Improving High Level Waste Solids Mobilization and Transfer through Hanford Double-Shell Tanks - 15099

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ABSTRACT

The Hanford Tank Operations Contractor (TOC) and the Hanford Waste Treatment and Immobilization Plant (WTP) contractor are both engaged in demonstrating mixing, sampling, and transfer system capabilities using simulated Hanford High-Level Waste (HLW) formulations. Efficient and effective handling of solid radioactive waste is essential to the successful completion of River Protection Project (RPP) mission and the Department of Energy's Hanford site. The TOC must transfer over 416 million[1] liters (110 million gallons) of HLW slurry through a complex system of 28 double shell tanks (DSTs) of approximately 3.8 million liters (1 million gallons) each as it is staged and delivered to the WTP. Through the use of scaled tanks and non-radioactive simulants, the TOC has identified operational methodologies for mixer pumps that enhance the movement of the solids through the DST system which will minimize the amount of solids remaining for final tank closeout.

BACKGROUND

Since 2011 three primary phases of scaled tests have been performed by TOC and its subcontractors addressing solids mobilization and transfer in support of the waste feed delivery mission; Scaled Performance, Limits of Performance (LOP), and Solids Accumulation [1]. Two scales of test vessels were utilized during these tests; 1:8 and 1:22 (304.8/120- and 109.7/43.2- cm/-in diameters, respectively) based upon a 2286 cm (900 in) diameter full-scale double-shell tank [2]. Although this testing was successful and produced large amounts of useful data, it demonstrated mixing and batch transfer capability without regard to dead zone (mound) formation. In some cases the simulant used was intentionally designed to enhance mound formation so that solids distribution and mound dynamics could be more readily observed, measured and analyzed. However, at full scale significant solids accumulation could result in inefficient operations and the potential to impact nuclear safety assumptions. These types of adverse mixing effects may complicate waste feed delivery and tank closure ultimately lengthening the overall treatment mission.

In July 2013, a test planning meeting was held to discuss programmatic and technical topics associated with recent and historic Small Scale Mixing Demonstration (SSMD) mixing, sampling and transfer studies for the purpose of developing follow-on test objectives. Substantial input was obtained from ORP and Savannah River National Laboratory, as well as from WRPS engineering and nuclear safety groups. As a result of this consensus input, three key testing priorities were identified to address operational uncertainties:

- Minimize Pile Formation [e.g., maximize Effective Cleaning Radius (ECR)] Testing (Category 1).
- One Pump Testing (Category 2).
- Effects on Mixing and Transfer Due to Minimization of Mixer Pump Impingement Forces Testing (Category 3).

In order to address these priorities Small Scale Solids Delivery Testing (SSDT) was performed.

DESCRIPTION

[1] This volume estimated from the Hanford Tank Waste Operating Simulator model and may change based upon future changes to waste feed delivery acceptance at the Waste Treatment Plant

SSDT was divided into two phases: 'exploratory' using simple water based simulant and 'category' using complex Newtonian simulant. Operational parameters including mixer pump rotational speed, rotational pattern, synchronization, nozzle jet offset, and position were varied to determine the most efficient mixer pump configuration for solids retrieval. The optimized operational parameters were determined by measuring the following performance parameters: ECR, amount of solids transferred and changes in mound volume throughout testing. The operating scenarios creating the largest % ECRs, largest % solids transferred and smallest mound volumes were identified as being "optimized." Test objectives for SSDT testing are presented in Table I.

TABLE I. SSDT Objectives and Success Criteria.

Test Objectives	Success Criteria
Exploratory tests will optimize mixer jet rotational rate, rotational direction, mixer pump synchronization, oscillation and nozzle position offset to maximize test results in Final Category 1 tests.	Successful exploratory tests will define the impact that the varied operational parameters have on tank bottom clearing and determine the most effective configuration for removing solids from the tanks.
Category 1) Using optimized operational parameters from exploratory tests demonstrate effective removal of solids using a complex simulant.	Demonstrate solids removal using complex simulant. Demonstrate mixer pump capability to retrieve solids below the minimum operational limit established for tank volume.
Category 2) Using operational parameters from previous test runs, determine the feasibility of using only one mixer pump to transfer consistent batches.	Measurement of batch transfer characteristics for comparison with previous equivalent tests operating with two mixer pumps.
Category 3) Using test parameters from previous test runs determine effects on mixing and transfer due to minimization of mixer pump impingement forces.	Measurement of batch transfer characteristics for comparison with previous equivalent tests operating with steady mixer pump flow and rotation.

Mixer pump operational parameters optimized during SSDT were based upon full scale pump capability and scaling factors that were previously determined for equivalent bottom clearing performance [3]. For example, the optimized rotational rate for the 1:8 scale mixer pumps of 0.49 rpm using a specified mixer jet velocity equates to 0.1 rpm at full scale [4]. The current full scale mixer pump design specifies a range of rotational speed between 0.05 and 3 rpm which would include the optimized rotational rate found at 1:8th scale. The same parameter selection was utilized for the 1:22 scale tank.

PERFORMANCE PARAMETERS

The three performance parameters (i.e., %ECR, weight % solids transferred, and mound volume) used to determine operational optimization are described in the following sections.

Effective Clearing Radius

The ECR is a measurement of the mixer jet pump's ability to clear the bottom of a tank. A smaller ECR equates to a greater amount of solids remaining on the bottom of the tank. A larger ECR means that a larger portion of solids were suspended by the mixer jets and transferred out leaving a greater area of the tank bottom cleared. A possible exception is if a mound grows vertically which could give the appearance that solids are being removed based on a growing ECR but in reality solids are being redistributed in the mound and remaining in the source tank. For this testing, ECR was directly measured through the transparent tank bottom as the jet sweeps past any mounds formed on the sides of the tanks. The ECR measurement was consistently taken from the center point of the mixer pump to the edge of the solids pile (or dead zone) while mixer pumps were running. When comparing ECRs at two different tank scales, it must be compared as a percentage so that tank diameter is not a factor. %ECR is determined as a ratio of the radius measured from the mixer pump to the edge of the mound over the fixed distance between the center of the mixer pump and the tank wall behind the mound. Consequently a 75% ECR is the same in a 109.7 cm (43.2 in.) diameter tank as it is a 304.8 cm (120 in.) diameter tank regardless of the actual ECR measurement in each tank. Therefore running the same exact test at two different scales should yield the same %ECR which has generally proven to be the case. When % ECR was maximized (or increased as a trend) this was a positive indication that operational parameters are being optimized.

Percent Solids Transferred

Percent solids transferred are an important indicator of how efficiently a specific operational configuration is working. Percent solids transferred can be determined both analytically and empirically. For exploratory testing and category 1 tests it was determined empirically, to support quick turnaround of results. Percent solids transferred for Category 2 and 3 testing was determined analytically[2] (this is further discussed in the results section of this paper). The empirical approach used is as follows: using a Coriolis meter, the mass of material transferred from the tank was determined by monitoring the mass flow rate and specific gravity of the slurry transferred from the tank. When % solids transferred is maximized (or increased as a trend) this was a positive indication that operational parameters are being optimized.

Mound Volume Estimation

Mound volume was estimated by first obtaining mound dimension measurements between each batch transfer and using those measurements to calculate a pile volume. Figure 1 shows how the tape measures were placed on exterior of the tank bottom and sides and the four dimensions that were collected; depth, length, height and width. Mound offset from the centerline of the tank was also measured and recorded. This data was then used to estimate mound volume using an excel spread sheet. Mound volume results were used to compare mound sizes as batch transfers were performed. When mound volume was reduced (or decreased as a trend) this was a positive indication that operational parameters are being optimized.

TEST PHASES

All tests began with a full tank of simulant (operating level) with thorough mixing performed prior to batch transfers. Each test included five equal batch transfers except for category 1 tests which included an additional 5 batch transfers (see below). All simulant batches were transferred into external holding ponds. Batch transfers occurred with either both mixer pumps and transfer pump operating or with just one mixer pump operating and transfer pump operating depending on the test objective (see Cat 2 description). Mixer pump velocity was the same value for each test and held constant except for when it was intentionally varied (see Cat 3 description). Measurements described above were collected between each transfer with the following exception: Coriolis data (fluid flow rate and bulk specific gravity) which was collected every second through a data acquisition system during batch transfers. ECR measurements were collected while the mixer pumps were still operating whereas mound measurements were collected with both mixers shut down. Analytical samples were collected pre-transfer and during the batch #5 pump down of each Category 2 and Category 3 test.

[2] Note the process of collecting samples for analysis and data processing was intentionally left out of the discussion for the sake of brevity.

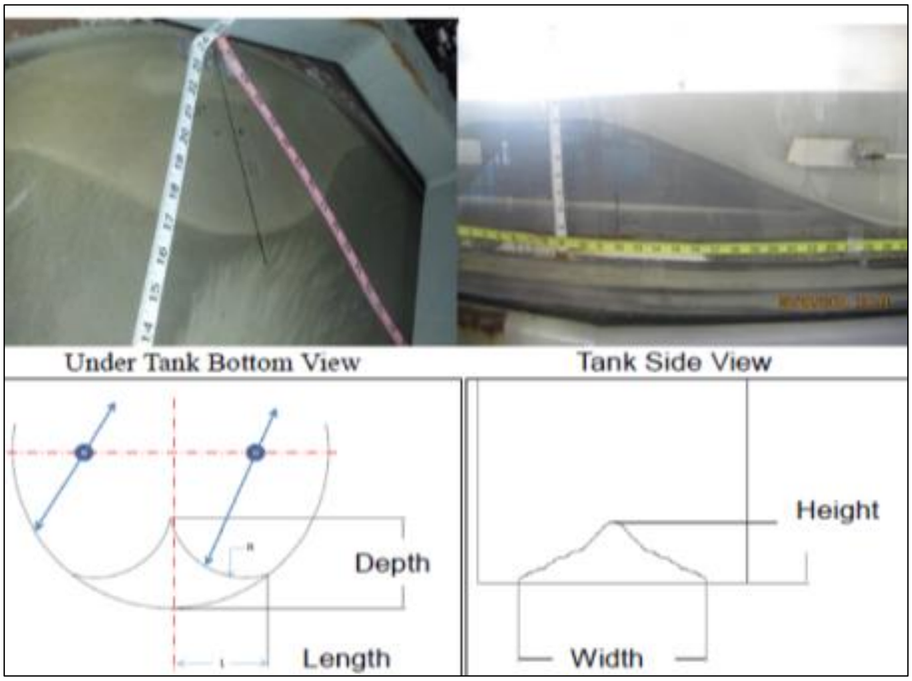

Figure 1. Illustration of Mound Measurements Collected during SSDT

Exploratory (simple simulant) testing utilized both mixer pumps and transfer pump through testing. Simulant included stainless steel, sand, and water as the suspending fluid. As a cost saving measure, exploratory testing optimized operational parameters using the smallest 1:22 scale tank (less cost for simulant and less time to run the tests). Then, using the same simulant, tests were performed in 1:8 scale tank to verify equivalent performance. Operational parameters (i.e., rotational rate rotational pattern, etc.) were equivalent between the two tank scales. The scaling process and equations used to determine initial test parameters used in exploratory testing are described in a separate document [5]. The initial operating parameters were used as a starting point to establish the range of operational parameter values used in the testing. Optimized operational parameters carried forward into Category 1 tests were based upon maximized performance parameters (see discussion on "performance parameters" above). Category 2 and 3 tests were performed using test operational parameters from selected Scaled Performance tests [1]. The equivalent Scaled Performance tests served as the reference cases for evaluating the performance impact of the operational changes made during the Category 2 and 3 tests. In addition to collecting mound dimension, ECR, and Coriolis data, batch transfer samples were collected and analyzed for Category 2 and 3 tests.

Category 1 (Minimize Pile Formation) tests utilized both mixer pumps and transfer pump operating throughout testing with the optimized operational parameters determined from Exploratory testing using complex (Typical/Typical and High/High) simulants (see Simulants description below)**.** The primary test objective (see Table I) was to determine how well solids can be transferred and how well mixer pumps can function below the standard minimum operating level. Cat 1 operational parameters were considered optimized as indicated by performance parameter results as discussed above. When performance parameters trended in different directions preference was given to operational parameters that maximized the % ECR and/or specific gravity of the slurry transferred from the tank. Additionally this testing included a complete solids removal phase (to extent practicable), which included adding a pure water at the end of the final batch in order to mobilize additional solids from the test vessel. Results were also compared back to original run sheets to validate test and analytical performance consistency. Additional batch volumes of water were added back into the tank after the 5th transfer was completed. After one to two batch volumes of water was added back in, the tank was mixed, then one to two batch volumes of slurry was pumped from the tank. This was repeated five times and labeled batches six through ten.

Category 2 (One Pump) tests initially operated both mixer pumps and transfer pump (batches 1 and 2). Batches 3, 4 and 5 were run with just one mixer pump operating. The objective of this test (see table II) was to simulate the loss of one pump during a transfer and determine the extent that mixing and batch transfer consistency is affected. Batches 1 and 2 were run using test operational parameters to a previously run reference case and to verify that the system was performing adequately under more standard conditions. Once standard conditions were met one pump was shut down and the remaining batches transferred. Complex simulants used for Cat 1 testing was also used for these tests. Tests performed had two sample sets. Sample set #1 included pre-transfer samples collected while operating both mixer pumps. These samples represent the feed qualification samples that would be compared to the waste acceptance criterion and are collected before any material is transferred from the tank. Sample Set #2 was collected during batch transfers. These samples are compared to the pre-transfer sample in order to evaluate how consistent the feed qualification samples are to the batches that are transferred. Results from the first two batch transfers were compared back to original run sheets to validate test and analytical performance consistency. Data from the final three batch transfers using a single mixer pump was compared to both the newly generated data using both mixer pumps and data from the reference case. The analytical results of the pre-transfer and transfer samples were compared to previous Scaled Performance test results (See Figure 5 below) and ECR measurements assessed in determining the viability of continued batch transfer in the event that one mixer pump is lost.

Category 3 (Minimize Impingement Forces) testing included use of both mixer pumps and transfer pump matching test operational parameters to a previously run reference case. Complex simulants used for Cat 1and Cat 2 testing was also used for these tests. The same sampling approach used for Category 2 was also used for this testing. Figure 2 below indicates areas in the mixer pump rotation that may require a reduction in mixer jet velocity to avoid unacceptable impingement forces on dry wells. The ±10 percent exclusion zone was determined through a previous engineering analysis [7]. Additional detail is provided in a second calculation [8]. The analytical results of the pre-transfer and transfer samples were compared to previous Scaled Performance test results (See Figure 6 below) and ECR measurements confirmed a reduction in bottom clearing performance when the jets are reduced to avoid damage to in-tank infrastructure.

Simulants

'Simple' simulant was used in performing all exploratory tests as described above. The suspending fluid was water, the solids composition was made up of sand and stainless steel. A bimodal particles size distribution was achieved for sand by blending two sands, small and large, with different particle size distributions. Mass fraction, density and particle size of each solids component are shown in Table II below. Total solids' loading was 15% by mass. In terms of tank waste rheology, particle composition, and solids loading, this composition was expected to be conservative (compared to actual tank waste) but allowed for an easy assessment of parameter effects on pile formation and solids transfer [9].

'Complex' simulant was used in all category tests. The suspending fluid, although water based, included sodium thiosulfate and glycerol as density and viscosity modifiers. Simulant solids (a.k.a. base particles) were mixtures of gibbsite, sand, stainless steel and zirconium oxide. Two simulant combinations were used to match the reference cases; the Typical/Typical uses the Typical supernatant listed in Table III along with the Typical base particles listed in Table II. Similarly, the High/High uses the High supernatant listed in Table III along with the High base particles listed in Table II. The Typical supernate refers to typical density and viscosity values for the projected feed to the WTP; High supernate refers to high density and viscosity values for the projected feed to the WTP The Typical base particles refers to a mixture of particles with a size and density distribution that is comparable to typical Hanford tank waste; High base particles refers to a mixture of particles with a size and density distribution that conservatively bounds the distribution of particle settling/suspension characteristics of most Hanford tank waste [9].

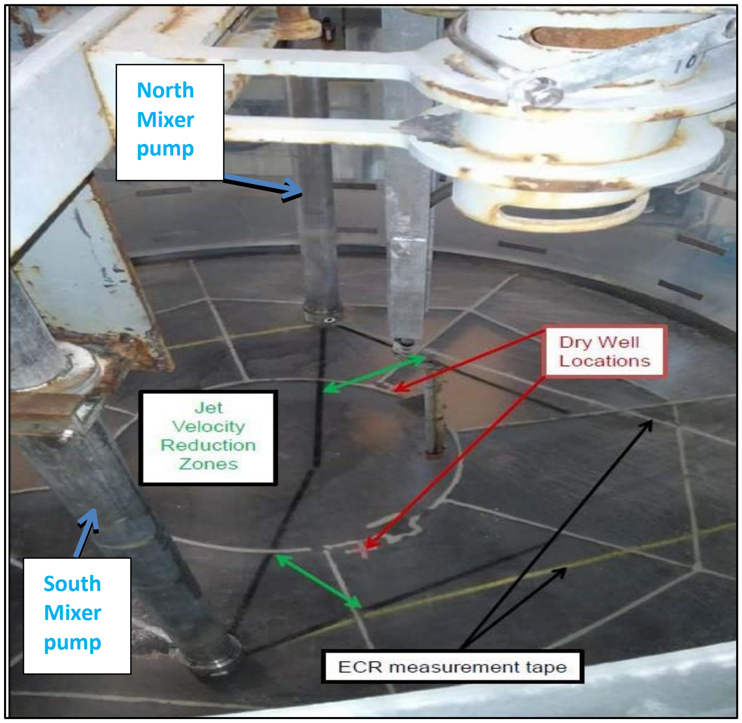

Figure 2. Category 3 Exclusion Zone Markings

TABLE II. Base Particles

Base Particles				
Compound	Solid Density (g/cm^3)	Median Particle Size (micron)	Mass Fraction	
			Typical	High
Small Gibbsite	2.42	1.3	0.27	0
Large Gibbsite	2.42	10	0.44	0.03
Small sand	2.65	57	0	0.35
Medium sand	2.65	148	0.13	0
Large sand	2.65	382	0	0.21
Zirconium Oxide	5.7	6	0.10	0.08
Stainless Steel	8.0	112	0.06	0.33

TABLE III. Newtonian Liquid Supernatant Simulant Characteristics.

Suspending Fluid Characteristics (density/viscosity)	Target Simulant Properties @ 20° C		Simulant Properties @ 20° C		Simulant Composition
	Density (g/ml)	Viscosity (cP)	Density (g/ml)	Viscosity (cP)	
Typical	1.29	3.3	1.284	3.60	31.5 wt.% Sodium thiosulfate
High	1.37	15	1.368	14.6	33.4 wt.% sodium thiosulfate and 19.5 wt.% glycerol

All 1:22 scale tests included both Typical/Typical and High/High simulants whereas 1:8 scale tests used only High/High simulant. Since tests results from Category 2 and 3 testing were compared back to previous test runs, it was necessary to test with both simulant types in the small tank. However all 1:8th scale tests were performed with only High/High simulant to confirm performance was consistent with that observed in the small tank.

TEST RESULTS FOR EXPLORATORY TESTING

Exploratory Tests (ET)--Rotational rate was the first operational parameter tested followed by rotational pattern (continuous rotation vs oscillation), nozzle offset, independent mixer pump operation (Ind Op) and, finally, fixed nozzle position. These are the only operational parameters that could easily be varied within this test platform and are the ones that had the most impact in previous mixing and transfer studies [5]. Mixer pump nozzle height (vertical) from the tank bottom and lateral position were fixed (see Figure 2). Each optimized result was carried forward into the next test segment (i.e., ET-1 best result was used for ET-2 testing and so on). Test progression assumed, without verification, that the optimized condition from one round to the next would be maintained with the next variation in operating conditions. The test matrix for the Exploratory Tests included 19 tests as shown in Table IV. The performance parameters (% ECR, % solids transferred, and mound volume reduction after the 5th batch) were recorded for all but 2 tests[3].

As compared to test result ET-1a (1:22 scale reference case) the operational parameters appearing to have the greatest impact on performance parameters were changes in rotational rate for the 1:22 scale tests and rotational rate and nozzle offset for the 1:8th scale tests (see Figure 3). % ECR and mound volume appears most impacted at the 1:8th scale. At the 1:22 scale only % ECR seems to have been impacted by rotational rate. However to a lesser degree % solids transferred in the 1:22 scale tests was adversely impacted by rotational pattern (rotation vs oscillation), and independent (non-synchronized) operation of the mixer pumps. Test ET-2a-2 which involved synchronized oscillation as opposed to full 360 degree rotation of the mixer pumps showed a 41% drop in solids removal as compared to test ET-1a.

Figure 4 shows how changes in rotational rate and pattern impacted mound volumes. It should be noted that mound volume results were used comparatively and had an undetermined percent error associated with them. The main error associated with mound volume calculations was assigning an appropriate mound shape. Mound volume estimation results were used in a qualitative/comparative manner to quickly determine if mound volume was decreasing between batch transfers as expected [6]. Figure 5 shows that the trend in the normalized mound volume between the 1:22 scale and 1:8th scale tank is generally the same, the volume decreases with increasing batch number. The normalized mound volume for ET-1e (1:8th scale) is higher than the mound volumes observed in the other two 1:8th scale tests (ET-2c and ET-5c). The scaled jet velocity for ET-1e is lower than that of the other two tests so the capability of the jets to re- suspend settled material was lower and resulted in larger mounds. The jet velocity for ET-2c and ET-5c was scaled from ET-1d using a scale factor exponent value a=0.2, but the rotational rates for the two tests were different. The mound volume for ET-2c is higher than ET-5c, which had the slower rotation rate. The initial and final normalized mound volume in ET-2c was nearly equal to scaled equivalent test from the 1:22-scale tank, but the intermediate values were higher. The mound volume after Batch 1 is likely higher because testing stopped after Batch 1 was completed and the mound measurements were made the next day after mixing to get the solids that settled overnight re-suspended. ET-1d and ET-5c had nearly equivalent scale-sized mounds.

However, the rotational rate for ET-5c was slightly lower than the scaled equivalent of ET-1d. This could explain the differences in normalized mound volumes, the lower equivalent rate in ET-5c resulted in lower scaled mound volumes. The difference could also be explained by a scale factor exponent that is not exactly 0.2.

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[3] Tests ET-5a and ET-5b did not yield a %ECR or mound volume data because the measurements required to calculate these values were not obtainable due to poor mixing performance. Therefore results for these tests were excluded from data analysis

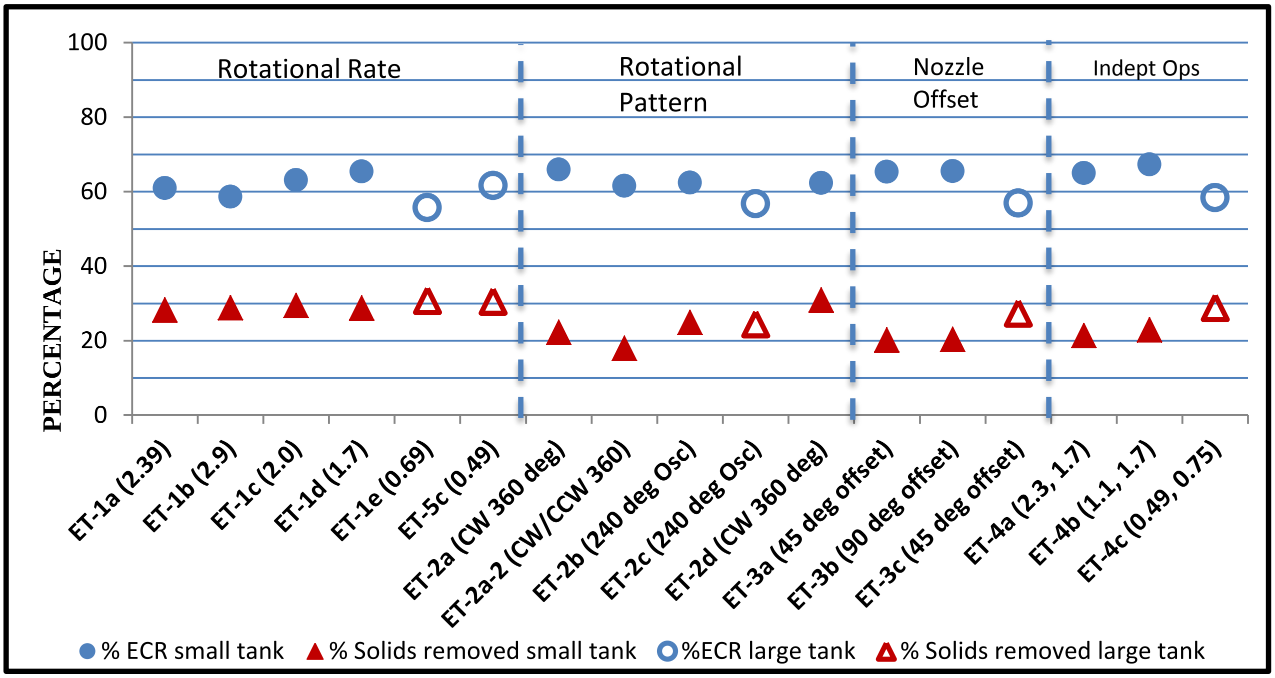

Figure 3. Effects of Performance Parameters on Operational Parameters 109.7 and 304.8 cm Tank for Exploratory Tests

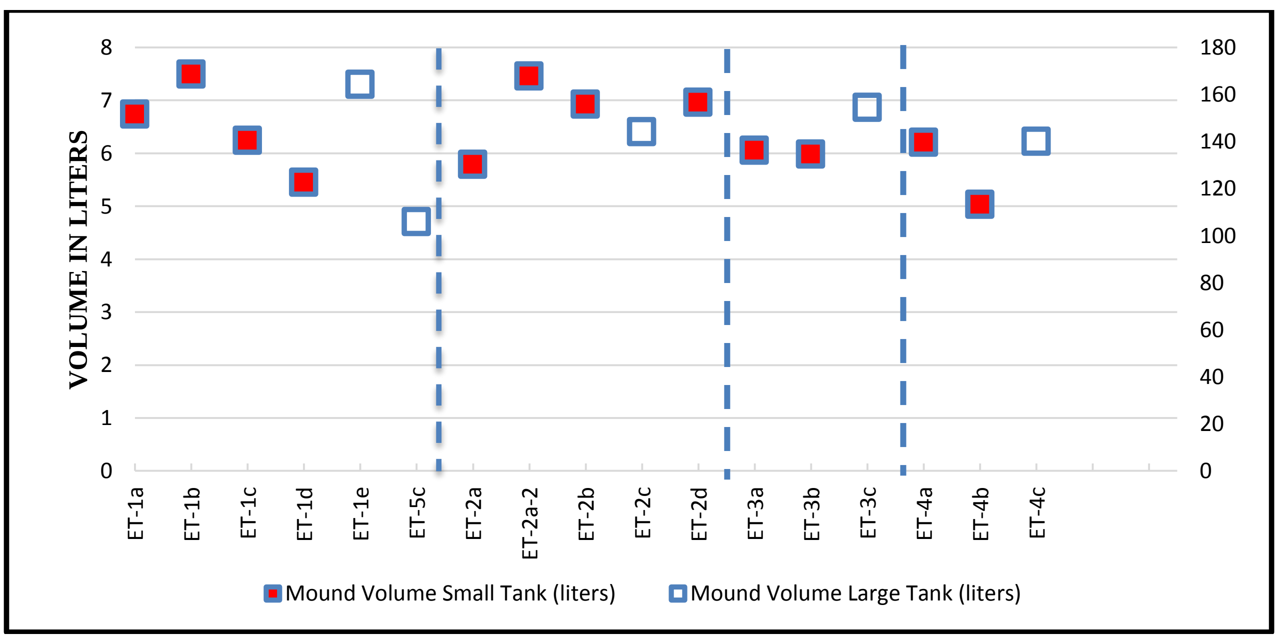

Figure 4. Effects of Performance Parameters on Mound Volume 109.7 and 304.8 cm Tank for ExploratoryTests

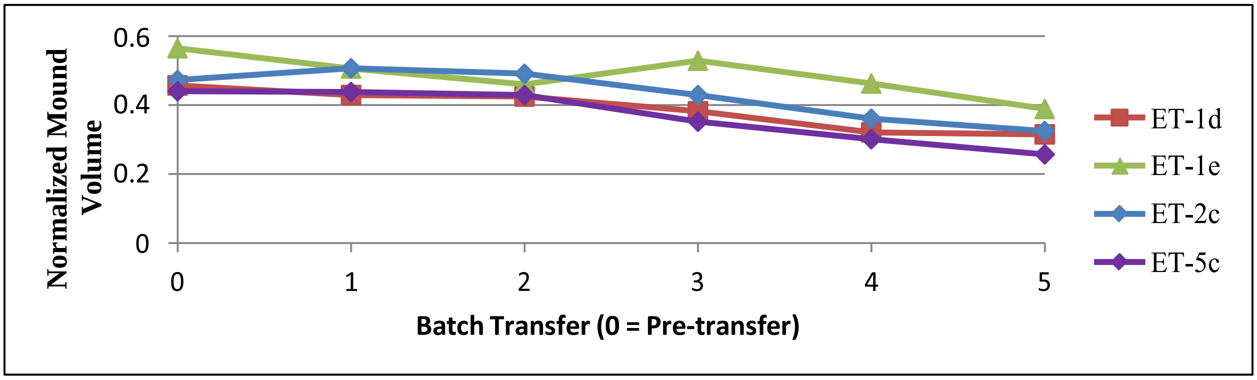

Figure 5 Rotation Rate Evaluation: Normalized Mound Volumes

TABLE IV. Exploratory Test Results

Test Number	Tank Diameter (inches)	Rotational Rate (RPM)	Rotational Pattern	Nozzle Offset	Independent Operation	Fixed Nozzle Position	% ECR after batch 5	Mound Vol liters (gallons) after batch 5 gallons	% Sol $_T$
ET-1a	43.2	2.39	CW 360 Continuous	0 degrees	No	No	60.9	6.74 (1.78)	28.2
ET-1b	43.2	2.9	CW 360 Continuous	0 degrees	No	No	58.6	7.50(1.98)	28.8
ET-1c	43.2	2.0	CW 360 Continuous	0 degrees	No	No	63.0	6.25 (1.65)	29.4
ET-1d*	43.2	1.7	CW 360 Continuous	0 degrees	No	No	65.4	5.45 (1.44)	28.7
ET-1e	120	0.69	CW 360 Continuous	0 degrees	No	No	55.6	164.29(43.4)	30.8
ET-5c*	120	0.49	CW 360 Continuous	0 degrees	No	No	61.6	105.99 (28.0)	30.6
ET-2a	43.2	1.7	CW 360 Continuous	0 degrees	No	No	65.9	5.79 (1.53)	22.2
ET-2a-2	43.2	1.7	one pump CW- one pump CCW, 360 degree rotation	0 degrees	No	No	61.5	7.45 (1.97)	17.9
ET-2b*	43.2	1.7	both pumps CW-CCW 60-300 degrees starting @ 180 degree (240 degree oscillation)	0 degrees	No	No	62.4	6.93 (1.83)	24.9
ET-2d	43.2	1.7	both pumps CW-CCW 60-300 degrees starting @ 180 degrees (240 degree oscillation)-Replicate	0 degrees	No	No	62.3	6.97 (1.84)	30.9
ET-2c*	120	0.75	CW 360 Continuous	0 degrees	No	No	56.7	144.22 (38.10)	24.5
ET-3a	43.2	1.7	CW 360 Continuous	45 degrees	No	No	65.3	6.07 (1.60)	20.1
ET-3b*	43.2	1.7	CW 360 Continuous	90 degrees	No	No	65.5	5.98 (1.58)	20.3
ET-3c*	120	0.75	CW 360 Continuous	45 degrees	No	No	56.9	154.44 (40.8)	27.4
ET-4a	43.2	2.3, 1.7	CW 360 Continuous	0 degrees	Yes	No	64.9	6.21 (1.64)	21.3
ET-4b*	43.2	1.1, 1.7	CW 360 Continuous	0 degrees	Yes	No	67.2	5.03 (1.33)	22.9
ET-4c*	120	0.49, 0.75	CW 360 Continuous	0 degrees	Yes	No	58.4	140.06 (37.0)	28.9
ET-5a	43.2	0							10.1
ET-5b	120	0							16.9

(*) denotes the best performers

(a) IndOP = Independent or Non-synchronized Mixer Pump Operation

Note that ET-2c (see Figure 4) is the only test that yielded results above the reference case in both %ECR and % solids transferred.

TEST RESULTS FOR FINAL (CATEGORY) TESTS

Category 1 Tests (Minimize Pile Formation)—as discussed under "Test Description" above results from exploratory tests were validated through using complex simulants in these tests (see Table V). An increase in performance (based upon the same success criteria) was expected because the suspending fluid went from 100% water to a water based fluid with density and viscosity modifiers. Particles generally stay suspended much longer with increased liquid density and viscosity. The greatest opportunity for particles to be removed from the tank is when the particles are suspended in the fluid that is entrained by the transfer pump. The longer particle suspension occurs, the greater the opportunity for the particles to be entrained in the slurry and the more efficient particle transfer will be. For completeness sake Category 1 results were also compared back to a previous scaled performance test run under similar conditions. Category 1 tests ran at a lower rotational rate based upon results obtained during exploratory testing. Table V, shows that based upon % ECR and % solids transferred the results were generally better from the Category 1 tests except for Cat-1a. Further analysis will be performed on Cat-1a results and presented in the SSDT results report. This indicates that Category 1operating parameters were optimized relative to the testing that was performed. In addition to the 5 standard batch transfers, 5 batch pump downs were performed with water only upon completion of the first 5 batches. This was to assess mixer pump capability regarding total solids retrieval. It was determined that the addition of water and subsequent pump outs allowed for additional solids to be removed from the tank.

TABLE V. Category 1 Test Results

Tank Size (cm)/(in.)	Simulant	Order of Tests	Test ID	% ECR (after 5th batch pump down)	Mound Volume Ave Volume (Liters) East and West (end of batch 5)	Estimated %Solids Removed	Notes
109.7/43.2	Typ /Typ	1	Cat 1a	89.00	N/A	Batches (1-5) = 62.9 Batches (6-10) = ~35.4 Total = ~98.3	Pile formation (mound dimensions were not measurable because at V5 solids were spread thinly across the tank bottom
109.7/43.2	Typ/Typ	N/A	Ref Test [1]	85.6	N/A	Batches (1-5) = 70.9	
109.7/43.2	High /High	2	Cat 1b	67.16	2.95	Batches (1-5) = 52.7 Batches (6-10) = 33.6 Total = ~86.3	
			Ref Test [1]	63.0	N/A	Batches (1-5) = 37.3	
304.8/120	High /High	3	Cat 1c	71.38	8.72	Batches (1-5) = 66.9 Batches (6-10) = ~22.8 Total = ~89.7	Batch 6-10 solids transfer was very low due the necessity to reduce jet flow at the low tank level. Reduced flow caused a large decrease in solids transferred
			Ref Test [1]	65.0	N/A	Batches (1-5) = 64.8	

Category 2 (One Pump tests)—as discussed in the "Test Description" section above these tests were to model mixing and transfer performance capability in the event one pump is lost during a waste transfer to WTP. Tests were run with the complex simulant. Figure 6 below shows a comparison of the average specific gravity (measured by Coriolis meter) vs batch transfer for the three tests that were performed. As shown once a pump is

disabled there is a large initial decline in specific gravity which levels off as batch transfers are made which directly correlates to a decrease in the amount of solids transferred. Compared to the Typical/Typical simulant combination, the decline is more pronounced for the High/High simulant combination that contains a larger proportion of faster settling solids. Readily suspended material, such as gibbsite that makes up 70% of the solids in the Typical/Typical simulant, remains suspended with just one mixer pump and can still be mobilized from the tank. Faster settling solids, such as the larger sand and stainless steel make up more than 54% of the solids in the High/High simulant and settle to the tank bottom away from the mixing action of the active mixer pump. Solids settling results in a decrease in the amount of solids mobilized to the transfer pump. Since the solids have a higher density than the fluid, the specific gravity of the slurry being removed from the tank is reduced.

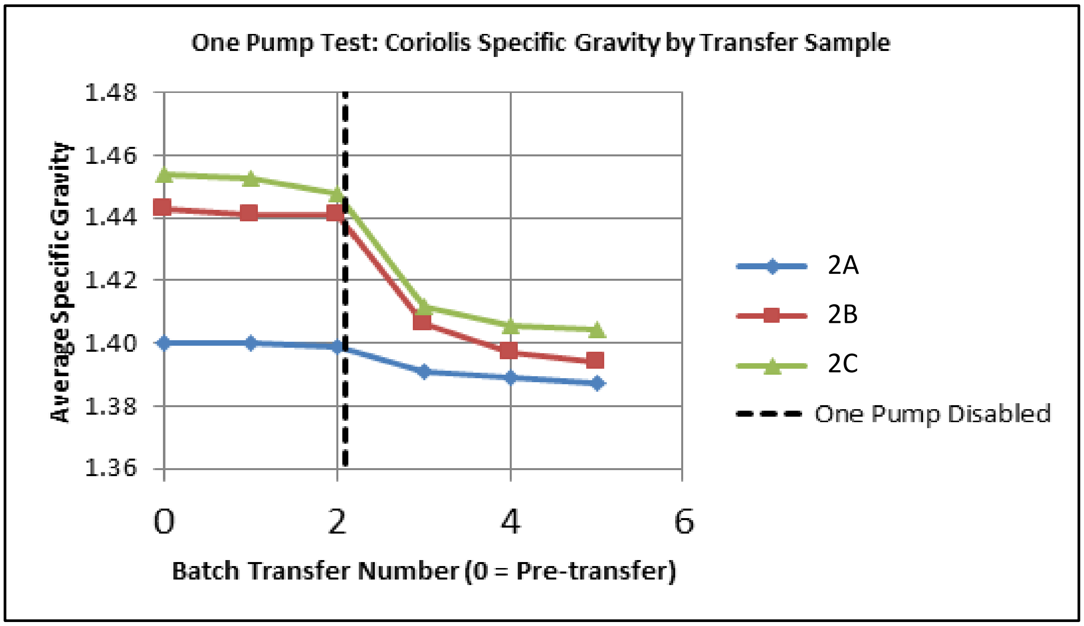

Figure 6. Category 2: Coriolis Bulk Specific Gravity by Transfer Sample

Figure 7 shows percent solids transfer results based upon laboratory analysis. Percent solids transferred (Concentration) is the quotient of the product of mass fractions determined analytically and the sample mass divided by the total amount of solids added times 100. The 'Reference Case' data is the result of a previous test run with the same simulant with two pumps operating continuously. CT-2a, 2b and 2c, show significant decline in solids transfer after one pump is abandoned (after batch 2). Compared to the pre-transfer sample and reference case, sand concentrations in the transfer batches decrease by up to 85% and stainless steel concentrations decrease by more than 95% after one pump is abandoned. In the reference cases some reduction from the pre-transfer concentration was observed for these components but the reduction is much greater after one pump is disabled. By contrast readily suspendible solids such as the zirconium oxide and gibbsite used in testing remain relatively unchanged from the pre-transfer sample or reference case. Test CT-2a, in which the simulant is comprised mostly (>70%) of slow settling solids, indicates the best potential for sustaining a transfer that is already in progress. Note that this data does not support initial mixing of waste with a single pump because this condition was not tested; both mixer pumps were used initially to mix the tanks. CT-2b and 2c using High/High simulant show less potential for allowing an ongoing transfer to continue after losing a pump. In addition to comparing solids delivery, ECR was observed. In all three tests, a mound of solids initially formed on the sides of the tank as indicated in Figure 1. The clearing radius was measured to this mound.
When one pump was disabled, the opposing motion of the two jets was removed and the operational jet was able to re-suspend the solids in the mound. Without the opposing force and motion in the tank from the other jet the suspended material settled on the tank bottom away from the operational jet; when the southernmost

mixer jet was abandoned, the mounds of solids accumulated along the southern perimeter of the tank.

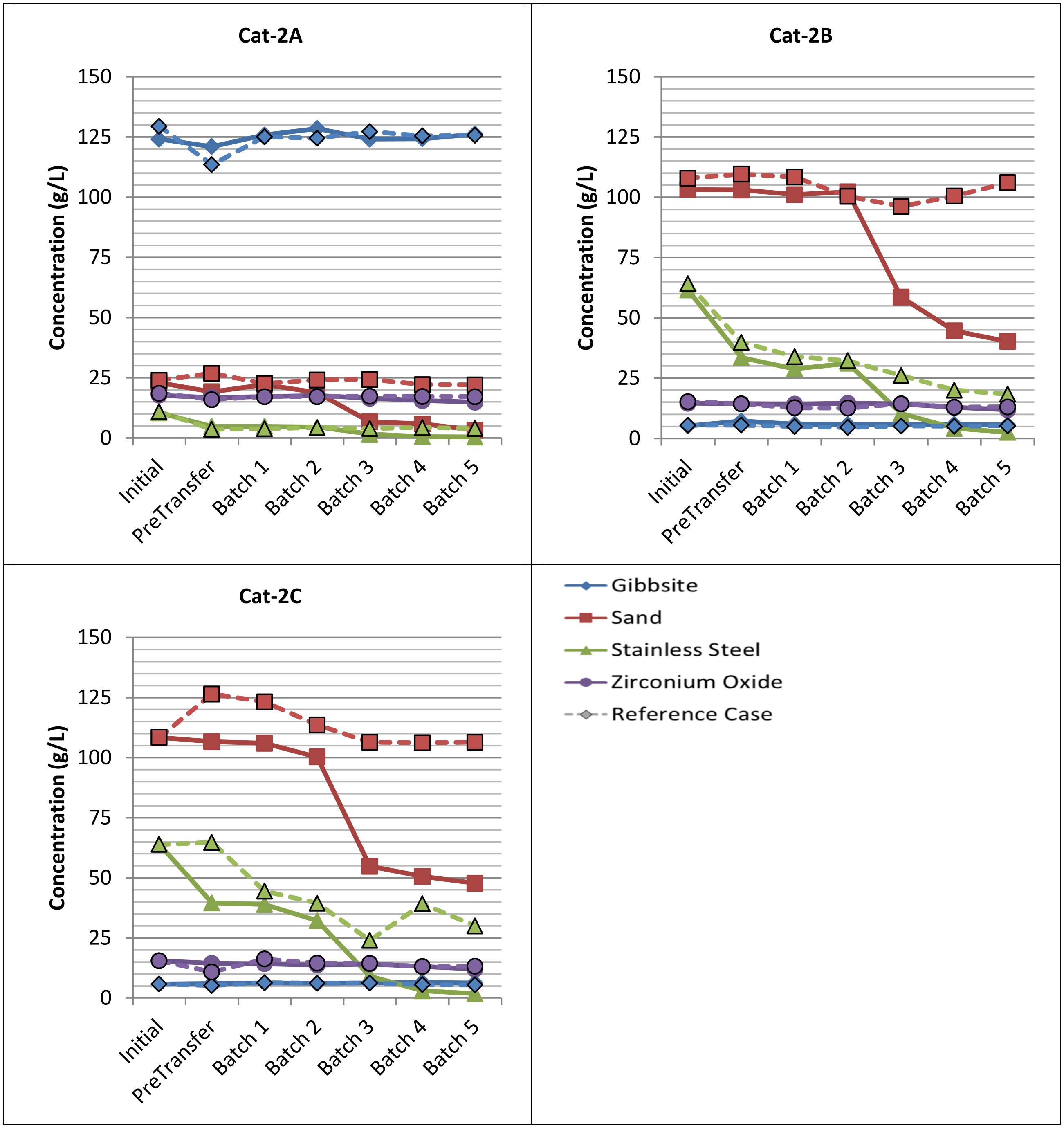

Figure 7. Category 2: Transfer Batch Concentrations Calculated from Analytical Data

Category 3 (Minimize Impingement Forces)-- as discussed in the "Test Description" section above these tests were to determine the effects of turning down mixer jet velocity by 40% (from 100 to 60%) on mixing and transfer capability (see Figure 2). Jet velocity reduction occurred through a specified phase angle (or exclusion zone). In reality the exclusion zone is meant to protect in-tank equipment based upon the internal configuration in certain DSTs. Some DSTs have drywells to house instrumentation (i.e. temperature indicators) that run almost the full vertical distance from the tank dome down to just above the tank bottom. Load calculations [5] indicate a high probability of damage if impingement forces are not properly mitigated; the drywells could break off at the inside tank dome interface causing significant damage to the dome and rendering the instrumentation useless.

Figure 8 shows the impact to mixing and transfer performance as the mixer jet velocity is reduced through the exclusion zone for all three tests. A reference case (dashed line) is again provided from previous testing which didn't model an exclusion zone or require velocity reduction during batch transfer. As expected these results show a decrease in the amount of solids being suspended and transferred. For the Typical/Typical case the reduction in solids from the reference case was negligible (<5% reduction). The concentration of stainless steel in the batch transfers increased over the reference case, but this trend was not observed with the High/High simulant. For the High/High simulant, solids delivery decreased by up to 28%. The reductions in solids delivered were due to reductions in transferring in stainless steel and sand concentrations were greater; sand concentrations decreased by up to 12% and stainless steel concentrations decreased by up to 35%. In addition to comparing solids delivery, ECR was observed.

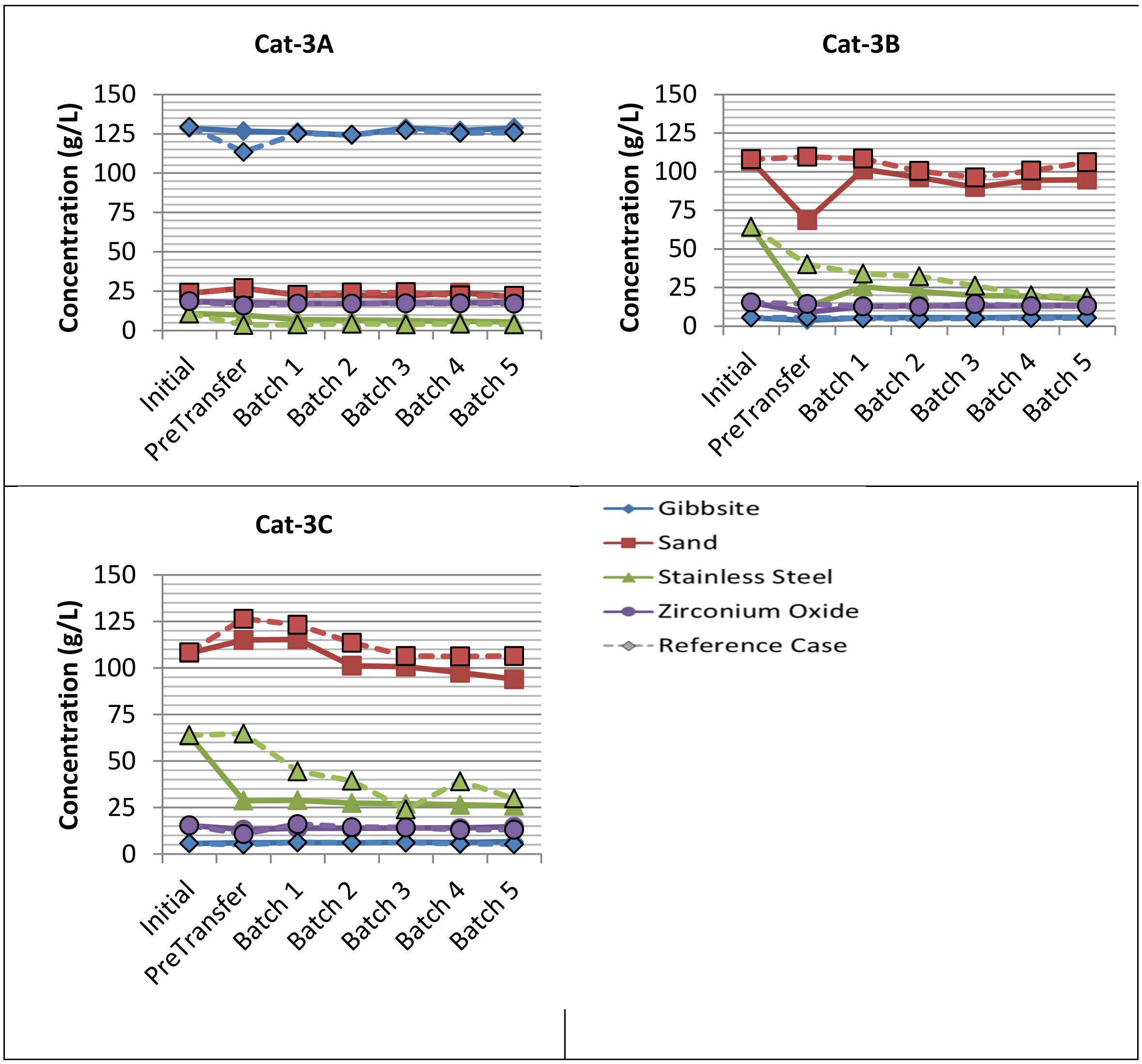

Figure 8. Category 3 Tests: Transfer Batch Concentrations

In all three tests, a mound of solids formed on the sides of the tank. The clearing radius was measured as described above. When measuring to the mounds, it was noted that the shape and dimension of the eastern mound, the side of the tank with the dry well exclusion zone, was different from the western mound; the mound footprint was larger and irregularly shaped. The size of the eastern mound increased because the reduction in jet velocity in the exclusion zone reduced the capability of the jets to clear settled solids. The shape of the mound was irregular because the jet velocity quickly increased after it rotated past the dry well exclusion zone. Once past the exclusion zone the jet was able to clear solids to a greater distance. The position of the exclusion zones resulted in a longer mound that protruded further in towards the tank center but was not as wide as at the tank wall. The general comparison between mound heights is shown in Figure 9. Although this represents just the 1:8th scale tank it is indicative of results obtained at both scales for Category 3 testing.

The difference in mound height (approximately 20 to 30%) can be attributed the western mound being more fully exposed to the highest mixer jet velocity. The effect of the full mixer jet force resulted in a constant erosion of the top of this mound as the mixer jet passed by. This erosion allowed for greater particle suspension which resulted in either those solids being removed or redistributed to the eastern mound.

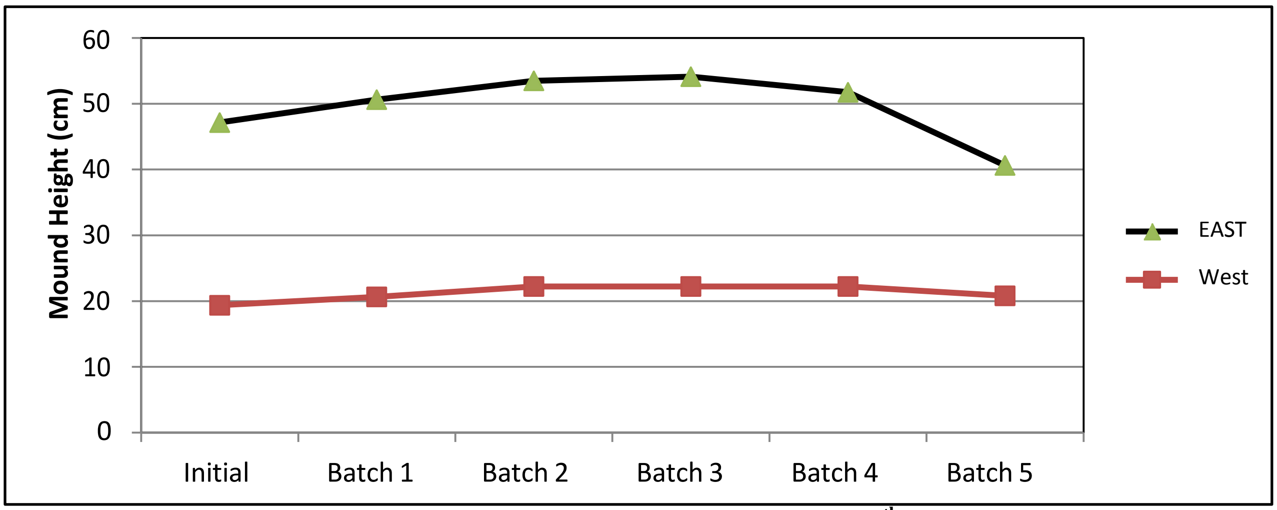

Figure 9. Mound Height for Category 3 Tests 1:8th Scale

CONCLUSION

The Solids Delivery test phase conducted 19 exploratory tests and 9 final tests to explore different tank mixing operational scenarios and mixing conditions. Exploratory testing maximized the use of the 1:22-scale tank and simple simulants to quickly study the effects of different operating conditions and specifically focused on how different mixer jet operations affected bottom clearing and solids removal from the mixed tank. Category 1 testing continued to investigate these effects with the optimized test operational parameters and a simulant that was considered to be more characteristic of Hanford tank waste.

Exploratory and Category 1 Test Conclusions

Exploratory testing determined the effects of varying several mixer pump operational parameters on mound formation and solids transfer using simple simulant. Data collection included Coriolis readings (bulk S.G. fluid velocity) and physical measurements (mound dimensions, effective clearing radius). The objective was to optimize specific operational parameters in support of future Tank Farms solids retrieval activity.

Category 1 (Minimize Pile Formation) tests used the best results from exploratory testing and complex simulant (which is rheologically similar to Tank waste) to determine if similar performance would be achieved. It was assumed that performance for solids removal would increase using complex simulant.

Based upon the testing performed the following conclusions can be made:

- Full 360 degree rotation and oscillation gave similar results in terms of % ECR, remaining mound volume and percent solids transferred is expected to be easier on the full-scale mixing equipment
- The slowest rotational rates evaluated produced the best ECRs. However, slowing the rotational rate to zero, i.e., fixed position is not effective for mixing the tanks and delivery solids.
- Zero degree nozzle offset was as good as or better than results obtained from either 45 or 90 degree offset.
- Adding additional water with synchronized operation of mixer pumps increased solids retrieval: Cat 1b (1:22 scale High/High) => 33.6/86.3= 38.9% increase and Cat 1c (1:8 scale High/High) => 23.4/90.0 = 25.7% increase.
- Comparison of Category 1 tests to a reference case (which used a higher rotational rate) yielded similar (slightly better) results. This difference in result could be attributed to error in analytical data produced in the reference case or in the calculation used for calculating % solids transferred for Category 1 tests. This difference will be analyzed further as part of finalizing the results report.

Category 2 Test Conclusions

Category 2 testing explored the consequences when one of the two mixer jet pumps used to mix the feed staging tanks failed. Prior to abandoning on pump, the contents of the tank were mixed with two operational pumps. The batch transfers with just one operational pump were performed without letting all of the suspended solids settle between transfers so that the tested condition is similar to the condition when a pump fails in the middle of a transfer, rather than at the start of a mixing campaign. Using a single pump to mix suspend settled solids was not evaluated in this one pump test. Based upon the testing performed the following conclusions can be made:

- Disabling one pump results in a noticeable drop in slurry specific gravity for High/High simulant, but only a minor drop for Typical/Typical simulant.
- The clearing radius around active jet increased when the opposition from the other jet was eliminated. This was not due to increased capability, but is a result of less interference/opposing motion from the second jet, which allowed the active jet to mobilize all of the solids to the other side of the tank.
- Batch transfer concentrations for slower settling solids (gibbsite and zirconium oxide, and potentially smaller sand particles) was not adversely effected; however, transfer concentrations of faster settling solids (larger sand particles and stainless steel) decreased when one pump was disabled.

Category 3 Tests Conclusions

Category 3 testing explored the consequences of reducing the jet velocity in exclusion zones to protect in-tank equipment from high impingement forces. Dry-well locations in close proximity to the mixer jet pumps may be damaged by high impingement forces, but these dry wells are not present in all feed staging tanks and only a few would require a jet reduction zone. Based upon the testing performed the following conclusions can be made:

- Reducing the jet velocity around the exclusion zone resulted in a larger mound of solids on the side of the tank with the exclusion zone.
- Batch transfer concentrations of readily suspended solids (gibbsite, zirconium oxide, and possibly smaller sand particles) were comparable to the reference cases. Batch transfer concentrations of faster settling solids (large sand particles and stainless steel) were reduced by up to 35%. The overall impact on solids delivery would depend on the proportion of faster settling solids in the waste, but reducing the jet velocity to protect in-tank equipment does result in lower solids delivery performance.

THE BENEFIT

Based upon conclusions stated above information gathered may be used to enhance mixer pump design, operating strategies and alternate waste feed transfer modes. Currently mixer pump design includes oscillation (0- 180 degrees) only. This is primarily due to pump motor electrical connections that would require rotation about a 360 degree rotation which is not a standard design. Although full rotation capability is likely more expensive, the potential time and effort saved by full rotation during solids retrieval should be assessed against this additional upfront design and construction costs. This testing has showed that full rotation of the mixer jets has provided the best performance regarding percent effective clearing radius and % solids transferred, which should reduce the overall effort to achieve safe and effective solids retrieval.

This testing also showed that waste feed transfer could continue after losing one mixer pump in a two pump configuration. The decision to continue will be impacted by the settling characteristics of the waste and impacts to WTP operations from stopping waste feed delivery. This assumes that the tank contents have been thoroughly mixed prior to failure and that the pump loss occurs during an active transfer.

Lastly the testing showed that mixing and transfer supporting a dry well exclusion zone is viable when considering smaller less dense particles. Excessive mound formation on the tank side opposite of the exclusion zone was clearly evident. However mound formation is sensitive to particle size distribution and it is possible that this operational mode could work with having a greater population of smaller particles than what was used in this testing.

The additional SSDT that was performed identified preferred operating conditions and addressed uncertainties in tank operating conditions that will provided for more effective solids transfer through the DSTs and enhance the efficiency of the Feed Delivery Mission.

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