with the waste.

Figure 4.1. Proposed Tank S-102 Saltcake Waste Retrieval System (not to scale)



4.2 LEAK DETECTION AND LEAK MONITORING SYSTEM DESCRIPTION

The baseline method for leak detection and leak monitoring involves gamma and neutron moisture surveys in the drywells surrounding the tank. This will be supplemented by static liquid level monitoring of a pumped-down pool performed between waste retrieval campaigns or at other times when retrieval operations are shut down and there is sufficient time to perform the static test. Less accurate in-tank process control parameters will be observed throughout the waste retrieval campaign to supplement the ex-tank drywell and in-tank static level methods and provide a defense-in-depth approach to identify indications of potential "gross" leaks. The following sections describe the equipment used for these methods. Operational specifics of this equipment are deferred until the final process control plan is developed.

4.2.1 Primary Leak Detection and Leak Monitoring System Description

4.2.1.1 Ex-Tank Leak Detection

Eight existing drywells surrounding tank S-102 will be used for monitoring leakage that may occur during waste retrieval operations (Figure 4.2). The 8 drywells that will be monitored are (in clockwise order around this tank) 40-02-01, 40-02-03, 40-02-04, 40-02-05, 40-02-07, 40-02-08, 40-02-10, and 40-02-11. Four of the drywells are within 11 to 12 feet from the tank, with the four other drywells at 8, 14, 18 and 25 ft locations from the tank wall. Additional drywells within the farm may be monitored to investigate whether observed changes at tank S-102 are localized or more widespread as would be expected from seasonal changes in precipitation. Existing truck-mounted logging systems will be used with gamma probes and with neutron moisture probes. The neutron moisture probes will be used to identify changes in water or moisture content surrounding a drywell. Manually deployed neutron moisture detectors will supplement the truck-mounted systems.

4.2.1.2 Static Liquid Level Monitoring

A direct Enraf™[1] level-sensing instrument in a centrally located stilling well will be used in tank S-102. This instrumentation has a high degree of resolution and repeatability and is well suited for the volumetric method in tanks with a measurable air-liquid interface. Currently, the Enraf™ gauge is contacting solids and cannot be used for static testing until sufficient waste is retrieved from the tank to create a cone shaped well (or pool) in the center of the tank. A description of the Enraf™ gauges and their use in the current monitoring program is provided in RPP-9645. This document also describes the loss of resolution under varying waste conditions.

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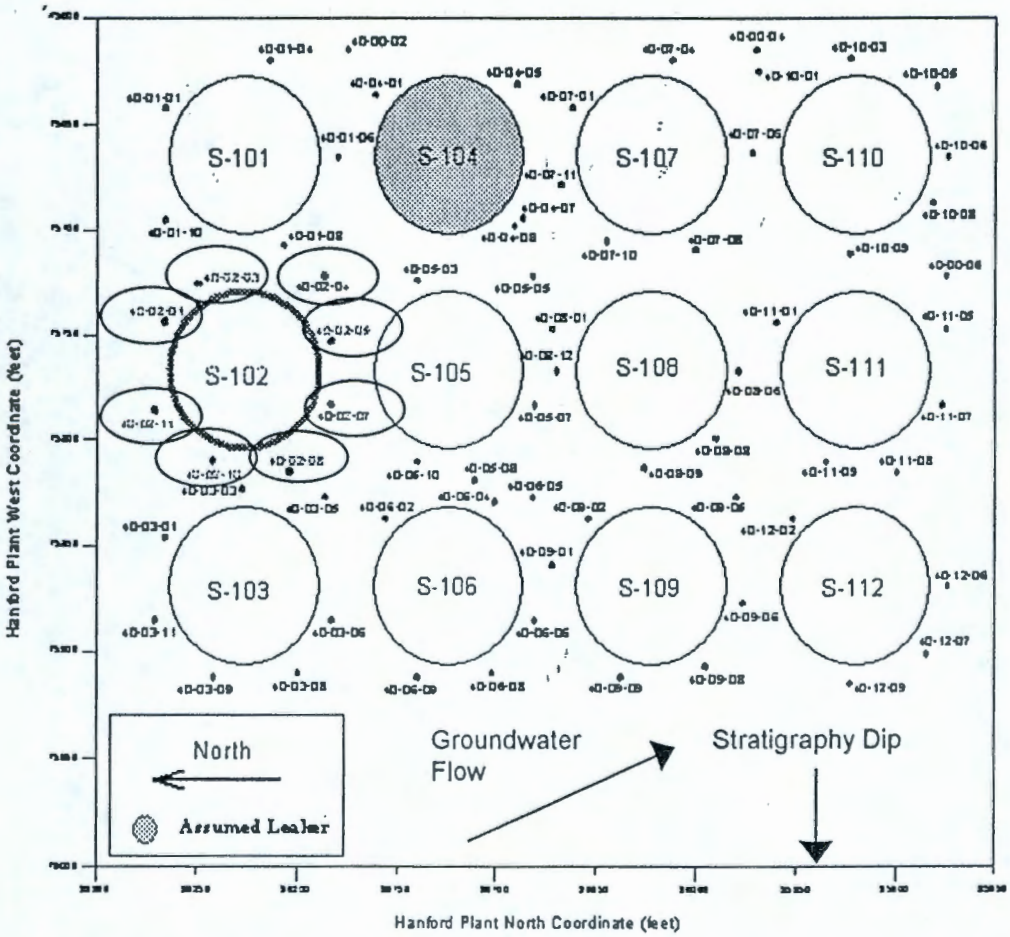
[1] Enraf™-Nonius Series 854 is a trademark of Enraf-Nonius, N.V. Verenigde Instrumentenfabrieken Enraf-Nonius CORPORATION NETHERLANDS Rontegenweg 1 Delft NETHERLANDS

Figure 4.2. S Tank Farm Plan View of Drywell Locations



`Legend: ⬭ = Drywells used for Tank S-102 baseline leak detection

4.2.1.3 Additional Data Collection

Ex-tank drywell monitoring has technical limitations associated with it despite its representing the best currently available technology. The S-102 retrieval activity will attempt to improve confidence in data obtained by the primary leak detection equipment by routinely collecting corroborating data from in-tank measurements, video surveillance, and process control data as potential indicators of a catastrophic leak.

The volumes of water introduced to tank S-102 and the volumes of liquid transferred out of the tank during waste retrieval will be recorded as an aspect of routine process control. This is accomplished by the use of flow meters, level gauges, and measurements of changes in specific gravity of the solution being pumped from the tank. Because of the large uncertainty (greater than 70,000-gallons, RPP-10413, Appendix A, Table A.6) in initial waste volume, mass balance monitoring will not be used as a primary leak detection method. This technique will provide potential indication of a catastrophic leak and will be used to provide defense in depth to the primary leak detection equipment. The advantage of this technology is that it can provide continuous real-time measurements, albeit of low quality. This method may be able to indicate a problem that causes immediate monitoring using the primary leak detection equipment.

4.2.2 Leak Detection in Transfer Lines and Pits

Liquid waste and slurries will be transferred from tank S-102 to tank SY-101 using temporary hose-in-hose over ground transfer lines and existing valve pits. Leak detectors located in the SY-101 drop leg, S-A valve pit, and S-02B distributor pit will be monitored in the tank S-102 retrieval control trailer. The waste retrieval system will shut down if a leak is detected in the transfer system.

Leakage from the primary over ground transfer hose (inner hose) will be contained by the secondary confinement system (outer hose) and detected by one of the three leak detectors. The secondary confinement system has been designed to drain any fluid released from the primary hose to a common point for collection, detection, and removal. The hydraulics of the tank S-102 to tank SY-101 over ground transfer line will cause any leakage to the secondary containment to drain towards either the S-A valve pit or the S-02B distributor pit. Leak detection elements installed in the pits actuate an alarm and annunciator light in the control room if a leak is detected and shut down the retrieval pump.

4.2.3 Leak Detection in the Receiver Double-Shell Tank

A leak from the primary vessel of tank SY-101 is detected by either a conductivity probe leak detection system installed in the annulus or a continuous air monitor that detects airborne radionuclides entrained in the annulus ventilation exhaust stream. Detection of a leak into the annulus of the tank by either system activates an audible alarm and an annunciator panel light.

The tank annulus is designed to collect and direct waste that leaks from the primary tank to the annulus for detection and transfer. Slots cut in the insulating concrete that supports the tank at the bottom are designed to drain any leakage to the annulus floor. Conductivity probe assemblies and a radiation monitor leak detection system are installed on the annulus ventilation system to detect tank leaks.

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5.0 UNCERTAINTY ANALYSES

This section summarizes results of leak detection uncertainty analyses, that were completed on proposed leak detection methods and technologies for the S-112 Project in RPP-10413, as applied to S-102 retrieval. The detailed analyses and interpretation of results are provided for in-tank dynamic mass balance and ex-tank drywell methods in RPP-10413, Appendices A and B, respectively. The purpose of these analyses was to investigate the uncertainties associated with each method and support the selection and implementation of the best available leak detection technology. This section summarizes the results of these analyses (for further details, refer to Appendices A and B of RPP-10413).

5.1 UNCERTAINTY OF MASS BALANCE METHODS

The S-112 Project used an integrated, multi-disciplinary team to provide the bases and details for the mass balance uncertainty analysis. As presented in Appendix A of RPP-10413, the homogeneous waste regions for the center-out mining strategy were identified, and material balance equations for the waste retrieval process were developed. Three leak volume models were developed from material balance equations for the total liquid mass, total water mass, and total liquid and solid mass inventories. The majority of the parameters in these models have significant uncertainties. The leak volume models were evaluated using Monte Carlo simulations. For this evaluation, the magnitude of the uncertainty (and not specific leak volumes) was evaluated. Regression analyses were also performed to identify the relative importance of parameters.

Parameter distributions were developed based on in-tank measurements, data reconciliation, Hanford tank farm data, chemical modeling, and instrumentation accuracy. Although individual parameter uncertainties are not additive, insight into the large uncertainty associated with in-tank methods can be gained by considering the large uncertainty in the initial waste mass. The initial waste mass uncertainty is a measure of how well the actual mass of the waste in the tank is known. This is composed of uncertainties associated with the physical properties of the tank such as waste volume, porosity, density, and retained gas volume. The initial condition uncertainty range is at least 70,000 gallons at the 95% confidence interval depending on the material balance methodology (see RPP-10413, Appendix A, Table A.6). This uncertainty is not easily reduced given the complex nature of the waste.

The resulting 95% confidence interval uncertainty range for leak volumes in tank S-112 for each of the mass balance models is summarized in Table 5.1 (from Section 5.0 of RPP-10413). As shown in the table, the uncertainty range is a function of the amount of waste retrieved from the tank. When 80% of the original waste has been retrieved, the total liquid mass balance method outperforms the other methods with a 95% confidence interval uncertainty range of 82,000 gallons. Generally the uncertainty increases throughout the waste retrieval process as the uncertainty with retrieval conditions increase. As shown in Table 5.1 the uncertainty with water mass balance is greater than liquid mass balance methods because of the uncertainty associated with the fraction of water in the liquid waste. The total mass balance has the largest uncertainty range because of the need to account for the solid mass and its associated uncertainty.

Table 5.1. 95% Confidence Interval Best Estimate Uncertainty Range in Leak Detection for Tank S-112

Equation	95% Confidence Interval Range (gallons)				
	Original Waste Retrieved (%)				
	10	20	40	60	80
Liquid mass balance	18,000	28,500	48,900	62,100	82,400
Water mass balance	18,000	29,700	52,200	66,400	90,800
Total mass balance	90,300	137,800	203,200	198,600	161,000

The results of the regression analysis showed that the ranking of parameters in terms of significance (the key contributors to the leak volume uncertainty) varied as a function of the amount of waste retrieved and by the type of mass balance. The results of the sensitivity analysis are presented in RPP-10413, Appendix A, Section A3.3. In general, the parameters that have the greatest influence on the total mass balance uncertainty include the following:

- Waste volumes at initial and retrieval conditions
- Mass fraction of water in the bulk waste
- Bulk density of the waste
- Volume of water added
- Density of the brine produced by dissolution of soluble solids.

Improvements in the ability to measure waste volume using the tank volume measurement system (laser based surface mapping) were evaluated separately in the uncertainty analysis and only reduced the uncertainty range by 4%, which is not considered significant.

Acknowledgment of the uncertainty associated with initial conditions and the increase in uncertainty throughout the waste retrieval process makes viable leak detection unachievable by mass balance methods. This requires the project to deploy a system that utilizes a combination of other technologies aimed at detecting different types of leaks (leak location and leak rates) to represent best available technology.

5.2 UNCERTAINTY OF IN-TANK STATIC LEVEL MONITORING

A detailed uncertainty analysis of static liquid level monitoring methods was not conducted. However, a qualitative assessment of in-tank conditions that may impact static level observations include the following:

- Evaporation from the central pool.
- Gas accumulation or release from the central pool.
- Liquids not yet at hydraulic equilibrium with the solids.
- Undissolved waste sloughing/falling into the pool.

After the liquids are pumped down it may take weeks for the liquid level to fully equilibrate. However, it is expected that the liquid level will asymptotically approach an equilibrium level and that deviations from this anticipated trend can be used as a potential indication of a leak. If there is a drop in the liquid level during this period of time, with the ventilation secured, it would be an indication of a leak. The accuracy of static level monitoring improves as the liquid level reaches an equilibrium level.

5.3 UNCERTAINTY OF EX-TANK DRYWELL MONITORING METHODS

The S-112 Project utilized expertise from the Tank Farms Vadose Zone Project to evaluate uncertainties associated with drywell logging methods (see Appendix B of RPP-10413). Determinations were made of best-case and worst-case scenarios to bound potential performance. A calculational method was used to describe leak volumes, volumes of soil contaminated, and changes in moisture content due to a leak. This was followed by a Monte Carlo analysis to assess the uncertainty range for leak detection using ex-tank drywell logging. Details on the ex-tank drywell monitoring leak detection evaluation are provided in RPP-10413, Appendix B.

For slow leak rates ranging from 0.03 gal/hr to 1.44 gal/hr, the travel time and associated leak volumes for a leak originating near a drywell are small. The theoretical leak volume and associated time required to reach a drywell from the center of the tank floor to a drywell (modeled as a 45-foot distance) are larger. Detection of a slow leak from the center of the tank floor with a drywell is unrealistic as the time required for sufficient liquid to leak from the tank and migrate to the drywell is significantly longer than the planned waste retrieval duration. Summary statistics for travel time and total volume leaked under slow leak conditions are shown in Table 5.2 (from Section 5.0 of RPP-10413). The mean values for travel times are 12 days for the 10-foot distance and 2.0 years for the 45-foot distance. The corresponding mean values for volume leaked are 100 gallons and 6,200 gallons. The 5th and 95th percentile values are also listed in Table 5.2. Approximately 90% of the results fall between these two extremes.

Table 5.2. Summary Statistical Results for Ex-Tank Leak Detection Response Time (for leaks less than 1.5 gal/hr)

Parameter	10-foot Distance (f = 0.75)	45-foot Distance (f = 0.50)
Mean travel time	12 d	710 d (2.0 y)
Median travel time	4.8 d	290 d (0.80 y)
5th percentile time	1.0 d	59 d
95th percentile time	43 d	2,600 d (7.1 y)
Mean volume leaked	100 gal	6,200 gal
Median volume leaked	73 gal	4,400 gal
5th percentile volume	20 gal	1,200 gal
95th percentile volume	300 gal	18,000 gal

Notes: The mean value is the sum of the times or volumes divided by the number of trials. The median value is the time or volume is the 50th percentile in the cumulative distribution (i.e., half the results lie below the median value). The 5th and 95th percentiles show the range of times or volumes that encompass 90% of the calculated results.

Additional uncertainty analyses were performed to evaluate a larger range in potential leak rates. Historical leak rates were reviewed that indicated a range of tank leak rates from 0.03 to 102 gal/hr. To account for the higher probability of a slow leak compared to a fast leak a lognormal distribution was assigned to the leak rate parameter (referred to as the lognormal leak rate model). For this leak range the 95th percentile volume at both the 10-foot and 45-ft distance increased over those shown in Table 5.2. The summary statistics for the larger leak rate range are provided in Table 5.3 (from Section 5.0 of RPP-10413). It is interesting to note the frequency charts in RPP-10413, Appendix B (Figures B1.6 and B1.7) for the lognormal leak rate model are highly skewed toward the low end, indicating that in all likelihood a leak, if one should occur, would show up sooner and have leaked a smaller volume than indicated by the 95th percentile values. It should be also noted that historical tank leaks have been recorded that did not follow this model, resulting in larger leaked volumes than shown in Table 5.3.

Table 5.3. Summary Statistical Results for Ex-Tank Leak Detection Response Time (for large leaks)

Parameter	10-foot Distance (f = 0.75)	45-foot Distance (f = 0.50)
Mean travel time	20 d	1,200 d (3.3 y)
Median travel time	2.2 d	130 d
5th percentile time	0.07 d	4.1 d
95th percentile time	72 d	4,400 d (12 y)
Mean volume leaked	100 gal	6,200 gal
Median volume leaked	73 gal	4,400 gal
5th percentile volume	20 gal	1,200 gal
95th percentile volume	300 gal	18,000 gal

Notes: The mean value is the sum of the times or volumes divided by the number of trials. The median value is the time or volume is the 50th percentile in the cumulative distribution (i.e., half the results lie below the median value). The 5th and 95th percentiles show the range of times or volumes that encompass 90% of the calculated results.

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