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Tank 15H Flowsheet

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1. Introduction

The SRS is a Federal facility managed by DOE. Since beginning operations in the early 1950s, uranium and plutonium recovery processes have generated liquid radioactive waste, which is currently stored in underground waste tanks in the F and H Areas at the site. The DOE intends to remove from service all of the waste tanks with priority being given to the old-style waste tanks that do not meet the standards established in Appendix B of the SRS Federal Facility Agreement (FFA). [WSRC-OS-94-42] Tank 15 does not meet the standards outlined in the FFA and therefore will be undergoing waste removal.

The first step in waste removal for waste tank closure is Bulk Waste Removal (BWR). This is where the bulk of the waste (supernate, salt and sludge) is removed by mechanical methods. The sludge from BWR efforts ultimately ends up in the Defense Waste Processing Facility (DWPF) as part of a sludge batch (SB). The latest revision (Revision 17) of the System Plan includes Tank 15 in Sludge Batch 11 after a campaign of low temperature aluminum dissolution (LTAD) occurs. [SRR-LWP-2009-00001] Tank 13 was to be the primary contributor to SB10, however BWR efforts in Tank 13 have shown that the amount of sludge in Tank 13 was less than the estimated value. Because of this, the schedule for Tank 15 has been accelerated and now current plans are to utilize Tank 15 sludge as the prominent composition of Sludge Batch 10 (SB10). Tank 33 is also planned for inclusion in SB10, but if Tank 33 is not available when needed, Tank 15 will become the only contributor. Should this be the case, if Tank 15 undergoes LTAD, it will not be able to contribute the mass needed for SB10. Therefore, to maximize the DWPF operational flexibility based on the options that will be presented in Revision 18 of the System Plan, LTAD is no longer planned for Tank 15 prior to BWR. In addition, there is no space for the storage of the leachate and processing through ARP/MCU. This flowsheet outlines the activities planned to support the use of Tank 15 in SB10 and to address concerns related to these activities.

2. Background

Tank 15 is a Type II waste tank located in H-Tank Farm. The tank is 85 feet in diameter and 27 feet high. It was constructed in 1956 and was placed into service in 1960 as a receiver of high heat waste supernate from Tank 16 during efforts to decrease leaking from the primary to the annulus of Tank 16. It continued to receive primarily high heat waste directly from H-Canyon until 1972. At this point the total waste volume was 952,000 gallons of which 320,000 gallons were sludge. Between 1972 and 1978 the supernate evaporated reducing total waste volume to 870,000 gallons. Supernate was decanted in 1978 and two sludge slurry transfers from Tank 16 in 1979 and 1980 brought the Tank 15 sludge volume to between 370,000 and 390,000 gallons with a total waste volume of 800,000 gallons. [WSRC-TR-98-00373] A final H-Canyon transfer of low heat waste was received into Tank 15 in 1980. [WSRC-TR-94-0191]

In 1982, two slurry pumps were installed in Risers 3 and 4 with a slurry transfer pump (STP) in Riser 7 as part of an in-tank sludge processing demonstration. As a result of this campaign, 727,000 gallons of sludge slurry (containing 125,000 gallons of sludge solids) were transferred to Tank 42. Since then the free supernate in Tank 15 has evaporated, leaving no free standing liquid, resulting in the designation "dry sludge tank". [WSRC-SA-2002-00007, Vol. 2]

Because of the slurry pump locations (installed in Risers 3 and 4 as shown in Figure 1), sludge was only disturbed from a portion of Tank 15. Three sludge soundings taken in 2010/2011 from Risers 1, 8 and 3'6" have given depth measurements of 70.1", 39.68" and 26.36" respectively. [SW11.1-WTE-7.2] These locations and sounding results are shown below in Figure 1. This indicates that the sludge heel is sloped with the lower sludge level reading in an area where sludge would have been disturbed by the slurry pumps from the waste removal demonstration in the early 80s.

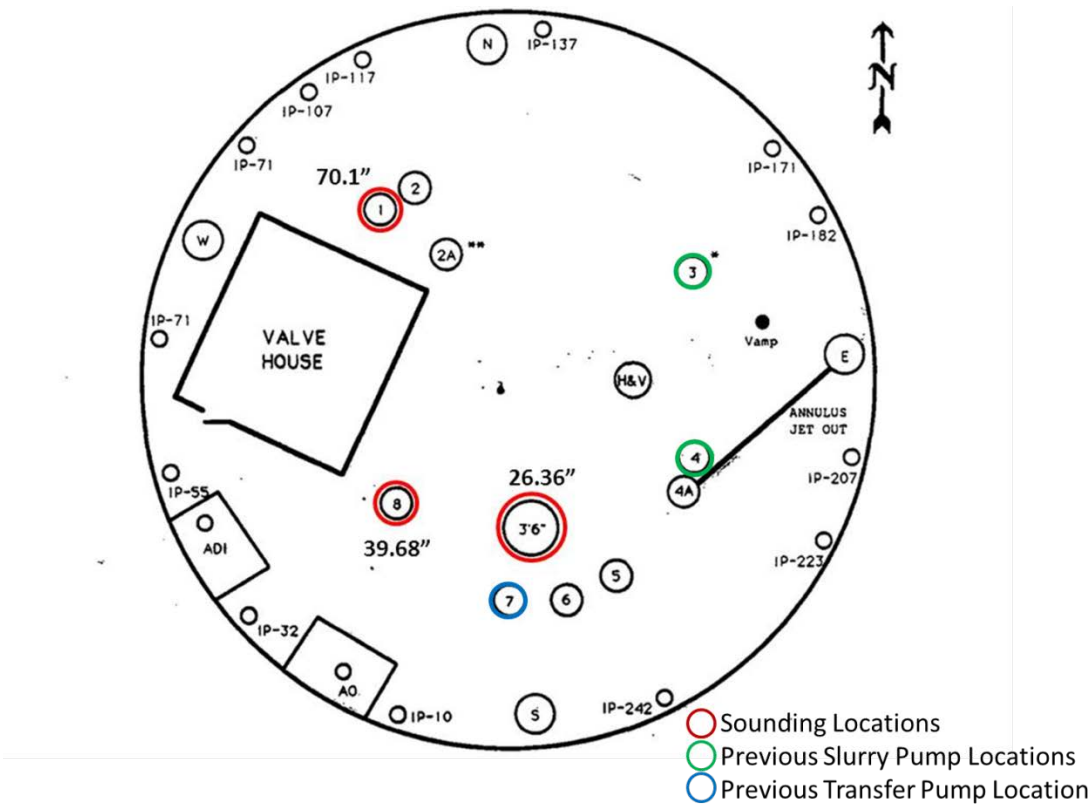

Figure 1: Sludge Sounding Locations and Depths

Tank 15 will require re-wet prior to future waste removal activities in preparation for sludge solids to be processed as part of SB10. Following re-wet of the dry sludge in Tank 15, between 150,000kg and 250,000 kg of solids will be transferred to Tank 13 during BWR. This flowsheet documents the process for completing BWR activities while outlining the pertinent parameters for successfully implementing the process and ensuring safety basis, regulatory, and project requirements/constraints are satisfied and downstream impacts are assessed.

3. Assumptions

1. The maximum sludge height is 70.1 inches and the minimum sludge height is 26.36 inches. The nominal sludge height is a linear slope from 70.1 inches to 26.36 inches. **Justification:** The maximum sounding level is 70.1 inches and the minimum sounding level reading is 26.36 inches, which indicates a sloped sludge heel. [SW11.1-WTE-7.2] This sloped level is considered most representative of the sludge in Tank 15. Since the exact nature of the slope is not known, however, it is considered linear for material balance purposes.

2. No scavenger concentrations ([NO_3] and [NO_2]) within the current sludge interstitial are credited. IW will characterize the interstitial liquid. **Justification:** Accurate estimations of current Tank 15 chemistries cannot be made since the tank has been inactive for 30 years. Prior to the inactivity, the corrosion sample chemistry was highly variable, which means, even during the active years, the chemistry was not well known. [X-ESR-H-00282] Despite the fact that it is reasonable to assume some NO_3 and NO_2 are present within the sludge matrix, the concentrations would be speculative. It is more conservative to assume concentrations of zero.

3. Tank 15 has a similar sludge composition comparable to that of Tank 12. **Justification:** Tank 12 and Tank 15 transfer histories show both waste tanks were receivers of high heat waste from H-Canyon and both received transfers of waste containing thorium in the 1960s. [Sludge 1.5]

4. Following Re-wet, the interstitial liquid in the sludge is considered to be the inhibited water (IW)/$NaNO_2$ mixture. **Justification:** Accurate estimations of current Tank 15 chemistries cannot be made since the tank has been inactive for 30 years. Prior to the inactivity, the corrosion sample chemistry was highly variable, which means, even during the active years, the chemistry was not well known. [X-ESR-H-00282] This makes it difficult to determine the chemistry of the interstitial liquid currently in the sludge. It is conservative with respect to weight percent (wt%) solids to assume that the only contributor to density is the media added during re-wet.

4. Process Methodology

4.1 Tank 15 Initial Conditions

Based on the sounding information and location of mixing pumps during previous waste removal operations, it is anticipated that the sludge level in the waste tank is sloped with a higher sludge level in the northwest quadrant and a lower sludge level in the southeast quadrant. From the three different sludge sounding results, three scenarios for the layout of the sludge in Tank 15 are considered to bound the volume of re-wet media needed and the volume of sludge remaining in the tank: a maximum sludge level, a nominal sludge level, and a minimum sludge level. These levels are shown in Figure 2 below.

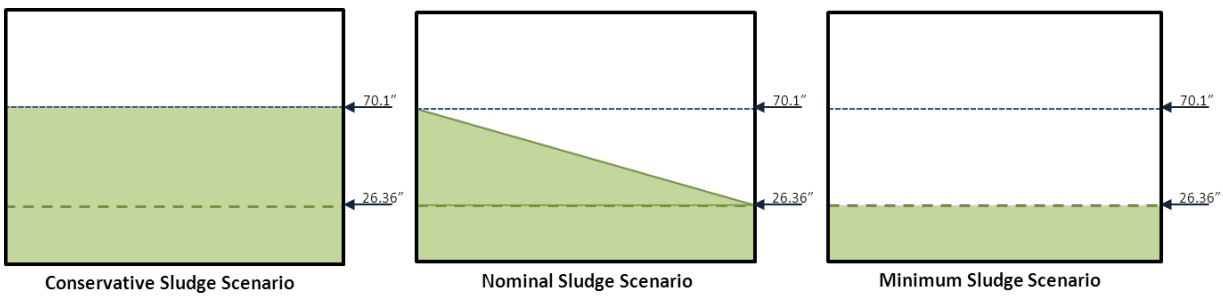

Figure 2: Sludge Volume Scenarios

At a uniform sludge level of 70.1", Tank 15 contains a maximum volume of 245,350 gallons of sludge (70.1 in. * 3,500 gal/in.). At a uniform sludge level of 26.36", Tank 15 contains a minimum volume of 92,260 gallons of sludge (26.36 in. * 3,500 gal/in.).

To determine the volume of sludge for the nominal sludge scenario, it was assumed that the sludge was linearly sloped from 70.1" to 26.36" across the waste tank. The sludge was broken up into two areas as shown in Figure 3.

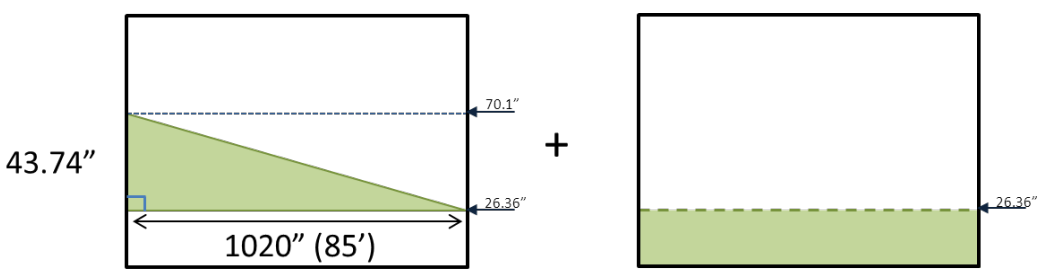

Figure 3: Sludge Levels for Nominal Sludge Scenario

Since the slope is linear, the volume contained in this triangular section was found by taking half of the volume that would be contained in a height of 43.74 inches of waste.

Eq. 1 $V_1 = ½ * h * f$

Where: h = Height of the waste, in
f = Type II tank fill factor, 3500 gal/in

$V_1 = ½ * 43.74 * 3500$

$V_1 = 76{,}545$ gallons

This volume was then added to the volume of sludge at the 26.36" level. The total sludge volume for the nominal sludge level is 168,805 gallons.

Initially sludge contains a solids volume fraction of 0.30 and the remaining 0.70 volume fraction is interstitial liquid. [DPST-82-502] Since Tank 15 is a dry sludge tank, some of this interstitial liquid has evaporated. For this reason the Tank 15 interstitial liquid fraction is assumed to be 0.48 [WCS 1.5] which leaves the remaining 0.22 as void space. This equates to 50,642 gallons of solids and 81,026 gallons interstitial liquid. The density of the sludge solids is assumed to be 3.0 kg/L [S-CLC-G-00235]. At the nominal sludge level the mass of the solids in Tank 15 is 50,642 gal * 3.785 L/gal * 3.0 kg/L = 575,040 kg. The range of conditions for Tank 15 prior to re-wet is shown in Table 1.

Table 1: Tank 15 Initial Conditions

	Waste Level	Free Supernate Volume	Sludge Volume	Interstitial Liquid Volume	Void Space Volume	Solids Volume	Solids Density	Solids Mass
	(in)	(gal)	(gal)	(gal)	(gal)	(gal)	(kg/L)	(kg)
Maximum	70.1	0	245,350	117,770	53,977	73,605	3	835,785
Nominal	26.36-70.1	0	168,805	81,026	37,137	50,642	3	575,040
Minimum	26.36	0	92,260	44,285	20,297	27,678	3	314,284

4.2 Tank 15 Re-Wet

Prior to BWR, Tank 15 will be re-wet with an addition of inhibited water (IW), bringing the liquid level to approximately ten inches above the highest sludge level. This ensures a layer of liquid will be available to minimize the release of airborne radioactivity, retard hardening of the waste, and initiate soaking of the dried waste to facilitate bulk waste removal. A re-wet strategy was developed to evaluate this IW addition. [X-ESR-H-00459] The re-wet media volume will be added until a 10-inch layer of liquid exists over the peak sludge height.

Based on the three sludge volume scenarios and accounting for the 0.22 void space fraction in the sludge and the volume that would be required to fill this, it was determined that between 89,000 and 208,000 gallons of IW are needed to re-wet Tank 15 to a level of 80.1". For this flowsheet evaluation, however, only the nominal operating case will be considered because it is the most representative of the current Tank 15 conditions.

4.2.1 Methodology

During Re-wet, liquid will be added to Tank 15 in 25,000 gallon increments to mitigate the possibility of overflowing the annulus pan should leakage through the primary wall occur. The liquid addition increments will occur in batches with 23,000 gallons of IW followed by 2,000 gallons of 40wt% $NaNO_2$. The liquid should be added to Tank 15 until the liquid level stabilizes approximately 10 inches above the sludge layer (nominally at ~80.1 inches). Because of the variance in the sludge level and the interstitial void fraction, the volume of liquid added may approach the ranges stated above (i.e., 89,000 gallons and 208,000 gallons) but is anticipated to be approximately 150,000 gallons for the nominal operating case. This equates to a total of 138,000 gallons of IW and 12,000 gallons of 40wt% $NaNO_2$ in 6 batches. Reverse mapping will be completed during liquid additions to confirm the sloped level of the sludge. This map will be used for determining SMP heights during BWR.

4.2.2 Flammability during Re-wet Operations

A GRM evaluation was completed that showed that the addition of IW alone as a re-wet media does not prevent Tank 15 from becoming RAPID. [X-CLC-H-00954] Because the supernate chemistry in Tank 15 is unknown, it was assumed that there were no contributions from NO_3 or NO_2 from the sludge interstitial liquid during re-wet. This made the $[NO_{eff}]$ ($[NO_3] + 0.5[NO_2]$) of the supernate following re-wet solely dependent on the contribution from the IW addition. This evalution showed RAPID modifications would be required prior to re-wet unless the chemistry was adjusted.

In order to prevent Tank 15 from reaching a TtLFL of less than 36 days and becoming RAPID, the re-wet media added to the waste tank should have an $[NO_{eff}] \geq 0.253M$. Therefore, in addition to IW, 40 wt% $NaNO_2$ will also be added during re-wet. There is not enough data to credit any $[NO_3]$ contribution from the salt in the Tank 15 sludge interstitial so $[NO_{eff}]$ is solely dependent on the contribution of NO_2. Enough $NaNO_2$ will be added so that the final $[NO_2]$ is 0.61M to bring the $[NO_{eff}]$ to 0.305M which is above the required 0.235M. This will allow Tank 15 to become a Slow waste tank.

4.2.3 Corrosion during Re-wet Operations

A corrosion evaluation looked at the corrosion chemistry for Tank 15 following the IW additions required for re-wet. [X-ESR-H-00282] Although the IW meets the corrosion control requirements outlined in the corrosion control program [WSRC-TR-2002-00327] as an influent, once it is added to Tank 15 as re-wet media, the chemistry is no longer compliant for a waste tank as outlined in Table 7 of the corrosion control program. While it is reasonable to assume some nitrite, nitrate, and hydroxide will be present in the

dry sludge of Tank 15, the only sample data available was prior to supernate evaporation. The sample data is shown in Table 2. The inconsistency of this data makes it impossible to predict quantities with any confidence. Following the sludge removal campaign in 1982, no liquid additions were added to Tank 15. The variability in the data over the years makes it hard to estimate a representative chemistry. The conservative approach is to assume no inhibitor contributions from Tank 15 sludge during rewet and instead use the IW chemistry as the representative supernatant chemistry.

Table 2: Corrosion Sample Data for Tank 15

Date	NO_2 (M)	NO_3 (M)	OH (M)
3/7/88	0.10	1.10	1.12
12/1/87	1.40	1.57	0.07
9/6/85	0.86	1.30	0.22
12/11/84	0.10	0.16	0.14
12/11/84	0.68	1.18	0.14
9/20/84	1.75	3.40	0.16
3/3/82	0.58	1.44	0.51
2/19/82	0.65	1.68	0.86
9/10/81	0.60	2.10	0.80
9/22/80	<0.1	0.20	0.40
4/25/80	0.80	4.10	1.20
3/3/79	0.35	3.00	1.52
12/19/72	1.1	3.6	1.0
2/7/66	1.2	4.35	0.86

With this assumption, Tank 15 will fall outside corrosion control limits. With a [NO3]<0.02M (in this case $[NO_3] = 0$), the minimum corrosion inhibitor concentrations needed are $[OH^-] = 1M$ *or* $[NO_2] = 0.033M$. The risk of only crediting IW is that there could be enough $[NO_3]$ salts within the sludge matrix that could result in a supernatant concentration of $[NO_3] \geq 0.02M$, in which case a $[NO_2] = 0.033M$ would not be sufficient. [WSRC-TR-2002-00327] With the addition of $NaNO_2$, the rewet media will maintain a 0.61M $[NO_2]$; therefore the potential of the final chemistry not meeting corrosion limits is considerably reduced than if the rewet media only maintained 0.033M $[NO_2]$.

At least two corrosion samples will be pulled. The first will occur after standing liquid becomes visible in the southeast section of the tank where the lowest sludge level is located. This is intended to characterize the interstitial supernatant within the sludge. The second will be a normal corrosion sample taken from the liquid surface layer within 30 days of the last rewet batch. Should the sample taken post re-wet still show that Tank 15 is out of corrosion compliance, it will be declared as entering the Cleaning Activities Life Cycle, which allows the suspension of corrosion control chemisty, annulus ventilation

and sample requirements but initiates a time constraint of 1460 days at which time the tank must be closed or reevaluated. After mixing pumps are installed and compliant transfer media for BWR is added to Tank 15, corrosion compliance can be ensured and an evaluation will be performed to determine if Tank 15 can exit the Cleaning Activities Life Cycle.

Temperature limits are also imposed on Tank 15 depending on the chemistry. Prior to slurrying, the supernate temperature limit is 40°C for the waste tank chemistry after re-wetting. Table 3 summarizes the temperature requirements for other chemistries.

Table 3: Maximum Temperature Limits for a Non-Slurried Waste Tank with [NO3] ≤ 1M

Supernate Concentration	T_{sup}		T_{ss}, T_w	
Hydroxide (M)	$[NO_3]\leq 0.02M$	$0.02<[NO_3]<1M$	$[NO_3]\leq 0.02M$	$0.02<[NO_3]<1M$
$0.01<[OH]\leq 1$	40°C	40°C	T_{ss} = 75°C T_w = 70°C	T_{ss} = 75°C T_w = 70°C
$1<[OH]\leq 8$	60°C	100°C	T_{ss} = 60°C T_w = 55°C	T_{ss} = 100°C T_w = 95°C
$[OH]>8$	60°C	60°C	T_{ss} = 60°C T_w = 55°C	T_{ss} = 60°C T_w = 55°C

4.2.4 Tank 15 Conditions Following Re-wet

The Tank 15 conditions following re-wet for the nominal operating case are shown below in Table 4.

Table 4: Tank 15 Following IW Addition

Waste Level	Volume of IW Added	Free Supernate Volume	Sludge Volume	Interstitial Liquid Volume	Solids Volume	Solids Mass
(in)	(gal)	(gal)	(gal)	(gal)	(gal)	(kg)
80.1	148,682	111,545	168,805	118,164	50,642	575,040

4.3 Bulk Waste Removal (BWR)

Following re-wet, Tank 15 will undergo BWR to remove sludge in preparation for SB10. Supernate from Tank 13 will be added to Tank 15 to bring the waste tank level to 195 inches. This level is approximately 125 inches above the highest sludge level as well as

the bottom of the highest Submersible Mixing Pump (SMP). Historically, it was assumed that the SMPs required a minimum of 120 inches of liquid in order to operate at full mixing speed. [SRR-LWP-2010-00069] A minimum of 44 inches of fluid level above the bottom of the SMP foot is required to prime and start the pump. [CBU-LWD-2005-00067] The additional 76 inches imposed on the required fluid level was conservatively used to prevent aerosolization of supernatant from the weep hole discharge into the vapor space. SMPs have been shown to operate fully without aerosolization at fluid levels below 120 inches, however, if the tank level drops below the top of the SMP stator core, which is approximately 85 inches above the bottom of the mounting foot, the operating speed may have to be reduced. [SW9.1-WTE(13)-2.1] To bring the Tank 15 liquid level from 80.1" to 195", approximately 402,100 gallons of supernate will be transferred into Tank 15.

Three SMPs will be installed in Tank 15 in Risers 2, 4A and 8. With a SMP effective cleaning radius (ECR) of 39 feet in a waste tank with no obstructions [M-TC-H-00080], these locations maximize the surface area affected by the pumps and minimize dead zones. The ECR of the three SMPs is shown in Figure 5. There are plans for a fourth SMP to be placed in Riser 3 should the need arise, however a dead zone of 80 inches is not expected in this location because the pump in R3 during the initial sludge removal campaign in 1982 should have removed a majority of the sludge from this area. After running the pumps, the resulting slurry will be transferred back to Tank 13 via a submersible transfer pump (STP) in Riser 7. The riser locations of the SMPs in Tank 15 are shown in Figure 4.

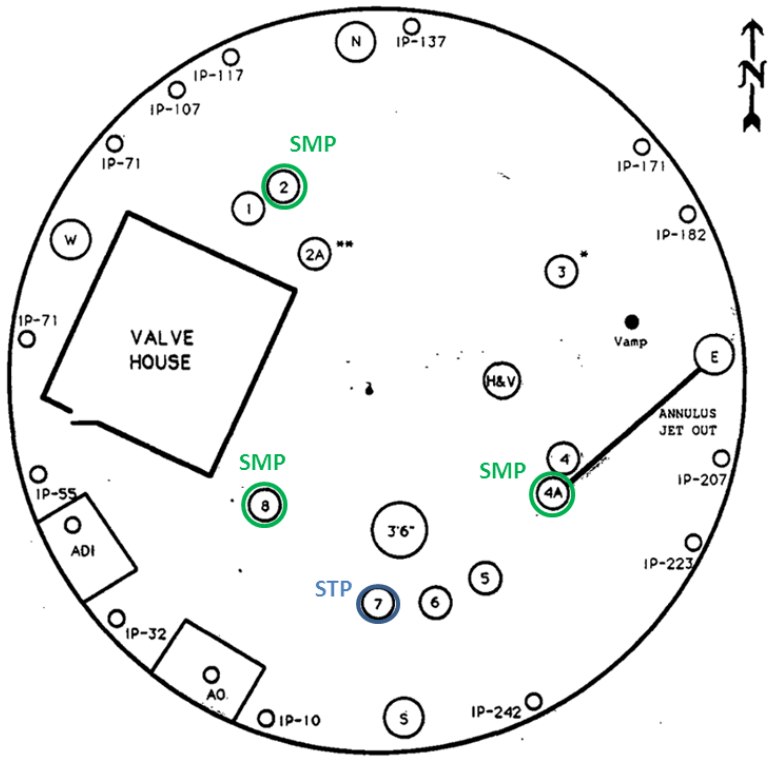

Figure 4: Tank 15 Pump Locations for BWR

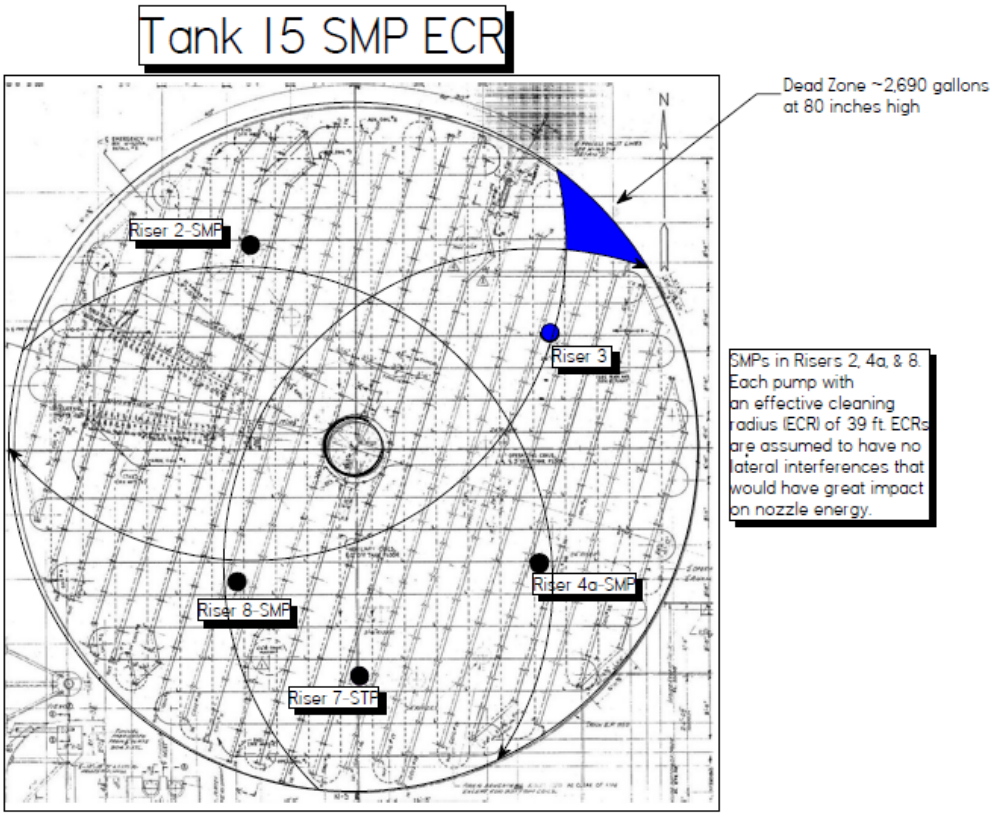

Figure 5: Effective Cleaning Radius for SMPs in Tank 15

4.3.1 Flammability during Bulk Waste Removal Operations

A flammability evaluation was completed for BWR using IW as the slurrying media. [X-CLC-H-00954] Since the supernate chemistry in Tank 15 is unknown, the fraction of hydrogen in trapped gas (H_{mix}) in the Tank 15 sludge was assumed to be 0.75 which is used for waste tanks with low nitrate concentration. [WSRC-SA-2002-00007, Vol. 2]
The results of this evaluation determined that up to 24 inches of sludge could be disturbed without entering GRM provided the safety analysis value (SAV) limit was increased from 25% to 60%. This would lower the TtLFL to 5.3 days which does not meet the Flammability Control Program requirements of 7 days, nor best engineering practice which allows for 10 days. In order to increase the TtLFL to 10 days, a minimum [NO_{eff}] of 0.251M is required. This requirement should be met with the $NaNO_2$ addition during re-wet coupled with the [NO_{eff}] from the supernate addition prior to BWR.

4.3.2 Corrosion during Bulk Waste Removal Operations

With the chemistry of Tank 15 unknown, a bounding assumption was made that 402,000 gallons of IW are added as the media for BWR and there are no inhibitor contributions

from Tank 15 following re-wet. Under these conditions, Tank 15 will fall outside corrosion control limits. With a [NO3]<0.02M (in this case $[NO_3] = 0$), the minimum corrosion inhibitor concentrations needed are $[OH^-] = 1M$ *or* $[NO_2] = 0.033M$. [WSRC-TR-2002-00327]

With the $NaNO_2$ addition during re-wet ($[NO_2]=0.61M$), along with inhibitor contributions from the Tank 13 supernate, the $[NO_2]$ should be sufficient to inhibit corrosion induced by $[NO_3]$. Samples following re-wet and a formal corrosion evaluation for BWR will be required to confirm that Tank 15 is corrosion compliant.

Temperature limits are also imposed on Tank 15 depending on the chemistry. Prior to slurrying, the supernate temperature limit is 40°C for IW chemistry. Following pump agitation of at least 3 hours and up to 30 days following pump/mixer shut-down, the waste tank is considered a slurried tank. The temperature limits for a slurried tank are shown below in Table 5. [WSRC-TR-2002-00327]

Table 5: Maximum Temperature Limits for a Slurried Waste Tank with $[NO_3]<1M$

Supernate Concentration	T_{sup}		T_{ss}, T_w	
Hydroxide (M)	$[NO_3]\leq0.02M$	$0.02<[NO_3]<1M$	$[NO_3]\leq0.02M$	$0.02<[NO_3]<1M$
$0.01<[OH]\leq1$	75°C	75°C	$T_{ss} = 75°C$ $T_w = 70°C$	$T_{ss} = 75°C$ $T_w = 70°C$
$1<[OH]\leq8$	60°C	100°C	$T_{ss} = 60°C$ $T_w = 55°C$	$T_{ss} = 100°C$ $T_w = 95°C$
$[OH]>8$	60°C	60°C	$T_{ss} = 60°C$ $T_w = 55°C$	$T_{ss} = 60°C$ $T_w = 55°C$

4.3.3 Disturbed Sludge Limitations

4.3.3.1 Rheology

During Tank 12 BWR, the slurry pumps were initially placed above the sludge layer. As sludge was suspended, the pumps were lowered in increments continuously suspending additional sludge. This was done to maximize sludge suspension while limiting the number of transfers required and had proven effective in Tanks 5F, 6F, 7F and 11F. However, the first two attempts at transferring the slurry out of Tank 12 proved unsuccessful. Sample results determined that unlike the sludge encountered in other waste tanks during previous waste removal campaigns, the Tank 12 sludge had a high yield stress at relatively low concentrations of solids. This was attributed to the thorium compounds in the Tank 12 waste. Suspensions of thorium compounds under caustic conditions have shown remarkable rigidity. Historical records indicate that significant dilution is needed to enable mobility of thorium hydroxide suspensions. There is also

speculation that the fine particles of suspended aluminum compounds (Gibbsite and Boehmite) may also contribute to the high yield stress. [SRR-CES-2009-00043]
To achieve a slurry mixture that would allow for pumping through the STP, the yield stress was limited to 10-12.5 Pa which corresponded to a solids weight percent (wt%) of 6.3 to 6.9. [U-CLC-H-00065]

Based on similar transfer histories, Tank 15 is assumed to have a sludge composition comparable to that of Tank 12. A rheological study was conducted on Tank 15 sludge during waste transfers to Tank 42. From the results of this analysis, the wt% insoluble solids corresponding to the same yield stress as was used for Tank 12 are approximately 10.5wt% to 11wt%. However, it is speculated that during the waste removal campaign in 1982, not all the sludge in Tank 15 was disturbed. Since most of the thorium was transferred to Tank 15 during its early years of service (just like Tank 12), if the bottom layer of sludge was undisturbed then there is a possibility that the rheology would behave more like Tank 12. For this reason, the wt% solids during transfer will be limited to 6.7wt% to remain within the range of 6.3 to 6.9 wt%.

A GRM evaluation was completed and it was determined that up to 24" of sludge could be disturbed if the pumps were placed at the sludge level without entering GRM if the proper constraints were met. However, due to rheology concerns, the sludge disturbance will be limited to a solids wt% in the slurry.

4.3.3.2 Determination of Wt% Solids

To find the wt% solids in a slurry with a known volume of disturbed sludge, the following equations can be applied.

Eq. 2 $$\text{wt\% Solids} = \frac{M_{solids}}{M_{solids} + M_{Lslurry}} * 100\%$$

Where: M_{solids} = Mass of solids in slurry, kg
$M_{Lslurry}$ = Mass of liquid in slurry, kg

Eq. 3 $$M_{Lslurry} = \rho_{Lslurry} * V_{Lslurry}$$

Where: $\rho_{Lslurry}$ = Density of the liquid in the slurry, Kg/L
$V_{Lslurry}$ = Volume of liquid in the slurry, L

Eq. 4 $$V_{Lslurry} = (V_{Interstitial} + V_{RW} + V_{T13}) * 3.785 \text{ L/gal}$$

Where: $V_{Interstitial}$ = Volume of interstitial liquid in disturbed sludge, gal
V_{RW} = Volume of re-wet media above the sludge level, gal
V_{T13} = Volume of Tank 13 supernate added to Tank 15, gal

Eq. 5 $$V_{Interstitial} = V_{sludge} * 0.7$$

Where: V_{sludge} = Volume of sludge disturbed, gal

Eq. 6 $$\rho_{Lslurry} = \frac{(\rho_{Interstitial} * V_{Interstitial}) + (\rho_{RW} * V_{RW}) + (\rho_{T13} * V_{T13})}{V_{Interstitial} + V_{RW} + V_{T13}}$$

Where: ρ_{RW} = Density of re-wet media, 1.02 kg/L (see Eq. 6b)
ρ_{T13} = Density of Tank 13 supernate, Currently 1.13 kg/L [WCS 1.5]
$\rho_{Interstitial}$ = Density of interstitial liquid in disturbed sludge (assumed to be re-wet media), 1.02 kg/L

Eq. 6b $$\rho_{RW} = \frac{(\rho_{IW} * V_{IW}) + (\rho_{NaNO2} * V_{NaNO2})}{V_{IW} + V_{NaNO2}}$$

Where: V_{NaNO2} = Volume of $NaNO_2$ added during re-wet, gal
V_{IW} = Volume of IW added during re-wet, gal
ρ_{NaNO2} = Density of $NaNO_2$, 1.28 kg/L [X-ESR-H-00282]
ρ_{IW} = Density of IW, 1.0 kg/L [S-CLC-G-00235]

Using the inputs from Section 3.2.1, the density of the re-wet media is:

$$\rho_{RW} = \frac{\left(1.0\frac{kg}{L} * 138{,}000 gal\right) + \left(1.28\frac{kg}{L} * 12{,}000 gal\right)}{138{,}000 gal + 12{,}000 gal} = 1.02 \text{ kg/L}$$

Inserting Eq. 4 and Eq. 6 into Eq. 3, Eq. 3 becomes:

Eq. 3' $$M_{Lslurry} = [(\rho_{Interstitial} * V_{Interstitial}) + (\rho_{IW} * V_{IW}) + (\rho_{T13} * V_{T13})] * 3.785 \text{ L/gal}$$

Eq. 7 $M_{solids} = \rho_{solids} * V_{solids}$

Where: ρ_{solids} = Density of solids in disturbed sludge, 3 kg/L [S-CLC-G-00235]
V_{solids} = Volume of solids in disturbed sludge, gal

Eq. 8 $V_{solids} = V_{sludge} * 0.3$

Using these equations, the wt% solids contained in the slurry can be determined.

4.3.4 Transfer Path

A Submersible Transfer Pump (STP) will be placed in Tank 15 Riser 7 and the resulting BWR slurry will be transferred through an above ground hose-in-hose (HIH) transfer line to Tank 13 Riser 6. The primary transfer path option is shown below in Figure 6.

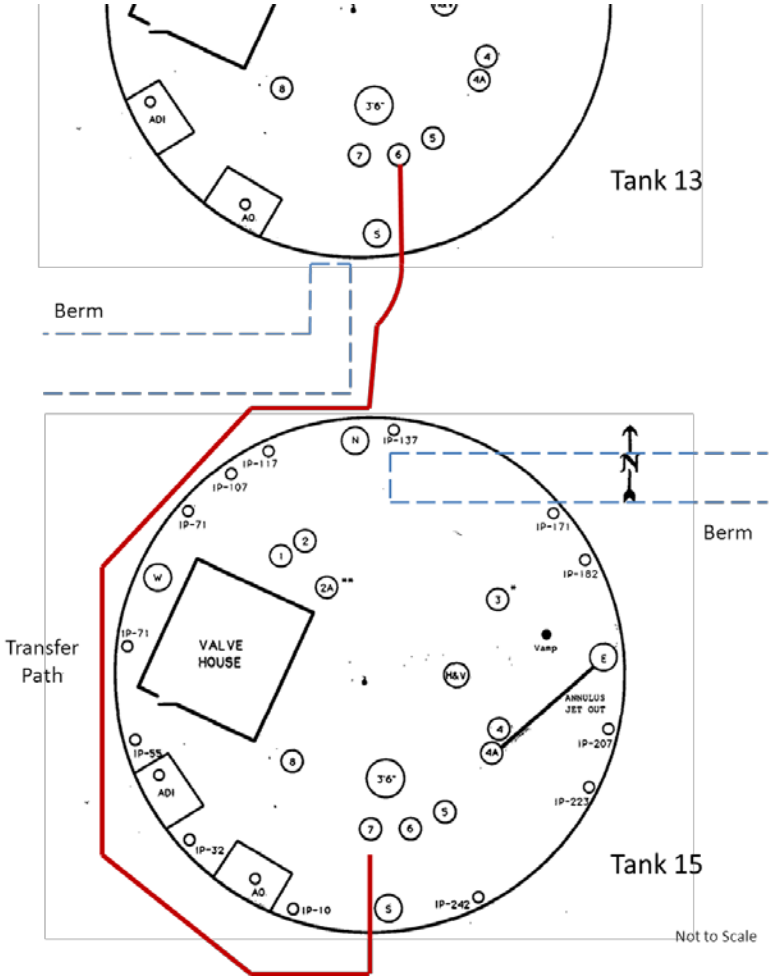

Figure 6: Transfer Path from Tank 15 R7 to Tank 13 R6

4.3.5 Transfer Media Selection

Tank 13 supernate has been chosen as the optimal slurrying media for Tank 15 BWR.

Using supernate already in the tank farms would not require additional volume to be added to the liquid waste system. However, it would require significant D&R prior to re-wetting and limited BWR could be accomplished prior to having to replace the transfer line hose. The use of supernate adds inhibitors to the Tank 15 system which increases operational flexibility with respect to corrosion, flammability and mixing pump heights. The higher density of the supernate (compared to IW which is discussed below) will allow for more sludge to be disturbed before reaching the 6.7wt% limit for transfer.

Using Stoke's Law, a higher density also decreases the settling velocity of the slurried particles:

$$\upsilon_s = \frac{2}{9} * \frac{(\rho_p - \rho_f)}{\mu} * g * R^2$$

Where: υ_s = Particle's settling velocity, m/s
ρ_p = Mass density of the particles, kg/m^3
ρ_f = Mass density of the fluid, kg/m^3
μ = Dynamic viscosity of the fluid, N*s/m^2
g = Gravitational acceleration, m/s^2
R = Radius of the particle, m

Assuming that $\rho_p > \rho_f$, a higer ρ_f (supernate versus IW) would result in a lower settling velocity. A lower settling velocity is beneficial because there is a waiting period between the shutdown of the SMPs and the transfer of the slurry to Tank 13 while the samples are being analyzed for wt% solids and dose.

The use of IW was also evaluated as a potential option for use during BWR. IW poses less of an exposure risk as it does not contain any radiological components. The lower density of the IW will allow for increased dissolution of salt in the sludge matrix. With such a large volume of IW introduced into the system, however, increased evaporator use will be needed to maintain adequate space in the tank farms for other waste removal activities.

4.3.5.1 History of Bulk Waste Removal Media in Other Waste Tanks

In December of 2000, Tank 8 underwent BWR activities with the addition of approximately 70,500 gallons of IW. With the aid of four slurry pumps, approximately 117,800 gallons of sludge was removed leaving a 15,000 gallon heel. The use of IW was decided because a viable flowpath for waste transfers (supernate) into Tank 8 was not available. [U-ESR-F-00009] In 2004, Tank 8 underwent heel removal with the addition of supernate from Tank 7. A series of transfers between Tanks 7 and 8 using four slurry pumps resulted in the additional removal of 10,900 gallons, leaving a sludge heel of 4,000 gallons. [U-ESR-F-00046] Both IW and supernate were successful in removing sludge from Tank 8.

During Tank 5 BWR efforts in 2005, supernate from Tank 7 was continuously recycled between Tanks 5 and 7. Supernate was chosen as the liquid medium to limit the volume of liquid added to the waste tanks. [U-ESR-F-00024] The Tank 5 BWR campaigns reduced the sludge heel from 34,000 gallons to 3,500 gallons. [SRR-CWDA-2011-00033]

Tank 13 used supernate from Tank 42 and 51 as the liquid media for BWR. After three mixing cycles, the sludge volume in Tank 13 was reduced from 277,000 gallons to

77,000 gallons. [WCS 1.5, SRR-LWE-2012-00161] Table 6 shows the chemistry of the supernate prior to addition into Tank 13 and then following addition. Comparing the chemistry to that of IW ([NO_2] = 0.011M, [OH] = 0.01M and [NO_3] = 0M) shows that using supernate allows for the addition of less chemicals to ensure corrosion and flammability compliance.

Table 6: Chemistry of Tank 13 Following Supernate Additions

Date of Transfer	Transfer Tank	Transfer Volume	Transfer [NO3]	Transfer [NO2]	Transfer [OH]	Transfer Tank SpG	Receipt Tank	Receipt Tank SpG	Mix [NO3]	Mix [NO2]	Mix [OH]	Mix SpG
		(gal)	(M)	(M)	(M)				(M)	(M)	(M)	
3/24/2012	42	277,079	0.35	0.46	0.67	1.09	13	1.24	0.37	0.51	0.85	1.06
3/25/2012	42	102,562	0.35	0.46	0.67	1.09	13	1.06	0.36	0.49	0.79	1.06
6/4/2012	42	286,346	0.52	0.66	1.51	1.11	13	1.27	0.69	0.66	1.44	1.10
8/1/2012	51	419,129	1.01	0.69	1.51	1.20	13	1.21	0.97	0.66	1.45	1.15

Based on the results of samples taken of the slurry following SMP mixing, an increase in [Na], [NO3], [NO2] suggests salt was dissolved during the BWR campaigns. This is also expected to occur during Tank 15 BWR activities. The fact that the higher SpG of the supernate (compared to IW SpG of 1) did not seem to limit salt dissolution in Tank 13 suggests similar events will occur in Tank 15. Since this was a contributing factor to the use of IW, this shows that supernate will be successful in sludge removal.
Table 7 shows the concentrations of sodium and the major salt components prior to SMP mixing and following the mixing campaign.

Table 7: Concentrations of Salt Components during Tank 13 BWR

Tank 13	Initial [Na]	Initial [NO3]	Initial [NO2]	[Na] Following Mixing	[NO3] Following Mixing	[NO2] Following Mixing	Reference
	(M)	(M)	(M)	(M)	(M)	(M)	
Cycle 1	2.53	0.36	0.49	6.50	1.70	0.82	WCS 1.5, SRNL-L3100-2012-00070
Cycle 2	2.91	0.69	0.66	N/A	1.10	0.68	WCS 1.5, SRNL-L3100-2012-00088
Cycle 3	2.72	0.97	0.66	5.10	1.37	0.87	WCS 1.5, SRNL-L3100-2012-00122

The supernate material to be used for Tank 15 at the time of BWR initiation is expected to be similar to that used for Tank 13 BWR. The results of the Tank 13 BWR suggest that supernate is an acceptable media for Tank 15 BWR.

4.3.6 Methodology

The map of the sludge created during re-wet will be used in determining the placement heights of the three SMPs. The SMPs will be placed such that no greater than 24 inches (84,000 gallons) of sludge will be disturbed at a time to meet the requirements in the GRM evaluation. Although the GRM evaluation determined up to 24 inches of sludge

could be disturbed if the pumps were placed at the sludge level without entering GRM if the proper constraints were met, this was a maximum value. Realistically the pumps are expected to disturb a height of 6-12 inches. [U-CLC-G-00032] For this flowsheet evaluation a height of 10 inches was chosen.

In order to determine the volume of sludge that can be disturbed to create a slurry that does not exceed a solids content of 6.7 wt% the following method was applied.

Because $V_{Interstitial}$ alters the density of the free liquid in the slurry and this density is used to calculate the total mass of the free liquid which determines the mass of solids required to keep the wt% below 6.7%, M_{solids} was solved as a function of $V_{Interstitial}$.

Eq. 9 $$M_{Solids} = \left(\frac{V_{Interstitial}}{0.7} * 0.3\right) * \rho_{Solids} * 3.785 \text{ L/gal}$$

The maximum amount of sludge that can be disturbed before reaching the solids wt% limit was found using Equations 2-9. These equations were solved simultaneously using Tank 13 supernate (ρ = 1.13 kg/L) as the BWR media. The resulting volume of sludge that can be disturbed to have a slurry with a 6.7wt% solids content is 48,300 gallons. With a solids density of 3.0 kg/L this corresponds to a solids mass of 164,490 kg which satisfies the lower target need of 150,000-250,000 kg for SB10.

Because the SMPs are expected to have a sludge disturbance depth of around 10 inches, a more realistic sludge disturbance volume would be 35,000 gallons (10 in * 3500 gal/in). This would be a mass of 119,227 kg at a solids density of 3.0 kg/L. To remove the mass necessary for SB10, at least two to three slurry campaigns will be required.

The SMP in R2 will be limited to a height of 70.1 inches. This is where the highest level of sludge was recorded. The pumps in R4A and 8 will be placed at a height where the total volume of sludge disturbed does not exceed 48,300 gallons. This height will be dependent on the results of the reverse map produced following re-wet

A sample will be taken following the shut-down of the SMPs. The sample will be analyzed for solids content and high/low rem. The slurry will then be transferred to Tank 13. A sounding will be completed following the slurry transfer. This data will be used for a new GRM evaluation as well as to determine if the pumps can be lowered for the next pump run.

4.3.7 Leaksite Constraints

Tank 15 has 20 known leaksites located between 30 and 200 inches from the bottom of the waste tank. Table 8 shows the locations of each of the leaksites. These have contributed to waste nodules on the annulus wall and a small amount of waste on the annulus floor. [C-ESR-G-00003] Leaksites 1-13 were discovered prior to the first sludge

removal campaign. During sludge removal operations in 1982, the highest waste level in Tank 15 was 271 inches. No leakage into the annulus was observed during this time. [DPSP-83-17-3]

Ultrasonic (UT) inspection of Tank 15 was conducted between April and July 2007. Twelve cracks were compared to a previous UT examination in 2002. Of these twelve cracks, nine cracks were located in the vapor space above the sludge layer. Comparison of the crack lengths measured in 2002 and 2007 revealed that crack growth had occurred in four of the six previously measured vapor space cracks (three new cracks were discovered in 2007 for a total of nine vapor space cracks). None of the cracks beneath the sludge showed evidence of growth. Impact of crack growth was analyzed and revealed that none of these cracks are expected to expand to instability. [C-ESR-H-00026] Because six of these leaksites are 100% through-wall, there is a possibility for some leakage into the annulus to occur during cleaning operations. Use of a lower density supernate during BWR operations could potentially dissolve the salt nodules that are currently plugging some of the cracks. Plans are in place to monitor for leakage and use of an existing Contingency Transfer System to transfer waste out of the annulus is outlined in the Scope of Work [U-SOW-H-00007] should the need arise.

During re-wet and BWR operations, liquid additions will be between the leaksite locations. The annulus will be monitored for signs of leakage. The re-wet strategy limits liquid additions to 25,000 gallon increments to prevent inadvertently overflowing the annulus pan should a leak occur. [X-ESR-H-00459] Operation of annulus ventilation during re-wet and BWR operations will help mitigate the potential effects of leakage into the annulus should it occur.

Cameras will be installed in three annulus risers and inspection frequency will be once every 24 hours during liquid additions and once every 72 hours after additions into the tank have been terminated or as directed by Engineering or the Shift Manager. Once pumps operations have begun, inspection frequency will be once every 12 hours during SMP operations and once every 72 hours after pump operations are terminated or as directed by Engineering or the Shift Manager. If liquid is observed on the annulus floor then inspections will be performed every six hours or as directed by Engineering or the Shift Manager. [SRR-LWE-2011-00146]

During re-wet, cameras will also be installed in the Tank 15 primary via Risers 1, 5 and 3’6”. These cameras will monitor the primary until liquid additions for re-wet are complete. [SRR-LWE-2013-00025]

Table 8: Tank 15 Leaksite Locations

Leaksite	Location	Height (in)	Waste Location
1	North	34	nodules on tank wall with trails to annulus floor and small amount of waste on annulus floor
2	North	34	
3	South	130	
4	North West	90	
5	North West	30	
6	North West	96	
7	North West	30	
8	North West	34	
9	North East	30	
10	North East	30	
11	North East	150	
12	North East	38	
13	North East	150	
14	East	150	
15	East	150	
16	West	200	
17	North West	30	
18	East	30	
19	North East	129	
20	East	31	

4.3.8 Sampling

The chemistry of the supernate in Tank 15 following re-wet is unknown. This drives decisions to be made based on bounding conditions. During re-wet, a sample will be taken when liquid begins to collect above the sludge layer. This sample data will be used to re-evaluate the GRM calculation to re-baseline the bounds for BWR. Following the IW additions for re-wet, a sample will be taken and evaluated for corrosion and flammability compliance.

Sampling of the slurry prior to transfer to Tank 13 will be done following each BWR campaign. These samples will be analyzed for the wt% solids in the slurry as well as the transfer dose to determine if the transfer will meet the low-rem requirements.

4.3.9 Inhalation Dose Potential (IDP)

An inhalation dose potential (IDP) evaluation was done on the waste in Tank 15 to determine if the slurry transfer from Tank 15 to Tank 13 could be considered a Low-Rem waste transfer. A Low-Rem transfer has an IDP less than or equal to 2.0E+08 rem/gal. [WSRC-SA-2002-00007, Vol. 2]

Using data from WCS 1.5, the total heat concentration of the sludge in Tank 15 is 7.27E+07 rem/gal for a sludge volume of 168,805 gallons. The total heat concentration in 796,600 gallons of Tank 13 supernate is 6.94E+04 rem/gal. For the first slurry transfer

containing 402,100 gallons of Tank 13 supernate and 48,300 gallons of sludge, the IDP is estimated to be 7.86E+06 rem/gal. This does not account for the 111,545 gallons of free supernate that is expected following re-wet. This makes the evaluation conservative as the extra volume would serve to dilute the concentration. Based on this preliminary evaluation, the slurry is anticipated to be a low-rem transfer.

4.3.10 Source Term

The total Cs-137 concentration for 168,805 gallons of sludge in Tank 15 is 1.87 Ci/gal. The total Cs-137 concentration for 796,600 gallons of Tank 13 supernate is 1.69 Ci/gal. [WCS 1.5] For the first slurry transfer containing 402,100 gallons of Tank 13 supernate and 48,390 gallons of sludge, the Cs-137 concentration is 1.71 Ci/gal. This does not account for the 111,545 gallons of free supernate that is expected following re-wet. This makes the evaluation conservative as the extra volume would serve to dilute the concentration.

4.3.11 Cooling Coils

The corrosion control program [WSRC-TR-2002-00327] limits the tank temperature during re-wet and BWR operations (Tables 2 and 4). During BWR, operation of cooling coils will help mitigate the mixing pump heat generated in Tank 15. Prior to BWR activities, the cooling coils will be hooked up to the chromated water system and tested to determine which coils are operational. [U-SOW-H-00007]

5. Operational Sequence

The process for Re-wet and BWR operations is outlined as follows:

1. Re-wet Tank 15 with IW and $NaNO_2$ until the waste tank level stabilized at 80.1 inches.
    - The liquid addtion will be treated with the following chemical composition:
        [NO2] = 0.61M
        [OH] = 0.01M

2. Reverse map during re-wet liquid addition.

3. Sample the supernate.
    - Sample when liquid visibly begins to collect above the lower sludge level
        Results will be used to find a representative H_{mix} and re-baseline the GRM constraints.
    - Sample following the cessation of liquid additions
        Results will be used to determine corrosion compliance as well as re-evaluate the flammability evaluations.

4. Implement DSA change.

- Remove references to Tank 15 as a dry tank

5. Prepare for BWR
   - Connect Chromated Water
   - Raise HLLCP to 200”

6. Initiate Bulk Waste Removal
   - SMP Heights:
     R2: 70.1”
     R4A: TBD following mapping and Flammability Evaluation revision
     R8: TBD following mapping and Flammability Evaluation revision

7. Transfer supernate from Tank 13 to Tank 15.

8. Begin mixing with SMPs.
   - If the SMPs in R4A and R8 are lower than the SMP in R2, start the SMPs in R4A and R8 prior to start-up of SMP in R2 to prevent sludge buildup around the R4A and R8 SMPs.

9. Sample the slurry.
   - Results will be used to determine solids content in the slurry as well as if the slurry transfer to Tank 13 will be a low rem transfer.

10. Transfer Tank 15 slurry to Tank 13.

11. Perform a sludge sounding on Tank 15.

12. Repeat Steps 7-11 as needed to meet SB 10 goal
    - Allow solids to settle in Tank 13 prior to supernate transfer back to Tank 15
    - Lower SMPs as needed following sludge sounding results and Flammability Evaluation revision

6. Opportunities

6.1 High Liquid Level Conductivity Probe (HLLCP) Height

For Type II waste tanks, the DSA outlines restrictions for the maximum HLLCP setpoint based on the trapped hydrogen fraction (H_{mix}) in the sludge. [WSRC-SA-2002-00007, Vol. 2] These limits are in Table 9. For waste tanks with low nitrate concentrations, the trapped hydrogen fraction is 0.75. This limits the HLLCP maximum set point. For Type II waste tanks with the mixer discharge clear of sludge and salt, the maximum set point is

284 inches for a trapped hydrogen fraction of greater than 0.375 or 304 inches if the trapped hydrogen fraction is less than 0.375. If the mixer discharge is partially or fully submerged, the setpoints are even lower. Analyzing a supernate sample for [NO_3] and [NO_2] following re-wet will allow for a new trapped hydrogen fraction to be calculated per DSA Section 3.4 and potentially increase the maximum HLLCP set points.

Table 9: HLLCP Limits for Type II Waste Tanks

Type II Waste Tank	HLLCP Max Setpoint if Mixer Discharge Clear of Sludge/Salt	HLLCP Max Setpoint if Mixer Discharge Partially or Fully Submerged in Sludge/Salt
H_{mix} >0.375	284	166
H_{mix} <0.375	304	245

7. Other Considerations

7.1 Tank 13 Salt-Out

Prior to Tank 13 BWR operations, it was discovered that approximately 4,944 gallons of salt had accrued on the cooling coils in Tank 13 and an additional 21,500 gallons of salt had formed a layer on top of the sludge. The salt accrual was due to the fact that the Tank 13 supernate had cooled to a point where the salt precipitated out of solution. Cooling coils placed into service in preparation for SMP operation to keep the supernate below the 65°C limit had cooled the waste tank to 36°C. An evaluation showed that based on the Tank 13 supernate chemistry, a dynamic precipitation of salt occurs between 39°C and 35°C. [SRR-LWE-2012-00066] The dissolution of salt in the sludge matrix of Tank 15 is expected during re-wet and BWR. The current Tank 13 supernate temperature is 30°C. Care should be taken to ensure that the slurry transfers from Tank 15 to Tank 13 are not saturated to the point where salt re-precipitation could occur or that the temperature is sufficient to prevent re-precipitation.

7.2 System Plan Impacts

Activities are continuously on-going throughout the entire liquid waste system. The System Plan [SRR-LWP-2009-00001] outlines these activities and their schedules such that they do not interfere with one another. It is possible that a delay in the Tank 15 schedule could impact another downstream activity or vice versa.

8. Open Items

None

9. References

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Attachment 2 (page 1 of 1)
TECHNICAL REPORT CHECKLIST

Report Number: X-ESR-H-00463 Revision: 0

Report Title: Tank 15H Flowsheet

The following checklist is used by checkers to ensure technical reports are complete and in compliance with Manual E7.
Add any notes or comments to the end of the checklist with the item number.

Item No.	Yes	No	N/A	Item
				Version/Format
1			✓	If revising an existing report, are you starting with the latest, approved version of the report obtained from DCR?
2	✓			Are all of the pages properly labeled with Report Number, Revision Number, and Sequential Page Number?
3	✓			Are the Subject and Purpose clearly stated and do they meet the end users needs?
				References
4	✓			Are all References properly documented within the report and can they be easily verified within Document Control, on-line, or within the library, etc.? If reference documents are not readily available, are they attached?
5	✓			Have the correct design bases documents been identified (e.g. Codes, Standards, DOE Orders, SRR Requirements, Regulatory Requirements)
				Open Items / Input
6	✓			Is there a reference/source for each input?
7	✓			Do the identified references/sources fully support the inputs?
8	✓			Are all assumptions used to support the report individually listed and numbered?
9*	✓			Is there a justification written for each assumption that includes a technical basis?
10	✓			Do the justifications adequately support the assumptions?
11			✓	If the report has open items, is there a method identified to track them?
				Results / Conclusion
12	✓			Are the results of the report consistent with the input and assumptions?
13		✓		Do the results of the report affect any other technical documents?
14	✓			Do the results substantiate the conclusion?
				Approvals
15	✓			Does the cover sheet identify the method of verification and checking and does it have a signature block for the verifier/checker?

Item No.	Comments

Checker/Verifier (Circle one):

Adam Hansen — Print/Type Name
[signature] — Signature
2-19-13 — Date