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History Sheet

Rev	Date	Reason for revision	Revised by
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Contents

Acronyms

AEA	Atomic Energy Act of 1954
DOE	US Department of Energy
ETF	Effluent Treatment Facility
HLW	high-level waste
LAW	low-activity waste
LAB	laboratory facility
LDB	leak detection box
LERF	Liquid Effluent Retention Facility
PT	pretreatment
PWD	plant wash and disposal
TFC	tank farm contractor
WAC	Washington Administrative Code

1 Summary

The minimum leak rates that can be detected within 24 hours are estimated for each of the double-walled underground transfer lines in the WTP facility. There are a total of 21 transfer lines whose encasements range in length from 289 ft to 1078 ft. Eight of the lines have a slope of 1:50, and the remaining 13 lines have a 1:200 slope.

The minimum leak rates (given to three significant figures) that can be detected within a 24 hour period range from 0.034 gal/hr for the shortest line to 0.141 gal/hr for the longest line, assuming that the leak is at the most remote location from the leak detection box.

The leak detection calculations reveal that the largest single component of the minimum detectable flow rate relates to the volume of leaked liquid required to wet the pipe (i.e., pipe holdup). For the longest line, this represents over 80% of the total minimum detectable flow rate. It is believed that holdup time due to wetting would not be significantly influenced by slope. If this is true, then the detectable leak rate varies primarily with the length of the line. Further, since the test data upon which wetting holdup time is based is accurate to only one significant figure, an estimate for the minimum detectable leak rate can be accurate to only one significant figure, i.e., the minimum detectable leak rate ≈ 0.1 gal/hr

2 Objective

This report addresses leak detection capability for all interfacility double-walled underground transfer lines within the WTP.

3 Description

The Preatreatment (PT) facility receives low-activity waste (LAW) feed and high-level waste (HLW) feed from the underground Double-Shell Tank System. This mixed waste feed is pumped through three double-walled underground transfer lines to the PT facility from the Tank Farm Contractor (TFC).

The PT facility pretreats the waste received from the Double-Shell Tank System and pumps it to the LAW vitrification facility through three double-walled underground transfer lines and to the HLW vitrification facility through four double-walled underground transfer lines. Secondary waste from the LAW facility is returned by pumped flow to the PT facility through four lines and by gravity flow from the HLW facility to the PT facility through four lines.

Analytical services are provided to each facility by the Laboratory Facility (LAB). Secondary wastes from the LAB are pumped to the PT facility for treatment and disposal through one double-walled underground transfer line.

Secondary waste is generated within the PT facility and pumped through two double-walled underground transfer lines to the Liquid Effluent Retention Facility (LERF)/Effluent Treatment Facility (ETF).

The regulatory requirements for leak detection are contained in WAC-173-303-640, Tank Systems, Section 4, Containment and Detection of Releases (Ref. 1). The regulatory requirements 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 (Ref. 2), ID No: DWP-2003-0371, Condition No: III.10.E.9.e.ii requires 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 Assumptions

Assumptions used for this assessment of underground transfer line leak detection are listed as follows. These assumptions are derived from Ref. 3.

- The liquid leaking is water at a temperature of 100 °F.
- The leak is at a constant rate over the twenty-four hour period.
- The leak is assumed to occur at the farthest point from the leak detection box (LDB).
- No evaporation will occur.
- The liquid does not foam in the LDBs.
- Hold-up in piping will be considered. Hold-up is defined as wetting of the pipe surface. Holdup due to spacers or other desgin features is not considered because. at low flow rates, spacers would not impede flow.
- 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.
- Leak detection instruments have not been purchased yet. The purchased unit will have a performance capability of positively detecting the liquid level of ½ inch.

5 Analysis

All underground transfer lines are double-walled pipe containing a 3-inch nominal stainless steel carrier pipe inside a 6-inch nominal carbon steel encasement pipe. All lines except the LERF/ETF lines are sloped toward the PT facility and the encasements terminate in the LDBs located within the PT facility pipe tunnels. The LERF/ETF lines slope toward the LERF/ETF facility and LDBs are located at the WTP facility boundary. Line slopes are indicated on the piping and instrument diagrams (Ref. 4, 5).

Pipe lengths and slopes are summarized as follows. Pipe lengths include 6 ft of piping to account for the drain portion leading from the encasement pipe to the LDB.

Transfer Line	Number of Lines	Line Length (ft)	Slope (ft/ft) [Ref]
HLW	8	289	1:50 [4]
Tank Farms	3	395	1:200 [4]
LERF/ETF	2	760	1:200 [5]
LAW	7	881	1:200 [5]
LAB	1	1078	1:200 [5]

The leak detection method employs LDBs at the low points of co-axial underground transfer lines in such a way that the outer pipe drains into them in the event that the primary inner pipe leaks. In each of the LDBs is a thermal conductivity type level instrument to detect the leak. There are a total of 19 LDBs within the PT facility servicing lines from the Tank Farms, to and from the HLW Facility, to and from the LAW Facility, and from the LAB Facility. LDBs for the lines to the LERF/ETF lines are located at the WTP facility boundary. Leak detection in secondary containment systems including buried co-axial transfer lines is described in Ref. 6.

6 Detectable Leak Rates

Detectable leak rate is the minimum leak rate that can be detected within 24 hours after the leak starts. As discussed in Section 7, this is primarily driven by the holdup (wetting) in the encasement line because this is a relatively large volume compared to the detectable volume in the LDB. It is believed that holdup time due to wetting would not be significantly influenced by slope. If this is true, then the detectable leak rate varies primarily with the length of the line. Illustration of these relationships are provided in Section 7, Bounding Calculations.

Results of the detectable leak rate analysis for each of the transfer lines, assuming that the leak is at the most remote location from the LDB, are summarized as follows. Note that the leak rates are stated with three significant figure accuracy, whereas the permit criteria (see Section 3) is stated with one significant figure, and test data upon which wetting holdup time is based is accurate to only one significant figure.

Transfer Line	Minimum Leak Rate Detectable Within 24 hours, gallons/hr
HLW	0.034
Tank Farms	0.047
LERF/ETF	0.097
LAW	0.113
LAB	0.141

7 Bounding Calculations

7.1 Methodology

The volume of water from a line leak that is required to accumulate within the transfer line and be detected within the LDB is the sum of three components:

- V_1 is the volume of the liquid (in gallons) which is required to accumulate within the LDB before it is detected by the leak detection instrumentation.
- V_2 is the volume of liquid that is accumulated within the pipe before it reaches the LDB. This is referred to as "holdup" and is the thin film of liquid that wets a small portion of the surface at the bottom of the pipe. This wetting occurs before any liquid is transported to the LDB.
- V_3 is the volume of liquid that is conveyed down the pipe to the leak detector after the pipe is wetted. This volume is based on the length and slope of the pipe.

V_1 is determined by calculating the quantity of liquid in the LDB that is required to trip the detector. This volume is determined from the geometry of the LDB and the assumed depth of liquid. The LDB consists of a 24-inch long section of an 8-in nominal Schedule 40S pipe with 8-inch standard pipe caps welded on each end. Each end cap consists of a straight cylindrical section and a 2:1 semi-ellipsoidal head. The leak detection chamber is isolated from the remainder of the box by a weir that is located 11-inches from one end (measured from the body/cap weld). The minimum quantity of liquid in the LDB that can be detected is based on a depth of liquid of 1/2-inch. The calculation of volume in the LDB involves use of standard handbook formulas for calculating the volumes of a partially filled pipe and the volume of a partially filled 2:1 semi-ellipsoidal head.

V_2, the "wetting" holdup is determined from test results on a 6-inch diameter Schedule 40 carbon steel pipe sloped at 1:400 (Ref. 7). The test results determined that 8 fluid ounces of water was required to wet the bottom of a 25 ft length of pipe (0.32 fluid oz per linear foot) before flow out of the pipe can occur.

$$V_{wet} = 0.32\frac{oz}{ft}$$

V_2 is calculated by multiplying the quantity (V_{wet}) of liquid that it will take to wet a linear foot of pipe by the total length of the pipe (L).

$$V_2 = \frac{V_{wet} * L}{128} \qquad 1 \text{ gal} = 128 \text{ oz}$$

The flow rate Q_2 in gal/hr is V_2/24 hr, where Q_2 is the flow required to wet the bottom of the pipe in 24 hours.

V_3 is the volume required to "convey" the leaked fluid down the pipe to the leak detector. This component of the flow can be thought of as a thin layer of fluid that is in excess of the quantity of fluid that represents the wetting film (V_2). This component of the flow is a flow boundary layer and is calculated using the boundary layer theory for uniform flow down an inclined plane. The velocity of flow, u, is determined according to the relationship (Ref. 8):

$$u = \frac{1}{3 * \upsilon}(g * So * d^2) \quad \text{Equation 7.1}$$

Where u = average flow velocity (ft/sec)
υ = kinematic viscosity (ft^2/sec)
g = gravitational constant (32.17 ft/sec^2)
d = depth of flow (ft)
So = Slope of the incline (dimensionless)

The depth of flow can be found by solving for d

$$d = \sqrt{\frac{3 * \upsilon * u}{g * So}} \quad \text{Equation 7.2}$$

An initial value for the average flow velocity u is calculated by dividing the pipe length by 24 hours. The depth of flow is then calculated from the above equation; then the cross sectional flow area of the liquid flow is calculated as follows (Ref. 9):

$$A_3 = d * \sqrt{1.766 * D * d - d^2} \quad \text{Equation 7.3}$$

where D is the inside diameter of the encasement pipe

The boundary layer flow rate Q_3 is calculated as the product of the cross sectional flow area A_3 and the average velocity u.

That is, $Q_3 = A_3 * u$ converted to gal/hr

The flow components Q_2 and Q_3 are added to obtain the total minimum detectable leak rate Q.

The calculation is repeated by adjusting for the time required to activate the leak detection alarm. The activation time is calculated by dividing the volume V_1 by the sum of flow components Q_2 and Q_3. This time is subtracted from 24 hours to calculate a revised average velocity u. Values of d, A_3, and Q_3 are recalculated based on the revised value of u. This iteration procedure is closed when repeatable values of u are calculated. The final sum of flows Q_2, and Q_3 is then the minimum detectable leakage rate in a 24-hour period.

7.2 Bounding Calculation

Using the methodology described in Section 7.1, calculation of the minimum leak rate detected within 24 hours is shown below for the longest line, the LAB transfer line encasement which is 1078 ft in length. Although slope of this transfer line is 1:200, for conservatism, the slope used in the calculation is 1:400, which corresponds to the slope used in the wetting holdup test.

7.2.1 Calculate the LDB Volume Required to Trip the Leak Detector

Using the calculation procedure discussed in Section 7.1, the calculated volume of liquid required to set off the leak detection alarm is determined to be 0.077 gal.

7.2.2 Calculate the Leak Rate Required to Wet the Surface

The component of the leak rate required to wet the surface is calculated as follows.

From the test data, the wetting holdup in the pipe at a 1:400 slope was determined to be 0.32 fluid oz/ft = V_{wet}

L = 1078 ft for the longest line (LAB)

$V_2 = V_{wet} * L / 128 = 2.70$ gal

$Q_2 = V_2/24 = 0.112$ gal/hr

7.2.3 Calculate the Leak Rate Required to Form the Flow Boundary Layer

Determine the component of the flow rate Q_3. This is the uniform flow rate necessary to convey the leakage to the LDB determined using the boundary layer theory for uniform flow on an inclined plane. The boundary layer theory (see Section 7.1) considers the properties of the liquid as well as the slope of the pipe.is the flow required to wet the bottom of the pipe in 24 hours.

Kinematic viscosity, υ, of water at 100F = 7.37E-6 ft^2/sec
Slope, S_0 = 0.0025 ft/ft
g = 32.17 ft/sec^2
D = 0.505 ft (inside diameter of encasement)

Equation 7.1 is used to calculate the initial iteration of the average velocity u. Then the first iteration of depth d (using Equation 7.2), the area A3 (using Equation 7.3), and Q3 are calculated. Total leakage rate is then calculated as Q = Q2 + Q3. The time to set off the leak detection alarm in the LDB is calculated as $t = V_1/Q$. This time is subtracted from 24 hours and the velocity u, in ft/sec, adjusted according to u = L/ ((24-t)/3600). Values of d, A3 and Q3 are recalculated until the iterations converge. In the final iteration, Q2 is determined to be 0.115 gal/hr and,

Q = 0.141 gal/hr

Note that the largest portion of the total required leak rate is to satisfy pipe wetting (0.115 gal/hr/0.141 gal/hr) or about 82% of the total flow required. Since the test data upon which wetting holdup time is based is accurate to only one significant figure, an estimate for Q can be accurate to only one significant figure, i.e.,

$Q \approx 0.1$ gal/hr

8 References

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2. WA 7890008967, *Dangerous Waste Portion of the Hanford Facility Resource Conservation and Recovery Act Permit for the Treatment, Storage, and Disposal of Dangerous, Waste,* Chapter 10 and Attachment 51, "Waste Treatment and Immobilization Plant."

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5. 24590-PTF-M6-PWD-P0058, Rev. 1, P&ID Plant Wash and Disposal System Underground Transfer Lines

6. 24590-WTP-PER-J-02-002, Rev. 1, *Low Point Leak Detection in Secondary Containment Systems Including Buried Co-Axial Transfer Lines*

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9. Nayyar, Mohinder L., *Piping Handbook,* Mc-Graw-Hill, 7th Edition