0051845

S

ENGINEERING CHANGE NOTICE

Page 1 of 2

1. ECN 656299

Proj. ECN

2. ECN Category (mark one)	3. Originator's Name, Organization, MSIN, and Telephone No.	4. USQ Required?	5. Date
Supplemental ○ Direct Revision ◉ Change ECN ○ Temporary ○ Standby ○ Supersedure ○ Cancel/Void ○	Phil Ohl, SST Programs, R2-89, 375-3374	○ Yes ◉ No	09/22/99
	6. Project Title/No./Work Order No. SST Program	7. Bldg./Sys./Fac. No. 200G	8. Approval Designator NA
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-WM-ES-378, Rev. 1	10. Related ECN No(s).	11. Related PO No. NA

12a. Modification Work	12b. Work Package No.	12c. Modification Work Completed	12d. Restored to Original Condition (Temp. or Standby ECNs only)
○ Yes (fill out Blk. 12b) ◉ No (NA Blks. 12b, 12c, 12d)	NA	NA Design Authority/Cog. Engineer Signature & Date	NA Design Authority/Cog. Engineer Signature & Date

13a. Description of Change

13b. Design Baseline Document? ○ Yes ◉ No

This is a direct revision to an earler document that describes leak detection, leak monitoring, and leak mitigation during single-shell tank retrieval. Direct revision to this report supports TPA milestone M-45-09D.

OCT 1999 RECEIVED EDMC

14a. Justification (mark one)	14b. Justification Details
Criteria Change ○ Design Improvement ○ Environmental ◉ Facility Deactivation ○ As-Found ○ Facilitate Const. ○ Const. Error/Omission ○ Design Error/Omission ○	Revision of this document supports TPA milestone M-45-09D.

15. Distribution (include name, MSIN, and no. of copies)

CC Haass R2-89
WJ Stokes R2-89
Central Files B1-07
RL Reading Rm. H2-53

RELEASE STAMP

SEP 23 1999
DATE:
STA: 15
HANFORD RELEASE
ID: 20

ENGINEERING CHANGE NOTICE

1. ECN (use no. from pg. 1): 656299

16. Design Verification Required	17. Cost Impact		18. Schedule Impact (days)
	ENGINEERING	CONSTRUCTION	
○ Yes	Additional ○ $ _____	Additional ○ $ _____	Improvement ○ _____
◉ No	Savings ○ $ _____	Savings ○ $ _____	Delay ○ _____

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD	☐	Seismic/Stress Analysis	☐	Tank Calibration Manual	☐
Functional Design Criteria	☐	Stress/Design Report	☐	Health Physics Procedure	☐
Operating Specification	☐	Interface Control Drawing	☐	Spares Multiple Unit Listing	☐
Criticality Specification	☐	Calibration Procedure	☐	Test Procedures/Specification	☐
Conceptual Design Report	☐	Installation Procedure	☐	Component Index	☐
Equipment Spec.	☐	Maintenance Procedure	☐	ASME Coded Item	☐
Const. Spec.	☐	Engineering Procedure	☐	Human Factor Consideration	☐
Procurement Spec.	☐	Operating Instruction	☐	Computer Software	☐
Vendor Information	☐	Operating Procedure	☐	Electric Circuit Schedule	☐
OM Manual	☐	Operational Safety Requirement	☐	ICRS Procedure	☐
FSAR/SAR	☐	IEFD Drawing	☐	Process Control Manual/Plan	☐
Safety Equipment List	☐	Cell Arrangement Drawing	☐	Process Flow Chart	☐
Radiation Work Permit	☐	Essential Material Specification	☐	Purchase Requisition	☐
Environmental Impact Statement	☐	Fac. Proc. Samp. Schedule	☐	Tickler File	☐
Environmental Report	☐	Inspection Plan	☐	None	☒
Environmental Permit	☐	Inventory Adjustment Request	☐		☐

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number/Revision
NA		

21. Approvals

	Signature	Date		Signature	Date
Design Authority			Design Agent		
Cog. Eng.	W. J. Stokes W. J. Stokes	9/23/99	PE		
Cog. Mgr.	C. C. Haass	9/23/99	QA		
QA			Safety		
Safety			Design		
Environ.			Environ.		
Other			Other		

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

S

1999 Leak Detection, Monitoring, and Mitigation Strategy Update

Phillip C. Ohl, P.E., Vista Research, Inc.
Lockheed Martin Hanford Corporation
Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 656299 UC: 2010
Org Code: 73500 Charge Code: 106493BA20 HN9A0211
B&R Code: EW3130010 Total Pages: 45

Key Words: LDMM, Leak Detection, Leak Monitoring, Leak Mitigation

Abstract: This document is a complete revision of WHC-SD-WM-ES-378, Rev 1. This update includes recent developments in Leak Detection, Leak Monitoring, and Leak Migigation technologies, as well as, recent developments in single-shell tank retrieval technologies. In addition, a single-shell tank retrieval release protection strategy is presented.

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America. To obtain copies of this document, contact: Document Control Services, P.O. Box 950, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

SEP 23 1999
DATE:
STA: 15
HANFORD RELEASE
ID: 20

Janis Aardal 9-23-99
Release Approval Date

Release Stamp

Approved For Public Release

RECORD OF REVISION	(1) Document Number HNF-SD-WM-ES-378	Page 1

(2) Title
1999 Leak Detection, Monitoring, and Mitigation Strategy Update

Change Control Record

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release (5) Cog. Engr.	(6) Cog. Mgr. Date
0	(7) Initial Report		
1	Revise "Allowable Leak" Verbage		
2 RS	Complete Document Revision ECN-656299	W.J. Stokes 9/23/99	C.C. Hughes 9/23/99

A-7320-005 (10/97)

1999 Leak Detection, Monitoring, and Mitigation Strategy Update

September 1999

Prepared for
U.S. Department of Energy
Office of River Protection

Prepared by
Lockheed Martin Hanford Corporation
with support from

VISTA RESEARCH, INC.

This page intentionally left blank

Executive Summary

This Leak Detection, Monitoring, and Mitigation Strategy Update is a complete revision to WHC-SD-WM-ES-378, Rev. 1 which was released in 1996. This revision incorporates information regarding recent developments in single-shell tank retrieval and leak detection, monitoring, and mitigation-specific engineering and technology development activities.

In addition to a summary discussion of leak detection, monitoring, and mitigation activities, an integrated single-shell tank retrieval release protection strategy is presented. The retrieval release protection strategy provides an approach with regulatory, technical, and programmatic bases that will integrate leak detection, monitoring, and mitigation with retrieval technologies and retrieval operations. The retrieval release protection strategy utilizes a cumulative single-shell tank closure source term comprised of past leaks, residual contamination, and retrieval releases to determine appropriate operational responses to detected releases during retrieval.

New concepts introduced in this revision include using a graded approach to apply increasing leak detection, monitoring, and mitigation controls to tanks with suspect integrity and higher-risk constituents. Utilizing application-specific leak detection, monitoring, and mitigation tools for specific retrieval technologies will allow integrated design efforts to optimize retrieval scenarios by minimizing releases. These application-specific leak detection, monitoring, and mitigation tools will provide quantitative information regarding retrieval releases that will allow appropriate operational response in the event of a release and quantitative defense for closure in the event of no release. Finally, by adopting consensus risk-based release response criteria through calculation of a single-shell tank closure source term leak detection, monitoring, and mitigation tools can be used to develop quantitative decision criteria and appropriate operational responses to any detected release.

The engineering and operational costs associated with retrieval of single-shell tank wastes range in the tens of millions of dollars for each tank. The engineering and operational costs associated with site remediation after a retrieval release can dwarf the waste retrieval costs. A risk-based graded approach that allows a range of operational responses to a detected release will ensure that waste retrieval operations continue where appropriate and cease before a release that could initiate a site remediation evaluation contaminates the surrounding soils.

Successful leak detection, monitoring, and mitigation during single-shell tank retrieval will make efficient use of existing River Protection Project operations and surveillance activities. Leak detection, monitoring, and mitigation activities directly support single-shell tank retrieval programs and indirectly support waste feed delivery and River Protection Project privatization goals.

Table of Contents

1.0 INTRODUCTION 1

2.0 STRATEGY DEFINITION 2
- 2.1 STRATEGY TRANSITION 3
- 2.2 BASES FOR RETRIEVAL RELEASE PROTECTION STRATEGY 3
  - 2.2.1 Regulatory Basis 5
  - 2.2.2 Technical Basis 6
  - 2.2.3 Programmatic Basis 5
- 2.3 SST CLOSURE SOURCE TERM 7
- 2.4 RELEASE RESPONSE ACTIONS 8

3.0 LDMM TECHNOLOGIES 9
- 3.1 LEAK DETECTION AND MONITORING TECHNOLOGIES 10
  - 3.1.1 Mass Balance 10
  - 3.1.2 Tracers 10
  - 3.1.3 Leak Detection Caissons (Where Existing) 11
  - 3.1.4 Electrical Resistance Tomography 11
  - 3.1.5 Volumetric Inventory Balance (Dynamic) 11
  - 3.1.6 Volumetric (Static) 11
  - 3.1.7 Post-Retrieval Soil Sampling 12
- 3.2 LEAK MITIGATION TECHNOLOGIES 12
  - 3.2.1 Auxiliary Pump 12
  - 3.2.2 Inherent Liquid Minimization 12

4.0 LDMM TECHNOLOGY PERFORMANCE 13
- 4.1 PRE-RETRIEVAL LDMM TECHNOLOGY PERFORMANCE 13
- 4.2 OPERATIONAL RETRIEVAL LDMM TECHNOLOGY PERFORMANCE 14
- 4.3 POST-RETRIEVAL LDMM TECHNOLOGY PERFORMANCE 15

5.0 LDMM PROGRAMMATIC ACTIVITIES 15

6.0 LDMM IMPLEMENTATION PLAN 17

7.0 CONCLUSIONS AND RECOMMENDATIONS 19

8.0 REFERENCES 20

Appendix

A SST Retrieval Leak Modeling and Analysis ..... A-i

Figures

1. Leak Minimization Triangle 2
2. Human Health Risk Triangle 2
3. SST Waste Retrieval, Release Response, and Tank Closure Process 4
4. Example Operational Flow Chart 17
5. Gantt Chart: LDMM Implementation Plan 18

Tables

1. Relevant Federal and State Regulations and Requirements 5
2. Example Release Response Actions 8
3. LDMM Technology Trade Study Update Summary 9
4. Leak Volumes for Various Retrieval Durations with Constant Leak Rates 13
5. Static Leak Test for Reference Conditions (Stop operations)* 14
6. Online Leak Detection Variabilities (During Operations) 15

List of Terms

DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERT	electrical resistance tomography
ILCR	incremental lifetime cancer risk
ILL	interstitial liquid level
LDMM	leak detection, monitoring and mitigation
LOW	liquid observation well
MDLR	minimum detectable leak rate
MEI	maximally exposed individual
ORP	Office of River Protection
POC	point of compliance
SIR	statistical inventory reconciliation
SST	single-shell tank

1.0 INTRODUCTION

The purpose of this document is to define a strategy for leak detection, monitoring, and mitigation (LDMM) at the Hanford Site 200 Area single-shell tanks (SSTs) that meets requirements specified in the M-45 series of milestones in the Hanford Federal Facility Agreement and Consent Order (Ecology et. al 1996). The Order is commonly referred to as the Tri-Party Agreement.

The purpose of LDMM is to ensure that SST waste retrieval:

- Minimizes hazardous waste releases to the environment
- Complies with applicable regulations and requirements
- Is technically practicable and defensible
- Meets the programmatic needs of the U.S. Department of Energy (DOE) Office of River Protection (ORP).

In 1996 a strategy was proposed that calculated an allowable leak volume based on constituents of concern and a baseline mass balance leak detection approach (WHC-SD-WM-ES-378, Rev.1). That strategy incorporated 19 criteria for establishing an allowable leak volume on a tank-by-tank basis. Once an allowable leak volume was established, operational responses to detected leaks approaching the allowable leak volume could be established.

The SST retrieval release protection strategy defined in this Revision 2 incorporates information regarding recent SST retrieval and LDMM-specific engineering and technology development. This revised strategy focuses on a graded approach of minimized retrieval releases through inherent liquid minimization retrieval technologies and in-tank volumetric leak detection capabilities. This revised strategy provides a path forward for development and design of retrieval technologies to support both Phase IB waste feed delivery and SST closure goals. This strategy will be accomplished through the use of the retrieval performance evaluation methodology described in Section 2.1, the SST closure source term described in Section 2.3 and the LDMM technologies described in Section 3.0.

This document defines the release protection strategy by explaining the transitions that brought the strategy to its current form, identifying the regulatory bases for the strategy, defining the SST closure source term that determines when which technologies and actions will be needed, and outlines planned responses to releases. The risk-based graded approach that allows a range of operational responses to a detected release and that will ensure that waste retrieval operations continue where appropriate and cease before a release that could initiate a site remediation evaluation contaminates the surrounding soils is described. The LDMM technologies and associated activities encompassed by the strategy are then addressed. Finally, conclusions and recommendations are provided.

2.0 STRATEGY DEFINITION

LDMM activities will be integrated into the development and demonstration phases of each defined retrieval technology. LDMM activities also form a cornerstone of the integrated SST retrieval release protection strategy that sets forth a mechanism for establishing retrieval release thresholds. LDMM systems combined with consensus action response criteria will ensure appropriate environmental protections during SST retrievals.

The following leak detection, leak monitoring, and leak mitigation definitions were formalized in WHC-SD-WM-ES-378, Rev. 1.

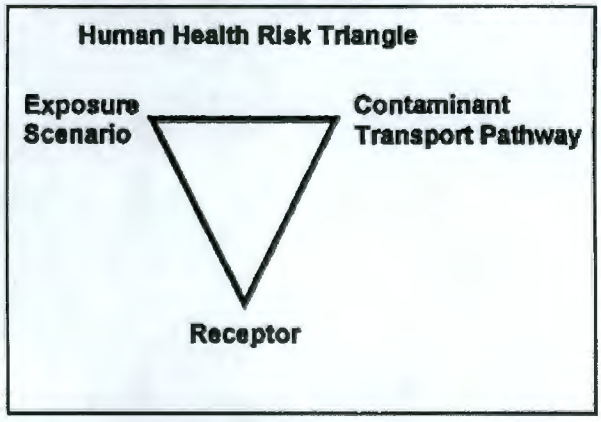
- **Leak Detection**—any method or system that can detect a leak.
- **Leak Monitoring**—any system that can map out the concentration and/or spatial extent of a contamination plume due to a release of the contaminant from a tank (or pipe).
- **Leak Mitigation**—any system that can prevent a leak during waste retrieval operations or can minimize its impact.

The primary goals in selecting and implementing a waste retrieval technology are to (1) minimize the total volume of liquid waste that would be released to the environment if a leak were to occur, and (2) minimize any potential human health risks posed by leaked waste. The triangle in Figure 1 links the three elements necessary for a release of liquid waste from a tank. If there are no leak paths in the tank (i.e., pits and cracks), then by definition there is no possibility of a leak. If however, there are one or more leak paths in the tank, the volume of liquid released can be minimized by controlling the volume of free liquid or the hydraulic head of the liquid. If any of the legs of the triangle are severed, then no leak can occur.

Figure 1. Leak Minimization Triangle

Figure 2 links the three elements required for a human health risk to occur. If any one of the three elements is not present there is no potential for human health risk. The level of human health risk posed by a release of tank waste is a function of the type and concentration of contaminants in a media (e.g., soil, groundwater, air) and the type and duration of the human exposure to the contaminated media (e.g., ingestion of contaminated groundwater).

Figure 2. Human Health Risk Triangle



In addition to the specific activities discussed in the body of this strategy document, parallel tank conditions assessments and retrieval technology developments and demonstrations will contribute to overall minimization of SST retrieval releases. This will in turn contribute to minimization of the potential for future human health risk and threat to the environment. Through leak investigations and parametric studies, tank condition assessments will aid in determining the potential for a release event and selecting the retrieval and leak detection technologies that should be deployed on a tank-by-tank basis. Retrieval technology development and deployment will aid in expanding the technologies available for deployment in support of the waste retrieval mission.

2.1 STRATEGY TRANSITION

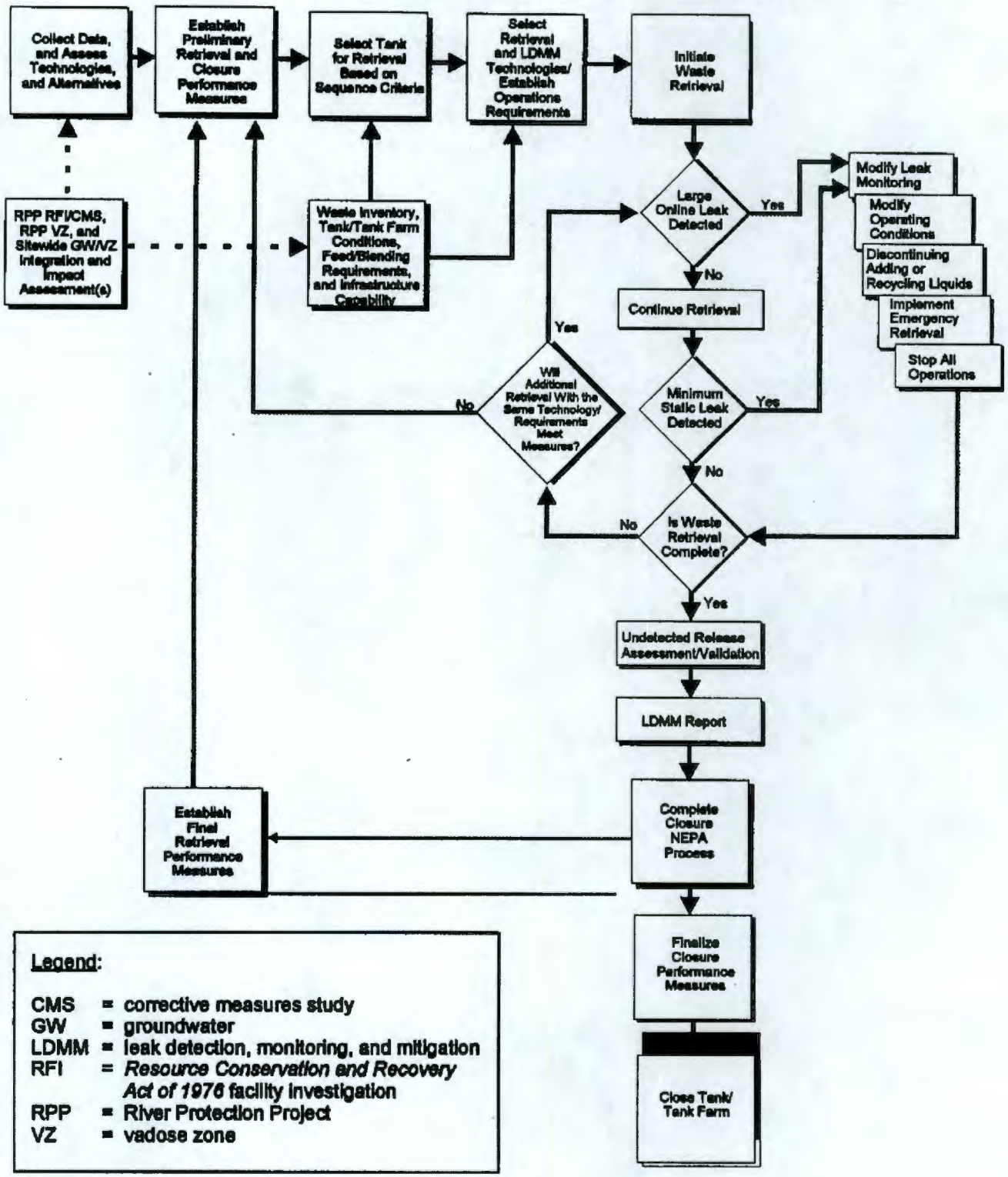
The 1996 strategy was submitted to Washington State Department of Ecology (Ecology) and stakeholders for review. The 1996 strategy proposed allowable or potential leak volumes based on constituents of concern. Ecology determined that the strategy appeared to be viable, however, the agency requested that ORP incorporate into its *Retrieval Performance Evaluation Methodology for the AX Tank Farm* (DOE/RL-98-72) a demonstration of how the strategy would be applied. Additionally, the agency requested that ORP involve Ecology, stakeholders and Tribal Nations in the development of the Retrieval Performance Evaluation.

The retrieval performance evaluation was completed in 1999 following extensive agency, stakeholder and Tribal Nation involvement. Comments received on the draft and final report from agency staff, the Vadose Zone Expert Panel, and Tribal Nations indicated wide acceptance of the methodology as a starting point for establishing tank-by-tank performance criteria for retrieval leaks. It was acknowledged in the Report that additional analysis was required before final criteria could be established for each SST. This additional analysis included evaluation of tank-specific releases within the context of the entire tank farm and other 200 Area waste sites, establishment of final closure criteria for the tank farms which would set cleanup standards for past releases and retrieval losses, and increased information on past releases, retrieval technologies, and leak detection capabilities.

2.2 BASES FOR RETRIEVAL RELEASE PROTECTION STRATEGY

The retrieval release protection strategy is founded in regulatory, technical, and programmatic bases. Regulatory bases include all of the EPA, Ecology, and DOE regulations that define retrieval and closure compliance. The technical bases include physical, chemical, and radiological parameters associated with retrieval and closure. Finally, the programmatic bases include the cost and schedule realities that come with supporting both waste feed delivery and SST retrieval goals for SST closure. Figure 3 provides a logical flow of the SST waste retrieval, release response, and tank closure process.

Figure 3. SST Waste Retrieval, Release Response, and Tank Closure Process



2.2.1 Regulatory Basis

The regulatory basis for the retrieval release protection strategy is found in federal and state regulations and DOE orders listed in Table 1.

Table 1. Relevant Federal and State Regulations and Requirements

Federal and State Regulations	Relevance
WAC 173-303	Dangerous waste regulations
WAC 173-303-640	Underground storage tank regulations
WAC 173-303-400	Interim status regulations
WAC 173-303-610	Closure requirements
WAC 173-303-646	Corrective action regulations
DOE Orders	
DOE Order 5820.2A/DOE O 435.1	Radioactive or mixed waste facility management
DOE P 450.2	Environment, safety and health requirement identification, implementation, and compliance
DOE O 440.1	Worker protection through reduction or prevention of accidental losses, injuries, and illnesses
DOE O 425.1	Nuclear facility startup and restart management
Tri-Party Agreement	
Tri-Party Agreement Milestone M-45-03	Complete SST waste retrieval demonstration
Tri-Party Agreement Milestone M-45-04	Provide initial single-shell tank retrieval system
Tri-Party Agreement Milestone M-45-08	Leak loss monitoring, mitigation, and detection requirement and capability development and implementation.
Tri-Party Agreement Milestone M-45-09	Submit annual progress reports on the development of waste tank leak monitoring/detection and mitigation activities in support of Milestone M-45-08

Interim closure requirements are established in the Tri-Party Agreement. According to Tri-Party Agreement Milestone M-45-00 closure will follow retrieval of as much tank waste as technically possible, with tank waste residues not to exceed 360 ft^3 (approximately 2,700 gal) in each of the 100-series tanks, 30 ft^3 (approximately 225 gal) in each of the 200-series tanks, or the limit of waste retrieval technology capability, whichever is less. If ORP believes that waste retrieval to these levels is not possible for a tank, then ORP will submit a detailed explanation to U.S. Environmental Protection Agency (EPA) and Ecology explaining why these levels cannot be

achieved, and specifying the quantities of waste that ORP proposes to leave in the tank. The request will be approved or disapproved by EPA and Ecology on a tank-by-tank basis (Ecology et al. 1996).

For the purposes of Milestone M-45-00 all units located within the boundary of each 200 Area tank farm will be closed in accordance with WAC 173-303-610. This includes contaminated soil and ancillary equipment that were previously designated as *Resource Conservation and Recovery Act of 1976* past-practice units. In evaluating closure options for SSTs, contaminated soil, and ancillary equipment, Ecology and EPA will consider cost, technical practicability, and potential exposure to radiation. Closure of all units within the boundary of a given tank farm will be addressed in a closure plan for the SSTs (Ecology et al. 1996).

The interrelationship of vadose zone and retrieval and closure milestones under the Tri-Party Agreement is depicted in Attachment Two to Change Control Form M-45-98-03. The attachment indicates that final requirements for retrieval of waste from SSTs, based on evaluation of long-term risks through the vadose zone and groundwater pathway, will be established following the completion of the *National Environmental Policy Act of 1969* process and following demonstration of retrieval system performance under the M-45-03 and M-45-04 series of interim and target milestones (Ecology et al. 1999). Closure options under WAC 173-303-610 as implemented in the Tri-Party Agreement and the Site Dangerous Waste Permit allow three types of closure for *Resource Conservation and Recovery Act of 1976* units:

- Clean closure
- Modified closure
- Landfill closure.

The current Site planning basis potential closure strategy is landfill closure of the tank farms. Regardless of the closure strategy, ORP must assess the potential for past leaks, retrieval releases and residual waste in tanks and ancillary equipment to migrate to groundwater at levels that (1) exceed groundwater quality standards and/or (2) pose unacceptable risks to human health (e.g., greater than 1×10^{-5} incremental lifetime cancer risk [ILCR] for contaminants that pose a cancer risk or 1.0 hazard index for noncarcinogenic contaminants based on State of Washington risk-based standards), at a designated point of compliance.

2.2.2 Technical Basis

The technical basis for the retrieval release protection strategy is rooted in the risk-based approach to retrieval and LDMM technology application. Both retrieval and LDMM technologies will be selected for specific tank conditions and waste applications. Additional technology development and demonstration efforts are planned for both retrieval and LDMM technologies. Specifically, online leak detection capabilities for large leaks combined with offline (static) leak testing capabilities for small leaks will provide a means for operational response commensurate with protection of human health and the environment. Data gathered during technology development and demonstration efforts will be utilized in development of level 1 specifications, which in turn will be incorporated into conceptual design reports for retrieval systems.

2.2.3 Programmatic Basis

There is a need to provide preliminary LDMM and release response procedures for tanks that will be retrieved to support demonstration of retrieval technologies and/or to support waste feed requirements for immobilization of high-level waste during Phase I. Therefore, a defensible interim strategy must be adopted prior to design and deployment of near-term retrieval and LDMM technologies to support meeting Waste Disposal Division waste feed requirements (i.e., delivery of SST waste supports waste feed requirements for the vitrification facility). Change Control Form M-45-98-03 acknowledges that a final risk-based release limit cannot be established for SSTs until following completion of the *National Environmental Policy Act of 1969* closure process. However, waste retrieval to satisfy the M-45-03 and M-45-04 milestones need to include LDMM and leak response procedures for those tanks retrieved prior to completing that closure process. Justification for LDMM and leak response procedures for these milestones may need to include an estimate of the long-term impacts that could result if these tanks leak during retrieval (HNF-2944).

2.3 SST CLOSURE SOURCE TERM

The source term associated with SST closure that will be used to establish tank-by-tank LDMM requirements will be comprised of three components:

Past Leaks
Residual Contamination
\+ Retrieval Releases
= SST Closure Source Term

The source term can be expressed in units of volume, concentration, or maximally exposed individual-incremental lifetime cancer risk (MEI-ILCR) (i.e., a criteria used to represent potential threat to human health by a retrieval leakage loss) depending on context. Regardless of the units, a source term is only relevant when accompanied with reference to the point of compliance (POC).

Past leak volumes are estimated in the monthly waste tank summary report (HNF-EP-0182-133). The basis for these leak volumes is discussed in detail in the SST leak history compilation (HNF-4872). The volumes and constituents associated with current past leak estimates may be the largest single component to the source term calculation.

Residual contamination will be the volume of waste left in an SST once retrieval is complete. The interim goal for this volume is currently required to be less than 360 ft^3 (approximately 2,700 gal) for 100-series tanks and less than 30 ft^3 (approximately 225 gal) for 200-series tanks. Residual contamination capabilities will be established during the retrieval technology development and demonstration activities. Retrieval technologies will be developed for specific tank conditions (e.g., leaker, catastrophic, sound) and retrieval applications (e.g., sludge, salt cake, supernate).

Retrieval releases will be controlled by the LDMM capabilities associated with the specific retrieval technology, tank condition, and retrieval application. Similar to retrieval technologies, LDMM capabilities will be established during the LDMM technology development and demonstration activities that will be integrated with the retrieval technology development and demonstration activities.

2.4 RELEASE RESPONSE ACTIONS

A graded approach to retrieval release response actions will be based on a projected source term using available characterization data for in-tank waste, vadose characterization data for past leaks, residual contamination estimates from retrieval technology selection activities, and minimum detectable leak projections. Prior to initiating SST retrieval, retrieval release response criteria must be established. Because the retrieval release protection strategy focuses on the MEI-ILCR at POC as a means of establishing graded response actions, the retrieval contribution to the overall source term must be clearly understood to affect retrieval operations.

In the event a release is detected, a total projected release will be calculated based on the detected release rate and the estimated remaining retrieval time. This projected release volume will then be included in the closure source term calculation, a calculation of the potential MEI ICLR will be completed, and an appropriate operations response will be initiated based on the MEI-ILCR at the POC. For tanks where the past leaks and residual contamination will exceed the established MEI-ILCR at POC criteria, tank-specific operational responses will have to be negotiated using a similar methodology following a tank-specific closure evaluation.

The values and operational responses in Table 2 are presented as an example of a graded approach to release response actions for a nonspecified SST. To properly fill out a tank-specific retrieval release response table, the MEI-ILCR must be calculated at the regulator-accepted POC and the operational response criteria must be also be accepted by the regulators. Once the POC and operational response criteria have been negotiated, the total source term associated with an MEI-ILCR at POC can be calculated and leak detection technologies that provide appropriate resolution can be deployed.

Table 2. Example Release Response Actions

Example Past Leak (gal)	Example Residual Contamination (gal)	Example Projected Retrieval Release (gal)	Example Projected Total Source Term (gal)	Example Projected MEI-ILCR at POC	Example Operational Response
8,000	2,000	0	10,000	$<10^{-7}$	Continue Retrieval
8,000	2,000	2,000	12,000	10^{-7} to 10^{-5}	Orderly Retrieval Shutdown – Alternate Retrieval Technology
8,000	2,000	8,000	18,000	10^{-5} to 10^{-4}	Emergency Shutdown – Alternate Retrieval Technology
8,000	2,000	20,000	30,000	$>10^{-4}$	Emergency Shutdown – Site Closure Re-evaluation

MEI-ILCR = maximally exposed individual – incremental lifetime cancer risk
POC = point of compliance

3.0 LDMM TECHNOLOGIES

Table 3 is taken directly from *LDMM Technology Trade Study Update* (HNF-SD-WM-ES-379). This report includes reviews of 15 LDMM technologies and makes recommendations for continuing development and demonstration with 10 of them. The core conclusions of HNF-SD-WM-ES-379 are that LDMM technologies should be selected for specific retrieval technologies and retrieval applications and that nationally recognized methodologies for quantified performance of leak detection systems should be applied.

Table 3. LDMM Technology Trade Study Update Summary

Retrieval Method	Technology		
	Leak Detection	Leak Monitoring	Leak Mitigation
No Action†	None	None	None
Enhanced Sluice	Volumetric	Post-Retrieval Soil Sample	Inherent Liquid Minimization
Low Flow Sluice	Volumetric	ERT	Auxiliary Pump
Confined Sluice	Volumetric	ERT	Auxiliary Pump
Mechanical Retrieval‡	None	Post-Retrieval Soil Sample	None
LVDG (Sprinkler) Dissolution	Volumetric	Post-Retrieval Soil Sample	Inherent Liquid Minimization

Source: HNF-SD-WM-ES-379, 1998, *LDMM Technology Trade Study Update*, Rev. 1, Vista Research, Inc., for Lockheed Martin Hanford Corporation, Richland, Washington.

† **No Action Retrieval** implies tanks that are ready for direct closure (i.e., tanks that contain very little residual waste due to previous sluicing or operational campaigns). For these cases, additional leak detection, leak monitoring, and leak mitigation while the tanks await closure are not necessary.

‡ **Mechanical Retrieval** implies a dry or nearly-dry retrieval process with no liquids to detect or leaks to mitigate. It may be appropriate to sample the surrounding soils after the retrieval is complete if leaching from an external liquid source (e.g., rain water) is suspected.

ERT = electrical resistance tomography.

LVDG = low volume density gradient (sprinkler).

The approach to overall release minimization is to first prevent releases by designing retrieval technologies with release mitigation parameters. The second line of defense in overall release minimization is to detect very small releases and estimate the projected source term associated with a particular release rate and the time to complete the retrieval. The final emphasis in overall release minimization is release monitoring. The underlying release monitoring philosophy is to only deploy release monitoring technologies if a release is actually detected or if the tank conditions are such that a release is expected based on previous leak history.

3.1 LEAK DETECTION AND MONITORING TECHNOLOGIES

The leak detection and monitoring technologies recommended for further consideration in HNF-SD-WM-ES-379 are:

- Mass balance
- Tracers
- Leak detection caissons (where existing)
- Electrical resistance tomography (ERT)
- Volumetric inventory balance (dynamic)
- Volumetric (static)
- Post-retrieval soil sampling

Two additional systems suggested for inclusion in the next technology update are 3-D laser or ramen tomography surface mapping and precision differential pressure cells deployed at the bottom of the tank.

3.1.1 Mass Balance

Mass balance techniques utilize both retrieval tank and receiver tank level indication such as ENRAFs™ [1], FICs™ [2], and in-tank video combined with characterization data to convert volume data to mass data. The mass data is then run through a simple algorithm to compare how much sluice material (by weight) went into the retrieval tank and how much waste material (by weight) came out of the retrieval tank. The errors associated with converting volume data to mass data make this technique only applicable to large leaks. In addition, this technique is limited to static measurements that require operational shutdown.

3.1.2 Tracers

Tracers are used extensively in the petroleum industry to detect and locate small leaks in underground storage tanks and transfer piping. The utility of tracers for leak detection in SSTs during retrieval is limited by the ability to sample the surrounding soils both spatially and temporally. The use of partitioning tracers such as difluoromethane and perfluoroacetone for leak detection provide excellent confirmation of a leak when the tracer is detected (Gauglitz 1999). However, missed detections (it is difficult to quantify a nondetection as a nonrelease) and deployment of sufficient injection and extraction wells are both issues.

Regardless of leak detection applications, unique tracers have a significant application in leak monitoring. By inoculating sluice water with unique tracers, contaminate plumes from SST retrieval can be tracked with improved certainty over current leak monitoring and vadose characterization where multiple tank and pipe leaks overlap.

[1] ENRAF is a registered trademark of Enraf, Inc, of Houston, Texas. Some Hanford Site SSTs (and double-shell tanks) utilize the Enraf 854 Servo Level Gauge for level indication.

[2] FIC is registered trademark of Food Instrument Corporation (no longer in business) level gauges that were installed in SSTs and double-shell tanks with liquid surfaces in the 1960s. Many FICs have been replaced with the more accurate and more reliable ENRAFs™.

3.1.3 Leak Detection Caissons (Where Existing)

Leak detection laterals and caissons are currently installed under the four tanks in the AX tank farm. Conductivity probes and radiation probes can provide an excellent confirmation of in-tank leak detection data. The utility of installing new leak detection laterals and caissons will depend largely upon improved methods for installing laterals. It should be noted that of the four leak detection caissons in the AX tank farm, only one is currently functional.

3.1.4 Electrical Resistance Tomography

ERT continues to be the most promising external leak detection and leak monitoring technology. This technology is based on the physical principle that conductive solutions will reduce the resistivity between two electrodes. A tomograph of soil resistivity can detect changes that are indicative of waste leaks during retrieval. The use of ERT is complicated by deployment of electrodes around the tank and the network(s) of waste transfer, raw water, and ventilation piping. Recent advances in ERT that utilize the tank structure as an electrode may improve the resolution of the system(s) that were tested in 1996.

3.1.5 Volumetric Inventory Balance (Dynamic)

The volumetric inventory balance method utilizes level instruments in the retrieval and receiver tanks along with flow meters to continuously balance the flow in and flow out of the retrieval tank. This method is similar to statistical inventory reconciliation (SIR) employed by the petroleum industry in distributions systems like gas stations. In petroleum systems, SIR techniques are able to detect releases comparable to static systems (i.e., on the order of 0.1 to 10 gal/hr). It is important to note that this technique has not been evaluated for SSTs and the complexities of waste solubility and evaporation combined with the scale difference between a local gas station tank and a 75-ft-diameter SST are significant. The advantage of this technology is that it provides a continuos online measurement. This technique may be sensitive to operational changes in the ventilation system during retrieval.

3.1.6 Volumetric (Static)

Volumetric methods utilize a static liquid surface to determine whether a the tank has an inflow, an outflow, or a constant level. Level instrumentation such as ENRAF™ and FIC™ gauges are currently used in SSTs with a continuous liquid surface. Neutron and gamma probes in liquid observation wells (LOWs) are currently used in SSTs with interstitial liquid levels (ILLs). For retrieval of salt cake and permeable sludge wastes where a supernate liquid level or ILL may be present, volumetric methods can provide accurate, reliable leak detection. For retrieval of impermeable sludge wastes, volumetric methods may not be applicable. Initial studies in *SST Sluicing History and Failure Frequency* (HNF-3018) indicate that releases on the order of 5 gal/hr are detectable using this technology.

3.1.7 Post-Retrieval Soil Sampling

Post-retrieval soil sampling technology simply applies standard soil sampling techniques to leak monitoring only if a leak is detected. The basic approach with this technique is to not deploy leak monitoring technologies if no release is detected. Post-retrieval soil sampling is a contingency technology to be used on SSTs that are not expected to leak.

3.2 LEAK MITIGATION TECHNOLOGIES

The leak mitigation technologies recommended for further consideration in HNF-SD-WM-ES-379 are:

- Auxiliary pump
- Inherent liquid minimization

Both of these technologies essentially minimize the "free" leakable liquid in a SST during retrieval either via a separate pump near the bottom of the tank or via a retrieval technology that removes liquid from the bottom directly.

3.2.1 Auxiliary Pump

Advances in self-priming pump technology have provided another means of responding to a leak that occurs during waste retrieval operations. Any free liquids (i.e., those that can leak out of the tank) are pumped directly to the waste receiver facility. Continuous self-priming bottom suction trash pumps, commonly referred to simply as "trash pumps" in petroleum sludge applications, provide enough pressure differential to prime the impellers continuously. This allows waste from the bottom of the tank to be continuously pumped to the waste receiver facility without allowing collection of free (leakable) liquids in the bottom of the tank. If the interstitial liquids are continuously pumped out of the tank; then the risk of a catastrophic[3] leak is minimized.

A novel application of a robust trash pump within the context of the waste retrieval operations would be to auger, lance, or push a trash pump to the bottom of an SST and then pump out any free interstitial liquids that have accumulated there. During the actual retrieval (whether by enhanced sluicing, low-flow sluicing, confined sluicing, or low volume density gradient (dissolution methods), the pump should be run at a flow rate 10% to 20% greater than that of the sluicing or dissolution water being added to the tank. In the event that a leak were to be detected, the flow of water to the tank would be stopped and the pump would continue to remove any free liquids. This scenario would require deployment of the trash pump as an auxiliary pump for low-flow sluicing and confined sluicing where the primary waste conveyance may occur at the top of the sludge or salt cake.

3.2.2 Inherent Liquid Minimization

Inherent liquid minimization technology provides a continuous removal of free (leakable) liquids from the SST during retrieval similar to that provided by use of auxiliary pumps. In cases of

[3] A "catastrophic" leak is defined in HNF-3018 as a leak greater than 50,000 gal.

enhanced sluicing with large flows (approximately 300 gal/min) an appropriately sized, continuous, self-priming bottom-suction trash pump would be used to provide the primary waste conveyance. In cases of low volume density gradient dissolution, an appropriately sized jet pump would be used to provide the primary waste conveyance. Both of these systems minimize free (leakable) liquids in the tank during retrieval. By minimizing free liquids, the response to a detected leak is to simply stop the sluicing operations and continue to pump until all of the free liquids have been removed.

4.0 LDMM TECHNOLOGY PERFORMANCE

Table 4 provides leak volumes for various leak rates and retrieval durations.

Table 4. Leak Volumes for Various Retrieval Durations with Constant Leak Rates

Leak Rate (gal/hr)	1 wk (gal)	2 wk (gal)	4 wk (gal)	6 wk (gal)	12 wk (gal)	6 mo (gal)
0.5	84	168	336	504	1,008	2,016
1.0	168	336	672	1,008	2,016	4,032
2.0	336	672	1,344	2,016	4,032	8,064
5.0	840	1,680	3,360	5,040	10,080	20,160
10.0	1,680	3,360	6,720	10,080	20,160	40,320
50.0	8,400	16,800	33,600	50,400	100,800	201,600

Effective retrieval durations are expected to range from three weeks to six months. It should be noted that unreviewed safety questions and other operational impacts could create six-month to one-year work stoppages that could significantly increase the overall retrieval time for any particular tank.

4.1 PRE-RETRIEVAL LDMM TECHNOLOGY PERFORMANCE

This pre-retrieval LDMM technology assessment will comprise an operational history review for evidence of leaks and a review of existing leak detection, dry well, and Tank Farm Vadose Zone Project data. For tanks with active instrumentation (e.g., non-stabilized SSTs with ENRAF™ and FIC™ gauges) and for stabilized SSTs with active ILL monitoring systems, candidate SSTs can be leak-tested using the existing tank farm surveillance and monitoring programs and the tank leak assessment process (HNF-SD-WM-PROD-021, HNF-3747). This pre-retrieval LDMM technology assessment will provide a baseline calibration of LDMM capabilities.

Tank-specific leak tests can also be designed using the methodologies presented in HNF-3018. In that report, uncompensated minimum detectable leak rates (MDLRs) using existing static level data were shown to be on the order of 0.5 to 5 gal/hr.

4.2 OPERATIONAL RETRIEVAL LDMM TECHNOLOGY PERFORMANCE

LDMM technology performance during operations will largely be dependent upon the retrieval technologies selected for the specific retrieval application and candidate SST. LDMM performance-assessment activities are currently underway to determine minimum detectable leaks using the methodologies presented in HNF-3018 with compensated data (e.g., temperature, barometric pressure). Similarly, assessment activities are underway to determine likely leak rates for a variety of tank leak scenarios. Appendix A contains excerpts from a technical report that describes the process for quantifying the performance of a leak test methodology (F029-99-02).

Table 5 shows some example leak test performance results based on test durations. This table illustrates the relationship between test duration and performance. This relationship is also dependent upon compensation of parameters such as temperature and barometric pressure.

Table 5. Static Leak Test for Reference Conditions (Stop operations)*

Duration (hrs)	MDLR (gal/hr)
8	15
24	8
48	5

***MDLR examples are included for scoping purposes only. Tank-specific calculations must be performed prior to initiating retrieval.**
MDLR = minimum detectable leak rate.

It is critical to note that minimum detectable leak rate results are a performance measurement of the test (typically set at 95% probability of detection and 5% probability of false alarm [40 CFR 280, ORNL/ER/Sub/92-SK263/1, 2050-91-FR-002]). The MDLR should not be confused with the smallest possible leak detected, nor should a conclusion be made that the MDLR is the maximum leak not detected. The current baseline mass balance technique requires a 24-hour test duration and can detect 8,000-gal variances, or 330 gal/hr (WHC-SD-WM-ES-379). This 24-hour test should not be confused with current operational requirements in the Basis for Interim Operation for leak detection during waste transfers (HNF-SD-WM-BIO-001).

Table 6 shows the sum of potential errors for online leak detection during a sluicing campaign. An engineering estimate of the total error can be made by summing the squares of the individual errors (variance) and taking the square root, a one standard deviation estimate of approximately 40 gal/hr or a 95% MDLR of approximately 80 gal/hr can be achieved. Similar to the static leak test information given in Table 4, these online MDLR examples are included for scoping purposes only. Tank-specific calculations must be performed prior to initiating retrieval.

Table 6. Online Leak Detection Variabilities (During Operations)

Source	Nominal Rate (gal/hr)	Error (gal/hr)
Sluice In	300	3
Pump Out	300	3
Evaporation	20	20
Solubility	30	30
Temperature	0	1
Level Measurement	0	10

Processing this information with SIR techniques, may improve the total error by a full order of magnitude which would yield an on-line MDLR on the order of 8 gal/hr. All of this remains to be demonstrated through empirical data on tank systems similar in scale to the SSTs.

4.3 POST-RETRIEVAL LDMM TECHNOLOGY PERFORMANCE

When a retrieval has been declared complete, an evaluation of the closure source term must be performed. If it can be shown through the leak detection data that a tank did not leak during the retrieval campaign, then no post-retrieval LDMM activities are necessary (i.e., the tank can either be closed or site remediation evaluations can be performed to determine if past leaks may hinder direct closure). However, if a tank is shown to leak during retrieval, then post-retrieval soil sampling may be necessary to accurately characterize the nature, location, and mobility of the contamination plume. To aid post-retrieval soil sampling, unique chemical tracers may be useful in the sluice water used for hydraulic retrievals. Unique chemical tracers that would not interfere with downstream treatments could significantly reduce uncertainty in plume origins and leak monitoring.

5.0 LDMM PROGRAMMATIC ACTIVITIES

LDMM activities will continue to evolve in support of TPA Milestones M-45-08 and M-45-09. Leak detection evaluations planned for fiscal year 2000 are centered around compilation of leak detection approaches using both in-tank and out-of-tank equipment. The following formal definitions are used for discussion of LDMM technology development:

Retrieval application—Physical, chemical, and radiological characteristics of the type of waste to be retrieved (e.g., sludge, supernate, salt cake)

Retrieval configuration—Hardware associated with the retrieval (e.g., confined sluicer, salt cake dissolution, dry retrieval)

LDMM configuration—Hardware associated with leak detection, monitoring, and mitigation during retrieval.

Once in-tank and out-of-tank approaches have been compiled and the sensitivities assessed, strategies for operation and deployment of the various systems will be developed according to application-specific tank configurations. Finally, required technology developments and demonstration needs will be identified for incorporation into retrieval system demonstration testing.

All of the work prepared in support of LDMM activities in fiscal 2000 will be documented in an annual report and submitted to a retrieval decision board for authorization to proceed. Once the candidate LDMM configurations have been identified and fully integrated with candidate retrieval configurations, the bulk of the LDMM activities will be performed under direction and planning of the individual retrieval technologies.

LDMM activities will focus on the development of LDMM configurations for specific retrieval configurations and applications. Once the LDMM configurations are defined, specific LDMM technology development and LDMM technology cold testing will be performed with the individual retrieval configurations and applications.

The first step toward identification of LDMM configurations is to make an initial listing of feasible LDMM approaches based on available information today. The initial listing will rely heavily on the latest revision of the LDMM technology alternative generation analysis and the latest revision of the LDMM strategy document.

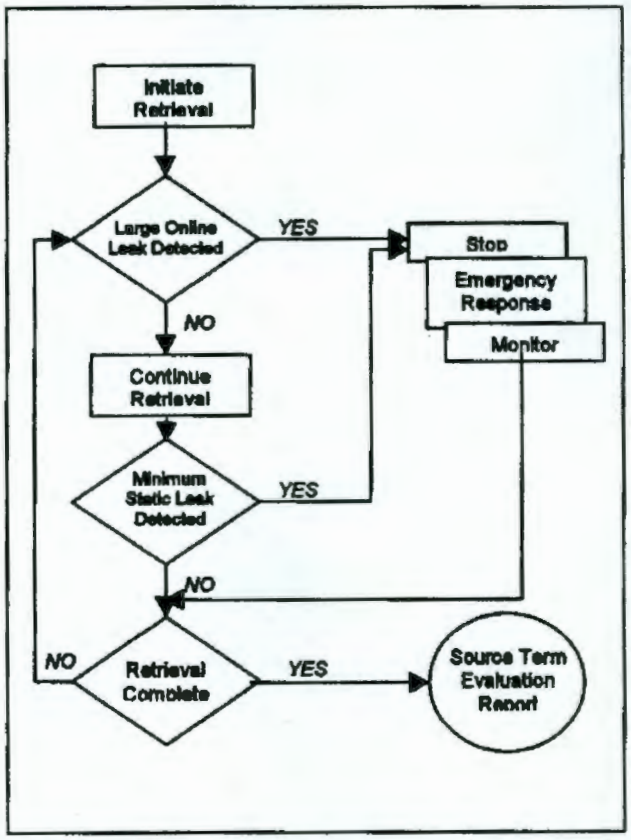
Following compilation of LDMM configurations, in-tank and ex-tank equipment sensitivity analyses will be performed to screen the feasibility of using specific LDMM in-tank and ex-tank configurations for use with specific retrieval configurations and applications. The in-tank and ex-tank equipment sensitivity analyses will include a review of potential performance, cost, and integration of in-tank LDMM hardware with structural hardware.

Once the leak detection approaches have been compiled and the in-tank/ex-tank sensitivity analyses have been performed, operational strategies must be developed. Operational strategies will include details such as required static monitoring, frequencies, operational checks, and automated alarms and interlocks. Similar to development of operational strategies, each LDMM system will require a strategy for deployment. The strategy for deployment will include such details as use of new or existing equipment and project integration for procurement and installation of any necessary hardware and instrumentation.

Figure 4 shows an example operational strategy for incorporation of LDMM activities into the operational decision process. Retrieval will continue unless a large leak is detected via online leak detection systems or a small leak is detection via static leak detection systems. In either case, a source term evaluation must be made at the end of retrieval to determine the impacts of a retrieval release. In the case where retrieval is stopped due to a detected release, the entire process is reinitiated with an alternate retrieval technology.

Once the processes for operation and deployment have been developed, an LDMM system configuration can be specified for each retrieval system configuration and application.

Figure 4. Example Operational LDMM Strategy



The LDMM system configurations should specify engineering principles of the measurement and detection system as well as necessary instrumentation to make the measurements and analyze the data. Initially, LDMM system configurations will be specified for the following retrieval systems currently planned for evaluation under the SST Waste Retrieval Project:

- Salt cake dissolution
- Confined sluicing
- Salt cake/sludge
- Dry
- Congested and limited access
- MUST

Once the LDMM system configurations have been specified, technology development gaps and technology demonstrations can be specified. Once this is complete, candidate LDMM configurations will become fully integrated with candidate configurations for specific retrieval applications.

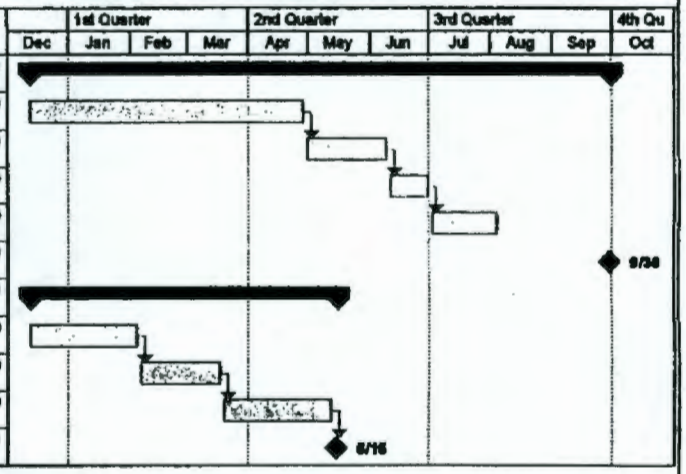
Finally, an annual update of LDMM activities will be prepared as a convenient method to track and ensure completion of TPA milestone M-45-09. The strategy document (WHC-SD-WM-ES-378) requires formal revision every two to three years to incorporate evolving technologies and strategies into the LDMM baseline.

6.0 LDMM IMPLEMENTATION PLAN

Figure 5 shows a Level 2 (Quarterly) schedule of planned activities for LDMM implementation in fiscal year 2000 with LDMM activities being fully integrated with specific retrieval technologies. For detail planning purposes, readers are referred to the FY 2000 Multi Year Work Plan.

Figure 6. LDMM Implementation Schedule

ID	Task Name	Start	Finish
1	LDMM Activities	Mon 12/13/99	Sat 9/30/00
2	Compile Technology and Field Data	Mon 12/13/99	Fri 4/28/00
3	Prepare Technology/Data Report	Mon 5/1/00	Fri 6/9/00
4	Issue Technology Data/Report	Mon 6/12/00	Fri 6/30/00
5	Leak Detection Technology Briefing	Mon 7/3/00	Fri 8/4/00
6	TPA M-45-09-E Milestone	Sat 9/30/00	Sat 9/30/00
7	Assess Tank Conditions	Mon 12/13/99	Mon 5/15/00
8	Prepare SOWs for Tank Condition Assessments	Mon 12/13/99	Fri 2/4/00
9	Perform Tank Condition Assessments	Mon 2/7/00	Fri 3/17/00
10	Prepare Tank Condition Assessment Report	Mon 3/20/00	Fri 5/12/00
11	Issue Tank Condition Assessment Report	Mon 5/15/00	Mon 5/15/00



Project: LDMM Implementation
Date: Wed 9/22/99

Task | Split | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Split | Rolled Up Milestone | Rolled Up Progress | External Tasks | Project Summary

Page 1

7.0 CONCLUSIONS AND RECOMMENDATIONS

The integrated waste retrieval release protection strategy described in this revision provides a sound path forward with appropriate regulatory, technical, and programmatic bases, specific conclusions and recommendations identified in the process of developing this strategy are included below.

The following are identified conclusions.

- LDMM activities should be fully integrated with SST retrieval technologies to provide appropriate LDMM capabilities. There is no one LDMM solution for all possible combinations of SST retrieval technologies. Retrieval technologies and LDMM technologies should be matched according to waste application (i.e., salt cake, sludge, supernate) and tank integrity (i.e., sound, suspect, catastrophic leaker).

- Both on-line and static leak detection systems are necessary to allow reasonable operational durations between scheduled leak tests.

- LDMM technologies are sufficiently mature to proceed with LDMM selection for supernate, salt cake and permeable sludge retrieval technologies and applications, however, there is much technology development work necessary prior to proceeding with LDMM design. The current leak detection systems for salt cake and permeable sludge appear to be inadequate for use with impermeable sludge wastes.

- Leak mitigation should be inherent in the successful retrieval technology design and implementation.

The following are identified recommendations.

1. Develop empirical performance data for both MDLR and fluid dynamics models for a variety of SST retrieval scenarios.

2. Fabricate a test facility for LDMM validations to validate MDLR and fluid dynamic models and optimize inherent leak minimization characteristics of retrieval technologies.

3. Design and test online volumetric balance techniques for use with all hydraulic retrieval technologies.

4. Develop LDMM applications for use on impermeable sludge wastes. Determine how many SSTs may be affected by impermeable sludge.

8.0 REFERENCES

2050-91-FR-002, 1991, *Evaluation of the ORNL/LT-823DP Differential Pressure Leak Detection Method*, Martin Marietta Energy Systems Purchase Order No. 41X-SH136V, Vista Research, Inc., Mountain View, California.

40 CFR 280, "Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks," *Code of Federal Regulations*, as amended.

DOE/RL-98-72, 1999, *Retrieval Performance Evaluation Methodology for the AX Tank Farm*, Rev. 0, Jacobs Engineering Group Inc for U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, EPA, and DOE, 1996, *Hanford Federal Facility Agreement and Consent Order*, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

F029-99-02, 1999, *SST Retrieval Leak Modeling and Analysis*, Vista Research, Inc., Richland, Washington.

Gauglitz, P. A., et. al., 1999, *Partitioning Tracers for Leak Detection During Waste Retrieval Operations*, Proposal to Environmental Management Science Program, Pacific Northwest National Laboratory, Richland, Washington.

HNF-2944, 1998, *Single-Shell Tank Retrieval Program Mission Analysis Report*, Rev. 0, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-3018, 1998, *SST Sluicing History and Failure Frequency*, Rev. 0, Vista Research, Inc. for Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-3747, 1998, *Tank Leak Assessment Process: Technical Background*, Rev. 0, Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-4872, 1999, *Single-Shell Tank Leak History Compilation*, Rev. 0, Vista Research, Inc. for Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-EP-0182-133, 1999, *Waste Tank Summary Report for Month Ending April 30, 1999*, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-SD-WM-BIO-001, 1997, *Tank Waste Remediation System Basis for Interim Operation*, Rev. 0, Lockheed Martin Hanford Company, Richland, Washington.

HNF-SD-WM-ES-379, 1998, *LDMM Technology Trade Study Update*, Rev. 1, Vista Research, Inc. for Lockheed Martin Hanford Corporation, Richland, Washington.

HNF-SD-WM-PROC-021, 1999, *Tank Leak Assessment Process*, Section 26.1, Rev. 2A, Lockheed Martin Hanford Corporation, Richland, Washington.

National Environmental Policy Act of 1969, Public Law 91-190, 42 USC 4321 et seq., as amended

ORNL/ER/Sub/92-SK236/1, 1994, *Leak Testing Plan for the Oak Ridge National Laboratory Liquid Low-Level Waste System (Active Tanks)*, Rev. 2, prepared by Vista Research, Inc., for the Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Resource Conservation and Recovery Act of 1976, Public Law 94-580, 90 Stat. 2795, 42 USC 901 et seq.

WAC 173-303, "Dangerous Waste Regulations," *Washington Administrative Code*, as amended.

WHC-SD-WM-ES-378, 1996, *Proposed Strategy for Leak Detection, Monitoring, and Mitigation During Hanford Single-Shell Tank Waste Retrieval*, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-ES-379, 1996, *Trade Study of Leakage Detection, Monitoring, and Mitigation Technologies to Support Hanford Single-Shell Tank Waste Retrieval*, Rev. 0, Foster Wheeler Environmental Corporation for Westinghouse Hanford Company, Richland, Washington.

This page intentionally left blank

Appendix A

SST Retrieval Leak Modeling and Analysis

(Reprinted from Vista Research Technical Memorandum F029-99-02, Excerpts Only)

SST Retrieval Leak Modeling and Analysis

Dennis G. Douglas, Phillip C. Ohl, Joseph W. Maresca, Jr. and James L. Nelson

Vista Research, Inc.
20 August 1999

(Technical Memorandum F029-99-02, Excerpts Only)

Modern tank leak testing began with efforts in the late 1980s made by the US Environmental Protection Agency (EPA) to reduce the releases from underground storage tanks containing petroleum and other hazardous chemicals. The EPA prepared and released a regulation[4], requiring the owners and operators of underground storage tanks (USTs) to undertake measures to detect and mitigate leaks from their tanks. The main thrust of the release detection portion of the EPA regulation was (and continues to be) to require the owners and operators of USTs to test their tanks for liquid integrity regularly and frequently, to follow a formal test protocol, and to use a *test method* whose *performance* has been determined to meet a specified standard. The EPA requires that volumetric methods used for monthly testing (the most common type and test frequency) must be evaluated and shown to detect a release of no greater than 0.2 gal/h, with a *probability of detection* (P_D) of at least 95% and a *probability of false alarm* (P_{FA}) of no more than 5%.

It is noted that in the Preamble of the UST Regulation, the EPA deferred regulation of tanks containing radioactive wastes. It did not exempt these tanks from regulation. A deferral was granted because the EPA tentatively accepted, but was unable to verify, Nuclear Regulatory Commission testimony during the comment period that erroneously advised EPA that leak testing such as proposed in 40 CFR 280 was already being done at DOE sites. Since the testimony was not confirmed, EPA simply deferred the tanks from regulation until further information could be obtained. By comparing the testing requirements imposed on the owners and operators of gas stations with those imposed on DOE-owned tanks containing substances that are potentially far more hazardous than gasoline, it is clear that the EPA would have included the DOE tanks in the UST regulation, had they been fully aware of the facts.

In the early 1990s, the Oak Ridge National Laboratory (ORNL) entered into a Federal Facilities Agreement between the DOE, the EPA, and the State of Tennessee[5]. A part of this FFA required leak testing of ORNL's single-shelled low-level radioactive waste tanks. In response to the FFA, ORNL adopted the essential leak testing requirements of the EPA's UST regulation; specifically the monthly testing program, the P_D and P_{FA} performance requirements, and a release criterion based upon available technology. In 1992, ORNL began a site-wide leak testing program for the

[4] U. S. Environmental Protection Agency, "Underground Storage Tanks: Technical Requirements, Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks", 40 CFR 280, *Federal Register*, Vol. 53, No. 185 (23 September 1988).

[5] "Federal Facilities Agreement Plans and Schedules for Liquid Low-Level Radioactive Waste Tank Systems at Oak Ridge National Laboratory, Oak Ridge, Tennessee", Report No. ES/ER-17&D1, prepared by the Waste Management and Remedial Action Division, Martin Marietta Energy Systems, Inc., Contract No. DE-AC05-84OR21400, Oak Ridge, Tennessee (March 1992).

singly contained tanks, together with a formal reporting program and annual structural integrity updates for the tanks.

Although there were many liquid integrity approaches available to ORNL, they selected a program that was rooted in the benefits afforded by the EPA regulations. ORNL also selected a volumetric method, based upon an existing level sensor in the tanks. This method measures the liquid surface level in the tank over time and, after compensating for known effects, compares the measured *volume rate* to a *threshold* value that had been previously determined. Test result reports are generated automatically and reported to site personnel.

An approach similar to ORNL's will be adopted by Hanford, and applied to the single shell tanks with measurable quantities of liquid to support the retrieval operations for those tanks. Following the previous DOE experience in this area, it is expected that Hanford's program will first establish a workable leak criterion based upon the existing (or needed) sensors in the tanks, and then apply that criterion during regular tests of the tanks while they are being retrieved. This is discussed below.

Leak Testing Program Approach

To the extent that a loss of liquid integrity of the tank would be signaled by a decrease in liquid volume in the tank, the volume rate data measured by a level sensor in the tank can be used to assess the integrity of the tank, after certain baseline measurements are made, and after the raw data is adjusted for known influences. The liquid integrity assessment method is described in detail below but in essence is comprised of forming estimates of the volume rate in the tank and comparing the measured value to a *threshold* value that has been previously determined. A tank whose volume rate exceeds the threshold (and where the exceedance has been validated) is deemed to have *failed* the test and may be leaking. A tank whose volume rate does not exceed the threshold is deemed to have *passed* the test and is deemed "tight" and non-leaking. The River Protection Program will adopt a similar approach to assess the integrity of the tanks during retrieval.

A liquid level sensor installed in a tank can measure the apparent volume in the tank, and the apparent volume changes over time (i.e., volume rate.) But since every measurement has noise or uncertainty associated with it, these measurements may or may not be the same as the true volume or volume rate. This depends on the calibration of the sensor in terms of its accuracy and precision, and whether or not the measurements are influenced by external factors. For example, at Hanford it is known that the measured level in some of the tanks varies with changes in the barometric pressure. These level changes are thought to occur as a result of gas bubbles entrained in the tank liquids and sludge that expand and contract as the barometric pressure decreases and increases, thus changing the apparent volume in the tank. Provided that these external influences are small or can be compensated, and provided that a leak in a tank will be evidenced by a liquid volume change, a volumetric method can be used to assess the liquid integrity of the tank over time.

A leak test or liquid integrity assessment requires that a two-phased program be established and carried out. First, a baseline set of data needs to be collected and used to establish a release

threshold value. Unless otherwise noted, the baseline analysis assumes that the tank being evaluated is tight and non-leaking when the threshold value is established. In the baseline program, the variability of the data is measured and operational and environmental factors that can influence the data are examined and quantified. Deterministic factors, such as temperature or barometric pressure influences on the volume data are used to *compensate* the data, where such compensation is feasible. Operational factors, such as calibration adjustments and equipment maintenance are identified in the data so that the effects produced by these operations can be accommodated in the analysis. Thus, in the first phase, the compensated "noise" of the system is established and used to estimate a noise histogram for that particular tank. From the noise data, a threshold value can be determined that will allow detection of a specified leak rate[6], at selected values of P_D and P_{FA}[7]. Also in this phase, the details of the test program are worked out, including the data sample frequency and the duration of each test record, the frequency of the tests, the test validation methodology is prepared, and the test analysis and reporting procedures are developed and documented. Taken together, the elements of the first phase of the work define the leak testing program.

In the second phase, the leak testing program is carried out, and the data is analyzed on a test-by-test basis. For a volumetric method, time-serial volume data is collected for the duration specified and the data is compensated for the known effects. The compensated volume rate is then estimated and compared to the threshold, and the results are validated and reported.

In the petroleum industry, the minimum frequency at which the leak tests are conducted is specified by EPA (or State) regulation. For the Hanford tanks program, the sampling and threshold values will be determined from the baseline data, and the test frequency will be determined based upon operational needs and the duration of the retrieval program.

The leak testing program planned for Hanford follows the program developed by EPA for the owners and operators of underground storage tanks, and by the Oak Ridge National Laboratory for the singly contained radioactive storage tanks there. Since these programs are statistical in nature, a *pass* test result does not necessarily mean that the tank is "not leaking". Rather, a *pass* result means that the tank is "not leaking, within the statistical uncertainly of the method". A missed detection is possible. Similarly, a fail result, does not necessarily mean that the tank is leaking; it means that the tank is not leaking within the statistical uncertainly of the method. A false alarm is possible. Application of the test results, however, follows the simpler interpretation. That is, if a test result is *pass*, subsequent operations are conducted assuming the tank is not leaking. If a test result is *fail* (and is verified), actions will be taken that assume the tank is leaking. Thus, while there is uncertainty in the method, the method and its application is robust and consistent with other leaking testing programs throughout the United States.

[6] In the case of the UST regulation, the EPA established the 0.2 gal/h criterion after examining the performance of dozens of methods. In the case of ORNL, DOE adopted the same 0.2 gal/h, but only after examining the data from the tanks and being assured that the criterion could be met using the extant level sensors. Thus, lacking a prescribed criterion, it is established from the data. A criterion and test duration for the Hanford Method will be determined after examining not only the noise in the level data, but also the expected retrieval times and cost-benefit tradeoffs of the existing sensors versus improved or alternate sensors.

[7] Although almost any combination of P_D and P_{FA} values could be considered, a P_D of 95% and a P_{FA} of 5% is almost universally accepted.

Since false alarms and missed detections are possible, it is important to minimize the number of their occurrences and their value. This is done by making choices that maximize the probability of detection and minimize the probability of false alarm, consistent with the program needs and goals. This requires a good understanding of the sensor system, the data it produces, and the tank system that is contributing to the noise in the measurement. This is discussed in more detail in the next section.

Hanford Leak Testing and Data Analysis Models

The following discussion describes the technical aspects of the development and conduct of a leak testing program, as it applies to the Hanford SSTs. As described above, the first portion of the program entails development of the data required to estimate the compensated noise (or uncertainty) in the measurements. The first step in the first phase is to acquire historical time series data that is, or is expected to be, relevant to the development of the integrity program, and any log data that can be used to help understand the volumetric data. For Hanford, this includes liquid level data from the ENRAF, FIC, and/or ILL gauges, temperature and barometric pressure data, prior leak assessment data, and pertinent operator logs.

After the time series is obtained, it is analyzed to examine the temporal characteristics and to identify anomalies. A sample analysis explained below uses the Manual ENRAF data from tank S-103 as an example (obtained from the TWINS website SACS database[8]), and shown in Figure 1. Figure 1a shows a plot of the raw liquid level (in inches) during the year 1996. A review of the SST data available from TWINS shows that the tank data typically contains missing points, spurious points and abrupt level shifts that are probably associated with calibration or other operations, but in any event are not likely leak-related. These anomalous values, seen in Figure 1a, can be edited from the data without compromising the integrity of the data. The edited data, shown in Figure 1b, is clearly improved in terms of anomalous behavior. A successful leak testing program will improve the operations and data collection procedures to reduce the number of anomalous data points, or implement a formal editing scheme that will accomplish the same end.

[8] http://twins.pnl.gov:8001/TCD/main.html, for example.

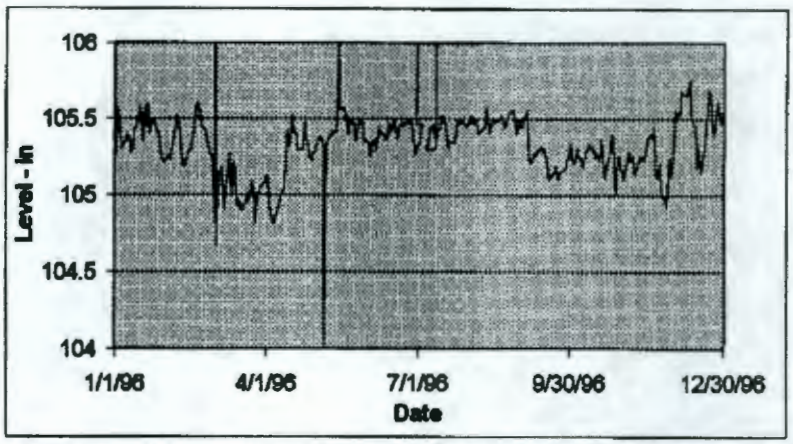


Figure 1a - A time series plot of the unedited liquid level in Tank S-103 during 1996.

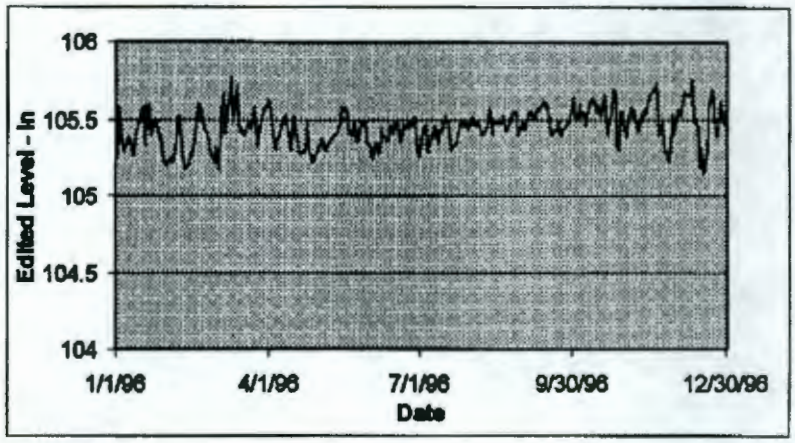


Figure 1b - A time series plot of the edited liquid level in Tank S-103 during 1996.

An important part in the development of a leak test program is to correlate the recorded level data with other observed phenomena, such as temperature or pressure. Figure 2a shows a plot of the daily average barometric pressure recorded in the Hanford East Area during 1996. Figure 2b shows a scatter plot of the (edited) level in S-103 as a function of the barometric pressure. If the observed changes in level were caused entirely by changes in barometric pressure, the data in Figure 2b would form a straight line following the fit, $y = Ix$ (or $y = -Ix$), where I is a constant that describes the strength of the *influence* of barometric pressure on the level. Although the data in Figure 2b isn't perfectly correlated, the figure does show that there is a distinct negative correlation with pressure. This means that at least some portion of the observed level fluctuations is caused by changes in barometric pressure. The negative slope of the relationship means that as pressure is increases, level decreases; this is consistent with the entrained (or dissolved) gasses explanation. A regression fit through the scatter plot data provides a measure of the strength of pressure effect, or the pressure influence coefficient, I_p. In the case of S-103, I_p has a value of -0.39. The pressure-compensated level, Lc, is calculated as

$$Lc(t) = Lo(t) - I_p * \Delta P(t),$$

Where $L_o(t)$ is the raw (but edited) ENRAF time series and $\Delta P(t)$ is the change in barometric pressure during the record period. Figure 2c shows a plot of the compensated volume for Tank S-103. Comparing this plot with Figure 1a shows that some variability has been removed from the data. The effect of this is to improve the precision of the level (or volume) estimates. From the perspective of liquid integrity, compensation reduces the *noise* in the leak detection process and improves the performance of the method.

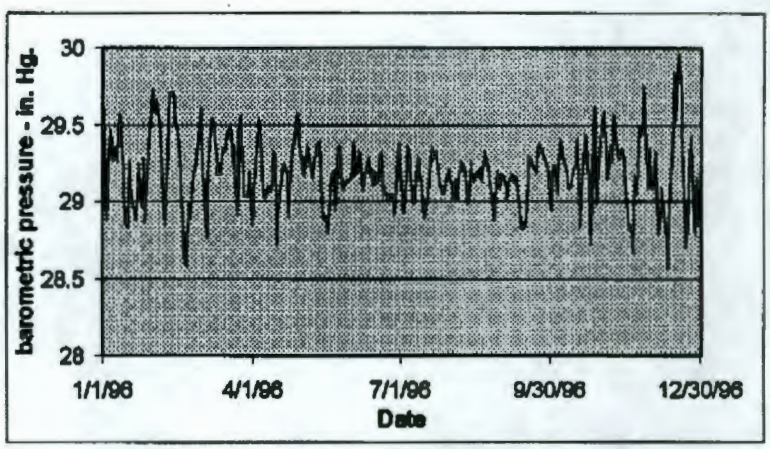


Figure 2a - Barometric pressure in the 200 East Area during 1996.

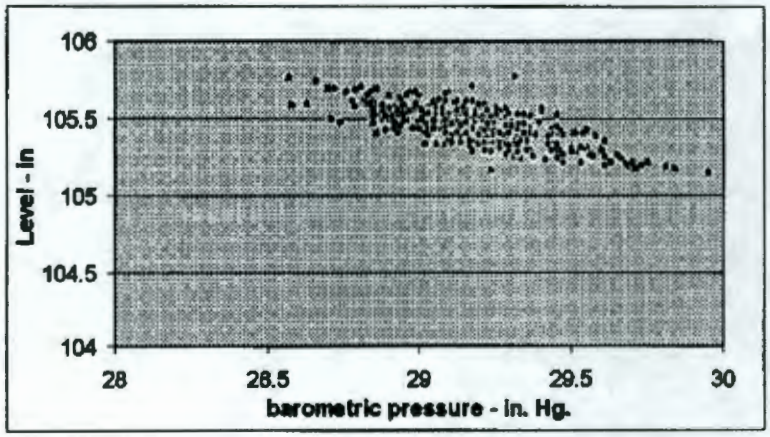


Figure 2b - Scatterplot of barometric pressure versus S-103 level in 1996.

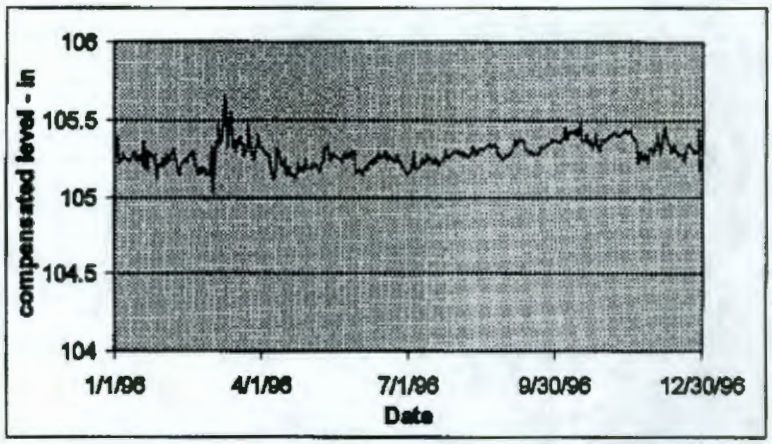


Figure 2c - 1996 S-103 level data compensated for barometric pressure.

A scatter plot analysis has shown that the ENRAF-measured level in S-103 is not affected by air temperature, but there is some evidence to suggest that temperature changes within the tank itself contribute to the measured data. To the extent that this influence is real and significant, it can be used to reduce the variability even further. These and other influences will be investigated further.

After compensation, the data is subdivided into individual data sets. In a recently completed examination of the noise in the level data, the data was divided into 30-day data sets [HNF 1998]. As many of these (nominally) month-long data sets were parsed from the available time serial data as could be obtained from the data. After parsing, the level time series was converted to volume time series, and a least-squares linear regression fit was made to each of the data sets. The slope of the regression line was saved as an estimate of the *volume rate* during the month-long period, and was expressed in terms of gallons per hour. The standard deviation of the y-estimate is also saved and is an estimate of the fluctuations during the period, or a description of how well behaved the data is during the period.

Although each tank at Hanford is expected to provide somewhat different measurements in terms of anomalies, all of the tanks examined in 1998 [HNF 1998] show some form of anomaly. Unless the spikes and abrupt volume changes like those shown in Figure 1a are edited out, and unless missing data is restored, these anomalies will cause unusually large and entirely spurious volume rate and standard deviation estimates. A final analysis set of volume rate data for S-103 is plotted in Figure 3.

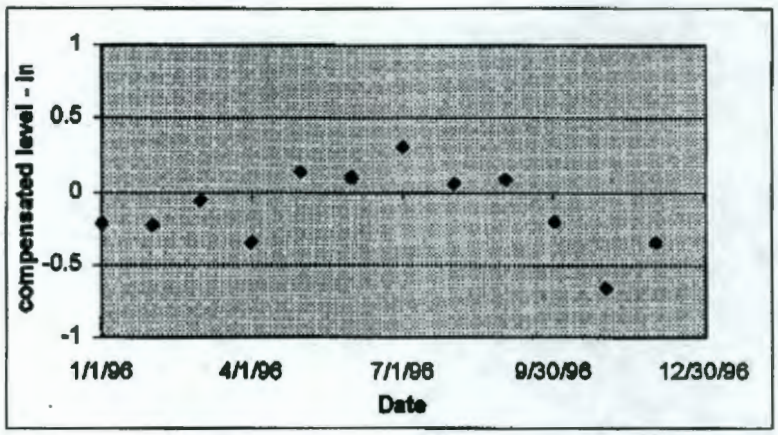


Figure 3. Monthly Volume Rate Estimates During 1996 from Tank S-103.

In the first phase of a leak test program, volume rate data similar to that shown in Figure 3 is used for the specification of a criterion, the performance estimates, and to determine the threshold. In the second phase of the program, test data is collected and formed into individual volume rate estimates; these are compared to the threshold for making the "pass" or "fail" liquid integrity decisions. While such a program could be established with the data shown in Figure 3, a test program based upon level estimates collected hourly instead of daily would result in a more rapid assessment of liquid integrity. Such data could allow a 24-hour test instead of a month-long test, albeit the criterion and threshold may be different than for the month-long test. This data will be examined in the next phase of the work, and a candidate criterion will be proposed.

Leak Testing Statistics

The EPA provides a concise approach for evaluating the performance of leak detection methods using a gaussian analysis[9]. This evaluation procedure, when applied to the Hanford tank data, allows an estimate to be made of the minimum leak that can be reliably detected in each tank, assuming that the data sets used are representative of the data in that tank. Using the final analysis set shown in Figure 3 as an example, the EPA's gaussian analysis first calculates a test statistic, t_s, given as

$$t_s = N^{1/2} (m / \sigma_y),$$

where N is the number of data sets that are usable after the data has been culled to remove anomalous data, m is the average volume rate over the entire analysis period (one year for the example), and σ_y is the standard deviation of the set of volume rates—that is, the fluctuation of the m's. In the case of the S-103 data, there were 12, 30-day sets of usable volume rate data after

[9] "Standard Test Procedures for Evaluating Leak Detection Methods: Automatic Tank Gauging Systems", EPA Report No. EPA/530/UST-90/006, US Environmental Protection Agency, Washington, D.C., (1990).

culling. These data have a mean volume rate of -0.14 gal/h and a standard deviation of m of 0.25 gal/h. The equation above yields a test statistic with an absolute value of 1.47.

The test statistic is then compared with a critical statistic, t_c, determined from a table of Student's t-values, for various one-sided confidence intervals. This comparison—a "null hypothesis test"—statistically determines whether the mean volume rate, m, is significant. That is, given the month-to-month fluctuations in the monthly values of volume rate, the test determines whether the measured value of m is statistically different from 0 gal, or whether that value likely occurs as a result of random occurrence. A Student's t-table gives a t_c value of 1.80 for a 5% error. Since t_s is less than t_c, we conclude that, with less than a 5% chance of error, the calculated average volume rate, m = -0.14 gal/h, cannot be distinguished from 0 gal/h and is due to pure chance. Thus, based on this data, it is likely that tank S-103 is not leaking.

Using this information, a threshold, T, is calculated that can be used to detect leaks from the tank, for various probabilities of false alarm, P_{FA}, and probabilities of detection, P_D. The relationship is,

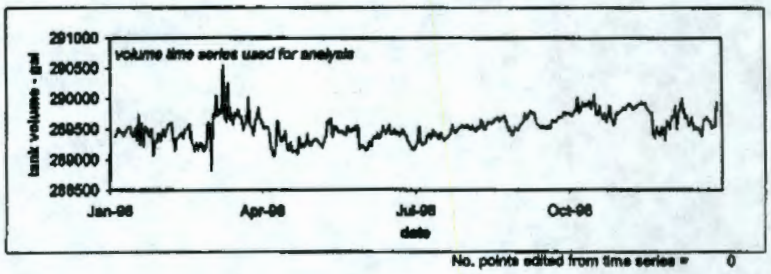
$$T_{PFA} = - t_c \times \sigma_y ,$$

where t_c is chosen to match the desired probability of false alarm, P_{FA}, and where the minus sign (-) indicates that a release from the tank will be detected by a negative volume rate that exceeds T. These calculations are illustrated in Figure 4. This figure shows that by using a threshold of -0.46 gal/hr, a minimum detectable leak of -0.92 gal/hr can be achieved if a P_{FA} of 5% is specified. In this case, P_D is ~ 99%.

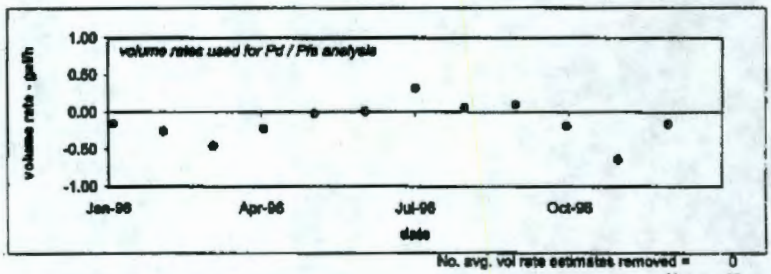
The selection of a threshold to match various P_D and P_{FA} requirements invariably entails compromise: Any attempt to reduce P_{FA} also reduces P_D. Within the leak detection community[10] however, a P_D of 95% is the commonly accepted standard. The statistical analysis used to make the performance estimates described above can be extended to improve the performance of the method by finding a threshold that minimizes P_{FA} consistent with a P_D of 95%. When this is done on the tank S-103 data, it is found that a threshold of –1.11 gal/h can be used. This will detect a release of –1.39 gal/h from the tank at a P_D of 95% with a P_{FA} of only 0.09% (compared to a P_{FA} of 5% at a threshold of –0.46 gal/hr). This is about a six-fold improvement in the performance of the leak detection capability for tank S-103, with no unacceptable loss in detection probability. The results of the calculation to minimize PFA are shown at the bottom of Figure 4.

[10] And many other detection-oriented communities as well, such as radar and sonar)

Data File: S-103 Data is from sensor type: Manual ENRAF



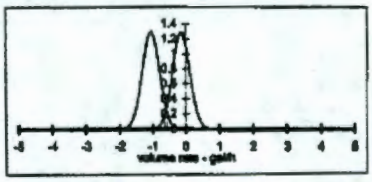
No. points edited from time series = 0



No. avg. vol rate estimates removed = 0
N = 12

During the analysis period, the average volume rate = -0.14 gal/h
The standard deviation of the volume rate estimates = 0.25 gal/h

For Pfa = 5%; Pd > 95%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.46 gal/h
Min. Detectable Leak: -0.92 gal/h



For this data, a threshold= -1.11 gal/h will detect a tank release of 1.39 gal/h at a Pd = 95%
The corresponding Pfa is 0.09%

Figure 4. Leak Testing Method Calculations Applied to Tank S-103

Minimum Detectable Leak Rate

Using the relationships described above, the *minimum detectable leak rate* (L_{MD} or simply MDL) at a probability of detection of 1-P_{FA}, can be calculated simply as 2xT. Figure 4 shows these calculations for P_D / P_{FA} of 95% / 5%.

The term *minimum detectable leak* or minimum detectable leak rate, or MDL, has a very specific meaning in the context of leak testing and leak detection systems: It is the volume rate that will be detected by the method at a probability of detection of 95% and a false alarm rate of 5%. It does not simply specify the smallest leak that can be detected. Neither does it indicate that leaks smaller than the MDL will *not* be detected. As a result, the MDL is used as a measure of performance of a leak detection system, not a value to be compared or tested against. This is an important distinction and is discussed in more detail below.

Consider a histogram of volume-rate (VR) measurements made on a non-leaking tank, as shown in Figure 5. The histogram (a) indicates that when we make VR measurements on a tank that is known to be non-leaking, we will record a range of VR values. A range of values instead of a single repeated value occurs because system noise, uncompensated environmental noise (temperature and pressure influences, for example), and operator and operations factors contribute and add variability to the measurement. The width of the histogram is a measure of the noise in the system, or the precision of the measurement. Thus, when we make a VR measurement on this tank, we *expect* to observe values that are different than 0 gal/h.

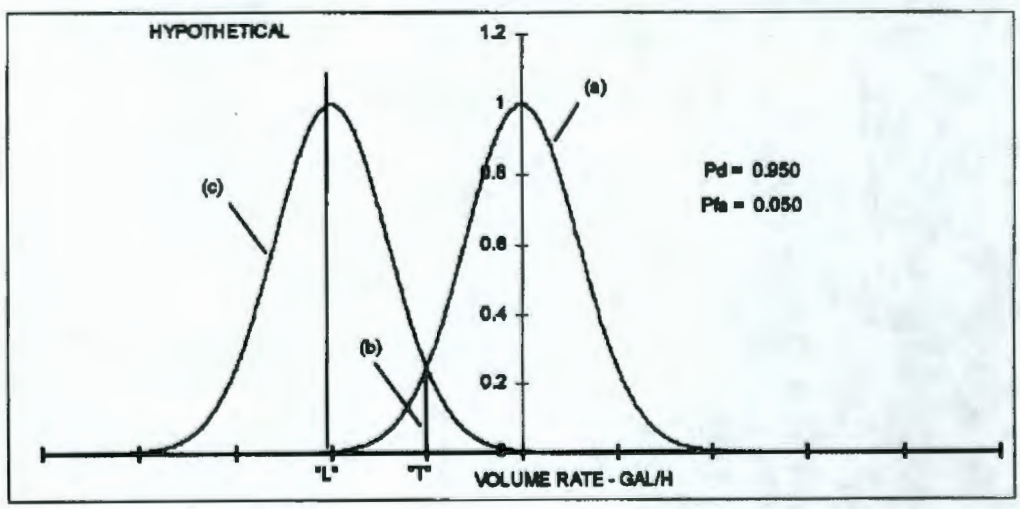


Figure 5. PD / PFA Curves for a Hypothetical Tank, with and without a leak of "L" gal/h.

In a leak detection system, VR measurements are made and *tested* against the threshold, T, described above. If the measured VR exceeds the threshold, the tank is said to have *failed* the test and (after validating the failed result) is declared to be leaking. If the measured VR falls

below the threshold, the tank *passes* the test and is declared to be sound or non-leaking[11]. The value of the threshold is based upon the desired (or allowable) *probability of false alarm*, or P_{FA}, that is also consistent with some desired or specified probability of detection, P_D. In the case of Figure 5, a threshold (b) is shown that gives a P_{FA} of 5%, which is a commonly used maximum value. For this threshold, 5% of the area under the histogram of non-leaking data lays to the left of the threshold and 95% of the area lays to the right. Using this threshold for tests, we expect that for 95 out of 100 VR measurements and comparisons to T on a non-leaking tank, our tests will correctly decide that the tank is non-leaking. For 5 of the 100 measurements, however, we will experience a *false alarm* wherein (without validation—usually accomplished by a confirmatory test) we would incorrectly declare the tank to be leaking.

Now consider making 100 VR measurements on a tank that is known to be leaking at some rate, L, using the same system as was used on the non-leaking tank. In this case, we would expect to observe another range of actual measurement, but with a histogram centered at L, as shown in (c) of Figure 5. In (c), the fraction of the area of the histogram that lays to the left of the threshold, T, is said to be the *probability of detection*, P_D. When T is selected such that P_D is 95%, L is said to be the *minimum detectable leak*, MDL. Thus, using the standard nomenclature used by the leak testing industry, the "minimum detectable leak" is the volume rate that can be detected with a 95% confidence, at a false alarm rate of 5%.

Note that for the data of Figure 5, a leak of L gal/h will not be detected some fraction of the time. This is a *missed detection* and the *probability of a missed detection*, P_{MD}, is usually specified as $1-P_D$. Thus, for a P_D of 95%, we will fail to detect actual leaks 5% of the time (in this example.) We would also fail to detect smaller leaks at a larger P_{MD} and larger leaks at a smaller P_{MD}. Note also that we cannot change P_{MD} without also changing P_{FA}. If we decrease T so as to decrease the number of missed detections, we simultaneously increase P_{FA} and experience more false alarms.

Taken all together, the threshold, T, P_D and P_{FA} of a leak detection method collectively describe the *performance* of the system. Although the performance of a system could be specified from a monetary perspective or a technological perspective, its selection is usually determined from the operations and regulatory consequences of false alarms and missed detections.

Based upon the above, the term "minimum detectable leak" will be used as a measure of the performance of a leak detection system installed on a tank. It will be not, however, be used as a value for making leak decisions.

[11] Strictly speaking, a null hypothesis test is conducted where the hypothesis is that the tank is non-leaking. If the test value is less than the threshold, it is said that "we fail to reject the null hypothesis."

Leak Test Strategy

Retrieval methods for each of the tanks will be selected, in part, on the performance of the installed leak detection system. For a given retrieval method, the release volumes contributing to the source term can be bounded. At the larger end, the maximum release volume can be used to determine a maximum test threshold, T, as:

RRV = Retrieval Release Volume
C (Criterion) = RRV/(expected retrieval time)
T (Threshold) = C/2 (for performance = 95% P_D, 5% P_{FA}).

At the smaller end, the performance of the leak test system can be used to estimate the potential contribution to undetected releases. As described above. the threshold, T, is determined from the historical data for each tank such that the P_{FA} will be no greater than 5% for a single test, consistent with a P_D of at least 95%.

To the extent that the T determined from the data is less than the T determined from the maximum release volume, the leak testing performance required by the planned retrieval method will be achieved. In this case, the retrieval leak testing program will adjust T so as to minimize P_{FA} consistent with a P_D of 95%.

To the extent that the T determined from the data is equal to or greater than the T determined from the maximum release volume, the leak testing method will not meet the retrieval requirements. In this case, either the retrieval method will be adjusted, or the leak detection method will be changed, or both.

Method Validation

It is important to validate the leak detection system before beginning the retrieval operation so that the relationship between a leak and the measured quantity is understood. Validation methods will be developed and implemented prior to retrieval. As an example of a validation technique applied to a volumetric leak detection method, a known quantity of water could be added to the tank about to be retrieved, at a known rate. To the extent the leak detection system can accurately measure the rate and quantity of added water, the method can confidently be used to detect leaks in the tanks where the volume would decrease instead of increase.

Detected and Undetected Releases

As described in [HNF-1998], a leak test will be performed at periodic intervals using a null hypothesis test applied to data collected from a system whose performance is known. To the extent that a VR is detected that exceeds the detection threshold, T (and is validated) a detected potential release volume will be estimated as the value of the detected release rate times the remaining retrieval time. For the case where the test value of VR is less than the threshold, the statistical inference is that VR is equivalent to 0 gal/h.

References

HNF 1998 Phillip C. Ohl, Dennis G. Douglas, and Joseph W. Maresca, Jr., "Single-Shell Tank Sluicing History and Failure Frequency," HNF-3018, Rev. 0, Lockheed Martin Hanford Corporation (Vista Research, Inc.), Richland, Washington, September 1998.

HNF 1999a B. M. Hanlon, "Waste Tank Summary Report for Month Ending May 31, 1999," (Published July 1999), HNF EP-0182-134, Rev. 0, Fluor Daniel Hanford, Inc., Richland, Washington, July 1999.

HNF 1999b James L. Nelson and Phillip C. Ohl, "Single-Shell Tank Leak History Compilation," HNF-4872, Rev. A (Draft), Lockheed Martin Hanford Corporation (Vista Research, Inc.), Richland, Washington, August 1999.

Vista 1999 Phillip C. Ohl, Jim Starr, and Joseph W. Maresca, Jr., "Non-Catastrophic Leak Rates in Hanford SSTs (A Fluid Dynamics Model)," Internal Report, Vista Research, Inc., July 6, 1999. (Transmitted to Lockheed Martin Hanford Corporation as Subcontract 3838 Contract Deliverable on July 6, 1999)