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# Leak Detection Capability in the Pretreatment Facility

Document title:

Document number: 24590-PTF-PER-M-04-0010, Rev 2

Contract number: DE-AC27-01RV14136

Department: Mechanical and Process Engineering

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Issue status: Issued for Permitting Use

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This bound document contains a total of 20 sheets

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# Notice

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# History Sheet

| Rev | Reason for revision | Revised by |
|---|---|---|
| 0 | Issued for Permitting Use | G. Chiaramonte |
| 1 | Correct permit condition reference to III.10.G.10.e.ii in Sections 1 and 3 | G. Chiaramonte |
| 2 | Updated to include current design | P. Rajagopalan |

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# Acronyms

| | |
|---|---|
| AEA | Atomic Energy Act of 1954 |
| C2 | contamination control zone 2 |
| C3 | contamination control zone 3 |
| DOE | US Department of Energy |
| DWP | Dangerous Waste Permit |
| FRP | Feed Receipt Process |
| LAW | low activity waste |
| PIH | Pretreatment In-cell Handling |
| PT | pretreatment |
| PTF | pretreatment facility |
| PWD | Plant Wash and Disposal |
| RDMC | Remote Decontamination Maintenance Cave |
| RFD | reverse flow diverter |
| RDP | Resin Disposal Process |
| RLD | Radioactive Liquid Disposal |
| TLP | Treated LAW Evaporation Process |
| WAC | Washington Administrative Code |
| WTP | Hanford Tank Waste Treatment and Immobilization Plant |

# 1 Summary

The Pretreatment (PT) facility black cell and hot cell sumps must satisfy the leak detection criteria of Washington Administrative Code (WAC) 173-303-640(4) and the Waste Treatment and Immobilization Plant Dangerous Waste Permit (DWP) WA 7890008967, Permit Conditions III.10.E.9.e.ii and III.10.G.10.e.ii for tank and miscellaneous treatment system secondary containment areas. This report evaluates the minimum leak rates that can be detected within 24 hours in the regulated secondary containment sumps.

The PT facility contains 25 sumps within the black cells and hot cell that are regulated under the DWP. Leaks of vessels or piping within the cells will flow along the floor and are collected in a sump and detected with level instrumentation. All sumps are dry type, that is, the sumps are dry unless there is a leak or condensation that reaches the sump. All sumps except one are the same size (nominally 30 inch OD schedule 10 pipe x about 28 inches deep) and use radar type leak detection. The exceptions are the sumps in the minus 45 ft elevation pit (PWD-SUMP-00040), which is much larger, rectangular in shape (60 in x 30 in x 30 in deep) and uses a conventional pneumatic bubbler with a level transmitter to detect leaks and the sump PWD-SUMP-00035 in cell P-0122A which uses a thermal conductivity switch instead of a radar type leak detection.

Leak detection for the remote filter cave (P-0335) is provided via drainage of leakage through floor openings to black cell sumps PWD-SUMP-00005 and PWD-SUMP-00006 directly below the filter cave (P-0335) in rooms P-0102A and P-0102, respectively.

The minimum leak flow rate that can be detected in 24 hours is calculated by estimating the volumes of two components of the leak, 1) the minimum detectable quantity of liquid in the sump and 2) the volume associated with the leak "rivulet" formed as the leak flows along the floor to the sump. The detectable volume of the leak in the sump is related to the size and geometry of the sump and the location and sensitivity of the leak detection instrumentation. The volume associated with the leak rivulet is related to the slope of the floor and the flow rate of the leak.

Minimum 24 hour leak detection rates are evaluated for each regulated sump in the PT facility. The leak detection rate varies with the travel distance of the leak, i.e., the longer the travel distance, the greater is the 24 hour leak detection rate. The bounding case for the 30-inch diameter round sumps indicates a maximum leak travel distance of 137 ft for PWD-SUMP-00026. The calculated minimum 24 hour leak detection rate for this sump is 0.09 gal/hr. Leak detection rates for all 30-inch diameter sumps range from 0.05 to 0.09 gal/hr.

For the larger, rectangular sump located in the minus 45 ft elevation pit (PWD-SUMP-00040), the maximum leak travel distance is 209 ft. The minimum 24 hour leak detection rate for this sump is 0.1 gal/hr.

# 2 Objective

The objective of this report is to document the minimum flow rate that can be detected within a 24 hour period for potential leaks that are collected in the PT facility secondary containment area sumps in the black cells and hot cell. The scope of this report includes:

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

Leaks collected in drain systems that flow to vessels or tanks are not in scope. Areas within the PTF that employ open floor drains for containment are routinely accessible and leak detection will be provided by daily visual inspection, or other approved method, and for that reason are not addressed in this report.

Leaks from ancillary equipment/piping that are detected by routine visual inspection are not in scope.

# 3 Description

The PT facility secondary containment area 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, Containment and Detection of Releases (Ref. 1) and are stated 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 (Ref. 2), , Conditions III.10.E.9.e.ii and III.10.G.10.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. 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 criteria must be approved by Ecology." [WAC 173-303-640(4)(c)(iii), WAC 173-303-806(4)(c)(vii)];

# 4 Inputs and Assumptions

## 4.1 Inputs

1. Sump type, leak detection type, and nominal sump dimensions are derived from "Sump Data for PT Facility" (Ref. 3).

2. The stainless steel liners in the vessel cells, filter cave (P-0335), and in the hot cell are sloped at a minimum slope of 1:100 (1 %) to direct potential leakage in these areas to their respective sump.

## 4.2 Evaluation Assumptions

1. The following group of assumptions were used to determine leak detection capability (Ref 4).
   a. The liquid leaking is water at a temperature of 100 °F.
   b. The leak is at a constant rate over the twenty-four 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 will be considered. Hold-up 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.
2. The furthest point from the sump is assumed to be bounded by the furthest corner of the cell which contains the sump with exception of the sump in the minus 45 ft elevation pit (PWD-SUMP-00040). The flow path for each cell is conservatively considered to be along the straight walls rather than diagonally across the cell.
3. For the minus 45 ft elevation pit, the furthest point from the sump is considered to be the furthest horizontal leak path via the pipe tunnels. The vertical drop from the tunnel to the pit floor is neglected.
4. 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.
5. The floor is uniformly sloped and the flow path is in straight lines (no meandering flow).
6. Radar leak detection is stated by the radar instrument supplier to be accurate within ±10 mm, i.e., the minimum level of liquid in the sump must rise to at least 10 mm before it is detected by the radar instrument. The radar guide tube is located 1/2 inch from the bottom of the sump. It is not necessary for the liquid level to be within the guide tube before the radar will detect it. However, because the bottom of the sump is dished (it is formed from an ellipsoidal head) and because the radar guide tube is offset from the center of the sump by no more than 8 inches, the level as measured from the center of the sump must rise slightly higher in the sump to be within the radar's 10 mm detection specification. Therefore, for conservatism, a 10% contingency is added to the vertical distance from the bottom of the sump to point of measurement, to bound the height requirement. It is assumed that all sumps listed in table 7.2 (except PWD-SUMP-00040) have level indicators located within 8" from the centerline; this dimension provides a bounding value to simplify calculations while demonstrating that the current design exceeds leak detection requirements.
7. The pneumatic bubbler leak detection instrument in the minus 45 ft elevation pit sump (PWD-SUMP-00040) uses a 1/2 inch Sch 40 pipe dip pipe with a straight end (not slanted). The bottom of the dip pipe is located 1/4 inch from the bottom of the sump. The leak detection instrumentation includes a pneumatic level transmitter that can detect a level that is 1 inch above the bottom of the dip tube. Therefore, added to the 1/4 inch dip tube clearance, the water must rise to a total depth in the sump of at least 1.25 inches before it can be detected.
8. The thermal conductivity switch in PWD-SUMP-00035 in Room P-0122A can detect liquid as soon as it reaches the level of the contacts. The switch will be located within 1/2 inch of the sump bottom, but the switch will be assumed offset from the center by up to 4 inches. Therefore, for conservatism,

it is assumed that the detectable level in this sump is one inch from the bottom of the sump measured in the center.

9. Sump PWD-SUMP-00040 has a "trough" in the bottom of the sump that is 30 inches long, 10 inches wide, and at least 1.25 inches deep. Leaks collected in the sump trough will meet the DWP leak detection requirements. This trough will be placed across the 30 inch width of the sump and is to be 10 inches wide. The minimum 1.25 inch depth is the minimum level the leak detection instrumentation can detect. The bottom of leak detection instrument is located 0.25 inches above the bottom of the trough in the sump.

# 5 Analysis

The PT facility contains 25 DWP-regulated sumps (Ref. 3). All sumps are dry type, that is, the sumps are dry unless there is a leak or condensation that reaches the sump. All sumps except one are the same size (nominally 30 inches O.D. x about 28 inches deep, hereinafter referred to as "round" sumps). The exception is the sump in the minus 45 ft elevation pit which is much larger and rectangular in shape (60 in x 30 in x 30 in deep). All sumps except the minus 45 ft elevation pit sump (PWD-SUMP-00040) and PWD-SUMP-00035 in Room P-0122A are provided with radar type leak detection. The pit sump (PWD-SUMP-00040) uses a conventional pneumatic bubbler and level transmitter to detect leaks. PWD-SUMP-00035 in Room P-0122A (Waste Packaging Area) uses a thermal conductivity switch.

Leaks in the remote filter cave (P-0335) would flow along the floor of the cave through the openings in the cave floor to PWD-SUMP-00005 or PWD-SUMP-00006 directly below the filter cave (P-0335) in a black cell (rooms P-0102A and P-0102, respectively).

Leaks from vessels or ancillary equipment/piping within the cells will flow along the floor and will be collected in a sump and detected with level instrumentation.

# 6 Detectable Leak Rates

Minimum 24-hour leak detection rates are evaluated for each of the secondary containment sumps in the PT facility. The leak detection rate varies with the travel distance of the leak, the longer the travel distance, the greater is the 24-hour leak detection rate. The bounding case for the 30-inch diameter round sump indicates a maximum leak travel distance of 137 ft which corresponds to PWD-SUMP-00026. The minimum 24 hour leak detection rate for this sump is 0.09 gal/hr. Leak detection rates for all 30-inch diameter sumps range from 0.05 to 0.09 gal/hr.

For the larger sump located in the minus 45 ft elevation pit (PWD-SUMP-00040), the maximum leak travel distance is 209 ft. The minimum 24 hour leak detection rate for this sump is 0.1 gal/hr.

Results of the evaluation for all PT facility sumps are provided in Table 6.1.

**Table 6.1 Minimum Leak Detection Rates for PT Facility Sumps**

| Sump PIN PWD-SUMP-000xx | Max. Leak Travel Distance ft | Volume of Leak to Reach Sump gal $V_r$ | Volume of Leak for Detection in Sump gal $V_s$ | Total Volume of Leak Detectable in 24 hours gal $V_t$ | 24-Hour Leak Rate Detected (rounded) gal/hr |
|---|---|---|---|---|---|
| 40 | 209 | 0.746 | 1.62 | 2.366 | 0.10 |
| 01 | 105 | 0.616 | 1.11 | 1.726 | 0.07 |
| 01A | 106 | 0.625 | 1.11 | 1.735 | 0.07 |
| 02 | 105 | 0.616 | 1.11 | 1.726 | 0.07 |
| 02A | 105 | 0.616 | 1.11 | 1.726 | 0.07 |
| 03 | 107 | 0.633 | 1.11 | 1.743 | 0.07 |
| 04 | 107 | 0.633 | 1.11 | 1.743 | 0.07 |
| 05 | 106* | 0.625 | 1.11 | 1.735 | 0.07 |
| 06 | 115* | 0.761 | 1.11 | 1.871 | 0.08 |
| 07 | 83 | 0.436 | 1.11 | 1.546 | 0.06 |
| 08 | 83 | 0.436 | 1.11 | 1.546 | 0.06 |
| 09 | 85 | 0.450 | 1.11 | 1.560 | 0.07 |
| 10 | 64 | 0.308 | 1.11 | 1.418 | 0.06 |
| 11 | 84 | 0.443 | 1.11 | 1.553 | 0.06 |
| 12 | 93 | 0.512 | 1.11 | 1.622 | 0.07 |
| 13 | 95 | 0.529 | 1.11 | 1.639 | 0.07 |
| 26 | 137 | 0.965 | 1.11 | 2.075 | 0.09 |
| 28 | 91 | 0.497 | 1.11 | 1.607 | 0.07 |
| 29 | 135 | 0.939 | 1.11 | 2.049 | 0.09 |
| 31 | 33 | 0.140 | 1.11 | 1.250 | 0.05 |
| 32 | 106 | 0.625 | 1.11 | 1.735 | 0.07 |
| 33 | 68 | 0.333 | 1.11 | 1.443 | 0.06 |
| 34 | 45 | 0.200 | 1.11 | 1.310 | 0.05 |
| 35 | 105 | 0.616 | 1.11 | 1.726 | 0.07 |
| 36 | 85 | 0.450 | 1.11 | 1.560 | 0.07 |
| | | | | | |

Note 1: PWD-SUMP-00005 (P-102A) and PWD-SUMP-00006 (P-102) consider distances traveled by leaks in the filter cave (P-0335) through the floor openings into the black cell rooms below and the distance in the black cells to the respective sumps.

* The distance traveled for PWD-SUMP-00005, is 90 ft in room P-0102A and 106 ft from P-0335 (Filter Cave Room). The bounding value of 106 ft is used. The distance traveled for PWD-SUMP-00006, is 82 ft in room P-102 and 115 ft from P-0335 (Filter Cave Room). The bounding value of 115 ft is used.

# 7 Bounding Calculations

## 7.1 Methodology

The minimum leak flow rate that can be detected in 24 hours is calculated by estimating the volumes of two components of the leak:

1. The minimum detectable quantity of liquid in the sump, $V_s$ (in gallons)
2. The volume associated with the leak "rivulet" as the leak flows along the floor to the sump, $V_r$ (in gallons)

The total volume of the leak is then $V_t = V_r + V_s$

The minimum detectable flow rate is then:

$Q = V_t/24$ hours, in units of gal/hr

### 7.1.1 Minimum Detectable Volume in the Sump

#### 7.1.1.1 Round Sumps

The round sumps are nominal 30 inches in diameter and about 28 inches in depth. The round sumps are formed from 30-inch Sch 10S pipe (I.D. = 29.376 in). The bottom consists of a 2:1 ellipsoidal head. The level indication for detecting a leak is not directly in the middle of the sump because of installation requirements. Off-center level indication means that the liquid level needs to rise up the curvature of the sump for detection.

$$y = \frac{1}{2}\sqrt{\frac{D^2}{4} - x^2}$$

Where, y = vertical distance from top of sump to off-center point, in
D = inside diameter of sump, in
x = horizontal distance from center of sump to off-center point, in

$$d = 0.25 * D$$

Where, d = height of ellipsoidal part of sump, in
D = inside diameter of sump, in

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

Where, h = minimum height of liquid for leak detection in sump, in
d = height of sump, in
y = vertical distance from top of sump to off-center point, in

z = instrument accuracy, in
C = margin, %

The minimum detectable volume in the sump is determined from the formula that relates depth in the ellipsoidal head to volume:

$$V_s = \pi D h^2 \left[1 - \frac{4h}{3D}\right]$$

Where $V_s$ = volume based on the liquid level h, cubic inches

h = height of liquid in the sump, inches
D = sump inside diameter, inches

$V_s$ in cubic inches is then converted to gallons with a conversion factor

#### 7.1.1.2 Rectangular Sump

The only rectangular sump in the PT facility is in the minus 45 ft elevation pit. This sump (PWD-SUMP-00040) is 60 in x 30 in x 30 inches deep (Ref. 3, Table 1).

The minimum detectable volume in the sump is

$V_s = L \times W \times h$

Where L = length, inches
W = width, inches
h = depth of liquid in sump, inches

$V_s$ in cubic inches is then converted to gallons with a conversion factor

### 7.1.2 Wetted Volume For Flow of Liquid Across the Floor of the Cell

When a liquid flows down an inclined surface at a low rate, separate rivulets form instead of a continuous film. The hydrodynamics of rivulet flow have been empirically measured and mathematically modeled (Ref. 5). The relationships provided in this reference are used to estimate the wetted volume for flow across the cell floor. In this reference, steady state theoretical solutions are developed for the laminar flow based on the reduced form of the Navier-Stokes equations using special boundary conditions that include contact angle (angle formed by the edge of the rivulet and the surface) and relations between the pressure inside and outside the curved interface. The shape of the interface and the velocity profile in the rivulet are obtained and an integration of this velocity profile gives a relation between the rivulet width and the flow rate. This relation contains the slope, contact angle of the liquid on the surface, and the fluid properties: viscosity, density and interfacial surface tension. In simpler terms, this analysis considers that the flow rate is a balance of gravitational forces which drive the flow and viscous forces which resist the flow.

In Ref. 5, experimental measurements consisting of rivulet width measurements as a function of rivulet flow rate were conducted for a variety of liquids including water. The data was checked against the models and found to be in good agreement.

Based on the information in Ref. 5, for the range of flow rates of interest in this calculation, the solution to the flow equations can be simplified by considering the rivulet as a relatively wide and flat rectangular shape. For this shape of rivulet, the maximum flow depth, $Y_o$ is given by:

$$Y_o = 2\sin\theta/2 \qquad \text{Equation 1}$$

Where θ = contact angle (angle formed at the edge of the rivulet where it contacts the surface)

The width of the rivulet, *I,* is determined by (see Equation 27 in Ref. 5) as follows:

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

Where:
α = angle of inclination (slope) between the surface and vertical (90° - slope in degrees)
γ = interfacial surface tension, dynes/cm = g/sec$^2$
μ = viscosity, g/cm sec
θ = contact angle (measured from the surface), degrees
ρ = density of liquid, g/cm$^3$
*l* = rivulet width, cm
Q = flow rate, cm$^3$/sec
g = acceleration of gravity, cm/sec$^2$

Note that centimeter, gram, second (CGS) units are used in this calculation for consistency with the reference. The volume and flow rate results then are converted to English units.

Rearranging and solving for *l* gives:

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

The contact angle, θ, is unknown, but according to Table 2, Ref. 5, at a flow rate of 6.3 cm$^3$/min (~0.1 gal/hr), the contact angle was measured experimentally at 9-12°. At lower flow rates, the measured contact angle varied from 3 to 8 degrees but did not show proportionality to flow rate possibly due to varying shape of the rivulet and/or the slope of the surface. Low contact angles applied in equations 1 and 3 yield results of disproportionately wide and shallow rivulets (*l* is very large compared to $Y_o$). In the experiments, rivulet width varied up to a maximum of about 4 cm with most of the widths in the range of 0.4 to 3 cm for the smallest incline tested. Rivulet widths below 3 cm correspond to a contact angle of about 6 degrees. Below 6 degrees, widths increase greatly and at contact angles of 4 degrees and lower, the solution does not converge. Therefore, for purposes of this calculation, for flow rates <0.05 gal/hr, contact angles between 6 degrees and 12 degrees are considered bounding, with the lower of the two angles yielding the highest flow rate. For flow rates of 0.1 gal/hr and higher, a range of 9 degrees to 12 degrees is used; 9 degrees yields the highest flow rate, so it is the most conservative.

The remainder of the calculation procedure is now iterative by performing the following steps:

Step 1 - Assume a contact angle and assume a starting flow rate, Q
Step 2 - Calculate the volume of the rivulet as follows:

Since the rivulet is approximated as rectangular, the cross-sectional area, *A,* of the rivulet is:

$A = Y_o l$, where A is in the units of $cm^2$

The total volume of the rivulet, in $cm^3$, is $V_r$

$V_r$ = A x flow path length (in cm)

$V_r$ is then converted to gallons by dividing by 3785 $cm^3$/ gal.

Step 3 - Calculate a total volume of liquid collected in 24 hours:

Add the rivulet volume, $V_r$, (in gallons) to the volume of liquid collected in the sump to get $V_t$, the total volume of liquid leaked in a 24 hour period.

i.e., $V_t = V_r + V_s$

Step 4 - Calculate an adjusted total 24 hour flow rate, i.e.,

$Q_{adj} = V_t/24$

This new adjusted Q takes the total volume of liquid into account whereas the starting Q only considered the volume of the sump. Therefore, $Q_{adj}$, may differ from the initial estimate for Q if the volume of the rivulet is significant relative to the volume of the sump, so an iterative trial and error is performed by setting the new trial $Q = Q_{adj}$ from the first trial. This is continued until the starting Q matches the final $Q_{adj}$ (i.e., the iteration converges).

## 7.2 Bounding Calculations

### 7.2.1 Calculation for the Longest Leak Travel Distance for the Sumps

The maximum leak travel distances for each sump in the facility is derived from the cell dimensions and sump locations as provided in the facility general arrangement drawings (Ref. 6, 7). As indicated in Assumption 2, the maximum leak travel distance is computed by summing the distance along the walls from the furthest corner of the cell, i.e., adding the north-south wall distance to the east-west wall distance. For the minus 45 ft elevation pit, per Assumption 3, the furthest distance is derived by summing the distance from the furthest point in the pipe tunnel (in this case the north tunnel is the longest distance) with the east-west distance along the north wall of the pit. A summary of distance data for each sump is provided in Table 7.1.

**Table 7.1 Maximum Leak Distances for Each Sump**

| Elev. | Room Number | Room Name | Sump PIN PWD-SUMP-000xx | Sump Location in Cell | N-S Distance | E-W Distance | Total Distance, ft (rounded up) |
|---|---|---|---|---|---|---|---|
| 0'-0" | P-0108B | Feed Receipt Cell | 1 | NW corner | 52'-6" | 52'-4" | 105 |
| 0'-0" | P-0108C | Feed Receipt Cell | 1A | SW corner | 53'-6" | 52'-4" | 106 |
| 0'-0" | P-0108A | Feed Receipt Cell | 2 | SE corner | 52'-6" | 52'-4" | 105 |
| 0'-0" | P-0108 | Feed Receipt Cell | 2A | SW corner | 52'-0" | 52'-2" | 105 |
| 0'-0" | P-0106 | Feed Evaporator/Ultra-Filtration Cell | 3 | S wall | 52'-0" | 55'-0" | 107 |
| 0'-0" | P-0104 | Ultra Filtration Cell | 4 | S wall | 52'-0" | 55'-0" | 107 |
| 0'-0" | P-0102A | HLW Receipt/Storage/ Blending Cell | 5 | S wall | 52'-0" | 38'-0" | 90 |
| 56'-0" | P-0335 | Filter Cave Room | 5* | N/A | 52'-0" | 54'-0" | 106 |
| 0'-0" | P-0102 | HLW Receipt/Storage/ Blending Cell | 6 | S wall | 52'-0" | 30'-0" | 82 |
| 56'-0" | P-0335 | Filter Cave Room | 6* | N/A | 52'-0" | 63'-0" | 115 |
| 0'-0" | P-0109 | Acidic/Alkaline Effluent Collection Cell | 7 | NE corner | 54'-0" | 28'-6" | 83 |
| 0'-0" | P-0111 | Cs Ion Exchange Cell | 8 | NW corner | 34'-6" | 48'-0" | 83 |
| 0'-0" | P-0112 | Cesium Effluent Recovery Cell | 9 | NE corner | 34'-6" | 50'-6" | 85 |
| 0'-0" | P-0113 | Reserved Space (TBD) | 10 | NW corner | 34'-6" | 29'-6" | 64 |
| 0'-0" | P-0114 | Treated LA W Collection Cell | 11 | NE corner | 34'-6" | 49'-6" | 84 |
| 0'-0" | P-0117 | Treated LA W Feed Cell | 12 | NW corner | 34'-6" | 57'-8" | 93 |
| 0'-0" | P-0117A | Treated LAW Feed Cell | 13 | NE corner | 34'-6" | 59'-10" | 95 |
| 0'-0" | P-0123 | Hot Cell | 26 | S wall | 51'-0" | 86'-0" | 137 |
| 0'-0" | P-0123 | Hot Cell | 28 | S wall | 51'-0" | 40'-0" | 91 |
| 0'-0" | P-0123 | Hot Cell | 29 | S wall | 51'-0" | 84'-0" | 135 |
| 0'-0" | P-0119 | Spent Resin Receipt | 31 | SW corner | 18'-0" | 15'-0" | 33 |
| 0'-0" | P-0123A | Remote Decon Maintenance Cave | 32 | SW corner | 51'-0" | 54'-6" | 106 |
| 0'-0" | P-0123A | Remote Decon Maintenance Cave | 33 | S wall | 51'-0" | 17'-0" | 68 |
| 0'-0" | P-0121A | Spent Resin Dewatering | 34 | SW corner | 18'-0" | 27'-0" | 45 |
| 0'-0" | P-0122A | Waste Packaging Area | 35 | SW comer | 52'-0" | 53'-0" | 105 |

**Table 7.1 Maximum Leak Distances for Each Sump**

| Elev. | Room Number | Room Name | Sump PIN PWD-SUMP-000xx | Sump Location in Cell | N-S Distance | E-W Distance | Total Distance, ft (rounded up) |
|---|---|---|---|---|---|---|---|
| 19'-0" | PM-0124 | Crane Maintenance | 35 | Drain | 51'-0" | 24'-0" | 75 |
| 0'-0" | P-0118 | Alkaline Effluent Collection Cell | 36 | SE corner | 54'-4" | 30'-6" | 85 |
| -45'-0" | P-B002 | HLW Drain Vessel Pit | 40 | W wall | 132'-0" | 77'-0" | 209 |

* The total distance traveled includes the distance in the filter cave (room P-0335) and the distance traveled in the room P-0102 and P-0102A respectively.

Based on the estimate of travel distances for leaks in each cell, the longest leak flow distance to any round sump was determined to be 137 ft for sump PWD-SUMP-00026 in the hot cell. The calculation for this bounding case is provided below.

### 7.2.1.1 Minimum Detectable Volume in the Sump

The level indication for detecting a leak is not directly in the middle of the sump and has installation requirements. Off-center level indication means that the liquid level needs to rise higher than the curvature of the sump for detection. The height from the top of the semi-ellipsoidal head to a point 8" off-center is determined by:

$$y = \frac{1}{2}\sqrt{\frac{D^2}{4} - x^2}$$

D = 29.376 in = inside diameter of a 30 inch Sch 10S pipe.
x = 8 inches (Assumption 6)

$$y = \frac{1}{2}\sqrt{\frac{(29.376in)^2}{4} - (8in)^2}$$

y = 6.159 in

$$d = 0.25 * D$$

D = 29.376 in = inside diameter of a 30 inch Sch 10S pipe.

$$d = 0.25 * 29.376in$$

d = 7.344 in

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

d = 7.344 in
y = 6.159 in
z = 10 mm or 0.394 in (assumption 6)
C = 1.10 (assumption 6)

$$h = (7.344in - 6.159in + 0.394) * 1.1$$

h = 1.737 in

The minimum detectable volume in the sump is calculated by:

$$V_s = \pi D h^2 \left[1 - \frac{4h}{3D}\right]$$

D = 29.376 in = inside diameter of a 30 inch Sch 10S pipe.
h = 1.737 in

$$V_s = \pi(29.376in)(1.737in)^2\left[1 - \frac{4(1.737in)}{3(29.376in)}\right]$$

$V_s$ = 256.5 cu in

Multiply by 0.00433 to convert cu in to gallons

**$V_s$ = 1.11 gal**

### 7.2.1.2 Wetted Volume For Flow of Liquid Across the Floor of the Cell

Based on the methodology described in Section 7.1.2, the bounding contact angle ,θ, is assumed to be 6°

Using Equation 1 (Section 7.1.2), the depth of the rivulet, $Y_o$, is calculated

$$Y_o = 2\sin\theta/2$$

$$Y_o = 2\sin 6\ \text{deg}/2$$

$Y_o$ = 0.105 cm

Next, the width of the rivulet is calculated using Equation 3 (Section 7.1.2)

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

α = (90° - 0.563°) = 89.437 degrees
γ = 69.9 dynes/cm = 69.9 g/sec$^2$
μ = 0.00678 g/cm sec
ρ = 0.993 g/cm$^3$
g = 980.7 cm/sec$^2$

The remainder of the calculation procedure is now iterative by performing the following steps:

Step 1 - Assume a starting flow rate, Q, and calculate the rivulet width, *l*

As a first estimate for Q, use the sump volume $V_s$/24 = 1.11 gal/24 hr = 0.046 gal/hr = 0.048 cm$^3$/sec

$$l = \frac{3(0.00678\ g\ /\ cm\ \sec)\ (0.048\ cm^3\ /\ \sec)\ \tan 89.437\ \deg}{8(69.9\ g\ /\ \sec^2)(\sin^3\ (6\ \deg/\ 2))} \sqrt{\frac{0.993\ g\ /\ cm^3 (980.7\ cm\ /\ \sec^2) \sin 89.437\ \deg}{(69.9\ g\ /\ \sec^2)}}$$

$l = 4.63$ cm

Step 2 - Calculate the volume of the rivulet as follows:

Since the rivulet is approximated as rectangular, the cross-sectional area, A, of the rivulet is:

$A = Y_o l$,

$A = 0.105$ cm x 4.63 cm = 0.486 $cm^2$

The total volume of the rivulet, in $cm^3$, is $V_r$

$V_r$ = A x flow path length, cm

Path length = 137 ft x 30.48 cm/ft = 4176 cm

$V_r = (0.486\ cm^2)(4176\ cm) = 2029.5\ cm^3$

$V_r$ is then converted to gallons by dividing by 3785 $cm^3$/gal.

$V_r = 0.54$ gal

Step 3 - Calculate a total volume of liquid collected in 24 hours:

Add the rivulet volume, $V_r$, (in gallons) to the volume of liquid collected in the sump to get $V_t$, the total volume of liquid leaked in a 24 hour period.

i.e., $V_t = V_s + V_r$

$V_t = (1.11\ gal + 0.54\ gal) = 1.65$ gal

Step 4 - Calculate an adjusted total 24 hour flow rate, i.e.,

$Q_{adj} = V_t/24$

$Q_{adj} = (1.65\ gal/24\ hr) = 0.069$ gal/hr

The initial estimate for Q was 0.046 gal/hr so an iterative trial and error is performed until the starting Q matches the final $Q_{adj}$ (i.e., the iteration converges).

When the iterations converge, the flow rate is:

**Q = 0.09 gal/hr**

### 7.2.2 Calculation for the Longest Leak Travel Distance for the Rectangular Sump (Minus 45 ft Elevation Pit)

#### 7.2.2.1 Minimum Detectable Volume in the Sump

Minimum detectable volume of the rectangular sump is determined from:

$V_s = L \times W \times h$

Where L = 30 in
W=10 in
h = 1.25 in (Assumption 7)
$V_s$ = (30 in)(10 in)(1.25 in) = 375 $in^3$ = 1.62 gal

#### 7.2.2.2 Wetted Volume For Flow of Liquid Across the Floor of the Cell

The same calculation process as performed in Section 7.2.1.2 is used to calculate the wetted volume for flow of liquid across the floor of the cell.

All input parameters are the same except:

The longest flow path length is 209 ft which is the distance through the north pipe tunnel into the sump. Contact angle is 9 degrees and starting flow rate for the iterations is 1.62 gal/24 hr = 0.068 gal/hr

Q is iterated until convergence is achieved.
At convergence the following are determined:

*1*= 2.820 cm
$Y_o$ =0.157 cm
A= 0.443 cm2
$V_r$ = 0.746 gal
$V_t$ = 2.366 gal
Q = 0.099 gal/hr

Therefore rounded to one significant figure:

**Q = 0.1 gal/hr**

### 7.2.3 Minimum Flow Rates for the Remaining Round Sumps

Calculations for the remaining 23 sumps in the PT facility are performed using the same methodology described in Section 7.1 The only variable is the leak travel distance to the sump. The results are summarized in Table 6.1.

# 8 References

1. WAC 173-303, *Dangerous Waste Regulations*, Washington Administrative Code

2. WA7890008967, "*Hanford Facility Resource Conservation and Recovery Act (RCRA) Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste*, Part III, Operating Unit 10, Waste Treatment and Immobilization Plant."
3. 24590-PTF-PER-M-02-006, Rev. 5, "Sump Data For PT Facility," January 14, 2003
4. CCN 097799, Leak Detection Capability Scope Statement, Revision 6, 8/19/04
5. Towell, G.D. and Rothfeld, L.B., "Hydrodynamics of Rivulet Flow," September, 1966, *AIChE Journal*, Vol. 12, No.5, Pages 972-980
6. Drawing 24590-PTF-PI-P01T-00001, Rev. 7, PT Facility General Arrangement Plan at El. 0'-0"
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