OFFICE OF RIVER PROTECTION
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

MAR 1 3 2019

19-ECD-0022

Ms. Alexandra K. Smith, Program Manager
Nuclear Waste Program
Washington State
Department of Ecology
3100 Port of Benton Blvd.
Richland, Washington 99354

Ms. Smith:

SUBMITTAL OF HANFORD FACILITY RESOURCE CONSERVATION AND RECOVERY ACT PERMIT MODIFICATION NOTIFICATION FORM 24590-LAB-PCN-ENV-19-002 AND 24590-LAW-PCN-ENV-19-002

References:
1. WA7890008967, "Dangerous Waste Portion of the Hanford Facility Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste, Part III, Operating Unit 10, 'Waste Treatment and Immobilization Plant.'"
2. BNI letter from V. McCain to B.T. Vance, ORP, "Submittal of Hanford Facility Resource Conservation and Recovery Act Permit Modification Notification Forms 24590-LAB-PCN-ENV-19-002 and 24590-LAW-PCN-ENV-19-002," CCN: 311771, dated February 19, 2019.

This letter transmits Hanford Facility Resource Conservation and Recovery Act Permit Modification Notification Forms 24590-LAB-PCN-ENV-19-002 and 24590-LAW-PCN-ENV-19-002, attached, for the Washington State Department of Ecology review and approval. The forms describe a requested Class 1 modification to Reference 1.

The permit change notices supersede the cancelled 24590-WTP-PCN-ENV-18-010 by generating separate permit change notices for the leak detection documents for the Analytical Laboratory and the Low-Activity Waste Facility.

The purpose of 24590-LAB-PCN-ENV-19-002 is to update the Leak Detection Capability document for the Analytical Laboratory facility in Appendices 11.18 of Reference 1. The purpose of 24590-LAW-PCN-ENV-19-002 is to update the Leak Detection Capability document in the Low-Activity Waste Facility in Appendix 9.18 of Reference 1.

Washington State Department of Ecology comments resulting from review of this modification notification form and the associated information have been dispositioned.

If you have any questions, please contact me, or your staff may contact Gae M. Neath, Environmental Compliance Division, (509) 376-7828.

Glyn D. Trenchard, Assistant Manager
Technical and Regulatory Support

ECD:GMN

Attachments: (2)

cc w/attachs:
D.E. Casey, BNI
R.J. Landon, BNI
V. McCain, BNI
D.C. Robertson, BNI
D.M. Yasek, BNI
J. Cantu, Ecology (7 hard copies & CD)
J.K. Perry, MSA
A.C. McKarns, RL
J. Atwood, YN
D. Rowland, YN
Administrative Record (WTP H-0-8)
BNI Correspondence
Environmental Portal

cc w/o attachs:
M. Johnson, CTUIR
A.S. Carlson, Ecology
S.L. Dahl, Ecology
J. Decker, Ecology
T.Z. Gao, Ecology
M.E. Jones, Ecology
D. McDonald, Ecology
J. Bell, NPT (Acting)
G. Bohnee, NPT
K. Niles, Oregon Energy
P.M. Pak, RL (Acting)
R. Longoria, YN (Acting)

Attachment 1
19-ECD-0022
(35 Pages Excluding Cover Sheet)

Hanford Facility RCRA Permit Modification Notification
Form 24590-LAB-PCN-ENV-19-002

Quarter Ending Mar. 31, 2019

24590-LAB-PCN-ENV-19-002

Hanford Facility RCRA Permit Modification Notification Form
Part III, Operating Unit 10
Waste Treatment and Immobilization Plant

Index

Page 2 of 3: Hanford Facility RCRA Permit, Part III, Operating Unit 10, Waste Treatment and Immobilization Plant Update the Leak Detection Capability in the LAB Facility document in Appendix 11.18.

Submitted by Co-Operator:		Reviewed by ORP Program Office:	
Roger J. Landon	1/30/19	Thomas W. Fletcher	3/12/19
Roger J. Landon	*Date*	*Thomas W. Fletcher*	*Date*

Quarter Ending Mar. 31, 2019 24590-LAB-PCN-ENV-19-002

Hanford Facility RCRA Permit Modification Notification Form

Unit:	Permit Part:
Waste Treatment and Immobilization Plant	**Part III, Operating Unit 10**

Description of Modification:

The purpose of this Class 1 prime modification is to update the leak detection document for the Lab facility in Appendices 11.18.

Appendix 11.18			
Replace:	24590-LAB-PER-M-04-0001, Rev. 0, LAB Minimum Leak Detection Capabilities for Leak Detection Boxes, Cell Sumps, and Pit Sumps	With:	24590-LAB-PER-M-04-0001, Rev. 3, Leak Detection Capability in the LAB Facility

This modification requests Ecology approval and incorporation into the permit of the changes described below. These revisions are the result of ongoing design. The following summarizes the changes to the attached permit documents.

Leak Detection Capability in the LAB Facility (24590-LAB-PER-M-04-0001, Rev. 3)

- Draft LAB and LAW Leak Detection Documents were previously submitted for informal review. Based on Ecology comments the PCNs were placed on hold.
- The EMF Leak Detection Document was generated with updated methodology to address Ecology comments and was approved as part of the 24590-BOF-PCN-ENV-15-002.
- Revision 1 of the LAB Leak Detection Document was generated to incorporate the confirmed LAB leak detection calculation.
- The LAB Leak Detection Document was revised from Revision 1 to Revision 2 to address revision of methodology, results, and summary to resolve PIER-MGT-11-0105-C, Action 09, and is consistent with the calculation methodologies used in both the EMF and LAW Leak Detection documents.
- Revision 3 was generated to incorporate Ecology comments generated during the informal review process.

In accordance with Permit Condition III.10.C.2.e, this permit modification includes the updated leak detection document for inclusion in Appendixes 11.18.

WAC 173-303-830 Modification Class:	Class 1	Class [1]1	Class 2	Class 3
Please mark the Modification Class:		X		

Enter relevant WAC 173-303-830, Appendix I Modification citation number: N/A

Enter wording of WAC 173-303-830, Appendix I Modification citation:

In accordance with WAC 173-303-830(4)(d)(i), this modification is requested to be reviewed and approved as a Class [1]1 modification. WAC 173-303-830(4)(d)(ii)(A) states, "Class 1 modifications apply to minor changes that keep the permit current with routine changes to facility or its operation. These changes do not substantially alter the permit conditions or reduce the capacity of the facility to protect human health or the environment. In the case of Class 1 modifications, the director may require prior approval."

Modification Approved/Concur: ☐ Yes ☐ Denied (state reason below)	Reviewed by Ecology:
Reason for denial:	S. Dahl Date

R11918978

ISSUED BY
RPP-WTP PDC

Document title: **Leak Detection Capability in the LAB Facility**

Document number: 24590-LAB-PER-M-04-0001, Rev 3

Contract number: DE-AC27-01RV14136

Department: Process and Mechanical Systems

Author(s): Annalene Decker

Originator
By: Annalene Decker - ADECKER
Org Name: Mechanical Systems
Placed: Sep 26, 2018

Checked by: Pietro Martinelli

Checked
By: Pietro Martinelli - pmartine
Org Name: MS Resident Engineering
Placed: Sep 25, 2018

Issue status: Issued for Permitting Use

Note: Contents of this document are Dangerous Waste Permit affecting.

Approved by: Alfredo Ceja

Approver's position: Mechanical Engineering Group Supervisor

Approver's signature: [signature] 10-4-18

Signature Date

NSE Review: The LAB Leak Detection capability report does not represent a design change and does not impact the PDSA or safety design bases.
No Comment. No SE required N19-10 Item! DRB

[signature] 9/26/2018

This bound document contains a total of 33 sheets

River Protection Project
Waste Treatment Plant
2435 Stevens Center Place
Richland, WA 99354
United States of America
Tel: 509 371 2000

24590-PADC-F00041 Rev 6 (1/22/2009)

Notice

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the US Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

History Sheet

Rev	Reason for revision	Revised by
0	Issued for Permitting Use	P. Martinelli
1	Update to reflect confirmed calculation 24590-LAB-M6C-RLD-00027, Rev 0.	P.E. Stanley
2	Minor revision of methodology, results, and summary based on revised report to resolve PIER-MGT-11-0105-C Action 09. Revision marks are not included.	J. Holway
3	Minor revision to address comments from Ecology. See revision lines in right margin.	A. Decker

Contents

Acronyms

AEA	Atomic Energy Act of 1954
BNI	Bechtel National, Incorporated
CCN	Correspondence Control Number
CGS	centimeter gram second units of measurement
DOE	US Department of Energy
DWP	Dangerous Waste Permit
LAW	Low Activity Waste
RLD	Radioactive Liquid Waste Disposal System
STD	Standard
WAC	Washington Administrative Code
WTP	River Protection Project-Waste Treatment Plant

1 Summary

The Analytical Laboratory (LAB) facility secondary containment must satisfy the leak detection criteria of the Washington Administrative Code (WAC) 173-303-640(4), Reference 8.4, and the Waste Treatment Plant Dangerous Waste Permit (DWP) number 7890008967, Condition No: III.10.E.9.e.ii and III.10.H.5.e.ii for tank and miscellaneous treatment system secondary containment areas, Reference 8.2. This report evaluates the minimum leak rates that can be detected within 24 hours in the regulated secondary containment sumps.

The LAB facility contains six DWP regulated sumps and eight leak detection boxes (LDBs). Leaks of vessels or piping within the cells will flow along the floor (or in containment piping), and are collected in a sump or LDB and are detected with level instrumentation. This report evaluates the time to detect a leak of 0.1 gallons per hour (gph) and determines if the time is within the DWP permit requirement of 24 hours for potential leaks that are collected. Regulated double-wall piping is sloped as provided on the associated P&ID to direct a leak towards the LDBs.

Since the DWP has established a minimum leak rate of 0.1 gph, this report determines the time to detect the minimum leak of 0.1 gph in the sumps based on the time to fill the sump plus the time for the 0.1 gph leak to flow to the sump. The time to fill the sump is calculated by first determining the minimum detectable volume in each sump and then the time required to reach this detectable column at a leak rate of 0.1 gph. If the "time to detect" is less than 24 hours for a flow rate of 0.1 gph for all sumps, the permit condition is met.

This Permit Document will document that the time to fill the sump to the detectable level is the critical factor for establishing a leak detection rate vs. the time for the leak (rivulet) to cross the floor or for the leak to wet and travel through the pipe. This approach has been previously presented to the Department of Ecology.

2 Objective

The objective of this report is to document the capability to detect a 0.1 gph leak of dangerous waste within 24 hours in the LAB facility secondary containment area sumps. The leakages include:

- Leaks from vessels, equipment and/or piping containing DWP regulated waste that flows by gravity directly to sumps containing leak detection instrumentation
- Leaks that flow by gravity to drains that are routed to another cell containing a sump with leak detection instrumentation.

3 Description

The LAB facility regulated sumps must satisfy the leak detection criteria of the WAC and DWP conditions for secondary containment systems. The regulatory requirements for leak detection are contained in WAC-173-303-640 (4), Tank Systems, Section 4, Containment and Detection of Releases and are restated as follows:

(b) Secondary Containment systems must be:
(ii) Capable of detecting and collecting releases and accumulated liquids until the collected material is removed.

(c) To meet the requirements of (b) of this subsection, secondary containment systems must be at a minimum:

(iii) Provided with a leak detection system that is designed and operated so that it will detect the failure of either the primary or secondary containment structure or the presence of any release of dangerous waste or accumulated liquid in the secondary containment system within twenty-four hours, or at the earliest practicable time if the owner or operator can demonstrate to the department that the existing detection technologies or site conditions will not allow detection of a release within twenty-four hours.

In addition, the Waste Treatment Plant Dangerous Waste Permit (Reference. 8.2), Conditions: III.10.E.9.e.ii and III.10.H.5.e.i require submittal of:

Detailed plans and descriptions, demonstrating the leak detection system is operated so that it will detect the failure of either the primary or secondary containment structure or the presence of any release of dangerous and/or mixed waste, or accumulated liquid in the secondary containment system within twenty-four (24) hours. Detection of a leak of at least 0.1 gallons per hour within twenty-four (24) hours is defined as being able to detect a leak within twenty-four (24) hours. Any exceptions to this criterion must be approved by Ecology [WAC 173-303-640(4)(c)(iii), WAC 173-303-806(4)(c)(vii)].

There are two dangerous waste vessels in the Analytical Laboratory (LAB). The first vessel is RLD-VSL-00164 (Ref. 8.19.5), laboratory area sink drain collection vessel, and will hereafter be referred to as the C3 vessel; this vessel is associated with RLD-SUMP-00041. The second vessel is RLD-VSL-00165 (Ref. 8.19.1), hotcell drain collection vessel and will hereafter be referred to as the C5 vessel; this vessel is associated with RLD-SUMP-00042. The sumps associated with these vessels will be included in this report along with the pit pump sumps.

4 Inputs/Assumptions

4.1 The vessel cell dimensions are summarized as follows

- C3 Effluent Vessel Cell (Rm No. A-B003), 13'-0" (East-West) x 27'-3" (North-South) (Ref. 8.24.3, Grid H5 & E6)
- C5 Effluent Vessel Cell (Rm No. A-B004), 21 '-0" (East-West) x 29'-0" (North-South) (Ref. 8.24.1, Grid D7 & B8)

4.2 The pit dimensions are summarized as follows:

- C3 Pump Pit (Rm No. A-B002), 13'-0" (East-West) x 14'-5 1/2" (North-South) (Ref. 8.24.3, Grid H7 & E8)
- C5 Pump Pit (South, Rm No. A-B007), 6'-9" (East-West) x 6'-5" (North-South) (Ref. 8.24.1, GridH7 & E8)
- C5 Piping Pit (Rm No. A-B006), 6'-9" (East-West) x 14'-0" (North-South) (Ref. 8.24.1, Grid H7 & F8)
- C5 Pump Pit (North, Rm No. A-B005), 6'-9" (East-West) x 6'-5" (North-South) (Ref. 8.24.1, Grid H7 & G8).

4.3 There are five leak detection boxes in C3 (Ref. 8.19.10) and three in C5 (Ref. 8.19.11) that are DWP regulated with the following details: NPS 8, horizontal, Schedule 40 pipe, with an NPS 8 cap welded on either end. A detectable leakage volume is built up in an 11inch segment of pipe, plus the cap, by a 2-inch high weir located in the middle of the device (Ref. 8.14 & 8.23).

4.4 The stainless steel liners in the vessel cells and in the pump pits are sloped at a minimum grade of 1 :100 (1 %) to direct potential leakage towards the sump (note 14 of Ref. 8.24.1 & 8.24.3).

4.5 The length of the longest runs of regulated, double-wall pipe is defined by the isometric drawings identified in Ref. 8.20.1 through 8.20.14 and Ref. 8.20.15 through 8.20.19 as tabulated in Table 4.1 & Table 4.2, respectively.

Table 4.1 Longest Double Containment Pipe from ARL-HOOD-00055 to LDB-00005

Isometric Drawing	Length, ft	Comments
24590-LAB-P3-RLD-WU02269051	6.87	Length to the most remote cleanout
24590-LAB-P3-RLD-WU02269052	11.15	
24590-LAB-P3-RLD-WU02269053	9.54	
24590-LAB-P3-RLD-WU02198051	6.92	
24590-LAB-P3-RLD-WU02198052	6.50	
24590-LAB-P3-RLD-WU02198053	33.00	
24590-LAB-P3-RLD-WU02198054	12.50	
24590-LAB-P3-RLD-WU02198055	18.05	
24590-LAB-P3-RLD-WU02227051	20.40	
24590-LAB-P3-RLD-WU02227052	24.25	
24590-LAB-P3-RLD-WU02227053	34.46	
24590-LAB-P3-RLD-WU02227054	10.05	
24590-LAB-P3-RLD-WU02227055	8.39	
24590-LAB-P3-RLD-WU02249001	15.33	Connection to RLD-LDB-00005
Total	217.41	

Table 4.2 Longest Drain Collection Header from C3 Maintenance Shop to LDB-00007

Isometric Drawing	Length, ft	Comments
24590-LAB-P3-RLD-WU02289051	20.83	C3 Maintenance Sink
24590-LAB-P3-RLD-WU0230052	38.39	
24590-LAB-P3-RLD-WU0230053	63.13	
24590-LAB-P3-RLD-WU0230054	67.35	
24590-LAB-P3-RLD-WU02250001	13.07	Connection to RLD-LDB-00007
Total	202.77	

4.6 There is one sump in each DWP vessel cell. RLD-SUMP-00041 is located in Room A-B003 (the RLD-VSL00164 vessel cell) and RLD-SUMP-00042 is located Room A-B004 (the RLD-VSL-00165 vessel cell) (Ref. 8.19.1, 8.19.5). These sumps are 30-inch nominal diameter and approximately 13-inch deep. Both sumps are made from a section of nominal pipe size (NPS 30) standard-wall pipe (or an equivalent rolled plate) and a 30-inch diameter, standard wall, pipe cap (or equivalent ellipsoidal-head section) (Ref. 8.24.1, 8.24.3, & 8.17). Details on the vessel cell sumps are provided in Table 4.3.

Table 4.3 Vessel Cell Sump Details

Sump	Location	Dimensions	Reference
RLD-SUMP-00041	A-B003 (C3 Vessel Cell)	13'-0" x 27'-3" (354.25 ft^2)	8.19.1, 8.19.5

Sump	Location	Dimensions	Reference
RLD-SUMP-00042	A-B004 (C5 Vessel Cell)	21'-0" x 29'-0" (609 ft^2)	8.19.1, 8.19.5

4.7 There is one sump in each pump pit and all are DWP regulated (Ref. 8.19.2, 8.19.3, 8.19.4, 8.19.6). The sumps are formed by a rectangular depression in the liner around the drain for the pit. A removal weir around the drain hole allows formation of a detectable volume before excess leakage is directed back to its associated vessel. Details on the pit pump sumps are provided in Table 2.4.

Table 4.4 Pit Pump Sump Details

Sump	Location	Dimensions	Reference
RLD-SUMP-00043A	A-B007 (C5 Pump Pit)	1'-6" x 3'-0" (4.5 ft^2 area)	8.24.2, 8.15, 8.24.5, 8.24.6
RLD-SUMP-00043B	A-B005 (C5 Pump Pit)	1'-6" x 3'-0" (4.5 ft^2 area)	8.24.2, 8.15, 8.24.5, 8.24.6
RLD-SUMP-00044	A-B006 (C5 Piping Pit)	2'-0" x 2'-6" (5 ft^2 area)	8.24.2, 8.15, 8.24.5, 8.24.6
RLD-SUMP-00045	A-B002 (C3 Pump Pit)	2'-0" x 2'-6" (5 ft^2 area)	8.24.3, 8.15, 8.24.7, 8.24.8

4.8 The pipelines of concern within this calculation are W11B, S32B, and S11E pipe class (Ref. 8.21.1,8.22.2, and 8.22.3), which contain the following details:

- Piping class S11E is 316L stainless steel, schedule 40S (STD) for 1/2" to 4" and 10S (STD) for 6" to 14" nominal diameter pipelines (Ref. 8.22.3).
- Piping class S32B (Double Containment) is a) for encasement/jacket: A106 carbon steel, schedule 40S (STD) for 3" to 10" nominal diameter pipelines and b) for carrier pipe: 316L SS, schedule 40S for 1" to 8" nominal diameter pipelines (Ref. 8.22.2) gravity drain lines for 1" to 2" diameter pipelines).
- Piping class WIIB (Double Containment) is a) for encasement/jacket: A106 Gr B, schedule 40S (STD) for 4" to 6" nominal diameter pipelines and b) for carrier pipe: UNS N06022 Hastelloy C-22, schedule 40S for 1.5" to 4" nominal diameter pipelines (Ref. 8.21.1).

The S11E pipe code is only discussed because these lines travel from the annulus of the W11B and S32B coaxial containment pipes to the leak detection boxes. All S11E single walled piping is located within the vessel cell or pump and piping pit secondary containment areas. Dimensions for nominal diameter pipes are illustrated in Table 2.5.

Table 4.5 Pipeline Diameter Details

Pipeline	Pipe Class Ref.	Carrier Pipe (Ref. 8.18, pg. B-16 & B-17)		Encasement Pipe (Ref. 8.18, p.B-17)		
		Nom. Pipe Size (inch) Sch. 40S or Std.	I.D. (inch)	Nom. Pipe Size (inch) Sch. 40S or Std.	I.D. (inch)	Cross-Sec Area (ft^2)
RLD-WU-02269-WIIB-02	8.21.1	2	2.067	4	4.026	0.0884
RLD-WU-02198-WIIB-03 RLD-WU-02227-WIIB-03	8.21.1	3	3.068	6	6.065	0.2006
RLD-WU-22010-WIIB-04 RLD-ZN-00001-WIIB-04	8.21.1	4	4.026	6	6.065	0.2006
RLD-WU-02302-S32B-01/2	8.21.2	1-1/2	1.610	4	4.026	0.0884
RLD-WU-02301-S32B-02	8.21.2	2	2.067	4	4.026	0.0884
RLD-WU-02224-S32B-03	8.21.2	3	3.068	6	6.065	0.2006

Pipeline	Pipe Class Ref.	Carrier Pipe (Ref. 8.18, pg. B-16 & B-17)		Encasement Pipe (Ref. 8.18, p.B-17)		
		Nom. Pipe Size (inch) Sch. 40S or Std.	I.D. (inch)	Nom. Pipe Size (inch) Sch. 40S or Std.	I.D. (inch)	Cross-Sec Area (ft²)
RLD-ZN-03433-S32B-03	8.21.2	3	3.068	6	6.065	0.2006
	8.21.2	3	3.068	8	7.981	0.3474
RLD-WU-02300-S32B-08	8.21.2	8	7.981	10	10.02	0.5475
RLD-WU-02249-S11E-01 RLD-WU-02239-S11E-01 RLD-WU-22013-S11E-01 RLD-WU-02250-S11E-01 RLD-WU-02310-S11E-01 RLD-ZN-03401-S11E-01 RLD-ZN-03435-S11E-01 RLD-ZN-03402-S11E-01	8.21.3	1	1.049	n/a	n/a	n/a

4.9 The double-wall (co-axial) piping has a minimum slope of 1:192 (1/16 inch per foot) (Ref. 8.19.1 note 9, 8.19.4 note 18, 8.19.5 note 10, 8.19.6 note 10, 8.19.7 note 11, 8.19.8 note 12, 8.19.9 note 11, 8.19.10 note 8, 8.19.10 note 8, 8.19.12 note 7).

4.10 The vessel cell and pit sumps have radar-type level detection instrumentation (Ref. 8.19.7, 8.19.2, 8.19.3, 8.19.4, 8.19.5, 8.19.6) with an accuracy of ± 0.5 inch (Ref. 8.12, Section 3.2.1). The leak detection boxes contain thermal dispersion type level detection instrumentation (Ref. 8.22).

4.11 The water properties at 100°F (Ref. 8.13, p. 30.37) are as follows:

Table 4.6

Constant	English Units	CGS Units
ρ, density	61.99 lbm/ft³	0.993 g/cm³
u, dynamic viscosity	1.648 lbm/ft·hr	0.00681 g/cm·sec
γ, surface tension	0.0048 lbf/ft	69.96 dyn/cm or 69.96 g/sec²

4.12 The following items (a through g) were derived from agreements between BNI, DOE, and Department of Ecology (Ref. 8.28):

a. The liquid leaking is water at a temperature of 100°F.
b. The leak is at a constant rate over the 24-hour period.
c. The leak is assumed to occur at the furthest point from the leak detection device.
d. No evaporation will occur.
e. The liquid does not foam in the sumps.
f. Hold-up of piping is considered and is defined as wetting of the surface.
g. Level detection instruments will be properly installed and calibrated upon installation. Periodic, normal maintenance and calibration will be performed on level instruments during operation of the facility and the instruments will be maintained in an operable condition.

4.13 The average velocity equation assigned to the leakage being conveyed within the sloped pipe is developed from boundary layer theory for flow down an inclined plane. This velocity equation is assumed to apply to the leakage flows in the annular-region of the double-wall pipe since this average velocity will be applied throughout the entire length of the pipe even when the pipe contains vertical drops (where the velocity would increase, thereby reducing the travel time to detection device).

4.14 The wetting factor from experimental data was found to be 0.32 fl oz/ft (Reference 8.16) for a NPS 6 pipe. The wetting factor will be conservatively increased by 100% to 0.64 fl oz/ft to provide additional margin to the calculated holdup time.

4.15 The rivulet flow in this report is based on the simplified model for a wide flat rivulet. Figure 5 of Reference 8.10 shows dashed lines that are asymptotic solutions for wide-flat rivulets at high Ω values and for narrow rivulets at low Ω values. For a contact angle of 5°, figure 5 shows that the wide flat rivulet model, represented by equations 26 and 27 of Reference 8.10, is applicable when Ω is larger than 0.001 and P is larger than 5. This assumption is verified by the evaluation of Ω and P using data from this report.

4.16 Reference 8.10, Table 2 shows for a rivulet flow rate of 6.2 mL/min (~0.1 gph), the corresponding contact angle, θ, is experimentally measured as 9 to 12 degrees. A conservative rivulet contact angle of 6 degrees is assumed for this report. The smaller contact angle results in a longer time to sump for a given flow path length from the following logic: a smaller contact angle yields a larger rivulet width, which yields a larger rivulet cross sectional area, which leads to a lower velocity (since the flow rate is fixed). This assumption is conservative.

4.17 The rivulet flow path for each cell is conservatively considered to be along the straight walls rather than diagonally across the cell: North-South + East-West distances. The floor is uniformly sloped and the flow path is in straight lines (no meandering flow).

4.18 There are no obstructions in the flow path. Leaks from any equipment or piping fall directly to the floor at the point of leakage and do not travel along pipes or other equipment and the rivulet does not split into multiple streams as it travels across the floor. While actual leaks may not conform to this scenario, it is beyond the objective of this report to assess every possible leak scenario. The intent is to provide a calculated leak detection volume that is not overly complex but still maintains sufficient accuracy to demonstrate leak detection capability within a reasonable level of uncertainty.

4.19 The level instrument response time (i.e., the time between the fluid reaching a specified level set point and the instrument responding to the process condition) is considered negligible with regards to the leak detection time requirement. The level instrumentation is anticipated to have response times on the order of seconds and therefore, the response time is insignificant based on the 24-hour detection limit.

4.20 For the sumps with circular/elliptical bases, it will be conservatively assumed that radar guide tube is offset from the center of the sump by 8 inches; therefore, the fluid level as measured from the center of the sump must rise slightly higher in the sump to be within the radar's 0.5" detection specification (Input 4.10). In addition, a 10% contingency will be added to the fluid level that is based on the radar's offset and its accuracy. These dimensions provide a bounding value and simplify the calculation; the physical layout and added margin make this assumption conservative

4.21 The LDBs have "thermal dispersion" level detection instrumentation that will be assumed to contain an accuracy of±0.5 inch in the reservoir (e.g. Ref. 8.11). This assumption is supported by the "Issued for Quote" datasheets (Ref. 8.22). The assumed performance characteristics reflect the capabilities of commercially-available thermal dispersion level switches: Instruments with accuracies of ±0.1 inch are available and a more common accuracy of ±0.25 inch is half of that required (Ref. 8.11), therefore this assumption is considered conservative.

4.22 Based on a review of the 3-D Model and Ref. 8.15, the two longest runs of pipe are anticipated to be either the C5 collection header from the C3 Maintenance Shop -Maintenance Decon Booth (60-MHAN-00003) or a C3 collection header from a lab sink or fume hood in the southeast comer of the Rad Lab Area. Both are estimated to be below 220 ft (Table 4.1 and Table 4.2); a length of 250 ft will be used to account for uncertainty in alternative pipe routes.

4.23 The curved head portion of the pipe cap (Input 4.6) that is used for the cell sumps (RLD-SUMP-00041/42) can be approximated by a 2:1 semi-ellipsoidal head. See Attachment A-1, note (b) for confirmation that pipe heads are ellipsoidal per ASME B16.9.

4.24 The removal weirs in the pit sumps contain a 4.25 inch diameter weir strainer and a 6 inch diameter by 1.25 inch height seal cover plate as provided on vendor drawing (Ref. 8.26, weir plate detail). The displaced volume the weir plates introduce in the sumps will be ignored; this is conservative since a larger fill volume will be required, increasing the time to fill.

5 Analysis

To establish if the LAB cell sumps/LDBs can detect a permit condition leakage rate of 0.1 gph within a 24-hour time, a total time is determined. This includes the time for a leak to travel to a sump (t_1) including travel within pipes and/or across the cell floor; the time to fill the sump to a detectable level (t_2); and the time it takes to wet the surface of a pipe or 'holdup' (t_3).

Leakage flowing inside pipes uses the boundary layer theory while leakage flowing on the floor is modeled as a rivulet of uniform width. The time taken by the liquid to reach the sump and time required for minimum liquid accumulation in the sump (before it can be detected) are determined in Section 6. The leak detection boxes will collect leakage through pipes only; floor leakage is taken care of by sumps.

The sumps associated with the C3 and C5 vessels will be included in this report along with the pit pump sumps.

The postulated piping leak is a leak into the annular space of in-slab coaxial piping. Piping leaks inside of a secondary containment area such as vessel cell or piping or pump pit are addressed by the postulated leak to a liner floor (rivulet flow method).

6 Detectable Leak Rates

6.1 Leakage Through Pipes-Leak Detection Boxes

The elapsed time to detect a leak that is flowing through a pipe is composed of three independent time components: (i) a liquid holdup time or elapsed time for leak to wet the interior surface, t_3, (ii) elapsed time for the leak to travel through the pipes to the sump, t_1, and (iii) the time to fill the sump to a level that can be detected by the associated leak detection instrumentation, t_2. Therefore, the total time for leakage detection through pipes is $t_{total} = t_1 + t_2 + t_3$. If the total time is less than 24 hours for a flowrate of 0.1 gph for all leak detection equipment, the permit condition is met.

6.1.1 Holdup Time within Coaxial Pipe, t_3

The elapsed time for the leak to wet the flow path (flow channel) from the most-remote location to its corresponding leak detection feature (e.g., a cell sump) is estimated based on an experimentally determined value of wetting holdup (Ref. 8.16) and the following equation:

$$t_3 = \frac{c\,L}{Q} \qquad \text{(Equation 6.1)}$$

Where:
t_3 = holdup time, hr
c = wetting factor, gal/ft or fluid ounces/ft (abbreviated as: fl oz/ft) with use of conversion factor: 128 fl oz/gal
L = travel distance, ft
Q = leakage volumetric flow rate, gal/hr

The maximum distance from any postulated leak to its respective LDB is obtained from Assumption 4.22. The line length from the pipe cleanout upstream of the furthest drain to the LDB is used; this length conservatively includes any straight-vertical drops (Assumption 4.13).

The wetting factor is equal 0.32 fl oz/ft for 6-inch pipes, however, a factor of 0.64 fl oz/ft is used (Assumption 4.14) for conservatism. Hence, the time required to wet the flow channel is:

L = 250 ft (Assumption 4.22)
Q = 0.1 gph (DWP requirement)

$$t_3 = \left(\frac{0.64\ fl.\,oz.}{ft}\right)\left(\frac{gal}{128\ fl.\,oz.}\right)\left(\frac{250\,ft}{1}\right)\left(\frac{hr}{0.1\,gal}\right) = 12.5\ hr$$

6.1.2 Leak Travel Time to Sump via Pipe, t_1

The time delay for the leak to reach or activate the detection equipment is calculated using equations derived from boundary layer theory for uniform flow down an inclined plane (Assumption 4.13). The average velocity distribution from boundary layer theory (Reference 8.5, p. 249 thru 251, Equation 9.4b) is:

$$v = \frac{g\ S_p\ d_p^2}{3\ n} \qquad \text{(Equation 6.2)}$$

where:
v = average leak velocity, ft/s
g = gravitation constant, 32.17 ft/s^2
S_p = Slope of the pipe, dimensionless
d_p = flow depth, ft
n = kinematic viscosity, ft^2/s

The general equation for volumetric flow rate is given by:

$$Q = Av \qquad \text{(Equation 6.3)}$$

where:

Q = volumetric flow rate, ft³/s
A = cross-sectional flow area, ft²

Therefore, combining Equation 6.2 and Equation 6.3, the flow depth, d_p, can be found by solving the following relationship:

$$d_p = \sqrt{\frac{3\,nQ}{g\,S_p A}} \qquad \text{(Equation 6.4)}$$

The geometry based cross-sectional area for gravity flow in a circular pipe is found from (Reference 8.6, p. 5)

$$A = \frac{(\theta_{fs} - \sin\theta_{fs})D_p^2}{8} \qquad \text{(Equation 6.5)}$$

where:
D_p = pipe diameter, ft
θ_{fs}= free surface angle (see Figure 1), radians

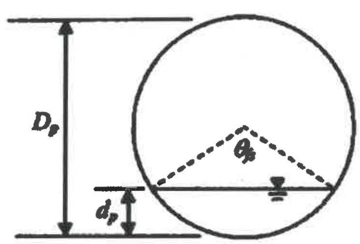


Figure 1. Partially Full Pipe Sketch

The depth of flow can be found by the following equation (Attachment A of Reference 8.7)

$$d_p = D_p \sin^2\left(\frac{\theta_{fs}}{4}\right) \qquad \text{(Equation 6.6)}$$

There are four unknowns (θ_{fs}, A, v, and d_p) to the set of four equations represented by Equation 6.3 through Equation 6.6. Though it is difficult to split theta in these equations in order to use a solve-and-substitute method, iterations are used instead.

The time delay for the leak to reach the detection box is simply

The time required for the leakage flow to travel from its point of origin to the sump is calculated from the Equations 6.3 through 6.6. The following constants are used:

D_p = 10.02 inch (0.835 ft) (Dp ranges from 4.026 inch (0.3355 ft) to 10.02 inch (0.835 ft). The larger, 0.835 ft, diameter is used since it yields a lower velocity (determined by performing calculation).
Q = 0.1 gph = 3.714 E-6 ft³/s
g = gravitation constant = 32.17 ft/s²
S_p = Slope of the pipe = 1/192 = 0.0052 (Input 4.9)
μ = dynamic viscosity = 1.648 lbm/ft·hr (Input 4.11)
ρ = 61.99 lbm/ft³ (Input 4.11)

Since kinematic viscosity *(n)* is equal to dynamic viscosity (μ) / density (ρ), kinematic viscosity found to be:

n = (1.648 lbm/ft·hr) / (61.99 lbm/ft^3) * (1 hr /3600 sec) = 7.39E-6 ft^2/sec

A Mathcad equation solve block is used to determine the unknowns, the results are:

d_p = 2.07 X 10^{-3} ft
A = 1.147 X 10^{-4} ft^2
θ_{fs} = 0.199 radians or 11.4 deg
v = 0.024 ft/sec

The travel delay for the leakage to reach the sump is:

$t_l = L$ / v * (hr /3600 sec) (Equation 6.7)

Where:
t_l = time to reach detection device, hr
v = average velocity of leak, ft/sec
L = travel distance, ft

Equation 6.7 applies to rivulet flow as well.

Substituting the values in Equation 6.7 yields:

$t_l = L$ / v * (hr /3600 sec) = (250 ft / 0.024 ft/sec) (hr /3600 sec) = 2.89 hr

6.1.3 Time to Minimum LDB Detectable Level, t_2

The amount of leakage required to obtain a detectible volume in a LDB, cell sump, or pit sump is determined using the physical dimensions and other characteristics of the LDBs or sumps.

Each of the eight LAB LDBs consists of a horizontal NPS 8 Schedule 40 pipe with a NPS 8 cap on either end (Input 4.3). A detectable leakage volume is created by a 2-inch weir located in the middle of the LDB; the detectable leakage volume is the partial volume sum of the 11-inch horizontal pipe section (created by the weir), the straight portion of the cap, and the curved portion of the cap.

The partial volume of the horizontal pipe can be determined by the following equations (Appendix E of Reference 8.8.)

$$\Phi = \arccos\left(\frac{R-h}{R}\right) \qquad \text{(Equation 6.8)}$$

Where:
Φ = the angle (in radians) formed by the edge of the fluid free surface and the vertical plane at the cylinder centerline
R = (1/2) d_o = inside pipe radius, ft
h = detectable liquid height, ft

Substituting the values into Equation 6.8,

R = (1/2) * (7.981 inch) *(ft/12 inch) = 0.3325 ft
h = 0.5 in * (ft/12 inch) = 0.0417 ft (Assumption 4.21)
d_o = (7.981 inch) *(ft/12 inch) = 0.6651 ft (8" Sch. 40 pipe, Reference 4.8, p. B-17)

$$\Phi = \arccos\left(\frac{0.3325 - 0.0417}{0.3325}\right) = 0.506 \text{ rad or } 29 \text{ deg}$$

The partial pipe volume equation is used with the fluid free surface angle.

$$\forall_p = R^2 l\left[\left(\frac{\pi\Phi^{\circ}}{180}\right) - \sin\Phi\cos\Phi\right] \qquad \text{(Equation 6.9)}$$

Where:
$\forall_p$ = partial volume of the pipe, ft^3
$R = (1/2)\, d_o$ = inside pipe radius, ft
l = cylindrical length of the detectable volume, ft
Φ° = the free surface angle, deg

Substituting the values into Equation 6.9,

l = 11 inch (see Input 4.3) + 2 inch of horizontal-section cap [(1)] = 13 inch (1.0833 ft)
Φ° = free surface angle = 29 deg

$$\forall_p = 0.3325^2 \cdot 1.0833\left[\left(\frac{\pi \cdot 29}{180}\right) - \sin(29)\cos(29)\right]$$

= 0.0098 ft^3 (or 0.0098 ft^3 * 7.48 gal/ $ft^3 \cong$ 0.073 gal

The partial volume of the horizontal cap can be determined by the following equation (Appendix D of Ref. 8.8.)

$$\forall_h = \frac{\pi\, h^2(1.5d_o - h)}{12} \qquad \text{(Equation 6.10)}$$

Where:
h = 0.5 inch (0.0417 ft) (Assumption 4.21)
R = 0.3325 ft

Substituting the values into Equation 6.10,

$$\forall_h = \frac{\pi\,(0.0417\ ft)^2[1.5 \cdot 0.6651\ ft - 0.0417\ ft]}{12} = 4.352 \times 10^{-4}\ ft^3\ (3.26 \times 10^{-3}\ gal)$$

The total volume required to produce a minimum detectable level is thus

$\forall_{total} = \forall_p + \forall_h$ = 0.073 gal + 3.26 x 10^{-3} gal $\cong$ 0.076 *gal*

The time required to obtain a detectible volume in a LDB is given by:

$$t_2 = \forall / Q \qquad \text{(Equation 6.11)}$$

t_2 = (0.076 gal) * (hr / 0.1 gal) = 0.76 hr

6.1.4 Total LDB Detection Time, t_{total}

The total detection time is the sum of the previously enumerated pipe wetting, transport, and LDB filling delays, in equation form:

$$t_{total} = t_1 + t_2 + t_3$$

$$t_{total} = 2.89 \text{ hr} + 0.76 \text{ hr} + 12.5 \text{ hr} \cong 16.2 \text{ hr}$$

The resultant value is less than 24 hours for a minimum leak rate of 0.1 gph, thus satisfying the permit requirement for leakage detection for LDBs.

6.2 Vessel Cell Sumps

The succeeding analysis determines the time to detect a leakage in the C3 and C5 vessel cells (RLD-SUMP-00041 and RLD-SUMP-00042).

The time to detect a leak traveling across a cell or pit floor liner is composed of two time components: t_1 and t_2. The first time component, t_1, is the time for the leak to reach the leak detection device (Equation 6.7). The second time component, t_2, is the time to fill the leak detection device to a level that can be detected by the associated leak detection device based on the minimum leak rate.

For each leak detection device, "t_2" is calculated by dividing the minimum detectable volume by the volumetric flow rate of the leak. The time component "t_1" is calculated using the methodology from Reference 8.10 (rivulet flow). The elapsed time to detect a leak, t_{total}, is the sum of these two time components: $t_{total} = t_1 + t_2$. If the total time is less than 24 hours for a flow rate of 0.1 gph for all leak detection devices, the permit condition is met.

Calculation of "t_1" for each leak detection device within a set (e.g. "t_1" for each pit sump) is not necessary; using the longest path length bounds the "time to detection." As indicated in Assumption 4.17, the rivulet leak travel distance is computed by summing the distance along the walls: adding the north-south wall distance to the east-west wall distance.

6.2.1 Leakage Travel Time to Cell Sump, t_1

The time required for the leakage flow to travel from its point of origin to the cell sump under rivulet flow conditions is calculated. Note: most of the units within this section are in grams, centimeters in order to stay consistent with Reference 8.10. The methodology in this section is as follows.

The "time to detection" is determined using the average leak velocity at the minimum leak rate of 0.1 gph. The methodology shown in Reference 8.10 for rivulet flow forms the basis for the rivulet leak velocity calculation. The method requires the calculation of the angle of inclination for the rivulet, the capillary constant, and the rivulet cross sectional area. To be consistent with the units in Ref. 8.10, most units within this section are presented in grams (g) and centimeters (cm).

The angle of inclination, α, which is the slope of the floor with respect to a vertical plane, as shown in Figure 2, is determined using trigonometry as shown with the following equation

$$\alpha = 90^\circ - \tan^{-1}(S_o) \qquad \text{(Equation 6.12)}$$

Where:

α = angle of inclination, degrees
S_o = slope of floor, ft/ft = 0.01 (1%) (Input 4.4)

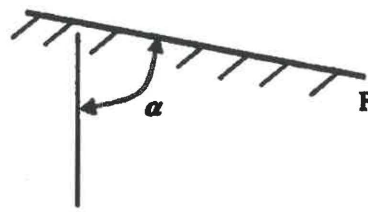


Figure 2. Inclination Angle for Rivulet Flow

From Input 4.4, S_o = 1/100 = 0.01. Substituting the values in the above Equation 6.12, we have:

$\alpha = 90° - \tan^{-1}(0.01) = 90° - 0.5729° = 89.427°$

Calculate the capillary constant, a

The capillary constant, the basis for the dimensionless width, is defined below (Reference 8.10, p. 973, equation following equation 9):

$$a = \sqrt{\gamma / \rho g \sin\alpha} \qquad \text{(Equation 6.13)}$$

where:
a = capillary constant, cm
γ = liquid surface tension, dyne/cm (= g/sec^2)
ρ = liquid density, g/cm^3
g = gravitational acceleration = 980.7 cm/sec^2

The liquid properties are based on water at 100 °F (Input 4.11) are as follows:

γ = 69.96 g/sec^2
ρ = 0.993 g/cm^3
α = 89.427°

Substituting these in Equation 6.13 above, we have:

$$a = \sqrt{\frac{69.96 \;\; g/\sec^2}{0.993 \;\; g/cm^3 \times 980.7 \;\; cm/s^2 \times \sin(89.427°)}}$$

a = 0.268 cm

Calculate the rivulet depth

For the wide flat rivulet, its depth is determined based on (Reference 8.10, 2nd equation following equation 25):

$$Y_0 = 2\sin\left(\theta/2\right) \qquad \text{(Equation 6.14)}$$

where:
Y_0 = dimensionless depth and is defined in Reference 8.10, definitions following equation 17 (2nd line following equation 17), as:

$$Y_0 = \eta_0 / a$$

where:
η_0 = rivulet depth, cm
θ = contact angle, degrees

Solving for η_0 yields:

$$\eta_0 = 2a\sin(\theta/2) \quad \text{(Equation 6.15)}$$

From Assumption 4.16 we have $\theta = 6°$. Substituting this in Equation 6.15 results in:
$\eta_0 = 2 \times 0.268 \text{ cm} \times \sin(6°/2)$
$\eta_0 = 0.02805 \text{ cm}$

Calculate the width of the rivulet

The rivulet width, l, is determined from Reference 8.10, Equation 27:

$$\frac{\mu Q \tan\alpha}{l\gamma}\sqrt{\frac{\rho g \sin\alpha}{\gamma}} = \frac{8}{3}\sin^3(\theta/2)$$

Rearranging the above equation to solve for l:

$$l = \frac{3\mu Q \tan\alpha}{8\gamma \sin^3(\theta/2)}\sqrt{\frac{\rho g \sin\alpha}{\gamma}} \quad \text{(Equation 6.16)}$$

where:
l = rivulet width, cm
μ = dynamic liquid viscosity, g/cm.sec
Q = volume flow, cm^3/sec

Substituting the values below into Equation 6.16 gives;

$\alpha = 89.427°$	
$\gamma = 69.96$ g/sec^2	(Input 4.11)
$\mu = 0.00681$ g/cm.sec	(Input 4.11)
$\rho = 0.993$ g/cm^3	(Input 4.11)
$g = 980.7$ cm/sec^2	
$\theta = 6$ degrees	(Assumption 4.16)
$Q = 0.1$ gph $= 0.1052$ cm^3 /sec	

$$l = \frac{3\cdot(0.0068\,g/cm\,sec)\cdot(0.1052\,cm^3/sec)\cdot\tan(89.427deg)}{8\cdot(69.96\,g/sec^2)\cdot(\sin^3(6deg/2))}\sqrt{\frac{(0.993\,g/cm^3)\cdot(980.7\,cm/sec^2)\cdot\sin(89.427deg)}{(69.96\,g/sec^2)}}$$

$l = 9.99$ cm

The rivulet cross-sectional area is determined using the approximation that the wide flat rivulet is rectangular (rectangular cross section for the wide flat rivulet is noted in Ref. 8.10, p. 975), thus the area is defined as:

$$A = l\cdot\eta_0 \quad \text{(Equation 6.17)}$$

Where:

A = rivulet area, cm^2

Substituting the values for l and η_0:

$$A = 9.99\,cm \cdot 0.02805\ cm$$
$$A = 0.2802\ \text{cm}^2$$

With the volumetric flow rate known, the rivulet velocity, v, can be calculated from rearranging Equation 6.3:

$v = Q / A$ (Equation 6.18)

Where:

$Q = 0.1$ gph $= 0.1052$ cm^3/sec

$$v = \frac{0.1052\ cm^3/\text{sec}}{0.2802\ cm^2}$$

$v = 0.3754$ cm/sec

Calculate Dimensionless Flow and Rivulet Width

The method used in this calculation is from Reference 8.10 and is based on a dimensionless flow rate, Ω, and dimensionless stream width, P, along with other parameters. The following equations for the dimensionless parameters, P and Ω, are used to calculate these values (from Reference 8.10, p. 974, equation following equation 17 and the 3rd equation following equation 17, respectively).

$P = l / a$ (Equation 6.19, Reference 8.10, equation 17)

where:

P = dimensionless width
l = rivulet width, cm
a = capillary constant, cm

The dimensionless rivulet width (P) is calculated using Equation 6.19 as follows:

P = 9.99 cm / 0.268 cm = 37.3

The Equation for Ω is defined in Reference 8.10 as:

$$\Omega = \frac{\mu \rho g Q}{\gamma^2} \cdot \tan\alpha \cdot \sin\alpha$$ (Equation 6.20, Reference 8.10, equation 17)

where:

Ω = dimensionless flow rate
Q = volumetric flow rate, cm^3/sec
γ = liquid surface tension, dyne/cm (= g/sec^2)
ρ = liquid density, g/cm^3
g = gravitational acceleration = 980.7 cm/sec^2
α = angle of inclination (slope), degrees

The dimensionless flow rate (Ω) is calculated using Equation 6.18 and the values below:

$\alpha = 89.427°$

$\gamma = 69.96$ g/sec^2 (Assumption 4.4)
$\mu = 0.00681$ g/cm.sec (Assumption 4.4)
$\rho = 0.993$ g/cm^3 (Assumption 4.4)
$g = 980.7$ cm/sec^2
$Q = 0.1$ gph $= 0.1052$ cm^3/sec

$$\Omega = \frac{0.00681\ g/cm.\sec \times 0.993\ g/cm^3 \times 980.7\ cm/\sec^2 \times 0.1052\ cm^3/\sec}{69.96^2\ g/\sec^2} \cdot \tan(89.427°) \cdot \sin(89.427°)$$

$\Omega = 0.014$

From Reference 8.10 (p. 977, Figure 5), the point at the coordinates of $\Omega = 0.014$ and P = 37.3 falls right on the asymptotic solutions for a wide rivulet close to $\theta = 5$ degrees. This confirms the assumption for a wide rivulet flow (Assumption 4.15).

Time to Flow to Sump

The time to sump is calculated for the sump with the longest rivulet travel distance. The distances from Input 4.1 are:

C3 cell (Rm A-B003): 13 ft + 27.25 ft = 40.25 ft
C5 cell (Rm A-B004): 21 ft + 29 ft = 50 ft

For the longest rivulet travel distance (the C5 cell), the time to flow to sump is determined from

$t_1 = L / v / 3600\ sec/\ hr$ (Equation 6.7)

Where:
L = path length, = 50 ft (1,524 cm)
v = 0.3754 cm/sec (previously calculated)

$$t_1 = \frac{1{,}524 cm}{0.3754 cm/s} \cdot \frac{hr}{3600 s}$$

t_1 = 1.13 hrs

6.2.2 Time to Obtain a Detectable Sump Volume, t_2

The time to fill the detection device, t_2, is calculated from the following equation

$t_2 = \forall / Q$ (Equation 6.11)

Where:
t_2 = time to fill the, hr
$\forall$ = volume to detection, gallons
Q = leak rate, 0.1 gph

The volumes of the different detecting devices are determined using the methodology shown below.

6.2.2.1 Detectable Volume of Round Sumps

A sketch is shown in Figure 1 to graphically depict the referenced dimensions for the round sumps with a 2:1 semi-ellipsoidal bottom head.

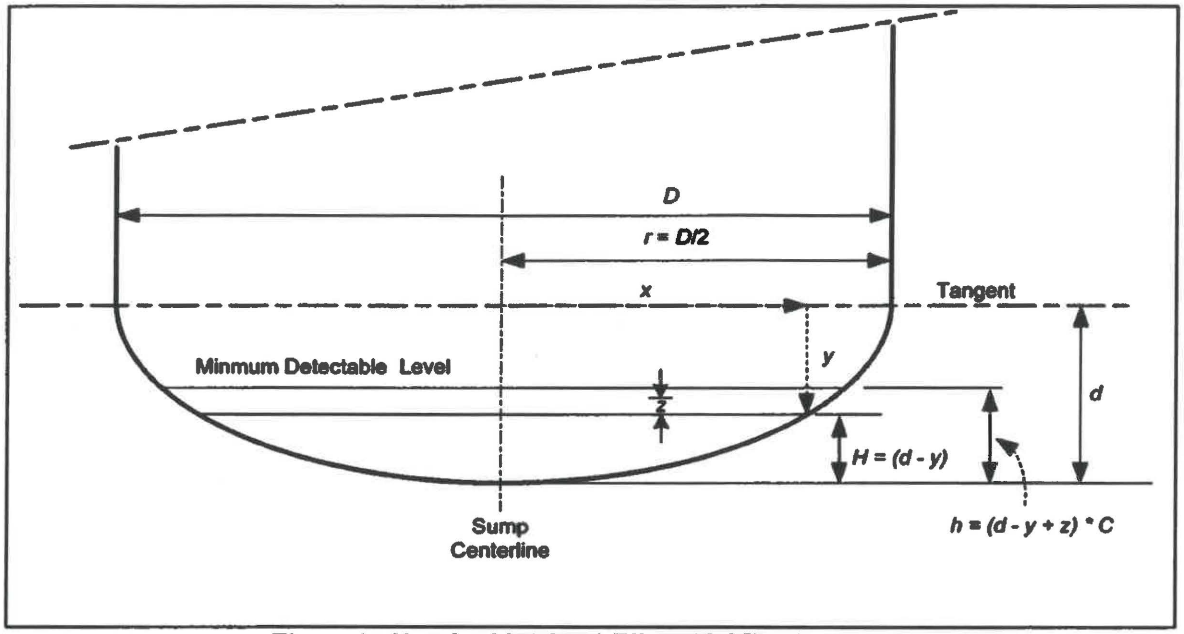


Figure 1. Sketch of 2:1 Semi-Ellipsoidal Head

The overall height of the semi-ellipsoidal head, *d*, is defined by (Ref. 8.25, p.5, equation 6-1):

$$d = 0.25 * D \qquad \text{(Equation 6.21)}$$

Where:
d = height of semi-ellipsoidal head (tangent to bottom of head), in
D = inside diameter of semi-ellipsoidal head, in

The level indication for detecting a leak in the sump is assumed to have installation requirements noted in Assumption 4.20. Off-center level indication means that the liquid level needs to rise up the curvature of the sump (2:1 semi ellipsoidal head, Assumption 4.23) for detection. The height requirement for this installation is determined by calculating:

- the height of the ellipsoidal head at an off-center point, and
- adding the minimum accuracy of the instrument.

The height of the ellipsoidal head at an off-center point, *y*, is calculated using the following equation from Appendix B of Reference 8.25.

$$y = \frac{1}{2}\sqrt{r^2 - x^2} \qquad \text{(Equation 6.22)}$$

Where:
y = vertical distance from top (tangent) of semi-ellipsoidal head to off-center point, inch
r = inside radius of ellipsoidal head, inch
x = horizontal distance from center of semi-ellipsoidal head to off-center point, inch

The height requirement for minimum accuracy of the instrument, *h*, is then calculated from the following equation

$$h = (d - y + z) * C$$ (Equation 6.23)

Where:
h = minimum height of liquid for leak detection in semi-ellipsoidal head, inch
d = height of semi-ellipsoidal head, inch
y = vertical distance from top of semi-ellipsoidal head to off-center point, inch
z = instrument accuracy, inch
C = margin, %

The minimum detectable volume in the sump is determined from the formula (Ref. 8.25, Equation 6-3, p.5) that relates depth in the ellipsoidal head to volume

$$\forall = \pi D h^2 \left[1 - \frac{4h}{3D}\right]$$ (Equation 6.24)

Where:
$\forall$ = volume based on the liquid level h, cubic inches
h = minimum height of liquid for leak detection in sump, in
D = sump inside diameter, in

$\forall$ in cubic inches is then converted to gallons with a conversion factor.

6.2.2.2 Detectable Volume of Leak Detection Boxes

The amount of leakage required to obtain a detectible volume in a LDB, cell sump, or pit sump is determined using the physical dimensions and other characteristics of the LDBs or sumps.

Each of the eight LAB LDBs consists of a horizontal NPS 8 Schedule 40 pipe with a NPS 8 cap on either end (Input 4.3). A detectable leakage volume is created by a 2-inch weir located in the middle of the LDB; the detectable leakage volume is the partial volume sum of the 11-inch horizontal pipe section (created by the weir), the straight portion of the cap, and the curved portion of the cap.

The partial volume of the horizontal pipe can be determined by the following equations (Appendix E of Ref. 8.8)

$$\Phi = \arccos\left(\frac{R - h}{R}\right)$$ (Equation 6.25)

Where:
Φ = the angle (in radians) formed by the edge of the fluid free surface and the vertical plane at the cylinder centerline
$R = (1/2)\, d_o$ = inside pipe radius, ft
h = detectable liquid height, ft

Thermal dispersion instrumentation exists for all leak detection boxes (Input 4.10), therefore the detectable liquid height is set equal to the thermal dispersion accuracy.

$$\forall_p = R^2 l \left[\left(\frac{\pi \Phi^{\circ}}{180}\right) - \sin\Phi \cos\Phi\right]$$ (Equation 6.26)

Where:
$\forall_p$ = partial volume of the pipe, ft^3
$R = (1/2)\, d_o$ = inside pipe radius, ft
l = cylindrical length of the detectable volume, ft

Φ° = the free surface angle, deg

The partial volume of the horizontal cap can be determined by the following equation (Appendix D of Ref. 8.8)

$$\forall_h = \frac{\pi h^2 (1.5 d_o - h)}{12} \quad \text{(Equation 6.27)}$$

The total volume is then just the sum of the individual volumes: $\forall = \forall_p + \forall_h$

6.2.2.3 Detectable Volume of Pump Pit Sumps

The pump pit sumps are rectangular in nature (Input 4.6) and the detectable volume is calculated with

$$\forall = L \times W \times h \quad \text{(Equation 6.28)}$$

Where:
L = length of the trough, in
W = width of the trough, in
h = detectable liquid height, in

$\forall$ is in cubic inches, it is then converted to gallons with a conversion factor.

Radar detection exists for the rectangular pit sumps (Input 4.10), therefore the detectable liquid height is set to equal the radar accuracy.

6.2.3 Time to Obtain a Detectable Vessel Cell Sump Volume, t_2

The curved head portion of the pipe cap that is used for the cell sump is approximated by a 2:1 semi-ellipsoidal head (Assumption 4.23). These round sumps contain the same dimensions; cap is NPS 30 (Input 4.6). The overall height of the 2:1 semi-ellipsoidal head, d, is defined as follows:

$d = 0.25 * D$ (Equation 6.21)
$D = 29.25$ inch (Reference 8.18, p. B-19 & Input 4.6)
$d = 0.25 * 29.25 inch$
$d = 7.3$ inch

The height from the top (tangent) of the semi-ellipsoidal head to a point 8" off-center is determined by

$$y = \frac{1}{2}\sqrt{r^2 - x^2} \quad \text{(Equation 6.22)}$$

Where:
$r = D/2 = 14.6$ inch
$x = 8$ inch (Assumption 4.20)

$$y = \frac{1}{2}\sqrt{14.6^2 - 8^2}$$

$y = 6.1$ inch

The height requirement for minimum accuracy of the instrument, h, is then calculated from the following equation:

$h = (d - y + z) * C$ (Equation 6.23)

Where:

$d = 7.3$ inch

$y = 6.1$ inch

$z = 0.5$ inch (Input 4.10)

$C = 1.10$ (Assumption 4.20)

$h = (7.3inch - 6.1inch + 0.5inch) * 1.1$

$h = 1.87$ inch

The minimum detectable volume in the sump is then calculated by

$$\forall = \pi D h^2 \left[1 - \frac{4h}{3D}\right]$$ (Equation 6.24)

Where:

$D = 29.25$ inch

$h = 1.87$ inch

$$\forall = \pi(29.25in)(1.87in)^2 \left[1 - \frac{4(1.87in)}{3(29.25in)}\right]$$

$\forall = 294\ in^3 = 1.27$ gal

The time for sump collection, t_2, is calculated from

$t_2 = \forall / Q$ (Equation 6.11)

$t_2 = 1.27$ gallons / 0.1 gph = 12.7 hrs

6.2.4 Total Detection Time, t_{total}

The total detection time is the sum of the previously enumerated transport time and cell sump filling time:

$t_{total} = t_1 + t_2$

$t_{total} = 1.13$ hr + 12.7 hr $\cong$ 13.8 hr

6.3 Pit and Piping Sumps

The succeeding analysis determines the time to detect a leak in the C3/C5 Pump Pits and C5 Piping Pit.

6.3.1 Leakage Travel Time to Pit Sump, t_1

The time required for the leakage flow to travel from its point of origin to its respective pit sump is calculated by using the velocity for the rivulet determined in Section 6.2.1. The velocity can be used because the geometry (e.g. angle of inclination) and fluid properties are considered to be the same, thus the rivulet velocity will be the same.

The rivulet travel distances are determined from Input 4.2 and summarized below:
C3 Pump Pit (Rm No. A-B002): 13 ft + 14.46 ft = 27.46 ft
C5 Pump Pit (south, Rm No. A-B007): 6.75 ft + 6.42 ft = 13.17 ft
C5 Piping Pit (Rm No. A-B006): 6.75 ft + 14 ft = 20.75 ft
C5 Pump Pit (north, Rm No. A-B005): 6.75 ft + 6.42 ft = 13.17 ft

The longest path is 27.46 ft and this will be used in the calculation. The estimated time for the rivulet to travel is determined with

$t_1 = L / v / 3600 \ sec/\ hr$ (Equation 6.7)

Where:
L = 27.46 ft (837 cm)
v = 0.3754 cm/sec (Section 6.2.1)

$$t_1 = \frac{837 cm}{0.3754 cm/\sec} \cdot \frac{hr}{3600 \sec}$$

t_1 = 0.62 hr

6.3.2 Time to Obtain a Detectable Pit Sump Volume, t_2

Based on inspection of Input 4.7, the two largest pit sumps are in the C3 Pump Pit or the C5 Piping Pit. These sumps are identical in size. The detectable volume in the sump is determined from

$\forall = L \times W \times h$ (Equation 6.28)

Where:
h = 0.5 inch (Input 4.10)
L = 2 ft (Table 4.4)
W = 2.5 ft (Table 4.4)

$\forall$ = 2.0 ft x 2.5 ft x 0.5 in x (144 in^2/ft^2) x (gal/231 in^3) ≅ 1.6 gal

The time to detect this volume is

$t_2 = \forall / Q$ (Equation 6.11)

t_2 = (1.6 gal) * (hr / 0.1 gal) = 16.0 hr

6.3.3 Total Pit Sump Detection Time, t_{total}

The total detection time is the sum of the previously enumerated transport and pit sump filling delays:

$t_{total} = t_1 + t_2$

t_{total} = 0.62 hr + 16.0 hr ≅ 16.6 hr

The resultant value is less than 24 hr, therefore the permit condition is satisfied for the pit sumps.

7 Results and Conclusions

The results of this analysis are compiled in Table 7.1. This table is a comprehensive list of all leak detection devices considered in this analysis and demonstrates that the LAB LDBs, cell sumps, and pit sumps are capable of detecting a permit condition leakage rate of 0.1 gal/hr within a 24-hour period, thus the permit condition for LAB is satisfied.

Table 7.1 Analytical Laboratory Facility, Time to Leak Detection Capability

Description of Leak Detection Area	Sump or LDB	Time to Fill t_2 (hr) (Sect. 6.1.3, 6.2.2, 6.3.2)	Time to Sump t_1 (hr) (Sect. 6.1.2, 6.2.1, 6.3.1)	Time to Wet t_3 (hr) (Sect. 6.1.1)	Time to Detect t_{total} (hr)
C3 Rad Lab Sink Collection Header	RLD-LDB-00005	0.76	2.89	12.5	16.2
C5 Hotcell Collection Header to RLD-VSL-00165	RLD-LDB-00002	0.76	2.89	12.5	16.2
C3 Transfer Line to C5 RLD-VSL-00165	RLD-LDB-00004	0.76	2.89	12.5	16.2
C3 PVA Drain Header	RLD-LDB-00006	0.76	2.89	12.5	16.2
C3 Sample Receiving/ Shipping Drain Header	RLD-LDB-00008	0.76	2.89	12.5	16.2
C5 Glove Box Header	RLD-LDB-00009	0.76	2.89	12.5	16.2
C3 Spare Collection Header (RLD-WU-02301-S32B-02)	RLD-LDB-00011	0.76	2.89	12.5	16.2
C3 Maintenance Drain Header	RLD-LDB-00007	0.76	2.89	12.5	16.2
C5 Vessel Cell, A-B004	RLD-SUMP-00042	12.7	1.13	n/a	13.8
C3 Vessel Cell, A-B003	RLD-SUMP-00041	12.7	1.13	n/a	13.8
C3 Pump Pit, A-B003	RLD-SUMP-00045	16.0	0.62	n/a	16.6
C5 Pump Pit, A-B007	RLD-SUMP-00043A	16.0	0.62	n/a	16.6
C5 Pump Pit, A-B005	RLD-SUMP-00043B	16.0	0.62	n/a	16.6
C5 Piping Pit, A-B006	RLD-SUMP-00044	16.0	0.62	n/a	16.6

8 References

8.1 24590-WTP-DB-ENG-01-001, Rev. 7, Basis of Design

8.2 WA 7890008967. Dangerous Waste Permit (DWP). Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste at the Hanford Waste Treatment and Immobilization Plant.

8.3 24590-LAB-PER-M-02-002, Rev. 2, "Sump Data for LAB Facility," 8/20/2004

8.4 WAC 173-303-640. Tank Systems, Section 4, Containment and Detection of Releases in Dangerous Waste Regulations, Washington State Administrative Code.

8.5 Roberson, John A. and Clayton T. Crow, Engineering Fluid Mechanics, Houghton Mifflin Co., Boston, MA, 1975

8.6 24590-WTP-GPG-M-033, Rev. 4, Fire Water Floor Drain System

8.7 24590-WTP-M6C-M11T-00004, Rev. 1, Supporting Calculation for Fire Water Floor Drain System Design Guide

8.8 Moss, D., Pressure Vessel Design Manual, Gulf Publishing Co., Houston, TX (1987).

8.9 R.G. Hudson, The Engineers' Manual, John Wiley & Sons, 2nd Edition

8.10 Towell, G.D. and Rothfeld, L.B. 1966. *Hydrodynamics of Rivulet Flow, AIChE Journal,* Vol. 12, No. 5, p 972-980

8.11 Product Brochure for FCI level switch: http://www.fluidcomponents.com/products/level-switches/flt93-series-level-switches/flt93f-level-switch

8.12 24590-WTP-3PS-JL10-T0002, Rev. 0, Engineering Specification for Radar Level Measurement

8.13 2009 ASHRAE Handbook – Fundamentals

8.14 24590-LAB-MX-RLD-00001, Rev. 1, Equipment Assembly - LAB Radioactive Liquid Waste Disposal System Secondary Containment Leak Detection Box

8.15 24590-LAB-P1-60-00007, Rev. 3, Analytical Laboratory General Arrangement Plan at EL (-)19'-2", Section E-E, F-F & G-G

8.16 CCN 093156, E-Mail Message from Danielle Mathews to Roosevelt Molina, dated August 20, 2004, Subject: Fluor Daniel Northwest Calculation No. W314-P-039, Encasement Leak Detection, October 19, 1998

8.17 24590-QL-BPO-DD00-00001-45-00033, Rev. B, DRAWING - ANALYTICAL LABORATORY C5 CELL SUMPS

8.18 "Flow of Fluids through Valves, Fittings, and Pipe", Technical Paper No. 410, Crane Co., 19

8.19 P&IDs

8.19.1 24590-LAB-M6-RLD-00001001, Rev. 1, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C5 COLLECTION AND TRANSFER RLD-VSL-00165

8.19.2 24590-LAB-M6-RLD-00001002, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C5 COLLECTION AND TRANSFER RLD-PMP-00183A

8.19.3 24590-LAB-M6-RLD-00001003, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C5 COLLECTION AND TRANSFER RLD-PMP-00183B

8.19.4 24590-LAB-M6-RLD-00001004, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C5 COLLECTION AND TRANSFER VALVE PIT

8.19.5 24590-LAB-M6-RLD-00002001, Rev. 1, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3 COLLECTION & TRANSFER RLD-VSL-00164

8.19.6 24590-LAB-M6-RLD-00002003, Rev. 2, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3 COLLECTION & TRANSFER RLD-PMP-00182A/B

8.19.7 24590-LAB-M6-RLD-00006001, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3 RAD LAB COLLECTION

8.19.8 24590-LAB-M6-RLD-00006002, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3 RAD LAB COLLECTION

8.19.9 24590-LAB-M6-RLD-00006003, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3 RAD LAB COLLECTION

8.19.10 24590-LAB-M6-RLD-00007001, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3 LEAK DETECTION BOXES

8.19.11 24590-LAB-M6-RLD-00008001, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM - C5 LEAK DETECTION BOXES

8.19.12 24590-LAB-M6-RLD-00008002, Rev. 0, P&ID - LAB RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C5 DRAIN COLLECTION HEADERS

8.20 Piping Isometrics

8.20.1 24590-LAB-P3-RLD-WU02269051, REV. 1, RLD-WU-02269-W11B-4 - LAB FACILITY ISOMETRIC

8.20.2 24590-LAB-P3-RLD-WU02269052, REV. 1, RLD-WU-02269-W11B-4 - LAB FACILITY ISOMETRIC

8.20.3 24590-LAB-P3-RLD-WU02269053, REV. 1, RLD-WU-02269-W11B-4 - LAB FACILITY ISOMETRIC

8.20.4 24590-LAB-P3-RLD-WU02198051, REV. 1, RLD-WU-02198-W11B-4 - LAB FACILITY ISOMETRIC

8.20.5 24590-LAB-P3-RLD-WU02198052, REV. 1, RLD-WU-02198-W11B-6 - LAB FACILITY ISOMETRIC

8.20.6 24590-LAB-P3-RLD-WU02198053, REV. 1, RLD-WU-02198-W11B-6 - LAB FACILITY ISOMETRIC

8.20.7 24590-LAB-P3-RLD-WU02198054, REV. 1, RLD-WU-02198-W11B-6 - LAB FACILITY ISOMETRIC

8.20.8 24590-LAB-P3-RLD-WU02198055, REV. 2, RLD-WU-02198-W11B-6 - LAB FACILITY ISOMETRIC

8.20.9 24590-LAB-P3-RLD-WU02227051, REV. 0, RLD-WU-02227-W11B-6 - LAB FACILITY ISOMETRIC

8.20.10 24590-LAB-P3-RLD-WU02227052, REV. 0, RLD-WU-02227-W11B-6 - LAB FACILITY ISOMETRIC

8.20.11 24590-LAB-P3-RLD-WU02227053, REV. 1, RLD-WU-02227-W11B-6 - LAB FACILITY ISOMETRIC

8.20.12 24590-LAB-P3-RLD-WU02227054, REV. 0, RLD-WU-02227-W11B-6 - LAB FACILITY ISOMETRIC

8.20.13 24590-LAB-P3-RLD-WU02227055, REV. 1, RLD-WU-02227-W11B-6 - LAB FACILITY ISOMETRIC

8.20.14 24590-LAB-P3-RLD-WU02249001, REV. 1, RLD-WU-02249-S11E-1 - LAB FACILITY ISOMETRIC

8.20.15 24590-LAB-P3-RLD-WU02289051, REV. 3, RLD-WU-02289-S32B-6 - LAB FACILITY ISOMETRIC

8.20.16 24590-LAB-P3-RLD-WU02300052, REV. 1, RLD-WU-02300-S32B-10 - LAB FACILITY ISOMETRIC

8.20.17 24590-LAB-P3-RLD-WU02300053, REV. 1, RLD-WU-02300-S32B-10 - LAB FACILITY ISOMETRIC

8.20.18 24590-LAB-P3-RLD-WU02300054, REV. 0, RLD-WU-02300-S32B-10 - LAB FACILITY ISOMETRIC

8.20.19 24590-LAB-P3-RLD-WU02250001, REV. 1, RLD-WU-02250-S11E-1 - LAB FACILITY ISOMETRIC

8.21 Piping Material Class Sheets

8.21.1 24590-WTP-3PB-P000-TW11B, Rev 21, PIPING MATERIAL CLASSIFICATION PIPE CLASS W11B

8.21.2 24590-WTP-3PB-P000-TS32B, Rev 26, PIPING MATERIAL CLASSIFICATION PIPE CLASS S32B

8.21.3 24590-WTP-3PB-P000-TS11E, Rev 12, PIPING MATERIAL CLASSIFICATION PIPE CLASS S11E

8.22 Instrument Data sheets for Thermal Level Switches

8.22.1 24590-LAB-JLD-RLD-61180, Rev. 3, RLD-LSH-6118 - THERMAL LEVEL SWITCH

8.22.2 24590-LAB-JLD-RLD-61200, Rev. 3, RLD-LSH-6120 - THERMAL LEVEL SWITCH

8.22.3 24590-LAB-JLD-RLD-62150, Rev. 3, RLD-LSH-6215 - THERMAL LEVEL SWITCH

8.22.4 24590-LAB-JLD-RLD-67010, Rev. 3, RLD-LSH-6701 - THERMAL LEVEL SWITCH

8.22.5 24590-LAB-JLD-RLD-67020, Rev. 3, RLD-LSH-6702 - THERMAL LEVEL SWITCH

8.22.6 24590-LAB-JLD-RLD-67030, Rev. 3, RLD-LSH-6703 - THERMAL LEVEL SWITCH

8.22.7 24590-LAB-JLD-RLD-67040, Rev. 3, RLD-LSH-6704 - THERMAL LEVEL SWITCH

8.22.8 24590-LAB-JLD-RLD-68010, Rev. 3, RLD-LSH-6801 - THERMAL LEVEL SWITCH

8.23 Leak Detection Boxes

8.23.1 24590-CM-POA-PY00-00003-04-00009, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.23.2 24590-CM-POA-PY00-00003-04-00010, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.23.3 24590-CM-POA-PY00-00003-04-00011, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.23.4 24590-CM-POA-PY00-00003-04-00012, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.23.5 24590-CM-POA-PY00-00003-04-00013, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.23.6 24590-CM-POA-PY00-00003-04-00014, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.23.7 24590-CM-POA-PY00-00003-04-00015, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.23.8 24590-CM-POA-PY00-00003-04-00016, Rev. D, DRAWING - LAB SECONDARY CONTAINMENT LEAK DETECTION BOX VESSEL WELDMENTS

8.24 Civil drawings

8.24.1 24590-LAB-DB-S13T-00018, Rev. 8, Analytical Laboratory C5 Cell Structural Concrete Forming Sections and Details

8.24.2 24590-LAB-DB-S13T-00019, Rev. 4, Analytical Laboratory C5 Cell Structural Concrete Forming Plans and Sections

8.24.3 24590-LAB-DB-S13T-00020, Rev. 2, Analytical Laboratory C2 Vault and C3 Cell Structural Concrete Forming Plans and Sections

8.24.4 24590-LAB-DB-S13T-00021, Rev. 2, Analytical Laboratory C2 Vault and C3 Cell Structural Concrete Forming Sections and Details

8.24.5 24590-LAB-DD-S13T-00091, Rev. 0, ANALYTICAL LABORATORY C5 CELL CONCRETE EMBEDMENT GRILLAGE PLANS AND SECTIONS

8.24.6 24590-LAB-DD-S13T-00092, Rev. 0, ANALYTICAL LABORATORY C5 CELL CONCRETE EMBEDMENT GRILLAGE SECTIONS AND DETAILS

8.24.7 24590-LAB-DD-S13T-00093, Rev. 0, ANALYTICAL LABORATORY C3 CELL CONCRETE EMBEDMENT GRILLAGE PLANS AND SECTIONS

8.24.8 24590-LAB-DD-S13T-00094, Rev. 0, ANALYTICAL LABORATORY C3 CELL CONCRETE EMBEDMENT GRILLAGE SECTIONS AND DETAILS

8.25 24590-WTP-GPG-M-019, Rev. 4, Vessel Sizing

8.26 24590-CD-POA-PY00-00009-04-00001, Rev. B, Drawing – Removable Weir Assembly

8.27 N/A

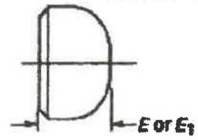
8.28 CCN 097799, Leak Detection Capability Scoping -Statement, Revision 6, 08/19/2004

8.29 24590-LAB-M6C-RLD-00027, Rev. 1, LAB MINIMUM LEAK RATE, DETECTION CAPABILITIES FOR CELL SUMPS, PIT SUMPS, AND LEAK DETECTION BOXES

Attachment A Pipe Cap Dimensions

ASME B16.9-2007

Table 10 Dimensions of Caps



Nominal Pipe Size (NPS)	Outside Diameter at Bevel	Length, E [Note (1)]	Limiting Wall Thickness for Length, E	Length, E_1 [Note (2)]
½	21.3	25	4.57	25
¾	26.7	25	3.81	25
1	33.4	38	4.57	38
1¼	42.2	38	4.83	38
1½	48.3	38	5.08	38
2	60.3	38	5.59	44
2½	73.0	38	7.11	51
3	88.9	51	7.62	64
3½	101.6	64	8.13	76
4	114.3	64	8.64	76
5	141.3	76	9.65	89
6	168.3	89	10.92	102
8	219.1	102	12.70	127
10	273.0	127	12.70	152
12	323.8	152	12.70	178
14	355.6	165	12.70	191
16	406.4	178	12.70	203
18	457.0	203	12.70	229
20	508.0	229	12.70	254
22	559.0	254	12.70	254
24	610.0	267	12.70	305
26	660.0	267	...	...
28	711.0	267	...	...
30	762.0	267	...	...
32	813.0	267	...	...
34	864.0	267	...	...
36	914.0	267	...	...
38	965.0	305	...	...
40	1 016.0	305	...	...
42	1 067.0	305	...	...
44	1 118.0	343	...	...
46	1 168.0	343	...	...
48	1 219.0	343	...	...

GENERAL NOTES:

(a) All dimensions are in millimeters.

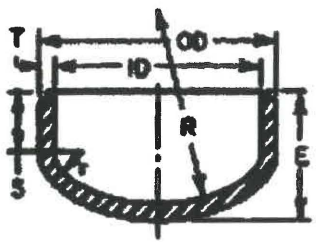
(b) The shape of these caps shall be ellipsoidal and shall conform to the requirements given in the ASME Boiler and Pressure Vessel Code.

NOTES:

(1) Length E applies for thickness not exceeding that given in column "Limiting Wall Thickness for Length, E."

(2) Length E_1 applies for thickness greater than that given in column "Limiting Wall Thickness" for NPS 24 and smaller. For NPS 26 and larger, length E_1 shall be by agreement between the manufacturer and purchaser.

TABLE A2.16 Dimensions of Typical Commercial Butt-Welding Standard Caps (ASME B16.9-1993 Except as Noted)



Nominal pipe size	Outside diameter (OD)	Inside diameter (ID)	Wall thickness *T*	Length *E*	Tangent *S*	Dish radius *R*	Knuckle radius *r*	Pipe schedule number*	Weight (approx) (lb)
½	0.840	0.622	0.109	1	0.74	0.54	0.10	40	0.1
¾	1.050	0.824	0.113	1¼	0.93	0.72	0.14	40	0.2
1	1.315	1.049	0.133	1½	1.10	0.92	0.17	40	0.3
1¼	1.660	1.380	0.140	1½	1.02	1.35	0.23	40	0.4
1½	1.900	1.610	0.145	1½	0.95	1.41	0.27	40	0.4
2	2.375	2.067	0.154	1½	0.83	1.81	0.34	40	0.6
2½	2.875	2.469	0.203	1½	0.68	2.15	0.41	40	0.9
3	3.500	3.068	0.216	2	1.02	2.69	0.51	40	1.4
3½	4.000	3.548	0.226	2½	1.39	3.11	0.59	40	2.1
4	4.500	4.026	0.237	2½	1.26	3.52	0.67	40	2.5
5	5.563	5.047	0.258	3	1.48	4.42	0.84	40	4.2
6	6.625	6.065	0.280	3½	1.70	5.31	1.01	40	6.4
8	8.625	7.981	0.322	4	1.68	6.98	1.33	40	11.3
10	10.750	10.020	0.365	5	2.13	8.77	1.67	40	20.0
12	12.750	12.000	0.375	6	2.62	10.50	2.00	▲†	29.5
14	14.000	13.250	0.375	6½	2.81	11.60	2.21	30	35.3
16	16.000	15.250	0.375	7	2.81	13.34	2.54	30	44.3
18	18.000	17.250	0.375	8	3.31	15.08	2.88	▲†	57
20	20.000	19.250	0.375	9	3.81	16.84	3.21	20	71
22	22.000	21.250	0.375	10	4.31	18.60	3.54	20	86
24	24.000	23.250	0.375	10½	4.31	20.35	3.88	20	102
26	26.000	25.250	0.375	10½	3.81	22.10	4.21	▲†	110
28	28.000	27.250	0.375	10½	3.31	23.85	4.54	▲†	120
30	30.000	29.250	0.375	10½	2.81	25.60	4.88	▲†	125
32	32.000	31.250	0.375	10½	2.31	27.35	5.21	▲†	145
34	34.000	33.250	0.375	10½	1.81	29.10	5.54	▲†	160
36	36.000	35.250	0.375	10½	1.31	30.85	5.88	▲†	175
42	42.000	41.250	0.375	12	1.31	36.10	6.88	▲†	230

* Pipe schedule numbers in accordance with ASME B36.10M.
† This size and thickness does not correspond with any schedule number.

Attachment 2
19-ECD-0022
(25 Pages Excluding Cover Sheet)

Hanford Facility RCRA Permit Modification Notification Form
24590-LAW-PCN-ENV-19-002

Quarter Ending Mar. 31, 2019 24590-LAW-PCN-ENV-19-002

Hanford Facility RCRA Permit Modification Notification Form
Part III, Operating Unit 10
Waste Treatment and Immobilization Plant

Index

Page 2 of 3: Hanford Facility RCRA Permit, Part III, Operating Unit 10, Waste Treatment and Immobilization Plant Update the Leak Detection Capability in the LAW Facility document in Appendix 9.18.

Submitted by Co-Operator:		Reviewed by ORP Program Office:	
Roger J. Landon	1/30/19	Thomas W. Fletcher	3/12/19
Roger J. Landon	Date	Thomas W. Fletcher	Date

Quarter Ending Mar. 31, 2019

24590-LAW-PCN-ENV-19-002

Hanford Facility RCRA Permit Modification Notification Form	
Unit: **Waste Treatment and Immobilization Plant**	Permit Part: **Part III, Operating Unit 10**

Description of Modification:

The purpose of this Class 1 prime modification is to update the leak detection document for the LAW facility in Appendices 9.18.

Appendix 9.18			
Replace:	24590-LAW-PER-M-05-002, Rev. 2, Leak Detection Capability in the LAW Facility	With:	24590-LAW-PER-M-05-002, Rev. 3, Leak Detection Capability in the LAW Facility

This modification requests Ecology approval and incorporation into the permit of the changes described below. These revisions are the result of ongoing design. The following summarizes the changes to the attached permit documents.

Leak Detection Capability in the LAW Facility (24590-LAW-PER-M-05-002, Rev. 3)

- The LAW permit document was revised from Revision 2 to Revision 3 to address revision of methodology, results, and summary to resolve PIER-MGT-11-0105-C, Action 08.
- The revised version is consistent with the calculation methodologies used in both the EMF and LAB Leak Detection documents.

In accordance with Permit Condition III.10.C.2.e, this permit modification includes the updated leak detection document for inclusion in Appendixes 9.18.

WAC 173-303-830 Modification Class:	Class 1	Class [1]1	Class 2	Class 3
Please mark the Modification Class:		X		

Enter relevant WAC 173-303-830, Appendix I Modification citation number: N/A

Enter wording of WAC 173-303-830, Appendix I Modification citation:

In accordance with WAC 173-303-830(4)(d)(i), this modification is requested to be reviewed and approved as a Class [1]1 modification. WAC 173-303-830(4)(d)(ii)(A) states, "Class 1 modifications apply to minor changes that keep the permit current with routine changes to facility or its operation. These changes do not substantially alter the permit conditions or reduce the capacity of the facility to protect human health or the environment. In the case of Class 1 modifications, the director may require prior approval."

Modification Approved/Concur: ☐ Yes ☐ Denied (state reason below) Reason for denial:	Reviewed by Ecology: S. Dahl Date

Document title: **Leak Detection Capability in the LAW Facility**

Document number: 24590-LAW-PER-M-05-002, Rev 3

Contract number: DE-AC27-01RV14136

Department: Process and Mechanical Systems

Author(s): Aaron Wand

Checked by: Brad Stiver

Issue status: Issued for Permitting Use

Note: Contents of this document are Dangerous Waste Permit affecting.

Approved by: ~~Jeanette Shoemaker~~ Carrie Roberts CER 3/14/2018

Approver's position: Mechanical Engineering Group Supervisor

Approver's signature: ______________ Signature   3/14/2018 Date

This bound document contains a total of 23 sheets

River Protection Project
Waste Treatment Plant
2435 Stevens Center Place
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Tel: 509 371 2000

Notice

Please note that source, special nuclear, and byproduct materials, as defined in the Atomic Energy Act of 1954 (AEA), are regulated at the US Department of Energy (DOE) facilities exclusively by DOE acting pursuant to its AEA authority. DOE asserts, that pursuant to the AEA, it has sole and exclusive responsibility and authority to regulate source, special nuclear, and byproduct materials at DOE-owned nuclear facilities. Information contained herein on radionuclides is provided for process description purposes only.

History Sheet

Rev	Reason for revision	Revised by
0	Issued for Permitting Use	R. Hanson
1	Modified sump depth from 15 inches to 12 inches.	R. Hanson
2	Changed diameter description from 24 inches to 30 inches in section 7.2.1.1	R. Hanson
3	Major revision of methodology, results, and summary based on revised calculation to resolve PIER-MGT-11-0105-C Action 08. Revision marks are not included.	A. Wand

Contents

Acronyms

AEA	Atomic Energy Act of 1954
ASX	Autosampling System
BNI	Bechtel National, Incorporated
CCN	Correspondence Control Number
CGS	centimeter gram second units of measurement
DOE	US Department of Energy
DWP	Dangerous Waste Permit
GPH	Gallons per hour
LAW	Low Activity Waste
RLD	Radioactive Liquid Waste Disposal System
STD	Standard
WAC	Washington Administrative Code
WTP	River Protection Project-Waste Treatment Plant

1 Summary

The Low Activity Waste (LAW) Vitrification facility secondary containment must satisfy the leak detection criteria of the Washington Administrative Code (WAC) 173-303-640(4), Reference 7.5, and the Waste Treatment Plant Dangerous Waste Permit (DWP) number 7890008967, Condition No: III.10.E.9.e.ii and III.10.H.5.e.ii for tank and miscellaneous treatment system secondary containment areas, Reference 7.6. This report documents the minimum leak rates that can be detected within 24 hours in the regulated secondary containment sumps.

The LAW facility contains seven DWP regulated Radioactive Liquid Waste Disposal System (RLD) sumps within the process/effluent cells. Leaks of vessels or piping within the cells will flow along the floor or in containment piping, and are collected in a sump equipped with full time level detection instrumentation. All sumps are the dry type, that is, the sumps are dry unless there is a leak that reaches the sump. All sumps are of the same size except for sump RLD-SUMP-00028 located in the minus 21-foot elevation C3/C5 cell. All sumps are provided with radar type leak detection.

Since the DWP has established a minimum leak rate of 0.1 gallons per hour (gph), this report documents the time to detect the minimum leak of 0.1 gph in the sumps based on the time to fill the sump plus the time for the 0.1 gph leak to flow to the sump. The time to fill the sump is calculated in Reference 7.2 and reproduced in this document by first determining the minimum detectable volume in each sump and then the time required to reach this detectable volume at a leak rate of 0.1 gph. If the "time to detect" is less than 24 hours for a flow rate of 0.1 gph for all sumps, the permit condition is met.

Note that there are several minor differences between the calculation in Reference 7.2 and this document. These differences include a simplified iterative process by use of Equation 6-6 and an increase of 0.2 feet in the maximum leak route in Table 4-3. The use of Equation 6-6 produces a slightly higher leak velocity of ~0.003 ft/sec. This velocity is in agreement with the leak detection flow rate of 0.1gal/hr and the calculated cross-sectional area of a partially full circular pipe (Equation 6-4). The leak detection time through the evaluated piping is reduced by six minutes in Table 6-3 due to the increase in velocity. The overall conclusion is unchanged and the leak rate of 0.1 gph is shown to be detectable in less than 24 hours.

This permit report documents that the time to fill the sump to the detectable level is the critical factor for establishing a leak rate versus the time for the leak (rivulet) to cross the floor or for the leak to wet and travel through the pipe. This approach has been previously presented to the Department of Ecology.

2 Objective

The objective of this report is to document the capability to detect a 0.1 gph leak of dangerous waste within 24 hours in the LAW facility secondary containment area sumps. The leakages include:

- Leaks from vessels, equipment and/or piping containing DWP regulated waste that flows by gravity directly to sumps containing leak detection instrumentation
- Leaks that flow by gravity to floor drains that are routed to another cell containing a sump with leak detection instrumentation. This includes process bulges in LAW.

3 Description

The LAW facility regulated sumps must satisfy the leak detection criteria of the WAC and DWP conditions for secondary containment systems. The regulatory requirements for leak detection are contained in WAC-173-303-640 (4), Tank Systems, Section 4, Containment and Detection of Releases and are restated as follows:

> (b) Secondary Containment systems must be:
>> (ii) Capable of detecting and collecting releases and accumulated liquids until the collected material is removed.
>
> (c) To meet the requirements of (b) of this subsection, secondary containment systems must be at a minimum:
>> (iii) Provided with a leak detection system that is designed and operated so that it will detect the failure of either the primary or secondary containment structure or the presence of any release of dangerous waste or accumulated liquid in the secondary containment system within twenty-four hours, or at the earliest practicable time if the owner or operator can demonstrate to the department that the existing detection technologies or site conditions will not allow detection of a release within twenty-four hours.

In addition, the Waste Treatment Plant Dangerous Waste Permit (Reference. 7.6), Conditions: III.10.E.9.e.ii and III.10.H.5.e.ii require submittal of:

Detailed plans and descriptions, demonstrating the leak detection system is operated so that it will detect the failure of either the primary or secondary containment structure or the presence of any release of dangerous and/or mixed waste, or accumulated liquid in the secondary containment system within twenty-four (24) hours [WAC 173-303-640(4)(c)(iii)]. Detection of a leak of at least 0.1 gallons per hour within twenty-four (24) hours is defined as being able to detect a leak within twenty-four (24) hours. Any exceptions to this criterion must be approved by Ecology [WAC 173-303-680, WAC 173-303-640(4)(c)(iii), and WAC 173-303-806(4)(i)(i)(b)].

4 Inputs/Assumptions

4.1 The RLD sump locations in the cells and the maximum total floor distances are summarized in Table 4-1. The distances are measured conservatively from the General Arrangement drawings (References 7.7 through 7.10) and have been rounded up. The maximum leak travel distance is conservatively computed by summing the distance along the walls (E-W and N-S) from the furthest point of the sump. Based on the estimate of travel distances for leaks in each cell, the longest leak flow distance on the floors to any sump is 87 feet. See Table 4-1, for sumps RLD-SUMP-00028 through -00032, -00035, and -00036. The sumps also have gravity drain piping from other floor drains or bulges that terminate in the sumps. The LAW samplers ASX-SMPLR-00012/00013 weir containments are included in Table 4-1. Table 4-3 summarizes the longest horizontal pipe run to the sump.

Table 4-1: RLD Sump Locations and Max Floor Distances

Room Number	Sump Name	RLD-SUMP -000xx	Sump Loc. in Cell	Elev.	N-S Dist.	E-W Dist.	Ref.	Max Total Distance, ft
L-B001B	C3/C5 Drain Collection Cell Sump	28	NE corner	-21'	16'-7"	23'-4"	7.3.8, 7.7, 7.11	40
L-0123	Process Cell 1 West Sump	29	W wall	+3'	38'-4"	48'-4"	7.3.9, 7.8, 7.11	87
L-0123	Process Cell 1 East Sump	30	E wall	+3'	38'-4"	48'-4"	7.3.9, 7.8, 7.11	87
L-0124	Process Cell 2 West Sump	31	W wall	+3'	38'-4"	48'-4"	7.3.9, 7.8, 7.11	87
L-0124	Process Cell 2 East Sump	32	E wall	+3'	38'-4"	48'-4"	7.3.9, 7.8, 7.11	87
L-0126	Effluent Cell West Sump	35	W wall	+3'	38'-4"	31'-4"	7.3.10, 7.8, 7.11	70
L-0126	Effluent Cell East Sump	36	E wall	+3'	38'-4"	31'-4"	7.3.10, 7.8, 7.11	70
L-0301	ASX-SMPLR-00012 Weir	NA	NA	+48'	~42"	~68"	7.10, 7.23, 7.24	<10
L-0301	ASX-SMPLR-00013 Weir	NA	NA	+48'	~42"	~68"	7.10, 7.25, 7.26	<10

4.2 The RLD sump dimensions are as follows.

4.2.1 The six process and effluent sumps (RLD-SUMP-00029/30/31/32/35/36) are 30 inches outside diameter x 12 inches deep (Reference 7.1, Table 1 and Reference 7.11). The sump is fabricated from 30-inch diameter by 3/8" thick pipe (I.D. = 29.25 in). The bottom consists of a flat plate.

4.2.2 The C3/C5 Drain Collection Cell sump (RLD-SUMP-00028) is 24 inches outside diameter and 30 inches in depth (Reference 7.1, Table 1 and Reference 7.11). The sump is fabricated from 24-inch diameter by 3/8" thick pipe (I.D. = 23.25 in). The bottom consists of a flat plate.

4.3 The secondary containment floors with stainless steel liners are sloped at a minimum grade of 1:100 to direct potential leakage in these areas to the respective sumps (Reference 7.7, 7.8, & 7.27).

4.4 Potential leak routes for DWP regulated equipment are summarized in Table 4-2.

Table 4-2: Potential Leak Routes for DWP Regulated Equipment

From[1] (Room)	To	Pipeline No.	References
RLD-BULGE-00001 (L-B001A)	RLD-SUMP-00028	RLD-ZF-00102-S11B-02	7.3.8, 7.3.6, 7.7
RLD-BULGE-00004 (L-0202)	RLD-SUMP-00036	RLD-ZF-33830-N11F-02	7.3.10, 7.3.3, 7.8, 7.9
LOP-BULGE-00002 (L-0202)	RLD-SUMP-00031	LOP-ZR-01503-N11F-02	7.3.9, 7.3.22, 7.8, 7.9
LOP-BULGE-00001 (L-0202)	RLD-SUMP-00029	LOP-ZR-01505-N11F-02	7.3.9, 7.3.20, 7.8, 7.9
LFP-BULGE-00002 (L-0202)	RLD-SUMP-00032	LFP-PB-00027-S12A-02	7.3.9, 7.3.18, 7.8, 7.9
LFP-BULGE-00001 (L-0202)	RLD-SUMP-00030	LFP-PB-01388-S12A-02	7.3.9, 7.3.16, 7.8, 7.9
LCP-BULGE-00003 (L-0202)	RLD-SUMP-00031	LCP-PB-00051-S12A-02	7.3.9, 7.3.14, 7.8, 7.9
LCP-BULGE-00002 (L-0202)	RLD-SUMP-00029	LCP-PB-01305-S12A-02	7.3.9, 7.3.12, 7.8, 7.9
LCP-BULGE-00001 (L-0202)	RLD-SUMP-00029	LCP-PB-01306-S12A-02	7.3.9, 7.3.11, 7.8, 7.9
LOP-ZS-01598-W11A-03 (LOP-WESP-00001) (L-0123)	RLD-SUMP-00028	RLD-ZS-06562-S11B-01 LOP-ZS-01598-W11A-03	7.3.21, 7.3.8, 7.3.5, 7.7, 7.8
LOP-ZS-01548-W11A-03 (LOP-WESP-00002) (L-0124)	RLD-SUMP-00028	RLD-ZS-03346-S11B-01 LOP-ZS-01548-W11A-03	7.3.23, 7.3.8, 7.3.5, 7.7, 7.8
ASX-SMPLR-00013 (L-0301)	RLD-SUMP-00028	RLD-ZS-03358-S11B-01 RLD-ZS-03359-W11A-04	7.3.8, 7.3.5, 7.3.24, 7.7, 7.10
ASX-SMPLR-00013 / RLD-BULGE-00001 (L-0301)	RLD-SUMP-00028	RLD-ZS-06558-S11B-01 RLD-ZS-06557-W11A-04	7.3.8, 7.3.7, 7.7, 7.10
ASX-SMPLR-00013 (L-0301)	LFP-BULGE-00001	LFP-PB-03198-S32B-04	7.3.24, 7.3.17, 7.9, 7.10
LFP-BULGE-00001 (L-0202)	ASX-SMPLR-00013	LFP-PB-03196-S32B-04	7.3.24, 7.3.17, 7.9, 7.10
ASX-SMPLR-00013 (L-0301)	LCP-BULGE-00002	LCP-PB-00023-S32B-04	7.3.24, 7.3.13, 7.9, 7.10
LCP-BULGE-00002 (L-0202)	ASX-SMPLR-00013	LCP-PB-01326-S32B-04	7.3.24, 7.3.13, 7.9, 7.10

[1] The samplers themselves are not DWP regulated, but the lower containment areas and the connecting pipelines directing drainage to the sumps are.

From[1] (Room)	To	Pipeline No.	References
ASX-SMPLR-00012 (L-0301)	RLD-BULGE-00004	RLD-ZF-01294-S32B-04	7.3.26, 7.3.3, 7.9, 7.10
RLD-BULGE-00004 (L-0202)	ASX-SMPLR-00012	RLD-ZF-03392-S32B-04	7.3.26, 7.3.3, 7.9, 7.10
ASX-SMPLR-00012 (L-0301)	RLD-BULGE-00004	RLD-ZS-03368-S32B-04	7.3.26, 7.3.4, 7.9, 7.10
RLD-BULGE-00004 (L-0202)	ASX-SMPLR-00012	RLD-ZS-06570-S32B-04	7.3.26, 7.3.4, 7.9, 7.10
ASX-SMPLR-00012 (L-0301)	LFP-BULGE-00002	LFP-PB-03203-S32B-04	7.3.25, 7.3.19, 7.9, 7.10
LFP-BULGE-00002 (L-0202)	ASX-SMPLR-00012	LFP-PB-03201-S32B-04	7.3.25, 7.3.19, 7.9, 7.10
ASX-SMPLR-00012 (L-0301)	LCP-BULGE-00003	LCP-PB-01366-S32B-04	7.3.25, 7.3.15, 7.9, 7.10
LCP-BULGE-00003 (L-0202)	ASX-SMPLR-00012	LCP-PB-01349-S32B-04	7.3.25, 7.3.15, 7.9, 7.10
RLD-ZF-03453-W11A-02 (RLD-VSL-00003) (L-0126)	RLD-SUMP-00028	RLD-ZF-03443-S11B-01 RLD-ZF-03453-W11A-02	7.3.8, 7.3.1, 7.7, 7.8
RLD-ZF-03454-W11A-02 (RLD-VSL-00005) (L-0126)	RLD-SUMP-00028	RLD-ZF-03444-S11B-01 RLD-ZF-03454-W11A-02	7.3.8, 7.3.2, 7.7, 7.8
LMP-LDB-00001 (Melter 1) (L-0112)	RLD-SUMP-00030	RLD-WS-20037-S11B-01 LMP-WS-20093-S11B-01	7.3.9, 7.3.27, 7.8
LMP-LDB-00002 (Melter 2) (L-0112)	RLD-SUMP-00032	RLD-WS-20033-S11B-01 LMP-WS-20094-S11B-01	7.3.9, 7.3.28, 7.8

4.5 The maximum pipeline length (from ASX-SMPLR-00012 (N10) to RLD-BULGE-00004 (N20/NI6) to RLD-SUMP-00036) is determined from the isometric drawings identified in References 7.4.1 through 7.4.5 and tabulated below.

Table 4-3: Maximum Leak Route

Isometric Drawing	Length, ft	Description
24590-LAW-P3-RLD-ZS03368001	35.7	Connection to ASX-SMPLR-00012 (N10)
24590-LAW-P3-RLD-ZS03368002	72.9	
24590-LAW-P3-RLD-ZS03368003	85.8	
24590-LAW-P3-RLD-ZS03368004	16.2	Connection to RLD-BULGE-00004 (N20 & N16)
24590-LAW-P3-RLD-ZF33830001	25.0	Open to RLD-SUMP-00036
Total	235.6	

4.6 The analyzed pipelines (i.e. pipelines noted in Input 4.5) are N11F and S32B pipe class (Reference 7.14 and 7.15). Per Reference 7.14, piping class N11F is AL-6XN, schedule 40S for 1/2" to 2" nominal diameter pipeline. Piping class S32B (encasement) is 316L stainless steel, schedule 40S (STD) for 1" to 8" nominal diameter pipeline (gravity drain).

Table 4-4: Pipe Dimensions

Pipeline	Pipe Class Ref.	Dimensions (Ref. 7.16, p. B-16 & B-17)	
		Nom Pipe Size (inch) Sch 40S	I.D. (inch)
RLD-ZF-33830-N11F-02	7.14	2	2.067
RLD-ZS-03368-S32B-04 (encasement / jacket)	7.15	4	4.026

4.7 The isometric piping noted in Input 4.5 contains a minimum slope that ranges from 1:30 (2/5 inch per foot) (Reference 7.4.3 & 7.4.4) to 1:50 (6/25 inch per foot) (Reference 7.4.1).

4.8 Waste is assumed to be like that of water at 100°F with the physical properties (Reference 7.12, p. 30.37) as shown in Table 4-5 below:

Table 4-5: Physical Properties of Water

Constant	English Units	CGS Units
ρ, density	61.99 lbm/ft³	0.993 gm/cm³
μ, dynamic viscosity	1.648 lbm/ft hr	0.00681 gm/cm sec
γ, surface tension	0.0048 lbf/ft	69.96 dyne/cm or 69.96 gm/sec²

4.9 The minimum detectable level within the LAW Secondary Containment System is assumed to be 0.5" above the bottom of each sump based on preliminary vendor information provided by C&I and a project specification for level measurement (Reference 7.20, Section 3.2.1).

4.10 The following items (a through g) were derived from agreements between BNI, DOE, and Department of Ecology (Reference 7.21):

a. The liquid leaking is water at a temperature of 100°F.
b. The leak is at a constant rate over the 24-hour period.
c. The leak is assumed to occur at the farthest point from the sump.
d. No evaporation will occur.
e. The liquid does not foam in the sumps.
f. Hold-up of piping is considered and is defined as wetting of the surface.
g. Level detection instruments will be properly installed and calibrated upon installation. Periodic, normal maintenance and calibration will be performed on level instruments during operation of the facility and the instruments will be maintained in an operable condition.

4.11 The wetting factor from experimental data was found to be 0.32 fl. oz/ft (Reference 7.13) for a NPS 6 pipe. The wetting factor will be conservatively increased by 50% to 0.48 fl. oz./ft to provide additional margin to the calculated holdup time.

4.12 The rivulet flow in this report is based on the simplified model for a wide flat rivulet. Figure 5 of Reference 7.17 shows dashed lines that are asymptotic solutions for wide-flat rivulets at high Ω values and for narrow rivulets at low Ω values. For a contact angle of 5°, figure 5 shows that the wide flat rivulet model, represented by equations 26 and 27 of Reference 7.17, is applicable when Ω is larger than 0.001 and P is larger than 5. This assumption is verified by the evaluation of Ω and P using data from this report.

4.13 Reference 7.17, Table 2 shows for a rivulet flow rate of 6.2 ml/min (~0.1 gph), the corresponding contact angle, θ, is experimentally measured as 9 to 12 degrees. A conservative rivulet contact angle of 6 degrees is assumed for this report. The smaller contact angle results in a longer time to sump for a given flow path length from the following logic: a smaller contact angle yields a larger rivulet width, which yields a larger rivulet cross sectional area, which leads to a lower velocity (since the flow rate is fixed). This assumption is conservative.

4.14 The floor is uniformly sloped and the flow path is in straight lines (no meandering flow).

4.15 The average velocity equation assigned to the leakage being conveyed within the sloped pipe is developed from boundary layer theory for flow down an incline plane. This velocity equation is assumed to apply to the leakage flows in the pipe since this average velocity will be applied throughout the entire length of the pipe even when the pipe contains vertical drops (where velocity would increase, thereby reducing the travel time to detection device).

4.16 The rivulet flow path for each cell is conservatively considered to be along the straight walls rather than diagonally across the cell: North-South + East-West distances. This is a conservative assumption.

4.17 There are no obstructions in the flow path. Leaks from any equipment or piping fall directly to the floor at the point of leakage and do not travel along pipes or other equipment and the rivulet does not split into multiple streams as it travels across the floor. While actual leaks may not conform to this scenario, it is beyond the objective of this report to assess every possible leak scenario. The intent is to provide a calculated leak detection volume that is not overly complex but still maintains sufficient accuracy to demonstrate leak detection capability within a reasonable level of uncertainty.

4.18 The level instrument response time (i.e., the time between the fluid reaching a specified level set point and the instrument responding to the process condition) is considered negligible with regards to the leak detection time requirement. The level instrumentation is anticipated to have response times on the order of seconds and therefore, the response time is insignificant based on the 24-hour detection limit.

4.19 All sumps within the LAW Facility are conservatively assumed to be dry. This maximizes the time required to fill the sumps to a detectable level.

5 Analysis

To establish if the LAW cell sumps can detect a permit condition leakage rate of 0.1 gph within a 24-hour time, a total time is determined. This includes the time for a leak to travel to a sump (t_1) including travel within pipes and/or across the cell floor; the time to fill the sump to a detectable level(t_2); and the time it takes to wet the surface of a pipe or 'holdup' (t_3).

Leakage flowing inside pipes uses the boundary layer theory while leakage flowing on the floor is modeled as a rivulet of uniform width. The time taken by the liquid to reach the sump and time required for minimum liquid accumulation in the sump (before it can be detected) are determined in Section 6.

6 Detectable Leak Rates

6.1 Leakage Through Pipes

The elapsed time to detect a leak that is flowing through a pipe is composed of three independent time components:

t_1 = Elapsed time for the leak to travel through the pipes to the sump
t_2 = Time to fill the sump to a level that can be detected by the associated leak detection instrumentation
t_3 = Liquid holdup time or elapsed time for leak to wet the interior surface

Therefore, the total time for leakage detection through pipes is $t_{total} = t_1 + t_2 + t_3$. If the total time is less than 24 hours for a flowrate (Q) of 0.1 gph for all leak detection equipment, the permit condition is met.

6.1.1 Holdup Time within Pipe, t_3

The elapsed time for the leak to wet the flow path (flow channel) from the most-remote location to its corresponding leak detection feature (i.e., a sump) is estimated based on an experimentally determined value of wetting holdup (Reference 7.13) and results in the following equation for determining the time to account for the holdup of water flowing through a pipe:

Equation 6-1: Holdup Time (t_3):

$$t_3 = \frac{c\,L}{Q}$$

c = wetting factor, gal/ft or fluid ounces/ft (abbreviated as: fl. oz/ft) with use of conversion factor: 128 fl. oz/gal
L = travel distance, ft
Q = leakage volumetric flow rate, gal/hr

Based on input 4.5, the longest run of pipe originates at ASX-SMPLR-00012, flows to RLD-BULGE-00004 and then to RLD-SUMP-00036 and is 235.6 feet. The entire length of the pipe route is considered when calculating leak travel time per assumption 4.15, however, for liquid holdup, the pipe vertical drop will be subtracted out since liquid holdup should be minimal in the vertical sections. The vertical pipe sections are approximately 44' (Reference 7.4.1 thru 7.4.5), therefore the length of piping that is considered for liquid holdup (L) is then: 235.6 ft -44 ft ~ 191 ft.

With the wetting factor (c) set 0.48 fl. oz/ft per assumption 4.11 and the flow rate (Q) set to 0.1 gph, the maximum holdup time from Equation 6-1 becomes:

$$t_3 = \left(\frac{0.48\ fl.\,oz.}{ft}\right)\left(\frac{gal}{128\ fl.\,oz.}\right)\left(\frac{191 ft}{1}\right)\left(\frac{hr}{0.1\ gal}\right) = 7.16\ hr$$

6.1.2 Leak Travel Time to Sump via Pipe, t_1

The time delay for the leak to reach the detection equipment is calculated using equations derived from boundary layer theory for uniform flow down an inclined plane (assumption 4.15). The average velocity distribution from boundary layer theory from Reference 7.18, p. 317, Equation 9.4b is:

Equation 6-2: Average Leak Velocity (v):

$$v = \frac{g\ S_p\ d_p^2}{3\ n}$$

$g =$ gravitation acceleration, 32.17 ft/s^2
$S_p =$ Slope of the pipe, dimensionless
$d_p =$ flow depth, ft
$n =$ kinematic viscosity, ft^2/s

Equation 6-3: General Equation for Volumetric Flow Rate (Q):

$$Q = Av$$

$A =$ cross-sectional flow area, ft^2

The wetted cross-sectional area for gravity flow in a circular pipe is found from (Reference 7.19, p. 5)

Equation 6-4: Wetted Cross-Section (A):

$$A = \frac{\left(\theta_{fs} - \sin\theta_{fs}\right)D_p^2}{8}$$

$D_p =$ pipe diameter, ft
$\theta_{fs} =$ free surface angle (see Figure 6-1), radians

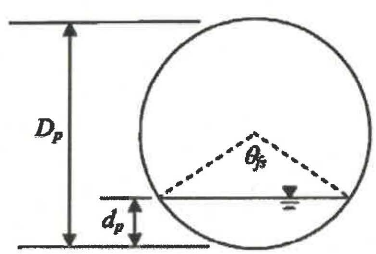

Figure 6-1: Partially Full Pipe Sketch

The depth of flow can be found by the following equation (Reference 7.22, Attachment A).

Equation 6-5: Depth of Partially Full Pipe (d_p):

$$d_p = D_p \sin^2\left(\frac{\theta_{fs}}{4}\right)$$

Substituting Equation 6-3 through Equation 6-5 into Equation 6-2:

Equation 6-6: Volumetric Flow Rate in Partially Full Pipe (Q_p):

$$Q_p = \frac{g S_p {D_p}^4 (\theta - \sin\theta)\left(\sin\frac{\theta}{4}\right)^4}{24n}$$

Equation 6-6 is solved by iterating the free surface angle (θ) until the volumetric flow rate (Q_p) equals the permit condition leakage rate (Q) of 0.1 gph. The constants in Table 6-1 are also substituted into Equation 6-6.

Table 6-1: Time for Leak to Travel through the Pipes to the Sump Calculation Constants

Constant	Value	Note
$D_p =$	4.026 inch (0.3355 ft)	Input 4.6 for encasement pipe
$Q =$	0.1 gph = 3.714 E-6 ft^3/s	Leak flow rate
$g =$	32.17 ft/s^2	Acceleration due to gravity
$S_p =$	1/50 = 0.02	Assumption 4.7, slope of pipe
$\mu =$	1.648 lbm/ft.hr	Table 4-5
$\rho =$	61.99 lbm/ft^3	Table 4-5

Since kinematic viscosity (n) is equal to dynamic viscosity (μ) / density (ρ), kinematic viscosity is calculated as:

$$n = (1.648 \text{ lbm/ft.hr}) / (61.99 \text{ lbm/ft}^3) \times (1 \text{ hr} / 3600 \text{ sec}) = 7.38\text{E-6 ft}^2\text{/sec}$$

The free surface angle (θ) is found to be 0.277 radians, or 15.86 degrees, by iterating Equation 6-6. Once the angle is determined, Equation 6-5 can be solved for the depth of the partially full pipe resulting in a value of 1.60e-3 feet. Substituting the depth into Equation 6-2 result in a velocity of 0.0747 ft/sec.

The travel delay for the leakage to reach the sump is calculated by dividing the length of pipe by the velocity. The results are converted to units of hours. Equation 6-7 applies to rivulet flow as well.

Equation 6-7: Time to Travel to Sump (t_1):

$$t_1 = L / v \times (hr / 3600 \sec)$$

Substituting the values in Equation 6-7:

$$t_1 = (235.6 \text{ ft} / 0.0747 \text{ ft/s}) \times (\text{hr}/ 3600\text{s}) = 0.88 \text{ hr}$$

6.1.3 Time to Obtain a Detectable Sump Volume, t_2

Based on inspection of Input 4.2, the largest sump contains a 30" diameter (3/8" thick) pipe. The sump detectable volume is determined from the equation for the volume of a cylinder.

Equation 6-8: Volume to Detection (∀):

$$\forall = \frac{\pi}{4} D_s^2 \times h \times \frac{gal}{231 \ in^3}$$

$D_s =$ 29.25 inch (Input 4.2.1) = sump diameter
$h =$ 0.5 inch (assumption 4.9) = detectable liquid height

The sump detectable volume determined from Equation 6-8:

$$\forall = \pi/4 \times (29.25 \text{ inch})^2 \times 0.5 \text{ in} \times (\text{gal}/231 \text{ in}^3) = 1.45 \text{ gal}$$

The time to fill the leak detection equipment, t_2, is calculated from the following equation:

Equation 6-9: Time to Fil Sump to Detectable Level (t_2):

$$t_2 = \forall / Q$$

Substituting the volume and permit condition leakage flow rate (Q) of 0.1 gph into Equation 6-9:

$$t_2 = (1.45 \text{ gal}) \text{ x } (\text{hr} / 0.1 \text{ gal}) = 14.5 \text{ hr}$$

6.1.4 Total Detection Time, t_{total}

The total detection time is the sum of the previously determined pipe wetting, transport, and sump filling delays, which can be expressed in equation form as:

$$t_{total} = t_1 + t_2 + t_3 = 0.88 \text{ hr} + 14.5 \text{ hr} + 7.16 \text{ hr} \cong 22.5 \text{ hr}$$

The resultant total detection time value of 22.5 hours is less than 24 hours for a minimum leak rate of 0.1 gph, thus satisfying the permit requirement for leakage detection.

6.2 Leakage Along Floor-Rivulet Flow

The time to detect a leak traveling across a floor liner is composed of two time components: t_1 and t_2. The first component, t_1, is the time for the leak to reach the leak detection equipment (Equation 6-7). The second component, t_2, is the time to fill the leak detection equipment based on the minimum leak rate.

For each leak detection equipment, t_2 is calculated by dividing the minimum detectable volume by the volumetric flow rate of the leak. The t_1 component is calculated using the methodology from Reference 7.17 (rivulet flow). The elapsed time to detect a leak (t_{total}) is the sum of these two time components: $t_{total} = t_1 + t_2$. If the total time is less than 24 hours for a flow rate of 0.1 gph for all leak detection equipment, the permit condition is met.

Calculation of t_1 for each leak detection equipment is not necessary; using the longest path length bounds the "time to detection." As indicated in Assumption 4.1, the rivulet leak travel distance is calculated by summing the distance along the walls: adding the north-south (N-S) wall distance to the east-west (E-W) wall distance.

6.2.1 Leakage Travel Time to Room Sumps, t_1

There is no need to calculate the flow rate of the leak across the floor since the permit has established a minimum leak rate of 0.1 gph. The approach illustrated here has been presented to and concurred by the Department of Ecology.

The "time to detection" is determined using the average leak velocity at the minimum leak rate of 0.1 gph. The methodology shown in Reference 7.17 for rivulet flow forms the basis for the rivulet leak velocity calculation. The method requires the calculation of the angle of inclination for the rivulet, the capillary constant, and the rivulet cross sectional area. In order to be consistent with the units in Reference 7.17, most units within this section are presented in grams (gm) and centimeters (cm).

The angle of inclination (α) which is the slope of the floor with respect to a vertical plane, as shown in Figure 6-2, is determined using trigonometry in Equation 6-10. The slope of the floor with respect to the horizontal plane is S_o.

Equation 6-10: Inclination Angle for Rivulet Flow (α):

$$\alpha = \tan^{-1}\left(\frac{1}{S_o}\right)$$

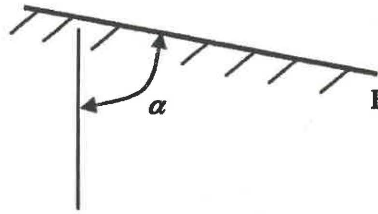

Figure 6-2: inclination Angle for Rivulet Flow

From Assumption 4.3, S_o = 1/100 = 0.01. Substituting the values in Equation 6-10:

$$\alpha = \tan^{-1}(1/0.01) = 89.427°$$

The capillary constant (a), the basis for the dimensionless width, is defined below (Reference 7.17, p. 973, equation following equation 9):

Equation 6-11: Capillary Constant (a):

$$a = \sqrt{\gamma / \rho g \sin\alpha}$$

a = capillary constant, cm
γ = liquid surface tension, dyne/cm (= gm/sec^2)
ρ = liquid density, gm/cm^3
g = gravitational acceleration = 980.7 cm/sec^2

The liquid properties are based on water at 100 °F (Assumption 4.8) and are listed in Table 4-5. Substituting these values into Equation 6-11:

$$a = \sqrt{\frac{69.96\ gm/sec^2}{0.993\frac{gm}{cm^3} \times 980.7\frac{cm}{sec^2} \times \sin(89.427°)}} = 0.268\ cm$$

For the wide flat rivulet, its depth is determined based on (Reference 7.17, 2nd equation following equation 25) where theta (θ) is the contact angle in degrees:

Equation 6-12: Dimensionless Depth of Wide Flat Rivulet (Y_o):

$$Y_0 = 2\sin\left(\theta/2\right)$$

The dimensionless depth, Y_0, is also defined in Reference 7.17, following equation 17 (2nd line following equation 17), as the ratio of the dimensional rivulet depth (η_0) and the capillary constant (a).

Equation 6-13: Dimensionless Depth of Wide Flat Rivulet (Y_o):

$$Y_o = \eta_0 / a$$

Substituting Equation 6-12 into Equation 6-13 and solving for the dimensional rivulet depth (η_0) yields:

Equation 6-14: Dimensional Rivulet Depth (η_0):

$$\eta_0 = 2a\sin(\theta/2)$$

From Assumption 4.13, the contact angel (θ) is 6 degrees. Substituting this in Equation 6-14 results in:

$$\eta_0 = 2 \times 0.268\ cm \times \sin(6°/2) = 0.02805\ cm$$

The rivulet width, l, is determined from Reference 7.17, Equation 27:

Equation 6-15: Rivulet Width (l):

$$\frac{\mu Q \tan\alpha}{l\gamma}\sqrt{\frac{\rho g \sin\alpha}{\gamma}} = \frac{8}{3}\sin^3(\theta/2),\ \text{Solving for } l\text{:}\ l = \frac{3\mu Q \tan\alpha}{8\gamma \sin^3(\theta/2)}\sqrt{\frac{\rho g \sin\alpha}{\gamma}}$$

The width of the rivulet can now be calculated using Equation 6-15 and the values in Table 6-2.

Table 6-2: Constants for Rivulet Width Equation 6-15

$\alpha =$	89.427°
$\gamma =$	69.96 gm/sec² (Assumption 4.8)
$\mu =$	0.00681 gm/cm-sec (Assumption 4.8)
$\rho =$	0.993 gm/cm³ (Assumption 4.8)
$g =$	980.7 cm/sec²
$\theta =$	6° (Assumption 4.13)
$Q =$	0.1 gph = 0.1052 cm³/sec

$$l = \frac{3\left(0.00681\frac{gm}{cm\ sec}\right)\left(0.1052\frac{cm^3}{sec}\right)\tan(89.427°)}{8(69.96 gm/sec^2)\sin^3(6°/2)}\sqrt{\frac{\left(0.993\frac{gm}{cm^3}\right)\left(980.7\frac{cm}{sec^2}\right)\sin(89.427°)}{69.96\ gm/sec^2}}$$

$$l = 9.99\ \text{cm}$$

The rivulet cross-sectional area is determined using the approximation that the wide flat rivulet has a rectangular cross-section (rectangular cross-section for the wide flat rivulet is noted in Reference 7.17, p. 975), thus the area is defined as:

Equation 6-16: Rivulet Cross-Sectional Area (A):

$$A = l\eta_0$$

Substituting values in Equation 6-16 we have:

$$A = 9.99\ \text{cm x } 0.02805\ \text{cm} = 0.2802\ \text{cm}^2$$

With the volumetric flow rate known (Q), the rivulet velocity (v) can be calculated from Equation 6-3.

$$v = Q/A = (0.1052\ \text{cm}^3/\text{s}) / (0.2802\ \text{cm}^2) = 0.3754\ \text{cm/sec}$$

The method used in this calculation is from Reference 7.17 and is based on a dimensionless flow rate (Ω) and dimensionless stream width (P) along with other parameters. The following equations for the dimensionless parameters, P and Ω, are from Reference 7.17, p. 974, equation following equation 17 and the 3rd equation following equation 17, respectively.

Equation 6-17: Dimensionless Rivulet Width (P):

$$P = l/a$$

Equation 6-18: Dimensionless Rivulet Flow Rate (Ω):

$$\Omega = \frac{\mu \rho g Q}{\gamma^2} \tan\alpha \sin\alpha$$

The dimensionless rivulet width (*P*) using Equation 6-17 is:

$$P = 9.99 \text{ cm} / 0.268 \text{ cm} = 37.3$$

The dimensionless flow rate (Ω) is calculated using Equation 6-18 and constants from Table 6-2:

$$\Omega = \frac{\left(0.00681 \frac{gm}{cm\ sec}\right)\left(0.993 \frac{gm}{cm^3}\right)\left(980.7 \frac{cm}{sec^2}\right)\left(0.1052 \frac{cm^3}{sec}\right)}{(69.96\ gm/sec^2)^2} \tan(89.472°) \sin(89.472°)$$

$$\Omega = 0.014$$

From Reference 7.17 (p. 977, Figure 5), the point at the coordinates of Ω = 0.014 and P = 37.3 falls right on the asymptotic solutions for a wide rivulet close to $\theta = 5$ degrees. This confirms the assumption for a wide rivulet flow (Assumption 4.12).

The time to flow to sump, t_1, is calculated for the sump with the longest rivulet travel distance. The longest distance (from Input 4.1) 87 feet. Equation 6-7 is used to calculate the time to flow to sump, t_1:

$$t_1 = L/v = \frac{87\ ft}{0.3754\ cm/sec} \times \frac{30.48\ cm}{ft} \times \frac{hr}{3600\ sec} = 1.96\ hr$$

6.2.2 Time to Obtain a Detectable Sump Volume, t_2

The time to obtain a detectable vessel sump volume is calculated in Section 6.1.3 and is:

$$t_2 = 14.5 \text{ hr}$$

6.2.3 Total Detection Time, t_{total}

The total detection time is the sum of t_1 (Section 6.2.1) and t_2 (Section 6.2.2):

$$t_{total} = t_1 + t_2 = 1.96 \text{ hr} + 14.5 \text{ hr} \cong 16.5 \text{ hr}$$

6.3 Results

The results of this analysis are compiled in Table 6-3. This table summarizes the leaks into two rows, leakage through pipes and across floors. This analysis demonstrates that the LAW sumps can detect a permit condition leakage rate of 0.1 gal/hr within a 24-hour period, thus the permit condition for LAW is satisfied.

Table 6-3 LAW Facility, Time to Leak Detection Capability

Description of Leak	Time to Sump t_1 (hr)	Time to Fill t_2 (hr)	Time to Wet t_3 (hr)	Time to Detect t_{total} (hr)
Leakage through Pipe	0.88	14.5	7.16	22.5
Leakage across Floor	1.96	14.5	n/a	16.5

7 References

7.1 24590-LAW-PER-M-02-001, Rev. 5, LAW Facility Sump Data, July 19, 2007

7.2 24590-LAW-M6C-RLD-00013, Rev. 1, Leak detection Capability in the LAW Facility-System RLD

7.3 P&IDs

7.3.1 24590-LAW-M6-RLD-00001001, Rev. 0, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM PLANT WASH VESSEL RLD-VSL-00003

7.3.2 24590-LAW-M6-RLD-00001003, Rev. 0, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM SBS CONDENSATE COLLECTION RLD-VSL-00005

7.3.3 24590-LAW-M6-RLD-00001005, Rev. 0, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM PLANT WASH & SBS CONDENSATE COLLECTION RLD-BULGE-00004

7.3.4 24590-LAW-M6-RLD-00001006, Rev. 0, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM PLANT WASH & SBS CONDENSATE COLLECTION RLD-BULGE-00004

7.3.5 24590-LAW-M6-RLD-00002001, Rev. 1, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3/C5 DRAINS/SUMP COLLECTION RLD-VSL-00004

7.3.6 24590-LAW-M6-RLD-00002003, Rev. 0, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3/C5 DRAINS/SUMP COLLECTION RLD-BULGE-00001

7.3.7 24590-LAW-M6-RLD-00002004, Rev. 0, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3/C5 DRAINS/SUMP COLLECTION RLD-BULGE-00001

7.3.8 24590-LAW-M6-RLD-00002005, Rev. 1, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM C3/C5 SUMPS RLD-SUMP-00010/11/28

7.3.9 24590-LAW-M6-RLD-00003002, Rev. 2, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM PROCESS CELL SUMPS AT EL 2 FT

7.3.10 24590-LAW-M6-RLD-00003003, Rev. 2, P&ID - LAW RADIOACTIVE LIQUID WASTE DISPOSAL SYSTEM PROCESS AND EFFLUENT CELL SUMPS AT EL 2 FT

7.3.11 24590-LAW-M6-LCP-00001001, Rev. 0, P&ID - LAW CONCENTRATE RECEIPT PROCESS SYSTEM LCP-BULGE-00001

7.3.12 24590-LAW-M6-LCP-00001004, Rev. 0, P&ID - LAW CONCENTRATE RECEIPT PROCESS SYSTEM LCP-BULGE-00002 (SHEET 1 OF 2)

7.3.13 24590-LAW-M6-LCP-00001005, Rev. 1, P&ID - LAW CONCENTRATE RECEIPT PROCESS SYSTEM LCP-BULGE-00002 (SHEET 2 OF 2)

7.3.14 24590-LAW-M6-LCP-00002001, Rev. 0, P&ID - LAW CONCENTRATE RECEIPT PROCESS SYSTEM LCP-BULGE-00003 (SHEET 1 OF 2)

7.3.15 24590-LAW-M6-LCP-00002002, Rev. 1, P&ID - LAW CONCENTRATE RECEIPT PROCESS SYSTEM LCP-BULGE-00003 (SHEET 2 OF 2)

7.3.16 24590-LAW-M6-LFP-00001005, Rev. 0, P&ID - LAW MELTER FEED PROCESS SYSTEM MELTER 1 FEED PREPARATION AND FEED LFP-BULGE-00001

7.3.17 24590-LAW-M6-LFP-00001006, Rev. 1, P&ID - LAW - LAW MELTER FEED PROCESS SYSTEM MELTER 1 FEED PREPARATION AND FEED LFP-BULGE-00001

7.3.18 24590-LAW-M6-LFP-00003005, Rev. 0, P&ID - LAW MELTER FEED PROCESS SYSTEM MELTER 2 FEED PREPARATION AND FEED LFP-BULGE-00002

7.3.19 24590-LAW-M6-LFP-00003006, Rev. 1, P&ID - LAW - LAW MELTER FEED PROCESS SYSTEM MELTER 2 FEED PREPARATION AND FEED LFP-BULGE-00002

7.3.20 24590-LAW-M6-LOP-00001003, Rev. 0, P&ID - LAW PRIMARY OFFGAS PROCESS SYSTEM MELTER 1 LOP-BULGE-00001

7.3.21 24590-LAW-M6-LOP-00001004, Rev. 2, P&ID - LAW PRIMARY OFFGAS PROCESS SYSTEM MELTER 1 LOP-WESP-00001

7.3.22 24590-LAW-M6-LOP-00002003, Rev. 0, P&ID- LAW PRIMARY OFFGAS PROCESS SYSTEM MELTER 1 LOP-BULGE-00002

7.3.23 24590-LAW-M6-LOP-00002004, Rev. 2, P&ID - LAW PRIMARY OFFGAS PROCESS SYSTEM MELTER 2 LOP-WESP-00002

7.3.24 24590-LAW-M6-ASX-00007001, Rev. 1, P&ID - LAW AUTOSAMPLING SYSTEM ISOLOK DETAILS ASX-SMPLR-0013

7.3.25 24590-LAW-M6-ASX-00009001, Rev. 1, P&ID - LAW AUTOSAMPLING SYSTEM ISOLOK ASX-SMPLR-00012

7.3.26 24590-LAW-M6-ASX-00009002, Rev. 0, P&ID - LAW AUTOSAMPLING SYSTEM ISOLOK ASX-SMPLR-00012

7.3.27 24590-LAW-M6-LMP-00012001, Rev. 0, P&ID - LAW MELTER PROCESS SYSTEM MELTER 1 FEED NOZZLES COOLING SYSTEM AND FEED NOZZLES

7.3.28 24590-LAW-M6-LMP-00042001, Rev. 0, P&ID - LAW MELTER PROCESS SYSTEM MELTER 2 FEED NOZZLES COOLING SYSTEM AND FEED NOZZLES

7.4 Piping Isometrics

7.4.1 24590-LAW-P3-RLD-ZS03368001, Rev. 1, RLD-ZS-03368-S32B-2-LAW VITRIFICATION BUILDING ISOMETRIC

7.4.2 24590-LAW-P3-RLD-ZS03368002, Rev. 1, RLD-ZS-03368-S32B-2-LAW VITRIFICATION BUILDING ISOMETRIC

7.4.3 24590-LAW-P3-RLD-ZS03368003, Rev. 1, RLD-ZS-03368-S32B-2-LAW VITRIFICATION BUILDING ISOMETRIC

7.4.4 24590-LAW-P3-RLD-ZS03368004, Rev. 1, RLD-ZS-03368-S32B-2-LAW VITRIFICATION BUILDING ISOMETRIC

7.4.5 24590-LAW-P3-RLD-ZF33830001, Rev. 0, RLD-ZF-33830-NIIF-2-LAW VITRIFICATION BUILDING ISOMETRIC

7.5 WAC 173-303-640. Tank Systems, Section 4, Containment and Detection of Releases in Dangerous Waste Regulations, Washington State Administrative Code.

7.6 WA 7890008967. Dangerous Waste Permit (DWP). Dangerous Waste Portion of the Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous Waste at the Hanford Waste Treatment and Immobilization Plant, Rev. 8C.

7.7 24590-LAW-P1-P01T-00001, Rev. 4, LAW VITRIFICATION BUILDING GENERAL ARRANGEMENT PLAN AT EL. (-)21'-0"

7.8 24590-LAW-P1-P01T-00002, Rev. 7, LAW VITRIFICATION BUILDING GENERAL ARRANGEMENT PLAN AT EL. 3 FEET - 0 INCHES

7.9 24590-LAW-P1-P01T-00004, Rev. 6, LAW VITRIFICATION BUILDING GENERAL ARRANGEMENT PLAN AT EL. 28 FEET - 0 INCHES

7.10 24590-LAW-P1-P01T-00005, Rev. 6, LAW VITRIFICATION BUILDING GENERAL ARRANGEMENT PLAN AT EL. 48 FEET - 0 INCHES

7.11 24590-LAW-DD-S13T-00014, Rev. 7, LAW Vitrification Building Main Building 24" and 30" Dia. Sump Detail

7.12 2009 ASHRAE Handbook Fundamentals

7.13 CCN 093156 E-mail Message from Danielle Mathews to Roosevelt Molina, dated August 20,2004, Subject: Flour Daniel Northwest Calculation No. W314-P-039, Encasement Leak Detection, October 19, 1998

7.14 24590-WTP-3PB-P000-TN11F, Rev. 18, PIPING MATERIAL CLASSIFICATION PIPE CLASS N11F

7.15 24590-WTP-3PB-P000-TS32B, Rev. 25, PIPING MATERIAL CLASSIFICATION PIPE CLASS S32B

7.16 "Flow of Fluids through Valves, Fittings, and Pipe", Technical Paper No. 410, Crane Co., 1988

7.17 Towell, G. D, and Rothfeld, L. B. 1996, Hydrodynamics of Rivulet Flow, AIChE, Journal, Vol. 12, No. 5, p. 972-980

7.18 Roberson, John A. and Clayton T. Crow, Engineering Fluid Mechanics 2nd Edition, Houghton Mifflin Co., Boston, MA, 1980

7.19 24590-WTP-GPG-M-033, Rev. 4, Fire Water Floor Drain System

7.20 24590-WTP-3PS-JL10-T0002, Rev. 0, Engineering Specification for Radar Level Measurement

7.21 CCN 097799, Leak Detection Capability Scoping Statement Revision 6, 08/19/2004

7.22 24590-WTP-M6C-M11T-00004, Rev. 1, Supporting Calculation for Fire Water Floor Drain System Design Guide

7.23 24590-QL-HC4-HAHH-00001-06-00959, Rev. C, DRAWING - AUTOSAMPLING SYSTEM ASX-SMPLR-00012 GLOVEBOX SUBASSEMBLY SHEET 1 OF 3

7.24 24590-QL-HC4-HAHH-00001-06-00960, Rev. C, DRAWING - AUTOSAMPLING SYSTEM ASX-SMPLR-00012 GLOVEBOX SUBASSEMBLY SHEET 2

7.25 24590-QL-HC4-HAHH-00001-06-00962, Rev. C, DRAWING - AUTOSAMPLING SYSTEM ASX-SMPLR-00013 GLOVEBOX SUBASSEMBLY SHEET 1 OF 3

7.26 24590-QL-HC4-HAHH-00001-06-00963, Rev. C, DRAWING - AUTOSAMPLING SYSTEM ASX-SMPLR-00013 GLOVEBOX SUBASSEMBLY SHEET 2

7.27 24590-LAW-DD-S13T-00001, Rev. 6, LAW Vitrification Building Main Building Liner Plate Grillage Details