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AVANTech COVER SHEET

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JEREMIAH JOSEPH ROGERS
STATE OF WASHINGTON
48968
REGISTERED
PROFESSIONAL ENGINEER
8/27/19

TITLE	TSCR Sump Pump Sizing

	Name	Initials	Date
Preparer	Jaclyn Siewert	JS	6/13/19
Title	Engineer		
Reviewer	Rob Wilson	RW	6/13/19
Title	Sr. Engineer		
Approver	Jeremiah Rogers	JR	6/12/19
Title	Sr. Engineering Specialist		

Revision Notes	2 – Incorporation of 90% Comments

CALCULATION REVIEW CHECKLIST

CALCULATION ID NUMBER	RPP-CALC-62504
REVISION NUMBER	2

Item	Yes	N/A*
1. Design Inputs such as design bases, regulatory requirements, codes, and standards are identified and documented, verified against customer specifications including edition and addenda.	✓	
2. Effect of design package on compliance with the Safety Analysis Report or Certificate of Compliance identified and documented.	✓	
3. Revision numbers correct on the list of drawings?	✓	
4. Assumptions reasonable?	✓	
5. Appropriate analysis method used?	✓	
6. Correct values used from drawings?	✓	
7. Answers and units correct?	✓	
8. Summary of results matches calculations?	✓	
9. Material properties properly taken from credible references?	✓	
10. Figures match design drawings?	✓	
11. Computer input complete and properly identified?	✓	
12. Documentation of all hand calculations attached?	✓	
13. Reference to Verification / Validation for software?		✓

* N/A, Explain	13. All computer software checked by hand calculation.

	Name	Initials	Date
Reviewed	Rob Wilson	RW	6/13/19

Table of Contents

1.0 PURPOSE **4**

2.0 REFERENCES **4**

3.0 DESIGN INPUTS AND ASSUMPTIONS **5**

4.0 APPROACH/METHODOLOGY **6**

5.0 COMPUTATION **7**

6.0 CONCLUSIONS **7**

APPENDIX A - CALCULATION SPREADSHEET **8**

APPENDIX B - HOSE DIMENSIONS **9**

1.0 PURPOSE

The TSCR secondary containment system consists of the following major components:

- sump drip pan,
- sump leak detector, and
- sump pump

These components work together to detect, contain and transfer liquid released from TSCR process components. These components meet the requirements of Washington Administrative Code (WAC) Chapter 173, Part 303, Section 640 (WAC-173-303-640) concerning the containment boundaries for Tank Systems. This calculation will determine the flow, Net Positive Suction Head available (NPSHa), and required horsepower for the TSCR Sump Pump (WP-P-604). Refer to H-14-024857, Sheet 6, TSCR Piping and Instrumentation Diagram (Ref. 2.4).

2.0 REFERENCES

2.1. Specification for the Tank-Side Cesium Removal Demonstration Project, RPP-SPEC-61910, Rev. 1.

2.2. H-14-111270 Rev. 1, "Piping Process Enclosure Treated LAW"

2.3. RPP-CALC-62500 Rev. 2, "Process Enclosure Secondary Containment Sizing Calculation"

2.4. H-14-024857 Rev. 2, "TSCR P&ID"

2.5. H-14-111252 Rev. 2, "General Arrangement Delay Tank"

2.6. RPP-RPT-59929, Rev. 1, TSCR and 241-AP Upgrades Conceptual Layouts – Buried Obstruction Evaluation

2.7. DS-1813-02, Rev. 1, "Delay Tank Data Sheet"

2.8. Fiskum SK, HA Colburn, RA Peterson, AM Rovira, and MR Smoot, Cesium Ion Exchange Using Crystalline Silicotitanate with 5.6 M Sodium Simulant, PNNL-27587, RPT-DFTP-008, 2018.

2.9. Walas, S. M., "Chemical Process Equipment: Selection and Design," 1990, p. 671.

2.10. Lide, David, R., Handbook of Chemistry and Physics, CRC, 84th Edition, 2003

2.11. ASME B36.19M-2004, Stainless Steel Pipe

2.12. Crane, "Flow of Fluids Through Valves, Fittings, And Pipe", Technical Paper No. 410, 1980

2.13. Tompson, Ambler, "NIST Special Publication 811", 2008 Edition, March 2008

2.14. Swamee-Jain, J. of Hydraulics Div., ASCE, 102(5), 1976

2.15. PNNL-15160, Hanford Site, Climatological Summary 2004 with Historical Data, May 2005

2.16. H-14-111244 Rev. 2, "TSCR Process Enclosure Layout General Arrangement"

2.17. Crane, Bulletin 90, 9/2007.

2.18. TFC-ENG-STD-02, Rev. A-12, "Environmental/Seasonal Requirements for TOC Systems, Structures, and Components," September 2017

2.19. RPP-RPT-61220, Rev. 0, "Tank Side Cesium Removal (TSCR) Control Logic Narrative"

2.20. RPP-CALC-62505, Rev. 0, "TSCR Reagent Chemical Requirements"

3.0 DESIGN INPUTS AND ASSUMPTIONS

3.1. SUMP LIQUID INPUTS

3.1.1. Within the Process Enclosure the largest single vessel is the Delay Tank (POR655-WP-TK-550). For sump pump sizing, the analysis assumes this tank has emptied its contents into the sump. According to the Delay Tank Data Sheet (Ref 2.7) the volume is 300 gallons (V_S).

3.1.2. Sump will be simultaneously filled with incoming reagent. According to the TSCR Reagent Chemical Requirements calculation (Ref 2.20) the reagent has a flowrate of 7 gpm (Q_I). An interlock is programmed to shut off the TSCR Feed Pump, Reagent Water Pump, and Caustic Pump. In the event of an interlock failure, the sump would continuously fill with up to 7 gpm of liquid.

3.1.3. Inflow from AP-107 is contained within the piping loop containing valves WP-V-303 and WP-V-305 due to an interlock that initiates automatic system shutdown (Ref. 2.19, Sections 5.2 & 15.3).

3.1.4. The Sump Pump is activated by a level transmitter (POR655-WP-LT-603) located 1-1/2 in. above the bottom of the Sump, adjacent to the pump (Ref 2.16). The pump will start automatically when the liquid level reaches 4 in. It will continue to run until the level is below the minimum required level of 1-1/2 in. If the level stops rising between 1-1/2 in. and 4 in., the pump can be manually started (Ref. 2.19). A dip leg is located 1/8 in. off the bottom of the sump to allow for the removal of remaining liquid via a pump connected outside the enclosure (Ref. 2.16).

3.2. DESIGN BASIS

3.2.1. The TSCR Design Engineer considers 10 minutes as the practical design basis for time required to empty the sump and associated reagent inflow. Ten minutes is a sufficient time to transfer leaked waste to AP-108 quickly, but also keep the sump pump to a reasonable size.

3.3. DESIGN INPUTS

3.3.1. Sump Capacity = 382.6 gal. (Ref. 2.3)

3.3.2. Liquid maximum density (ρ) = 1.35 g/mL (Ref. 2.1)

3.3.3. Liquid maximum viscosity (μ) = 8 cP (Ref. 2.1)

3.3.4. Largest particle size = 1-mm (0.039”) (Ref. 2.8, Figure 2.1)

3.3.5. Pump Discharge Piping: (Ref. 2.2, Sheet 3)

a. 18.25 in. (1.52 ft.) x 1½” pipe vertical discharge
b. 40.375 in. (3.36 ft.) x 1½” pipe horizontal run to drain manifold
c. 23.75 in (1.98 ft.) x 2” pipe to HIHTL interface
d. 140 ft x 2” hose to AP-108 (B. Chamberlain email, Dated 10/8/2018 – Appendix B)
e. 1 x 1½” 90 degree elbow
f. 1 x 1½” Tee

3.3.6. Conservative Inputs

a. Static head above the pump centerline is assumed to be zero ($p_{(S)}$).

b. Fluid and water temperature is assumed to be 20°C (Ref. 2.1).

c. Vapor Pressure temperature is assumed to equal the maximum TSCR feed of 35°C (Ref 2.1).

d. A non-volatile substance dissolved in a liquid will always cause a lowering of the vapor pressure. Therefore, 5 to 6 M sodium tank waste has a lower vapor pressure (higher boiling point) than water. As a conservative design input, the vapor pressure of water will be used in this calculation.

1. Vapor pressure of water at 35°C is 5.813 kPa (43.6 mmHg) (Ref. 2.10, pg. 6-3). In this calculation, $p_{(V)}$ is equal to 0.84 psia.

3.4. DESIGN MARGIN

3.4.1. Add 20% to pipe friction losses.

3.4.2. Add 20% to pump inflow (M_D).

4.0 APPROACH/METHODOLOGY

4.1. Determine the minimum pump flow rate.

The minimum required flow rate for the pump is the rate at which a full sump can be emptied within the design basis time for sump evacuation (t_E = 10 min). This value is defined as the initial volume in the sump plus the volume of inflow (V_I), divided by the design basis time.

4.2. Determine actual line velocity.

The fluid velocity (v) in the pump discharge and drain piping is calculated from the minimum pump flow rate and the line size. This value is an input for determining the pipe friction losses.

4.3. Determine Reynolds Number.

The Reynolds Number (Re) characterizes the fluid flow as turbulent or laminar based on fluid velocity, density, and viscosity. It is an input for determining the pipe friction losses.

4.4. Determine equivalent pipe lengths for pressure loss calculations.

Pipe fittings such as elbows and tees increase the pipe friction losses on the fluid. Each fitting has an associated equivalent resistance (ER) and combined with the length of straight pipe gives a total length of pipe (L) to be used in determining the pipe friction losses.

4.5. Determine pipe friction losses.

The pipe friction losses (h_L) are the pressure loss the fluid will experience between the pump discharge and the HIHTL. The pump must be able to increase the fluid pressure to this value in order for the fluid to travel through the piping to the HIHTL and AP-108.

4.6. Determine pump head differential head and NPSHa.

The Net Positive Suction Head available (NPSHa) is the sum of the atmospheric and static pressure on the incoming fluid minus the vapor pressure and any piping losses upstream of the pump. This value must be greater than the NPSH required (NPSHr), which is a property of the selected pump.

4.7. Determine pump horsepower.

The hydraulic horsepower ($HP_{(Hyd)}$) is the power required to pump a fluid at a certain flow rate and pressure. Using the calculated values of minimum flow rate and pump head (H), the horsepower can be determined and is used in selecting the appropriate pump. A conservative pump efficiency (e_p) was chosen and used to calculate the brake horsepower ($HP_{(Pump)}$). The actual pump efficiency is dictated by the chosen pump.

5.0 COMPUTATION

See Appendix A.

6.0 CONCLUSIONS

AVANTech engineers used the methodology in Section 4 to determine the required size of the primary enclosure sump pump. When selecting a sump pump, the pump should be rated for at least 39 gpm with a hydraulic horsepower of 0.17 Hp.

APPENDIX A - CALCULATION SPREADSHEET

Column→	B	C	D	E	F
Row ↓	**DETERMINE SUMP PUMP FLOW RATE (Minimum)**		**Calc-1**		
3	**Parameter**	**Description**	**Value**	**Units**	**Reference**
4	t_E	Time for Sump Evacuation	10	min	TSCR Design Engr.
5	Q_I	Rate of Inflow	7	gal/min	RPP-CALC-62505
6	M_D	Design Margin	20%	- - -	TSCR Design Engr.
7	V_I	Volume of Inflow	84.0	gal	=(D5*(1+D6))*D4
8	V_S	Initial Volume in Sump	300.0	gal	DS-1813-02, Delay Tank Data Sheet
9	Q_O	Rate of Outflow (Sump Pump Flow), Minimum	39	gal/min	=ROUNDUP((D8+D7)/D4, 0)
10	Q_O	Rate of Outflow (Sump Pump Flow), Minimum	0.087	ft3/s	=D9/7.48052/60
11	**DETERMINE LINE VELOCITY**		**Calc-2**		
12	**Parameter**	**Description**	**Value**	**Units**	**Reference**
13	$D_{(1)}$	ID of 1 1/2" Sch. 40 Pipe	1.610	in	ASME B36.19M-2004
14	$D_{(2)}$	ID of 2" Sch. 40 Pipe	2.067	in	ASME B36.19M-2004
15	$v_{(1)}$	Line velocity in 1 1/2" Sch. 40 Pipe	6.1	ft/s	=$D$10/((PI()/4*D13^2)/12^2)
16	$v_{(2)}$	Line velocity in 2" Sch. 40 Pipe	3.7	ft/s	=$D$10/((PI()/4*D14^2)/12^2)
17					
18	**DETERMINE REYNOLDS NUMBER**		**Calc-3**		
19	**Parameter**	**Description**	**Value**	**Units**	**Reference**
20	ρ	Fluid density (max.)	1.350	g/mL	TSCR Specification RPP-SPEC-61910
21	ρ	Fluid density (max.)	84.28	lbs/ft3	=62.428*D20
22	μ	Fluid viscosity (max.)	8.000	cP	TSCR Specification RPP-SPEC-61910
23	CF	Conversion Factor	47880.260	cP to lbf·s/ft2	NIST Special Publication 811, 2008, p. 67
24	μ	Fluid viscosity (max.)	1.671E-04	lbf·s/ft2	=D22/D23
25	g	Acceleration due to gravity	32.174	lbm·ft/lbf·s^2	Ref. 2.9
26	$Re_{(1)}$	Reynolds Number in 1 1/2" Pipe	12,928	- - -	=(D13/12*D15*$D$21)/($D$24*$D$25)
27	$Re_{(2)}$	Reynolds Number in 2" Pipe	10,069	- - -	=(D14/12*D16*$D$21)/($D$24*$D$25)
28					

Column→	B	C	D	E	F
29	**DETERMINE EQUIVALENT PIPE LENGTHS**		**Calc-4**		
30	**Parameter**	**Description**	**Value**	**Units**	**Reference**
31	$ER_{(EL-1)}$	Equivalent Resistance of 1 1/2" long radius elbow	2.8	ft-pipe/elbow	Ref. 2.17
32	$ER_{(T-1)}$	Equivalent Resistance of 1 1/2" tee	9.0	ft-pipe/tee	Ref. 2.17
33	$L_{(1)}$	Length of 1 1/2" pipe	4.9	ft	Ref. 2.2, Sheet 3
34	$L_{(1\text{-total})}$	Equivalent Length of 1 1/2" pipe (total) (w/ Design Margin)	20.0	ft	=(D33+D32+D31)*(1+$D$6)
35	$L_{(2)}$	Length of 2" pipe (HIHTL to AP-108)	142.0	ft	WRPS Communications (Appendix B); Ref. 2.2
36	$L_{(2\text{-total})}$	Equivalent Length of 2" pipe (total) (w/ Design Margin)	170.4	ft	=D35*(1+$D$6)
37					
38	**DETERMINE PIPE FRICTION LOSSES**		**Calc-5**		
39	**Parameter**	**Description**	**Value**	**Units**	**Reference**
40	$\in$	Roughness	0.0015		Ref. 2.12, pp.A-23
41	$f_{(1)}$	Friction factor (1 1/2" Sch. 40 Pipe)	0.03067		Ref. 2.14, pp.657-664
42	$f_{(2)}$	Friction factor (2" Sch. 40 Pipe)	0.03216		Ref. 2.14, pp.657-664
43	g	Gravitational acceleration	32.174	lbm·ft/lbf·s2	Ref. 2.9
44	$h_{L(1)}$	Head loss, 1 1/2" Piping	2.69	ft(waste)	=D41*(D34/(D13/12))*((1*D15^2)/(2*D43))
45	$h_{L(1)}$	Head loss, 2" Piping and HIHTL	6.87	ft(waste)	=D42*(D36/(D14/12))*((1*D16^2)/(2*D43))
46	$h_{L(Total)}$	Head loss, Total	9.56	ft(waste)	=D45+D44
47					
48	**DETERMINE PUMP DIFFERENTIAL HEAD and NPSHa**		**Calc-6**		
49	**Parameter**	**Description**	**Value**	**Units**	**Reference**
50	$\rho_{(H2O)}$	Water density (70°F)	62.305	lbs/ft3	Ref. 2.12, pp. A-6
51	$\Delta p_{(Total)}$	Head loss, Total	12.93	ft(water)	=D46*(D21/D50)
52	$\Delta p_{(Total)}$	Head loss, Total	5.60	psi	=D51/2.31
53	$p_{(atmos)}$	Atmospheric pressure on Hanford site	14.35	psia	Ref. 2.18
54	$p_{(S)}$	Pressure at pump suction	0	psia	Assumes minimum liquid level
55	$p_{(V)}$	Vapor pressure	0.84	psia	Water @ 35°C, Ref. 2.10 (conservative)

Column→	B	C	D	E	F
56	NPSHa	Net Positive Suction Head (available)	13.51	psia	=D53+D54-D55
57	NPSHa	Net Positive Suction Head (available)	31.20	ft(water)	=D56*2.31
58					
59	**DETERMINE PUMP HORSEPOWER**		**Calc-7**		
60	**Parameter**	**Description**	**Value**	**Units**	**Reference**
61	H	Pump head (differential head)	12.9	ft(water)	=D51
62	$HP_{(Hyd)}$	Hydraulic horsepower	0.17	Hp	=D9*D61*D21/247000
63	e_p	Pump efficiency	50%		Engineering Estimate
64	$HP_{(Pump)}$	Brake horsepower	0.34	Hp	=D62/D63

APPENDIX B - HOSE DIMENSIONS

From: Chamberlain, Blake E <blake_e_chamberlain@rl.gov>
Sent: Monday, October 08, 2018 5:52 PM
To: Tracy Barker
Cc: David Langan; Fuentes, Karen L; Ard, Kevin E
Subject: [External] FW: HIHTL length

Tracy, see below from Mario. The DST Upgrades group has moved the location slightly north and routed lines differently. As such, HIHTL lengths are revised in red below.

Blake Chamberlain
TSCR Design Authority
Treatment Facility Projects Engineering
509-376-5114

From: Servin, Mario A
Sent: Monday, October 08, 2018 11:06 AM
To: Chamberlain, Blake E <blake_e_chamberlain@rl.gov>
Cc: Engeman, Jason K <jason_k_engeman@rl.gov>; Ard, Kevin E <kevin_e_ard@rl.gov>
Subject: FW: HIHTL length

See below.

Mario A. Servin, PE
TFP Engineering
Washington River Protection Solutions, LLC
Contractor of the Department of Energy
Office: (509) 376-0676
Cell: (562) 335-1041

From: Wade Arndt <warndt@arescorporation.com>
Sent: Monday, October 8, 2018 10:54 AM
To: Servin, Mario A <mario_a_servin@rl.gov>; Paul Dorsh <pdorsh@arescorporation.com>
Subject: HIHTL length

Please see Table below with the new Approximate lengths marked in red.

Thanks,

Wade

Table B-3. Approximate Transfer Line Lengths.

Transfer Route	Approximate Line Length (ft)
TSCR #1 HIHTL Treated Waste to AP-106	175 205
TSCR #1 HIHTL Waste Feed from AP-107	250 325
TSCR #1 HIHTL Waste Return to AP-107	250 325
TSCR #1 HIHTL Plant Wash to AP-108	120 140
TSCR #1 HIHTL Vent Line to AP-108	120 140
TSCR #2/3 Treated Waste to AP-106	300
TSCR #2/3 Waste Feed from AP-107	315
TSCR #2/3 Waste Return to AP-107	315
TSCR #2/3 Plant Wash/Drain to AP-108	200
TSCR #2/3 Vent Line to AP-108	200
WFD from AP-06A to AP-02D (Layout #1)	609.32
WFD from AP-06A to AP-02D (Layout #2)	645.44
WFD from AP-06A to SN-700 (Layout #3)	581.07