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Rev. 5

Tank 8 Waste Removal Operating Plan

Waste Removal Programs

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Summary of Revisions

9/99 - Revision 0; Initial Issue

5/00 - Revision 1; Major revision to all Sections. Addressed changes to slurry pump startup controls for trapped gas releases, corrosion controls for a well-mixed solution, reduced differential settlement monitoring requirements, and minor miscellaneous changes.

10/00 - Revision 2;

Section 2 - reflected Tank 8 addition of well water and concentrated nitrite to Diagram 1 and corrosion control descriptions
- Changed TTP lowering from two steps (64" to 34" then 34" to 4") to a single step (64" to 4") on Diagram 1
- Added 30 day Tank 8 dry sludge evaluation after completion of transfer
- added TTP 2-point lift and suction screen loading information
- acknowledged the activities to be performed in Tank 8 to support silicon settling studies (i.e., turbidity measurements and sampling)

Section 3 - revised operating steps to align with the Tank 8 to Tank 40 transfer procedure
- Added detail to allow dilution of the slurry in FPT-1 using IW from the DIWF during the transfer
- revised the sampling requirements to acknowledge the Tank 8 to Tank 40 WCP
- clarified the free gravity draining discussion and added calculation references

11/00 - Revision 3;

Section 3 - updated Diagram 2 to reflect the removal of the blanks in Valve Boxes 1, 2, and 3
- Corrected Table F to show Tank 8 to FPT-1 flow limit of < 50 gpm to shut down transfer
- Clarified 50 gpm Tank 8 to FPT-1 flow limit in the Sludge Hydraulics Studies subsection

12/00 - Revision 4;

Section 2 - added slurry pump dimensions and materials of construction information to the Slurry and Transfer Pumps subsection

Section 3 - corrected Diagram 2 to show that the blank was not removed from Valve Box 2

- revised Diagram 3 to reflect the tie in of Tank 49 Transfer Valve Box to HDB-7 as a credible transfer path
- added steps to the Operational Sequence subsection for: temporary transfer shut down and Tank 8 dilution with IW, and lowering the TTP impeller to rest on the casing prior to backflushing the TTP
- clarified HPT-7 drainback in the Process Control Parameters subsection
- added reference to structural qualification of the Tank 8 to Tank 40 transfer lines and removed redundant information in the Waste Transfer Structures and Lines subsection
- Added reference to FTF IW flush pressure calculation in the Transfer Pumps Performance and Overpressure Studies and additional monitoring of IW header pressure during initial Tank 8 to FPT-1 line flushing in the Operational Sequence subsection

3/01 - Revision 5;

Section 2 - added additional information to slurry pump equipment specifications and added TTP equipment specifications

Section 3 - clarified the VFD setpoints and hardwired interlock setpoints for transfer over-pressurization in the Transfer Pumps Performance and Overpressure Studies subsection and added sludge inventory in Tank Heel subsection.

Section 6 - added all information in this Section

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Section

1

General Information

GOAL

The goal of Waste Removal is to mobilize the High Level Waste in the F and H Tank Farm storage tanks and transfer the waste to the Extended Sludge Processing (ESP) facilities for further processing.

PURPOSE

The purpose of this Operating Plan is to develop the processing window for Tank 8 waste removal operations and document the operational requirements and technical basis. The intended use of this Plan is to provide:

- operational information for procedure development,
- guidance to the operating team during the waste removal evolutions, and
- a retrievable reference for future waste removal efforts.

This Plan assumes that standard concentration, storage and transfer procedures/programs (including the Authorization Basis) are in place to support waste removal efforts. Therefore, the focus of this document is upon the unique aspects of waste removal operations. If the standard procedures/programs are not changed by waste removal operations, then they are not re-iterated in this Plan.

SCOPE

The scope of Tank 8 waste removal is the suspension and transfer of sludge solids to Tank 40 in HTF-East Hill Extended Sludge Processing facility. Typically, there are three major processing operations within the waste removal scope. This Plan is organized to address each of these operations:

- bulk waste suspension,
- bulk waste transfers to HTF-East Hill, and
- heel removal from the primary and, if necessary, annular spaces.

BACKGROUND

Tank 8 construction was completed in 1953 as one of the Site's original twelve waste receipt tanks. In total, 6.05 million gallons of PUREX and non-canyon wastes were received in Tank 8 throughout the period of 1956 to 1980: 3.77 million gallons of Low Heat Waste (LHW), 1.58 million gallons of High Heat Waste

(HHW), and 0.70 million gallons of SRTC curium processing waste[1]. This resulted in 182,000 kgs (dry weight) of settled sludge[2]. The supernate layer above the sludge evaporated and began exposing the sludge to the tank atmosphere in February 1985[3]. The sludge depth at that time was 87 inches (approximately 236,000 gallons). Since that time, the sludge has slowly dehydrated, and the level has receded to approximately 49 inches.

The effects of sludge dehydration suggest that the surface of the sludge hardened as it dried. Supporting observations are:

- Visual photographic inspections revealed a dry surface,
- An impact drop test, using a 10-pound weight dropped from a one foot height, was performed around 1993 and demonstrated that the surface is hard and unyielding, and
- SRTC sludge samples from tanks of similar history as Tank 8 were discovered in a dehydrated condition after a long storage period. Some of these samples were found difficult to resuspend with inhibited water solutions.

The depth of this effect into the sludge layer and the irreversibility of the hardening have yet to be determined. Inhibited water was introduced into Tank 8 in October 1998 to rewet the sludge surface. This action stopped the dehydration process and allows time for rehydration before sludge removal operations.

Section

2

Sludge Suspension and Mixing Operation

This section is organized to introduce the important facets of sludge suspension, provide a general sequence of events for the operation, detail the slurry sampling attributes, and identify special monitoring and response requirements for the suspension process. Supporting technical information is also provided at the end of this section.

INTRODUCTION

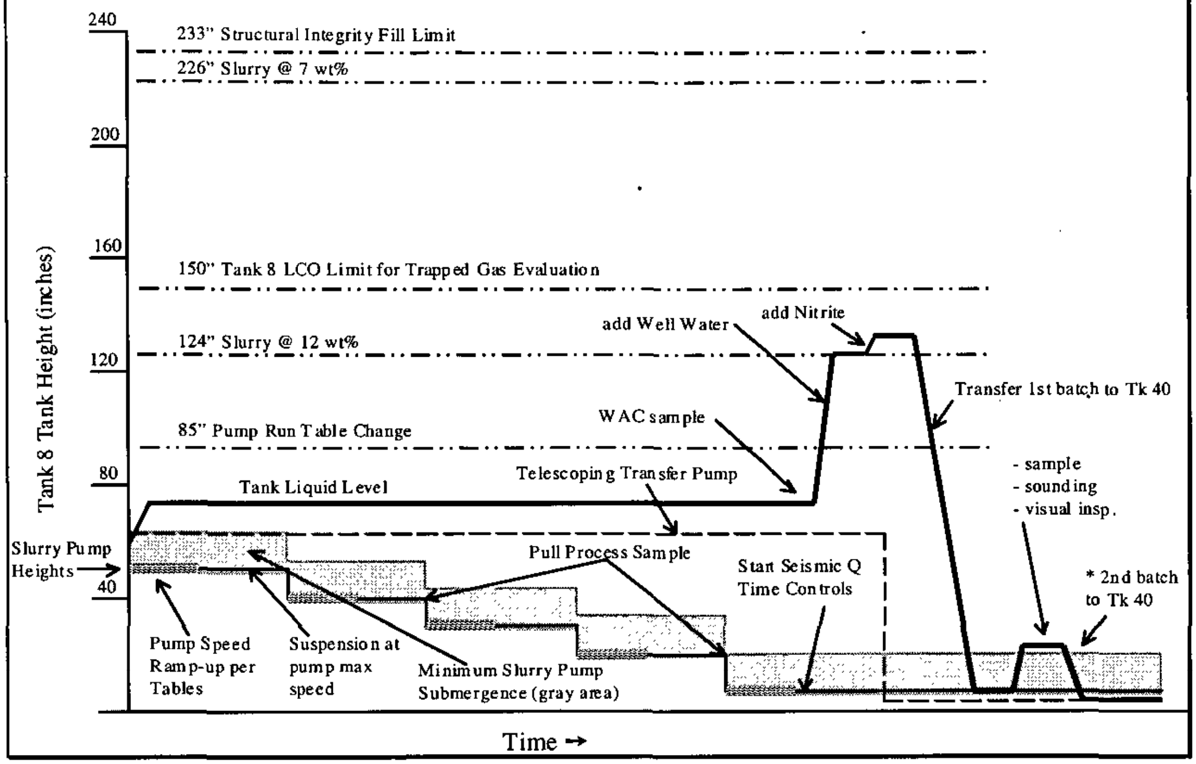
Four slurry pumps will be utilized to suspend and mix the settled sludge in Tank 8. The pumps will be initially set above the sludge surface at a nominal 50" above tank bottom (Pump Height Level). The pumps will be incrementally lowered in four steps (nominally 10" per step) into the tank during the suspension process. A Pump Run Program is required to ramp each pump up to maximum speed at each nominal pump height. The purpose of the Pump Run Program is to gradually de-inventory the settled sludge of trapped gas (containing hydrogen) in a safe and methodical manner. Slurry dip samples will be gathered and analyzed to provide process information for evaluation by Engineering. Inhibited water (or well water with concentrated inhibitor addition) will be added to the tank to dilute the slurry to the proper solids concentration. Use of existing supernate from other tanks in the tank farm was not considered a dilution option because a viable flowpath for waste transfers into Tank 8 is not available. Diagram 1 gives a general picture of sludge suspension and removal. The operating sequence required for sludge suspension is provided in the next subsection.

SPECIAL MANNING REQUIREMENTS

Due to the technical nature of the suspension operations, engineering support resources will be required as follows:

- dedicated FTF STE while in Tank 8 Bulk Sludge Mixing status, and
- dedicated Waste Removal engineering support to provide back up for the FTF STE.

Diagram 1



* After completion of first transfer batch, the second batch was not needed due to the small volume of sludge remaining. See Section 6 for details.

Operational Sequence

The sequence steps for sludge suspension and mixing are listed below. These steps are grouped by segments to provide structure to the looping steps in the sequence.

Segment A: One-Time Prerequisites for Waste Removal Operations

1.0 Add inhibited water to Tank 8 supernate to bring the tank level to approximately 75" to avoid roostertailing/vortexing (see discussion below under Technical Studies – Slurry and Transfer Pump Placement) and provide the needed cooling coil contact area.

1.1 The Flammability Fill Limit evaluation and a review of the Pump Run Table impact shall be completed prior to each addition of inhibited water to Tank 8.

1.2 Inhibited Water (IW) additions are limited to no more than 22 kgals without a 12-hour waiting period before additional IW additions can be made. The 12-hour limit allows time to detect if a primary tank leak site is encountered while adding IW in amounts greater than 3000 gallons. The 22 kgal limit protects the annulus pan volume such that, in the event a leak site is encountered, the transferred volume will not overflow the annulus pan.

2.0 Verify that a baseline pump structure settlement survey has been documented for each slurry pump within one month prior to initiating waste removal operations.

3.0 An operating portable VAMP shall be located within close proximity to the H&V skid demister during waste removal operations.

4.0 Establish/maintain tank cooling coil flowrate[4] through the available coils at a minimum of 200 gpm total flow as read by M&TE flow measurement device(s). Additional flow readings may be required upon request. If 200 gpm can not be achieved, then supernate temperature readings will be required on a more frequent basis (every 4 hours vs. shiftly). The 200 gpm flowrate requirement assumes that 35 of the 36 cooling coils are operational. If less than 35 coils are available for operation, have CST Engineering calculate the required cooling coil flowrate.

5.0 Perform a sludge sounding from Riser 4 reel tape to document a baseline of the sludge interface level.

Segment B: Prerequisites to Start 1st Slurry Pump at Each Pump Height

6.0 If Tank 8 is categorized as a non-slurried tank per PCO 2.6, then pull a corrosion control sample within one week prior to initiating slurry pump operation,

7.0 Verify that each designated thermocouple will be in the proper phase during suspension operations for pumps at this nominal height. [PCO 2.6.1, PSR 3.6.1.7]

8.0 Verify that the storm water monitoring system for Tank 8 is manually diverted.

9.0 Verify the following [Tk 8 Hydrogen Depletion SE DID control]:

9.1 The correct number of spacer cans are installed on each pump corresponding to the expected pump operational height.

9.2 The tank liquid level is < 95" for pump heights of 50", 40" and 30"; or that the liquid level is < 155" for pump heights of 20" and 10".

9.3 The engineering evaluation of the previous pump height level (via gas chromatograph data) determined that the hydrogen concentration in the settled sludge is within the AB requirements of < 9 vol. %. This is not applicable to starting pumps at the 50" pump height.

10.0 Within 24 hours prior to initiating slurry pump operation, perform an instrument loop verification (including calibration) of the installed H&V skid CLFL monitor. [LCO 3.4.1, SR 4.4.1.1]

11.0 Within 24 hours prior to initiating slurry pump operation, calibrate the purge exhaust Gas Chromatograph (GC). Receive Engineering approval to proceed if the GC is not operable.

12.0 Within the same shift prior to initiating slurry pump operation, calibrate the portable CLFL monitor. This readies the monitor for the CLFL reading to be taken 30 minutes after the 1st pump is started.

Segment C: Prerequisites to Start Each Pump

13.0 Verify Tank 8 is in the Bulk Sludge Mixing Operating mode. This will assure that all specific surveillances that are invoked by Bulk Sludge Mixing are current prior to pump operation.

13.1 Initiate monitoring the special waste removal monitoring requirements specified in Table E, as appropriate.

14.0 Specify the applicable Pump Run Table below that will apply to each slurry pump prior to initiating startup of that pump. If this is the initial pump start up at this pump height, receive Engineering concurrence on Pump Run Table selection. These four Tables were chosen from the 16 possible tables provided in the TSR Administrative Controls[15] and the Safety Evaluation (SE) for Tank 8 Hydrogen Depletion[42]. These were selected to provide the best blend of efficiency and simplicity to accomplish pump start ups given the expected tank liquid levels during waste removal operations.

14.1 Table A = Standard Pump Run Table, applicable at both the nominal 50" and 40" pump heights and tank liquid level < 90". (Table C-2 of the TSR[15])

14.2 Table B = Standard Pump Run Table applicable for all nominal pump heights ≤ 30" and tank liquid level < 90". (Table C-4 of the TSR[15])

14.3 Table C = Standard Pump Run Table applicable for all nominal pump heights < 50" and tank liquid level ≥ 90" and < 150". (Table C-8 of the TSR[15])

14.4 Table D = Restricted Pump Table applicable for all liquid levels < 150". This Table will be applied for all remaining pump startups at that pump height if the %CLFL exceeds the LCO 3.4.1 limits. (Table C-8F of the TSR[15])

15.0 Verify that the Tank 8 H&V skid ventilation flowrate has been ≥ 0.45 inwc (635 cfm) for more than 12 continuous hours prior to slurry pump operation.

16.0 Verify that the Tank 8 reel tape is parked at the appropriate level:

16.1 85" for Pump Run Tables A or B,

16.2 145" for Pump Run Table C, and

16.3 Either 85" or 145" for Pump Run Table D.

17.0 If the pump will be started in a rotating step per the applicable Table, start the pump turntable for the slurry pump and operate clockwise at 1/5 revolutions per minute.

18.0 If the pump will be started at the beginning of an indexed step per the applicable Table, rotate the turntable to the "0" indexed position and stop the turntable. Markings are placed on each pump and turntable to verify the indexed position is within the tolerance required (± 7°).

Segment D: Startup of Slurry Pumps at Minimum Speed

19.0 Reset the Speed Controller pot for the slurry pump to be started to the "zero" position (turned counterclockwise until the "0" appears and the dial stops). This should start the pump at approximately 450 rpm when the start button is pushed.

20.0 Start the slurry pump and ramp up to 600 rpm. The final speed should be achieved within 10 minutes of starting the ramping operation, and should be set as close to the Table value as possible (allowing the ± 20 rpm range for process fluctuations).

20.1 If the pump is started at the beginning of an indexed step, then the following requirements apply:

20.1.1 The Pump Q Time clock starts when the pump is started.

20.1.2 The Pump Q Time is listed in the ERD, specific to nominal pump height and tank liquid level.

20.1.3 The minimum hold times for all indexing sub-steps, including the final rotational sub-step, shall be completed prior to the Pump Q Time allowance listed in the ERD.

20.1.4 If the indexing steps are not completed prior to the Pump Q Time, shut down the pump and restart per Segment G.

20.2 Adhere to the appropriate Pump Run Table minimum hold time requirements.

20.2.1 Only one slurry pump should be in a minimum hold time status at any point in time with the following exceptions:

20.2.1.1 Once a pump has completed its minimum hold time at 1600 rpm at a given pump height, then restarts of that pump can occur while other pumps are in a minimum hold time status if within the Pump Q Time. This provision is important to allow immediate restart of all slurry pumps after temporary shut downs to perform sludge soundings, dip samples, etc. Otherwise, it would take 24 to 36 hours to restart the pumps at 1600 rpm, which does not support the daily soundings requirement in Step 46.0.

20.2.1.2 Pumps operating at less than 1600 rpm can be operated with multiple active minimum hold time statuses under the direction of Supervision.

21.0 Perform the following unique monitoring requirements over and above Table E.

21.1 If the pumps are at the nominal 50" pump height, then take vibration readings at each Pump Run Table speed for each pump.

21.2 If this is the first pump to be started at this pump height, then obtain a CLFL reading of the Tank 8 vapor space 30 minutes after pump startup using the portable CLFL monitor.

21.3 Monitor slurry pump current during initial startup of the pump. If current is fluctuating > ±10%, then contact Engineering to evaluate. This is to ensure the pump loads up properly.

21.4 If the speed is found outside of the ± 20 rpm range allowance, adjust the pump speed to the Table value immediately.

21.4.1 If the speed was found lower than the 20 rpm allowance below the Table value, then re-perform the minimum hold time after the speed has been adjusted back into the range.

22.0 If Tank 8 is categorized as a non-slurried waste tank per the Corrosion Control Program[5] PCO 2.6.1, then initiate the Corrosion Control Program requirements for a slurried waste tank after the first 3 hours of continuous slurry pump operation.

22.1 Apply the slurried tank supernate temperature limit listed in the ERD to the temperature limits identified in the roundsheet.

23.0 If the slurry pump(s) are shut down for reasons other than indexing, then restart the pump(s) per Segment G.

24.0 If the pump is in an indexing sub-step (except for the final rotational sub-step) and the minimum hold time is met, the slurry pump shall be shut down to proceed to the next indexing sub-step. The pump shall be restarted per Segment G.

25.0 After the rotational step (or indexing rotational sub-step) minimum hold time has been completed for the pump at this speed, field verify:

- the pump turntable is still rotating,
- the H&V skid flowrate is ≥ 0.30 inwc, and
- tank vacuum is ≥ 0.30 inwc.

25.1 If the H&V skid flowrate or the tank vacuum is less than 0.30 inwc, enter LCO 3.4.1.

25.2 If the turntable is found not rotating and it can be immediately restarted, then re-establish rotation and re-perform the minimum hold time at the rotational step. If the turntable can not be immediately restarted (i.e., requires Maintenance work), then shut down the pump and restart per Segment G.

25.3 If the turntable is found rotating and the skid flowrate and tank vacuum readings are acceptable, then the minimum hold time requirements for the pump at that speed and pump height are declared satisfied.

25.3.1 If the rotational step is at the end of a series of indexing sub-steps, then stop the Pump Q Time clock for that pump.

25.3.2 If this is the first or second pump started at the 50" pump height, then continue ramping this pump to maximum speed via Segments E and F. [Tk 8 Hydrogen Depletion SE DID control]

25.3.3 If this is not the first or second pump started at the 50" pump height, then it is preferred to start all slurry pumps at their minimum speed prior to ramping each to its maximum speed. The purpose of this is to avoid mounding sludge over the non-operating pumps, causing potential difficulty starting them.

Segment E: Prerequisites to Increase Speed for Each Pump at Each Slurry Pump Height

26.0 Verify the following 74F control room indications:

26.1 The pump speed is within the allowable range.

26.2 The Tank 8 H&V skid %CLFL is < 4%.

26.3 The Tank 8 H&V skid flowrate is > 0.35 inwc (530 cfm.)

26.4 The Tank 8 H&V skid is not in Trouble alarm.

26.5 The Tank 8 liquid level reel tape is not in alarm in the parked position.

Segment F: Increase Each Pump to Maximum Operable Speed

27.0 The maximum allowable pump speed for each pump shall be 1600 rpm unless otherwise specified by Engineering.

27.1 The maximum allowable pump speed could be lower than 1600 rpm due to pump performance difficulties,

27.2 To increase the pump speed to 2000 rpm, the following apply:

27.2.1 Engineering evaluation shall be conducted for motor and tank internals impact,

27.2.2 All four slurry pumps shall complete their minimum hold times at 1600 rpm prior to increasing any pump to 2000 rpm.

28.0 Riser 5 and Riser 3 slurry pumps should be the first pumps ramped to maximum speed, unless they are unavailable. The Effective Cleaning Radius (ECR) of these pumps[6,7,8] includes the Riser 4 reel tape location, therefore initial process information concerning suspension effectiveness can be obtained with the first two pumps.

29.0 If the next step in the Pump Run Table is a rotational step, then ramp the applicable slurry pump to the next allowable Pump Run Table speed. The new speed should be achieved within 10 minutes of starting the ramping operation, and should be set as close to the Table value as possible (allowing the ± 20 rpm range for process fluctuations).

30.0 If the next step in the Pump Run Table is at the beginning of an indexed sub-step, then rotate the turntable to the "0" indexed position. The following requirements apply:

30.1 The Pump Q Time clock starts when the turntable is stopped.

30.2 The Pump Q Time is listed in the ERD, specific to nominal pump height and tank liquid level.

30.3 The minimum hold times for all indexing sub-steps, including the final rotational sub-step, shall be completed prior to the Pump Q Time allowance listed in the ERD.

30.4 If the indexing sub-steps are not completed prior to the Pump Q Time, shut down the pump and restart per Segment G.

31.0 Perform the following unique monitoring requirements over and above Table E.

31.1 If the pumps are at the nominal 50" pump height, then take vibration readings at each speed for each pump during the first ramp up to maximum pump speed.

31.2 If the speed is found outside of the ± 20 rpm range allowance, adjust the pump speed to the Table value immediately.

31.2.1 If the speed was found lower than the 20 rpm allowance below the Table value, then re-perform the minimum hold time after the speed has been adjusted back into the range.

32.0 If the slurry pump(s) are shut down for reasons other than indexing, then restart the pump(s) per Segment G.

33.0 If the pump is in an indexing sub-step (except for the final rotational sub-step) and the minimum hold time is met, shut down the pump and restart per Segment G.

34.0 After the rotational step (or indexing rotational sub-step) minimum hold time has been completed for the pump at this speed, field verify:

- the pump turntable is still rotating,
- the H&V skid flowrate is ≥ 0.30 inwc, and
- tank vacuum is ≥ 0.30 inwc.

34.1 If the H&V skid flowrate or the tank vacuum is less than 0.30 inwc, enter LCO 3.4.1.

34.2 If the turntable is found not rotating, then re-establish rotation and re-perform the minimum hold time at the rotational step.

34.3 If the turntable is found rotating, then the minimum hold time requirements for the pump at that speed and pump height are declared satisfied.

34.3.1 If the rotational step is at the end of a series of indexing sub-steps, then stop the indexing Pump Q Time clock for that pump.

34.3.2 Perform Segment E and F to increase the pump speed to the next allowable setting per the Pump Run Table.

35.0 Once the slurry pump has satisfied the minimum hold time at its maximum allowable operating speed, then:

35.1 If it is the first or second pump started at the 50" pump height, then [Tk 8 Hydrogen Depletion SE DID control]

35.1.1 Shut down the pump.

35.1.2 Perform an engineering evaluation to determine the hydrogen concentration in the settled sludge.

35.1.3 Verify that the hydrogen concentration is < the AB requirements of 9 vol.% prior to proceeding with starting the next pump per Segment C.

35.2 The turntable direction should be reversed every 24 hours of pump operation.

35.2.1 Turntable operation may be suspended to perform special actions (e.g., sludge mound erosion) with the approval of Engineering.

35.3 Increase the next pump to its maximum allowable speed by performing Segments E and F for that pump.

35.4 If the pump operating at maximum allowable speed is at the nominal 50" pump height, then perform a visual structural engineering inspection of the pump support structure.

36.0 The Seismic Q program for periodic pump runs shall be initiated if all of the following are true:

36.1 All four slurry pumps have satisfied their Pump Run Table minimum hold time requirements at the 10" nominal pump height and 1600 rpm.

36.2 All four slurry pumps have satisfied an additional 8 hour minimum hold time requirement at pump speeds between 1580 and 1600 rpm.

36.2.1 The 8 hour minimum hold time shall be re-performed if any of the following are true:

36.2.1.1 the pump speed is found outside the 1580 to 1600 rpm range,

36.2.1.2 the pump turntable is not rotating,

36.2.1.3 the H&V skid flowrate is < 0.30 inwc, or

36.2.1.4 tank vacuum is < 0.30 inwc.

37.0 After all operable pumps have satisfied their minimum hold times at the maximum allowable speed, perform sludge suspension activities at this pump height per Segment H.

Segment G: Slurry Pump Re-start Requirements

38.0 If shut down occurs in an indexing sub-step for any reason other than the high CLFL indications (i.e., H&V skid high CLFL alarm, or H&V skid CLFL indication > 5%, or portable tank vapor space readings of $\geq$ 10%), then the following restart requirements apply:

38.1 If the minimum hold time was completed at that indexing sub-step, and it is expected that the pump can still complete all of the indexing sub-steps prior to the Pump Q Time, then do the following:

38.1.1 Re-position the turntable to the next indexing sub-step in the Pump Run Table. The indexing marks on the pump and the turntable maintain the ± 7° tolerance required for the indexing positioning.

38.1.2 Re-start the pump and ramp to the pre-shut down speed and perform the minimum hold time for the next indexing sub-step.

38.1.2.1 To restart the pump, reset the Speed Controller pot for the slurry pump to be started to the "zero" position (turned counterclockwise until the "0" appears and the dial stops). This should start the pump at approximately 450 rpm when the start button is pushed. Then start the slurry pump and ramp up to the pre-shut down speed. The desired speed should be achieved within 10 minutes of starting the ramping operation, and should be set as close to the Table value as possible (allowing the ± 20 rpm range for process fluctuations).

38.1.3 Continue in the Pump Run Table per the appropriate Segment (D or F).

38.2 If the minimum hold time was not met at that indexing sub-step and it is expected that the pump can still complete all of the indexing sub-steps prior to the Pump Q Time, then do the following:

38.2.1 Re-start the pump and ramp to the pre-shut down speed and re-perform the minimum hold time for that sub-step.

38.2.2 Continue in the Pump Run Table per the appropriate Segment (D or F).

38.3 If the Pump Q Time has expired or can not be met prior to completing all of the indexing sub-steps (including the final rotational sub-step), then do the following:

38.3.1 If the Pump Q Time can be met by re-performing a previously completed rotational step, it is acceptable to re-perform that step by doing the following:

38.3.1.1 Initiate clockwise rotation of the pump turntable.

38.3.1.2 Re-start the pump and ramp to the previously completed rotational speed and re-perform the minimum hold time for that step. Note that previously completed hold times at speeds greater than this step are no longer valid and shall be re-performed.

38.3.1.3 Continue in the Pump Run Table per Segment F.

38.3.2 If the Pump Q Time has expired or can not be met by re-performing a previously completed rotational step, then do the following:

38.3.2.1 Return to step 1 of the Pump Run Table

38.3.2.2 Perform Segment C to complete the pump startup prerequisites.

38.3.2.3 Start the pump at minimum speed and ramp up per the Pump Run Table per Segments D, E and F.

39.0 If shut down occurs in an indexing sub-step for high CLFL conditions in Tank 8 (i.e., H&V skid high CLFL alarm, or H&V skid CLFL indication > 5%, or portable tank vapor space readings of ≥ 10%), then re-start the pump per the following:

39.1 Ensure that LCO 3.4.1 has been exited and that Tank 8 is in Bulk Sludge Mixing mode status.

39.2 If the slurry pump was in Pump Run Table D at the time of the high CLFL indication, have Engineering perform a safety analysis prior to any slurry pump operation.

39.3 If the slurry pump can be restarted and complete the minimum hold time, in Pump Run Table D at the next lower rotational step (including the rotational sub-step at the end of a series of indexing sub-steps) below the pre-shut down speed prior to the Pump Q Time, then do the following:

39.3.1 Re-perform Segment C. Selection of Pump Run Table D will be required for the remaining pump startups at this nominal pump height.

39.3.2 Re-start the pump in Table D and ramp up to the last completed minimum hold time rotational step. If the pre-shut down speed was 600 rpm, then ramp up to 600 rpm upon restart.

39.3.3 Continue in the Pump Run Table per the appropriate Segment (D or F).

39.4 If the slurry pump can not be restarted prior to the Pump Q Time, then re-start the pump per the following:

39.4.1 Re-perform Segment C. Selection of Pump Run Table D will be required for the remaining pump startups at this nominal pump height.

39.4.2 Re-start the pump at Step 1 of the Pump Run Table (minimum speed) via Segment D.

40.0 If shut down occurs in a rotational step, determine the maximum shut down time per pump without requiring the re-start of that pump at Step 1 of the appropriate Pump Run Table (i.e., unrestricted re-start to the speed of the last completed hold time).

40.1 Based upon nominal pump height and Tank 8 liquid level, identify the Pump Q Time listed in the ERD for each shut down pump.

40.2 Calculate the Allowable Pump Q Time by subtracting 1 day from the ERD Pump Q Time. This accounts for two shifts to re-start the pump at the pre-shut down speed and satisfy the minimum hold time per the appropriate Pump Run Table.

41.0 If the Seismic Q Time program is applicable (see Segment F), then determine the maximum shut down time per pump which allows for pump re-start (via the Pump Run Table) and 8 hour continuous operation before Seismic Q time expires.

41.1 Based upon Tank 8 liquid level, identify the Seismic Q Time listed in the ERD for each shut down pump.

41.2 Calculate the Allowable Seismic Q Time by subtracting 7 days from the ERD Seismic Q Time. This accounts for 113 hours to reach maximum speed by Pump Run Table C or D (assuming all four pumps are ramped up simultaneously through the Pump Run Tables), 8 hours to satisfy the mixing time requirement, and a 46 hour buffer for unexpected delays during pump re-start.

42.0 If a pump is in a rotational step and it is shut down due to high CLFL conditions in Tank 8 (i.e., H&V skid high CLFL alarm, or H&V skid CLFL indication $> 5\%$, or portable tank vapor space readings of $\geq 10\%$), then re-start the pump per the following:

42.1 Ensure that LCO 3.4.1 has been exited and that Tank 8 is in Bulk Sludge Mixing mode status.

42.2 If the slurry pump was in Pump Run Table D at the time of the high CLFL indication, have Engineering perform a safety analysis prior to any slurry pump operation.

42.3 If the slurry pumps are in Pump Run Tables A, B or C and the re-start of any slurry pump will be initiated within the Allowable Pump Q Time for that pump, then:

42.3.1 Re-perform Segment C. Selection of Pump Run Table D will be required for the remaining pump startups at this nominal pump height.

42.3.2 Re-start the pump and ramp up to the last completed minimum hold time rotational step (including the rotational sub-step at the end of a series of indexing sub-steps) speed in Table D. If the pre-shut down speed was 600 rpm, then ramp up to 600 rpm upon restart.

42.3.3 Continue in the Pump Run Table per the appropriate Segment (D or F).

42.4 If the slurry pump can not be restarted prior to the Allowable Pump Q Time, then re-start the pump per the following:

42.4.1 Re-perform Segment C. Selection of Pump Run Table D will be required for the remaining pump startups at this nominal pump height.

42.4.2 Re-start the pump(s) at Step 1 of the Pump Run Table (minimum speed) via Segment D.

42.4.3 Increase speed via Segments E and F using Pump Run Table D requirements. Continue in the Pump Run Table per Segment F.

43.0 If a pump is in a rotational step and it is shut down for any reason other than: 1.) high CLFL indications, or 2.) to lower the pump to a different nominal pump height, then perform the following to re-start the pump:

43.1 If the re-start of the slurry pump will be initiated within the Allowable Pump Q Time for that pump, then:

43.1.1 Re-perform Segment C.

43.1.2 Re-start the pump and ramp up to the last completed minimum hold time rotational step (including the rotational sub-step at the end of a series of indexing sub-steps) speed in Table D. If the pre-shut down speed was 600 rpm, then ramp up to 600 rpm upon restart.

43.1.3 Continue in the Pump Run Table per the appropriate Segment (D or F).

43.2 If the re-start of any slurry pump will not be initiated within the Allowable Pump Q Time for that pump, then:

43.2.1.1 Return to Step 1 of the applicable Pump Run Table

43.2.1.2 Perform Segment C to complete the pump startup prerequisites.

43.2.1.3 Start the pump at minimum speed and ramp up per the Pump Run Table per Segments D, E, and F.

44.0 If the Seismic Q Time program is applicable (see Segment F) and the re-start of a slurry pump has not been initiated within the Allowable Seismic Q Time for that pump, then have Engineering perform a safety analysis prior to re-starting that slurry pump.

Segment H: Sludge Suspension Activities

45.0 Continue slurry pump operation monitoring per Table E.

46.0 Perform sludge soundings daily (this frequency may be extended to weekly with Engineering approval). Additional steel taping at the Center and #7 Risers may be requested. This will require the temporary shut down of all slurry pumps to perform.

46.1 If the slurry pumps can be lowered based upon Engineering judgement, go to Segment I.

46.2 If the sludge interface level is not decreasing have Engineering evaluate if a transfer of slurried material to Tank 40 is appropriate. If so, go to Segment J.

47.0 If identified in Segment I, perform an inhibited water transfer into Tank 8 from the 10K Inhibited Water tank. Multiple batch transfers from the 10K tank may be necessary.

47.1 Prior to adding inhibited water, ensure that the slurry pump columns and the transfer pump column is filled and under pressure with bearing water.

47.2 Prior to adding inhibited water, verify the corrosion inhibitors will remain within the corrosion limits after the addition is complete [PCO 2.6.2, PSR 3.6.2.5].

47.3 Prior to adding inhibited water, ensure a manual supply valve from each of the Dilute Inhibited Water Facility and the Well Water system are closed to isolate the 10K Inhibited Water tank from any potential makeup sources.

47.4 Prior to adding inhibited water, shut down the slurry pumps and place the reel tape in seek mode for material balance purposes. (Note, the Allowable Pump Quiescent time shall be recalculated based upon the expected post-addition tank liquid level and applied to the pumps at this time).

47.5 Within 24 hours prior to adding inhibited water, verify that the intended liquid level will not exceed the flammability fill limit after the addition is complete [PCO 2.14.1, PSR 3.14.1.6].

47.6 Within 24 hours after adding inhibited water, verify that the liquid level does not exceed the flammability fill limit based upon the actual Tank 8 liquid level [PCO 2.14.1, PSR 3.14.1.4].

47.7 After adding inhibited water and before any slurry pump operation, establish the proper Pump Run Table controls for each pump based upon the actual Tank 8 liquid level [LCO 3.4.3, SR 4.4.3.1].

48.0 If the slurry pump(s) are shut down, then restart the pump(s) per Segment G.

Segment I: Lowering of the Slurry Pumps

49.0 For the first slurry pump to be lowered below the nominal 40" or 20" pump heights, prepare for pulling process slurry samples.

50.0 Shut down the slurry pumps and, if required, immediately obtain a process slurry sample for analysis per the Suspension Sample Requirements in this Section.

50.1 Upon receipt of the sample analysis, have Engineering evaluate if, and how much, inhibited water should be added to maintain the sludge slurry below 18 wt%IS and less than 1.5 SpG. This evaluation is not a prerequisite to lowering or operating the slurry pumps at the next level.

51.0 Lower the slurry pumps no more than a nominal 10" spacer can height. The pumps are required to operate at each nominal pump height prior to lowering them to the next pump height in order to fulfill the hydrogen evaluation defense-in-depth controls of the Tank 8 Hydrogen Depletion SE[42].

52.0 Slurry pump operation at the new pump height shall start at Segment B and perform all subsequent Segments.

Segment J: Prerequisites for Slurry Transfer

53.0 Dilute the slurry to a maximum of 12 wt% insoluble solids for transfer. Tank 8 corrosion chemistry supports either Inhibited Water (IW) or well water addition for dilution[9]. If well water is used, then the slurry pumps must be operating during the addition to ensure the solution is well mixed and no localized low pH regions exist.

54.0 Operate all slurry pumps (a minimum of 3 slurry pumps is required) at the maximum allowable speed for a minimum of 48 hours.

55.0 Have Engineering perform the evaluation for low gamma leak detection requirements based upon slurry sample analysis and establish Area Radiation Monitors (ARMs) per the requirements of the low gamma evaluation.

56.0 Lower the Telescoping Transfer Pump (TTP) to the appropriate height determined by Engineering.

56.0 Verify that each designated thermocouple will be in the proper phase during and after the slurry transfer. [PCO 2.6.1, PSR 3.6.1.7]

57.0 Initiate the transfer from Tank 8 to Tank 40 per the Transfer Sequence in Section 3.

57.1 Monitor slurry pump operation via Segment H. Daily sludge soundings and inhibited water additions will not be performed during transfer operations.

Segment K: Post-Transfer Activities

58.0 After each transfer sequence is complete, visually inspect and document (video/photographs) the Tank 8 primary for sludge mounding or hardened chunks remaining.

58.1 If large mounds of sludge will remain uncovered for more than 30 days between transfers, perform an Engineering evaluation for dry sludge control requirements.

59.0 After all transfers for bulk sludge removal are complete:

59.1 Perform visual inspection of the Tank 8 primary tank wall and annulus to verify post transfer, and post waste removal, integrity of the tank vessel.

59.2 Complete an Engineering evaluation for dry sludge, abnormal emissions, and flammability controls requirements within 30 days of declaring bulk sludge removal complete.

59.3 If slurry pump operation is required, restart the slurry pumps per Segment G and continue in Segment H.

Table A
Pump Run Table for 50" and 40" Nominal Pump Heights and Tank 8 Liquid Level < 85"

(Note: 85" is the operating level to protect the 90" LCO limit)

Step Number	Pump Speed (rpm)	Turntable	Minimum Hold Time (hours)
1	600	Rotating	4
2	800	Rotating	6
3	1000	Rotating	11
4	1200	Rotating	3
5	1300	Rotating	4
6	1400	Rotating	4
7	1500	Rotating	5
8	1600	Rotating	8

Table B

Pump Run Table for 30", 20" and 10" Nominal Pump Heights and Tank 8 Liquid Level < 85"

(Note: 85" is the operating level to protect the 90" LCO limit)

Step Number	Pump Speed (rpm)	Turntable	Minimum Hold Time (hours)
1a	600	Indexed at 0°	3
1b	600	Indexed at 30°	3
1c	600	Indexed at 60°	3
1d	600	Indexed at 90°	3
1e	600	Indexed at 120°	3
1f	600	Indexed at 150°	3
1g	600	Rotating	3
2	800	Rotating	3
3a	1000	Indexed at 0°	3
3b	1000	Indexed at 30°	3
3c	1000	Indexed at 60°	3
3d	1000	Indexed at 90°	3
3e	1000	Indexed at 120°	3
3f	1000	Indexed at 150°	3
3g	1000	Rotating	3
4	1100	Rotating	3
5	1150	Rotating	3
6	1200	Rotating	3
7	1250	Rotating	3
8	1300	Rotating	3
9	1350	Rotating	3
10	1400	Rotating	3
11	1450	Rotating	3
12	1500	Rotating	3
13	1550	Rotating	4
14	1600	Rotating	8

Table C
Pump Run Table for All Nominal Pump Heights and Tank 8 Liquid Level ≤ 145"

(Note: 145" is the operating level to protect the 150" LCO limit)

Step Number	Pump Speed (rpm)	Turntable	Minimum Hold Time (hours)
1a	600	Indexed at 0°	3
1b	600	Indexed at 30°	3
1c	600	Indexed at 60°	3
1d	600	Indexed at 90°	3
1e	600	Indexed at 120°	3
1f	600	Indexed at 150°	3
1g	600	Rotating	3
2	700	Rotating	6
3	800	Rotating	6
4a	1000	Indexed at 0°	3
4b	1000	Indexed at 30°	3
4c	1000	Indexed at 60°	3
4d	1000	Indexed at 90°	3
4e	1000	Indexed at 120°	3
4f	1000	Indexed at 150°	3
4g	1000	Rotating	3
5	1050	Rotating	3
6	1100	Rotating	3
7	1150	Rotating	4
8	1200	Rotating	4
9	1250	Rotating	4
10	1300	Rotating	4
11	1350	Rotating	5
12	1400	Rotating	5
13	1450	Rotating	6
14	1500	Rotating	6
15	1550	Rotating	7
16	1600	Rotating	8

Table D
Fall Back Pump Run Table for All Nominal Pump Heights and Tank 8 Liquid Level < 145"

(Note: 145" is the operating level to protect the 150" LCO limit)

Step Number	Pump Speed (rpm)	Turntable	Minimum Hold Time (hours)
1a	600	Indexed at 0°	3
1b	600	Indexed at 30°	3
1c	600	Indexed at 60°	3
1d	600	Indexed at 90°	3
1e	600	Indexed at 120°	3
1f	600	Indexed at 150°	3
1g	600	Rotating	3
2	650	Rotating	3
3	700	Rotating	3
4	750	Rotating	3
5	800	Rotating	3
6a	1000	Indexed at 0°	3
6b	1000	Indexed at 30°	3
6c	1000	Indexed at 60°	3
6d	1000	Indexed at 90°	3
6e	1000	Indexed at 120°	3
6f	1000	Indexed at 150°	3
6g	1000	Rotating	3
7	1050	Rotating	3
8	1100	Rotating	3
9	1150	Rotating	4
10	1200	Rotating	4
11	1250	Rotating	4
12	1300	Rotating	4
13	1350	Rotating	5
14	1400	Rotating	5
15	1450	Rotating	6
16	1500	Rotating	6
17	1550	Rotating	7
18	1600	Rotating	8

Table E

Monitoring Requirements During Slurry Pump Operation

	CLI	Description	Recording Frequency	Alarm /RS Limit	Alarm / Roundsheet Out-of-Range Response
Radiation Monitoring	RME	Tk 8 tank top (pump risers) and H&V skid (demister and HEPA) Radcon surveys	Daily	High radiation or contamination	Shut down slurry pumps
	RME	Tk 8 annulus radiation air monitor	Weekly Filter paper Change out	High radiation	Shut down slurry pumps
	RAH-8033C	Tk 8 tank top VAMP	N/A	RAH	Shut down slurry pumps and all liquid transfers
	RISH-3442 (241-013F)	West pump house (241-013F) VAMP	Shiftly	UA-3442	Shut down slurry pumps. If appropriate, investigate Tk 8 cooling coils for failure
	RIT-2205	Tk 8 H&V skid CAM radiation	Shiftly	N/A	
	RAH-2205	Tk 8 H&V skid CAM radiation	N/A	5000 cps	Shut down slurry pumps and all liquid transfers
	FI-105	Tk 8 H&V skid CAM sample flow	Shiftly	N/A	Adjust flow back into range
CLFL Monitoring	AI-2200 (241-74F)	Tk 8 H&V duct CLFL reading	Hourly	CLFL $\geq$ 4%	No new pump starts or pump speed increases allowed until CLFL < 4%.
	AI-2200 (H&V skid)	Tk 8 H&V duct CLFL reading	Shiftly	CLFL $\geq$ 4%	No new pump starts or pump speed increases allowed until CLFL < 4%.
	AAH-2200 (241-74F)	Tk 8 H&V duct CLFL	N/A	AAH	Perform a calibration check after the LCO 3.4.1 Required actions are initiated
	Portable CLFL Monitor	Tk 8 vapor space CLFL	Shiftly	CLFL $\geq$ 4%	If AI-2200 is reading zero, investigate H&V duct CLFL monitor for operability
	Portable CLFL Monitor	Tk 8 vapor space CLFL	Shiftly	CLFL $\geq$ 8%	No new pump starts or pump speed increases allowed until CLFL < 4%.
	H_2 GC	Operability of the Tank 8 Gas Chromatograph	Shiftly	N/A	If inoperable, receive Engineering approval to proceed with additional pump starts or speed changes
	TI-new	74F ambient air temperature	Hourly	Temp $\leq$ 41°F	Shut down slurry pumps, provide freeze protection for bearing water lines inside slurry pump housings
	TI-new	74F ambient air temperature	Hourly	Temp $\leq$ 40°F	Declare Tk 8 CLFL monitor inoperable
Slurry Pump Monitoring	SC-1, SC-2, SC-3 and SC-4	Tk 8 slurry pump VFDs for current (amps) and power (kW)	Shiftly, and at Each speed chg	N/A	
	SI-6010, SI-6015 SI-6030 and SI-6040	Tk 8 slurry pump speeds (rpm)	Hourly	N/A	Adjust speed back into range
	FG-2301, 2302, FG-2303, 2304, FG-2305, 2306, FG-2307, 2308	Tk 8 bearing water flow for the slurry pumps	Shiftly	Flow $\geq$ 2 gpm from any pump	Shut down the slurry pump with the high flowrate
	PI-2311, PI-2312 PI-2313, PI-2314	Tk 8 bearing water pressure for the Slurry pumps	Shifty	N/A	

CLI	Description	Recording Frequency	Alarm /RS Limit	Alarm / Roundsheet Out-of-Range Response
Primary H&V Monitoring				
UR-2125 (241-74F)	H&V skid purge flowrate	Shiftly	< 635 cfm or > 800 cfm	Adjust dampers V-60 and/or V-67 to maintain flow between 570 and 800 cfm.
FI-2125 (H&V skid)	H&V skid purge flowrate	Shiftly	< 0.5 inwc or > 0.8 inwc	Adjust dampers V-60 and/or V-67 to Maintain flow between 0.4 and 0.8 inwc.
FAL-2125	H&V skid purge flowrate	N/A	0.41 inwc	Take local flow reading (FI-2125) to determine if entry into LCO 3.4.1 required.
PDI-2001	Tk 8 primary vacuum (purge inlet)	Shiftly	< 0.4 inwc	Investigate sources of tank/ventilation inleakage
PDI-8034	Tk 8 primary vacuum (purge exhaust)	Shiftly	< 0.4 inwc	Investigate sources of tank/ventilation inleakage
PDI-2001 (H&V skid)	H&V skid demister differential Pressure	Shiftly	< 0.2 inwc > 3.0 inwc	Investigate for potential pluggage. Flush as necessary
PDI-2008	H&V skid HEPA differential Pressure	Shiftly	> 3.0 inwc	Shut down slurry pumps. Investigate for potential blinding. Replace as necessary
TI-2006	H&V skid reheater inlet temp	Shiftly	N/A	
TI-2010	H&V skid reheater outlet temp	Shiftly	N/A	
YA-2209	H&V trouble alarm	N/A	H&V equip, CLFL monitor, and CAM	Investigate H&V skid and determine if H&V equip, CLFL monitor, or CAM for operability. If any are inoperable, shut down slurry pumps.
Annulus H&V Monitoring				
PDA-2185	Tk 8 annulus pressure	N/A	High or Low	Shut down slurry pumps
TI-2002	Tk 8 annulus supply temp	Shiftly	N/A	
TI-2006	Tk 8 annulus exhaust temp	Shiftly	N/A	
Tank Monitoring				
LI-8031	Tk 8 Reel Tape (via Parked Position alarm or level seeking)	Daily	> Pump Run Table limits	Shut down slurry pumps and all liquid transfers
LAH-2190	Tk 8 HLLCP	N/A	LAH	Shut down slurry pumps and all liquid transfers
LAH-8032	Tk 8 Annulus Conductivity Probes	N/A	LAH	Shut down slurry pumps and all liquid transfers
TI-2049	Cooling water supply temp	Shiftly	N/A	
TI-2040	Cooling water return temp	Shiftly	N/A	
TI-2039	Tk 8 H&V condenser exit temp	Shiftly	N/A	
LI-2042	Cooling water surge tank level	Shiftly	N/A	
LAL-5134	Cooling water surge tank level	N/A	LAL	If Tk 8 suspected, shut down slurry pumps and individually valve out coils adjacent to slurry pumps to isolate source
PAL-2056	Cooling water header pressure	N/A	PAL	Increase monitoring frequency of TI-6982 to every 4 hours.
TI-6982	Tk 8 sludge / slurry / vapor Space temperatures	Shiftly	Slurry temp > 70° C	Shut down slurry pumps
Camera	Tk 8 primary inspection w/slurry pumps operating	Weekly	N/A	

SAMPLING REQUIREMENTS

The primary purpose of sampling during sludge suspension is to monitor the corrosion control inhibitor levels and suspension processing parameters (wt% insoluble solids, SpG, gross gamma).

The following lists the sampling requirements during suspension activities. The transfer compliance sample requirements are described in Section 3.

- A corrosion sample is required monthly.
  - The sample analysis should report the following, at a minimum: OH^-, NO_2^-, and NO_3^-.
  - One standard 100 ml dip sample should be gathered and submitted to F-Canyon lab for quick turnaround analysis.
- A process controls sample is minimally required when the first slurry pump to be lowered below the nominal 40" or 20" pump height, and additionally upon request.
  - If the slurry liquid level above the settled sludge interface level is greater than 70", then each sample set shall consist of three 100 ml dip samples: one taken at the top of the slurry liquid, the second at the approximate mid-point between the settled sludge interface and the liquid surface, and the third at the settled sludge interface with the slurry. This will provide solids concentration gradient information. The analysis should report wt%IS, SpG and total gamma radiation.
  - If the slurry liquid level above the settled sludge interface level is less than 70", then each sample set shall consist of one 100 ml dip sample taken at the approximate mid-point between the settled sludge interface and the liquid surface. The analysis should report wt%IS, SpG and total gamma radiation.
  - These samples shall be submitted to SRTC high level caves for analysis.

In support of the evaporator feed specification program, turbidity measurements and sampling for silicon settling rates will be conducted in Tank 8 after it has been diluted for slurry transfer. These samples will be drawn per separate requirements established by the evaporator program.

SUPPORTING INFORMATION

The important operating limits and targets for process control are identified under the Process Control Parameters subsection below. Additional technical information for sludge suspension follows in the Technical Studies subsection.

Process Control Parameters

The parameters governing the sludge suspension and mixing process are: slurry solids concentration, slurry temperature, and tank liquid level.

Slurry Solids Concentration

The concentration of solids in the slurry is defined in terms of weight percent insoluble solids (wt%IS). The solids concentration will be measured and monitored via slurry sample analysis (see Sampling Requirements in this Section). There are two sets of bounds established for solids concentration: the operating target range and the operating limits (see Sludge Hydraulic and Rheological Studies in this Section for further information).

The operating target range shall be 7 to 12 wt%IS. The lower target supports the ability to move the entire Tank 8 sludge inventory to Tank 40 for single batch processing at ESP. The upper target maintains the slurry in the turbulent flow region at the minimum flowrate of 70 gpm[10]. The Tank 8 sludge slurry inhalation dose[11] is 6.39E+07 rem/gal at the current tank level of approximately 65". Any inhibited water additions would only reduce the inhalation dose level. This is an order of magnitude below the AB limit[87] of 2.3E+09 rem/gal. Therefore, inhalation dose is not a limiting issue for Tank 8 waste removal.

The operating limits shall be 5 to 18 wt%IS. The lower limit protects the hindered settling rate assumption of 0.2 in/hr[12,13,14]. At solids concentrations below 5 wt%IS, the settling rate increases significantly. This lower limit only applies to the bulk slurry in Tank 8 just prior to transfer to Tank 40. This supports the well-mixed slurry assumption for consistent transfer properties in Tank 8. The solids concentration in the transfer lines is expected to be less than 5 wt%IS during initial slurry transfer and flushing operations. The upper limit protects the F-area Pump Tank #1(FPT-1) Inter-Area Line (IAL) transfer pump design capacity (greater than 70 gpm flowrate at less than 225 psig pump discharge pressure based on the rheology of the slurry).

Slurry Temperature

The Tank 8 slurry temperature will be measured and monitored via the thermocouple bundle in the thermowell in Riser 4. Corrosion control and abnormal emissions control establishes the temperature limits for Tank 8 suspension. Additional temperature limits exist for slurry transfers (see Transfer Technical Basis below)

The temperature limit for abnormal emissions control[87] is 80°C. The temperature limit for corrosion control is 75°C for the expected hydroxide levels while Tank 8 is designated a slurried tank per PCO 2.6.1. The hydroxide, nitrate and nitrite concentrations will be monitored via sample analysis (see Sampling Requirements in this Section).

Tank Liquid Level

The tank liquid level will be measured and monitored via the tank reel tape. This reel tape will be upgraded to perform both liquid interface and sludge sounding readings prior to Tank 8 Waste Removal.

The normal Operating Fill Limit for Tank 8 will be constrained by the Structural Integrity Fill Limit[5], the Flammability Fill Limit, and the Hydrogen Depletion Controls[15] applicable during Bulk Sludge Mixing. The Structural Integrity Fill Limit for Tank 8 is 233". The Flammability Fill Limit[63] is 217". The Hydrogen Depletion Controls LCO 3.4.3 limits the maximum liquid level to < 150".

The tank level should be initially increased from its present level of ≅ 65" to a minimum of 76" to provide adequate liquid depth for initial slurry pump operation (see Slurry and Transfer Pump Placement Studies in this Section).

The slurry will be diluted just prior to transfer to achieve a pumpable suspension. A maximum 12 wt% insoluble solids concentration is required, which is equivalent to ≈ 124" tank level. The slurry will be diluted further, based upon recent Tank 42 to 51 experience, to 135" (≈ 11 wt%) to offset a solids concentration phenomena in the send tank during transfer of sludge slurries.

Technical Studies

This subsection contains:

- Slurry and Transfer Pumps
- Sludge Rheological Studies
- Corrosion Chemistry Studies
- Heat Balance Studies
- Thermocouple Elevation Study
- Purge H&V Skid System Studies
- Flammable Gas Studies
- Slurry Pump Forces on Tank Internal Structures Studies
- Ballast Requirements
- Nuclear Criticality Safety Assessment

Slurry and Transfer Pumps

The current sludge level reading for Tank 8 was measured on 3/28/98 at a level of 48.7 inches[2] and confirmed during re-wetting operations in October '98. This is a single point reading; therefore, it is not accurate for the five riser locations for the pumps. However, based upon tank history and photographs, the surface of the sludge should be relatively level for the entire tank. Because of sludge dehydration, the surface is expected to be hard relative to earlier sludge waste removal operations where the sludge was pliable. Due to this difference, the slurry and transfer pumps will not be submerged into the sludge layer for initial pump placement as performed in previous tank farm sludge removal operations.

Tank 8 risers 1, 3, 5, 6, and 8 were probed in May, 1988[16]. The documentation concluded that no obstructions were detected in any riser, however, the actual depth data recordings are not documented. The horizontal cooling coil design for Type I tanks [D116001] did not require clearance beneath the eight 24" risers [D116048]. An overlay of the riser locations with the horizontal cooling coils design indicates potential interferences with either the coil piping or the field located angle iron cooling coil supports. The overlay for riser 6, however, does not indicate any coil structure interference. The angle iron supports are 9" high. The maximum insertion depth of the four slurry pumps ranges from 8 ¾" for risers 1 and 8, to 12 ¾" for riser 3 as measured from the tank bottom to the bottom of the pump strainer screen (± 2") [P-DCF-F-00261]. Therefore, there is a potential for interference between the risers 1 and 8 slurry pumps and the horizontal cooling coil supports at the maximum pump insertion height. This is addressed under "Slurry Pumps" below. The maximum insertion depth for the Telescoping Transfer Pump (TTP) in riser 6 is approximately 2 ½" from the tank bottom to the pump strainer screen. Based upon the design data for riser 6, the TTP should not experience an interference with the horizontal cooling coils or supports.

<u>Slurry Pumps</u>

The clearance between the lower surface of the suction strainer and the top of the sludge surface should not exceed 16 inches for slurry pump effectiveness[17]. Because the slurry pump jets will not be impinging directly on the settled sludge, a loss of initial suspension effectiveness is expected. To minimize this loss, the slurry pumps should be placed at their minimum clearance level above the sludge surface for proper pump operation. The calculated bottom-of-pump heights (bottom of strainer) above the tank bottom at initial pump settings are 48" (Risers 1 and 8), and 51" (Risers 3 and 5) [P-PM-F-0164]. The pumps have been successfully deployed at these heights using careful monitoring of a rigging dynamometer. It is recognized that Risers 1 and 8 pumps are below the stated sludge surface level of 49", thus indicating that they are in the sunken sludge trough between the cooling coils. The reel tape probe reading to obtain the sludge height when it was dry (in Riser 4) was observed to be between the trough bottom and the peak (along the cooling coils) during visual inspection prior to Tank 8 re-wetting. The dynamometer option lends itself for use during subsequent lowering of the pumps during the waste removal process. The spacer can design for the slurry pumps provides for lowering by increments of 9", 10", 19" or 29" over a total span of 39". The pump vendor (Lawerance Pump) recommends not exceeding a *1000 lb. loading force on the pump suction screen. Therefore, the slurry pump* lowering evolution can be acceptably performed using a dynamometer unloading limit of 1000 lbs.

Minimum submergence levels for standard slurry pumps have been studied for operation without vortex formation in the suction and discharge nozzle roostertailing[18]. Slurry pumps should be submerged in a minimum of 16 inches of liquid above the bottom of the pump (pump screen). This is 10 inches above the centerline of the pump discharge nozzles [AB16788C-014]. Based upon Riser 3 and 5 initial pump heights, the minimum liquid level required is 67". However, based upon the Heat Balance Studies, the initial supernate level will be set at 76" to maintain enough cooling coil heat transfer surface area to keep the cooling water flowrate no higher than 200 gpm. During slurry transfer out of Tank 8 with the slurry pumps lowered to their full insertion height, minimum submergence will be between 25 and 28 inches of tank liquid level. The slurry pump speeds shall be ramped down to maintain stable operation when operating below their minimum submergence level.

A minimum 15 minute delay should be maintained between shut down and restart of the same pump. The slurry pumps should not be operated for any extended duration below 600 rpm based upon motor cooling (i.e., operate > 30% of the design operating speed). Based upon TNX experience, resonant frequencies for the slurry pumps occur between the following ranges. A structural evaluation[19] of the slurry pump vibration on the support structures concluded that vibration readings and a Structural Engineering evaluation should be conducted upon initial startup of the pumps. The slurry pumps shall not be operated in these ranges except to ramp up (or down) through the resonant range to reach an acceptable operating speed:

- 54 to 66 rpm (2 Hz),
- 270 to 330 rpm (10 Hz),
- 820 to 980 rpm (30 Hz), and
- 1620 to 1980 rpm (60 Hz).

The Effective Cleaning Radius (ECR) for the slurry pumps has been evaluated[6,7] and a 32' ECR for the Tank 8 configuration at a pump speed of 1780 rpm has been determined. Based upon a review[8] of the ECR's at lower pump speeds, a small area at the tank wall between Risers 1 and 8 (beneath the cooling coil valve house) will not be cleaned at 1600 rpm. However, given the resonance restrictions at 1780 rpm, operation of the slurry pumps at 1600 rpm will effectively clean all but an insignificant area[8]. Therefore, this speed is acceptable for use as the minimum requirement for demonstrating that the tank is effectively slurried prior to invoking the Seismic Q Program. From an operational perspective, a minimum of 1450 rpm should be maintained to avoid mounding between all of the pumps due to loss of ECR overlap at the tank wall.

An evaluation[20] was conducted at various slurry specific gravities (SpG) to determine the maximum run-away speed of the slurry pumps. The maximum speed is defined as the point where the torque demand of the pump exceeds the torque ability of the motor, resulting in motor stall and loss of rotation. The maximum speed of 2390 rpm at a SpG of 1.5 provided the maximum ECR (44') for a run-away pump condition within the SpG range expected in the slurry. There are current protection devices (fuse and a programmable breaker) set at values which will stop the pump at lower speeds than the maximum run-away speed. These are also addressed in the evaluation[20].

A methodology[21] was developed to estimate the ECR of a slurry pump, volume of sludge disturbed, and volume of trapped hydrogen gas released given settled sludge and slurry properties are known or can be estimated.

To avoid potential contamination of the bearing water inside the pump columns, the columns should be filled and pressurized with bearing water prior to any liquid additions into Tank 8.

Slurry pump dimensions and materials of construction for the major components (the materials of construction is not a exhaustive listing, but the primary components that contact the waste):

Manufacturer	=	Lawrence
Length	=	45'
Weight (empty + motor)	=	9,500 lbs
Weight (full + motor)	=	11,900 lbs
Motor	=	Reliance, Vertical, TEFC,150 HP, 1785 RPM, 460V, 3PH, 60Hz, S.F-1.15, Amps-165,
Rated discharge @ 1750 RPM	=	1200 gpm
Discharge Nozzle	=	Two, 1 ½" dia
Seized shaft	=	yes, after several months in Supernate
Well water in column	=	yes, > 6 months (during installation)
Shaft	=	Nitronic-50
Shaft coating	=	Tungsten carbide
Shaft size	=	2.500" dia, upper 140.94" middle 195.69" lower 214.62"
Column	=	SS 304L
Product lube bushing	=	SiC
Clearance (in)	=	0.003 – 0.006
Product lube ID geometry	=	spiral groove
Interior bearings	=	Graphalloy, GM-111.3
Clearance (in)	=	0.004 – 0.006
# column bearings	=	8
Column bearing spacing (ft)	=	5
Top mech. Seal Mfr.	=	Burgmann
Top mech. Seal faces	=	SiC on Carbon
Top mech. Disaster seal	=	carbon/316 SS
Top mech. Seal o-rings	=	EPDM/Grafoil
Top mech. Seal bellows	=	Hastelloy C
Bottom mech. Seal Mfr.	=	Burgmann
Bottom mech. Seal faces	=	SiC on SiC
Bottom mech. Disaster seal	=	carbon/316 SS
Bottom mech. Seal o-rings	=	Grafoil
Bottom mech. Seal bellows	=	Hastelloy C

Telescoping Transfer Pump

The fully assembled Telescoping Transfer Pump (TTP) design has an initial height setting of 62 ½", or approximately 12 ½" clearance between the sludge surface and the bottom of the strainer screen. The spacer can design for the TTP provides for lowering in increments of 30" over a total span of 60". This pump will be lowered after sludge suspension by the slurry pumps but prior to the first waste removal transfer from Tank 8 to Tank 40. A structural evaluation[22] has determined that a two-point lift of the TTP is acceptable, provided the pump motor is properly attached to the motor support stand. This evaluation also stated that the pump suction screen can withstand a point load of 800 lbs., resulting in an 1/8" permanent deflection. Therefore, the TTP lowering evolution can be acceptably performed using a dynamometer unloading limit of 800 lbs.

The minimum operating speed for the TTP is 1100 rpm [multi-speed pump curve in BPF 213350]. Based upon TNX testing[23], resonant frequencies for the transfer pump occur in the normal operating range. The transfer pump should not be operated in these ranges except to ramp up (or down) through the resonant range to reach an acceptable operating speed:

- 600 to 900 rpm (10 to 15 Hz, due to pump column and motor), and
- 1500 to 1800 rpm (25 to 30 Hz, due to pump column only).

A resonant frequency exists between 1200 and 1300 rpm. This range should be avoided if a balanced transfer pump operation (TTP, FPT-1, and HPT-7) can be obtained outside this range. However, it is acceptable to operate in this range based on the following:

- The vibration is associated with the motor and not the pump or pump column; therefore, if a failure occurs, it can be easily replaced on the tank top.
- The total run time of the TTP in Tank 8 should be less than one month, and
- The peak velocity reading[23] was less than 0.3 in/s which is below the warning alarm level specified by Industry[24].

TTP pump/motor specifications and materials of construction for the major components including some of the important dimensions are given below for ready reference.

Manufacturer	=	Barrett, Haentjens & Co., Hazelton, PA
Type	=	2 ½" AN Spec. "VSB" Pump.
Length	=	45'
Pump Weight (empty)	=	4,800 lbs
Pump Weight (with water)	=	61,31 lbs
Motor	=	Westinghouse, TEFC,75 HP, 3600 RPM, 460V, 3PH, 60Hz, S.F-1.15, Amps-81.9,
Discharge @ 1300-2250 RPM	=	80 –100 gpm

Discharge Nozzle	=	2 ½" dia
Seized shaft	=	yes, after several months in Supernate
Well water in column	=	yes, > 6 months (during installation)
Shaft	=	Nitronic-50
Shaft coating	=	Tungsten carbide
Shaft size	=	2.500" dia, upper 140.94" middle 195.69" lower 214.62"
Column	=	SS 304L
Casing	=	304
Impeller	=	304
Clearance, Impeller to Csing	=	0.030"
Shaft-Pump & Motor End	=	17.4PH
Bearing-Intermediate	=	Carbon
Packing Rings	=	Grafoil, (4)
Duplex Thurst bearings (FF)	=	Steel
Oil Seal	=	Buna N
Mech. Seal Mfr.	=	Burgmann

Sludge Rheological Studies

Sludge slurry rheological and hydraulic properties must be balanced with the pumping system capabilities to establish an operating target for effective slurry transfer. The fundamental slurry properties which affect the pumping system controls (e.g., pressure and flowrate) are the slurry yield stress, consistency, and SpG. The concentration of insoluble solids in the slurry can be related to these fundamental properties and can be measured during waste removal operations via slurry sampling. A correlation between the measured insoluble solids concentration and the slurry yield stress and consistency is provided below. The Transfer Pumps Performance Studies in Section 4 utilize the slurry yield stress and consistency to develop non-newtonian system performance curves for the Tank 8 to Tank 40 transfer path. Thus, a relationship between the measurable insoluble solids concentration in the slurry and the predicted transfer line pressures and flowrates is established.

SRS sludge has been shown to behave as a Bingham plastic[27]. Bingham plastics are characterized by the properties of yield stress and consistency. Yield stress is the measure of force required to start the sludge moving. Consistency is a measure of the additional force required to maintain flow[25]. Five sludge samples were obtained from Tank 8 and analyzed for rheological properties[26] in 1984 (prior to the total loss of supernate over the sludge). The results of the 1984 analysis suggest both a good correlation and an exponential relationship between weight percent insoluble solids (wt%IS) and either yield stress or consistency. This study also noted that the high aluminum sludges (typically H-Area HM waste) increase more rapidly in yield stress as a function of insoluble solids than the low aluminum sludges (such as F-Area Purex waste). Therefore, the low aluminum sludges, such as Tank 8, can be more concentrated in insoluble solids and still meet the hydraulic requirements for transfer than the high aluminum sludges. Also, the dissolved solids concentration did not appear to contribute to either yield stress or consistency.

The correlation between density and wt%IS is not reliable enough for process control purposes due to the significant standard deviation (+/- 3.6 wt%IS) coupled with the flatness of the change in density with changes in wt%IS. This is not unexpected, since density is a function of more than just insoluble solids (e.g., dissolved salts, inhibitor levels, etc.). It may be possible to monitor density to get a relative sense for the change in wt%IS in the slurry during slurry pump operation when the only significant variable changing would be the solids concentration. However, due to the flatness of the relationship between density and wt%IS, the ability to provide even useful relative data will be highly sensitive to localized slurry fluctuations in density (noise) and instrument inaccuracies.

Previous studies[27] have described sludge slurry behavior as a flocculent suspension. This has important implications on deposit velocities (sludge settling) in order to maintain a slurry suspension in both the tank and transfer lines. The results of these studies indicate that sludge slurries will be in compression (no free liquid, the floc particles are all touching each other with only interstitial liquid remaining) above 5 wt%IS. This results in low deposit velocities (< 0.2 in/hr in the target operating range). Between 1 and 5 wt%IS, floc settling becomes slightly less hindered (roughly 1 to 3 in/hr), and below 1 wt%IS the deposit velocity rises very rapidly to over 48 in/hr. A flocculent in compression can consolidate to a higher density, squeezing out interstitial liquid, due to gravity over time and the weight of material overhead. This suggests that the settled sludge at the bottom of the total sludge volume will be of higher density and yield stress, and thus will be more difficult to suspend. Two differences between Tank 8 sludge and the studied sludge must be considered. The study was based on: (1) washed sludge (expected to have a higher deposit velocity than unwashed sludge), and (2) HM-type waste (higher insoluble solids volume % to wt% ratio[26] and therefore a lower deposit velocity than Purex waste). Although these effects are not documented in a quantitative manner, the effects are opposing in nature. Therefore, it is reasonable to expect that the deposit velocities for Tank 8 sludge slurries will be similar to those reported above. In addition to implications on deposit velocities, a flocculent suspension can peptize into a colloidal solution under conditions of high or continuous shear stress[12]. A colloidal solution will not undergo liquid-solid separation by gravity settling. This would affect the downstream processing efficiency of the Extended Sludge Processing facility. The sludge solids in Tank 8F are mostly agglomerated particles of ~0.5 microns and won't size reduce under high shear from the slurry pumps. The shear from the slurry pumps would only break up the agglomerates. This action would make the mixture easier to pump. However after a short period of time, with stirring, the particles would reagglomerate (i.e. in Tank 8F or the Extended Sludge Processing Facility) unless the soluble salts were reduced to less than 1% (which could allow the sludge to peptize and remain suspended). Due to corrosion concerns and the large amount of water required to obtain this level of dissolved salts, this concentration is not approached in the tank farm. Since this level of salt solution is not approached, peptizing of the sludge during waste removal or sludge processing operations is not an issue.

The IAL pumping requirements study[10] shows that at high slurry yield stresses (> 30 dynes/cm^2) slurry flow is laminar at the minimum flowrate of 70 gpm. Based upon the above rheological data for Tank 8 sludge, yield stresses above 30 dynes/cm^2 correlates to slurries containing 15 wt%IS or greater. This is well within the low deposit velocity range for solids settling. Therefore, solids settling is not a significant concern in the line for Tank 8 sludge slurries exhibiting laminar flow properties (assuming the velocity is maintained at a minimum of 3 ft/sec). At slurry yield stresses below 20 dynes/cm^2 (12 wt%IS) the slurry flow is well into the turbulent region; therefore, line mixing via turbulence assists in maintaining the solids in suspension. The deposit velocity is not a significant concern in the transfer line for yield stresses above 20 dynes/cm^2. However, the upper operating target will be set at 12 wt%IS to take advantage of any additional line mixing that turbulent flow provides.

The Tank 8 insoluble solids data fit the following exponential functions[26]:

- $y = 2.87e^{(0.1598x)}$, where y is yield stress (in dynes/cm^2) and x is wt%IS, and
- $y = 2.08e^{(0.0872x)}$, where y is centipoise and x is wt%IS.

This generates the following values for Tank 8 sludge slurries:

Wt%IS	Dynes/cm^2	Cp
5	6	3
7	9	4
12	20	6
18	51	10

Corrosion Chemistry Studies

The concentration of inhibitors in Tank 8 during waste removal dilution operations has been evaluated. This evaluation assumed dilution water from the Dilution Inhibitor Water Facility (DIWF) would be utilized to add water to Tank 8 and provide pre and post transfer flush water. The DIWF inhibitor levels and metering controls were found acceptable based upon corrosion control requirements[28]. The slurry is expected to remain above 0.02 M nitrate and 0.01 M sodium hydroxide at all allowable tank levels. A maximum temperature limit of 75°C has been established for Tank 8 waste removal operations[29]. This limit was based on a required slurry sampling frequency of monthly[30]. This temperature limit also protects the the Abnormal Emissions Administrative Control Program[87] of 80°C. An additional study was performed to allow addition of well water instead of IW to Tank 8 for final dilution prior to transfer[9].

This study was conducted primarily to determine the volume of nitrite addition required in Tank 8 to maintain the corrosion chemistry requirements in Tank 40 during the transfer. Tank 40 will transition from a hydroxide inhibited tank to a nitrite inhibited tank, but additional nitrite is required to maintain the minimum ratio of nitrite to nitrate. Ordinarily, the nitrite would be added directly to Tank 40 prior to the transfer, but that option was schedule impactive, therefore the nitrite will be added to Tank 8 prior to transfer. The volume of nitrite added will maintain a 40°C. temperature limit for Tank 40 (controlled at 36°C via roundsheet limits). To raise the temperature limit by 4°C. would require twice the volume of nitrite (50kgal vs. 25kgal). This additional temperature margin was not deemed worth the large additional volume of inhibitor required.

Heat Balance Studies

Tank 8 waste removal suspension was modeled to determine the impact of operating the four slurry pumps on the temperature of the sludge slurry[31]. The results of this study show that 200 kgal of sludge slurry will rise at an average rate of 0.33 C°/hr with no cooling coils operating, and at 0.20 C°/hr with 25 vertical coils in operation. The timeframe of the model was limited to 100 hours. Neither cooling coil case achieved an equilibrium temperature within 100 hours. The modeling also determined that a variance in the primary purge flowrate between 200 cfm and 600 cfm had no significant effect on the rate of temperature rise. This model predicts conservative results when compared to empirical data available from Tank 1[32] and Tank 16[14] studies.

The Tank 16 waste removal demonstration evaluated the effect of cooling coil operation on slurry temperature with three slurry pumps in operation. The demonstration determined that 93,000 gal (27") of sludge slurry reached an equilibrium temperature of 32°C. with 360,000 Btu/hr cooling coil duty, and 51°C. without cooling coils (after approximately 72 hours of operation). An empirical heat transfer rate to the environment of 20,700 Btu/hr-°C. was documented[14]. Although Tank 16 (a Type II tank) is larger than Tank 8 (85' dia. vs. 75'), the concrete support walls/floor and annular space are similar, and the thermal loads are comparable (pumps, radiolytic, and cooling coils). This is similar to the most demanding volume of Tank 8 slurry to cool while the slurry pumps are in operation (73,000 gal during initial suspension where the 27" of supernate above the settled sludge is absorbing all of the pump heat).

The Tank 1 (a Type I tank) supernate cooling test developed a heat transfer coefficient correlation for the cooling coils relative to cooling water flowrate through the coils. This correlation was used to determine the minimum cooling flowrate requirements for Tank 8 waste removal[4]. The Tank 1 heat load (due only to decay heat) was similar to the slurry pump and decay heat load expected during waste removal in Tank 8 (1,200,000 Btu/hr vs. 1,300,000 Btu/hr, respectively).

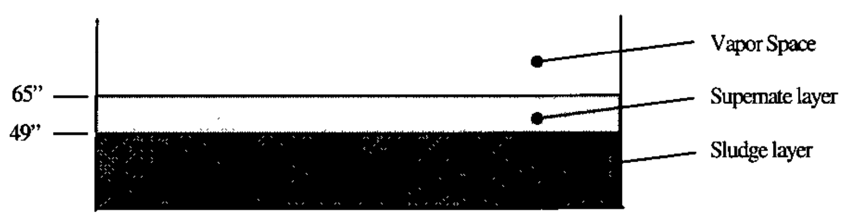
The heat load gains (radiolytic and slurry pumps) for the Tank 1 and Tank 16 tests were comparable to that modeled[31] for Tank 8. Heat losses to the environment (everything except the cooling coils) were approximately 1,000,000 Btu/hr[32] @ 45°C for Tank 1 and 750,000 Btu/hr[14] for Tank 16 @ 51°C. Tank 8 modeled the heat losses to the environment as 110,000 Btu/hr[31] @ 65°C. Therefore, use of the Tank 8 modeled heat losses to the environment should provide a conservative basis for the cooling duty required of the cooling coils. The calculated[4] cooling duty requires 170 gpm of cooling water to maintain the worst case Tank 8 sludge suspension at a 70°C equilibrium.

Thermocouple Elevation Study

Three phases of material shall be monitored for temperature during all aspects of waste removal: (1) sludge, (2) supernate/slurry, and (3) vapor space. The elevation of these phases will change as sludge is suspended and batch transfers are made to Tank 40. Therefore, the elevation of the thermocouples shall account for these variations.

Tank 8 design supports a redundant pair of thermocouples at four elevations within the tank thermowell in Riser 4 [M-M6-F-3186]. The initial condition of the three phases establishes three of the four thermocouple elevations.

Tank 8 Initial Sludge & Supernate Levels



The sludge thermocouple (TE-6982A) should be set at the lowest position possible (3" from tank bottom) to provide monitoring of the sludge phase throughout the sludge suspension operation. The vapor space thermocouple (TE-6982D) should be set above the Structural Integrity Fill Limit (233"from tank bottom) to assure that it will always remain in the vapor space. The third thermocouple (TE-6982C) should be set to monitor the initial supernate layer (between 49" and 65" from tank bottom).

During sludge suspension, the sludge level will decrease and the supernate/slurry level will increase. Therefore, the thermocouple elevations given above for the initial conditions will also support monitoring all three phases during sludge suspension operations.

However, during the first batch transfer, the slurry level will drop below TE-6982C and expose it to the vapor space. Therefore, the fourth thermocouple (TE-6982B) should be set to monitor the supernate/slurry phase at low tank levels to support the second sludge suspension effort and potential future heel removal operations. The supernate/slurry level after the 1st transfer is expected to be 34". The minimum level for slurry pump operation is approximately 25"[89]. Therefore, to monitor supernate/slurry temperature during mixing and transfer operations for the 2nd and subsequent batches, the thermocouple should be set below 25".

Based upon the above information, the following thermocouple elevation settings (from tank bottom) are required to adequately monitor all three material phases (sludge, supernate/slurry, and vapor space) during waste removal operations:

TE-6982A (sludge)	= 3"
TE-6982B (sludge & supernate/slurry)	= 20"
TE-6982C (supernate/slurry & vapor space)	= 60"
TE-6982D (vapor space)	= 270"

A calculation[33] has been performed to determine the appropriate thermocouple lengths from a known reference point for verifiable installation. As required for Tank 8 by PCO 2.6.1, an engineering study[34] has been performed to designate the appropriate thermocouples for the sludge and supernate phases. This study will be reviewed to ensure the proper thermocouples are designated to read the appropriate phases upon each lowering of the slurry pumps and transfer of waste to Tank 40.

The Tank 8 thermowell was discovered to be bent at approximately 151" above tank bottom [2000-NCR-22-0042]. The affect of the bend on the installed thermocouple heights was calculated[33]. It was determined that a sharp bend, with an angle of 8.7°, raised the lower three thermocouple elevations to the following maximum height:

TE-6982A (sludge)	= 4.68"
TE-6982B (sludge & supernate/slurry)	= 21.5"
TE-6982C (supernate/slurry & vapor space)	= 61"
TE-6982D (vapor space)	= 270"

Purge H&V Skid System Studies

A study was conducted to evaluate the Tank 8 purge exhaust H&V skid performance[35]. The system operating point for the H&V skid is approximately 900 cfm, assuming clean filters and fully open dampers. This operating point drops to about 500 cfm for HEPA filters loaded to a 3" pressure drop. This capability is significantly higher (≈ 100%) than the existing exhaust purge system; therefore, it provides extra capacity for handling the higher water vapor loads expected during waste removal. The study suggests a target operating flowrate of 400 cfm for sludge suspension and transfer operations. A higher flowrate may be required during spray washing and annulus cleaning to maintain primary tank vacuum. The limiting component was identified as the demister throughput. The maximum demister design velocity is 8 ft/s (≅ 800 cfm). The demister has a service factor rating of 1.1. However, flowrates above 800 cfm will tend to carry moisture droplets through the demister, causing a higher heat load on the reheater and water vapor load on the HEPAs. Considering the high moisture loading observed during Tank 16[14] and Tank 42[36] waste removal operations, the primary exhaust flowrate should not exceed the maximum demister design velocity. This study also concluded that the purge exhaust H&V skid maintains adequate:

- flow for radiolytic hydrogen dilution and removal,
- primary vapor space vacuum,
- annulus-to-primary pressure differential, and
- water vapor removal and reheat to keep the HEPAs from blinding.

The blower exhaust gas relative humidity is below 50% in the operating range identified and no appreciable temperature loss was noted between the reheater exhaust and the HEPA exhaust for purge gas temperatures approximately 35°F above the ambient. This provides operating margin to avoid wall condensation between the reheater and the HEPA for cold weather conditions where the delta between the purge gas temperature and ambient will be greater. While not required, this study recommended insulation be added to the exhaust piping between the reheater and the HEPA filters to assure no wall condensation occurs in extreme cold weather. The H&V skid is equipped with condensate drains at the reheater and the HEPA housing.

The Trapped Gas Safety Evaluation[42] identified a minimum purge exhaust flow requirement of 300 scfm. An evaluation[37] of the instrument loop tolerances (including M&TE and temperature effects of the reheater) was conducted to establish the alarm setpoint LCO limit of 0.31 inwc (491 cfm). Based on flow verification results[38] using an independent flow measurement by the Air Balance Group, an additional 7% margin was added to establish the alarm setpoint of 0.45 inwc (600 cfm) to protect the LCO limit from calibration range concerns. Additionally, the TSR Administrative Control program[15] identified a tank low vacuum requirement of 0.3 inwc based upon the uncertainty calculation[39] for primary purge vacuum gage instrument loops in ITP/ESP which are equivalent in configuration and gage selection to Tank 8. Both the primary inlet vacuum gage (PDI-2001) and the primary exhaust vacuum gage (PDI-8034) were credited for Tank 8. Additional margin was added to establish the roundsheet lower range limit of 0.5 inwc to protect the LCO limit from out-of-calibration concerns.

Flammable Gas Studies

The Trapped Gas Justification for Continued Operations[40] (JCO) requires a Time-to-LFL (TLFL) evaluation prior to disturbing the sludge with slurry pumps. This evaluation has been completed[41] and establishes a slurry pump run program that will enable the tank to be agitated without exceeding a flammable gas content of 25% of the composite lower flammability limit (CLFL) in the tank vapor space. Credited slurry pump operational controls have been identified in the Safety Evaluation for Tank 8 Hydrogen Depletion[42]. These controls have been incorporated into the Operational Sequence documented earlier in this Section. Additional non-credited controls identified in the Safety Evaluation include: 1.) hardwired interlocks to shut down the slurry pumps (independent of the VFD) upon receipt of a high CLFL alarm in the control room, and 2.) independent verification of pump height, liquid level, and hydrogen gas release volumes via procedure 241-F-4241.

Slurry Pump Forces on Tank Internal Structures Studies

Equipment and instrumentation will extend into the primary tank space during waste removal operations. The proximity of the equipment and instrumentation to the slurry pump discharge and the potential effects of the slurry jet forces are described below. There are conduit and piping which extend below the riser plugs into the riser, but not into the primary tank vapor space (e.g., the HLLCP conduit in Riser 4). These are not addressed because they are significantly above the maximum fill level (HLLCP) for the tank.

Tank Walls

The last annual Tank 8 primary tank wall inspection[43] found the tank intact without any observed cracks or flaws. The erosion corrosion effects of slurry pump operations were studied[44]. The results of the study indicate that SRS waste tanks will not experience erosion corrosion to any significant degree during slurry pump operations. Erosion corrosion in carbon steel structures at reported pump discharge velocities is dominated by electrochemical (corrosion) processes. Interruption of those processes, as by the addition of corrosion inhibitors, sharply reduces the rate of metal loss from erosion corrosion. The study indicates that a time-averaged erosion corrosion rate of 2.4 mils per year (mpy) was observed for similar slurry characteristics and tank wall velocity (8 ft/sec), but at a much higher temperature (102°C) than allowed during waste removal (maximum of 75°C). Therefore, due to the lower temperature and the intermittent jet impingement on the tank wall (due to slurry pump rotation), the actual erosion corrosion rate is expected to be << 2.4 mpy. Additionally, the jet impingement forces were studied and found to be negligible compared to the normal hydrostatic pressures exerted on the tank wall from the stored waste[45]. Annual inspection for the Tank 8 visible portions of the primary wall and annulus is current and without known leak sites[44].

Cooling Coils

The effects of the slurry pump jet impact force upon the cooling coil supports was studied for Type I and II tanks[46]. The cooling coils are hung from the tank top using ¾" rod hangers and held in position on the bottom by ½" guide rods [D116048]. The analysis calculated a maximum force of 350 lbs for a coil placed directly at the pump discharge. This force translates to a yield stress of 108,000 psi on the bottom supports of the cooling coils which is more than 4 times the engineered yield stress of 24,000 psi. The calculated jet force reduced dramatically to less than 50 lbs within the first foot from the discharge nozzle. The minimum spacing between vertical cooling coils is approximately 3' [D116048]. Therefore only the coils directly adjacent to the slurry pumps are of potential concern. The analysis[46] utilized standard jet theory to calculate the jet forces. The theory for jet behavior is valid for regions of established flow[46] (i.e., > 5 – 7 nozzle diameters or approximately 8 inches from nozzle). At distances closer than 8 inches, the theory provides an approximation. TNX testing[46] demonstrated that jet forces are roughly one half that predicted by theory for distances less than 5 – 7 nozzle diameters. This finding is supported by actual waste removal experience on

Tank 16. Jet forces are a function of nozzle diameter, slurry velocity, and slurry density. Waste removal efforts on Tank 16 utilized the same slurry pump design as Tank 8. The density of the bulk slurry in Tank 16 was 1.3, on average[14], which is equivalent to that predicted for Tank 8 slurry. Therefore, the jet forces experienced during Tank 16 waste removal should be similar to the forces expected during Tank 8 pump operation. A visual inspection of the Tank 16 coils after extensive use of the slurry pumps concluded that no coil damage or deformation occurred as a result of slurry pump operation. In actual practice, the Tank 8 coil supports should not experience any appreciable forces from the slurry pump discharge until nearly all of the settled sludge is suspended, leaving the bottom loop of the coils free to swing against the coil supports.

Based upon this information, all Tank 8 cooling coils should remain in operation during waste removal. Due to the potential that the bottom supports for the vertical coils adjacent to the slurry pumps could exceed their allowable stresses, the following measures will be taken:

- The coils will be monitored weekly via video surveillance for excessive movement during slurry pump operation.
    - If a coil is exhibiting signs of cooling coil support failure then valve out the cooling coil.
- The chromate cooling water system surge tank will be monitored each shift for level decreases.
    - If a Tank 8 cooling coil leak is suspected, then isolate the coils directly adjacent to the slurry pumps first to see if the leak is abated [D116048].
        - Adjacent coils for Riser #1 pump are: 7, 8, 25 and 26
        - Adjacent coils for Riser #3 pump are: 14, 15, 32 and 33
        - Adjacent coils for Riser #5 pump are: 12, 13, 30 and 31
        - Adjacent coils for Riser #8 pump are: 3, 4, 21 and 22

Coil # 34 has been isolated due to leakage [M-M6-F-3164]. The horizontal cooling coils are also available and will not be affected by the slurry pump jet forces because they are below the full insertion height of the slurry pump discharge nozzles. An evaluation of cooling coil duty was conducted to determine the minimum cooling water flowrate required to maintain steady state slurry pump operation[4].

Fixed Length Jet

To allow for installation of the TTP in Riser 6, the primary tank fixed length jet was relocated to the Tank 8 center riser for storage. The jet will not serve any operational function for waste removal. The effects of the slurry pump jet impact force upon the fixed length jet was studied for this configuration[47,48]. The purpose of this study was to ensure the jet itself would not fail and fall into the tank, and that the lateral movement of the jet would not affect cooling coil operation. The results of this study concluded that the stresses on the jet are less than the allowable stress levels; therefore, failure of the jet is not expected. However, a maximum lateral deflection of 42" at the bottom of the jet is possible due to slurry pump forces. The vertical cooling coils are spaced approximately 3' apart [D116048], and the jet will be stored along the centerline of operating cooling coil #9 (and auxiliary coil #27). The jet installation design for the center riser[47] oriented the jet in a manner that it will not impact the vertical legs of the adjacent cooling coils (operation coil #9 and auxiliary coil #27). However, it is possible at near maximum deflection, the jet could contact operating coil #8 or auxiliary coil # 28. This is acceptable since the contact force between a deflected jet and coils should be slow and minor. Therefore no damage to the coil is expected. This expectation will be monitored via weekly video surveillance of the tank internals.

Thermowell

The Tank 8 thermowell is located in Riser 4. The effects of the slurry pump jet impact force upon the thermowell was studied for this configuration[49,50]. The results of this analysis concluded that the stresses on the thermowell are expected to be above the allowable stress levels. The service life was estimated at > 40,000 Riser #5 slurry pump runtime hours (56 months of continuous operation) based upon a 1600 rpm pump speed. This analysis is conservative because the thermowell will be fixed at the lower end by settled sludge throughout most of the suspension operations and therefore will not experience the cyclic deflection causing the fatigue until most of the sludge has been suspended. Therefore, because the cyclic fatigue life is much greater than the expected operation of the slurry pumps for sludge suspension, it is acceptable to conduct waste removal operations with the existing thermowell. The thermowell will be monitored weekly by video surveillance to identify signs of thermowell failure.

A maximum lateral deflection of 4' at the bottom of the Tank 8 thermowell is possible due to slurry pump forces[50]. Riser 4 is located between operating cooling coils #14 & #15 (auxiliary coils #32 & #33) and the thermowell extends to 2" from the tank bottom [D182318]. This configuration suggests that vertical coils #15 & #33 and both horizontal coils (#18 & #36) could be impacted on thermowell deflection. The contact force between the deflected thermowell and the coils should be slow and minor. Therefore no damage to these coils is expected. This expectation will be monitored via weekly video surveillance of the tank internals.

The Tank 8 thermowell assembly was discovered bent approximately 151" above tank bottom[33]. The direction of the 8.7° bend is toward the tank wall (West), perpendicular to the Riser 5 pump jet force, based upon video footage and [D186552]. The Riser 5 pump provides the dominate deflection source for the thermowell assembly[50]. Due to the perpendicular orientation of the bend to the pump jet force, and the small size of the bend, the results of the deflection analysis[50] and the conclusions on deflection interferences stated above are considered still valid.

Reel Tape

The Tank 8 reel tape is located in Riser 4. This reel tape has both liquid level and sludge interface sounding features. Typically, the reel tape will be placed in the parked position during slurry pump operation for suspension and transfer. However, at specific points in time, it will be necessary to seek the actual liquid level in Tank 8. The reel tape is in close proximity to the Riser 4 thermowell (approximately 1' away [D186552]). It is possible, based upon the Riser plug orientation [W742557], that the thermowell could deflect toward the reel tape. The following should be performed to avoid possible entanglement of the reel tape with the thermowell or the cooling coils:

- Monitor the thermowell deflection weekly using video surveillance to determine if the reel tape exhibits signs of entanglement,
- To obtain liquid level readings, all slurry pumps should be either slowed to minimum speed or shut down just prior to performing the readings (based upon ESP experience), and
- To obtain sludge interface sounding readings, all slurry pumps should be shut down prior to inserting the reel tape probe into the slurry to seek for the sludge interface. If possible, video inspection support of the sounding evolution should be conducted initially to determine the standard amount of time required for the tank liquid to become stationary enough to perform soundings without the reel tape bob hitting interferences (e.g., the thermowell assembly).

Hydrogen Monitoring Dip Tubes

Dip tubes installed for hydrogen monitoring are located in the Center Riser. These dip tubes extend a maximum of 19" into the top of the primary tank vapor space [P-PA-F-0222]. These dip tubes are above the Structural Integrity Fill Limit for Tank 8 waste removal. Therefore will not experience slurry pump discharge forces.

Chemical Addition Downcomer

The chemical addition downcomer was installed in Riser 7 to support the re-wet evolution for Tank 8. This downcomer will be used to add concentrated caustic and/or nitrite for corrosion control purposes, if required. The height at the bottom face of the downcomer nozzle is 254", as compiled below. This is above the TSR limit for Flammability Controls of 150". Therefore, the chemical addition downcomer will not experience slurry pump discharge forces.

The derived chemical addition downcomer height, starting with the known elevation of Riser 7:

276.99'	Top of Riser 7 elevation	[W742565]
+ 0.25'	Top of 8" Riser pipe sleeve	[D186553]
+ 0.02'	Top of ¼" downcomer plug plate	[FTF-TMC-98-008]
- 16.0'	Length of the downcomer	[FTF-TMC-98-008]
261.26'	Bottom of downcomer nozzle face elevation	

276.99'	Top of Riser 7 elevation	[W742565]
- 10.56'	Riser height	[W149522]
- 1.83'	Tank concrete thickness	[W149522]
- 0.04'	½" plate primary tank	[W145379]
- 24.5'	Inside dimension of primary tank	[W145379]
240.06'	Bottom of Tank elevation	

Therefore, the height of the downcomer nozzle face is 261.26' – 240.06' = 21.2' (or approximately 254").

Dip Sampler

The Tank 8 100ml dip samples will be taken from available blank riser plugs. These dip samples will be taken at various slurry depths (see Sampling Requirements in this Section). Therefore, all slurry pumps should be shut down prior to slurry dip sampling.

Video Surveillance

The Tank 8 video surveillance will be taken from available blank riser plugs. These video surveillances will be taken in the primary tank vapor space. Maintaining the in tank video equipment above the liquid surface during camera operation is self-monitoring. However, when not in use, the in tank video equipment should be stored above the Flammability Fill Limit to ensure tank dilution operations will not put the equipment in jeopardy of being damaged.

Slurry Pump and Steel Platform Vibration Studies

The effects of slurry pump induced vibration on Type I and Type II tank structures was evaluated[51]. The study concludes that the vibration in the platform due to slurry pump operation will not cause fatigue crack initiation or propagation of existing cracks in the waste removal tank or surrounding tanks. The pump platform foundations are located on areas with different compaction characteristics. Therefore, it is possible for the platforms to settle at different rates which could cause the pump columns to skew out of alignment with the tank risers. A baseline settlement reading should be conducted within 30 days prior to initial pump operation. The platform settlement marker locations have been identified and labeled in the field [P-PE-F-2618]. Pump vibration should be measured at each operating speed the first time the pump is ramped to its maximum speed at the nominal 50" pump height (see Pump Run Table - Table A). A Structural Engineering inspection of the pump platform should be conducted after each pump has reached its maximum operating speed at the nominal 50" pump height. There are no restrictions on multiple pump operation during the inspections.

Ballast Requirements

The effects of ground water pressure on Type I tanks were analyzed[52]. It was determined that no damage would occur unless the water table rises to 36 ft. above the bottom of the concrete base slab. The highest water table level recorded for all eight wells around Tanks 1 through 8 between 1973 and 1980 was approximately 1 foot above the bottom of the Tank 1 concrete base slab[52]. Recent measurements (1986 to 1998) from the well adjacent to Tank 8 (FTF-5) have detected the highest level at more than 8 ft below the bottom of the base slab[53]. Therefore, no special precautions or restrictions are required due to hydraulic forces from ground water.

Nuclear Criticality Safety Assessment

The Nuclear Criticality Safety (NCS) Assessment identified no required nuclear criticality safety criteria for the Tank 8 waste removal activities[54]. Large margins between the required and the actual process inventory neutron poison to fissile material ratios are the rationale behind the absence of NCS criteria.

The areal density of equivalent ^{235}U for Tank 8 is approximately 30 grams per square foot (g/ft^2). This is an order of magnitude below the ANSI/ANS 8.1 single parameter limit of 371 g/ft^2. The sludge contains poisons which also help prevent criticality potential. The most significant poison available in the sludge is iron. The overall iron to fissile equivalent uranium weight ratio for the bulk sludge was determined to be 288:1, which is approximately 4 times the required limit of 76:1. Additionally, the overall equivalent enrichment of the Tank 8 waste was determined to be 0.64% ^{235}U, which is less than natural uranium. The waste removal process does not introduce a mechanism to selectively concentrate fissionable material or remove poisons. Therefore, the Tank 8 sludge will remain subcritical because the mixed slurry cannot achieve a critical state in any formation at this low enrichment.

Section

3

Slurry Transfer Operation

This section is organized to introduce the important facets of slurry transfer, identify the transfer path, provide a general sequence of events for the operation, detail the transfer sampling attributes, and single out special monitoring and response requirements for the transfer process. Supporting technical information is also provided at the end of this section.

INTRODUCTION

Tank 8 sludge will be transferred to Tank 40 and comprise part of Sludge Batch 2[55]. This transfer operation will be conducted between F Tank Farm, H Tank Farm, and ESP. The IAL, two pump tanks, three diversion boxes, and three transfer pumps are required to perform the intended transfer. The three transfer pumps must operate at steady state with respect to flowrate. Transfer line and pump tank flushing is required at the completion of sludge slurry transfers to remove the sludge solids from these areas.

TRANSFER PATH

The Tank 8 to Tank 40 transfer route is depicted on Diagrams 2 and 3 below. These diagrams highlight the intended transfer lines, the credible transfer lines, the line leak detection location, the first and second isolation valves, and the inadvertent transfer destinations. The vent and drain lines for this transfer route have been identified in the F-Tank farm siphon evaluation report[56].

Transfer Route Notes and Assumptions

- FDB2 will have two continuous flow paths. One from Tank 8 to FPT-1 and another from FPT-1 to IAL HiPT. The installed jumpers are not independent and are separated by single valves (WTS-V-92 and WTS-V-94). Failure or mispositioning of these valves could result in low slurry flow in the IAL.
- The flush line 16052 for LDB-17, which is in the credible transfer path, does not have secondary containment. Therefore, valve V557 shall be leak checked and placed under administrative control. To reduce the possibility of a pressurized leak, valve V546 shall remain in the open position during the waste transfer to drain any leakage through valve V557 back into LDB-17.
- F-Tank Farm TSR Section 1.7 exempts FDB-1 from leak detection requirements by stating that single valve isolation alone (with blank nozzle at N30) is sufficient to isolate FDB-1 from FPT-1.
- HDB-7 valve V59 is known to leak. Therefore, the credible path extends into HDB-2 for both first and second isolation points.

Diagram 2

Credible Transfer Paths From Tank 8 to HPT-7

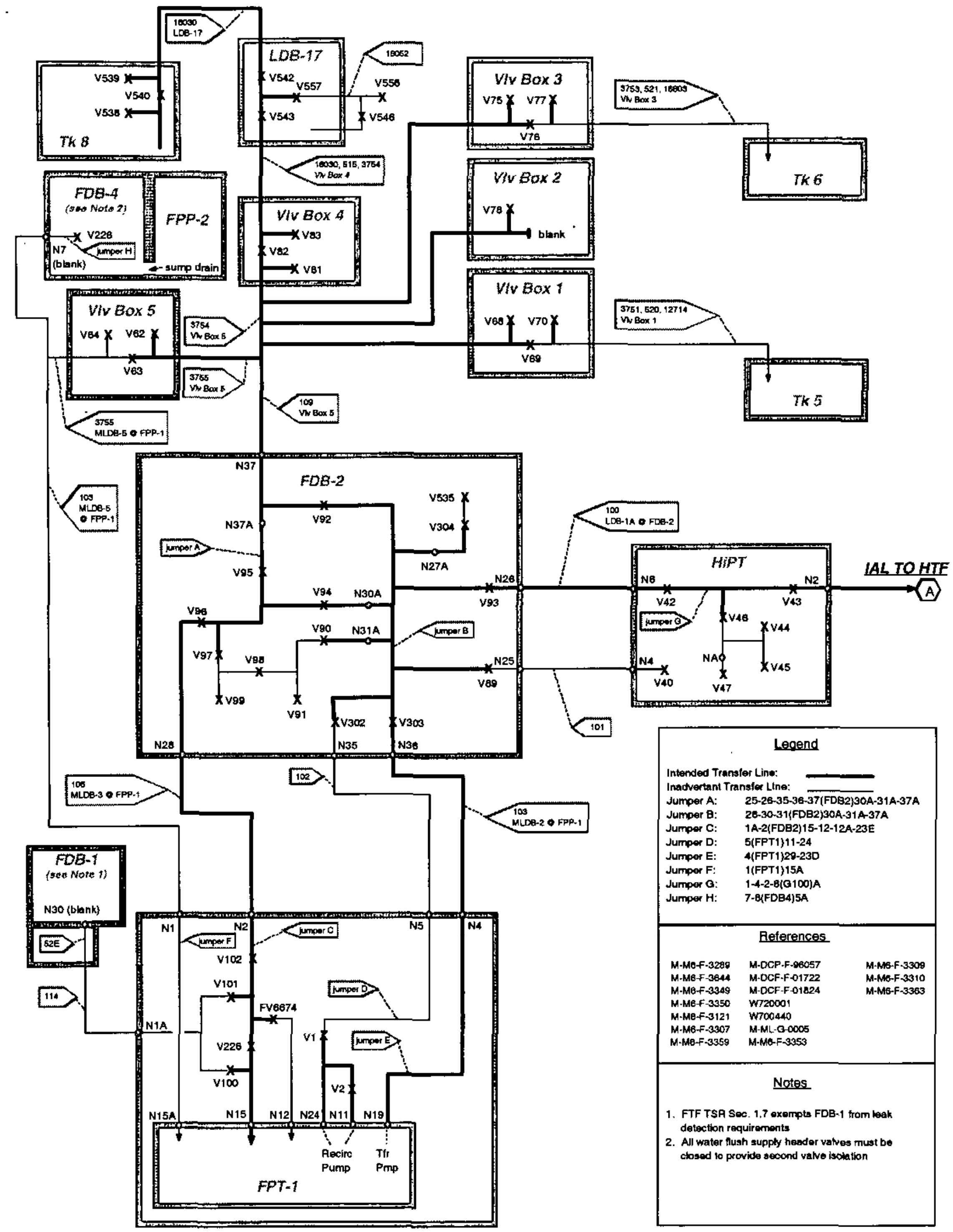
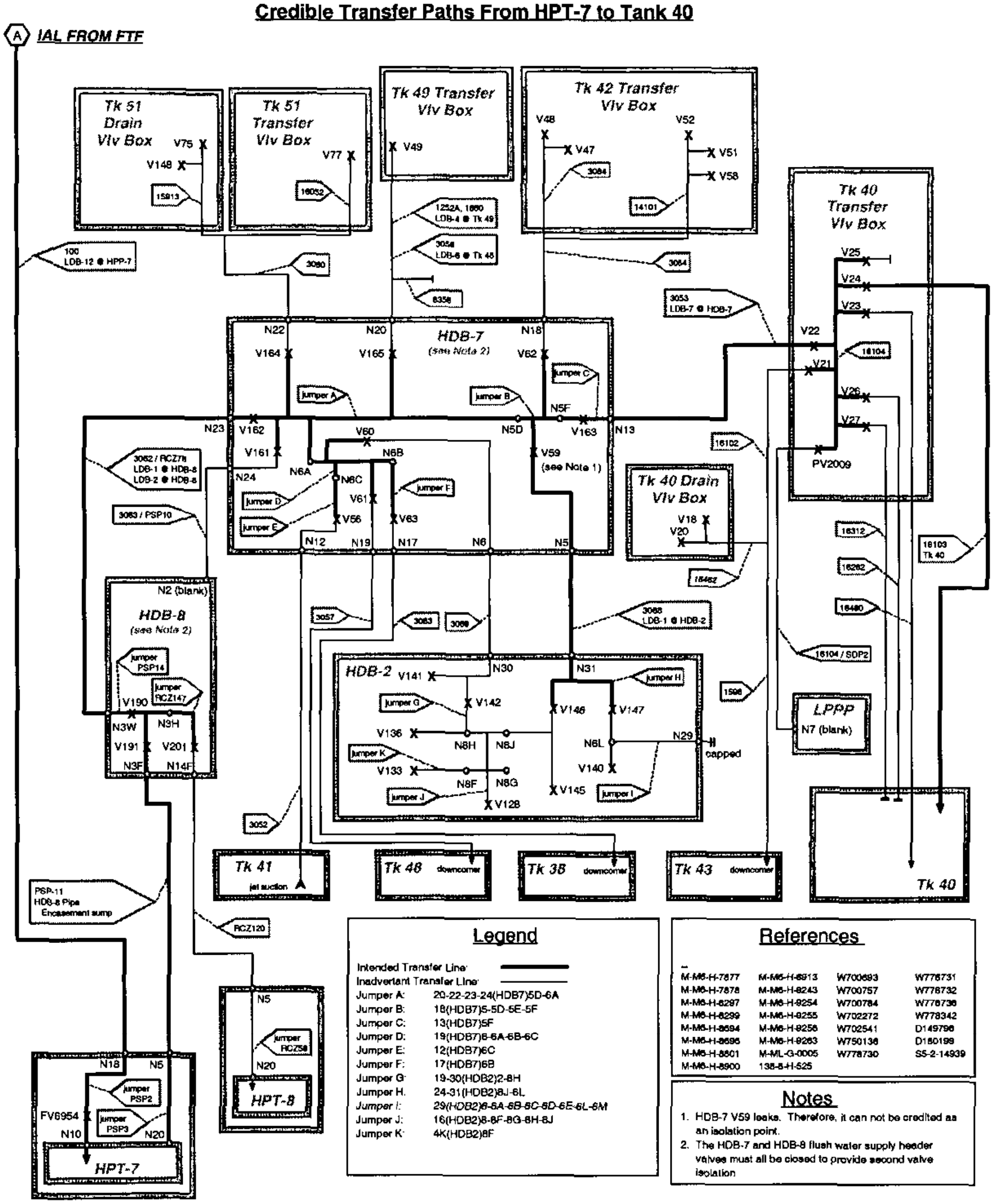


Diagram 3

Credible Transfer Paths From HPT-7 to Tank 40



Legend

Intended Transfer Line: (heavy line)
Inadvertant Transfer Line: (light line)

Jumper A:	20-22-23-24(HDB7)5D-6A
Jumper B:	18(HDB7)5-5D-5E-5F
Jumper C:	13(HDB7)5F
Jumper D:	19(HDB7)6-6A-6B-6C
Jumper E:	12(HDB7)6C
Jumper F:	17(HDB7)6B
Jumper G:	19-30(HDB2)2-8H
Jumper H:	24-31(HDB2)8J-6L
Jumper I:	*29(HDB2)6-6A-6B-6C-6D-6E-6L-6M*
Jumper J:	16(HDB2)8-8F-8G-8H-8J
Jumper K:	4K(HDB2)8F

References

M-M6-H-7877	M-M6-H-6913	W700693	W776731
M-M6-H-7878	M-M6-H-8243	W700757	W776732
M-M6-H-8297	M-M6-H-8254	W700784	W776736
M-M6-H-8299	M-M6-H-8255	W702272	W778342
M-M6-H-8594	M-M6-H-8256	W702541	D149796
M-M6-H-8596	M-M6-H-8263	W750136	D160199
M-M6-H-8801	M-ML-G-0005	W778730	S5-2-14939
M-M6-H-8900	138-8-H-525		

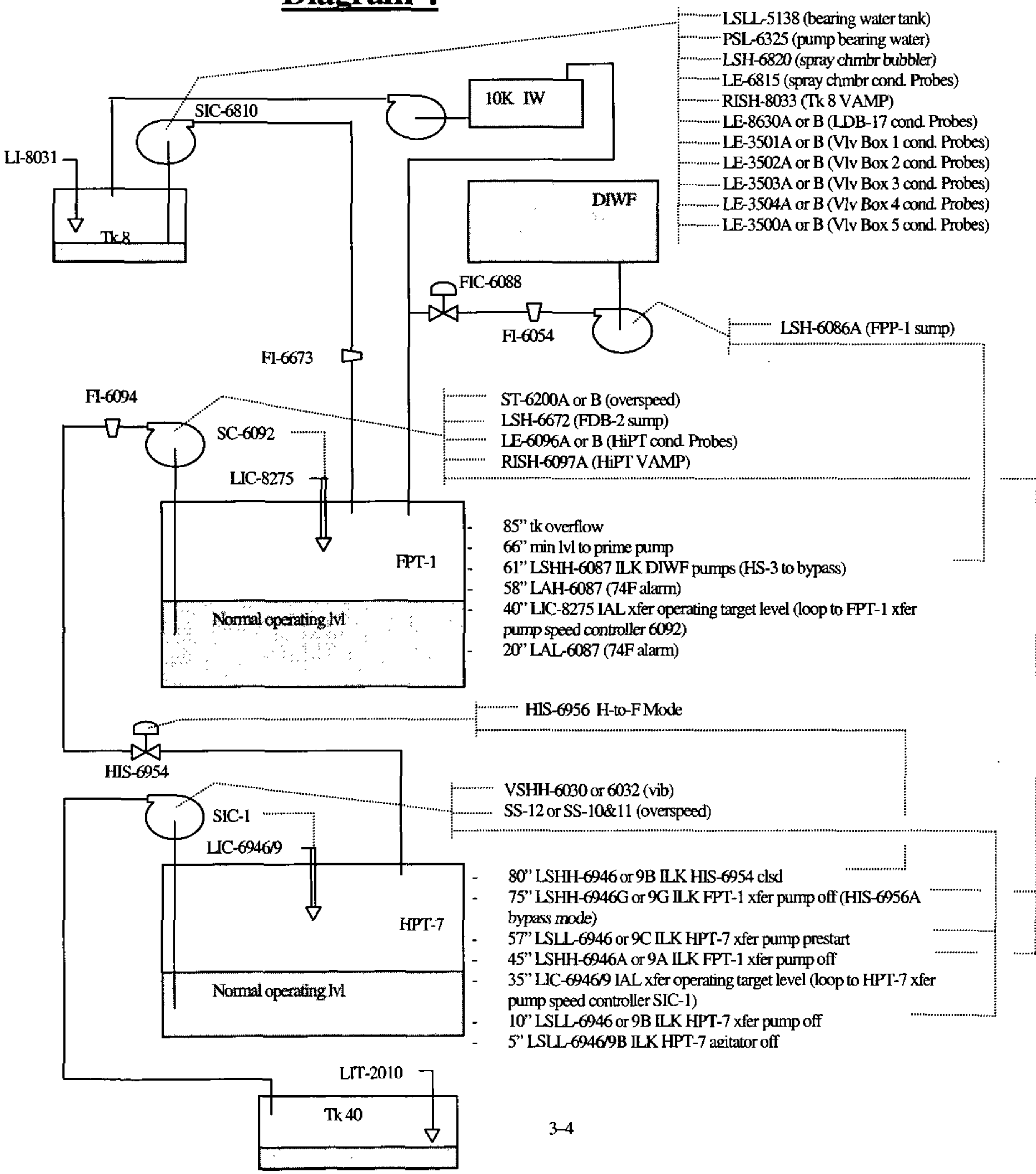
Notes

1. HDB-7 V59 leaks. Therefore, it can not be credited as an isolation point.
2. The HDB-7 and HDB-8 flush water supply header valves must all be closed to provide second valve isolation

OPERATIONAL SEQUENCE

The general process controls for the transfer are shown in Diagram 4 below. The steps to perform a sludge slurry transfer follow Diagram 4. Steps 1 through 10 cover the transfer path verification, steps 11 through 13 cover the slurry transfer, and steps 14 through 18 cover transfer line flushing. Diagram 4 provides a simplified depiction of the essential transfer equipment.

Diagram 4



Transfer Sequence Steps

1.0 Have CSTE perform the evaluation for low gamma leak detection requirements based upon slurry sample analysis

  1.1 Establish Area Radiation Monitors (ARMs) per the requirements of the low gamma evaluation.

2.0 Ensure the appropriate shielding and/or postings are implemented for the Tank 8 Riser 6, the above grade transfer line 16030, and the LDB-17 valve box.

3.0 Verify that the storm water monitoring system for the transfer path from Tank 8 to Tank 40 is manually diverted or has functional beta monitoring capability.

4.0 Perform leak check of LDB-17 flush water valve V557 prior to start of the transfer.

5.0 Operate a minimum of 3 slurry pumps at the maximum allowable speed for a minimum of 22 out of 24 hours prior to a Tank 8 to Tank 40 transfer (per Section 2). Monitor Tank 8 slurry operations per Table E.

6.0 Begin monitoring the transfer evolution per Table F.

7.0 Prime the FPT-1 IAL transfer pump using DIWF inhibited water directly to FPT-1. An FPT-1 level of approximately 66" is required.

8.0 Start the FPT-1 IAL transfer pump to prime the HPT-7 transfer pump. An HPT-7 level of approximately 57" is required.

  8.1 Reduce the FPT-1 level to 40" by adjusting the FPT-1 IAL transfer pump speed.

  8.2 Start the HPT-7 agitator while filling HPT-7.

9.0 Start the HPT-7 transfer pump.

  9.1 Reduce the HPT-7 level to 35" by adjusting the HPT-7 transfer pump speed.

10.0 Verify that the transfer path between Tank 8 and Tank 40 is established.

  10.1 Tank 40 level is rising,

  10.2 The inadvertent transfer path tank levels are stable, and

  10.3 The credible transfer path conductivity probes are not in alarm.

11.0 Start the FPT-1 pulse-tube agitator.

12.0 Start the Tank 8 TTP to initiate the sludge slurry transfer.

  12.1 Adjust the inhibited water addition to FPT-1.

13.0 Maintain IAL steady-state slurry flow at a target of 100 gpm or greater (IAL transfer minimum of 70 gpm).

  13.1 It is recommended that the HPT-7 transfer pump speed be controlled by the automatic level controller, and both the FPT-1 IAL transfer pump and the Tank 8 TTP speeds be adjusted manually to maintain a balanced maximum flow within the resonant operating zones of the Tank 8 TTP.

13.2 Monitor transfer flowrate and pump speed for signs of line pluggage or pumping problems.

13.3 Add DIWF inhibited water to FPT-1 to dilute the slurry if the FPT-1 IAL transfer pump shows signs of decreasing flowrate due to increasing solids concentration. This is expected to occur approximately at the original settled slurry level of 43".

13.4 Monitor the slurry pumps for loss in motor amps indicating vortex-type air entrainment from low liquid level above the pump suction. Reduce slurry pump speed to maintain mixing at low Tank 8 slurry levels.

13.5 If Tank 8 TTP discharge flowrate drops below 50 gpm, shutdown the transfer temporarily and add a maximum of 22,000 gallons of IW to Tank 8 and restart the transfer.

14.0 Stop the Tank 8 TTP when the Tank 8 liquid level is near the TTP suction height and the TTP discharge flowrate drops below 50 gpm or a loss in TTP motor amps is observed.

14.1 Maintain FPT-1 and HPT-7 transfer pumps in operation.

15.0 Initiate a transfer flush by adding DIWF inhibited water directly to FPT-1. The flush should be continued for a minimum of 4 hours[57] at an average flowrate of 100 gpm. This will remove enough sludge solids from FPT-1 and HPT-7 to designate them as non-slurry pump tanks.

16.0 Flush the Tank 8 TTP to FPT-1 transfer leg. When complete, vent and drain.

16.1 Prior to flushing the line from LDB-17 to Tank 8 TTP, the TTP motor should be disconnected and pump shaft lowered to arrest reverse rotation of the impeller and/or shaft.

16.2 When initiating the flush, slowly open the IW valves to pressurize the line and monitor the IW header pressure to ensure the pressure is maintained below 140 psig.

17.0 When flushing is complete, perform standard vent and drain of the H-area transfer lines and the IAL.

18.0 Tank 8 TTP pump clearances should be re-established for future pump operation.

19.0 Stop the FPT-1 pulse tube mixer.

Table F
Monitoring Requirements During Slurry Transfer Operation

Section	CLI	Description	Recording Frequency	Alarm / Limit	Alarm / Roundsheet Out-of-Range Response
DIWF Monitoring	FI-6054	DIWF inhibited water flowrate	Hourly during DIWF use	N/A	
	PI-2003 or PI-2004	DIWF caustic metering pumps discharge pressure	Shiftly	Pressure reads Zero	Startup redundant metering pump if available
Tk 8 TTP Monitoring	FI-6673	Tk 8 to FPT-1 flowrate	Hourly	Flow < 50 gpm	Shut down transfer
	FG-2309 and FG-2310	Tk 8 bearing water flow for the telescoping transfer pump	Shiftly	Flow ≥ 2 gpm	Shut down the transfer pump
	PI-2315	Tk 8 bearing water pressure for the telescoping transfer pump	Shifty	N/A	
	SC-13	Tk 8 TTP VFD current (amps), power (kW)	Hourly	N/A	
	SIC-6810	Tk 8 TTP speed	Hourly	N/A	
FPT-1 Monitoring	SI-6200	FPT-1 IAL transfer pump speed	Hourly	N/A	
	SC-9	FPT-1 IAL VFD current (amps)	Hourly	N/A	
	FI-6094	FPT-1 IAL transfer pump discharge flowrate	Hourly	N/A	
	FAL-6094	FPT-1 IAL transfer pump discharge flowrate low	N/A	FAL	Shut down transfer
	UR-6087 and UR-8275	FPT-1 level	Hourly	N/A	
	UR-6087 and UR-8275	FPT-1 Specific Gravity	Hourly	SpG > 1.45	Shut down transfer
	LAH-6087	FPT-1 level high	N/A	LAH	Shut down transfer
	LAL-6087	FPT-1 level low	N/A	LAL	Shut down transfer
	YA-8276	FPT-1 IAL transfer pump failure	N/A	YA	Shut down transfer.
HPT-7 Monitoring	SIC-1	HPT-7 transfer pump VFD current (amps), speed (rpm)	Hourly	VFD failure or Speed < 1400 Rpm	Shut down transfer
	LR-6946	HPT-7 level	Hourly	N/A	
	DI-6946 or DI-6949	HPT-7 density	hourly	N/A	
	TI-6790	HPT-7 temperature	Hourly	N/A	
	DAH-6946 or DAH-6949	HPT-7 density high	N/A	DAH	Shut down transfer
	JI-6791	HPT-7 agitator current	Hourly	Amps drops To zero	Shut down transfer

SAMPLING REQUIREMENTS

Sample analysis requirements to support the transfer of sludge solids from Tank 8 to Tank 40 are defined in the Waste Compliance Plan[58] (WCP) for this evolution. The WCP is still draft at the issuance of Revision 3 of this Operating Plan, therefore the requirements affecting Tank 8 waste removal operations are listed as follows:

- A Tank 8 slurry analysis is required to meet the general reporting criteria and specific acceptance criteria listed in the ESP Waste Acceptance Criteria[59] (WAC).
- The sample analysis results are not required as a prerequisite for slurry transfer to Tank 40.
- Two variable depth 100 ml dip samples shall be taken at the approximate mid-point of the slurry liquid level.
- These samples shall be submitted to SRTC high level caves for analysis.

SUPPORTING INFORMATION

Process Control Parameters

The parameters governing the transfer process are: flowrate, pressure, slurry specific gravity, pump tank levels, and pump tank post-flush solids concentration.

Flowrate

The flowrate will be measured and monitored via Tank 8 Telescoping Transfer Pump (TTP) discharge flow meter, FPT-1 pump discharge flow meter, and material balances between Tanks 8 and 40. The target flowrate is 100 gpm. The actual flowrate may vary due to pump speeds, solids concentration, and slurry specific gravity.

The minimum intra-area flowrate is 50 gpm. This maintains fluid velocities greater than 2 ft/s, which is the point where sliding beds were observed during TNX studies and partial pluggage occurred during Tank 18 to FPT-1 slurry transfers. Due to the length of the IAL (nearly 10X longer than the other two transfer legs), the minimum IAL flowrate limit is 70 gpm to provide a processing margin above the 50 gpm limit. This will maintain a minimum 3 ft/s fluid velocity in the IAL to avoid solids settling and pluggage concerns (see Sludge Hydraulic Studies in this Section). There is no maximum flowrate limit.

Pressure

The pressure will be maintained below the transfer line maximum operating limits via overspeed protection on each of the three transfer pumps (Tank 8 TTP, FPT-1, and HPT-7). The maximum operating pressure for the F and H intra-area lines is 150 psig. The maximum operating pressure for the IAL is 225 psig. The pump overspeed setpoints are detailed in the Technical Studies subsection "Transfer Pumps Performance and Overpressure Studies" below. Based on the transfer system performance curves[60,70] the maximum expected pump discharge pressures at the target flowrate of 100 gpm and a SpG of 1.5 are 32, 195, and 75 psig for Tank 8 TTP, FPT-1, and HPT-7, respectively.

To prevent overpressurizing the transfer lines due to waterhammer conditions, the applicable transfer lines shall be vented prior to starting any transfer pump. If the transfer is shutdown prior to flushing, the slurry solution in the transfer lines is not expected to free gravity drain[61]. Therefore, the transfer pumps should be started at their minimum speed and slowly ramped up to their operating speed in order to reduce the potential for pressure surges in the transfer line during re-initiation of a transfer.

Slurry Temperature

The Tank 8 slurry temperature will be measured and monitored via the thermocouple bundle in the thermowell in Riser 4 to verify the temperature limits for transfer are met.

The IAL design limit is 75°C.[64] The design for the IAL pipeline anchors was based on the assumption that both lines would simultaneously contain waste at the maximum temperature of 75°C.

The Tank 40 WAC requires that the temperature of the liquid waste in Tank 40 be maintained within the corrosion limits allowed based upon the inhibitor levels of Tank 8 and 40 mixed. The temperature limit will be established by an engineering evaluation prior to the transfer. Tank 8 temperature will be monitored to support the Tank 40 corrosion limit.

Slurry Specific Gravity

The slurry Specific Gravity (SpG) will be measured and monitored via slurry sample analysis (see Sampling Requirements in this Section) and bubblers in FPT-1 and HPT-7. The SpG upper limit is 1.5 utilized by several applicable analyses: transfer system performance curves[70], transfer line overpressurization studies[81,69], and the H-area Diversion Box #8 (HDB-8) design basis[67].

Pump Tank Liquid Levels

There are two pump tanks in the transfer system from Tank 8 to Tank 40: FPT-1 and HPT-7. The pump tank liquid levels will be monitored via the pump tank bubbler level instruments. The steady state operating levels for each pump tank are 40" for FPT-1 and 35" for HPT-7.

The maximum FPT-1 liquid level is 58". This protects the pump tank volume required to receive IAL and FDB-2 to Tank 8 transfer line drainback volumes without overflowing FPT-1. This level can be exceeded temporarily to prime the transfer pump.

The maximum HPT-7 liquid level is 45". This protects the HPT-7 overflow limit for the drainback volumes of both the IAL and the HDB-8 to Tank 40 Valve Box transfer lines. The IAL receipt valve to HPT-7 is closed upon IAL transfer shutdown to retain this inventory in the transfer line while the HPT-7 is pumped down to have a controlled vent & drain of the IAL transfer lines. The 45" level can be exceeded temporarily to prime the transfer pump.

Pump Tank Post-Flush Solids Concentration

The objective of the transfer system flush is twofold: (1) provide the standard 3 transfer line volume flush, and (2) remove enough sludge solids such that, upon agitator operation and trapped gas evolution, the pump tank can not exceed 100% of the LFL for hydrogen with the liquid level at pump tank overflow.

The minimum flush time for the transfer system shall be 3 hours, assuming a 100 gpm flush flow rate. The transfer line is approximately 13,000' in length[62] containing[63] 0.38 gal/ft, or approximately 5000 gallons of fluid. Three line volumes of flush at 100 gpm would require 2 ½ hrs of flush time. To protect the flammability requirements for the pump tanks, 4 hrs of flush time[57] is required at 100 gpm (for a total of 23,000 gallons).

Previous Sludge Slurry Waste Removal Experience

A review of the 1986 inter-area sludge slurry transfers from Tank 18F to Tanks 42H / 51H. and the more recent Tank 42 to 51 transfers provides the following summary points:

- Loss of even one slurry pump will have a dramatic effect on sludge solids gradient and inconsistency of slurry feed to the transfer pump. This caused significant discharge flowrate fluctuations and, if multiple slurry pumps were down, eventual loss of transfer pump suction (cavitation),
- Slurry pumps at mid-tank level did not suspend sludge at the tank bottom or could not overcome a significant solids gradient,
- Slurry pumps at/near the tank bottom provided more consistent slurry mixing from the top to the bottom of the slurry layer (a lower suspended solids gradient),
- Low slurry transfer flowrates in intra-area lines (less than 50 gpm) over the course of the transfer will lead to intermittent line plugging due to sliding bed formation that was self-clearing by the transfer pump. The IAL (10 times the typical intra-area line length) showed no signs of self-clearing once a line plug ensued.
- Lack of effective pump tank agitation over the course of the transfer will eventually plug (cavitate) the pump tank transfer pump. This occurs as the sludge settles around the pump casing and slides into the well generated by the pump suction. Significant fluctuations in flowrate will occur, and slugs of high solids slurry will be introduced into the transfer lines. Lack of agitation will also cover the bottom of the level/SpG dip tubes to the point where erratic readings are observed.
- The solids concentration of the slurry in the send tank tends to concentrate during the transfer, even with the slurry pumps operating. This caused transfer pumping problems and shut down at slurry levels below the settled sludge level for high solids concentration slurries (>18 wt%). This was successfully overcome by adding dilution water to the send tank at the onset of transfer pumping concerns (e.g. transfer pump speed increases required to maintain a constant flowrate). Typical

dilution rates observed equated to 1 gallon of dilution water added allowed 2 additional gallons of slurry to be transferred from the send tank.

- The process of sludge suspension should be continued until the entire tank inventory of sludge has been suspended, if possible, before a tank-to-tank transfer is initiated.

Technical Studies

This subsection contains:

- Sludge Hydraulic Studies
- Waste Transfer Structures and Lines
- Transfer Path Shielding Study
- Low Gamma Leak Detection Scoping Study
- Transfer Pumps Performance and Overpressure Studies
- Water Hammer Studies
- Transfer Line Leak Detection Studies
- HPT-7 Hydrogen Generation Rate Study
- Tank Heel

Sludge Hydraulic Studies

The transfer system hydraulic properties of interest are flowrate, pressure, temperature, and gravity draining.

The minimum fluid velocity for an IAL sludge slurry transfer has been established[13] at 3 ft/s ($\cong$ 70 gpm for 3" line). The purpose of this limit is to maintain enough solids momentum and turbulence to avoid solids settling and line pluggage. Originally, the IAL section of the transfer system was built to support supernate transfers only[64]. The minimum velocity basis for these supernate transfers was derived from earlier work performed to establish the tank farm minimum velocity for evaporator concentrate through the concentrate transfer loop[65]. The IAL was upgraded for sludge slurry service[66] in 1986. TNX testing[13] and subsequent sludge waste removal experience from Tank 18 have shown that the 3 ft/sec minimum fluid velocity is valid for transfer of sludge slurries through the IAL. TNX testing and Tank 18 to FPT-1 slurry transfer experiences indicate that below velocities of 2 ft/sec (47 gpm in a 3" line), the momentum of the slurry was not great enough to displace sludge particles settling in the line and "sliding beds" (partial pluggage) were observed.

To recover from an increasing solids concentration in Tank 8 during the transfer, dilution water may be added to FPT-1 or Tank 8. The FPT-1 will respond quickly to the addition of dilution water, however, Tank 8 will not. It is preferable to maintain the Tank 8 to FPT-1 transfer flowrate > 70 gpm, however, if dilution is required in the FPT-1, this may not be possible. Therefore, it is acceptable to continue transfer operation for Tank 8 to FPT-1 flowrates in the 50 to 70 gpm range. However, the transfer should be shut down if the flowrate decreases below 50 gpm. The temporary operation of an intra-area line above 50 gpm is supported by operating experiences at ESP, Tank 18 waste removal, and TNX. The IAL flowrate shall be maintained above 70 gpm at all times based upon the fact that the IAL pump will be operating at near maximum speed and will have little additional force available to clear a line plug should one occur. This allows time to respond to decreasing flowrates at a constant pump speed by adding dilution water to FPT-1 to lower the solids concentration (thus rheological properties) to avoid line plugging.

The maximum operating line pressure allowed for intra-area transfers is 150 psig[69]. The IAL maximum operating pressure was increased to 225 psig when the line was upgraded for sludge slurry service[67]. A maximum slurry yield stress of 50 dynes/cm^2 was determined for a 225 psig and 70 gpm operating bound[10]. The yield stress limit can correlated to a measurable slurry property of weight percent insoluble sludge solids concentration. This is done under Section 2, "Sludge Rheological Studies". Over-pressurization calculations have been performed[68,69,70] to establish the appropriate transfer pump speed settings. These calculations assumed a bounding slurry specific gravity of 1.5.

Free gravity draining of sludge slurry in sloped pipeline has been tested[13]. The tests demonstrated that a slurry of 1.17 SpG and $\geq$ 40 dynes/cm^2 yield stress would not initiate gravity flow in pipelines sloped at 0.5%. This is a reasonable bounding slope given that the Tank 8 slurry is expected to have a higher SpG; therefore, more momentum to initiate gravity flow. Segments of the transfer line are sloped significantly less than 0.5%. The most limiting case is a 3200' section of the IAL which is sloped at 0.27% [W234806]. Free gravity draining is not expected in these low sloped lines[61]. However, testing has indicated that a sludge slurry left stagnant in a pipeline for seven days can be resuspended and flow re-established[13].

Waste Transfer Structures and Lines

Diagrams 2 and 3 depict all structures and lines within the credible transfer path between Tank 8 and Tank 40. The Structural Integrity (SI) Program[5] implements the qualification requirements for waste transfers. The structural analysis[71], including static and dynamic loads, has been completed qualifying these lines for waste transfer service.

Transfer Path Shielding Study

A shielding evaluation[72,73,74] was conducted for the Tank 8 to Tank 40 transfer path. This evaluation concluded that the Tank 8 Riser 6, the above grade transfer line 16030, and the LDB-17 valve box will exceed the 5 mrem/hr Radiation Area posting limit based upon a sludge slurry at the upper operating range of 12 wt% insoluble solids. Therefore, additional shielding and/or posting requirements will be necessary prior to initiating a slurry transfer from Tank 8.

Low Gamma Leak Detection Scoping Study

A scoping study was conducted to evaluate the gamma source term for a sludge slurry diluted to 200 inches in Tank 8. This study concluded that there is potential for the sludge slurry to be less than 1.0 Ci/gal within the slurry solids operating range (using the methodology identified in the study[11]). At that dilution, ARM coverage would be required within a 50' radius of identified potential surface leak sites (e.g., covers for valve boxes, diversion boxes, pump pits). Therefore, prior to slurry transfers from Tank 8, an low gamma evaluation shall be performed based upon slurry sample analysis to determine if the low gamma transfer AB requirements apply for surface leak detection[87]. If it is determined to be a low gamma transfer, then the appropriate AB requirements identified in the low gamma evaluation for leak detection monitoring shall be implemented prior to slurry transfer.

Transfer Pumps Performance and Overpressure Studies

To provide steady-state operation of the Tank 8 to Tank 40 transfer, the performance of three pumps in series shall be balanced: Tank 8 TTP, FTP-1, and HPT-7 (see Diagram 4 in this Section). The pump performance and system curves for the FTP-1 and HPT-7 pumps and their associated transfer line segments have been evaluated over a range of sludge slurry specific gravities (1.0 to 1.5) and consistencies (up to 10 centipoise)[69]. These evaluations were developed based upon the standard Darcy Newtonian fluid approach. However, an informal review of these results verses several non-newtonian approaches revealed that there are significant differences in the system curves between the newtonian and non-newtonian approaches for fluids exhibiting Tank 8 rheology. The system curves for the Tank 8 to Tank 40 transfer pumps have been evaluated[70] utilizing a non-newtonian model developed by industry[75] for Bingham Plastics. In summary, the Tank 8 to Tank 40 transfer system can maintain steady state balanced flowrates for both newtonian and non-newtonian fluids. Two important observations are noted below:

(1) The FPT-1 transfer pump has the limiting flow capacity of the system and should be operated at the upper end of its operating range to maintain optimum performance of the other two transfer pumps

(2) The Tank 8 TTP-to-FPT-1 transfer line segment system curve identified that the standard TTP performance would outpace the FPT-1 pump capacity. A review of the possible throttling options is given in the bullets below. Trimming the impeller from 11" to 8" in diameter was selected as the preferred option. Subsequent testing of this reduced impeller[76] demonstrated that the Tank 8 TTP will operate in an acceptable non-resonance range (1100 – 1500 rpm) and maintain balanced pump performance with FPT-1 and HPT-7 pumps.

- All Waste Removal TTP's were purchased under the same specification; therefore, it must meet the demands of all possible future waste tank transfer requirements. However, Tank 8 will be pumping a minimal distance to its receipt tank (FPT-1); therefore, it has extra capacity for this configuration. Waste removal from F-Area Tanks 4 though 7, 26, 33, and 34 will have similar concerns.

- The technically viable throttling options are:
  - Trimmed impeller. This is the primary option chosen for all sludge waste tanks that require a smaller capacity pump, including Tank 8. Typically, there are no convenient places to install a throttling ball valve in these piping systems.
  - Motor replacement. This is a backup option available for other Tank waste removal applications due to the anticipated long lead time required for an 1800 rpm (vs. the current 3600 rpm motor) motor procurement.
  - Throttling valve. This is a backup option available to Tank 8 at the TTP flush box LDB-17 and to the other F-Area sludge tanks at FPP-1 jumper valve FV-6674 (currently inoperable).

Transfer line over-pressurization calculations have been performed to establish the bounding pump operating speeds for transfer of a 1.5 SpG sludge slurry. The maximum allowable speeds to protect from over-pressurization of the transfer lines are:

- Tank 8 TTP VFD operating setpoint of 2250 rpm[77]. No hardwired overspeed interlock is required for the Tank 8 TTP with an 8" impeller[78,79]. At a speed of 2250 rpm, the maximum pressure delivered is 66 psig[80],
- FPT-1 IAL VFD operating setpoint of 1864 rpm[81]. The hardwired interlock maximum setpoint is 1896 rpm[81].
- HPT-7 Pump #1 VFD operation setpoint of 2000 rpm[69,82]. The hardwired interlock maximum setpoint is 2161 rpm[67].

Because the Tank 8 to FPT-1 transfer leg is flushed using a pump other than the slurry transfer pump (i.e., the 10K IW system pumps), an overpressure calculation[83] was also performed of the flushing line segment. This segment includes both the IW header piping as well as the waste transfer line piping from LDB-17 to FPT-1. This evaluation concluded that, while the discharge pressure of the IW pump itself was below the 150 psig operating limit, the potential exists to have a maximum deadhead pressure of 180 psig at the entrance to FPT-1 due to the static head between the IW tank level and FPT-1. This is only of concern if flushing is initiated with a waste transfer line pluggage. To preclude a pressure spike in this scenario, the flush water should be slowly valved in while monitoring the IW header pressure to ensure it is in the expected pressure range for full flow flushing (< 140 psig).

Water Hammer Studies

The water hammer evaluation performed for the Tank 8 to Tank 40 transfer concluded that two actions are necessary to avoid a water hammer condition in the transfer lines[56].

- Vent and Drain (if possible) all transfer lines prior to transfer pump restart, and
- Start the transfer pumps at minimum speed and ramp slowly to operating speed.

A detailed modeling analysis[84] and structural adequacy assessment[85] was utilized as the basis of the IAL portion of this evaluation. The modeling analysis held the FPT-1 transfer pump discharge pressure to a constant 150 psig and varied the fluid SpG for a resultant flowrate to calculate the momentum forces expected. The IAL pressure is expected to exceed 150 psig during normal operation; therefore, the model analysis[84] is non-conservative. The effect of this non-conservatism is that the transient pressure could be higher than that calculated, and possibly greater than the pressure limit for the flanges in the line[85]. This non-conservatism further supports the position that a modification is necessary to the IAL HPT-7 air operated valve to reduce the water hammer concern.

Transfer Line Leak Detection Studies

All transfer lines for the Tank 8 to Tank 40 sludge slurry transfer have secondary containment jackets and leak detection capability for the purpose of detecting a core pipe leak during a waste transfer. Because the slurry exhibits Bingham Plastic behavior, it is expected that slurry leaked into the secondary jacket will not initiate gravity flow immediately[86], and thus impede the ability to detect the leak. The ability to detect a core pipe leak during a sludge slurry transfer rests on several assumptions and accepted risks:

- Assumptions
  - For a small leak site, supernate solution preferentially leaks into the secondary and solution flows like water to the leak detection probe, and
  - For a larger leak site, the sludge solids will gradually settle allowing enough low yield stress solution to flow to the leak detection box.
- Accepted Risks
  - Undetected Leaks
    - Small leak sites may not leak enough volume to make it to the leak detection probe.
  - Jacket pluggage
    - Larger leak sites may not settle fast enough to keep up with the leak flowrate, resulting in full annular plug flow of the slurry in the jacket until it reaches a segment of the line sloped enough for gravity flow or it is finally pushed into the detection device, or
    - The effect of slurry solids settling may be self-plugging (particularly at core pipe anchors/supports).

The Tank Farm safety analysis[87] addressed the scenario for a non-detected leak into the transfer line jacket by the bounding HDB-1 deflagration accident analysis. This is valid since the maximum transfer line material at risk (for line RCZ-78 between HDB-8 and HDB-7) is an order of magnitude less than that of HDB-1. Therefore, the standard Structural Integrity Program controls[5,62] for transfer lines are the only applicable controls.

HPT-7 Hydrogen Generation Rate Study

The hydrogen generation rate per gallon of slurry shall not exceed 1.2E-05 ft^3/hr-gal for waste transferred through the HPT-7[87]. The H_2 production rate has been calculated[88] for Tank 8 diluted with uninhibited water to both 95" and 155". Converting this to a per-gallon basis will provide a range of hydrogen generation rates which can be compared to the limit stated above.

$$\text{per-gallon Generation Rate} = \frac{\text{H}_2\ \text{Production Rate}}{\text{Tank 8 Slurry Volume}}$$

Rate at 95" liquid level:

$$\text{Generation Rate} = \frac{0.8\,\text{ft}^3/\text{hr}}{(95\,\text{in})\left(2710\,\text{gal}/\text{in}\right)}$$

$$\text{Generation Rate} = 3.1 \cdot 10^{-6}\ \text{ft}^3/\text{hr} \cdot \text{gal}$$

Rate at 155" liquid level:

$$\text{Generation Rate} = \frac{1.16\,\text{ft}^3/\text{hr}}{(155\,\text{in})\left(2710\,\text{gal}/\text{in}\right)}$$

$$\text{Generation Rate} = 2.8 \cdot 10^{-6}\ \text{ft}^3/\text{hr} \cdot \text{gal}$$

Therefore, this is less than the limit allowed for transfers through HPT-7.

Tank Heel

It is the intention of this Operating Plan to remove as much of the sludge in Tank 8 as possible with the existing waste removal technology and equipment. This both maximizes the DWPF Batch size and minimizes the residual sludge left behind for further processing during tank cleaning and closure. The maximum estimated sludge inventory remaining in the tank heel from a calculation performed in 1999 is 11,200 kg of sludge solids[89]. Upon completion of the transfer on 1/25/01, the estimated sludge mass remaining in the tank is only 5,700 kg[109]. There are two factors that contributed to the inventory: 1) The sludge mound on the east Tank wall (2,700 kg) and 2) The amount left in the heel volume below the transfer pump suction (3000 kg). The maximum estimated solids loading in the sludge slurry heel is 18 wt% IS and 29.6 wt%IS for the sludge mound. More details on the remaining sludge is discussed in Section 6.

Section

4

Heel Removal Operation

Not applicable for Tank 8 waste removal at this time.

Section

5

Contingency Transfer Operation

INTRODUCTION

In the event that the Tank 8 primary vessel begins leaking into the annulus during the sludge suspension operations, a contingency transfer to remove the liquid contents from Tank 8 may be necessary. The information in this Section is provided for expeditious facility planning if this unlikely event occurs.

PRE-SLURRY CONTINGENCY TRANSFER SYSTEM REQUIREMENTS

The following requirements have been established[90] as listed below:

- DOE approved Safety Evaluation to address transfer controls
- Permanent annulus transfer system installed, including gang valving/piping as required
- Transfer procedure will be through validation and ready for approval
- Tank 8 primary jet replaced with the TTP
- Credible transfer path configured and made functional to allow the transfer:
    - including FDB-2 nozzle 37 blank removal,
    - FDB-2 jumpers restored to operation (including leak testing),
    - blanks installed in Valve boxes 1, 2, and 3,
    - conductivity probes installed and surveillances completed,
    - transfer line structural integrity surveillance completed,
    - TTP emergency shutdown and overspeed surveillances completed, and
    - Jersey Bumpers installed at Tank 8 and Valve Boxes 1 through 5.
- Intended transfer path seismically evaluated (not qualified)

TRANSFER PATH

Leaking material from the primary tank to the annulus will be jetted back to the primary tank via the annulus jet and installed transfer line from the annulus North riser to the primary tank Riser #2. This will require that the annulus jet and associated gang valve be operable for sludge suspension operations.

Two F Tank Farm waste tanks were considered for a Tank 8 contingency transfer: Tank 26 and Tank 33. Tank 26 is the recommended receipt tank because the transfer path avoids non-agitated pump tanks and organic tank PISA controls (required on FPT-3 and Tank 33). However, Tank 26 is the 2F evaporator feed tank; therefore, evaporator operation will be affected until the sludge solids settle and the evaporator feed pump suction height is adjusted.

Several options are available to improve the alternate emergency transfer path to Tank 33. However, each will require field work to align the two tanks; therefore, they are not desirable for an emergency transfer.

- Fabricate and install a new FDB-3 jumper to eliminate FDB-4/FPT-3 from the transfer path (a non-agitated pump tank), or
- Swap the Tk 33 C1 riser jet and downcomer and use the existing valves in FDB-3 to eliminate FDB-4/FPT-3 from the transfer path.

If a Tank 8 primary leak is detected, an engineering evaluation (considering Tank 26 freeboard, Tank 8 level, and source term impact on Tank 26 CLFL) shall be conducted to determine if Tank 26 has enough space to receive an contingency transfer from Tank 8. The maximum volume of slurry inventory required for transfer is approximately 400,000 gallons (145" tank level). If Tank 26 does not have enough space, then an additional standard transfer from Tank 26 to other waste tank will be required prior to the contingency transfer from Tank 8.

Therefore, the Tank 8F to Tank 26F Intended Transfer Route is:

Tank 8: Annulus North Riser → line 504 → Riser 2 downcomer → Riser 6 telescoping transfer pump → line 16030 → line WF515 → line WT3754 → Valve Box 4 → line WT3754 → line 109 → FDB-2

FDB-2: entering floor nozzle 37 (note: nozzle 37 currently is blanked) → jumper 25-26-35-36-37(FDB2)30A-31A-37A → floor nozzle 37A → jumper 28-30-31(FDB2)30A-31A-37A → exiting wall nozzle 30 → line 111 → FDB-3

FDB-3: entering floor nozzle 16 → jumper 10(FDB3)4-2-16 → exiting wall nozzle 10 → line 1472 → FDB-4

FDB-4: entering wall nozzle 8 → jumper 7-8(FDB4)5A → jumper 10-11(FDB4)5A-5B-5C-5 → jumper 16-17(FDB4)16D-5C → jumper 12-13D(FDB4)16D → exiting wall nozzle 12 → line 109 → Tank 26 Riser C1 downcomer

Section

6

Data Collection and Analysis

PURPOSE

The purpose of this Section is to present the data collected during Tank 8 waste removal operations and provide engineering analysis of that data, as appropriate. The objective is to provide a retrievable reference with both planned and empirical information, which can be utilized for future waste removal planning efforts.

CHRONOLOGY

General Waste Removal Strategy

As detailed in Section 2 earlier, the general approach for mobilizing the settled sludge was to use the slurry pumps to gradually mine their way to the tank bottom. This was accomplished by running the pumps initially at 50 inches above tank bottom until the criteria for lowering the pumps had been met. Because the surface of the sludge had dehydrated, the topography was not even. As the sludge dried, it shrank, causing the sludge surface to create valleys between the vertical cooling coil runs as the sludge adhered somewhat to the coils. The valleys were estimated to be 1' below the "peaks" adhering to the coils. The initial sludge level was measured using the sounding function of the reel tape and found to be 43". Based upon photos of the reel tape bob in the dry tank, the reel tape bob was measuring on the side of the slope (near the bottom) between the sludge "peak" adhering to the cooling coils and the valley between the coils. It was estimated that this level was a good representation of the average height of the sludge initially before slurry pump operation. It was expected that these peaks would be removed during slurry pump operation at the 50" level. After the criteria was met at the 50" pump height for lowering the pumps, the pumps were lowered in 10 inch increments and the process repeated four additional times until the pumps had completed their operation at the full insertion height (10 inches above tank bottom). The purpose for this step-wise approach was twofold: 1) to gradually release the hydrogen gas trapped within the settled sludge, and 2) to allow the turbulent jet action of the pumps to carve away enough settled sludge to allow a 10" pump lowering. Basically, the sequence for the pump run at each pump height was as follows:

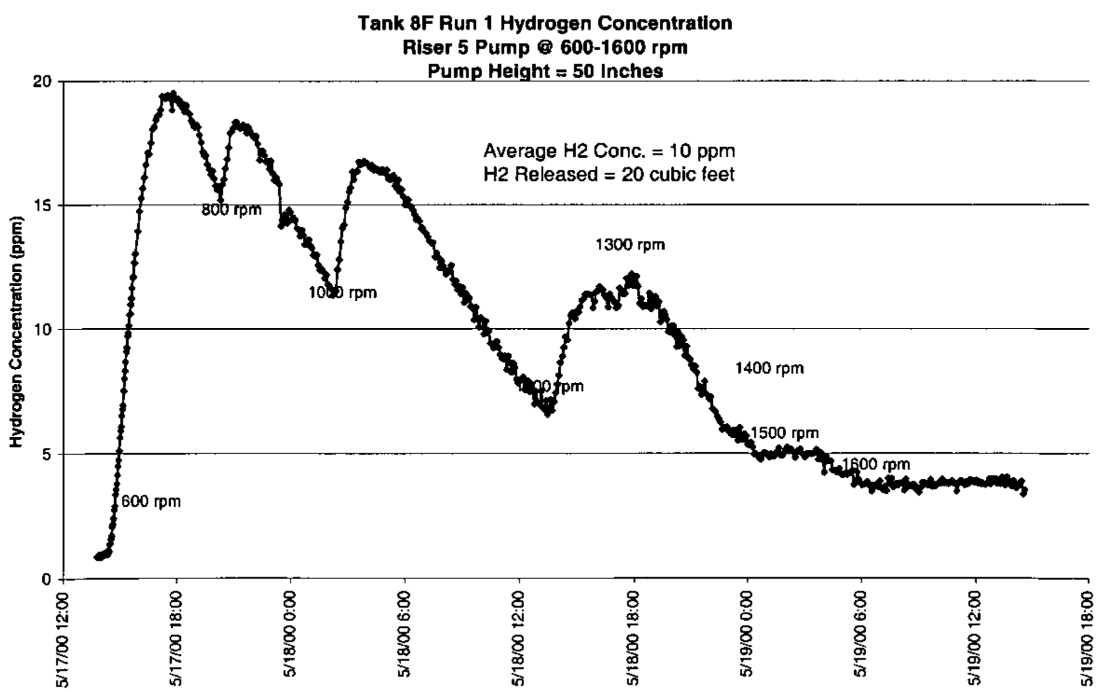
a) The pumps were gradually ramped up from 600 rpm to 1600 rpm (per the Pump Run Tables shown in Section 2) to gradually release the trapped hydrogen gas.

b) Then the pumps were operated at 1600 rpm for a period of time to carve out the additional settled sludge necessary to meet the criteria for pump lowering.

The specific criteria for lowering the pumps were defined in Engineering Path Forwards issued just prior to each slurry pump run at a particular pump height. These Engineering Path Forwards (EPFs) provided a common agreement between Operations and Engineering on a measurable point of success to determine when it was appropriate to lower the pumps to the next level for operation. These EPFs are referenced in the paragraphs, which follow. Once the slurry pumps were fully inserted and the settled sludge fully mobilized, the Seismic Q-time program was implemented (which officially maintains the sludge trapped hydrogen gas inventory below LFL) and preparations were made to transfer the sludge slurry to Tank 40 for further processing as DWPF Sludge Batch 2.

Slurry Pump Operation @ 50" Pump Height

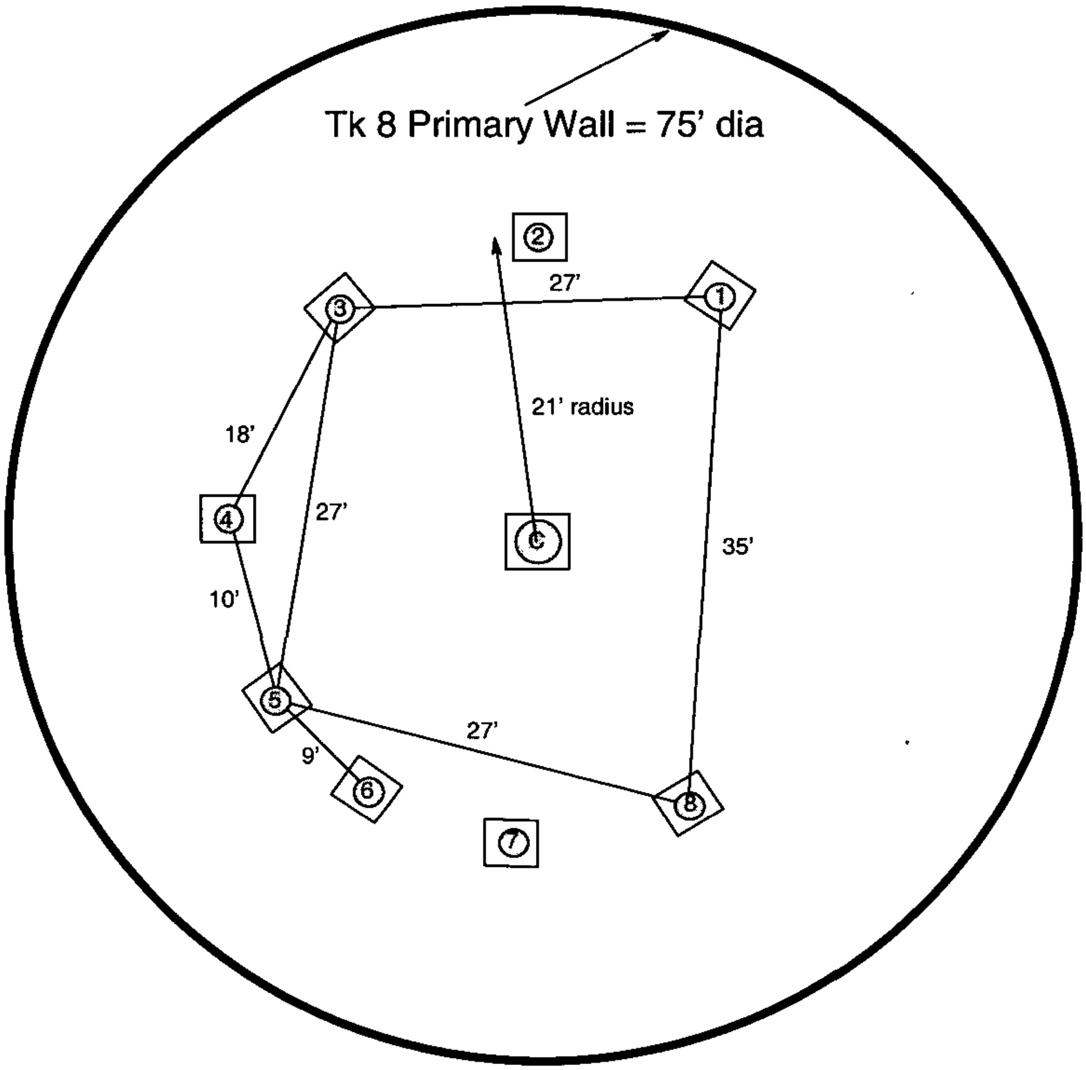
Tank 8 sludge removal was initiated on May 17, 2000 with the slurry pumps set at 50 inches. Pump height is the distance between the bottom of the pump suction screen and the bottom of the tank. The liquid level was maintained at approximately 75" throughout the sludge mobilization pump runs. CSTE-SO-2000-001[90] requires hydrogen release evaluations for Tank 8 at different intervals during the waste removal phase. Three evaluations of the slurry pumps were performed at the 50-inch pump level. There was one evaluation at the conclusion of each of the 40, 30, and 20 inch levels. The Riser 5 slurry pump initiated sludge mobilization by operating individually over a 50 hour run time. The pump was at the maximum speed of 1600 rpm for 8 hours, the previous 42 hours were spent ramping up through Table A (Section 2) to get to 1600 rpm. Pump motor vibration data was



collected and found acceptable. The hydrogen gas releases were monitored with a Gas Chromatograph tapping a sample from the primary purge exhaust stack. The hydrogen trace is shown below.

A full evaluation of the hydrogen releases was reported[91] which determined that the hydrogen gas fraction of the settled sludge volume was 2.3% on average. As noted from the hydrogen trace, the maximum H_2 peak in the vapor space was < 20 ppm (0.05% of the LFL) during this pump run. A summary of this report is given later in this Section. After the pump run, a sludge sounding was conducted using the reel tape in Riser 4.

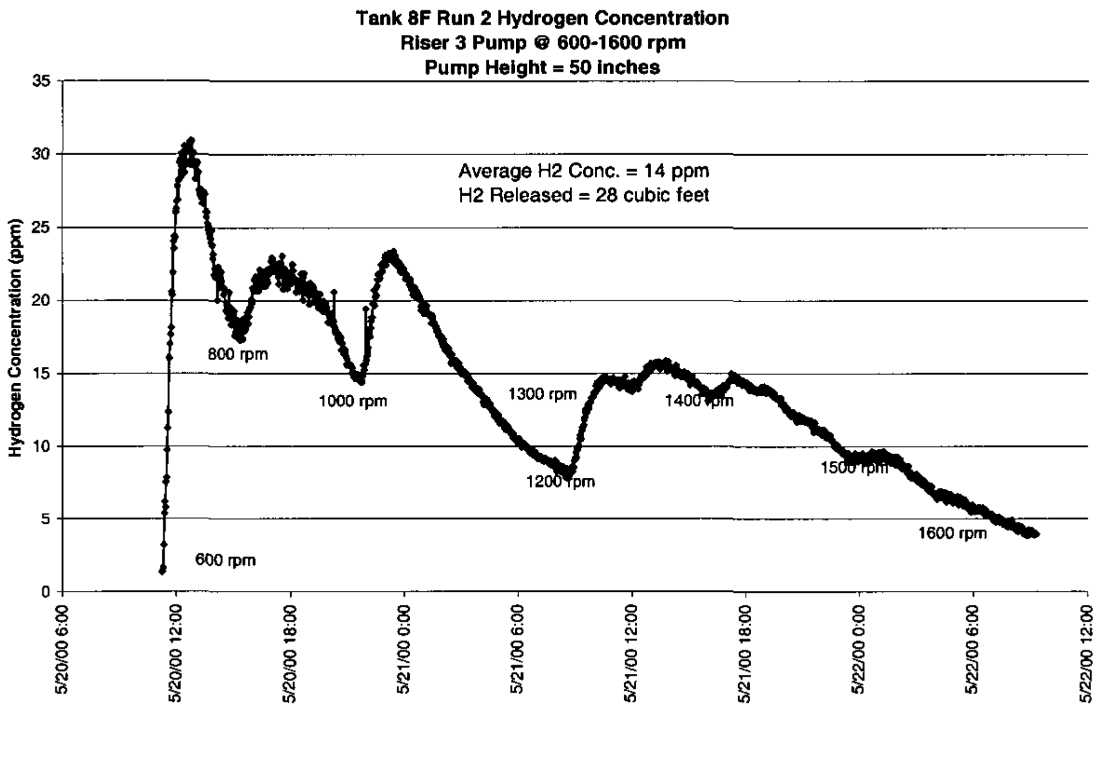
Tank 8 Plan View



The reel tape measurement is 10' from the Riser 5 slurry pump discharge nozzles. During this run, the sludge interface level dropped 7": from 43" to 36". This indicates that the slurry pump jet force was able to develop an Effective Cleaning Radius (ECR) > 10' in a short period. At the 50" pump height, the centerline of Riser 5 discharge nozzles is at 58", or

15" above the sludge surface (on average). Slurry pump speeds of 1300 rpm or greater are required to achieve a disturbance depth > 15" at Riser 4. Therefore, the sludge at Riser 4 experienced 22 hours of pump runtime, which disturbed the sludge at this location. The slurry pump turntable rotation was measured at approximately ½ rpm. This equates to one pump discharge jet pass per minute for a pump with 2 discharge nozzles. Thus, 1300 jet passes, which disturbed sludge, were experienced at the Riser 4 location during this run. Experience from Tank 16 sludge removal[92] demonstrated that ECRs develop radially outward over time, and over 200 hours of pump operation was required to achieve a fully developed ECR of 30' in Tank 16. Therefore, it is expected that while the Riser 5 pump ECR was greater than 10', it did not achieve a fully developed ECR in the 50 hours of its operation. A standard corrosion sample was pulled from Tank 8 between Riser 5 and Riser 3 runs. The analytical results indicated a slight reduction in nitrate concentration, but nitrite and hydroxide changes were insignificant.

The Riser 3 pump conducted a similar run over a 46 hour run time. The pump was at the maximum speed of 1600 rpm for 8 hours, the previous 38 hours were spent ramping up through Table A (Section 2) to get to 1600 rpm. Pump motor vibration data was collected and found acceptable. The hydrogen gas releases were monitored with a Gas Chromatograph and the hydrogen trace is shown below.



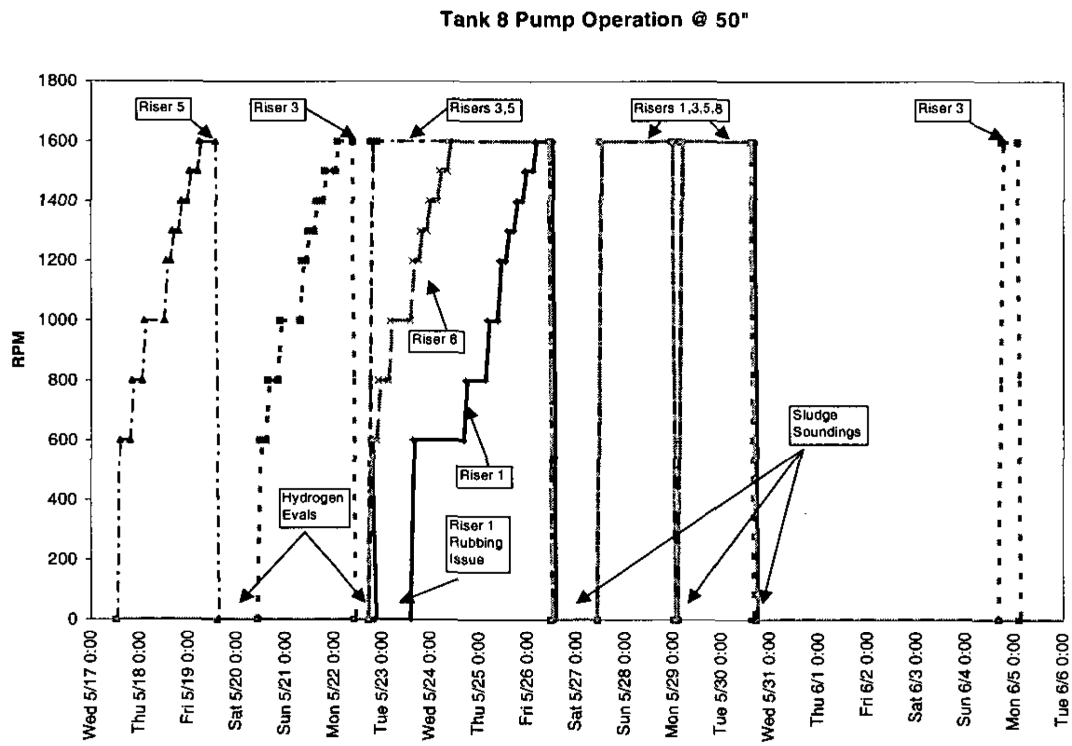
This trace is very similar to the Riser 5 pump run, showing an initial spike (0.08% of the LFL) at pump startup and smaller spikes at speed increases. The peak from this run was the highest observed during the entire mobilization efforts at all pump heights using the Pump Run Tables (Section 2). This H_2 release profile was consistent for pump operations at 50", however, the profiles at all the lower pump heights are just the opposite: increasing H_2

release peaks as the pump speeds are increased. This supports the conclusion reached[91] that loosely held H_2 is contained at or near the sludge surface which is easily disturbed by the slurry pumps and released. Hydrogen trapped in the lower levels of the sludge required more force and time to release, and therefore typically required higher pump speeds and more time for release.

After the pump run, a sludge sounding was conducted using the reel tape in Riser 4. This measurement is 18' from the Riser 3 slurry pump discharge nozzles. During this run, the sludge interface level increased 10": from 36" to 46". This indicates that the slurry pump jet force was not able to develop an Effective Cleaning Radius > 18' in a short period. This level increase would be expected just outside the ECR where the heavy solids that got disturbed by the slurry pump, but not mobilized into a slurry, would tend to pile up. At the 50" pump height, the centerline of Riser 3 discharge nozzles is at 58.75", or 15.75" above the sludge surface. Slurry pump speeds of 1300 rpm or greater are required to achieve a disturbance depth > 15.75" at Riser 4. Therefore, the sludge at Riser 4 experienced 23 hours of pump runtime, which disturbed the sludge at this location. Thus, 1400 jet passes, which disturbed sludge, were experienced at the Riser 4 location during this run.

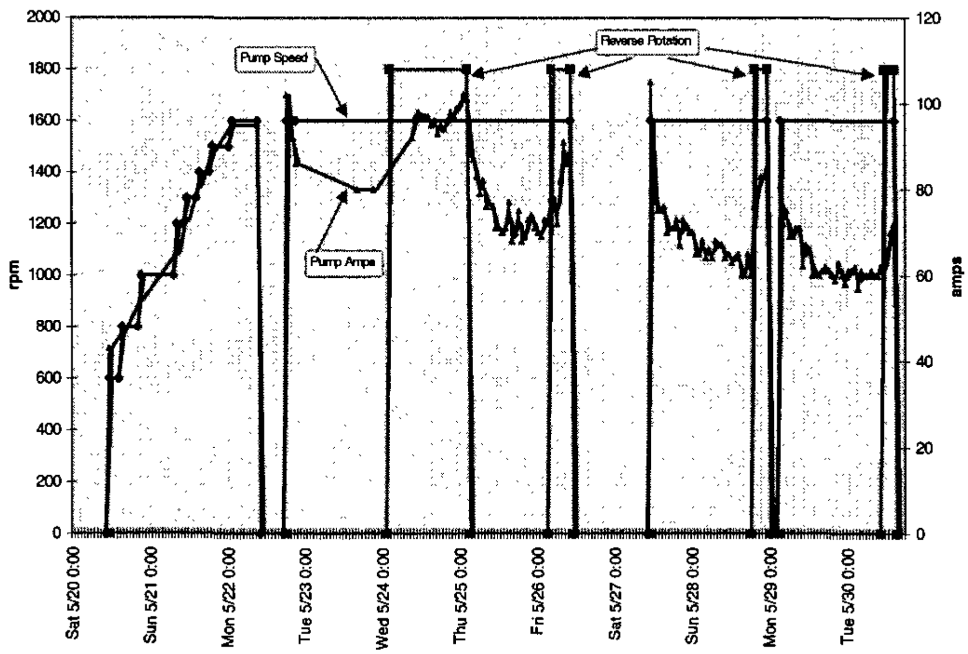
The third pump run at 50" brought all four slurry pumps to maximum speed from May 22nd to May 30th. Risers 3 and 5 were ramped immediately to 1600 rpm as allowed by the pump run program, and Risers 1 and 8 were started at the minimum speed of 600 rpm. A rubbing sound was heard at Riser 1 pump, so it was shut down for investigation. Riser 8 was ramped to 1600 rpm using the Pump Run Tables. The cause of the rubbing in Riser 1 was determined to be from a pre-existing condition identified during the installation of the slurry pumps. The risers are not perfectly cylindrical and, in some cases (as in Riser 1), required hydraulic jacking in an effort to reshape the riser from oblong to circular shape. This was done to fit the slurry pump through the > 9' vertical riser section where the clearance is tight (riser ID is 23", and pump OD is 22") [W149522]. It was determined that the slurry pump was indeed rubbing slightly on the metal riser tube, but without detriment to the pump, turntable or riser[93]. Therefore, Riser 1 pump was re-established at 600 rpm and ramped to 1600 rpm after Riser 8 had successfully reached maximum speed. The slurry pumps were shut down twice during the run to obtain sludge sounding readings, and a final reading was gathered after the run was completed.

The criteria established in the Engineering Path Forward[94] to state that the mobilization effort at the 50" pump height was successful was operation of the slurry pumps for a minimum of 72 hours after achieving a reading of < 38.8" from both Riser 2 and Riser 4 sludge soundings. The 38.8" limit was the pump screen height of the two lowest slurry pumps (Risers 1 & 8) at the next (40") pump height position. The 72 hour requirement was the time estimated to radially increase the ECR by 9' (from 18' to 27') based upon Tank 16 test experience. A more accurate basis was developed for subsequent lowering of pumps using turbulent jet constant velocity profile methodology, hydrogen release data, and temperature readings. Both Risers 3 and 5 pumps contributed to the disturbance depth experienced at Riser 4, and Risers 1 and 3 contributed to Riser 2's depth. The first sludge sounding was conducted after 89 hours of 1600 rpm operation. Riser 4 sounding was 31.8" and Riser 2 sounding was 42.9". The pumps were operated for an additional 61 hours and shut down for soundings: Riser 4 sounding was 31.42" and Riser 2 sounding was 41.45". The pumps were operated for an additional 38 hours and shut down for soundings: Riser 4 sounding was 31.02". A sounding was not attempted at Riser 2. A total of 188 hrs of maximum speed operation was logged for Risers 3 and 5. Several observations are noted



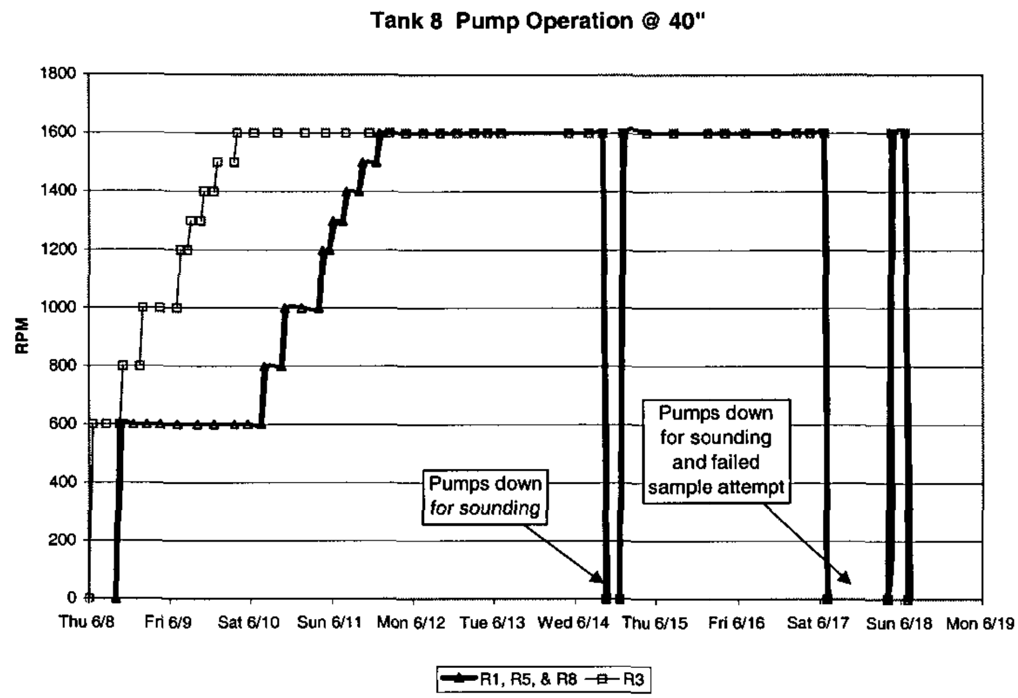
from the sounding data: Riser 4 easily met the criteria for success and demonstrated effective mobilization of the settled sludge material (a total disturbance depth from the pump discharge nozzle of 27.7 inches equating to an ECR of 35 feet, after 22,500 discharge jet passes); but Riser 2 showed little progress from the initial assumed sludge height of 43" (no baseline sludge soundings were available for Riser 2). Riser 3 pump had experienced some amp loading problems during the 50" runs, but both Risers 1 and 5 were operating consistently, therefore differences in pump operation didn't explain the Riser 2 sounding readings. It was concluded that either Riser 2 was sounding on an obstruction in the tank (such as the original thermowell guide bar noted in the Riser 4 location) or that the sludge mass was harder to mobilize in that area of the tank. In either case, it was considered a local phenomenon, and additional slurry pump operation was not delivering significant incremental improvement. The risk of the Riser 1 and 3 slurry pumps hitting sludge before reaching the 40" pump height during the pump lowering evolution was mitigated by rigging dynamometer monitoring to ensure there was no load loss (pump resting on sludge) during the lowering effort. Therefore, lowering of the slurry pumps was approved to proceed after shut down on 5/30/00, however, due to the Riser 3 amp loading problem, an additional 8 hour pump run was conducted on 6/4/00 using only Riser 3 to troubleshoot. All during the multiple pump runs at 50", Riser 3 pump exhibited unusual behavior where the turntable was operated in the forward direction, the pump loading dropped from approximately 100 amps to a nearly unloaded condition of 60 amps over a 24 hour period. However, when the turntable was changed to the reverse direction, the loading would gradually return to 100 amps. An Engineering Path Forward[95] was issued to direct the troubleshooting efforts to discern the cause. The pump, motor, and VFD all checked out good, and the loss of loading was essentially cleared after indexing Risers 1 and 5 towards the pump. Thus, it was concluded that the pump suction was experiencing some form of pluggage. This phenomenon was observable during Riser 3 pump operation at lower pump heights, but not to the degree that it was an operational concern. The slurry pumps were successfully lowered to the 40" pump height. No "unloading" was observed on the rigging dynamometer during the lowering evolutions.

Riser 3 Pump Load @ 50" Pump Height Operation



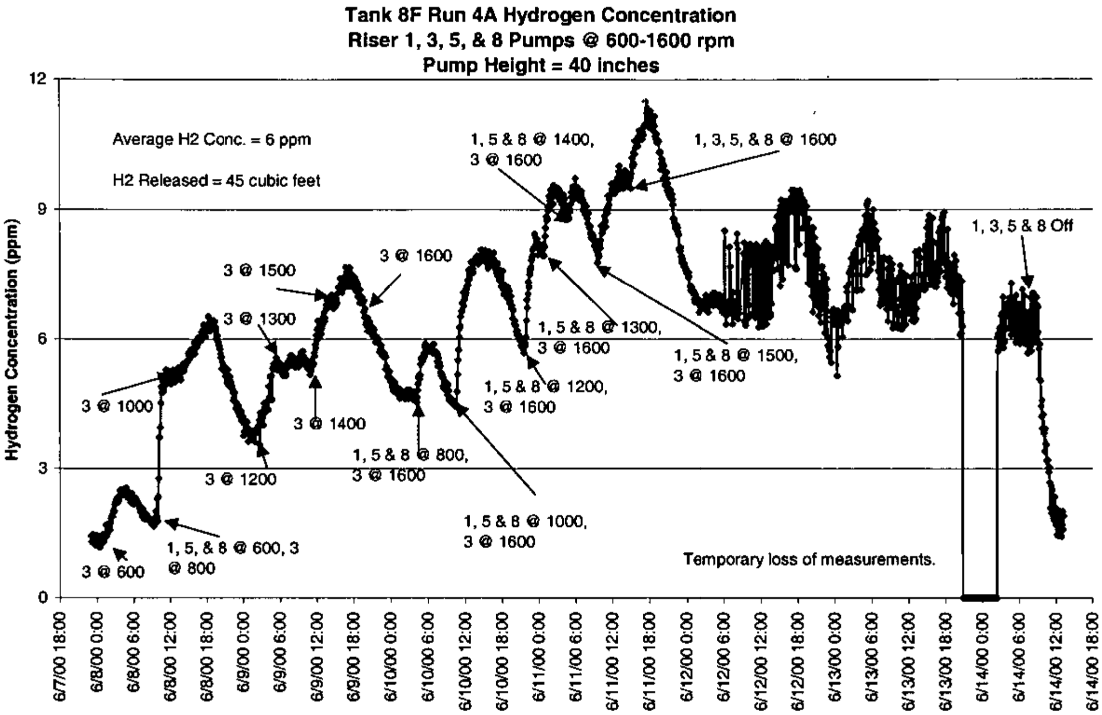
Slurry Pump Operation @ 40" Pump Height

Sludge mobilization was initiated on 6/8/00 at the 40" pump height. To monitor hydrogen release effects at this level, Riser 3 pump was started at 600 rpm and allowed to complete its minimum hold time requirements. The hydrogen release was insignificant (see figure below), therefore, the other 3 pumps were allowed to start simultaneously. The same approach was used on pump speed ramping: Riser 3 pump was ramped to 1600 rpm via Pump Run Table A while the other 3 pumps remained at 600 rpm. Minimal increases in hydrogen were observed at each speed increase, but the maximum did not peak above 10 ppm. Therefore, the remaining 3 pumps were allowed to ramp to maximum speed simultaneously. As can be seen, this approach was successful, and demonstrated the effectiveness of incremental pump height lowering and slow pump speed rampup in controlling the rate of trapped hydrogen released during initial mobilization of the sludge. It should be noted again that the general trend of the hydrogen concentration was increasing as the pumps were increased in speed. This was consistent with all of the pump height operations except at 50", where the trend was just the opposite: relatively high peak at initial

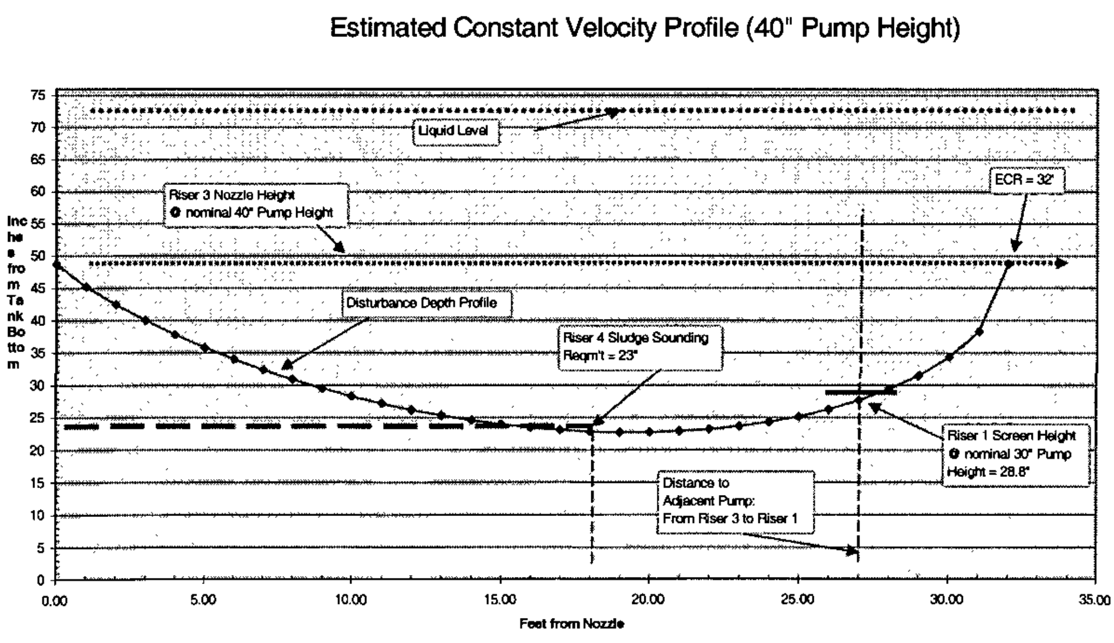


pump startup and decreasing concentration as pump speeds increased. The ventilation rate during all slurry pump operations was maintained between 720 and 740 cfm. The vapor space contains approximately 79,500 ft^3 of space at the 74" liquid level. The hydrogen concentration peaked within the first 30 minutes of pump speed increases, indicating that the ventilation flowrate was sufficient to purge and maintain the vapor space at safe hydrogen levels. It is evident from all of the hydrogen trends that the slurry pumps disturb more sludge/trapped gas initially at startup or speed changes than noted after a period of time at the same speed. This agrees with the Tank 16 single pump testing[92] and the Tank 8 50" pump operation that illustrated that the settled sludge is disturbed radially outward from the slurry pump at a decreasing radial rate until the full ECR is established.

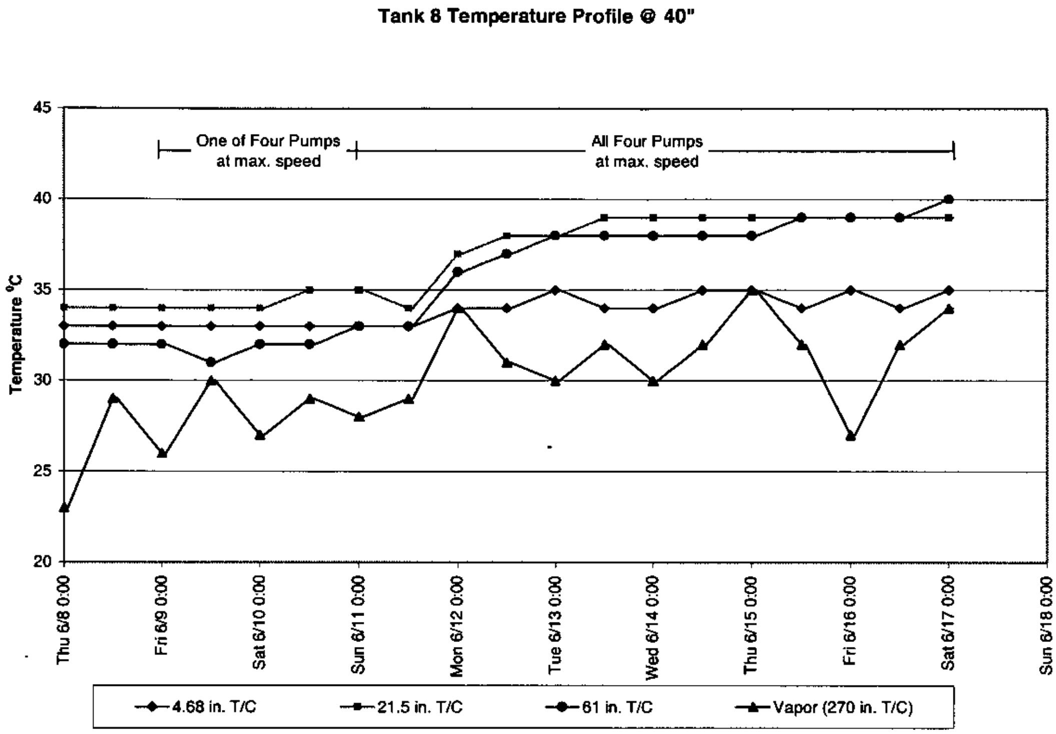
The criteria established in the Engineering Path Forward[96] to state that the mobilization effort at the 40" pump height was successful was operation of the slurry pumps at maximum speed for a minimum of 72 hours and a subsequent reading of < 23" from Riser 4 sludge soundings. The 23" limit was established utilizing turbulent jet constant velocity profile methodology incorporating the sludge disturbance information from the 50" pump run and the assumed ECR of 32'. The strategy was to ensure that enough settled sludge had been disturbed beneath each pump by the adjacent pump to allow lowering the pump to the next pump height. This approach did not credit the suction flow effect for mining a hole beneath each pump, or the possibility of submerging the pumps into the settled sludge for the next pump run. The reason for this conservative tactic was due to the uncertain nature of the settled sludge (the degree of hardening due to dehydration was not known). See the diagram below for a visual picture of this tool.



The actual slurry pump ECR of 26' was validated after the removal of the waste to Tank 40 (see Sludge Disturbance Monitoring subsection below). Therefore, although this tool was used at that time in the slurrying operation to establish the criteria for pump lowering (the expected sludge interface level recorded from the Riser 4 reel tape) and the pump lowering evolutions were very successful, the tactic to depend only on the adjacent pump to clear the



sludge for pump lowering did not actually occur in the tank. The other mechanisms (suction flow mining, pump submergence in sludge during lowering) were the dominate factors in the success experienced prior to lowering the pumps.



The first sludge sounding was conducted after 123 hours (Riser 3) and 81 hours (Riser 5) of ≥ 1300 rpm operation. Riser 4 sounding was 23.98". The pumps were operated for an additional 60 hours and shut down for soundings: Riser 4 sounding met the lowering criteria at a reading of 21.68". The sounding reading was confirmed by the temperature trend during the run. As the sludge was mobilized down to the 21.5" thermocouple, the temperatures between the 61" and 21.5" thermocouples tracked together and distanced themselves from the 4.68" thermocouple reading. This indicates that the 21.5" was reading from the same phase as the 61" thermocouple (the sludge slurry vs. the settled sludge).

A single variable depth process sample was required immediately after pump shut down to analyze for wt% solids and rheology. However, Operations experienced difficulty lowering the sample vial past the obstructions in the Center Riser, so the evolution was halted until the sampling glove bag could be moved to a different access plug on the Center Riser. Therefore, the pumps were started and operated for an additional 5 hours to re-mix the slurry for the second sampling attempt. Unfortunately, transportation issues did not allow this slurry sample to be shipped to the SRTC High Level Caves (HLCs) for analysis until the second set of variable depth samples were pulled in August. At that point, the lab analysis of this variable depth sample was not useful, so the sample was placed in the HLC archives. One of the purposes of the sample analysis was to determine if inhibited water was required to maintain a slurry of less than 18 wt% and 1.5 SpG. Without that data, a review of the slurry pump loading was conducted which showed no increase in loading, therefore no pump limitations were anticipated. This, coupled with the original estimation that the total sludge mass would dilute to an 18 wt% slurry at 75" liquid height, provided the basis to continue mobilization without inhibited water dilution.

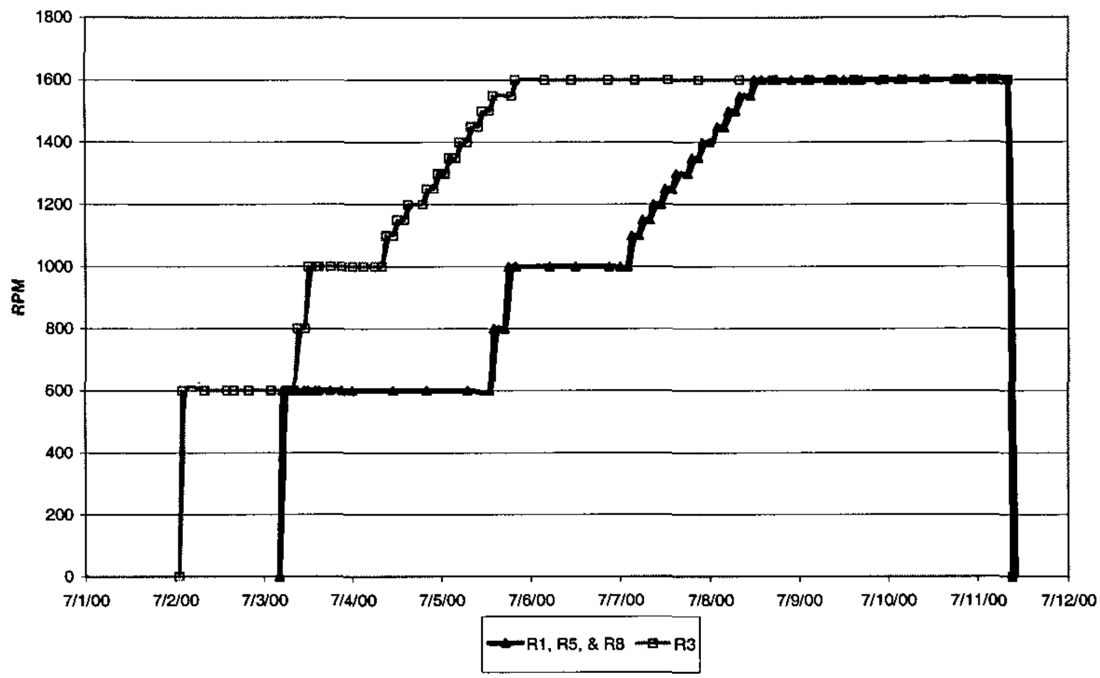
After slurry pump shut down on 6/18/00, the flexible hose for the bearing water connection to the Riser 3 pump was relocated to correct an interference with a structural member that would not allow lowering to the 30" level. The slurry pumps were lowered to the 30" pump height level without incident or rigging dynamometer indication of unloading due to sludge interference. Operations experienced difficulty starting up the bearing water system due to repeated bursting of the pressure relief rupture disk while pressurizing the bearing water header to Tank 8. The bearing water pumps deliver a higher pressure than the rupture disk setting (≈ 60 psig vs. 33 psig), and therefore the pressure is regulated using a recirculation line and a pressure control valve. The relief device setting was established to protect the slurry pump lower mechanical seals from the combined pressures of pump and static head. The cause of the ruptures is suspected to be the inability of the pressure control valve to respond quickly enough during the transient condition of pressurizing the header (e.g. back pressure pulses as the flowing bearing water hits the closed valves at the end of the header). Changing the location of the pressure control valve impulse line from the discharge piping of the operating bearing water pump to the parallel non-operating pump did not improve the situation. The issue was solved by a procedure change, which opened the vent path valving from the pump columns to the tank to allow a vent path while filling the bearing water header. Once the header was filled, the vent path valves were closed.

Slurry Pump Operation @ 30" Pump Height

Sludge mobilization was initiated on 7/2/00 at the 30" pump height. The Engineering Path Forward[96] requirements for slurry pump startup were based upon the success at the 40" run for simultaneous pump startups. Due to the low hydrogen releases during ramp up of Riser 3 pump, these requirements were modified[97] to allow ramp up of the remaining three pumps once Riser 3 had completed the 1450 rpm minimum hold time. The pump lowering criteria established in the Engineering Path Forward[98] was successful operation of the slurry pumps at maximum speed for a minimum of 72 hours and a subsequent reading of < 13" from Riser 4 sludge soundings.

The first sludge sounding was conducted after 154 hours (Riser 3) and 90 hours (Riser 5) of ≥ 1300 rpm operation. The reel tape in Riser 4 ran out of tape at 10.4" and started wrapping up the pay out wheel on the other side when it stopped with a failure alarm. Maintenance was able to repair the reel tape, but due to this deficiency, the reel tape was only operational above 10.4". Therefore, the sludge interface level was assumed to be 10.4", which met the lowering criteria and established the largest sludge disturbance depth recorded during Tank 8 mobilization efforts: approximately 28" below centerline of the pump discharge. An additional steel tape sounding of 35.7" was recorded from Riser 2. This was a 5.8" drop from the readings gathered during the 50" run, which suggests that a localized mound of denser sludge existed under Riser 2. Since this local effect did not impact lowering the pumps to 30", and the Riser 4 soundings exceeded the criteria by a large margin (≈ 3"), proceeding with pump lowering to the 20" pump height was recommended.

Tank 8 Pump Operation at 30"



Slurry Pump Operation @ 20" Pump Height

Sludge mobilization was initiated on 7/18/00 at the 20" pump height. The simultaneous ramp up of all four pumps was allowed[98] based upon the minimal hydrogen concentrations achieved in the vapor space during the 3 pump simultaneous ramp ups at the 40" and 30" runs.

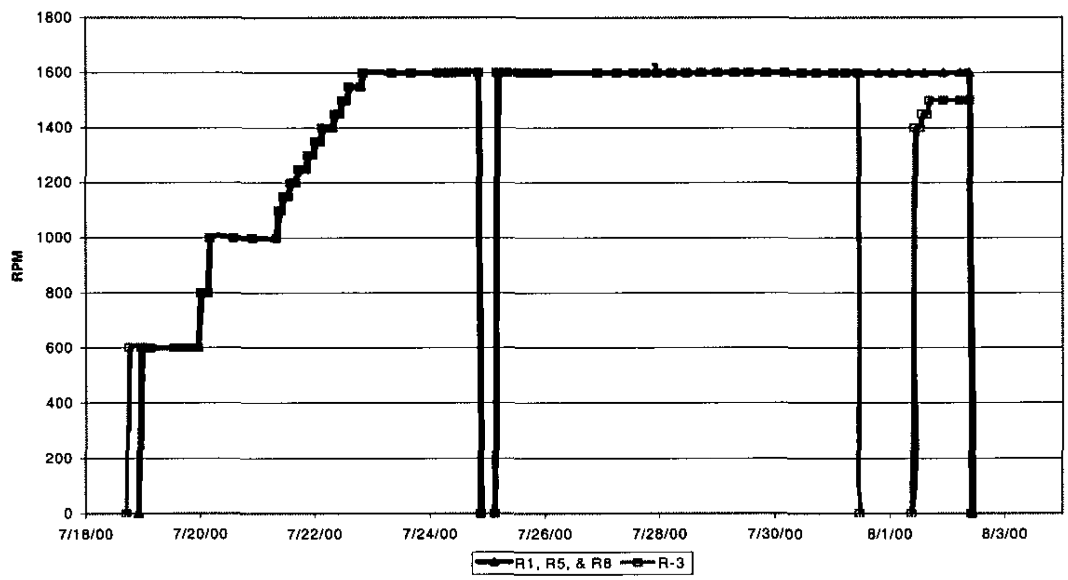
The peak concentration reached during simultaneous ramp up of all four pumps was < 25 ppm (0.06% of the LFL). This low concentration is attributed to the slow disturbance of the settled sludge as it developed its full ECR.

The primary measured indicator for pump lowering criteria was changed from reel tape readings to hydrogen concentration readings utilizing the Gas Chromatograph for the 20" run. The criteria established[99] required the hydrogen concentration return to a baseline value as the indication that no more sludge was being disturbed. This criteria was established for the following reasons:

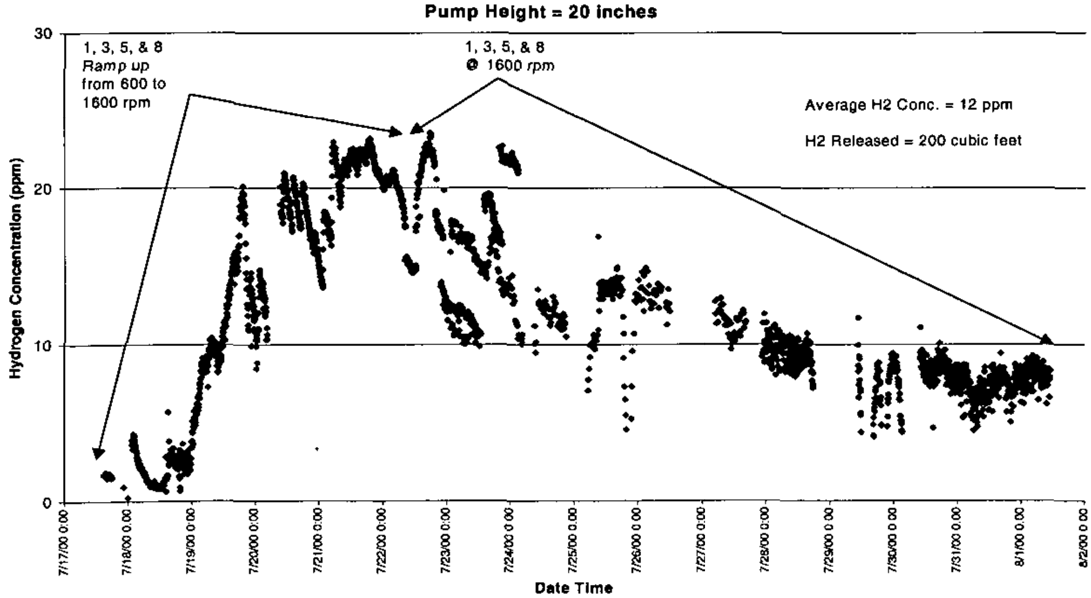
- The reel tape was not functional below 10.4"
- Given the previous sludge disturbance depths achieved, operation at the 20" level should mobilize sludge to the tank bottom
- There was concern that the relatively short pump run at the 30" level did not fully disturb the sludge at the farther reaches of the tank, as indicated by the still-descending hydrogen trend at the time of pump shut down

- The localized dense mound of material beneath Riser 2 would require additional slurry pump operating time to determine, how efficiently the slurry pump technology could mobilize/erode the mass
- There was concern that once the slurry pumps were lowered to the 10" level, their effectiveness may be hindered due to the additional interferences by the horizontal cooling coils and the lower loops of the vertical cooling coils
- Given that the formal seismic Q time controls would come into force after only 8 hours of maximum speed operation at 10", assurance that the slurry pumps had disturbed as much sludge as practical (i.e., the pumps achieved a full ECR) was important

Tank 8 Pump Operation @ 20"

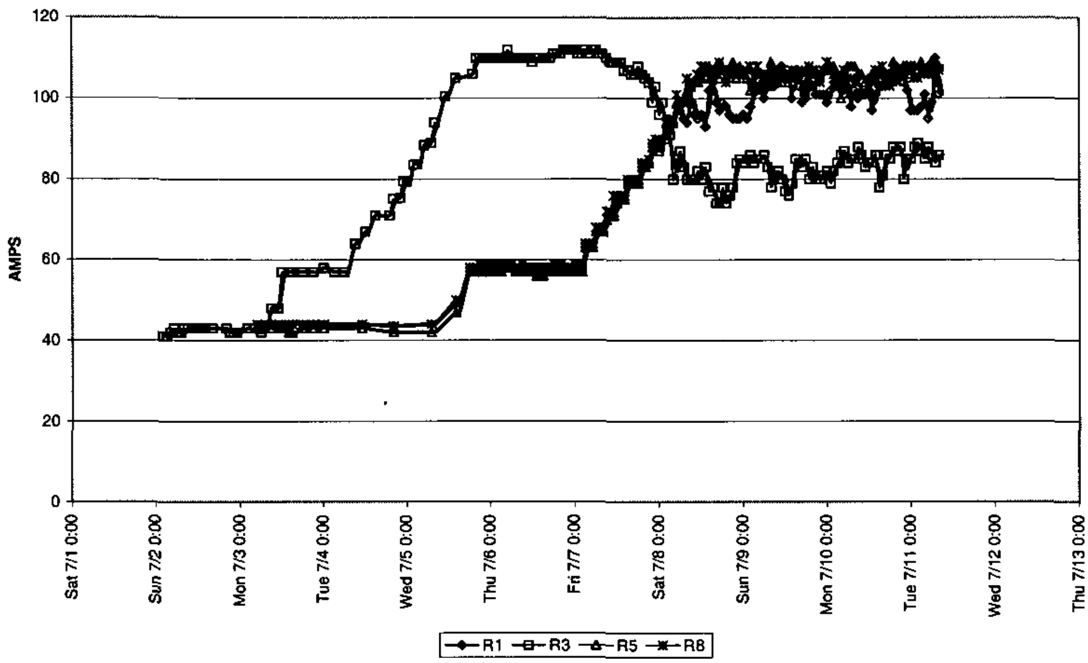


Tank 8F Run 6 Hydrogen Concentration
Riser 1, 3, 5, & 8 Pumps @ 600-1600 rpm
Pump Height = 20 inches

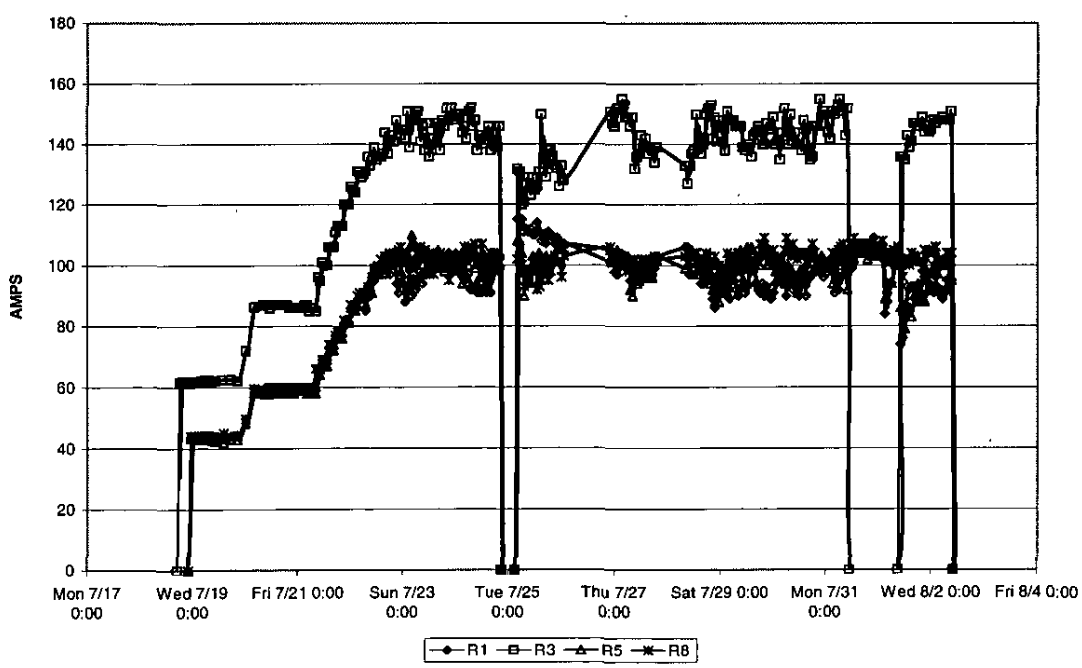


Other than a short outage on 7/25/00, the slurry pumps were operated continuously for 270 hours at speeds ≥ 1300 rpm. However, Riser 3 experienced bearing water leakage 7/31/00 indicating partial failure of one of the mechanical seals. The slurry pump was shut down upon discovery of the bearing water leak, restarted, and inspected. It was determined that the leak was occurring at the lower mechanical seal. The pump was restarted 23 hours later

Pump Loading at 30"

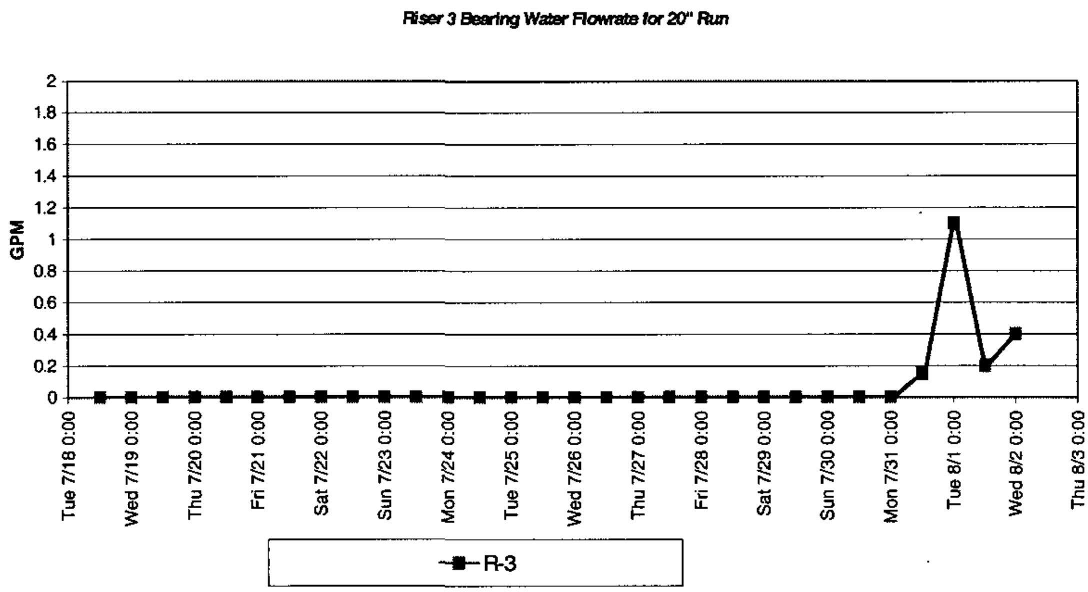


Pump Loading at 20"

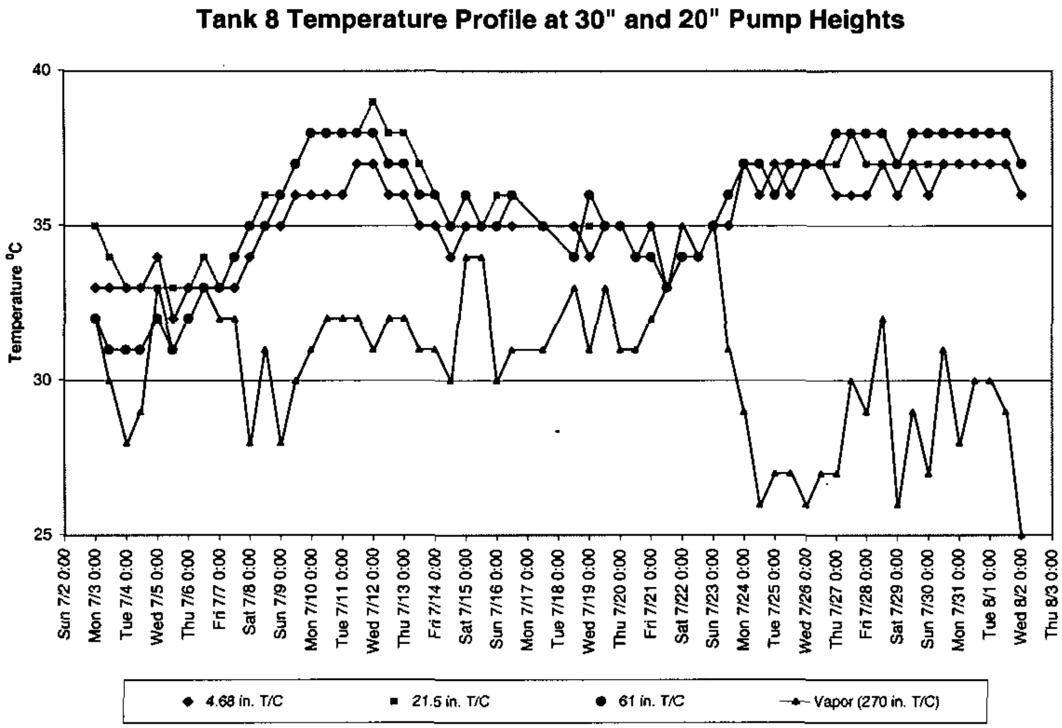


for a total runtime of 247 hours at ≥ 1300 rpm. The slurry pumps were shut down on 8/2/00. Riser 3 pump loading (amps) was not consistent with the other 3 pumps. During multi-pump operation for the 30" run, Riser 3 loading was typically 20 amps below the other pumps. However, at the 20" level, Riser 3 loading was consistently 50% higher throughout the entire run.

It appears that the change in Riser 3 loading occurred between the 30" and 20" runs. It is not clear, whether this occurred as a result of lowering the pump or a failing mechanical seal. The bearing water leak rate peaked at 1.1 gpm and then declined to 0.4 gpm at the end of the run. The slurry pumps are equipped with a disaster bushing designed to limit the leak rate to approximately 2 gpm in the event of a mechanical seal failure. Experience at TNX with failed mechanical seals determined that a leak rate of 1.2 gpm is typical through the disaster bushing. The failure of the mechanical seal is not aligned with the higher pump loading. Although the increased loading could be attributed to early failure signs of the seal, there wasn't any significant change in loading at the actual time of the failure, therefore it is not certain that the seal failure is the cause of the higher loading experienced by this pump.



The original strategy for this run was to operate the slurry pumps until the hydrogen concentration in the vapor space returned to 3 ppm (baseline). It was evident at the end of the run that the H_2 concentration was leveling out at about 8 ppm. Therefore, an evaluation[100] was issued acknowledging that little additional sludge mobilization was expected at the 20" level. Therefore, to conserve pump run time for 10" operation and mixing during the transfer to Tank 40, lowering of the slurry pumps to the 10" level was initiated. Based upon the GC data, the slurry pumps developed their full ECR after 9 days of operation. This is in complete agreement with the slurry pump experience in Tank 16[92]. A sludge sounding of 7.45" was measured from Riser 2 indicating that the localized dense sludge mass had been effectively mobilized during the 20" campaign. The temperature plot indicates that the 4.68" sludge thermocouple in Riser 4 started to consistently tracked with the 21.5" thermocouple readings at the end of the 30" pump run, and continued tracking closely throughout the 20" run. The sludge was mobilized to near the tank bottom within the first few days of operation at 20".

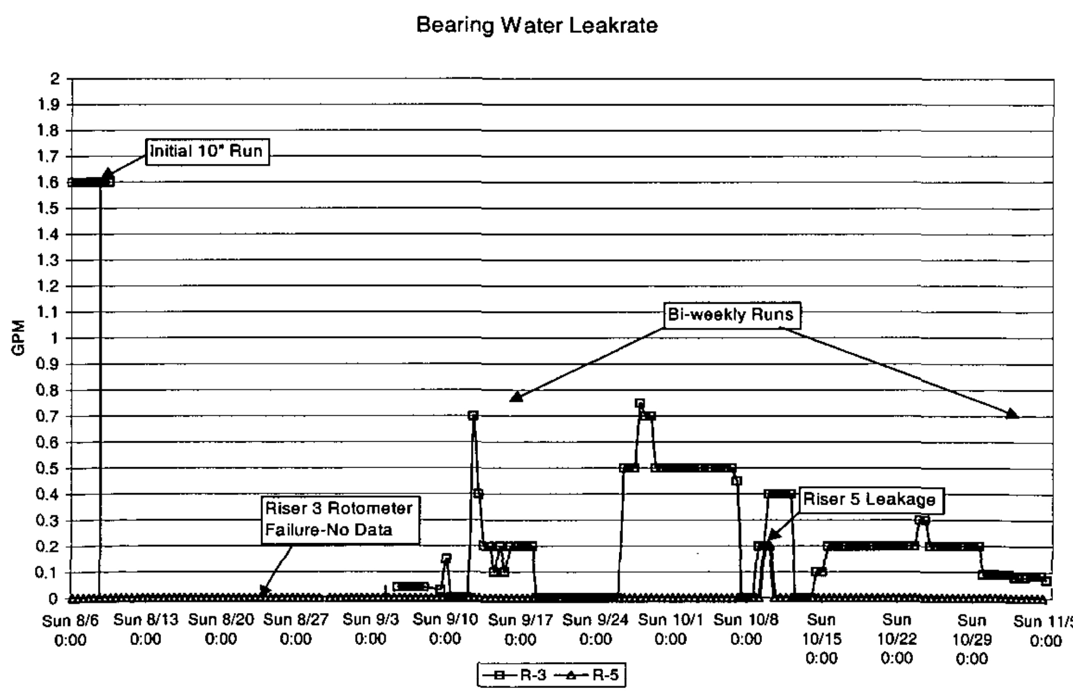


Three variable depth samples were pulled immediately after pump shut down for solids and rheological analysis[101]. Based upon the analysis, the Tank 8 slurry was at 19.3 wt% insoluble solids (38.5 wt% total solids and 23.8 wt% dissolved solids) and exhibited a yield stress of 3.06 Pa and consistency of 10.28 centipoise. The sample was diluted to 11.3 wt% insoluble solids to align with the plan to dilute Tank 8 slurry to 11 wt%, and the rheological properties were again analyzed: yield stress of 1.44 Pa and consistency of 4.06 centipoise. These rheological properties were in good agreement with the original rheological measurements performed in the mid-80's on Tank 8 sludge before it was dehydrated[26]. Therefore, it appears that dehydration and rehydration of settled sludge does not have a significant effect on the rheological properties of the sludge in a slurried state.

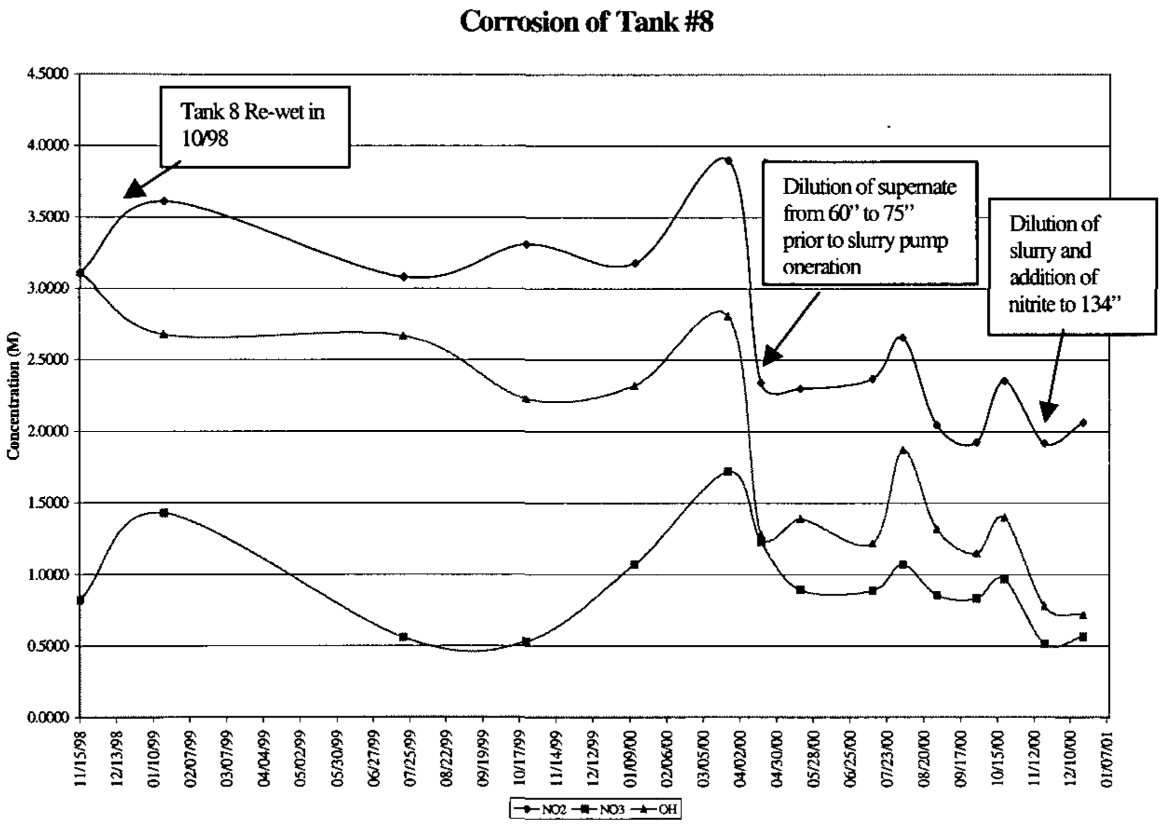
<u>Slurry Pump Operation @ 10" Pump Height</u>

Sludge mobilization was initiated on 8/6/00 at the 10" pump height. The pumps were ramped up simultaneously and operated for 60 hours at speeds of 1300 rpm and greater. The purpose of the 10" run was to achieve sufficient mixing to declare the seismic Q time program active[102] while minimizing the run time hours put on the pumps. This tactic was pursued as a result of the silicon to the evaporator feed technical issue which delayed Tank 40 "ready to receive" Tank 8 material from August to November. Therefore, due to the concern that Riser 3 pump was showing signs of seal failure, the actual completion of a fully developed ECR at 10" was obtained through the bi-weekly pump runs until Tank 40 was ready to receive waste. These bi-weekly pump runs were required to satisfy pump rotation and Q time requirements[104]. After the pumps were shut down on 8/11/00, three variable depth samples were pulled from the slurry to satisfy the WAC analysis requirements. During initial sample preparations in the SRTC High Level Caves, it was noted that the variable depth sample taken at the surface was thick with some small "clumps" 1/16" to 1/8" in diameter, but that the other two samples taken at lower depths were not as thick and were only two-thirds full. The suspected cause of this was twofold: 1) the surface sample was too close to the surface and collected the floating solids that have been observed consistently after each slurry pump shut down; and 2) the samples were not left in the waste long enough to fully dissolve the aluminum foil "cap" which allowed the sample vials to get to the proper tank level before filling the vial. The representation of the sample was considered suspect to satisfy the WAC requirements, but was analyzed to get a relative sense of the concentrations of major elements and noble metals. The result of this analysis was documented by SRTC[103]. A second set of WAC variable depth samples was gathered after Tank 8 was diluted to its final level prior to the transfer.

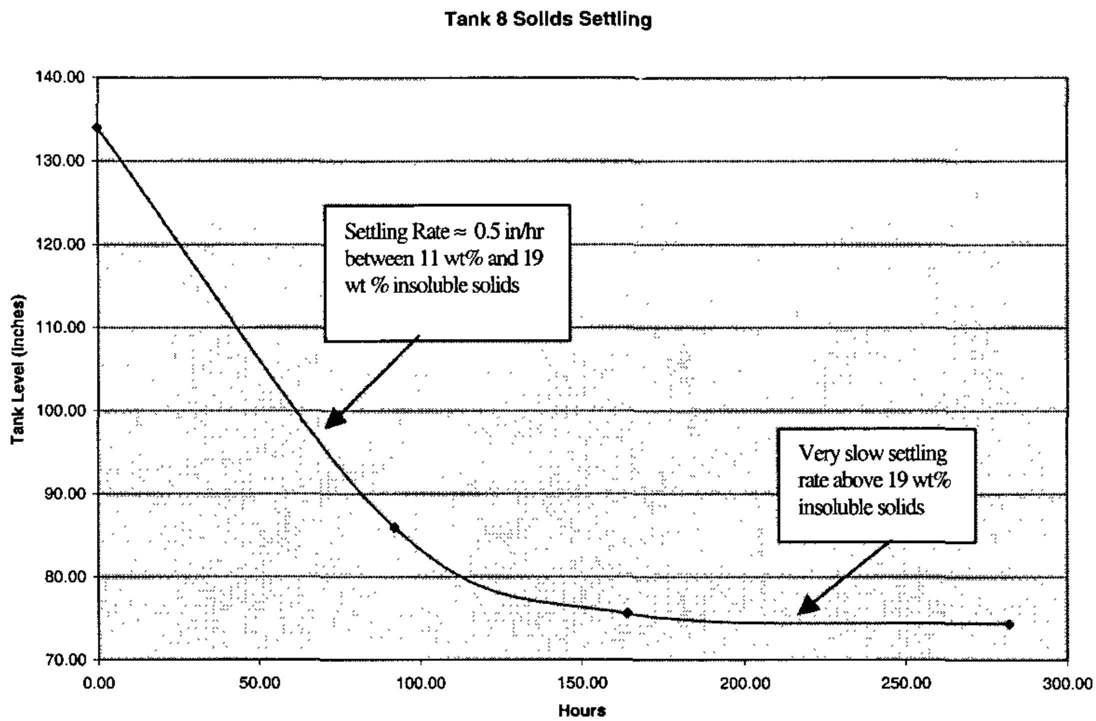
The bearing water leakage rate from Riser 3 pump was consistently 1.6 gpm during the initial pump run from 8/6/00 through 8/11/00. A program was implemented to reduce the bearing water pressure to a minimum to ensure a positive pressure at the bearing water connection above the pumps during the period when the pumps were shut down. The pressure was then returned to normal operating pressure for the infrequent pump operation. This was done to decrease the bearing water leakage rate. Interestingly, the leakage rate trended down during the period of infrequent use. Riser 5 experienced bearing water leakage for a short duration on 10/10/00. This was the only occurrence of leakage from this pump.



Tank 8 was diluted to approximately 11 wt% insoluble solids (134" liquid level) at the end of October, 2000. The corrosion evaluation[104] determined that it was acceptable to dilute with uninhibited well water provided the slurry pumps were operating during the addition to prevent any localized areas of low inhibitor concentrations in the liquid. Additionally, concentrated sodium nitrite was added to provide the minimum inhibitor levels in Tank 40 during and after the transfer of material from Tank 8. The trend of the corrosion inhibitors sample analysis indicates that the inhibitor levels remained constant during sludge mobilization, with a small peak after the 20" run. Dilution of the tank to the 134" level changed the dominant inhibitor from hydroxide to nitrite, as expected.



To support resolution of the evaporator feed silicon issue, turbidity analysis was performed[105] on Tank 8 after dilution to 134". An error was discovered with the level measurement of the first turbidity meter reading. This resulted in collecting some solids in the 86.3" sample, and an inability to remove the 78.3" sample due to high rad rates from sludge adhering to the outside of the sample vial (this sample was cut and dropped into the tank). This error was corrected prior to subsequent turbidity readings. Plotting the data[106], assuming the first turbidity reading of the sludge interface was approximately 86", gives the solids settling rate shown in the following graph. The 19 wt% insoluble solids concentration was derived from the sample data results[101] at a slurry level (and liquid level) of 75".



Tank 8 to Tank 40 Transfer

The Tank 8 to Tank 40 sludge slurry transfer evolution was initiated in the last week of November, 2000. An Engineering Path Forward[107] was issued to define the decision logic for anticipated judgements concerning transfer pump operation, inhibited water dilution, slurry pump speed ramp down to avoid rooster tailing, and transfer completion criteria. Later, as the transfer evolution started, we gained experience, and modifications to the transfer manual were made to improve operation. Initially we were not successful in initiating the transfer due to some equipment problems. The transfer was rescheduled to mid-January, 2001 after several unsuccessful attempts. Some of the significant changes to the procedures are noted below.

- The leak test of WTS-V-557 at LDB-17 prior to the transfer required draining of line into the LDB sump which initiated a conductivity probe alarm. This liquid accumulation had to be evaporated using heat guns which was a lengthy process, resulting in transfer delay. In the future, this test will be performed ahead of time to eliminate schedule impact.

- After the initial vent and drain of the IAL, the need for further vent and drain following every transfer interruption was considered unnecessary. The IAL is frequently used, unlike in the past, and post transfer vent and drain is considered adequate to justify the elimination of initial vent and drain for the future transfers. However, this will require a change to 200-FH-PHR-311 to delete the requirement of initial vent and drain in the transfer procedure.

- Vent and drain of both sides of the IAL in F and H area can be performed simultaneously instead of following one another, since it saves valuable time and resources. This was implemented during Tank 8 to 40 transfer.

- The maximum allowable levels in pump tanks FPT-1 and HPT-7 during vent and drain operation were raised. This imposed additional responsibility and scrutiny on conduct of operation to safeguard Manual 2S philosophy. But it allowed operations to perform vent and drain with higher pump tank levels and save significant time in the schedule.

- Prevailing practice of emptying HPT-7 to Tank 38 per established procedure was changed to allow emptying directly into Tank 40, which maintained continuity during the transfer.

During initial starting of the Tank 8 transfer pump, the motor tripped repeatedly on overload. Troubleshooting indicated that the clearance between the impeller and the casing was extremely low and was only 0.002" instead of vendor specified 0.030". After adjusting the clearance, the pump ran satisfactorily. Occasional verification of the impeller to casing clearance is recommended in the vendor manual. For future uses of TTP's, a verification will be included in the transfer procedure to ensure the above clearance is maintained.

SLUDGE MOBILIZATION EQUIPMENT PERFORMANCE

Slurry Pumps:

The evaluation of the slurry pumps consists of the analysis of many different aspects of pump operation. The pump performances such as, loading, power, bearing water usage and vibration is examined. The discussion of these areas will include their basic operations and any problems or failures experienced.

The expected pump loading (in amperes) can be evaluated given the TNX test data on the slurry pumps and the Tank 8 sample results for specific gravity (SpG). The specific gravity of the Tank 8 contents, varied from 1.3 prior to slurry pump operation to 1.51 upon completion of sludge mobilization. Therefore, the pump load at 1600 rpm is expected to vary from 91 amps initially to 102 amps upon completion based on the following:

- $\frac{BHP_1}{BHP_2} = \frac{SpG_1}{SpG_2}$

- $BHP = V \times I \times \eta_{eff} \times P.F.$ (where V is the line voltage, I is the motor current, η_{eff} is the motor efficiency, and P.F. is the power factor)

- Manufacturer and TNX Slurry Pump data

The pump motor current varied between 80 amps and 110 amps at 1600 rpm, with the exception of the Riser 3 pump. The current for the Riser 3 slurry pump motor varied between 80 amps and 158 amps, but during the 10" pump run, the loading peaked at 169 amps (for about 2 hours). The nameplate rating of the motor is 165 amps at 1785 rpm. Initially it was thought that the sludge mass in the close vicinity may be hard to mobilize. However, the Riser 3 pump loading did not change even after the pump was driven for longer period. The loading of the other three pumps were consistent and the reason for higher loading for pump 3 at lower pump height could not be properly understood.

The pump vibration data were obtained for all four slurry pumps at various motor speeds. Analysis of both axial and radial readings indicated that even the maximum vibration reading in the tank never exceeded 0.07in/sec, which is well below the prescribed limit of 0.2in/sec. The vibration data matched with the previous data collected at TNX, which is also 0.07in/sec. The pumps were never run in the predetermined resonance speed region and vibration was never considered a problem.

During coupling of pump shaft to the motor in September 1999, a binding problem was observed in Riser 1, 3 and 8 Slurry Pumps, which were installed at the operating level of 50" from the tank bottom. The slurry pumps were in direct contact with the waste. Riser 5 Slurry Pump, which was installed in the vapor space at 66" was also then lowered to the operating level and coupled to the motor with no abnormal shaft resistance noted immediately during the process. The binding problem was attributed to a 8-10 mil thick Tungsten Carbide (WC) coating in the immediate area of the lower product lube bushing. The coating was applied via a spray process (Jet-Kote) using Cobalt (12% wt) as the binder agent. Test of the coating material demonstrated that the WC coating was susceptible to corrosion causing physical breakdown of the coating due to the exposure of the radioactive waste material. It was concluded that the most probable cause of the binding is accumulation of corrosion products and coating particles between the product lube bushing at the pump shaft. The above conclusion was consistent with the field experience we later had in Riser 5 when the Slurry Pump became bound only after two weeks of exposure to the waste material.

Besides the above binding problem, there were some minor mechanical problems experienced during the actual running of the pumps. The problems did not interfere with the routine operation of the slurry pumps, each of which completed almost 1500 hours of running with progressive lowering from 50" to 10" level. Some of the problems associated with the Slurry Pump running have been covered in the Slurry Pump Operation section at different pump heights in the previous pages.

However, the following experience will be used as lesson learned for future slurry pump installations.

a) A rubbing noise was observed in Riser 1 Slurry Pump during operation. The noise was more pronounced at 50" and 10" levels. Engineering evaluation indicated insufficient clearance between the pump and riser since the riser was not perfectly cylindrical and the gusset on the pump column was rubbing against the riser. The vibration reading was taken and was found within limits. It was decided to keep the pump running. The motor current consumption of the turntable was not affected due to this indicating that the rubbing may not interfere with the turntable operation. In the future, a template will be utilized during the installation of the pump to maintain sufficient clearance between equipment.

b) Contamination was detected on the rain covers of the slurry pumps in Risers 1, 5 and 8 near the rotating union for the BW connection during preparation for the Tank 8 to 40 transfer. Surprisingly, Riser 3 Slurry Pump, which had a known seal leak did not indicate a similar contamination problem. The rotary joint for the bearing water flexible coupling attached to the slurry pump in Riser 5 failed due to freezing temperature and failure of the temperature controller to switch on the heat tracing. The contamination was detected during the lockout and repairs of the rotating union and follow up RCO survey. The likely cause of the contamination was determined to be due to migration of contaminants through the static systems on Risers 1, 3 and 5 by diffusion. The affected risers were deconned to reduce the level of contamination.

c) The bearing water pressure switch was initially installed at a high level in the slurry pump riser platform requiring seismic scaffolding for accessibility during calibration. In the future, the pressure switches will be relocated on the platform to eliminate the need for scaffolding.

d) The design of the flexible line clamps supporting the bearing water line needs modification. The existing clamp was difficult to adjust when needed during lowering of the slurry pump.

Tank Cooling Systems:

A heat balance study was performed on Tank 8 to analyze heat transfer during sludge mobilization. An equilibrium temperature of 38°C was reached when the slurry pumps were at the 20" level (July 18 to August 2, 2000) and the tank supernate level was 75". Therefore, the heat balance was performed from the data recorded at that pump level[112].

The heat sources added to the Tank were as follows:

a) 244,000 BTU/hr from the slurry pumps (assuming 36% conversion efficiency of motor energy to heat).

b) The average radiolytic decay heat was 90,000 BTU/hr.

c) The amount of heat dissipated from the hotter annulus to the tank was 66,000 BTU/hr.

The sources of heat removal from the Tank were as follows:

a) Heat dissipation through the cooling coils is 330,000 BTU/hr (Based on the operation of 15 out of 34 vertical cooling coils and the 2 horizontal cooling coils with an average chromate cooling water flow rate of 145 gpm.)

b) The heat dissipation from the vapor space through the tank purge exhaust system is 7,200 BTU/hr (Based on average flow rate of 730 cfm.)

c) The heat loss to the surrounding environment is 108,000 BTU/hr at 38°C.

Bearing Water System:

The bearing water system performed satisfactorily but had the following problems:

- The pressure relief device ruptured at least four times during initial startup/pressurization of the BW header. The BW line pressure was adjusted from 30 psi to 27 psi but that did not help. The problem was attributed to incorrect valving sequence in the procedure, which was corrected. Additional reviews should be performed before the system is used for Tank 7 waste removal to ensure that the pressure relief device does not rupture.

- There were several rotometer/slip joint failures due to freezing temperature. Heat tracing was restored for the slip joint and insulation and temporary halogen lights were used to keep the rotometers from freezing. In the future heat tracing tape should be installed to protect against such failure.

- Migration of contamination from the pump columns into supply lines. This problem is not resolved since the migration is suspected to be finding its way through the bearing seals.

- Interference with flex-hose routing at the pumps with structural members during pump lowering. This problem needs to be resolved for future installation.

Gas Chromatograph

Initially, the Gas Chromatograph was very reliable, with the time required between regeneration and calibration being less than 5 days. However, as time went on, the equipment was less dependable. By the 20 and 10 inch runs, some data was lost due to the gas chromatograph inoperability. This inoperability was primarily caused by start/stop shifts for the hydrogen curve integration (software) and to a lesser extent, moisture in the system requiring frequent regeneration. Additionally, the support plate to which the manual valving and rotometers were attached vibrated excessively due to the GC pump operation, which caused the valve settings to drift and the flows to fall out of range. The GC was not designed for the round-the-clock service demanded of it, and therefore was less reliable for continuous duty.

CLFL Monitor

The CLFL monitor never indicated any out of limit condition or alarm during sludge mobilization or transfer. The controller for the CLFL monitor mounted on the HVAC skid has a low operating temperature limit of 32°F and needed protection in freezing temperature. A temporary enclosure with heat tracing was installed to protect from freeze failure. In future design, the location of the outdoor controller should be reviewed for adequate freeze protection.

Reel Tape

The new style wet and dry reel tape installed in Tank 8 did not operate below 10.4". The use of the reel tape was restricted for material balance purpose below the tank level of 100", while the slurry pump was in operation due to potential for entanglement with the bent thermowell pipe. In FDB-2 there are two Mag-flow monitors installed on the supply and discharge sides of the transfer pump. Those flow monitors were utilized for material balance purpose for the first time with prior calibration and validation. The reel tape should be replaced in the future to operate at the 0" level.

Valve Box Conductivity Probes

Several spurious alarms were initiated during cold and rainy weather due to accumulation of condensate. Such alarms were difficult to clear due to lack of accessibility inside the valve box. Heat lamps were used to evaporate the moisture and keep the air dry which was a slow process. There were Gem pak relay failures in the alarm control circuits, which had been identified as a chronic problem. An improved design used in limited applications have been found successful and will be implemented.

Instrument Air Supply

The instrument air supply was reliable. The air supply was lost only once, but Operations responded quickly and restored portable air before the CLFL monitor was impacted.

Slurry Pump Local Switches

These were installed but not used for over a year while construction finished other work for WR on Tank 8. During this time, the slurry pump local stop/reset switches lost conductance (probably due to oxidation) and on one occasion would not allow starting of the pumps when set in the reset position.

FPT-1 Pulse Tube Agitator (PTA): Although our objective of keeping the pump tank agitated was successfully achieved, the operation of the pulse tube agitator was far from satisfactory.

The agitator was susceptible to failure particularly during freezing temperature. The supply nozzle was blocked with frozen condensate and traces of oil particles were cleaned during troubleshooting. A compressor with an oil separator and air drier was deployed to resolve the problem.

In addition to the above problem, the operation of the PTA was also unpredictable. The PTA had repeated shutdowns after a few cycles of operation without indicating any error code and would restart after resetting the Prescon Controller without any adjustment. It was found that the Prescon Controller is connected to the same duplex receptacle where a portable room heater was also connected. The room heater was disconnected to eliminate possible interference, but that did not solve the problem. The vendor of the Prescon Controller has committed to furnishing an updated model of the controller to determine if the cause of the repeated shutdowns were due to a faulty controller. A "Lessons Learned" will be issued at the conclusion of the PTA trouble shooting effort.

Transfer System Performance

A study of the transfer system performance using the field readings and comparing with the predicted system behavior, was performed for the three transfer pumps cascade operation. The transfer from Tank 8 to 40 involved three pumping systems coupled in series. The first system is from Tank 8 to pump tank FPT-1 (located at FDB-2). The second system is from FPT-1 to pump tank HPT-7 (located at HDB-8). The third system is from HPT-7 to Tank 40. The system performance for all three subsystems was evaluated using a non-Newtonian fluid flow model and using rheology of 11 wt% insoluble solids. Earlier review of the pump curves and transfer line length indicated that the limiting leg is between FPT-1 and HPT-7 and that the Tank 8 TTP flow rate was too high. It was determined that the limiting leg will be restricted to 100 gpm. The TTP impeller was trimmed from 11" in diameter to 8" to obtain a more favorable flow and head performance.

Overall, it may be concluded that the following objectives were successfully achieved during the sludge transfer evolution.

a) Desired flow rate through inter area transfer line was maintained at an average of 100 gpm.

b) Succeeded in maintaining a continuous and synchronized transfer between the three independent sub-systems of pumps and pump tanks in F and H-Area, which are approximately 2 miles apart.

c) The campaign to mobilize the maximum possible sludge in a single continuous transfer was successfully completed.

d) During movement of the sludge/ slurry, which exhibited the characteristics of a Bingham plastic fluid, no line pluggage interrupted the transfer in the two and a half mile long transfer route .

Performance of the Individual sub-systems during the transfer can be summarized as follows:

Tank 8 to FPT-1 Transfer System

This is the relatively shortest leg compared to the entire transfer route. The Tank 8 TTP was operated at various speed ranges from 1455 to 1500 rpm and 1802 to 1807 rpm. The flow rate was measured corresponding to each speed with mag flow meter readings. FDB-2 has two mag flow meters installed on the supply and discharge sides which provide volumetric flow rate and total flow data. The statistical average of flow rate was calculated to obtain the average flow rate for the target speed of 1500 rpm and 1800 rpm. The expected flow rate at 1500 rpm and 1800 rpm are derived from the system/pump performance curves. The values for the actual and the expected flow rate are tabulated below[111]. It can be seen that the actual flow rate is 23 to 24% below the expected flow rate. The deviation is attributed to the variation of static head during the transfer, difference in transfer line resistance due to restrictions, possible inaccuracy in the pump curve developed after the impeller trimming, etc. However, in spite of the deviation, the desired average flow rate of 100 gpm was maintained.

Pump Speed (rpm)	Expected Flow rate (gpm)	Actual Flow rate (gpm)
1500/ 1800	120/ 157	92.1/118.1

FPT-1 to HPT-7 Transfer

This system included the two mile long inter area line which is significantly longer compared to the other two sub systems. The FPT-1 pump speed was measured in frequency output, which is converted into rpm. The FPT-1 pump was operated in a range of 1617 rpm to 1764 rpm. The flowrate was measured from the inter area line discharge flow loop mentioned in the previous paragraph. The expected flowrate was derived from the pump performance curve. The following table provides the actual and predicted flow rate for the operating range of pump speed[111].

Pump Speed (rpm)	Expected Flow rate (gpm)	Actual Flow rate (gpm)
1617 - 1764	87 – 95.3	86.7 - 105

The actual and the predicted flow rates are in very close agreement for the pump speed between 1600 rpm and 1650 rpm (<1%). However, at higher speeds the actual flow rate was 7-9% higher than the predicted flowrate, which is an acceptable deviation considering the transfer distance and the number of variables. A significant observation during transfer interruption was that the natural movement of the slurry between the high point and HPT-7 was very sluggish possibly due to the insufficient slope of the line. It appeared that significant amount of slurry was left in the line and did not drain to HPT-7.

HPT-7 to Tank 40

This system is comprised of a relatively short leg with a pump size considered adequate to maintain a target flow rate of 100 gpm. There is not a flow meter installed in this leg and we relied on indirect measurement for determining the flow rate. Initially the pump was operated on "Manual" but once the system stabilized, the pump was placed on "Auto". With "Auto" control the pump speed is adjusted to maintain a pre-set pump level. Assuming the level was maintained constant in HPT-7, the pump discharge was the same as the inlet flow. Hence, the flow rate measured in the FPT-1 to HPT-7 system was used for comparison with the predicted flow rate. The HPT-7 pump was operated between 1796 rpm and 1843 rpm. The statistical average speed was 1825 rpm and the expected and actual flow rate for the average speed is tabulated below[111]. It is found that the actual flow rate is 22% below the predicted flow rate. It is interesting to note that the results are similar and in very close proximity to the Tank 8 to FPT-1 flow comparison. The parameters influencing the flow rate are also similar to the ones described for Tank 8 to FPT-1.

Pump Speed (rpm)	Expected Flow rate (gpm)	Actual Flow rate (gpm)
1825	125	97.3

The above analysis utilized Darby's approach[111] for the solution of Bingham Plastic fluid (such as sludge/slurry). A similar comparison for future transfers will help us understand if a pattern of consistent discrepancy exists between the expected and actual flow and applying a correction factor will be appropriate.

Flush Water Usage During and Post Transfer period

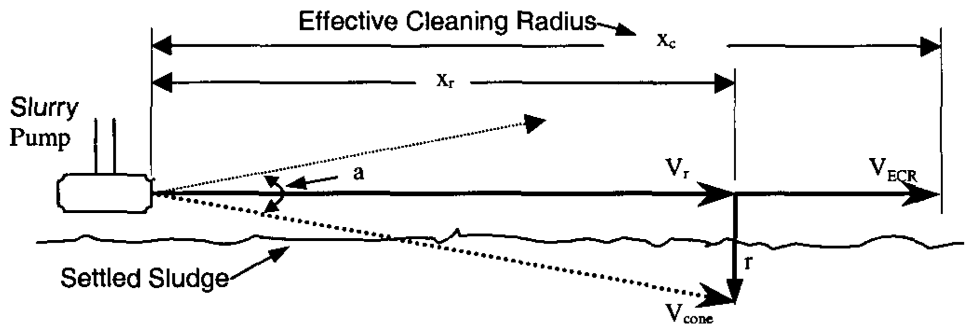
The amount of flush water added to Tank 40 during confirmation of the transfer path through the IAL was more than anticipated. Approximately 30,000 gals were added to Tank 40 during the pre-transfer flush and initial transfer line verification. The excessive amount of flush water usage was due to the various problems encountered during stabilization of the operation of the pump tanks and the coordination required between FPT-1 and Tank 40 before the transfer. A calculation was performed to determine the maximum acceptable sludge concentration in the FPT-1 and HPT-7 in order for the pump tanks to be declared "non-slurry" tanks. The calculation also determined the amount of flush water needed to dilute the pump tanks slurry concentration after the transfer. The maximum acceptable slurry concentration was calculated to be 1.4 wt%[59] insoluble solids. The approximate volume of flush water required to obtain 1.4 wt% insoluble solids is 23,000 gallons[59] (flushing from FPT-1 to Tank 40). The post transfer flush was achieved by flushing for 4 hours at 100 gpm. An additional 1,000 gallons of flush water was used to flush between FPT-1 and Tank 8.

SLUDGE DISTURBANCE MONITORING

The ability of the slurry pumps to disturb and mobilize the settled sludge was evaluated using sludge sounding, waste temperature, and hydrogen release data. During the pump runs at the 50", 40" and 30" pump heights, sludge soundings were utilized to determine the amount of sludge disturbed and when it was acceptable to lower the pumps. The rate is higher at the beginning of the pump run at a particular height, and then gradually decreases until the ECR is fully developed (where the rate goes to zero because the turbulent jet forces at that disturbance depth can not overcome the yield stress of the settled sludge). This profile agrees with the hydrogen data, which also suggested that more sludge/trapped gas is disturbed initially during the pump run than after a period of time at the same pump speed. The maximum measured disturbance depth, vertically from the centerline of the discharge nozzle, was 28". This was measured at Riser 4 using the reel tape in the sounding mode. A method was investigated to estimate the disturbance depth under each slurry pump developed by the adjacent pump. This was used to establish a reasonable criterion for lowering the slurry pumps that could be measured by existing field instrumentation. Assuming the yield stress of the settled sludge is homogeneous, and the slurry pump discharge behaves as a turbulent jet in the slurry, a disturbance depth profile can be charted based on turbulent jet theory solved for constant velocity. The velocity "force" at the settled sludge interface is equal to the yield stress required to disturb and mobilize the sludge. Therefore, knowing a disturbance depth from the jet centerline to the sludge interface (sludge sounding) at a specific radial dimension from the slurry pump discharge nozzle (distance from Riser 3 to Riser 4), a disturbance depth profile can be charted. Applying this technique, a maximum sludge sounding height requirement at Riser 4 was calculated at the 40" and 30" runs to determine when the slurry pumps had cleared enough sludge beneath the adjacent pump to allow unhindered lowering of the pumps to the next level.

The empirical formula (Eq. 2) used in the turbulent jet theory to determine the disturbance depth profile uses a constant (40) applicable when air is the jet fluid and medium. When the medium is a sludge/slurry, the constant needs to be evaluated for likely change. Because the jet angle is a function of slurry density and viscosity, the radial distribution (sludge disturbance depth) characterized by turbulent jet theory must be a curve to provide an appropriate relationship for sludge/slurry applications. In the following application, a new constant was derived applicable for sludge/slurry based on Tank 8 operating data.

This constant velocity curve is derived from the turbulent jet theory as follows:



$$\frac{V_{ECR}}{V_0} = K\frac{D_0}{ECR}$$ Velocity along jet centerline[108] Eq. (1)

$$\log\left(\frac{V_r}{V_{cone}}\right) = 40\left(\frac{r}{x_r}\right)^2$$ Radial velocity along jet cone[108] Eq. (2)

where:

V_{ECR} = centerline fluid velocity at the ECR
V_0 = fluid jet velocity at the nozzle
K = constant
D_0 = jet nozzle inside diameter
ECR = x_c =maximum centerline distance from jet nozzle
V_r = centerline fluid jet velocity at distance from the jet nozzle
V_{cone} = fluid velocity at surface of the turbulent jet "cone" at distance x_r from the jet nozzle
r = disturbance depth of the jet at distance x_r
x_r = centerline distance from jet nozzle to jet cone radius r
40 = constant applicable for air (modified for sludge/slurry application)

Rearranging Equation 1 for V_{ECR} gives:

$$V_{ECR} = \frac{KV_0 D_0}{ECR} \qquad \text{Eq. (3)}$$

Now, set V_{ECR} (Equation 1) equal to V_{cone} (Equation 2). The ECR is defined as the point at which the force of the turbulent jet is just equal to the yield stress of the settled sludge along the centerline of the jet. The closer to the jet nozzle, the greater the velocity, thus the sludge is mobilized in this area. When further from the jet nozzle and the velocity less than at the ECR, the force is not great enough to mobilize the sludge. By setting V_{ECR} equal to V_{cone}, the profile of the sludge boundary where the force of the jet is equal to the yield stress is defined. This profile is the disturbance depth of the jet.

Thus, Equation 3 becomes:

$$V_{Cone} = \frac{KV_0 D_0}{ECR} \qquad \text{Eq. (4)}$$

Rearranging Equation 1 for V_r gives:

$$V_r = \frac{KV_0 D_0}{x_r} \qquad \text{Eq. (5)}$$

Combining Equations 4 and 5 and simplifying gives:

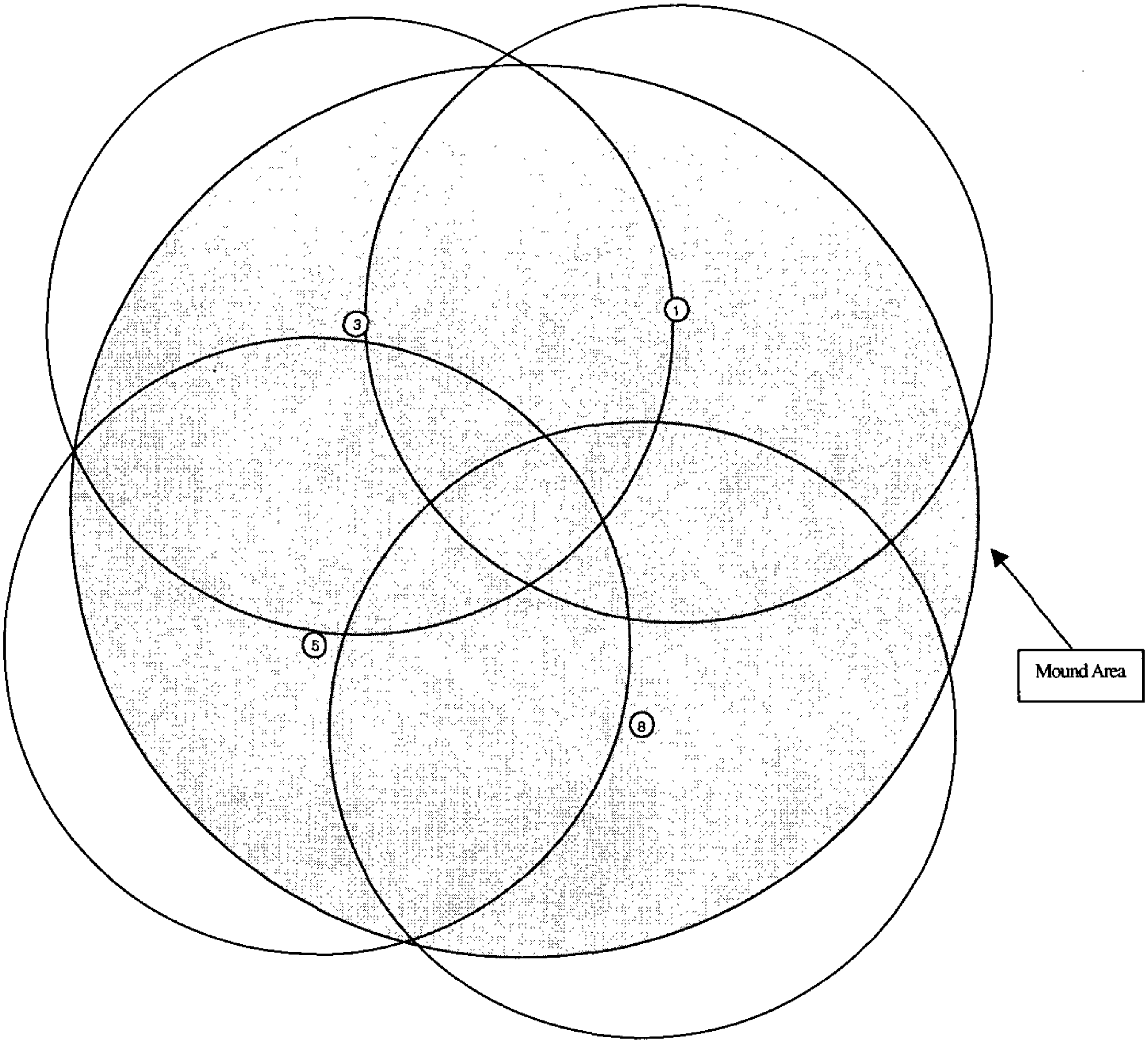
$$\frac{V_r}{V_{Cone}} = \frac{ECR}{x_r} \qquad \text{Eq. (6)}$$

Substituting Equation 6 into Equation 2 and solving for r gives:

$$r = x_r \left(\frac{\log\left(ECR/x_r \right)}{40} \right)^{0.5} \qquad \text{Eq. (7)}$$

From Equation 7, a radial profile can be generated of the sludge disturbance depth. The value for x_r is 18' (the distance between Riser 3 slurry pump and Riser 4 reel tape). This Equation can be modified for sludge/slurry from reel tape sludge soundings and visual determination of ECR. The maximum sludge disturbance depths measured using the Riser 4 reel tape were 27.73" (at 50" pump height), 27.07" (at 40" pump height), and 28.35" (at 30" pump height). After the sludge slurry was transferred to Tank 40, the remaining sludge inventory was estimated[109]. Only one mound remained in the East Side of the tank. The size of the mound, and the lack of mounds in the North, West, or South quadrants, agrees remarkably well with a 26' ECR footprint shown below.

Tank 8 @ 26' ECR

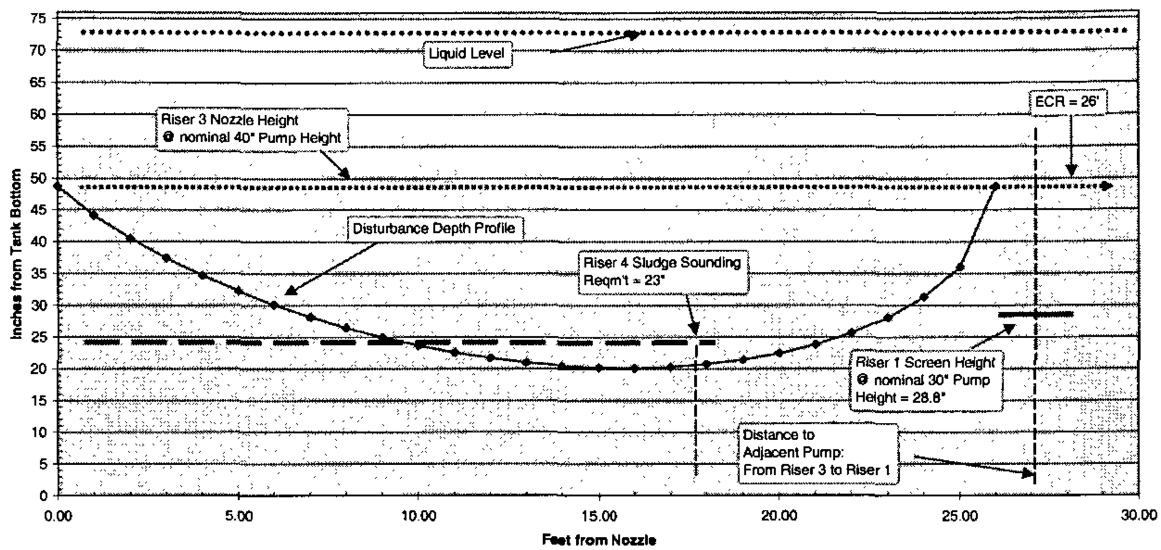


Therefore, adjusting the constant in Equation 7 using a 26' ECR and a 28" disturbance depth, yields a new value of 9.5 for Tank 8 application. Thus, Equation 7 becomes:

$$r = x_r \left(\frac{\log\left(\frac{ECR}{x_r} \right)}{9.5} \right)^{0.5} \qquad \text{Eq. (8)}$$

Plotting Equation 8 for the 40", pump height provides:

Constant Velocity Profile (40" Pump Height)



The Tank 8 evidence supports this radial profile in that sludge disturbance levels were measured by reel tape, and corroborated by temperature profile readings, and that the remaining mound was located outside of the ECR with a relatively steep slope. Based upon this, several conclusions can be made:

- When adjusted to a speed of 1780 rpm, the ECR achieved for Tank 8 was 29'. This is similar to the ECR obtained in Tank 16[92] (30') at a speed of 1780 rpm. Thus, the effects of the dehydration history did not have a significant impact on the effectiveness of the slurry pumps. This agrees with the conclusions of the rheological analysis of the sludge slurry performed at the 20" pump height.

- The ECR did not clean beneath the adjacent slurry pump, therefore, the ability to lower the pumps was a result of pump suction flow effects (a 12" mobilization depth required to clear for 10" lowering) as well as settled sludge that yielded without detection by the rigging dynamometer.

Final Sludge Volume Remaining in the Tank

Upon completion of the transfer, the final sludge inventory was estimated using the video recordings of Tank 8 on the last day of the transfer, 1/25/01. Since no direct measurement is possible, we relied on visual estimation, only utilizing internal tank equipment as landmarks. It has been observed that there is a sludge mound of significant size on the East Side of the tank wall. There are small valleys or pockets with accumulation of liquid supernate throughout the tank bottom. The column bases and the top of the horizontal cooling coils are visible on the east half of the tank, where as it is immersed on the west side. A sludge sounding reading was obtained from riser 2 on 2/01/01 using a steel tape, which indicated a heel level of 6.7". The steel tape reading confirmed that the bottom thermocouple in Riser 4 is still operational. However, visual estimation from the video recording indicated that the average sludge level is less than 6.7"and the sludge distribution is uneven. Since the sludge level left is so low, reel tape measurement is impossible. Review of the exposed column bases, the vertical cooling coil supports and the exposure of the horizontal cooling coil, indicated that the level varied from the West Side to the East Side of the tank. This may have resulted from the fact that the bottom clearance of the Riser 1 and 8 slurry pumps, which are located on the east half of the tank is, approximately 8 ¾" and the clearance for Riser 3 and 5 slurry pumps is 12" to 12 ¾". The average level on the east side is estimated at 3" and on the west side, it is estimated at 5". This simplified assumption, together with the visual estimation of the contour of the sludge mound and the water marks on the east wall were used in calculating the sludge mass. The total sludge mass remaining in the tank is approximately 5,700 kg[109]. The sludge mound itself is 2,700 kg, which is included in the total sludge mass calculation. The total remaining sludge volume is estimated to be 15,000 gallons[109]. Since the above estimated sludge volume met the targeted transfer goal as defined in the path forward logic[107], and the level of sludge was only 3"-5" (excluding the mound) which was very close to the minimum effective transfer pump level, a second slurry transfer was not required.

An evaluation[110] has already been performed to determine if the exposed sludge can become dry in the near future increasing the radiological risk factor and if any compensatory measure is warranted. It is concluded that no action is required immediately and a re-evaluation should be performed within a maximum of a one-year period. Tank 8 lay-up will be prepared to address the long-term operational status of the tank.

Section 7

References

[1] WSRC-TR-96-0325, P. E. Zapp, "Inhibitor Limits for Tank 8F During Sludge Removal," October 1996

[2] Electronic file, "WCS Characterization Database – WCSystem.xls," Server WG-08

[3] DPSP-85-21-2, "Waste Management Programs Report for February 1985," February 1985

[4] M-CLC-F-00584, Rev. 2, E. J. Freed, "Tank 8 Waste Removal Cooling Water Flowrate Requirements," May 15, 2000

[5] G-TRT-G-00003, Rev. 18, "LRWHF TSR Administrative Control Compliance Requirements," February 2000

[6] Memorandum, M. L. Wikle to P. J. Shippy, "Type I Tank Slurry Pump Requirements Study," October 30, 1984

[7] M-CLC-F-00617, Rev. 0, P. J. Bhatt, "Tank 8 Slurry Pump ECR," December 23, 1999

[8] S-CLC-F-00318, Rev. 0, H. Bui and M. J. Turek, "Evaluation of Tank 8F Actual Sludge Versus Theoretical Sludge Agitated During Slurry Pump Operations," December 16, 1999

[9] HLW-STE-2000-00458, B. Wiersma to E. J. Freed, "Addition of Sodium Nitrite to Tank 8," October 26, 2000

[10] Memorandum, A. F. Michelini to J. T. Granaghan, "Inter Area Sludge Transfer Pumping Requirements," November 18, 1982

[11] HLW-STE-99-00298, Rev. 1, M. J. Turek to E. J. Freed, "Tank 8F to Tank 40H Sludge Slurry Transfer Path ARM Requirements for Inhalation Dose Protection," September 27, 1999

[12] DPST-84-100, T. Motyka, "Technical Data Summary for In-Tank Sludge Processing," April 1984

[13] DPST-87-271, J. M. Fazio, "Results of Sludge Slurry Pipeline Pluggage Tests," February 6, 1987

[14] DPSP 79-17-17, C. Comly, "Tank 16 Demonstration Multipump Test Results," June 29,1979

[15] WSRC-TS-96-14, Rev. 6, "F-Area Tank Farm – Technical Safety Requirements," May 2000

[16] WMP-88-3605, C. H. Ashford, "Project S-2081 Waste Removal Program Revised Riser Probing Schedule," August 16, 1988

[17] WSRC-RP-96-273, M. R. Poirier, "Tank 8 Sludge Removal Operating Plan," April 30, 1996

[18] WER-HLE-930638, C. L. Sharpe to M. J. Mahoney, "Pump Level Limit Study," May 12, 1993

[19] C-CLC-G-00332, Rev. 1, S. Khan, "Slurry Pump & Structural Steel Platform Vibration Interface Evaluation for Type I & II Tanks," November 29, 1999

[20] M-ESR-F-00016, Rev. 0, P. N. Bhatt and R. W. Simmons, "Tank 8 Slurry Pump Postulated Over-Speed Condition," April 5, 2000

[21] X-CLC-F-00208, Rev. 0, E. J. Freed, "Methodology for Slurry Pump ECR and H_2 Release," April 27, 2000

[22] PEC-EAT-00-0035, C. A. McKeel to E. J. Freed, "Transfer Pump Lifting," August 9, 2000

[23] Bode Plots, pump and motor vibration, TNX Tank 8 TTP Test with 8" impeller, May 26, 1999

[24] R-0993-4PK, Technical Associates of Charlotte, Inc., "Criteria for Overall Condition Rating (Peak Overall Velocity, in/sec)," 1993

[25] J-DCP-F-95024, Rev. 0, "System Piping of the F to H Area Inter-Area Line (IAL), Transfer Pump Limits," June 27, 1995

[26] DPST-84-439, B. A. Hamm, , "High Level Caves Rheological Studies of Tanks 15H, 42H, and 8F Sludge/Slurries," April 11, 1984

[27] DPST-81-324, T. Motyka, "Estimating the Floc Size and Concentration of Waste Slurries for Use in Determining Transport Conditions for Inter-Area Transfers," March 16, 1981

[28] HLW-HLE-97-0150, C. I. Aponte, "DIWF Well Water/Inhibitor Ratio for Inter-area Transfer Line Flush After Tank 34F to Tank 39H Transfer," May 19, 1997

[29] WSRC-TR-99-00415, P. E. Zapp, "Recommendation of Sampling Frequency for Tank 8," October 1999

[30] WSRC-TR-98-00130, Rev. 1, "Sample Frequency for Tanks that Contain Waste with a High Hydroxide Concentration," October 1999

[31] M-CLC-F-00488, Rev. 0, K. Kwon, "Tank 8F Heat Balance Analysis," October 21, 1998

[32] DPSP-56-405, C. G. Waite, "Study of Heat Evolution and Heat Transfer in F Area High Level Waste Tank No. 1," February 7, 1956

[33] M-CLC-F-00589, Rev. 1, E. J. Freed, "Tank 8 Waste Removal Thermocouple Elevations," April 20, 2000

[34] J-ESR-F-00006, Rev. 1, E. J. Freed, "Tank 8 Thermocouple Designations," 10 May 2000

[35] M-ESR-H-00056, Rev. 0, P. J. Bhatt, "Tank 8 H&V System Evaluation," October 29, 1998

[36] HLW-WPT-99-0039, F. A. Simonetti, "Investigation Report on Increasing Activity at Tanks 51 and 42 HEPA Filters," May 12, 1999

[37] J-CLC-F-00206, Rev. 0, S. J. Strohmeier; "Tank 8 Purge Exhaust Flow Instrumentation Evaluation," December 20, 1999

[38] HLW-STE-2000-00178, P. S. Mukherjee to E. J. Freed, "Tank 8 Purge Exhaust Monitor PMT Flow Verification by Air Balance Group," April 24, 2000

[39] J-CLC-H-00609, Rev. 0, E. Y. Hwang, "ITP Instrumentation Uncertainties Evaluation – ITP/ESP Waste Tank Primary Purge Vacuum Gage Instrument Loops HB-241-940-HV-PDI-2048A, et al, Uncertainties," July 17, 1997

[40] WSRC-TR-99-00205, "CST/WPT Facilities Justification for Continued Operations," August 1999

[41] S-CLC-F-00316, Rev. 1, J. K. Norkus and D. K. Allison, "SRS Tank 8F Agitation Via Slurry Pump Operation," December 16, 1999

[42] WSRC-TR-99-00450, Rev. 2, C. D. Cope, "Safety Evaluation for Tank 8 Hydrogen Depletion," May 2000

[43] WSRC-TR-99-00069, F. G. McNatt, "Annual Radioactive Waste Tank Inspection Program – 1998," April 1999

[44] WSRC-TR-93-595, P. E. Zapp, "Potential for Erosion Corrosion of SRS High Level Waste Tanks," January 1994

[45] T-CLC-H-00394, Rev. 0, V. N. Chaudhari, "Type I Tank Shell Forces for Normal Operating Conditions & Seismic Loads," May 24, 1999

[46] DPST-82-472, A. W. Wiggins, "Jet Impact Force Studies," May 5, 1982

[47] M-DCP-F-98031, Rev. 1, "Tank 8 – Relocate Fixed Length Jet from Riser #6 to Center Riser," February 23, 1999

[48] T-CLC-F-00138, Rev. 0, C. A. McKeel, "Stress Analysis for Tank 8 Fixed Length Jet," April 15, 1999

[49] PEC-EAT-99-0051, C. A. McKeel, "Tank 8 Riser 4 Thermowell," August 27, 1999

[50] T-CLC-F-00153, C. A. McKeel, "Tank 8 Riser 4 Thermowell Stress Analysis," August 26, 1999

[51] C-CLC-G-00332, Rev. 1, S. Khan, "Slurry Pump & Structural Steel Platform Vibration Interface Evaluation for Type I & II Tanks," November 29, 1999

[52] Memorandum, R. L. Boyleston to G. M. Johnson, "Ballast Requirements During Waste Removal," February 27, 1981

[53] Memorandum, J. Newman to E. J. Freed, "Tank 8 Ground Water Level Information Request," September 9, 1998

[54] WSRC-TR-98-00160, R. H. Ross, "Nuclear Criticality Safety Assessment of Tank 8F Sludge Removal," April 27, 1998

[55] HLW-OVP-98-0037, Rev. 10, "High Level Waste System Plan," June 1999

[56] M-ESR-F-00011, Rev. 5, J. J. Purohit, "F-Tank Farm Waste Transfer System Credible Transfer Path; Siphon and Water Hammer Evaluation," August 7, 2000

[57] M-CLC-F-00676, M. J. Singleton, "Tank 8 Waste Removal Pump Tank Concentrations During Dilution Operations," November 2000

[58] WSRC-RP-2000-00183, Rev. 0, E. T. Ketusky, "Waste Compliance Plan for Liquid Waste Transfers from Tank 8 to WPT/ESP Tank 40," December 6, 2000

[59] X-SD-H-00001, "Waste Pretreatment Facility Waste Acceptance Criteria for Waste Entering the Extended Sludge Processing Tanks 40, 42, and 51," November 1999

[60] M-CLC-F-00577, Rev. 0, T. B. Caldwell, "System Curve Prediction Tank 8F to FPT1" July 18, 2000

[61] M-CLC-F-00586, Rev. 0, E. J. Freed, "Tank 8 Waste Removal Slurry Gravity Draining in Core Pipes," July 17, 1999

[62] M-ML-G-0005, Rev. 5, E. Nomm, "Structural Integrity Database (F/H Areas)," September 9, 1999

[63] N-ESR-G-00001, Rev 65, "F/H Tank Farm Emergency Response and Waste Tank Status Data," February 28, 2000

[64] Memorandum, B. L. Taber to J. A. Monier, "Inter area Waste Transfer Pipelines – Design Related Operating Limits," November 6, 1967

[65] DP-1136, C. B. Goodlet, "Transfer of Radioactive Slurries", June 1968

[66] DPSOX 9955, B. A. Hamm, "Transferring Sludge Slurries Via the Inter Area Line," April 21, 1986

[67] M-CLC-H-01008, Rev. 1, A. K. Vovides, "NWTF Transfer Lines Pressure Limitations," March 31, 1995

[68] M-CLC-H-01242, J. J. Purohit, "Transfer Pumps Operating Speed Ranges for Inter Area Line," December 7, 1995

[69] M-CLC-G-00263, J. J. Purohit, "Over Pressurization – F&H Area Waste Transfer System," September 9, 1998

[70] M-ESR-H-00075, Rev. 1, P. J. Bhatt, "Tank 8 Transfer Study," June 2, 1999

[71] HLW-STE-2000-00469, Rev. 1, H. G. Desai to D. J. Martin, "Structural Qualification of Transfer Lines from Tank 8 to Tank 40," December 5, 2000

[72] ESH-HPT-99-0059, N. L. Savin to M. J. Turek, "Shielding Evaluation for Transferring Tank 8F Sludge to Tank 40H," March 16, 1999

[73] ESH-HPT-99-0096, N. L. Savin to M. J. Turek, "Shielding Evaluation of Updated Transfer Route for Transferring Tank 8F Sludge to Tank 40H," April 20, 1999

[74] ESH-HPT-99-0205, N. L. Savin to M. J. Turek, "Shielding Evaluation for Transferring Tank 8F Sludge to Tank 40H Using the Corrected Sludge Source Term," September 20, 1999

[75] J.J. McKetta, "Encyclopedia of Chemical Processing and Design," Vol. 51, pp 37-51, Marcel Dekker, 1995

[76] HLWMD-F-190, G. A. Johnson, "Tank 8 Telescopic Transfer Pump TNX Pre-Installation Test", June 10, 1999

[77] J-JX-G-0001, "CSTE Setpoint Database"

[78] M-CLC-F-00649, Rev. 0, E. J. Freed, "Tank 8 Waste Removal TTP VFD Failure Transfer Line Pressure," July 18, 2000

[79] HLW-WRE-2000-00031, S. A. Saunders to M. S. Miller, "Tank 8 Telescoping Transfer Pump Over-Pressurization," July 20, 2000

[80] M-CLC-H-02005, Rev. 0, P. N. Bhatt, "Tank 8 to FPT-1 Transfer Line Pressure Calculation," November 9, 1999

[81] M-CLC-F-00587, Rev. 1, S. J. Strohmeier, "Tank 8 Waste Removal TTP and FPT-1 Pump Overspeed Limits," November 16, 1999

[82] U-TRC-H-01128, J. S. Ledbetter, "Reprogram HPT-7 VFD to Support HTF Intra-Area Waste Transfers," June 15, 1998

[83] M-CLC-F-00682, Rev. 0, "Tank 8 Inhibited Water Flush System Over-Pressurization," November 27, 2000

[84] M-ESR-H-00030, Rev. 0, "Water Hammer Analysis in Inter-Area Liquid Waste Transfer Lines," October 16, 1995

[85] T-CLC-H-00238, Rev. 1, D. A. Amin, "Structural Adequacy Assessment for Postulated Surge Pressure," December, 12, 1995

[86] M-CLC-F-00585, Rev. 0, E. J. Freed, "Tank 8 Waste Removal Slurry Gravity Draining in Pipe Jackets," July 21, 1999

[87] WSRC-SA-33, Rev. 3, " LRWHF Safety Analysis Report," August 1999

[88] M-CLC-F-00629, Rev. 0, G. J. Hutchens, "Estimates of Tank 8 Quiescent Times," December 17, 1999

[89] X-CLC-F-00167, Rev. 0, E. J. Freed, "Tank 8 Waste Removal Sludge Solids in Tank Heel," September 20, 1999

[90] HLW-CST-2000-001, M. D. Johnson to C. A. Everatt, "Tank 8 Pump Startup State Of Readiness," January 25, 2000

[91] WSRC-TR-2000-00366, J. R. Hester, "Hydrogen Releases During Tank 40H and Tank 8F Slurry Runs," September 2000

[92] DPSP 79-17-12, W. West to R. Maher, "Tk 16 Demonstration Single-Pump Test Results,"April 26, 1979

[93] HLW-WRE-2000-00006, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-001; Tank 8 Riser 1 Slurry Pump Rubbing," May 23, 2000

[94] HLW-WRE-2000-00009, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-002; Decision Logic for Lowering Tank 8 Slurry Pumps," May 24, 2000

[95] HLW-WRE-2000-00012, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-003; Riser 3 Slurry Pump Low Amp Concern," June 1, 2000

[96] HLW-WRE-2000-00018, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-005; Decision Logic for Lowering Tank 8 Slurry Pumps from 40" to 30" Pump Height, and Subsequent Startup of Slurry Pumps at 30"," June 15, 2000

[97] HLW-WRE-2000-00025, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-006; Decision Logic for Ramping Slurry Pumps at 30" to Maximum Speed," July 5, 2000

[98] HLW-WRE-2000-00028, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-009; Decision Logic for Lowering Tank 8 Slurry Pumps from 30" to 20" Pump Height, and Subsequent Startup of Slurry Pumps at 20"," July 10, 2000

[99] HLW-WRE-2000-00032, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-010; Decision Logic for Lowering Tank 8 Slurry Pumps from 20" to 10" Pump Height, and Subsequent Startup of Slurry Pumps at 10"," July 24, 2000

[100] HLW-WRE-2000-00038, M. S. Miller to W. C. Clark, "Evaluation in Support of Path Forward WR-PF-2000-010; Decision Logic for Lowering Tk 8 Slurry Pumps from 20" to 10" Height," August 2, 2000

[101] WSRC-RP-2000-00900, Rev. 0, T. L. Fellinger, "Rheological and Physical Data Results for Tank 8 Variable Depth Samples," October 18, 2000

[102] HLW-WRE-2000-00059, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-015; Operation of Slurry Pumps at 10"," August 22, 2000

[103] WSRC-RP-2000-00962, Rev. 0, Swingle, Bibler and Fellinger, "Tank 8F Sludge Slurry Analysis Results," December 13, 2000

[104] HLWE-STE-2000-00458, B. J. Wiersma to E. J. Freed, "Addition of Sodium Nitrite to Tank 8," October 26, 2000

[105] HLW-WRE-2000-00059, Rev. 1, M. S. Miller to W. C. Clark, "Path Forward WR-PF-2000-015, Rev. 1; Operation of Slurry Pumps at 10"," October 26, 2000

[106] HLW-WRE-2000-00088, M. Singleton to B. L. Lewis, "Tank 8 Turbidity Measurements and Variable Depth Samples," November 16, 2000

[107] HLW-WRE-2000-00084, Rev. 0, Miller/Monahon to Clark/Davis/Wells, "Path Forward WR-PF-2000-0021, Rev. 0; Tank 8 to Tank 40 Sludge Slurry Transfer," November 9, 2000

[108] Perry & Chilton, "Chemical Engineers' Handbook," Fifth Edition

[109] X-CLC-F-00233, Rev. 0, M. Singleton, "Tank 8 Post Transfer Sludge Volume," February 6, 2001

[110] HLW-REG-2001-00016, Sludge Exposed in Tank 8, J. Buczek to S. Strohmeier, February 22, 2001

[111] M-ESR-F-00026, Rev. 0, P. N. Bhatt, "Tank 8 to 40 Waste Transfer System Evaluation", (Draft)

[112] M-CLC-F-00720, Rev 0, Ki Kwon, "Tank 8F Heat Balance and Equilibrium Temperature Study ", (Draft)