U.S. Department of Energy
P.O. Box 450, MSIN H6-60
Richland, Washington, 99352

12-WTP-0192

MAY 2 9 2012

The Honorable Peter S. Winokur
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, NW, Suite 700
Washington. DC 20004-2901

Dear Mr. Chairman:

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.5.3.6

This letter provides you the deliverable responsive to Commitment 5.5.3.6 of the U.S. Department of Energy plan to address Waste Treatment and Immobilization Plant (WTP) Vessels Mixing Issues; IP for DNFSB 2010-2.

An attachment provides the test plan to establish Tank Farm performance capability. Testing will be conducted to determine the range of waste physical properties that can be retrieved and transferred to WTP and determine the capability of Tank Farm staging tank sampling systems to provide samples that will characterize waste and determine compliance with the waste acceptance criteria.

This test plan also identifies and describes supplemental testing activities that will be performed to address the technical risks associated with waste feed delivery mixing and sampling. Test requirements and test plan for the supplemental work will be prepared separately so that the initial test results can inform supplemental testing.

Large-Scale Integrated Mixing System Expert Review Team review comments and resolution are also included with this transmittal.

If you have any questions, please contact me at (509) 376-8830, or your staff may contact Ben Harp, WTP Start-up and Commissioning Integration Manager at (509) 376-1462.

Sincerely,

Scott L. Samuelson, Manager
Office of River Protection

WTP:WRW

Attachments

cc w/attachment: See page 2

cc w/attachment:
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W. W. Gay, BNI
F. M. Russo, BNI
R. G. Skwarek, BNI
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R. H. Lagdon, Jr., US
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S. A. Saunders, WRPS
M. G. Thien, WRPS
BNI Correspondence
WRPS Correspondence

ATTACHMENT
to
12-WTP-0192

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.5.3.6

WRPS letter to S. E. Bechtol, U.S. Department of Energy, "Contract Number DE-AC27-08RV14800, One System – Washington River Protection Solutions LLC Transmittal of Defense Nuclear Facilities Safety Board Recommendation 2010-2 Implementation Plan Requirements for Commitment 5.5.3.6, WRPS-1202074-OS, dated May 18, 2010." *(with the following enclosures)*

- Enclosure 1 - RPP-PLAN-52005 Rev. 0, "One System Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan"
- Enclosure 2 – Large-Scale Integrated Mixing System Expert Review Team (ERT) Review Comments Letter
- Enclosure 3 – WRPS-1201884-OS, WRPS ERT Review Comment Response Letter to L. M. Peurrung, ERT Chair, Including: ERT Comment Dispositions, and Draft Document with Reviewers Comment Incorporations
- Enclosure 4 – Updated ERT-16 Comment Dispositions
- Enclosure 5 – ERT Comment Response Concurrence Letter

(Total Number of Pages including coversheet: 257)

washington river protection solutions
PO Box 850
Richland, WA 99352

May 18, 2012

WRPS-1202074-OS

Ms. S. E. Bechtol, Contracting Officer
U.S. Department of Energy
Office of River Protection
Post Office Box 450
Richland, Washington 99352-0450

Dear Ms. Bechtol:

CONTRACT NUMBER DE-AC27-08RV14800 –ONE SYSTEM-WASHINGTON RIVER PROTECTION SOLUTIONS LLC TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD RECOMMENDATION 2010-2 IMPLEMENTATION PLAN REQUIREMENTS FOR COMMITMENT 5.5.3.6

One System transmits the enclosed documents to support the U.S. Department of Energy, Office of River Protection (ORP) transmittal of the commitment requirements to the Defense Nuclear Facilities Safety Board (DNFSB). In accordance with the Washington River Protection Solutions LLC 2010-2 Commitment Document Review Plan, we have completed the work that fulfills the initial DNFSB Recommendation Commitment 5.5.3.6 and are providing the appropriate documents to ORP. Support documents include the following:

- RPP-PLAN-52005 Rev. 0, "One System Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan"
- Large Scale Integrated Mixing System Expert Review Team (ERT) Review Comments Letter
- WRPS-1201884-OS, WRPS ERT Review Comment Response Letter to L. M. Peurrung, ERT Chair. Including: ERT comment dispositions, and Draft document with reviewers comment incorporations
- Updated ERT-16 comment dispositions
- ERT Comment Response Concurrence Letter

As previously discussed with ORP and DNFSB staff, this initial test plan does not cover all necessary testing, and additional test plans will be provided within 15 days of the start of associated testing. This change to a sequential delivery of test plans will be reflected in the proposed revision to the DNFSB 2010-2 Implementation Plan currently being developed.

If you have any questions concerning this matter, please contact Mr. M. G. Thien at 372-3665 or Mr. S. A. Saunders, at 372-9939.

Sincerely,

(Signature Attached)

R. J. Skwarek, Project Manager
One System Integrated Project Team

(Signature Attached)

C. A. Simpson
Contracts Manager

MGT:MDE

Enclosures:
1. RPP-PLAN-52005 Rev. 0, "One System Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan" (89 pages)
2. Large Scale Integrated Mixing System Expert Review Team (ERT) Review Comments Letter, dated April 27, 2012 (4 pages)
3. WRPS-1201884-OS, WRPS ERT Review Comment Response Letter to L. M. Peurrung, ERT Chair: Including: ERT Comment Dispositions, and Draft Document with Reviewers Comment Incorporations, dated May 10, 2012 (127 Pages)
4. Updated ERT-16 Comment Dispositions (30 pages)
5. ERT Comment Response Concurrence Letter, dated May 10, 2012 (2 pages)

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WRPS-1202074-OS
Enclosure 1

DOCUMENT RELEASE FORM

(1) Document Number: RPP-PLAN-52005	**(2) Revision Number:** 0	**(3) Effective Date:** 5/15/2012	
(4) Document Type: ☐ Digital Image ☐ Hard copy ☒ PDF ☐ Video	**(a) Number of pages (including the DRF) or number of digital images** ~~89~~ 88 LS 5/16/12		
(5) Release Type ☒ New	☐ Cancel	☐ Page Change	☐ Complete Revision

(6) Document Title: One System Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan

(7) Change/Release Description: Initial release

(8) Change Justification: N/A

(9) Associated Structure, System, and Component (SSC) and Building Number:

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(b) System Designator: N/A	**(d) Equipment ID Number (EIN):** N/A	

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N/A	N/A	N/A

(11) Approvals:

(a) Author (Print/Sign): Kearn Patrick Lee **Date:** 5/15/2012

(b) Reviewer (Optional, Print/Sign):

______ Date: ______ ______ Date:

______ Date: ______ ______ Date:

______ Date: ______ ______ Date: ______

(c) Responsible Manager (Print/Sign): Mike Thien **Date:** 5/15/2012

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Release Stamp

DATE: May 16, 2012

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(13) Clearance	(a) Cleared for Public Release	(b) Restricted Information?	(c) Restriction Type:
	☑ Yes ☐ No	☐ Yes ☑ No	

(14) Clearance Review (Print/Sign):

APPROVED

By G. E. Bratton at 1:21 pm, May 16, 2012

Date:

One System Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan

Kearn Patrick Lee
Washington River Protection Solutions, LLC

Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-08RV14800

EDT/ECN:	NA	UC:	NA
Cost Center:	2PD00	Charge Code:	201342
B&R Code:	NA	Total Pages:	~~86~~ 88 geb 5-16-12

Key Words: One System, Tank Farm Mixing and Sampling, Waste Feed Delivery, DNFSB Recommendation 2010-2, Limits of Performance, Small Scale Mixing Demonstration, Remote Sampler Demonstration, Solids Accumulation

Abstract: This plan addresses the technical approach and test requirements for the Small-Scale Mixing Demonstration Limits of Performance, Remote Sampler Demonstration Limits of Performance, Full-Scale Transfer Pump Limits of Performance, and Solids Accumulation Scouting Studies being performed under the Mixing and Sampling Program to support waste feed delivery to the Hanford Waste Treatment and Immobilization Plant. The program will include activities to determine the range of waste physical properties that can be retrieved and transferred. It will also determine, based on testing and analysis, the capability of the tank farm mixing, sampling, and transfer systems to obtain samples that can be characterized to assess the bounding physical properties important for the Waste Acceptance Criteria comparison.

DATE:
May 16, 2012
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APPROVED
By G. E. Bratton at 1:37 pm, May 16, 2012

Release Approval   Date   Release Stamp

Approved For Public Release

EXECUTIVE SUMMARY

The primary purpose of the Tank Operations Contractor Mixing and Sampling Program is to mitigate the technical risks associated with the ability of the tank farms feed delivery systems to mix and sample High Level Waste feed adequately to meet the Hanford Waste Treatment and Immobilization Plant Waste Acceptance Criteria. The Tank Operations Contractor will conduct tests to determine the range of waste physical properties that can be retrieved and transferred. It will also determine, based on testing and analysis, the capability of the tank farm mixing, sampling, and transfer systems to obtain representative samples to assess properties important for the Waste Acceptance Criteria comparison. The tests being conducted to define the capabilities of the mixing, sampling, and transfer system are focused on three areas: Limits of Performance, Solids Accumulation and Scaled Performance.

Limits of performance testing will be conducted to determine the range of waste physical properties that can be mixed, sampled, and transported under varying modes of operation. These tests will use both the Remote Sampler Demonstration platform and the Small Scale Mixing Demonstration platform. In addition, a test using a full-scale slurry transfer pump will be performed. Testing will evaluate the capabilities of the systems to mix, sample, and transfer large and dense particulate solids in simulant slurries that are characteristic of Hanford tank waste. With the exception of the full-scale transfer pump testing, limits of performance testing will use the Small Scale Mixing Demonstration and Remote Sampler Demonstration test platforms used in previous Waste Feed Delivery Mixing and Sampling Program test activities; however, the operating conditions and simulants tested will be expanded to allow evaluation of each system's capabilities.

Solids accumulation testing will be conducted to understand the behavior of remaining solids in a double-shell tank during multiple fill, mix, and transfer operations that are typical of the feed delivery mission. Testing will evaluate the propensity of the mixing and transfer system to accumulate fast settling particulate solids in simulant slurries that are characteristic of Hanford tank waste by simulating the multiple fill and transfer operations that are planned for a feed staging tank. Solids accumulation testing will use the Savannah River National Labs Mixing Demonstration Tank to develop appropriate test methods that will be executed at both scales in the Small Scale Mixing Demonstration test platform. Supplemental testing will use the developed methods to perform additional solids accumulation tests using the Small Scale Mixing Demonstration test platform.

Scaled performance testing will be conducted to demonstrate mixing, sampling, and transfer performance using a realistic simulant representing a broad spectrum of Hanford waste. These tests will use both the Small Scale Mixing Demonstration and Remote Sampler Demonstration test platforms used in previous Waste Feed Delivery Mixing and Sampling Program test activities; however, the operating conditions and simulants tested will be expanded to collect additional performance data. Small Scale Mixing Demonstration data will be collected to increase the confidence in the scale up relationship for mixing, sampling, and transfer. Remote Sampler Demonstration test data will be collected and analyzed to provide additional confidence in the systems capabilities to sample a wider range of Hanford waste characteristics.

This test plan is one of multiple test plan documents that will be prepared to address Defense Nuclear Facilities Safety Board DNFSB 2010-2 Sub-Recommendation 5 Commitment 5.5.3.6, "Test Plan to establish Tank Farm performance capability", and addresses the technical approach and test requirements for the Limits of Performance test activities and developmental Solids Accumulation testing being performed to support waste feed delivery. For each test activity covered in this test plan, the test objectives along with success criteria are identified. The necessary equipment to conduct the tests and collect the necessary data is identified and described. The simulants that are appropriate for testing are identified and qualified in accordance with the recommendations in RPP-PLAN-51625, *Waste Feed Delivery Mixing and Sampling Program Simulant Definition for Tank Farm Performance Testing*. Different simulants are proposed for the different tests to explore the capabilities of the individual systems. Because the test objectives for all Limits of Performance activities are similar, the test matrices evaluate similar test conditions (e.g., base simulant components, spike components, supernatant properties, and mass loadings). The most important properties that have been identified for Limits of Performance work include variations to: mixer jet nozzle velocity (Small Scale Mixing Demonstration only), Newtonian slurry solids simulant composition, spike particle characteristics (size and density), supernatant density and viscosity, Newtonian solid simulant mass loading, spike particle mass loading, and the yield strength of a non-Newtonian slurry simulant.

This test plan also identifies and describes supplemental testing activities that will be performed to address the technical risks associated with the Waste Feed Delivery Mixing and Sampling Program. The testing requirements and test plan for the supplemental work will be prepared separately so that the test activities can be informed by the results of the test activities described in this test plan.

CONTENTS

FIGURES

TABLES

TERMS

Abbreviations and Acronyms

ASME	American Society of Mechanical Engineers
BNI	Bechtel National, Inc.
CEES	Columbia Energy and Environmental Services, Inc.
DOE	U.S. Department of Energy
DNFSB	Defense Nuclear Facilities Safety Board
DST	double-shell tank
DQO	data quality objective
FBRM	Focus Beam Reflectance Measurement
HLW	high-level waste
ICD	Interface Control Document
LSIT	Large-Scale Integrated Testing
MDT	SRNL mixing demonstration tank
ORP	Office of River Protection
RPP	River Protection Project
RSD	Remote Sampler Demonstration
SRNL	Savannah River National Laboratory
SSMD	Small-Scale Mixing Demonstration
TOC	Tank Operations Contract
WC	Tungsten carbide grit
WAC	waste acceptance criteria
WFD	Waste Feed Delivery
WRPS	Washington River Protection Solutions, LLC
WTP	Hanford Waste Treatment and Immobilization Plant

Units

°C	degrees Celsius
cP	centipoise
ft	feet
in	inch
g	gram
gpm	gallons per minute
l	liter
ml	milliliter
Pa	Pascal
s	second

1.0 INTRODUCTION

1.1 INTRODUCTION

The primary purpose of the Tank Operations Contractor (TOC Waste Feed Delivery (WFD) Mixing and Sampling Program is to mitigate the technical risks associated with the ability of the tank farms feed delivery systems to adequately mix and sample High Level Waste (HLW) feed to meet the Hanford Waste Treatment and Immobilization Plant (WTP) Waste Acceptance Criteria (WAC). The TOC has identified two critical risks TOC-12-64 and TOC-12-65 per the TFC-PLN-39, Rev. G , *Risk Management Plan*, which address sampling method and emerging WAC requirements. In addition, in November 2011, the U.S. Department of Energy (DOE) issued the implementation plan for the Defense Nuclear Facility Safety Board (DNFSB) Recommendation 2010-2 (DOE Rec. 2010-2, Rev. 0, *Implementation Plan for Defense Nuclear Safety Board Recommendation 2010-2*), which addresses safety concerns associated with the ability of the WTP to mix, sample, and transfer fast settling particles.

Report RPP-PLAN-41807, *Waste Feed Delivery Mixing and Sampling Program Plan and Test Requirements* defines the three test requirements for continued WFD Mixing and Sampling Program testing as follows:

- Limits of performance - determine the range of waste physical properties that can be mixed, sampled, and transported under varying modes of operation. These tests will use both the Remote Sampler Demonstration (RSD) platform and the Small Scale Mixing Demonstration (SSMD) platform. In addition, a test using a full-scale slurry transfer pump will be performed.
- Solids accumulation - perform scaled testing to understand the accumulation and distribution of the remaining solids in a double-shell tank (DST) during multiple fill, mix, and transfer operations that are typical of the HLW feed delivery mission. These tests include activities at the Savannah River National Laboratory (SRNL) Mixing Demonstration Tank (MDT) and the SSMD platform.
- Scaled/system performance - demonstrate mixing, sampling, and transfer performance using a realistic simulant representing a broad spectrum of Hanford waste to meet WTP waste acceptance criteria Data Quality Objectives (DQO) sampling confidence requirements. These tests will use both the SSMD and the RSD platforms. The RSD platform is full scale; therefore, RSD system performance testing activities will collect additional system performance data at full scale.

This represents a broadening of objectives from earlier SSMD and RSD testing. The simulants and operating conditions in this earlier testing were intended to simulate the particle size and density distribution and operating configuration of Hanford DST 241-AY-102, the first tank waste to be delivered to WTP. Simulants and operating conditions will now need to be developed to represent the complete range of physical properties for the broader spectrum of Hanford waste tanks, and to address specific testing requirements summarized above.

The TOC will conduct tests to determine the range of waste physical properties that can be retrieved and transferred to WTP, and determine the capability of tank farm staging tank sampling systems to provide samples that will characterize the tank waste to determine compliance with the WAC. These tests will reduce the technical risk associated with the overall mixing, sampling, and transferring of HLW feed to WTP so that all WAC requirements are met.

This test plan is one of multiple test plan documents that will be prepared to address DNFSB 2010-2 Sub-Recommendation Commitment 5.5.3.6, "Test Plan to establish Tank Farm performance capability". It also addresses the technical approach and test requirements for the SSMD Limits of Performance, RSD Limits of Performance, Full-Scale Transfer Pump Limits of Performance, and SSMD Solids Accumulation Scouting Studies being performed to support feed delivery to the WTP. This test plan also identifies and describes supplemental testing activities that will be performed to address the technical risks associated with the WFD Mixing and Sampling Program. The testing requirements and test plan for the supplemental work will be prepared separately so that the test activities can be informed by the results of the test activities described in this test plan. Also, additional information will be generated as part of parallel work that may result in further refinements to the test requirements. This parallel work includes Commitment 5.5.3.2, which estimates, based on current information, the range of waste physical properties that can be transferred to WTP and Commitments 5.7.3.1 and 5.7.3.4, which identify potential new WAC requirements based on preliminary documented safety analyses coupled with projections of potential WAC requirements based on recent assessments. Decisions on how to adjust test requirements based on these evolving requirements will be made and documented in updates to the issued test plans.

1.2 BACKGROUND

The Office of River Protection (ORP) has defined the interface between the two prime River Protection Project (RPP) contractors, Bechtel National, Inc. (BNI) and Washington River Protection Solutions (WRPS), in a series of interface control documents (ICDs). The primary waste interface document is 24590-WTP-ICD-MG-01-019, *ICD-19-Interface Control Document for Waste Feed* (aka ICD-19). Iterative updates to ICD-19 are anticipated as new information is generated. ICD-19 identifies a significant incompatibility between the TOC baseline equipment configuration and capabilities and the WTP baseline design and regulatory assumptions requirements for tank WFD to WTP. Section 2.3 states that the TOC baseline sampling plans and capabilities are not currently compatible with WTP sample and analysis requirements as described in 24590-WTP-PL-PR-04-0001, *Integrated Sampling and Analysis Requirements Document (ISARD)*, 24590-WTP-RPT-MGT-11-014, *Initial Data Quality Objectives for WTP Feed Acceptance Criteria*, and 24590-WTP-RPT-MGT-04-001, *Regulatory Data Quality Optimization Report*.

The original objective of the WFD Mixing and Sampling Program was to mitigate the technical risks associated with the ability of the tank farms WFD systems to mix and sample HLW feed adequately to meet the WTP waste acceptance criteria. These risks address emerging WAC and sampling method requirements. The focus of the original testing was to model the particle size and density distribution of DST 241-AY-102. DNFSB 2010-2 testing will expand the range of waste physical properties considered. Historically, testing performed by WTP used simulants consistent with the WTP design basis and is further discussed in Appendix A of RPP-PLAN-

51625, *Waste Feed Delivery Mixing and Sampling Program Simulant Definition for Tank Farm Performance Testing*.

In November 2011, the DOE issued the Implementation Plan for the DNFSB 2010-2, which addresses safety concerns associated with the ability of the WTP to mix, sample, and transfer fast settling particles.

To ensure tank farms and WTP mixing and sampling systems are integrated and compatible (i.e., execution of the One System approach) and the uncertainties identified by testing to date are addressed, the WFD Mixing and Sampling Program has been expanded to include the following:

- Define DST mixing, sampling, and transfer system limits of performance with respect to the ability to transfer waste to the WTP with varying physical properties, solid particulates sizes and densities, and under various modes of operation (i.e., defining the expected range of particle size and density and consideration of data uncertainty).
- Define propensity of solid particulates to build up, and the potential for concentration of fissile material over time in DSTs during the multiple fill, mix, and transfer operations expected to occur over the life of the mission.
- Define ability of DST sampling system to collect representative slurry samples and in-line critical velocity measurements from a fully mixed waste feed staging tank.
- Develop sufficient data and methodology to predict full-scale DST mixing, sampling, and transfer system performance confidently; such that a gap analysis against WTP feed receipt system performance can be adequately completed.

The WTP dynamic processing analysis and batch processing planning currently assumes each staged HLW feed tank is mixed and delivered in consistent feed delivery batches of up to 145,000 gallons (ICD-19). Consistent, as used here is intended to mean that the first 145,000-gallon batch has the same solids chemical composition and physical attributes (e.g., mass loading) as the last 145,000-gallon batch. Small-scale testing completed to date (RPP-50557, *Tank Waste Mixing and Sampling Update*, Rev. 0B) concludes that the first feed tank (241-AY-102) can likely be mixed and sampled adequately using DST mixing systems. Additional uncertainties related to data uncertainty, optimizing system performance, applicability to all feed tanks, and understanding emerging WTP solids handling risks still need to be addressed.

The WFD Mixing and Sampling Program has focused on the first HLW planned for transfer to WTP, (241-AY-102) and now will apply knowledge gained to the remaining planned feed delivery DSTs. Initial SSMD project results have demonstrated that equivalent mixing performance, from a solids distribution perspective, can be achieved at approximately 1:21-scale (43.2-inch diameter) and 1:8-scale (120-inch diameter). These results are documented in RPP-47557, *SSMD Test Platform – Small Scale Mixing Demonstration Initial Results Report*, RPP-49740, *SSMD Test Platform – Small Scale Mixing Demonstration Sampling & Batch Transfers Results Report,* and RPP-RPT-48233, *Independent Analysis of Small Scale Mixing Demonstration Test.* The scaling factors derived for equivalent performance for varying nozzle velocities ranged from 0.18 to 0.33, and varied for different performance objectives (e.g., bottom clearing, solids distribution, batch-to-batch consistency, etc.). These results provide a foundation for beginning to explore other performance parameters which were investigated in the sampling and batch transfer phase. Using a simulant that is characteristic of the first HLW feed that will be delivered to the WTP, the sampling and batch transfer testing results have indicated that the feasibility of mixing the tanks adequately to provide a representative sample to the transfer system. The results indicated that fast settling particles can be delivered to the transfer system.

Initial RSD project results conducted using a full-scale sampling system determined that the tank waste could be sampled from the transfer piping. Additional testing is needed to optimize the configuration to improve the performance of the system, which when oriented horizontally tended to collect samples that were biased high (measured more than expected) for particles that have high densities and particles sizes (>8.0 g/ml and >50 microns) (RPP-RPT-51796, *Remote Sampler Demonstration (RSD) Phase I Sampling Results Report*). When oriented vertically, the performance of the sampler improved, but additional testing in the vertical configuration was recommended.

While the initial work for the SSMD and RSD projects has demonstrated the concept functionality for the first feed tank, uncertainties remain that must be addressed. Uncertainties remain to be resolved by the WFD Sampling and Mixing Program related to optimizing system performance, the applicability of data to all tank waste, and understanding emerging WTP solids handling risks.

DNFSB Recommendation 2010-2 has raised WTP safety issues related to tank farms ability to mix, sample, and transfer solids. In response, DOE developed an implementation plan to resolve these issues (DOE Rev. 0 2010-2). As discussed in Section 1.0, this test plan is one of multiple test plan documents that will be prepared to address Commitment 5.5.3.6 of the Implementation Plan. This test plan also is being prepared to address the outstanding key uncertainties pertaining to the bounds of the SSMD and RSD equipment performance identified during the TOC Mixing and Sampling workshop held in Richland, Washington between October 10 – 12, 2011 (WRPS-1105293, *Small Scale Mixing Demonstration Optimization Workshop Meeting Minutes)*. Other test plans are being prepared to address the remaining priorities identified by the workshop participants.

1.3 SCALING PHILOSOPHY

The WFD Mixing and Sampling Program is performing both full-scale and small scale tests to evaluate mixing, sampling, and transfer performance between the Hanford HLW feed staging tanks and the receipt tanks at the WTP. Full-scale tests using prototypic equipment and operating conditions are being used to demonstrate the performance capabilities of the HLW sampling and transfer system that will be used to characterize the waste prior to transferring it to the WTP. Full-scale testing of components provides experimental data that can be used to evaluate the performance of the integrated system without the need to consider scale. Sampling and transfer testing at full-scale is manageable both fiscally and operationally. However, after considering economics, schedules, and operating complexities, performing full-scale tests of the mixing system was not practical. Therefore, it has been determined that mixing tests would be performed at small scales and full-scale performance will be evaluated using scale-up relationships. Operating at smaller scales is desirable because it reduces the cost of materials (i.e. simulants), labor, and time necessary to perform tests. For example, a full-scale transfer of 950,000 gallons of HLW at the maximum transfer flow rate (140 gpm) would take nearly five days of continuous operation. Using smaller scales, the transfer could be completed in a single work shift. However, operating at smaller scales requires that scaling relationships be understood to predict full-scale performance adequately.

The SSMD test platform contains two scaled systems that are geometrically similar to the DST and transfer system that will be used for first delivery to the WTP (DST 241-AY-102). The scaled properties are provided in Table 1-1. Full-scale DST properties are provided for 241-AY-102 and 241-AW-105. The SSMD test platform was constructed according to scale from 241-AY-102. According to ORP-11242 Rev. 6, *River Protection Project System Plan*, 241-AW-105 will participate in numerous feed transfers to the WTP receipt tank, accounting for about 24% of the total waste volume that will be transferred to the WTP from the 13 feed staging tanks (SVF-2110, *TRANSFER_PLOTS_4MINTIMESTEP(6MELTERS)-MMR-11-031-6.5-8.3R1-2011-03-18-AT-01-31-58_V7.XLSM*). Therefore, DST 241-AW-105 has been selected as the model tank for investigating solids accumulation.

The dimensions of the scaled test tanks and placement of the mixing and transfer equipment (e.g., tank diameter, bottom configuration, waste volume, mixer jet and transfer pump spatial locations, mixer jet nozzle diameter, mixer jet pump suction diameter and general tank obstructions) are directly scaled (i.e., proportional) to a full-scale DST filled with actual or anticipated volumes of waste. However, scaling is not full similitude. Consistent with general industry practice for mixing studies and previous testing with the SSMD platform, simulant properties, including particle sizes are not scaled. In addition, to mitigating line plugging with the unscaled simulant, the scaled dimensions for the transfer pump suction inlet diameter and transfer line conduit diameter are also not in direct proportion to a full-scale system. To avoid plugging, the diameter of the pipe should be 3 to 10 times the size of the particles being transferred. Hanford waste simulants are 10s to 100s of microns in size; therefore, the smallest diameter piping that was considered for the scaled systems was ¼-inch (6350 microns), which is much larger than would be used if the pipe diameter was proportionally scaled.

Similarly, scaling the flow rate through a proportionally scaled transfer pump inlet was also not practical for flow hydraulic concerns. For the 1:8 scale system, a proportionally scaled system would pump 12 – 19 gallons of slurry per minute through an approximate 0.3-inch diameter inlet yielding a transfer velocity of at least 54 feet per second (ft/s), well above the expected capture velocities in the full-scale system. The range for the transfer pump flow rates at each scale are specified to equate the fluid velocity through the inlet. The size and shape of the inlet and the fluid velocity through the inlet establish the velocity gradient into the pump inlet. Particles that enter the area of influence of the pump suction will only be captured by the pump if the pump suction, together with any upward motion induced by mixing, is sufficient to overcome any opposing motion due to particle settling and mixing. For the anticipated range of 90 – 140 gallons per minute, the fluid velocity through the 2.25 to 2.4 inch diameter inlet ranges between 6.4 and 11.3 feet per second. Because the particles are not scaled, the velocities through the inletof the scaled systems are equated to full-scale velocities to get equivalent particle capture performance. The transfer pump flow rate is calculated as the product of the fluid velocity, 6.4 and 11.3 feet per second, and the pump suction inlet area in the scaled system.

Table 1-1: SSMD Tank Geometrically Scaled Properties

Property	**Full-Scale DST(AY-102)**	**Full-Scale DST(AW-105)**	**1:8 Scale**	**1:21 Scale**
Diameter (in)	900	900	120	43.2
Scale Factor	1	1	0.1333	0.048
Fill Height (in)	343	399	45.7	16.5
Bottom Geometry	Flat w/12-inch corner radius	Flat	Flat w/1.6-inch corner radius	Flat w/0.6-inch corner radius
Fill Volume[1] (gallons)	944,620	~1,100,000	~2,200	~100
Mixer Jet Pump 1 Location[2]	Riser-001 0°, 22 feet	Riser-007 270°, 20 feet	90°, 2.9 feet	90°, 0.96 feet (12.7 in as-built)
Mixer Jet Pump 2 Location[2]	Riser-003 180°, 22 feet	Riser-008 85°, 20 feet	270°, 2.9 feet	270°, 0.96 feet (12.7 in as-built)
Mixer Jet Pump Suction Elevation[3] (in)	5±1	5±1	0.67±0.13	0.24±0.05
Mixer Jet Pump Suction Diameter (in)	11	11	1.47	0.53
Mixer Jet Pump Nozzle Diameter (in)	6	6	0.80	0.29
Mixer Jet Pump Nozzle Elevation[3] (in)	18	18	2.4	0.86
Transfer Pump Location[2]	Riser-030 90°, 6 feet	Riser-012 270°, 3 feet	0°, 0.8 feet	0°, 0.29 feet
Transfer Pump Suction Inlet Diameter (in)[4]	2.25-2.40	2.25-2.40	0.3125	0.25
Transfer Pump Suction Inlet Height (in)[4]	6	6	0.8	0.28
Transfer Line Diameter (in)	3.07 (3-inch Schedule 40)	3.07 (3-inch Schedule 40)	½"-poly tubing	¼"-poly tubing
Tank Obstructions	Air Lift Circulators (ALCs)	None	Simulated ALCs (removable)	Simulated ALCs (removable)

[1] Fill volume is determined by linear scaling of the tank diameter and sludge volume height.

[2] The reference point for DST locations presented in this table defines 0° as the top (241-AY-102) or bottom (241-AW-105) of the tank in a plan view drawing of the tank. Provided distances are design distances from the center of the riser to the center of the tank.

[3] Elevation is relative to the tank bottom.

[4] The pump suction inlet diameter of the Full-Scale Transfer Pump is underdevelopment and the tabulated value is based on similar transfer pumps used on the Hanford site to convey waste. The inlet size on the 1:21 scale tank is not geometrically scaled. The resulting inlet size was too small to accommodate the particle sizes targeted.

If the scaling relationship is known, data collection from small-scale experiments performed at two or more different scales can be used to predict full-scale performance. Scaled performance experiments can be conducted at multiple scales to establish or refine scaling relationships. In order to develop scaling relationships, equivalent performance within the scaled systems must be established for known operating conditions. Developing the scaling relationship is performed by using generally accepted scaling relationships, which can be theoretically based or empirically determined from similar experiments, to establish a test matrix for the scales of interest. For SSMD scaled performance testing, the generally accepted scaling relationship used for equivalent mixing among scales, as relates to the distribution of solids throughout the mixed volume, is the equal power-per-unit-volume relationship (see Equation 1-1). The derivation of the relationship is provided in Appendix A.

$$U_{jet2} = U_{jet1}\left(\frac{d_{tank2}}{d_{tank1}}\right)^{\frac{1}{3}} \qquad \text{Equation 1-1}$$

Equation 1-1 assumes that equal performance is attained when the applied power to mix is directly proportional to the volume to be mixed. The mixer jet pumps are being designed to sustain a flow rate of 5,200 gallons per minute from each of two 6-inch diameter nozzles on each mixer jet. The nozzle velocity exiting the full-scale pump is about 59 ft/s. Using a 1/3 scale factor exponent, nozzle velocities of approximately 30 ft/s and 21 ft/s are determined for the 1:8 and 1:21 scale systems, respectively.

Initially scaling between the two scales in the SSMD test platform was performed to demonstrate that the scaled tanks could be scaled from the full-scale system using the equal power-per-volume scale factor exponent. While this relationship is suitable for mixing, it may not be suitable for other performance metrics, such as the effective cleaning radius, off-bottom suspension, or particle transfer. Equal performance between scales is not just limited to mixing, it could also consider the transfer pumps ability to capture and convey the slurry solids. Therefore, the equal power per unit volume relationship with a scale factor exponent of 1/3 may not be the best relationship to use to scale the integrated system. Equation 1-2 replaces the 1/3 scale factor exponent with an unknown value, a, that can be determined for different performance metrics.

$$U_{jet2} = U_{jet1}\left(\frac{d_{tank2}}{d_{tank1}}\right)^{a} \qquad \text{Equation 1-2}$$

The scale factor exponent can be determined through scaled testing. For example, as reported in RPPRPT-48233, the mixing data from nine mixer jet pump flow rates at 1:8-scale and 1:21-scale illustrated that equal mixing performance of zirconium oxide in water, as defined by equivalent slurry densities at equal scaled heights, was attained with flow rates of 102.0 gallons per minute (32.6 ft/s) and 9.0 gallons per minute (21.9 ft/s), respectively. The scale factor exponent for the point where mixing performance at the two scales became equal was determined to be 0.39. It should be noted that the metric evaluated equal mixing, not adequate mixing as defined by a consistent density at all heights within the tank. The latter was achieved at higher nozzle velocities and equivalent mixing between the scales was maintained at the higher velocities. At the identified flow rates the specific gravity of the zirconium oxide slurry used in the tests was higher at lower heights in both tanks, indicating that the solids (presumably the larger particles) were not being dispersed throughout the entire tank volume. The results also indicate that with increasing nozzle velocities (decreasing scale factor exponent values), mixing performance becomes adequate and plateaus.

Because there is uncertainty in the appropriate scale factor for the performance of the integrated system with simulants characteristic of other Hanford tanks, future tests will be performed using two scales and a range of different mixer jet pump nozzle velocities. In addition, the program will begin to evaluate the appropriateness of applying the same scaling relationships to Newtonian and non-Newtonian slurries. Equal performance, as measured by a specific performance metric (e.g., distribution of solids, effective cleaning radius, off-bottom suspension, or particle transfer), will be used to refine previous scaling work.

The rotation rate for the mixer jet pump, ω, is also a scaled property of the integrated system. Similar to work described in Section 2.1.2 of PNNL-1443, *Recommendations for Advanced Design Mixer Pump Operation in Savannah River Site Tank 18F,* the scaling parameter for the mixer jet pump rotational rate equates the number of revolutions that occur in the time required to circulate an entire tank volume through the mixer jet pump inlet (PNNL-14443 Section 2.1.2). Equation 1-3 provides the relationship, the derivation of which is provided in Appendix A.

$$\omega_{tank2} = \frac{\omega_{tank1}}{SF^{1-a}} \qquad \text{Equation 1-3}$$

In SRNL-STI-2010-00521, *Demonstration of Mixer Jet Pump Rotational Sensitivity on Mixing and Transfers of the AY-102 Tank*, the effect of the rotational velocity of the mixer jets was evaluated at 1:22-scale and shown to have little effect on the amount of solids transferred in each transfer batch. However, it is noted that the nozzle velocity of the mixer jet was selected so that no "dead zones" were observed in the tank during testing. The testing did not assess whether or not the rotational rate would influence the amount of solids transferred if solids were allowed to accumulate in "dead zones". PNNL-14443 showed that the effective cleaning radius of a mixer jet decreased with increasing mixer jet rotational velocity and decreasing mixer jet nozzle velocity. It can be reasoned that performance metrics aimed at bottom cleaning or metrics that are strongly influenced by the solids on the bottom of the tank would need to evaluate the impact of both mixer jet rotational rate and nozzle velocity.

These scaling relationships set the initial conditions for Limits of Performance and Solids Accumulation Scouting Studies test activities, but the relationships will be refined in accordance with performance data developed at multiple scales during Scaled Performance testing.

Table 1-2 lists the properties and scaling basis for initial test conditions.

Table 1-2: Initial SSMD Tank Non-Geometrically Scaled Properties

Property	Scaling Basis	Full-Scale DST	1:8 Scale	1:21 Scale
Transfer Pump Flow Rate (gpm)	Equivalent inlet velocity (6.4 – 11.3 ft/s)	90-140	1.5-2.7	0.98-1.7
Initial Mixer Jet Pump Nozzle Flow Rate (gpm) (two per pump)	Nozzle velocities determined using Eq 1-2 (a=1/3)	~5200 (59 ft/s)	47.0 (30 ft/s)	4.3 (21 ft/s)
Initial Mixer Jet Pump Nozzle Flow Rate (gpm) (two per pump)	Nozzle velocities determined using Eq 1-2 (a=1/5)	~5200 (59 ft/s)	61.7 (39.4 ft/s)	6.6 (32.1 ft/s)
Mixer Jet Rotation Rate (rpm)	Equivalent number of rotations per tank turnover time (mixer jet pump basis) ($\omega\Theta$); (a=1/3)	0.2	0.77	1.5
Mixer Jet Rotation Rate (rpm)	Equivalent number of rotations per tank turnover time (mixer jet pump basis) ($\omega\Theta$); (a=1/5)	0.2	1.0	2.3

2.0 SCOPE

The original objective of the WFD Mixing and Sampling Program was to mitigate the technical risks associated with the ability of the tank farms feed delivery systems to adequately mix and sample HLW feed to meet the WTP WAC. Testing focused on the ability to achieve adequate mixing and representative sampling, minimizing variability between batches transferred to WTP. Testing to date (RPP-49740) has demonstrated the potential ability to adequately mix, deliver, and sample 241-AY-102 simulated waste using prototypic DST mixing and transfer systems.

While several uncertainties remain regarding the ability to characterize DST waste adequately, larger mission uncertainties related to the compatibility of tank farms feed systems with the WTP receipt systems remain to be addressed. The current WFD Mixing and Sampling Program being executed to address the issues is being performed in a phased approach that will:

- Optimize requirements.
- Demonstrate the viability of systems to meet those requirements in small-scale or full-scale environments, and upon successful demonstration.
- Exhibit system capability in a full-scale DST (i.e., a DST that will be providing hot commissioning feed to WTP).

This plan is one of multiple test plans being prepared to define test requirements to address tank farm mixing, sampling, characterization, and transfer system capability, to meet the expanded requirements associated with DNFSB Recommendation 2010-2. This test plan documents planned activities that will be performed to support a gap analysis of capabilities to sample characterize and transfer waste to WTP that conforms with ICD-19. As described in RPP-PLAN-41807 the objectives of the test activities are to determine the range of waste physical properties that can be retrieved and transferred to the WTP and determine the capability of the tank farm staging, tank sampling systems to obtain samples that can be characterized to assess the bounding physical properties important for the WAC. The three major areas of testing that will be executed by the WFD Mixing and Sampling Program include Limits of Performance, Solids Accumulation, and Scaled/system performance. Specifically seven testing activities are planned:

- SSMD Limits of Performance (performed by Energy*Solutions*)
- RSD Limits of Performance (performed by Energy*Solutions*)
- Full-Scale Transfer Pump Limits of Performance (performed by Columbia Energy and Environmental Services (CEES))
- SSMD Solids Accumulation Scouting Studies (performed by SRNL)
- SSMD Solids Accumulation Performance Evaluation (performed by Energy*Solutions*)
- SSMD Scaled Performance (performed by Energy*Solutions*)
- RSD System Performance (performed by Energy*Solutions*)

This plan defines test requirements to address the first four test activities, including all Limits of Performance scope and the initial Solids Accumulation development work. Subsequent test plans will provide the test requirements for SSMD Solids Accumulation Performance Evaluation scope and the two scaled/system performance activities. Figure 2-1 shows test sequence and portrays how information learned from early testing activities is used to develop the test plans for subsequent scope.

Waste Feed Delivery Mixing and Sampling Program testing is performed in accordance with Phase I testing described in TFC-PLAN-90, *Technology Development Management Plan* and implements a graded application of the quality assurance program requirements. While not specifically required for Phase I testing, WFD Mixing and Sampling Program test planning, test review, test control, and test results reporting are guided by testing principles described in TFC-ENG-DESIGN-C-18, *Testing Practices*. WFD Mixing and Sampling Program testing falls outside the scope of TFC-PLAN-26, *Test Program Plan*, which defines additional requirements for oversight, development, and the conduct of factory acceptance, construction acceptance, and operational acceptance tests for demonstrating the operability and integrity of new or modified tank farm facilities and systems.

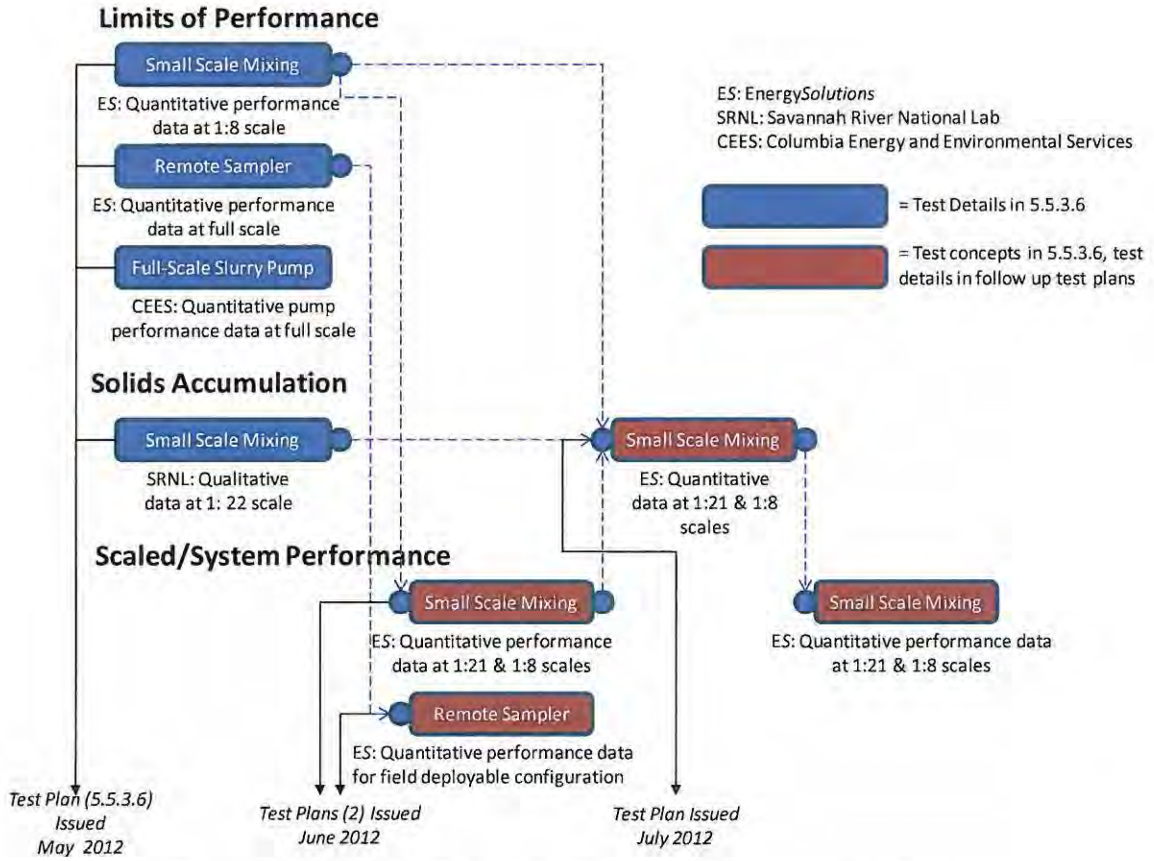

Figure 2-1. WFD Mixing and Sampling Program Test Sequence

2.1 LIMITS OF PERFORMANCE

The objective of Limits of Performance activities is to determine the range of waste physical properties that can be mixed, sampled, and transported under varying modes of operation. The capability gap between the TOC and the WTP is defined by the capability of the TOC's capability to mix, sample, and transfer large and dense particles, and the WTP's capability to process these particles. Therefore, integral with defining the gap in capabilities is the selection of appropriately complex simulants, integrated with WTP simulant selection, and supported by accurate analytical techniques to characterize the material of interest. As detailed in RPP-PLAN-51625, particle size and density are expected to be the most important solids properties. Liquid density and viscosity are expected to be important liquid phase properties. Particle shape is being considered consistent with recommendations in SRNL-STI-2012-00062, *Properties Important to Mixing for WTP Large Scale Integrated Testing*, which recommends that simulants for pulse jet mixer limits of performance testing should include a variety of particle shapes and that spherical particles should be considered for at least a portion of the particles at the high end of the Archimedes number distribution. Particle hardness, which is important for understanding the longevity of the plant equipment, is not considered an important factor for accessing the capability of the WFD system to mix, sample, and transfer HLW slurry.

2.1.1 Small Scale Mixing Demonstration

The SSMD Limits of Performance test activities documented in Section 2.1.1 are performed by Energy*Solutions* for WRPS.

2.1.1.1 Objective

The objective of SSMD Limits of Performance activities is to determine the range of waste physical properties that can be mixed and transported by the SSMD test platform under varying modes of operation. Testing will be performed at 1:8-scale to determine the capability of the scaled test system to transfer large and dense particles that are characteristic of the to-be-delivered tank waste. Testing will also identify whether the capability of the SSMD 1:8-scale test system is limited by the mixing system or the waste transfer system. Understanding the limits of the test system will provide insight into understanding the performance of the fully integrated scaled system. Specifically SSMD Limits of Performance testing will identify the capability of the rotating mixer jet pumps to deliver large and dense particles to the area of influence of the transfer system so that the transfer pump can mobilize the particles from the tank.

Using spike particulates with densities that are representative of the average density solids in the Hanford tank waste, including uncertainties, successful testing will identify the largest waste particle size that can be transferred by the 1:8-scale tank waste transfer system. In addition, using spike particulates with densities that are representative of the high density fissile material, successful testing will also identify the largest particle that can be transferred by the 1:8-scale tank waste transfer system. Successful testing will also identify whether or not the large and dense particles can be suspended inside the mixing tank and delivered to the waste transfer pump suction inlet.

The test objectives are summarized in Table 2-1.

Table 2-1. SSMD Limits of Performance Test Objective

Objective	Success Criteria
Demonstrate the capability of the 1:8-scale mixing and transfer system to transfer large and dense particles.	Mixing and transfer tests are performed at different operating conditions in the 120-inch diameter SSMD mixing tank with a base simulant, a supernatant simulant and spike particles that are distinguishable in collected samples by size and another physical property (color, density, etc.). Large and dense particles that can be mobilized to a sample location downstream of the transfer pump discharge are identified and quantified according to fraction of each particle size and density transferred in each transfer batch relative to the starting composition. Correlations relating the fraction of particles of each size and density transferred are evaluated with respect to the changes in the operating conditions.
Demonstrate whether the mobilization of large and dense particles is constrained by the mixing system or the transfer system.	Mixing and transfer limitations of the integrated SSMD test platform are identified.

2.1.1.2 Technical Approach

The SSMD Limits of Performance activities described in this test plan will use the SSMD test platform (Figure 2-2) located at Monarch Machine & Tool Company, Inc. in Pasco, WA to determine whether large and dense particles can be mixed and transferred by the prototypic mixing and transfer system. The SSMD platform does not include a prototypic sampling system similar to that in the RSD platform; sampling is performed by collecting samples of the slurry discharged through a valve at the end of the transfer line. Preliminary testing was performed to identify suitable spike particles for fully integrated testing in a scaled and prototypic test tank. Testing in this manner was being performed to determine the capability of the scaled test system to transfer large and dense particles. To date, SSMD performance testing has focused on developing the SSMD test platform and then demonstrating that the scaled system is capable of adequately mixing and sampling a simulant that is characteristic of the first HLW feed batch that will be delivered to the WTP. The SSMD work scope has not specifically addressed the capability of the system to evaluate simulants characteristic of other tanks that may contain other dense fissile material.

Testing will be designed to bound system performance without taking into account the uncertainty of known waste characteristics. The size of the spike particles in the limits of performance test activities exceeds the largest anticipated size of high density material that may be in the tanks. The size of these high densities particles is uncertain, but is not expected to be comparable in size to the 1500-micron particles that are included as spikes, but this will be confirmed through on-going work (DNFSB 2010-2 Commitment 5.5.3.2) and evaluated in the initial gap analysis (DNFSB 2010-2 Commitment 5.5.3.1). Scale-up of the performance limits to full scale is not anticipated from the tests, which are only being performed at one scale. Preliminary work will be performed to evaluate the capability of the SSMD test platform 1:8-scale tank transfer system to convey large and dense particles. Once the capability of the transfer system is known, then the 1:8-scale integrated system will be used to determine the capability of the mixing system to deliver the large and dense particles to the transfer pump suction inlet. Supplemental testing described in Section 2.1.3 will be performed to evaluate the capability of a full-scale slurry transfer pump to convey large and dense particles out of a tank.

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection, and data analysis are provided in Section 3.2.1.

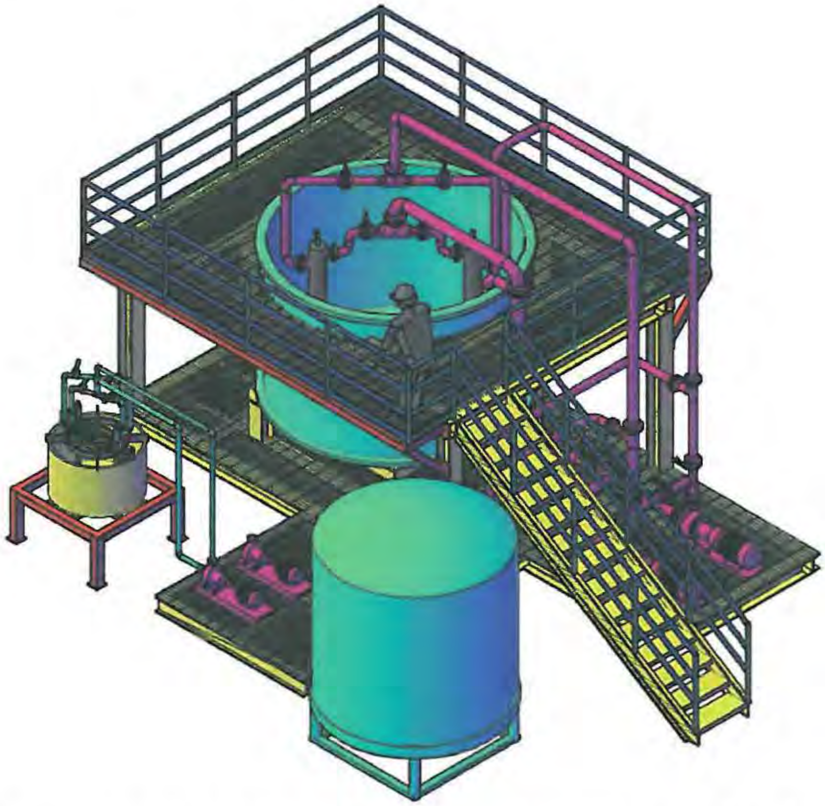

Figure 2-2. Schematic of Small Scale Mixing Demonstration Test Platform

2.1.2 Remote Sampler Demonstration

RSD Limits of Performance test activities documented in Section 2.1.2 are performed by Energy*Solutions* for WRPS.

2.1.2.1 Objective

The objective of RSD Limits of Performance activities is to determine the range of waste physical properties that can be sampled by the RSD test platform under varying modes of operation. Testing will determine the capability of the Isolok®[1] sampling system to sample large and dense particles that are characteristic of the to-be-delivered tank waste. RSD Limits of

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[1] Isolok® is a registered trademark of Sentry Equipment Corp. of Oconomowoc, WI

Performance testing will emphasize the capability of the Isolok® Sampler; the simulants used in testing are selected to challenge the sampler.

Using spike particulates with densities that are representative of the average density solids in the Hanford tank waste, including uncertainties, successful testing will identify the largest waste particle size that can be consistently sampled by the Isolok® Sampler without plugging. In addition, successful testing will also identify the largest particle with a density characteristic of fissile material that can be consistently sampled by the Isolok® Sampler without plugging.

The test objectives are summarized in Table 2-2.

Table 2-2. RSD Limits of Performance Test Objective

Objective	Success Criteria
Demonstrate the capability of the Isolok® Sampler to sample large and dense particles in different simulant compositions (using both cohesive and non-cohesive simulants).	Isolok® sampling tests are performed in the RSD flow loop with a base simulant, a supernatant simulant, and spike particles that are distinguishable in collected samples by size and another physical property (color, density, etc.). Large and dense particles that can be sampled by the Isolok® Sampler without degrading equipment performance are identified and quantified according to fraction of each particle size and density sampled relative to a full diversion sample. Collected sample volumes are within 5% of the expected volume. The sampled concentration of large and dense particles collected by the Isolok® Sampler is within 5% of the concentration determined from comparable full diversion samples taken from the flow loop. Correlations relating the fraction of particles of each size and density captured in the Isolok® sample are evaluated with respect to the changes in the testing conditions (e.g., simulant variations and loadings).

2.1.2.2 Technical Approach

The testing described in this test plan will use the RSD test platform (Figure 2-3) located at Monarch Machine & Tool Company, Inc. in Pasco, WA to test progressively larger particle sizes and densities to identify the largest size and density particle that can be sampled consistently by the Isolok® Sampler. The Isolok® Sampler will collect 500 ml samples in increments of 5.3 ml per sample plunger actuation. Collecting the sample takes approximately 22 minutes. Once the sample is collected, the collected volume will be sieved to separate the different sizes of spike particles. Testing in this manner is being performed to determine the capability of the full-scale sampler system to sample large, dense particles that may be characteristic of the to-be-delivered tank waste. The largest size that can be consistently sampled by the sampler is constrained by the diameter of the internal sampling needle (approximately 3,400 micron). To date, RSD performance testing has focused on developing the RSD test platform, and then demonstrating that the system is capable of adequately sampling a simulant that is characteristic of the first

HLW feed batch that will be delivered to the WTP. The RSD work scope has not specifically addressed the capability of the system to evaluate simulants characteristic of other tanks that may contain larger and denser material. The RSD Limits of Performance testing is being conducted to address the uncertainty in the capability of the Isolok® Sampler (shown in red in Figure 2-3). Testing the capability of the Isolok® Sampler will be designed to bound system performance without taking into account the uncertainty of known waste characteristics. The RSD Limits of Performance testing will use a simulant that is consistent with the SSMD Limits of Performance testing, with the exception that spike particles will be restricted to a size less than the internal sampling needle.

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection, and data analysis are provided in Section 3.2.2.

Although Figure 2-3 includes the Ultrasonic PulseEcho system (shown in blue in Figure 2-3), this system has been previously evaluated, as reported in PNNL-19441, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments*, and is not being evaluated for limits of performance. The Ultrasonic PulseEcho system will be further evaluated during RSD system performance testing.

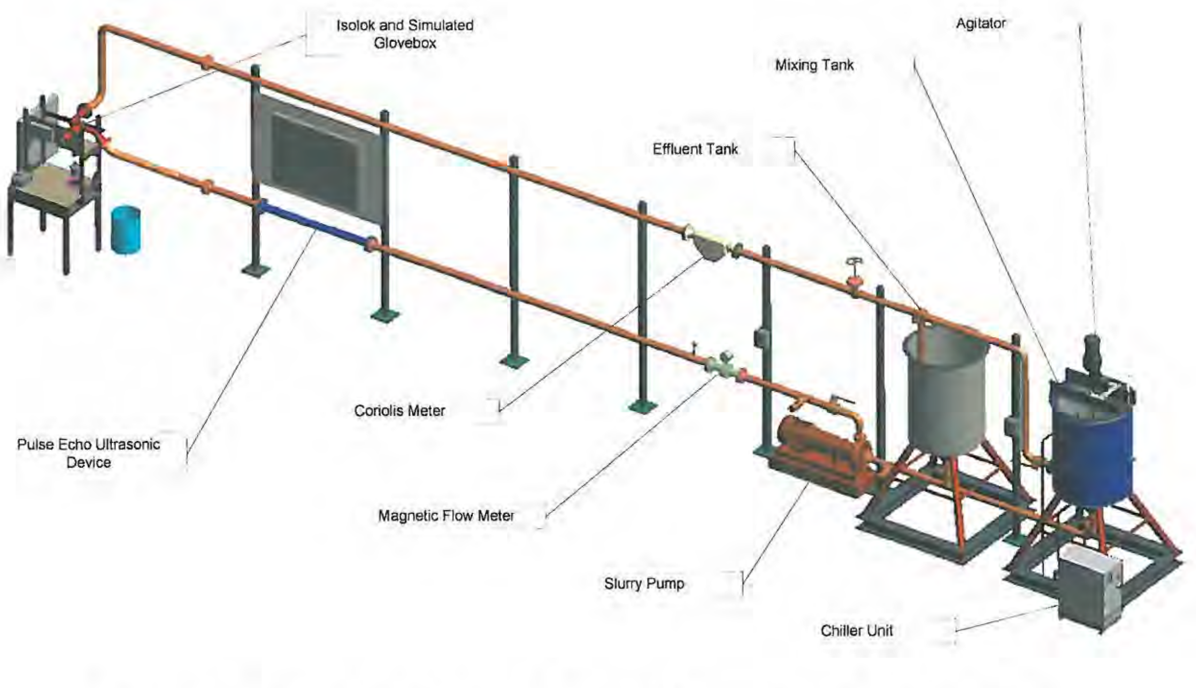

Figure 2-3. Schematic of Remote Sampler Demonstration Test Platform

2.1.3 Full-Scale Transfer Pump Limits of Performance

Full-Scale Transfer Pump Limits of Performance test activities documented in Section 2.1.3 are performed by CEES for WRPS.

2.1.3.1 Objective

The objective of Full-Scale Transfer Pump Limits of Performance activity is to determine the range of waste physical properties that can be transferred from a mixed DST to the WTP receipt tanks. Testing will determine the capability of the WFD transfer pump to capture and convey large and dense particles in a configuration that is similar to the transfer configuration planned for the WFD feed staging tanks. Testing will also evaluate the capability of the transfer pump to mobilize solids in an unmixed tank at different transfer pump suction inlet heights.

Using spike particulates with densities that are representative of the average density solids in the Hanford tank waste, including uncertainties, successful testing will identify the largest waste particle size that can be transferred by a full-scale slurry transfer pump. Testing will also identify the largest particle with a density characteristic of fissile material that can be transferred by the pump.

The test objective is summarized in Table 2-3.

Table 2-3. Full-Scale Transfer Pump Limits of Performance Test Objective

Objective	Success Criteria
Demonstrate the capability of the full-scale WFD slurry transfer pump to transfer large and dense slurry particles in different simulant compositions and under different operating modes (semi-quiescent tank, mixed tank, variable pump suction height).	Transfer tests are performed at different operating conditions with a base simulant, a supernatant simulant and average density and high density spike particles that are distinguishable by size and density. Large and dense particles that can be mobilized to a sample location downstream of the transfer pump discharge under mixing and quiescent conditions are identified and quantified according to fraction of each particle size and density transferred relative to the starting composition. Correlations relating the fraction of particles of each size and density transferred are evaluated with respect to the changes in the operating conditions.

2.1.3.2 Technical Approach

The testing described in this test plan will procure a commercially available submersible slurry pump that has hydraulic properties similar to the next generation transfer pump sought by the TOC to convey HLW slurry between the DST feed staging tank and the WTP receipt tank. The TOC has evaluated commercially available pumps and has determined that a submersible slurry pump that is capable of conveying the HLW slurry from the bottom of the DST to the WTP receipt tank without an intermittent booster pump or exceeding the pressure limits of the transfer piping is not available. The TOC is pursuing the development of a customized pump to meet

WFD requirements, but development of this pump will not be completed in time to support Limits of Performance testing and the initial gap analysis. Therefore, a commercially available pump that has the flow capability and inlet velocity of the proposed pump without the high head requirements will be used for Full-Scale Transfer Pump Limits of Performance test activities.

The procured transfer pump will be placed into a mixing tank such that the pump inlet is located consistently with the DST 241-AY-102 transfer system configuration. Simulant, including large diameter spike particles, will be mixed and pumped through a network of pipes that mimic the flow from the bottom of a DST to the location of the Ultrasonic PulseEcho system in the WFD characterization flow loop. The slurry will be pumped vertically through55 feet of 3-inch diameter Schedule 40 piping, through a 90° bend and then horizontally through 20 feet of 3-inch diameter, transparent Schedule 40 plastic piping so that the flow can be observed. The spike particulates in the mobilized slurry will be collected and quantified from the end of the horizontal run, so that the capability of the pump to transfer large and dense particles out of the DST can be assessed. After testing is completed, the horizontal transfer line will be flushed (>140 gpm) and the discharge will be screened to collect the large and dense particles that were captured by the pump but settled out in the transfer line prior to reaching the sample location. The screened material will then be sieved to separate the different particle sizes. The spatial distribution of the large and dense particles remaining in the mixing tank will be evaluated and reported so that the mixing system capability to deliver the large and dense particles to the area of influence of the pump can be analyzed and considered.

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection, and data analysis are provided in Section 3.2.3.

2.2 SOLIDS ACCUMULATION

The objective of Solids Accumulation activities is to perform scaled testing to understand the behavior of the remaining solids in a DST during multiple fill, mix, and transfer operations that are typical of the HLW feed delivery mission. Testing will focus on accumulation of total solids over time and the propensity for simulated fissile material to concentrate over time.

2.2.1 Scouting Studies

The SSMD Solids Accumulation Scouting Studies documented in Section 2.2.1 are performed by SRNL for WRPS.

2.2.1.1 Objective

The SSMD project testing activities to date have developed two scaled test platforms to evaluate the baseline design for mixing and transferring slurry from DST 241-AY-102, the first staged HLW feed to the WTP. SRNL constructed a 1:22-scale Mixing Demonstration Tank (MDT) to perform mixing and transfer studies. Energy*Solutions* has also constructed a test platform that includes both a 1:21-scale and a 1:8–scale mixing tank and transfer system. The objective of the SSMD Solids Accumulation Scouting Studies is to simulate a series of full WFD to WTP transfer and refill operations using the 1:22-scale MDT and evaluate the bulk material that remains in the tank after the series of pump-out and refill operations are performed. Testing will determine the amount of bulk solids remaining and the concentration and approximate locations where the fastest settling particles accumulate in the tank heel and estimate the error associated with the collected measurements. Providing insight into how fast settling particles are distributed in a WFD feed staging tank is important to criticality evaluations that include the accumulation of dense plutonium and uranium containing solids. The scope of the work is limited to preliminary scoping studies, the results of which will be used to define supplemental test work that will be performed using the test platform operated by Energy*Solutions*.

Integral with this activity is the selection of appropriately complex simulants that are integrated with WTP simulant selection and supported by accurate analytical techniques to characterize the material of interest. Using simulants characteristic of high-density solids in the Hanford tank waste, including uncertainties, successful testing will identify a simulant that can be readily characterized by standard analytical techniques, a sampling technique for characterizing the residual tank waste solids that accumulate in the tank after a series of transfer and refill operations are performed, and a technique for quantifying the residual solids in the tank after each transfer and refill operation is completed.

The test objectives are summarized in Table 2-4.

Table 2-4. Solids Accumulation Scouting Studies Test Objectives

Objective	Success Criteria
Demonstrate at two jet nozzle velocities the potential accumulation of solids in the DST after several transfer and re-fill operations are conducted.	Mixing and transfer tests are performed at two different jet nozzle velocities with a base simulant that contains moderately sized (100 microns), dense particles to represent fissile material in the Hanford tank waste. The spike particles are distinguishable in collected samples by a physical property that can be exploited for quantification. Very fast settling particles that can accumulate inside a DST used for several staged feeds are quantified relative to the amount of the solids added to the tank. The relative quantities of solids in each transfer batch are estimated. The accumulation of heel solids is evaluated after each tank volume transfer by observing changes in the heel volume. The accumulation of heel solids is quantified after the 1st, 5th and last (e.g., 10th) tank volume transfer by measuring the volume of heel in the tank. The distribution of the very fast settling solids in the heel is described using quantitative results from collected heel samples. Correlations relating the fraction of very fast settling solids transferred and remaining in the tank are evaluated with respect to each transfer batch and after multiple tank volume transfers.
Develop and demonstrate quantification techniques to characterize the residual tank waste in-situ.	Techniques to sample and quantify the volume of residual solids are identified and documented. Different heel volume measurement techniques are compared.

2.2.1.2 Technical Approach

The SSMD Solids Accumulation Scouting Studies described in this test plan will use the MDT platform (Figure 2-4) at SRNL to simulate a DST transfer campaign to characterize the solids that remain in the tank after a series of tank transfers have been performed. A DST transfer campaign includes a series of transfer and refill operations that fill the MDT mixing tank with simulant and then pump-out the material to one or more receipt tanks using 6.5 consecutive batch transfers. This number reflects the anticipated number of transfers needed to reduce the tank contents in a full feed DST to 72-inches using 145,000 gallon batches. The residual volume of 72-inches of solids and supernatant is an operating limitation to avoid cavitation when the mixer jet pumps are operating at full speed. A tank volume transfer operation is completed when 6.5 batches of slurry are transferred from the MDT to the receipt tank(s). Following a successful tank volume transfer, the solids remaining in the MDT will be characterized and additional simulant will be added to refill the mixing tank. A series of tank volume transfers with subsequent refills, up to ten, will be performed in a campaign. Fewer tank volume transfers may be performed if it is demonstrated that the volume of residual solids stabilizes despite performing additional fill and transfer cycles. The solids remaining in the tank after each transfer campaign will be characterized and compared to the total solids that are added during testing. Quantification in the residual solids and in each transfer batch will specifically target the very fast settling particles. However, the volume of the other solids constituents will also be measured. Once a campaign is completed, a second campaign will be performed at a different mixer jet nozzle velocity to evaluate the effect of the mixer jet nozzle velocity on the accumulation of very fast settling particles.

Solids Accumulation Scouting Studies will investigate and develop techniques to sample the residual solids with minimal disturbance, measure the residual solids volume, and refill the tank after each transfer operation. Testing in this manner is being performed to determine the location of the very fast settling solids that remain in a tank after several transfer and refill operations to evaluate the potential to accumulate fissile material in the residual tank solids. To date, SSMD performance testing has focused on developing the SSMD test platform, and then demonstrating that the scaled system is capable of adequately mixing and sampling a simulant that is characteristic of the first HLW feed batch that will be delivered to the WTP. Although some effort has begun to understand the accumulation of solids in the tank, the SSMD work scope has not specifically addressed the accumulation of material in the tank after successive transfer operations are performed.

Once adequate sampling and analysis methods are developed through these scoping studies, the SSMD test platform 1:21-scale and a 1:8–scale mixing tanks will be used to perform more precise evaluations (see Section 2.2.2).

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection, and data analysis are provided in Section 3.3.1.

Figure 2-4. Mixing Demonstration Tank Test Platform

2.2.2 Performance Evaluation

SSMD Solids Accumulation Performance Evaluation test activities documented in Section 2.2.2 are performed by Energy*Solutions* for WRPS.

SSMD Solids Accumulation Performance Evaluation testing is introduced in this test plan because it is being conducted to address DNFSB 2010-2 work scope; however, a separate test plan will document the tests that will be performed to evaluate the accumulation of solids in the scaled systems further. Developing appropriate tests details to evaluate solids accumulation will be informed from the SSMD Limits of Performance test results and SRNL Solids Accumulation Scouting Studies test results.

2.2.2.1 Objective

The objective of the SSMD Solids Accumulation Performance Evaluation testing is to perform a series of full WFD to WTP transfer and refill operations using the 1:21-scale and a 1:8–scale mixing tank and transfer systems at Monarch Machine and Tool Company, Inc. in Pasco, WA. These tests will evaluate the bulk material that remains in the tanks after a series of pump-out and refill operations are performed. Testing will be conducted at two nozzle velocities for each of two scales and the results will be compared using the scaling relationship for waste transfer and other performance metrics (e.g., bottom cleaning). The scaling relationship for waste transfer will be developed/refined during SSMD Scaled Performance test activities (see Section 2.3.1) prior to the start of this work scope. Testing will determine the amount of bulk solids remaining and the concentration and approximate locations where the fastest settling particles accumulate in the tank heel. Providing insight into how fast settling particles are distributed in a WFD feed staging tank is important to criticality evaluations that include the accumulation of dense plutonium and uranium containing solids. The work that will be performed is expected to use methods refined by SRNL during the SSMD Solids Accumulation Scouting Studies (Section 2.2.1). The work will build on the work performed by SRNL by expanding the scope to include the larger scale.

The test objectives are summarized in Table 2-5. The objective(s) of SSMD Solids Accumulation Performance Evaluation testing are subject to change as on-going and planned work being performed by the WFD Mixing and Sampling Program is completed.

Table 2-5: Solids Accumulation Performance Evaluation Test Objectives

Objective	Success Criteria
Demonstrate, at two scales, the potential accumulation of solids in the DST after several transfer and re-fill operations are conducted.	Mixing and transfer tests are performed at two different jet nozzle velocities and at two different scales with a base simulant that contains moderately sized (approximately 100 microns), dense particles to represent fissile material in the Hanford tank waste. The spike particles are distinguishable in collected samples by a physical or chemical property that can be exploited for quantification. Very fast settling particles that can accumulate inside a DST used for several staged feeds are identified and quantified relative to the amount of the solids added to the tank. The relative quantities of typical solids in each transfer batch are quantified. The accumulation of heel solids is evaluated after each tank volume transfer by estimating the volume of heel in the tank after each tank volume transfer. The accumulation of heel solids is quantified after the 1st, 5th and last (e.g., 10th) tank volume transfer by measuring the volume of heel in the tank. Correlations relating the fraction of solids transferred and remaining in the tank are evaluated with respect to each transfer batch and after multiple tank volume transfers. The spatial distribution of the residual solids after several transfer and re-fill operations are characterized.
Evaluate solids accumulation at two scales and compare the tests results to the scaling relationship for waste transfer.	Solids accumulation data at two nozzle velocities for each of two scales is collected. Comparisons using the scaling relationship for waste transfer and bottom cleaning are performed.

2.2.2.2 Technical Approach

The SSMD Solids Accumulation Performance Evaluation testing will use the 1:21-scale and a 1:8–scale mixing tank and transfer systems to perform multiple DST transfer campaigns to characterize the solids that remain in the tank after a series of tank transfer and refill operations have been performed. A DST transfer campaign includes a series of tank volume transfers and refill operations that fill the mixing tanks with simulant and then pump out the material to one or more receipt tanks using 6.5 consecutive batch transfers. This number reflects the anticipated number of transfers needed to reduce the tank contents in a full feed DST to 72-inches using 145,000 gallon batches.

The residual volume of 72-inches of solids and supernatant is an operating limitation to avoid cavitation when the mixer jet pumps are operating at full speed. A tank volume transfer is completed when 6.5 batches of slurry are transferred from the mixing tanks to the receipt tank(s). Following a successful tank volume transfer operation, the solids remaining in the mixing tanks will be characterized and additional simulant will be added to refill the mixing tanks. A series of transfer and refill operations, up to ten, will be performed in a campaign. The solids remaining in the tanks after each transfer campaign will be characterized and compared to the total solids that are added during testing.

Testing in this manner is being performed to determine the composition and location of the solids that remain in the tanks after several transfer and refill operations are performed to evaluate the potential to accumulate fissile material in the tanks. The SSMD work scope continues the work conducted by SRNL to address the accumulation of material in the tank after successive transfer operations are performed. Unlike SRNL Scouting Studies that only quantify the very fast settling solids, the performance evaluation will quantify all solids in the transfer batches and left in the tank.

Solids Accumulation Performance Evaluation testing will use a complex simulant recommended by previous testing activities that include but are not limited to the Solids Accumulation Scouting Studies, SSMD Limits of Performance, and SSMD Scaled Performance test activities. The SRNL method to characterize the quantity of very fast settling solids that are and are not transferred will be used or refined so that monitoring the accumulation of very fast settling particles can be performed as successive transfer and refill operations are performed.

The technical approach for SSMD Solids Accumulation Performance Evaluation testing will be refined as on-going and planned SSMD test activities and other related work (e.g., simulant development) are completed. Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis will be provided in a future test plan.

2.3 SCALED/SYSTEM PERFORMANCE

While test data collected to date has provided some insight to mixing, sampling, and transfer performance (e.g., RPP-50557), more data is needed to predict full-scale performance that covers the range of physical properties of Hanford waste confidently. The objective of SSMD Scaled Performance activities is to test mixing and transfer performance at two scales using a realistic simulant representing a broad spectrum of Hanford waste to meet WTP WAC DQO sampling confidence requirements. The objective of RSD system performance activities is to evaluate the performance of the RSD, including the Ultrasonic PulseEcho system, in a configuration that addresses field deployment constraints.

2.3.1 Small Scale Mixing Demonstration

SSMD Scaled Performance test activities documented in Section 2.3.1 are performed by Energy*Solutions* for WRPS.

SSMD Scaled Performance testing is introduced in this test plan because it is being conducted to address DNFSB 2010-2 work scope; however, a separate test plan will document the tests that will be performed to evaluate the performance of the scaled system further. Developing appropriate tests details to evaluate SSMD Scaled Performance will be informed from the SSMD Limits of Performance test results and SSMD Solids Accumulation Scouting Studies test results.

2.3.1.1 Objective

The objective of SSMD Scaled Performance testing is to improve the knowledge and understanding of the scaled mixing systems further by conducting additional mixing tests. The SSMD Scaled Performance testing will extend previous work using simulants that are representative of other tank wastes. SSMD testing will be performed using three nozzle velocities at both the 1:21 and 1:8-scale test systems to build confidence in the scaling models that are used to predict full-scale performance.

The objective of SSMD Scaled Performance testing is subject to change as on-going and planned work being performed by the WFD Mixing and Sampling Program is completed. The on-going and planned work is being performed to identify the gaps that exist between the WFD's capability to deliver consistent HLW waste slurry batches and the WTP's capability to accept and process any variations in batch consistency and any potential deviation from the WAC.

The test objective is summarized in Table 2-6.

Table 2-6: SSMD Scaled Performance Test Objectives

Objective	Success Criteria
Use the 1:8- and 1:21-scale SSMD platforms to build confidence in the pre-transfer sampling representativeness and the predictions of full-scale performance.	Mixing and transfer tests are performed at multiple jet nozzle velocities with a base simulant that contains moderately sized (approximately 100 microns), dense particles to represent hard to transfer waste particles in the Hanford tank waste. The spike particles are distinguishable in collected samples by a physical or chemical property that can be exploited for quantification. Performance data (i.e., sample composition of each transfer batch) is collected at two scales and is used to refine the scaling relationship for the integrated mixer jet pump and slurry transfer system. The scaling relationship is refined and used to predict waste transfer performance at full-scale.

2.3.1.2 Technical Approach

The testing described in this test plan will use the SSMD test platform located at Monarch Machine & Tool Company, Inc. in Pasco, WA to evaluate the system performance when operating parameters for mixing and transfer are varied. The operating parameters that may be varied during testing include: the mixer jet nozzle velocity, the mixer jet rotational velocity and the transfer pump capture velocity. The selection of the appropriate test configuration will be informed from SSMD Limits of Performance testing and SRNL Solids Accumulation Scouting Studies. Equivalent tests will be performed in the 1:21- and 1:8-scale test systems. The SSMD platform will be modified in accordance with any recommendations from previous work. Evaluating the effect of transfer pump capture velocity and mixer jet rotational velocity would provide additional scale-up data for evaluating full-scale performance. To date, SSMD performance testing has focused on developing the SSMD test platform and then demonstrating that the scaled system is capable of adequately mixing and sampling a simulant that is characteristic of the first HLW feed batch that will be delivered to the WTP. On-going SSMD work scope will evaluate the capability of the system to mix and transfer simulants characteristic of other tanks that may contain other dense fissile material. SSMD Scaled Performance work will perform additional performance evaluations with simulants that are characteristic of other tank wastes operating under different conditions.

The technical approach for SSMD Scaled Performance testing will be refined as on-going and planned SSMD test activities and related work (e.g., simulant development) are completed. Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis will be provided in a future test plan.

Based on previous scaled testing of jet mixed tank performance, it is assumed that equivalent flow regimes are maintained across scales. As results are analyzed and performance anomalies identified between scale are founds, the impact of potentially operating under different flow regimes will be considered.

2.3.2 Remote Sampler Demonstration

RSD system performance test activities documented in Section 2.3.2 are performed by Energy*Solutions* for WRPS. Evaluating the RSD and Ultrasonic PulseEcho system has previously been classified as RSD Scaled Performance. The activities are now referred to as RSD system performance because the RSD flow loop (i.e., the Isolok®, PulseEcho, and piping) is not a scaled system, it is full-scale.

RSD system performance testing is introduced in this test plan because it is being conducted to address DNFSB 2010-2 work scope; however, a separate test plan will document the tests that will be performed to evaluate the performance of the RSD system further. Developing appropriate test details to evaluate RSD system performance will be informed from the SSMD Limits of Performance test results and RSD Limits of Performance test results.

2.3.2.1 Objective

The objective of RSD system performance test activities is to continue to optimize the configuration of the Isolok® Sampler system to improve the performance of the sampler to obtain reliable samples from the waste characterization flow loop. Operating parameters that will be investigated include variations in simulant composition (base solids, supernatant, and spike particles), simulant mass loading and flow velocity. Additionally, RSD system performance testing will use the Ultrasonic PulseEcho system for monitoring solid settling (i.e., the onset of Critical Velocity) in the flow loop. Critical velocity evaluations will expand upon any testing performed during RSD Limits of Performance testing (Section 2.1.2). In addition, the system design will be evaluated against field deployable constraints and limitations.

The objectives of RSD system performance testing are subject to change as on-going and planned work being performed by the WFD Mixing and Sampling Program is completed. The on-going and planned work is being performed to identify the gaps that exist between the WFD's capability to deliver consistent HLW waste slurry batches and the WTP's capability to accept and process any variations in batch consistency and any potential deviation from the WAC.

The test objectives are summarized in Table 2-7.

2.3.2.2 Technical Approach

RSD system performance testing will continue to use the RSD test platform developed at Monarch Machine and Tool Company, Inc. in Pasco, WA. The RSD test platform was constructed using a full-scale Isolok® Sampler and Ultrasonic PulseEcho system and the pipe diameter in the flow loop was full-scale. Supplemental performance testing that is performed as part of the RSD system performance effort will be informed by the previous RSD test results and incorporate any recommendations from previous testing, which includes RSD Phase I development testing, RSD Phase II mechanical handling testing and RSD Limits of Performance testing. For instance, system performance testing will evaluate whether the presence of challenging particles, as identified during RSD Limits of Performance testing, affect the reliability of the sampler to quantify other solids in the flow loop. Additionally, the RSD platform will use visual observations facilitated by transparent sections and the Ultrasonic PulseEcho system observe and detect particle settling in the flow loop, respectively. The flow velocity at which particle settling is observed and detected by the Ultrasonic PulseEcho system will then be correlated with the flow velocity that is measured by an independent instrument, e.g. a Coriolis mass flow meter.

Slurry flow velocities between 2 ft/s and 6 ft/s will be used to determine the critical flow velocities of the simulants. It should be understood that measurements performed by the PulseEcho system are representative only of the fraction of the slurry that is present and circulating in the flow loop. The PulseEcho sensors are installed at discrete locations on the flow loop and are monitoring the conditions only at those locations. The assumption is that the conditions at these locations are representative of those along the entire horizontal section of the flow loop.

PulseEcho testing at RSD is follow-on to previous testing performed by PNNL at their PDL-East facility in Richland WA. Results of this testing can be found in PNNL-20350 *Hanford Tank Farms Waste Certification Flow Loop Phase IV: PulseEcho Sensor Evaluation* and PNNL-19441.

The technical approach for RSD system performance testing will be refined as on-going and planned RSD test activities and other related work (e.g., simulant development) are completed.

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection, and data analysis will be provided in a future test plan.

Table 2-7: RSD System Performance Test Objectives

Objective	Success Criteria
Demonstrate, with different simulant compositions, the capability of the Isolok® Sampler to collect representative samples in the vertical configuration.	Isolok® sampling tests in the vertical configuration are performed in the RSD flow loop with a base simulant that contains moderately sized (approximately 100 microns), dense particles to represent hard to transfer waste particles in the Hanford tank waste, a supernatant simulant and some challenging spike particles that are distinguishable in collected samples by size and another physical property (color, density, etc.). Collected samples are analyzed for chemical composition and quantified relative to a full diversion sample. Sampler performance is evaluated against a 5% relative difference criteria. Correlations relating the relative difference between the Isolok® samples and full diversion samples are evaluated with respect to the changes in the operating conditions.
Continue the evaluation of the Ultrasonic PulseEcho system for monitoring solid movement in the flow loop.	Identify critical velocity of simulants as measured with the PNNL Ultrasonic PulseEcho system to be within 0.1 feet per second (2.3 gallons per minute) of the critical velocity value determined through visual monitoring of the settled slurry.
Define operational steps for the Isolok® Sampler and describe functional requirements for supporting systems necessary for field deployment.	Develop operational protocols for the Isolok® Sampler system that allow consistent and integrated sample collection of HLW slurries coming from a mixed DST, and document results in a report. Identify field deployment considerations for the remote sampling system, based on the experience gained during the RSD activities.

3.0 TEST REQUIREMENTS

Test requirements and test guidance have been developed to meet the SSMD Solids Accumulation Scouting Studies, SSMD Limits of Performance, RSD Limits of Performance, and Full-Scale Transfer Pump Limits of Performance test objectives and technical approach identified in Section 2.0. Test requirements and test guidance has not been developed for SSMD Scaled Performance, RSD system performance and SSMD Solids Accumulation Performance Evaluation as the test conditions for these activities will be determined by on-going test activities or other activities that are under development. Separate test plans will be developed for these activities later.

In addition to this and future test plans, each testing contractor will develop operational procedures that include or reference the test configuration, test objectives, test requirements and provisions for assuring that prerequisites and suitable environmental conditions are met, adequate instrumentation is available and operational, and that necessary monitoring is performed.

3.1 TEST SIMULANTS

The simulants used for WFD Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies test activities are based upon guidance documented in RPP-PLAN-51625. Simulant selection considers parameters (e.g., particle size, density, viscosity, and yield stress) important to solids accumulation and mixing, sampling and transfer performance. Simulant properties, such as hardness, that are important to evaluating erosion and wear of the tank and pipe walls and the mixing and transfer equipment are not primary considerations for understanding the capability of the system to accumulate solids and mix, sample, and transfer large and dense particles. However, simulant selection does favor materials that result in less wear on the test equipment when alternatives that match the critical characteristics are available.

Simulant procurement, preparation, and simulant property data collection are performed to enhanced quality assurance standards as defined in TFC-ESHQ-Q_ADM-C-01, *Graded Quality Assurance*. As such, additional level of controls beyond the providers published or stated attributes of the item, service, or process are needed to verify critical attributes of the simulants. Simulant materials procured as commercial grade items shall be prepared and qualified to match the critical characteristics of the simulants. The critical characteristics for the Newtonian base simulant and spike materials are the particle size distribution and density of the materials. The particle size distributions and densities of the components in the composite slurry are used to calculate performance metrics (e.g., distribution of Archimedes numbers) for the composite to qualify the simulant for use. For the supernatant, the critical characteristics are the liquid density and liquid viscosity. For non-Newtonian simulants the critical characteristics are yield stress and density. To qualify the supernatant and non-Newtonian slurry for use, the critical characteristics will be measured when the simulant batches are prepared.

Newtonian simulant batches of base material, spikes, and supernatant are prepared according to prepared recipes. By specifying the mass fraction of each solid component (base and spikes), the density of each solid component, the density of the supernatant, the solids loading and the batch volume, the required amounts of each solid component are fully defined. Supernatant and non-

Newtonian slurry recipes are determined from test batches prepared to match the critical characteristics. The base simulant, supernatant simulant, and spike particles for Newtonian simulants and the non-Newtonian simulant described in this test plan are described below. Selection and justification of the simulants to be used in each test activity are provided in the test requirements for each test activity.

3.1.1 Base Simulant

3.1.1.1 Base Simulant Description

The base simulant is the mixture of solid particles in the Newtonian slurry representing the Hanford tank waste. RPP-PLAN-51625 recommends three base simulants for WFD Mixing and Sampling Program test activities, Low Conceptual, Typical Conceptual, and High Conceptual. The Low Conceptual base simulant is a single component base composed of gibbsite particles. As described in RPP-PLAN-51625, the Low Conceptual simulant is similar to the least challenging waste with respect to the distribution of Archimedes numbers and jet velocity needed to achieve a certain degree of solid suspension. Considering these same two metrics, the High Conceptual simulant is generally more challenging then the waste and the Typical Conceptual simulant is in between these two and is similar to much more of the waste. The Typical Conceptual and High Conceptual base simulants are complex simulants composed of gibbsite particles, sand particles, zirconium oxide particles, and stainless steel particles. Differences in recommended particle sizes of gibbsite and sand, as well as, differences in the mass fractions of each component mixture distinguish the Typical and High Conceptual simulants. Table 3-1 provides the composition of the base simulants recommended in RPP-PLAN-51625. The selected base simulant used in each test is specific to the objective of the test and justified in the Test Simulants section of the test plan.

In addition, following the recommendations in RPP-PLAN-51625, tests will also be performed using a non-Newtonian slurry with a Bingham yield stress between 3 and 10 Pa. Tests requiring a non-Newtonian, cohesive slurry will be made from EPK kaolin clay. Based on initial laboratory work performed to develop simulant recipes at lab scale quantities, a non-Newtonian slurry with a yield stress of 3 Pa and a density of about 1.16 g/ml is obtained by adding 20-22 weight percent Kaolin to tap water. A non-Newtonian slurry with a yield stress of 10 Pa and a density of about 1.22 g/ml is obtained by adding 28-30 weight percent (wt %) Kaolin to tap water. Test samples shall be prepared to confirm these quantities and the critical properties (i.e., the yield stress and density) of the test batch shall be confirmed prior to testing. Table 3-1 includes the properties for the non-Newtonian simulant. For a non-Newtonian slurry with a yield stress of 3 Pa and a higher density, sodium thiosulfate at 28 wt % can be added to 16 wt % Kaolin in tap water.

Kaolin slurries with a targeted yield stress of 3 Pa are determined to be acceptable in the range of 2 to 4.5 Pa and slurries with a targeted yield stress of 10 Pa are determined to be acceptable in the range of 7 to 13 Pa. This is based on the time varying nature of a non-Newtonian simulant and the necessary accuracy needed to resolve the effect of the yield stress on the capability to transfer large and dense particles.

Table 3-1: Base Particulate Simulant Characteristics

Newtonian Base					
Compound	**Solid Density (g/ml)**	**Median Particle Size (micron)**	**Mass Fraction**		
			Low	**Typical**	**High**
Small Gibbsite	2.42	1.3	1.00	0.27	0
Large Gibbsite	2.42	10	0	0.44	0.03
Small Sand	2.65	57	0	0	0.35
Medium Sand	2.65	148	0	0.13	0
Large Sand	2.65	382	0	0	0.21
Zirconium Oxide	5.7	6	0	0.10	0.08
Stainless Steel	8.0	112	0	0.06	0.33
Non-Newtonian Base					
			Yield Stress		
			Slurry Density (g/ml)	**3 Pa**	**10 Pa**
Kaolin clay	NA	NA	~1.2	22 wt%	28 wt%
Kaolin clay w/ sodium thiosulfate	NA	NA	1.37	16 wt% Kaolin 24 wt% sodium thiosulfate	23.4 wt% Kaolin 17 wt% sodium thiosulfate

3.1.1.2 Base Simulant Qualification

As described in RPP-PLAN-51625, particle size distributions, particle density, and mass fractions of the components in the composite simulant can be used to determine the distributions of Archimedes numbers and jet velocities needed to achieve a certain degree of solid suspension for the composite simulant. As discussed in PNNL-20637, *Comparison of Waste Feed Delivery Small Scale Mixing Demonstration Simulant to Hanford Waste*, the Archimedes number is closely related to the settling velocity and is also a parameter in other mixing and transfer metrics such as pump intake, jet suspension velocity, critical shear stress for erosion, critical suspension velocity, suspended particle cloud height, and pipeline critical velocity. The jet velocity needed to achieve a certain degree of solid suspension comparison correlates the particle size and density to the jet velocity of a radial wall jet needed to suspend solids in a tank. Base simulant qualification is performed by comparing the distribution of Archimedes numbers and jet velocities needed to achieve a certain degree of solid suspension calculated for the procured simulants to the distributions documented in Figures 8-1 and 8-2 in RPP-PLAN-51625. To provide comparable results, performance metrics are calculated using the same assumptions used to calculate the metrics for the three conceptual simulants. Metrics are calculated using particle densities and particle size distributions obtained on samples from each procured lot. The particle size distribution provided by the vendor is not adequate for simulant qualification. Appendix C of RPP-PLAN-51625 includes additional performance metrics, such as the critical shear stress for erosion of non-cohesive particles, just suspended impeller speed, pulse jet mixer critical suspension velocity for non-cohesive solids, pulse jet mixer cloud height for non-cohesive solids, and pipeline critical transport velocity. The procured material will also be compared to the conceptual simulants using these metrics.

The metrics calculated for the conceptual simulants in RPP-PLAN-51625 include typical distributions for some of the components. Therefore, the calculated values represent target values and deviations from the conceptual simulants are anticipated. The appropriateness of candidate material will be evaluated before simulant procurement. For procurement purposes, in absence of samples from actual lots, vendor supplied information (e.g., particle size distributions and particle density) and targeted mass fractions can be used to calculate the performance metrics for comparison to the conceptual simulants. For simulant qualification, calculations will be based on laboratory analysis of samples taken from the procured material and actual weight measurements recorded during testing.

Tests using a non-Newtonian slurry with a Bingham yield stress between 3 and 10 Pa will be made from EPK kaolin clay. The yield stress will be measured to be within the tolerances specified in Section 3.1.1.1 prior to testing. The yield stress measurements will be performed on-site with a rheometer calibrated in accordance with Requirement 12, Control of Measuring and Test Equipment, in ASME NQA-1-2004 including addenda, or a later version. Appropriate instrumentation for measuring the yield stress of the non-Newtonian fluid is a programmable rheometer capable of taking controlled shear rate and controlled shear stress measurements. The rheometer should also have the capability to control sample temperatures. Data collection shall be performed in accordance with Requirement 11, Test Control in ASME NQA-1-2004 including addenda, or a later version. Yield stress measurements will be collected prior to the start of testing to ensure that the time varying qualities of the non-Newtonian slurry do not change significantly before testing is initiated. In addition, yield stress will also be measured at the completion of testing, and during testing if necessary, to assess rheological changes that may occurring during the course of testing.

3.1.2 Supernatant Simulant

3.1.2.1 Supernatant Simulant Description

The supernatant simulant is the liquid phase of the simulant slurry. For WFD Mixing and Sampling Program test activities, RPP-PLAN-51625 recommends four supernatant simulants, which are characterized by liquid density and liquid viscosity. The four supernatant characteristics are taken from Table 6-1 in RPP-PLAN-51625, which is summarized in Table 3-2. Table 3-2 also provides the weight percentages of the components that can be used to produce the targeted characteristics. These compositions are informed from chemical handbooks and previous testing and were confirmed by preparing test batches at a laboratory scale. The tabulated supernatant simulants are limiting supernatants and were developed for testing activities that attempt to mobilize large and dense particles. The selected supernatant simulant used in each test is specific to the objective of the test and justified in the Test Simulants section of the test plan. The target density and viscosity will be achieved by adding sodium thiosulfate, or other readily available sodium salt (e.g., sodium bromide), to water to achieve the targeted density. Glycerol will be added as necessary to increase the viscosity to the targeted value required for testing.

A typical supernatant is also considered when it is not necessary to evaluate the capability of the test system to mobilize large and dense particles (i.e., Solids Accumulation Scouting Studies). The liquid density for this supernatant is the median density from the same dataset used to derive the low and high density values in RPP-PLAN-51625. The dataset is the liquid density of the feed batches to the WTP calculated using the Hanford Tank Waste Operations Simulator model (RPP-RPT-48681, *Hanford Tank Waste Operations Simulator Model Data Package for the River Protection Project System Plan Rev. 6 Cases*). The typical supernatant is characterized as having a liquid density of about 1.29 g/ml ±5% and a liquid viscosity of 3.3 ±1 cP. The viscosity of the supernatant is determined by the salt used to attain the desired density, and is comparable to the value determined using the relationship in Figure 6-2 of RPP-PLAN-51625. An aqueous solution of 31.5 wt % sodium thiosulfate will produce a supernatant with these characteristics.

Table 3-2: Newtonian Liquid Supernatant Simulant Characteristics

Supernatant	**Liquid Density (g/ml)**	**Liquid Viscosity (cP) @ 20°C**	**Aqueous Solutions**
Low Density / Low Viscosity	1.1	1	12 wt% Sodium bromide or Sodium Thiosulfate
Low Density/high Viscosity	1.1	8	55wt% glycerol
High Density / Low Viscosity	1.37	1	37 wt% sodium bromide
High Density/high Viscosity	1.37	15	33.5 wt% sodium thiosulfate and 19.9 wt% glycerol
Typical Density and Viscosity	1.29	3.3	31.5 wt% sodium thiosulfate

3.1.2.2 Supernatant Simulant Qualification

The simulant recipe for the supernatant simulant was developed in the laboratory, but will need to be scaled to the volume needed for each test. Small test batches will be prepared to confirm the relative amounts of each constituent needed to achieve the targeted results using the procured materials at testing conditions. Test batches shall be within 5% of the target density and within 20% of the target viscosity. Then scale up to testing volumes will be performed and the liquid density and liquid viscosity will be measured to confirm that the prepared batch is within the required range for liquid density and viscosity. For low density and low viscosity fluids, 1.1 g/ml and 1 cP, respectively, the acceptable range of liquid densities is ±5% and 0.5 cP. The low density and low viscosity liquid will be attained using a sodium salt (e.g., sodium thiosulfate). The two properties cannot be adjusted independently using the single component and a broader tolerance is allowable for liquid viscosity. For higher density and viscosity fluids, the acceptable range for the density is ±5%. The tolerance on the liquid viscosity at levels above 5 cP is ±20% when the measurement is determined at testing temperatures. High viscosities will be attained by adding glycerol. The viscosity of glycerol is dependent on concentration and temperature, increasing as concentration increases and temperature decreases. For a specified concentration, a temperature correlation will be developed so that the viscosity at the measured temperature can be used to evaluate the viscosity at the testing temperature to determine if the prepared simulant meets the 20% tolerance on viscosity. The liquid property measurements will be measured on-site with the appropriate instrumentation (e.g., hydrometer, viscometer, rheometer) calibrated in accordance with Requirement 12, Control of Measuring and Test Equipment, in ASME NQA-1-2004 including addenda, or a later version. Appropriate instrumentation for measuring liquid viscosity of the Newtonian fluid is a programmable rheometer capable of taking controlled shear rate and controlled shear stress measurements. The rheometer should also have the capability to control sample temperatures. Data collection shall be performed in accordance with Requirement 11, Test Control in ASME NQA-1-2004 including addenda, or a later version. To ensure that the prepared simulant is appropriate for use, liquid properties will be measured prior to adding base simulant solids and therefore will be performed at the start of testing. In addition, viscosity will also be measured at the completion of testing, and during testing if necessary, to assess changes that may occurring during the course of testing.

3.1.3 Spike Particulates

For Limits of Performance test activities, additional particles will be added (spiked) to the simulant slurry consisting of the base simulant and the liquid supernatant. For Solids Accumulation Scouting Studies, the very fast settling solids are accounted for in the stainless steel base material and no supplemental spiking material is necessary. Report RPP-PLAN-51625 recommends four materials for the spike particulates, sand, stainless steel, tungsten carbide grit (WC), and tungsten grit. Sand is a simulant for large particles that have a density comparable to the average density of Hanford waste particles. Stainless steel, tungsten carbide, and tungsten, which have densities of approximately 8 g/ml, 14 g/ml and 19 g/ml, respectively, are simulants for high-density plutonium containing compounds [e.g., plutonium oxide (~11 g/ml)] in the Hanford tank waste. The sand and stainless steel spike particulates are chemically similar to the components in the base simulant and therefore must be distinguishable from the base materials to be quantified. The spike materials will be distinguishable by particle size; size exclusion (e.g., sieving) will be used to separate the spike particles from the chemically similar base materials.

Table 3-3 identifies the spike materials for Limits of Performance testing. Procured samples of very large sand material (>7000 microns silica) were irregularly shaped and had a broad particle size distribution despite being classified by sieving to a single sieve size. Borosilicate glass or soda-lime glass spheres will be used as a surrogate for very large sand particles. The glass spheres are chemically inert, have a density similar to sand, but have consistent sizes in 1,000 micron or 1/16-inch increments because they are manufactured products. Having a consistent shape will facilitate separation of the spike particles by sieving.

The sizes of the glass, stainless steel, and tungsten carbide spike particulates in Table 3-3 are for spheres, which are readily available in the sizes listed. Consistent with recommendations in SRNL-STI-2012-00062, spherical particles are considered because, compared to irregularly shaped particles with more surface area per volume, spherical particles would settle faster from suspensions, creating a greater challenge to mix, transfer, and sample challenging particles. The spike particles listed are commercially available items that have an industrial purpose and are manufactured to size tolerances that exceed the tolerances necessary to distinguish the different sized spike particles by sieving. Commercial sources for the listed particles manufacture the particles in either 1/32-inch or 1/16-inch increments for metal spheres and 1mm increments for glass spheres with size variations that typically do not exceed several microns. Qualification of the metal spike particles is limited to demonstrating that 99.9% of a one pound sample taken from each delivered lot is retained on the sieve used to separate that size from the other particles. Qualification of the glass spike particles, which are manufactured to a lower tolerance for shape, is limited to demonstrating that 98% of a one pound sample taken from each delivered lot is retained on the sieve used to separate that size from the other particles.

The spike materials listed in Table 3-3 have densities characteristic of Hanford tank waste and are provided for test planning purposes; the densities of procured spike materials may be different due to differences in manufacturing processes. Table 3-3 also includes two properties that are relevant to mixing, the Archimedes number, and the free settling velocity. The tabulated Archimedes numbers, Ar, are calculated according to Equation 3-1. The Archimedes number indicates general settling characteristic, particles with higher Archimedes values tend to settle faster than particles with lower Archimedes values. The reported values are calculated for the high density (1.37 g/ml) and high viscosity (15 cP) supernatant. The tabulated free settling velocity, V_t, is calculated in the same supernatant liquid according to Equation 3-2. The free settling velocities result in Reynolds numbers, Re, (Equation 3-3) in the Intermediate Law regime (between 0.3 and 1000).

$$Ar = \frac{\left(\frac{\rho_s}{\rho_l} - 1\right) g d^3}{\upsilon^2} \qquad \text{Equation 3-1}$$

$$V_t = \left(\frac{4gd(\rho_s - \rho_l)}{3\rho_l \left(\frac{18.5}{Re^{0.6}}\right)} \right)^{0.5} \qquad \text{Equation 3-2}$$

$$Re = \frac{\rho_l V_t d}{\mu} \qquad \text{Equation 3-3}$$

Where ρ_s is the particle density, ρ_l is the liquid density, g is the gravitational constant, d is the particle diameter, v is the kinematic viscosity of the liquid and μ is the dynamic viscosity of the liquid. The selected spike particulates, including particle size and spike concentration, used in each test are specific to the objective of the test and justified in the Test Simulants section of the test plan. Alternatives to the spike materials require the concurrence with the TOC technical representative(s) before the material is procured.

Table 3-3: Limits of Performance Simulant Spike Candidates

Compound	Solid Density (g/ml)	Characteristic Particle Size (micron)	Archimedes Number[1]	Free Settling Velocity[1] (ft/s)
Very Large Sand or Gravel	2.65	1500-9510	258-65,700	0.24-1.0
Borosilicate Glass	2.23	1000	51.4	0.14
		2000	411	0.25
		3000	1390	0.34
		5000	6420	0.51
		7000	17,600	0.67
Soda-Lime Glass	2.52	1000	68.7	0.16
		2000	540	0.28
		3000	1820	0.39
		5000	8430	0.59
		7000	23,100	0.77
Stainless Steel (SS)	8.0	1587.5 (1/16")	1580	0.58
		3175 (1/8")	12,700	1.0
		4762 (3/16")	42,800	1.4
		6350 (1/4")	101,000	1.7
Tungsten Carbide (WC)	14.2	1587.5 (1/16")	3070	0.80
		2380 (3/32")	10,300	1.1
		3175 (1/8")	24,500	1.4
		4762.5 (3/16")	82,800	1.9
		6350 (1/4")	196,000	2.4

[1] Calculated for a fluid having a liquid density of 1.37 g/ml and a viscosity of 15 cP.

3.2 LIMITS OF PERFORMANCE

3.2.1 Small Scale Mixing Demonstration

The SSMD Limits of Performance test activities documented in Section 3.2.1 are performed by Energy*Solutions* for WRPS. This test plan does not identify specific test requirements for development work that has been performed to investigate appropriate spike particulates to use for testing; however, a description of the preliminary work is provided for information in Section 3.2.1.1.

3.2.1.1 Development Activities

Preliminary studies have been performed with particles having very high values for particle size and density in a non-prototypic mixing environment to determine the capability of the SSMD 1:8-scale transfer pump to deliver large and dense solids to a sample location downstream of the transfer pump. Although this transfer pump is not prototypic of the submersible pump anticipated to be used to transfer waste to the WTP, understanding the limits of the current transfer pump can be used to assess the limits of the entire 1:8-scale mixing platform. In the event that large and dense particles included in the mixing test are not recovered in the transfer batch samples withdrawn from the mixing tank, it can only be concluded that the mixing performance is inadequate to deliver these particles to the transfer system if it is known that the transfer system is capable of conveying the particles to the sample collection location.

Evaluating the capability of the transfer pump from the 1:8-scale system was performed using a simplistic test set up (i.e., without filling the SSMD platform 120-inch diameter mixing tank). The transfer system of the 120-inch diameter mixing tank in the SSMD test platform at the Monarch Machine and Tool facility in Pasco, Washington was placed into an auxiliary vessel and operated at approximately 2.8 gpm; the scaled transfer rate for the 1:8-scale system. The operating flow rate resulted in a flow velocity of approximately 11.7 ft/s through the 5/16-inch diameter pump suction inlet, which was mounted at the scaled height of 0.8 inches above the tank bottom.

For developmental testing, the spikes were added to a vessel filled with water and the transfer pump suction was brought to operating conditions. Table 3-4 lists the spike materials that were included in the preliminary tests. The Archimedes Number and free settling velocity are calculated using Equations 2-1 through 2-3 for a supernatant having a density of 1.37 g/ml and a viscosity of 15 cP. All free particle settling occurs in the Intermediate Law regime. The list of spike particles tested exceeded what is recommended as spike particulates in RPP-PLAN-51625, but evaluating multiple components built confidence that the right particles would be selected for testing. With the exception of the sand/silica, which was irregularly shaped, the spike particles were spherically shaped. Mixing was started and the particles that were entrained in the pumpage were captured in a trap and quantified.

Mixing in the auxiliary vessel was implemented using different methods including no mixing, mixing using a paint mixer attached to a portable drill, and mixing using simulated jets. Testing progressed from the no mixing condition, to the paint mixer condition, to the simulated jet mixing condition. The static condition resulted in very few large particles being transferred when the transfer pump suction inlet height was set at the scaled height. Mixing using a paint mixer resulted in vortexing and was not prototypic. Mixing using the simulated jets attempted to result in "representatively mixed" conditions within the vessel. In this usage, "representatively mixed" means that the particles in the vicinity of the transfer pump suction should have had a velocity and direction similar to that anticipated in the 120-inch diameter test tank. For static conditions, the pump suction inlet height was lowered until particle transfer occurred and the height at the time of transfer was recorded.

Table 3-4: Preliminary SSMD Limits of Performance Simulant Spike Candidates

Compound	Solid Density (g/ml)	Characteristic Particle Size (micron)	Archimedes Number[1]	Free Settling Velocity[1] (ft/s)
Very Large Sand / Silica	2.7	7000	27,200	0.83
		8000	40,700	0.93
Borosilicate Glass	2.23	3175 (1/8")	1640	0.36
		4762.5 (3/16")	5550	0.49
		6350 (1/4")	13,200	0.62
Stainless Steel	8.0	1587.5 (1/16")	1580	0.58
		3175 (1/8")	12,700	1.0
		4500	36,100	1.3
		4762 (3/16")	42,800	1.4
		6350 (1/4")	101,000	1.7
		7938 (5/16")	198,000	2.8
Tungsten	19.0	7200	393,000	3.1
		7800	500,000	3.3
Copper	8.9	4500	41,000	1.4
Aluminum	2.7	2381.25 (3/32")	1070	0.35
		3175 (1/8")	2540	0.443

[1] Calculated for a fluid having a liquid density of 1.37 g/ml and a viscosity of 15 cP.

The results of the static tests showed that even the largest, most dense particle tested, 7800 micron tungsten spheres, could be entrained in the pump suction if the pump suction was close enough to the particle (approximately 0.3 inches). No particle larger than ¼-inch in diameter was transferred when the transfer pump suction inlet height was equal to the scaled height of 0.8 inches. Smaller particles with densities up to 9 g/ml were transferred at the scaled height. Using drill mixing, the large silica could be transferred when the pump suction inlet was placed at the scaled height. When jet mixing was used to create a representatively mixed tank, no transfer of ¼-inch stainless steel or tungsten spheres was observed when the pump suction inlet was placed at the scaled height. The preliminary test results suggest that the largest stainless steel sphere to be used in the SSMD Limits of Performance testing should be ¼-inch and that tungsten sizes could be constrained to even smaller diameters.

Once the capability of the transfer system was established, with respect to simulant spike particle size and density, the transfer system can be used to assess the capability of the fully integrated 1:8-scale mixing and transfer system.

3.2.1.2 Test Equipment and Instrumentation

Fully integrated 1:8-scale testing will be performed using the SSMD test platform at the Monarch Machine and Tool facility in Pasco, Washington. A schematic of the SSMD test platform is shown in Figure 2-2. The SSMD test platform has been used for previous test activities and will continue to be used to address uncertainties in the WFD Mixing and Sampling Program. The SSMD test platform was constructed to perform mixer jet pump testing at two different scales, approximately 1:21 (43.2-inch diameter tank) and 1:8 (120-inch diameter tank). The 1:8-scale tank is appropriate for limits of performance testing. Due to much smaller transfer pipe diameters (1/4" as shown in Table 1-1), which are likely to be smaller than the largest particle that can be transferred, the smaller scale tank is not appropriate for limits of performance testing to determine the largest size of a dense particle that can be transported from the mixing tank.

The SSMD test platform has been used previously for SSMD testing work and will continue to be used without significant modifications to assess the capability of the system to mix tank waste simulants and deliver the solids to a receipt tank. SSMD Limits of Performance testing shall use the 1:8-scale system. The main components of the test platform include: a 3,000-gallon flush tank, a 2,358-gallon clear acrylic test tank (TK-301), the dual rotating mixer jet pump assembly and the slurry transfer pump. The slurry transfer pump is not a submersible pump located inside TK-301. The slurry transfer pump is a progressive cavity pump located outside of the test tank; the inlet of the pump is connected to a suction line that is placed within the tank. The end of the suction line inside the tank is fitted with a machined orifice matching the requirements in Table 1-1. Scaled dimensions for TK-301 are also provided in Table 1-1. Ancillary equipment, such as the support structure, the control system, video monitoring, and simulated piping to transfer the material from the tank are also part of the test platform. The test system shall be configured similarly to previous SSMD test activities using the 241-AY-102 configuration. Mixing in TK-301 shall be performed using two rotating mixer jets, each having two opposing nozzles placed near the tank bottom. The transfer pump suction inlet shall be placed consistent with the location of Riser 30 and the scaled height of the pump suction inlet should be equivalent to the height of the transfer pump inlet in the full-scale DST transfer system, 0.8 inches (see Table 1-1).

The transfer system piping, valving, and instrumentation (e.g., in-line Coriolis meters, and magnetic flow meters) should replicate the transfer system from previous testing reported in RPP-49740. The test configuration shall include a closed recirculation loop from the tank. The recirculation loop shall accommodate sample collection. Flow control shall be automated using programmable logic controllers connected to a human–machine interface. System data, including flow conditions and specific gravity measurements, shall be monitored and recorded using a data acquisition system.

The internal passageway of the transfer pump is larger than the transfer line; therefore, large and dense particles that can be captured and transferred may settle in the pump because the velocity through the pump is reduced below the critical velocity of the particles. To prevent the buildup of large and dense particles in the pump, the transfer line upstream of the pump inlet shall be modified to include a particle collection trap. The trap will increase the cross sectional area of the transfer line to reduce the transfer velocity through the trap, allowing the large and dense particles to settle to the bottom of the trap. The trap shall accommodate emptying without requiring that the transfer operation be stopped. Downstream of the transfer pump, slurry shall be discharged through a No. 14 or No. 16 screen to separate the spike particles from the base material. When operating in a recycling mode, the base material that passes through the screen shall be discharged back into the tank. When operating in batch transfer mode, the base material that passes through the screen is sent to waste collection. The spike particles retained by the screen shall be collected and segregated by cascading sieves (see Section 3.2.1.5) to separate the different sized particles. The particles collected in the trap shall also be introduced to the cascading sieves for quantification. The amount of each spike transferred shall be quantified by counting or by weighing the separated material after it has been washed and dried. The quantity of the transferred spikes shall be recorded.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted, and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented in a test log.

3.2.1.3 Test Simulants

The simulants used in the SSMD Limits of Performance testing are selected in accordance with the recommendations in RPP-PLAN-51625. Simulant properties and qualifications are described in Section 3.1. Selecting particular simulants for SSMD Limits of Performance test activities is discussed below. The test matrix showing the combinations of base simulant, liquid supernatant, and spike particulates is discussed in Section 3.2.1.4.

The SSMD Limits of Performance simulants shall include Newtonian and non-Newtonian simulants spiked with large and dense particles. The Newtonian simulant shall be a complex simulant containing base particulates and spike particulates. The liquid phase shall be a supernatant simulant. The non-Newtonian simulant will be kaolin clay with spike particulates. Sodium thiosulfate will be added to increase the density of the non-Newtonian slurry when required in the test matrix. Recipes for the simulants discussed below are tabulated in Table 3-1 and Table 3-2.

The effect of the base simulant on the capability of the system to transfer large and dense particles has not been previously investigated using the recommended simulants; however, it is expected that the presence of solids in the slurry should hinder settling, which could enhance waste transfer if the spike particulates become suspended by the rotating mixer jets. Two base simulants are selected for evaluating the effect of the base simulant on the capability of the system to transfer large and dense particles. Figure 8-10 in RPP-PLAN-51625 provides the basis for selecting two of the three conceptual simulants recommended in RPP-PLAN-51625. The figure suggests that changes in the base simulant composition will influence the movement of the spike particles. Although the basis for the metric shown in the figure is developed for impeller mixed tanks using the Zweitering correlation, the functional form is similar to metrics for jet mixed systems [i.e., the jet velocity needed to achieve a certain degree of solid suspension (Equation 2.9 in PNNL-20637)]. Excluding the properties of the tank or mixing system, the exponential dependence on the fluid properties (kinematic viscosity, liquid density) and particle properties (density, size, and mass loading) are similar; when the two equations are compared to one another, the exponents on these terms vary by 0.13 or less. The calculation provided in Figure 8-10 of RPP-PLAN-51625 suggests that the Low Conceptual simulant should have the greatest capability to transfer large and dense particles, and that for a specific power input there is very little difference in the spike transfer capability of the Typical and High Conceptual simulants. If there is sufficient mixing energy introduced into the tank to suspend all the material, the additional large sized base material in the Typical and High Conceptual simulants may hinder settling of the spike particles, which could promote spike particle transfer over the other simulant bases. However, there is insufficient evidence to predict which conceptual simulant would be more likely to the transfer the large and dense particles. The High Conceptual simulant was selected as a second simulant for testing. Choosing the High Conceptual simulant is consistent with RSD Limits of Performance testing, which is using this simulant to try and plug up the internal passages of the RSD sampler. Conducting tests with the Low and High Conceptual simulants is also consistent with the high uncertainty in the characterization of Hanford tank waste, especially as it is blended and staged for WFD to the WTP. The two base simulants that have a broad distribution of Archimedes numbers and using these two limiting cases is appropriate for Limits of Performance testing because much of the Hanford waste is uncharacterized with respect to particle size and density distributions, and the waste which has been characterized suggests a wide distribution of Archimedes numbers for tank waste. Evaluating the effect of the limiting cases reduces the risk that uncharacterized waste could have a capability that has not been quantified. The SSMD Limits of Performance testing will use the Low Conceptual and High Conceptual simulants to quantify the effects of each on the capability of the system.

To investigate the effects of solids loading, two base simulant loadings, high and low, will be investigated during SSMD Limits of Performance testing. For the high loading, the weight percent shall be 15% and is based on the ICD-19 allowable limit of 200 g/l. For the Low Conceptual simulant in the Low density supernatant the solids loading is approximately 180 g/l when 5 wt % spike solids are added to the base. For the High Conceptual simulant in the High-density supernatant, the solids loading is approximately 227 g/l at the same spiking level. The resulting slurry density ranges between 1.20 g/l and 1.51 g/ml, the latter being slightly above the action level identified in ICD-19. A second, low loading, weight percentage is based on a feed solids composition of 125 g/l. A mass loading of 9 wt % yields a solids concentration between 104 and 131 g/l, depending on the base simulant and supernatant composition selected. The resulting slurry density ranges between 1.16 g/ml and 1.45 g/ml.

To investigate the effects of the supernatant density and viscosity, two supernatant compositions will be investigated, high and low. For the high supernatant, the targeted slurry density is 1.37 g/ml and the targeted liquid viscosity is 15 cP. The targeted values are consistent with the high density/high viscosity recommendation in Table 3-2 and have an acceptable tolerance of 5% for the liquid density and 20% for the liquid viscosity. Liquid viscosity tolerance is evaluated at the operating temperature of the test tank, if the temperature of the sampled material differs from the bulk volume. The high values for liquid density and liquid viscosity are selected because higher densities and higher viscosities are expected to increase the buoyancy effecting solid particles in the mixing tank and reduce critical suspension and settling velocities. Increasing buoyancy and subsequently reducing the critical suspension velocity and settling velocities is expected to promote particle suspension, facilitating the movement of large and dense particles to the transfer pump suction inlet. To confirm this expected correlation, a second supernatant simulant with a lower density and viscosity will be evaluated. The targeted slurry density for the low supernatant is 1.1 g/ml and the targeted liquid viscosity is 1 cP. The selected quantities are equivalent to the Low Density/Low Viscosity supernatant listed in Table 3-2. For the Low supernatant, the acceptable tolerance on the density is ±5% and the acceptable tolerance on the viscosity is 0.5 cP.

In addition, tests shall be performed using a non-Newtonian slurry with a Bingham yield stress of 3 Pa ±50%. A 50% tolerance is added to the yield stress measurement because of dynamic changes in the slurry viscosity as it is prepared and mixed. Kaolin slurries are slightly rheopetic and may thicken when mixed. A non-Newtonian test should be used to verify the expectation that slurries having a yield stress result in better batch transfer of spike particulates, as reported in SRNL-STI-2011-00278, *Demonstration of Mixing and Transferring Settling Cohesive Slurry Simulants in the AY-102 Tank.* For verification tests requiring a non-Newtonian, cohesive slurry kaolin clay shall be used to increase the Bingham yield stress of the simulant to values up to 3 Pa, as measured at the beginning of testing. Bingham yield stress measurements shall also be collected at the end of each test to quantify any changes in the test conditions that occur during testing. If necessary, as indicated by measurements that exceed the specified tolerance at the end of testing, supplemental measurements should be taken to monitor changes in the slurry as mixing progresses. With the expectation that higher yield stresses should facilitate the movement of larger and denser particles, the 3 Pa limit was selected because it is similar to values that have been used in mixing tests in the past and is expected to be manageable in the 120-inch diameter tank. A 3 Pa kaolin mixture has a density around 1.16 g/ml, which means that the fluid density would be comparable to the Newtonian low density supernatant. For comparisons to higher density, Newtonian supernatants, sodium thiosulfate will be added to a kaolin slurry to increase the slurry density, without spikes, to 1.37 g/ml ±5%. Yield stress measurements should be performed prior to testing and at subsequent startups if the slurry is idle for more than 8 hours in between testing.

The spike material representing the large and dense particles should be composed from solids having a very narrow size distribution range so that all of the particles from a single lot are essentially the same size. Qualification of the spike particles is limited to demonstrating that 99.9% of a one pound sample taken from each delivered lot is retained on the sieve used to separate that size from the other size particles. The spike particulates included in each test include multiple sizes of particles at two different densities. The size increments for each particle type are at least 1000 microns so that the particles can be readily separated by sieving on-site. Having multiple sizes of particles allows for positive confirmation that smaller particles can be transferred when larger particles are not transferred. This allows for an estimation of the capability limit of the system.

Furthermore, to reduce the number of tests that need to be conducted, two different density materials (of multiple sizes) shall be included in each test. The spike particulates added in each test have a different density so that differences in density and differences in sizes transferred can be used together to assess the limits of the integrated mixing and transfer system. Differences in particle density may also facilitate the separation of the spike particulates for quantification. The largest particles of high spike particulates are those that could be conveyed during preliminary test activities. Smaller particles are also included. Table 3-5 provides the composition and particle sizes for the simulant spikes. Soda-lime glass is selected as a spike material instead of sand, one of the recommended spike materials in RPP-PLAN-51625, because it has a comparable density to sand and the spherical shape will facilitate separation of the different sized particles by sieving. Furthermore, glass spheres are available in size increments that are different from the stainless steel or tungsten carbide spheres so that different sieve sizes can be used to segregate the material (see Section 3.2.1.5). For tests including a non-Newtonian simulant, kaolin clay is spiked with the same particle types and masses used in comparable Newtonian tests.

The quantity of the spike particles added to the test tank shall initially be 5 wt % (total) of the solids and may need to be increased prior to the first transfer if the observed movement of the particles suggests that there is a very low probability of mobilizing the solids to the transfer pump suction inlet. In addition, in preliminary testing with the 1:8-scale transfer system the volume of captured glass spheres was significant and tended to result in line plugging at high particle loadings. In the initial tests the loadings were not typical of the loading in the 1:8-scale tank. If continued testing indicates that line plugging continues to be a problem for readily mobilized particles, the quantity of readily mobilized particles added to the tank may need to be reduced. Any changes to the initial loading amount would need concurrence from the TOC technical leads. The 5 wt % value was selected so that an adequate number of particles are present in each test and does not reflect any expected condition in the uncharacterized waste. Figure 8-10 in RPP-PLAN-51625 provides the basis for choosing a spike loading between 1 and 10%. The result suggests that for impeller mixed systems, or similarly jet mixed systems as described previously, the mixing power necessary to suspend a certain sized particle does not change significantly when the spike loading is changed from 1% to 10%. Although the required energy changes for different base materials and different sized spike particles, a spike loading between 1 and 10% does not change the dynamics of the system considerably. In order to satisfy RPP-PLAN-51625 Requirement 2 that states that the mass of spikes added should not change the performance of the system additional observations will be made during testing. The relationship in Figure 8-10 of RPP-PLAN-51625 suggests that the performance of the system with a Typical and High Conceptual simulant would not be significantly affected but that performance with the Low Conceptual simulant could change. This is not an unexpected result, the Low Conceptual simulant is comprised of a small, low density solid that is readily suspended. Adding large spike material to the tank requires additional energy to suspend the spike particles. However, if the normal operating conditions exceed the conditions necessary to suspend the base simulant, then the performance of the system may not be compromised by adding the spikes. Therefore, prior to adding the spikes to a test with the Low Conceptual simulant, the tank will be operated and mixing conditions (e.g., cloud height, mound formation, etc) in the tank will be monitored. The spike will be added and the mixing conditions will be re-measured to determine if addition of the spike results in any changes on mixing performance.

Ideally, the mass distribution of particle sizes in the specified mass loading would represent the expected distribution of the waste. A review of the data reported in PNNL-20646, *Hanford Waste Physical and Rheological Properties: Data Gaps*, indicates that tank waste samples tend to have few very large particles (>1000 microns) and more moderate sized particles (10s to 100s of microns).

Two allocation methods that result in greater number of smaller spike particles compared to the largest spike particles would be to equate the masses of each represented size or distribute the masses in proportion to the ratio of the particle diameters. In the latter approach, a system with 1/16-inch, 2/16-inch, 3/16-inch, and 4/16-inch spike particles uses weight percentages of 10%, 20%, 30% and 40% for the particles, respectively. Comparing the two techniques, the latter approach reduces the number of the smallest particles and increases the number of larger particles over the former. This method is preferred because it increases the number of the largest spike particles relative to the equal mass method. Increasing the number of the largest spike particles increases the probability of capturing a representative number of the larger particles. Using the preferred method 2.5 wt % tungsten at the lowest solids loading level (9 wt %) and four size particles places more than 5,000 ¼-inch diameter, tungsten carbide spheres into the tank during each test. The number of ¼-inch diameter spheres included in each test increases for the less dense materials.

Table 3-5: SSMD Limits of Performance Spike Simulant

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)
Soda Lime Glass	2.52	2000 3000 5000 7000
Stainless Steel (SS)	8.0	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")
Tungsten Carbide Grit (WC)	14.2	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")

3.2.1.4 Operating Parameters and Test Methods

The operating conditions for the SSMD Limits of Performance testing should be consistent with previous SSMD performance testing. The mixer jets shall rotate continuously with no rotational offset between mixer jet pumps, the streams will be synchronized to meet in the center of the tank. The rotational speed of the jets (ω) shall be set in accordance with Equation 1-3, but mixing performance using two different nozzle velocities shall be evaluated. The nozzle velocities used in the capability testing shall be scaled according to the full-scale flow rate of 5,200 gallons per minute per nozzle using Equation 1-2. The values for the scale factor exponents (1/3 and 1/5) are the consensus path forward recommendations for the starting point for scale-up testing from the SSMD Workshop held in Richland, WA in October 2011 (Table 3.0 in WRPS-1105293). The scale factor exponents are the selected values to be used to determine the nozzle velocities and rotational rates during batch transfers. Prior to performing batch transfers, the system will be operated in a recirculation mode to gather limit of performance data under different operating conditions that include nozzle velocity variations.

It is anticipated that the very fast settling spike particulates may collect in the "dead zones" that are formed if the nozzle velocity is insufficient to clear the bottom. If all of the spike particles are stuck in the accumulating piles, then it would indicate that the operating conditions would not promote the transfer of the spike particulates even though it may be possible for the transfer pump to capture and convey the spikes. Previous experience shows that pile dynamics (i.e., formation of "dead zones") is highly dependent on the nozzle velocity, and whether or not the rotation of the mixer jets is synchronized, offset, or fixed. For Limits of Performance testing, piles could trap the spike particles rendering them unavailable for transport. In order to evaluate the role of pile dynamics, different pile conditions will be evaluated. Pile formation for the Low Conceptual simulant is expected to be minimal because the base material is small, low-density gibbsite particles, which are readily suspended in the tank. For the High Conceptual simulant the effect of pile dynamics will be investigated by changing the size of the piles through changes in the nozzle velocity and rotational rate of the mixer jets. Prior to performing batch transfers that remove material from the tank, the system shall be operated in a recirculation mode and the nozzle velocity shall be varied to determine which spike particulates are conveyed by the integrated system at the prevailing nozzle velocities. Nozzle velocities shall initially be set according to a scale factor exponent value of 1/3 and then be gradually increased, allowing time for mixing to distribute the solids throughout the tank. Previous operator experience indicates that approximately 10-20 rotations of the mixer jets pumps is sufficient to result in a stabilized state, therefore the minimum number of revolutions of the mixer jets to collect particles at each velocity shall be 20 rotations. Nozzle velocity variations shall be performed in 2 to 2.5 ft/s increments and shall be performed until the largest, most dense spike particle is transferred, until spike accumulation in the "dead zones" is eliminated or until the nozzle velocity reaches 59 ft/s, the full-scale nozzle velocity.

As discussed previously in Section 3.2.1.2, the particles shall be collected downstream of the transfer pump suction inlet. The capture system shall be operated to minimize the amount of the base simulant withdrawn from the system during spike particulate collection in the recirculation mode. After the minimum number of mixer jet rotations have been realized, the number of spike particles transferred of each size and density shall be separated using the cascading sieves and quantified either by counting the recovered particles or washing, drying, and weighing the collected particles. After the material is quantified, the material shall be returned to the tank for testing at the next nozzle velocity. The quantity of each particulate size and density shall be recorded in a test log along with the operating conditions and duration allowed for data collection. The nozzle velocity shall be incremented and the quantity of spike particulates should be similarly quantified over an equivalent duration. The test is repeated at higher velocities until the largest and most dense particles are transferred or until no "dead zones" are observed during operations. If necessary, the transfer pump should be turned off to allow the tank to achieve a stable state before testing resumes.

In addition to evaluating the effects of changing the nozzle velocity, the effects of increasing the mass loading of the spike particles shall also be investigated in the recirculation mode. The weight percent of the spike particles shall start at 1/4 the targeted value (5 wt %) and are incrementally increased until the targeted weight percent is attained. Similar to the velocity testing, transferred particles at each mass loading shall be quantified when a minimum of 20 mixer jet rotations is reached. The collected particulates shall be quantified as previously described and returned to the tank. Then the weight percent of the spike particles shall be increased and the system shall be allowed to reach the stable state before particle collection is resumed. When evaluating the effects of mass loading and nozzle velocity in the same test, the nozzle velocities shall be varied for each mass loading. Once the data for spike particulate transport for each nozzle velocity variation has been collected, the nozzle velocity is returned to the lowest setting and the mass loading is incremented for the next set of nozzle velocity observations. The cycle is repeated until the range of nozzle velocities is evaluated over the range of mass loadings.

The test activities investigating the correlation between nozzle velocity and mass loading do not need to be replicated for each Limit of Performance test and to the extent described. At a minimum, the nozzle velocity and spike mass loading investigation should be performed with the high density/high viscosity supernatant, which is expected to be the most capable of transporting the most challenging particles. The extended testing is not necessary when the testing is replicated at a second nozzle velocity. Extended testing in recirculation mode can also be eliminated by concurrence from the technical representatives from Energy*Solutions* and the TOC. An example of when tests can be curtailed is when the largest of the dense particles is captured at intermediate conditions.

Once the investigative tests at various nozzle velocities and mass loadings are completed, the effects of fill height shall be investigated by performing batch transfers and quantifying the spike particulates that are collected downstream of the transfer pump suction inlet. The SSMD test platform should be operated in a recirculation mode until a stable state is established. The stable state is indicated by a consistent mass flow rate reading from the Coriolis meter, after adjusting for cyclical variations caused by the rotating jets or a steady cloud height or mixer jet zone of influence. Once the tank reaches the stable condition, batch transfers are initiated at the maximum flow rate provided in Table 1-2. The batch volume should be screened to separate the spike particles from the base material and the material passing through the screen should be discharged to a waste collection pond. The discharged volume should be passed through a screen or filter that facilitates isolation of the spikes particles from the rest of the discharge. If easily separated, the entire transfer volume should be screened for the large spike particles; otherwise the sample collection duration should be adequate to collect a representative sample.

The collection and separation of the transferred spike particles from the base simulant will be performed on-site using cascading sieves. A transfer sample may need to be collected if the spike simulant cannot be readily separated from the base particulates (e.g., segregated based on size exclusion, magnetism, etc.). The need for collecting and analyzing a transfer sample will be identified by technical representatives from the testing contractor, the TOC, and the DOE. If necessary, previously established practices for collecting slurry samples from the SSMD test platform will be followed.

Table 3-6 provides the test matrix for these tests. The test included in the test matrix should be performed in any order. The specific variations in the test conditions were selected using a computer algorithm. This method, known as a Bayesian D-optimal design algorithm, essentially selects the "best" test runs from the set of all possible combinations of the settings of the specified design factors, where "best" translates to small variability and small correlation of the coefficients in the design model. For SSMD Limits of Performance, the design model includes all of the linear (main) effects of the design factors. Additionally, the design algorithm includes the ability to provide a check for the presence of any of the two-factor interaction effects among the design factors. Note that a much larger experiment is required to estimate each of the two-factor effects. The design factors include the jet nozzle velocity, the base simulant composition, the spike particulate composition, the supernatant composition, and the solids loading.

Replicate analyses have not been included in the test matrix, but the design is such that estimates of variability can be determined. In addition, the reproducibility of the tests without performing replicates can be assessed because equivalent glass spheres are included in each of the 12 tests that are being performed. Data analysis using the test results from all 12 tests together will identify the capability of the system relative to the different operating conditions (see Section 3.2.1.5). Using the test design and subsequent analysis to identify the capability of the system relative to the main effects and the uncertainty in the importance of each effect and any interaction effects allows for an estimate in the variability caused by each effect. Furthermore, the test design allows the results to be obtained efficiently without having to anticipate the results or change the test parameters as the test evolves. The analysis results would then be compared to expectations to provide confidence in the collected data. If the analysis is inconclusive or is contrary to expectations, additional testing may be necessary to resolve any discrepancies.

The data collected from each experimental run will consist of the mass of each of the spike particles transferred. These data from the entire experiment will then be analyzed, using multiple regression analysis, to determine the relationship between the spikes transferred and the specific factors that were manipulated in the experiment, i.e., jet nozzle velocity, base simulant composition, spike particulate composition, supernatant composition, and solids loading. Note that the actual response values used in the analysis may be some function of the measured mass, e.g., fraction of particles transferred, as appropriate. Note also that the regression model that will be fit will only include the linear (or main) effects of each of experiment factors, due to the resource constraints imposed on the experiment effort. Including all higher-order effects, e.g., interaction or quadratic, would have required more experimental runs than were available within the budget and time constraints. Given these constraints, the specific experiment design chosen was the most efficient design to allow estimation of the main effects of the design factors, while also providing some ability to check for the presence of the interactions. Evaluating higher-order effects would require an expanded test matrix to be able to estimate the interaction effects. The test matrix has been constrained to 12 tests in the 1:8-scale tank. Performing 12 tests was based on conducting an appropriate number of tests to characterize the variability over the test variables while minimizing the test schedule and associated costs.

Table 3-6: SSMD Limits of Performance Test Matrix

Test Number	Nozzle Velocity Scaling Factor Exponent (a)	Base Simulant Constituent	Spike Particulate	Supernatant Simulant Properties[1]	Solids Loading[2]
1	0.33	High	Glass/WC	High	Low
2	0.33	High	Glass/SS	Low	High
3	0.33	Low	Glass/WC	High	High
4	0.33	Low	Glass/SS	High	Low
5	0.33	non-Newtonian	Glass/WC	3 Pa, 1.16 g/ml	High[3]
6	0.33	non-Newtonian	Glass/SS	3 Pa, 1.37 g/ml	Low[3]
7	0.2	High	Glass/WC	Low	Low
8	0.2	High	Glass/SS	High	High
9	0.2	Low	Glass/WC	Low	Low
10	0.2	Low	Glass/SS	Low	High
11	0.2	non-Newtonian	Glass/WC	3 Pa, 1.37 g/ml	High[3]
12	0.2	non-Newtonian	Glass/SS	3 Pa, 1.16 g/ml	Low[3]

[1] High supernatant properties: density = 1.37 g/ml, viscosity = 15 cP; Low supernatant properties: density = 1.1 g/ml, viscosity = 1 cP; non-Newtonian slurry properties, Bingham yield stress = 3 Pa and density modified to be 1.16 g/ml or 1.37 g/ml as listed [2] High solids loading is 15 wt %; Low solids loading is 9 wt %. [3] Solids loading is used to determine the quantity of spike particles used and is equivalent to a compare test with a Newtonian slurry.

3.2.1.5 Sample Collection and Analysis

Test progress should be monitored using a Coriolis meter to monitor mass flow rate and specific gravity of the transferred slurry. Monitoring the mass flow rate and slurry specific gravity will allow an assessment of the systems capability to mix and convey the complex simulant.

Samples shall be collected downstream of the transfer pump suction inlet at either the large particle trap upstream of the transfer pump, at the discharge back into the tank when operating in recirculation mode, or at the end of the transfer line. Samples shall collect the large and dense spike particulates, but allow the smaller solids to be recirculated back into the tank or be discharged to the waste collection. During recirculation mode, the amount of each size and density spike particulate shall be separated (see below) and quantified (as a dried mass or count of particles). Results shall be recorded in the test log. The duration for collecting the samples, expressed as a number of tank turnover volumes or mixer jet rotations, shall also be recorded in the test log. It is anticipated that the spike particulates can be segregated from the base material using properly sized screens or sieves. An appropriately sized screen has a mesh opening smaller than the smallest size of the spike particles, but larger than the largest constituent in the base simulant. For the spike particles identified a No.14 or No. 16 sieve size would capture all of the spike particulates. Screening the discharge will facilitate visual confirmation of the transferred material and allow for quantification of the amount of the spike particulate transferred. Different sized spikes shall be separated by appropriately sized sieves.

Separation of the spike material will be based on size exclusion and some manual selection. Based on the sizes proposed the spikes could be separated from the base material using a No. 14 or No. 16 sieve but testing with the base material will be performed to ensure that slurry throughput through the sieve can be maintained. The largest particles (7000 micron glass and 6350 micron metal spheres will be separated using a No. 3.5 sieve (5660 micron) and subsequent separation of the glass and metal spheres. Based on preliminary test results, the transfer of 6350-micron metal spheres is expected to be minimal so that manual separation of the metal spheres may be achievable with high accuracy. For the next largest size particles 5000um glass and 4762.5um metal spheres, a No. 5 sieve (4000 micron) will be adequate because the next largest sieve size, a No. 4 (4760 micron), would not be adequate to separate the two different sized materials. Based on preliminary test results, the transfer of 4762.5-micron metal spheres is expected to be minimal so that manual separation of the metal spheres may be achievable with high accuracy. For the next largest size particles 3000 micron glass and 3175 micron metal spheres, a No. 7 sieve (2830 micron) will be adequate because the next largest sieve size, a No. 6 (3360 micron), would not be adequate to separate the two different sized materials.

Supplemental separation of the glass and metal spheres will need to be performed and exploiting the different settling velocities of the materials (0.4 ft/s vs. 1 ft/s) may be necessary if manual separation of the particles is not practical because of the quantity of each material recovered. Particles that are improperly sorted by the settling velocity method will be manually sorted into the correct category. For the smallest sized spheres of each type (2,000 micron glass and 1587.5 micron metal) a No. 12 sieve (1680 micron) may be adequate to separate the glass and metal spheres.

The spikes retained by the sieves will be washed, dried, and weighed. The spike particle sizes are selected such that the separation of spikes of differing size is performed using sieves that are at least two sizes apart. The particles are also manufactured as spheres so that separation by sieving is expected to be readily accomplished. For the two largest particles included in each test, manual separation of the particles is expected to be performed with high accuracy because of the different physical appearance of the glass and metal particles and the low recovery expected for the metal particles. For the smallest particles included in each test, separation of the particles is expected to be performed with high accuracy because sieves are available to separate the glass spheres from the metal spheres. The differences in the physical appearance of the particles will facilitate sorting error corrections prior to weighing the particles. However, separation of the 3000-micron glass particles from the 3175-micron metal particles is subject to additional error because the expected recovery of the metal spheres is unknown, and there is not a sieve available to separate the glass spheres from the metal spheres. The acceptable error rate for manually misclassifying metal spheres is 1 in 1000 (0.1%) and is based on misclassifying one sphere per square foot of mesh in a No. 7 sieve. The acceptable error rate for manually misclassifying glass spheres, which have a different industrial purpose and are manufactured to a lower tolerance is 1 in 100 (1%). The error in quantifying the particulates also includes the accuracy of weighing the washed and dried material. The accuracy of the scale for weighing the recovered spikes is ±0.1%. The sorting error is expected to be additive for a total quantification tolerance of ±1.1%.

Segregation of different density particles retained by a sieve shall be at the discretion of the test director but could include separating similarly sized particles based on density methods (floating less dense material out of a sample container) or by manual methods based on other physical characteristics (e.g., color, magnetism, etc.). The segregated material should be cleaned, dried, and weighed to quantify the mass of each large particulate type transferred in each batch. Alternatively, in lieu of weighing, particle counts are acceptable if the number of particles transferred is low and the particulates of a certain size are uniform. The mass of the simulant spike shall be determined for each transfer batch. The segregated material shall be cleaned and dried before quantifying the mass of the transferred spike material.

If it is not practical to collect and analyze the transferred particles from an entire transfer batch, subsampling will be performed during each batch transfer. Samples shall be collected to avoid sample bias that could be introduced by the position of the rotating mixer jet nozzles. The subsample should be collected and sieved to separate the large and dense particles from the base material for quantification.

After the batch transfer is completed, the system should be reconfigured to recirculate the waste until a stable state condition is re-established. Once the stable state condition is re-established, a second transfer and sampling operation should be initiated and will proceed like the first transfer and sampling operation. The process is repeated until five transfers have occurred. After the last transfer is completed, a description of the solids remaining in the tank, including a photographic or video record, should be prepared and then the tank should be emptied.

Assessing the capability of the mixer jets to deliver large and dense particles to the transfer system will be determined by comparing the fraction of each spike particulate transferred during each operating condition. Fractional information is expressed in terms of the initial loading of each particulate into the tank. For comparisons at different operating conditions (e.g., nozzle velocity variations, mass loadings, simulant characteristics), the amount of particles transferred over an equivalent duration can be directly compared to develop correlations between the operating conditions and the capability of the system. In addition, limits of the system will be assigned based upon observations where spikes of a certain size and density are not captured and transferred by the integrated system.

Data analysis shall compare how the distributions of the spike simulants varied in each transfer batch within a test and among tests with different test conditions. The objective of the data analysis is to develop correlations, whether quantitative or qualitative, to support findings on the systems capability to transfer large and dense particles.

From the collected data, the interaction of the mixer jets and transfer pump will be evaluated to support predicting full-scale performance. However, predicting full-scale performance requires information that is being obtained during other DNFSB 2010-2 test activities and full scale performance may not be predictable until all the testing is completed. The collected data from the SSMD Limits of Performance testing will be used to identify favorable mixing conditions that support transfer of the large and dense spike particles. Full-Scale Transfer Pump testing will provide capability data for conveying the large and dense particles at full scale. Constraining the capability of the system to the range of waste physical properties, including uncertainties, will be performed using input from DNFSB 2010-2 Commitment 5.5.3.2. Scaled Performance data will be used to develop the scaling relationship that can be applied to predict full scale results.

Together this information will feed the gap analysis that evaluates the full capability of the tank farms feed delivery system to send challenging particles to the WTP.

3.2.2 Remote Sampler Demonstration Limits of Performance

The RSD Limits of Performance test activities documented in Section 3.2.2 are performed by Energy*Solutions* for WRPS.

3.2.2.1 Test Equipment and Instrumentation

Integrated testing for the Isolok® Sampler evaluations shall be performed using the RSD test platform constructed at the Monarch Machine and Tool facility in Pasco, Washington. The RSD test platform includes a mixing tank and agitator, an effluent tank, a slurry pump, a Coriolis meter, the Isolok® Sampler, the integrated mechanical handling system, the Ultrasonic PulseEcho system (not operational during RSD Limits of Performance testing), a simulated glove box and all associated piping to connect these components. A schematic of the flow loop is shown in Figure 2-3. The RSD test platform also includes a sampling valve to collect full diversion samples. Although it is not expected to be used during RSD Limits of Performance testing, the Ultrasonic PulseEcho system will be used during RSD System Performance testing to detect particle settling, which will be correlated with an independently measured flow velocity to determine critical velocity of the simulant.

The RSD test platform has been used previously for related testing work, including integrated testing using the mechanical handling system (in process at the time of development of this test plan). With the exception of adding the Ultrasonic PulseEcho system into the flow loop in anticipation of RSD system performance testing, the RSD platform shall be used without significant modifications from previous work that demonstrated the mechanical handling component of the system. However, an evaluation shall be performed to confirm that the mechanical agitator in the mixing tank provides adequate mixing for the RSD Limits of Performance test simulants. The mechanical agitator was previously sized according to average waste characteristics and may not be appropriate for RSD Limits of Performance testing. With this confirmation, the RSD test platform is appropriate for Limits of Performance testing. It was constructed at full scale, with the exception of the mixing and transfer system, to demonstrate the capabilities of the Isolok® Sampler, the Mechanical Handling System, and the Ultrasonic PulseEcho system.

The RSD flow loop includes 3-inch diameter, schedule 40 pipe with a centrifugal pump capable of pumping at slurry velocities from 2 ft/s to 8 ft/s; below 2 ft/s pump cavitation is experienced.

To establish the proper flow conditions required to demonstrate the capability of the Ultrasonic PulseEcho system, the flow loop contains approximately 15-18 feet (60-70 pipe diameters) of straight horizontal pipe before the Ultrasonic PulseEcho system and approximately 4 feet (15 pipe diameters) of straight horizontal pipe after the device. The flow loop shall be equipped with a data acquisition system connected to a Coriolis meter to monitor and record the mass flow rate and the specific gravity of the slurry. The Ultrasonic PulseEcho system includes a separate data acquisition system to collect relevant data.

The flow loop shall contain the Isolok® Sampler oriented in the vertical configuration. The Ultrasonic PulseEcho system is not required to be operational during the RSD Limits of Performance testing. For testing purposes, evaluating the capability of the Isolok® system is independent of evaluating critical flow velocities. Actual in-field sampling of waste will require confirmation of critical velocity before slurry samples are collected so that resampling is minimized. Evaluating the capability of the Isolok® system to collect representative samples of large and dense particles is independent of evaluating the mechanical handling of the collected samples. However for completeness testing should be performed with the fully integrated system including the Isolok® Sampler and the mechanical handling system to retrieve the prototypic sample containers.

The RSD flow loop shall also accommodate a mechanism to increase the pressure in the transfer line. Increasing the transfer pressure will establish the capability of the Isolok® Sampler to collect representative samples at elevated operating pressures up to the working range of the sampler, which is 275 psi. The operating pressure is the pressure when the performance of the Isolok® Sampler begins to deteriorate, but the system has been tested up to 600 psi. However, elevated pressure testing is not expected to be required during RSD Limits of Performance testing because pump discharge pressure calculation for the flow loop indicate that the pressure at the Isolok during sampling will be well below the operating limit. Although higher pressures are needed to transfer waste to the WTP, the Isolok® Sampler will not collect samples during these transfers.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted, and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented in a test log.

3.2.2.2 Test Simulants

The simulants used in the RSD Limits of Performance testing are selected in accordance with the recommendations in RPP-PLAN-51625. Simulant properties and qualification is described in Section 3.1. Selecting particular simulants for RSD Limits of Performance test activities is discussed below. The test matrix showing the combinations of base simulant, liquid supernatant, and spike particulates is discussed in Section 3.2.2.3.

The simulants used in RSD Limits of Performance testing shall be a complex simulant containing base particulates and spike particulates to characterize the capability of the sampling system to sample large and dense particles.

For RSD Isolok® performance evaluations, the Low and High Conceptual simulants presented in Table 3-1 will be used. The Typical and High Conceptual simulants are composed of similar particles, just in different proportions. Any interference with the large and dense particles would be similar using either base composition. The High Conceptual simulant was selected over the Typical Conceptual because it contains larger particles that could enhance plugging of the sample needle when the large spike particles are captured. The Low Conceptual simulant is a single component simulant comprised of small particles that are not expected to enhance plugging in the sample needle. Selecting the Low and High Conceptual simulants is also consistent with the base simulants selected for SSMD Limits of Performance testing.

To investigate the effects of solids loading the weight percent of the base simulant shall reach a maximum value of 15 wt %, but the base particulate shall be added incrementally as discussed in Section 3.2.2.3. The 15 wt % is based on the ICD-19 allowable limit of 200 g/l. For the Low Conceptual simulant in the low-density (1.1 g/ml) supernatant the solids loading is approximately 180 g/l when 5 wt % spike solids are added to the base. For the High Conceptual simulant in the high-density supernatant (1.37 g/ml) the solids loading is approximately 227 g/l at the same spiking level. The resulting slurry density ranges between 1.16 g/l and 1.51 g/ml, the latter being above the action level identified in ICD-19. Although the ICD-19 control value for solid content has an constraint of 200 g/l, successful testing with simulants that vary over the anticipated range will add confidence that the sampler can collect representative samples of the transferred material regardless of the slurry content.

To investigate the effects of the supernatant density and viscosity, two Newtonian supernatant compositions will be investigated, high and low. For the high supernatant, the targeted slurry density is 1.37 g/ml and the targeted liquid viscosity is 15 cP. The targeted values are consistent with the high density/high viscosity recommendation in Table 3-2 and have an acceptable tolerance of 5% for the liquid density and 20% for the liquid viscosity. Liquid viscosity tolerance is evaluated at the operating temperature of the test tank if the temperature of the sampled material differs from the bulk volume. The high values for liquid density and liquid viscosity are selected because higher densities and higher viscosities are expected to increase the buoyancy effecting solid particles in the flow loop, increasing the potential to capture the large and dense particles in the vertically oriented flow stream. To confirm this expected correlation, a second supernatant simulant with a lower density and viscosity will be evaluated. The targeted slurry density for the low supernatant is 1.1 g/ml and the targeted liquid viscosity is 1 cP. The selected quantities are equivalent to the Low Density/Low Viscosity supernatant listed in Table 3-2. For the low supernatant, the acceptable tolerance on the density is ±5% and the acceptable tolerance on the viscosity is increased from ±20% to 0.5 cP. For the low supernatant, the tolerance on the viscosity is increased because the rheology change is expected to be achieved using a single sodium salt and the density and viscosity for a single sodium salt cannot be specified independently. The initial properties of the supernatant will be lower than the target values, which will be reached at the end of the test evolution as discussed in Section 3.2.2.3. Sample measurements shall be collected from the mixing tank and the liquid density and viscosity should be measured and adjusted until the target range is attained before the next test evolution is performed. For adjusting the liquid rheology, sodium thiosulfate is the preferred sodium salt with glycerol being a secondary additive to increase the viscosity to the targeted values. Supernatant compositions matching the targeted characteristics are provided in Table 3-2. As described in Section 3.1.2.2, viscosity measurements are collected at the beginning of each test and at the completion of testing to identify any changes that occurred during testing.

In addition, tests shall be performed using a non-Newtonian slurry with a Bingham yield stress of up to 10 Pa. For test requiring a non-Newtonian, cohesive slurry, kaolin clay shall be used to increase the yield stress of the simulant to values up to 10 Pa The initial properties of the slurry will be lower than the maximum value of 10 Pa, which will be reached at the end of the test evolution as discussed in Section 3.2.2.3. Sample measurements shall be collected from the mixing tank and kaolin clay shall be added until the yield stress meets the acceptance criteria. As described in Section 3.1.1.2, Bingham yield stress measurements are collected at the beginning of each test and at the completion of testing to identify any changes that occurred during testing.

Small test batches should be prepared to determine the relative amounts of each constituent to achieve the targeted results at testing temperatures and using the procured materials.

The limits of performance of the Ultrasonic PulseEcho system are not being evaluated in this test activity; therefore, the size of the sample needle is the constraint for the upper particle size used during RSD Limits of Performance testing. The largest dense particle that results in acceptable performance during developmental testing will be added as a spike to a complex simulant. The simulant spikes may be different from the large and dense particles that can be transferred by the transfer system due to the size constraint of the Isolok® sample needle. The spike material representing the large and dense particles should use the largest particles of high-density solids that could be sampled through the internal needle in the sampler's double needle (approximately 3,400 microns) or can be repeatedly sampled without plugging the sampler. Tests are also being conducted with particles of a smaller size to determine the capability of the system to collect reliable samples of large and dense particles. Table 3-7 provides the particle size range for the simulant spikes.

Note that although the Isolok® primary needle inner diameter is 0.135-inches (approximately 3400 microns), which is larger than the individual spikes, it is assumed that some combination (aggregation) of large spikes and small particles (base simulant) will effectively plug the needle. Moreover the commercially available products tend to be produced in 1/32-inch (approximately 800 microns) increments so that the next available size for each spike listed in Table 3-7 is greater than 3400 microns, limiting the maximum spike size to below the target. Soda-lime glass is selected as a spike material instead of sand, one of the recommended spike materials in RPP-PLAN-51625, because it has a comparable density to sand and the spherical shape will facilitate separation of the different sized particles by sieving.

The quantity of the spike particle added to the test tank shall initially be 5 wt % of the total solids added during a test sequence. The 5 wt % value was selected so that an adequate number of particles are present in each test and does not reflect any expected condition in the uncharacterized waste. Ideally, the distribution of different sized particles should represent the expected distribution of the waste. A review of the data reported in PNNL-20646 indicates that tank waste samples tend to have few very large particles (>1000 microns) and more moderate sized particles (10s to 100s of microns). However, to determine the capability of the system to sample very large particles, the sampler must have the opportunity to sample these particles. Therefore, the concentration of the large particles should be greater than the expected distribution of large particles in the tank waste to increase the probability that a large particle is present in the flow stream at the time that the Isolok® Sampler collects a sample. Two allocation methods that result in greater number of smaller spike particles compared to the largest spike particles would be to equate the masses of each represented size or distribute the masses in proportion to the ratio of the particle diameters. In the latter approach, a system with 1/16-inch, 2/16-inch, 3/16-inch, and 4/16-inch spike particles uses weight percentages of 10%, 20%, 30%, and 40% for the particles, respectively. Comparing the two techniques, the latter approach reduces the number of the smallest particles and increases the number of larger particles over the former. This method is preferred because it increases the number of the largest spike particles relative to the equal mass method, which increases the probability of collecting the larger particles in the sampler.

Table 3-7: RSD Limits of Performance Spike Simulant

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)
Soda Lime Glass	2.52	1000 2000 3000
Stainless Steel	8.0	1587.5 (1/16") 2380 (3/32") 3175 (1/8")
Tungsten Carbide (WC)	14.2	1587.5 (1/16") 2380 (3/32") 31758")

3.2.2.3 Operating Parameters and Test Methods

The RSD platform shall be configured to adequately suspend the simulant in the mixing tank and transfer the contents to the inlet of the transfer pump. The speed of the mechanical agitators shall be increased until the specific gravity in the transfer line, monitored by a Coriolis meter, stabilizes. For Isolok® sample collection in the vertical configuration, the transfer pump flow rate shall be maintained at 140 ± 5 gallons per minute.

Once the RSD flow loop has stabilized, as evidenced by stable mass flow rates and specific gravity readings from the Coriolis meter, the Isolok® Sampler shall be activated to collect three 500 ml samples. After the third sample, a full diversion sample shall be collected. The amount of each spike particle type in each sample collected shall be determined and recorded by size and density. Due to the small sample size and large particles it may be possible to count the number of particles of each size. If not the particles shall be separated by size using sieves, washed, dried and weighed to quantify the mass of each particle captured by the sampler. The amount can be expressed as a particle count or sampled mass. After characterization, the collected sample, including the slurry shall be returned to system for the next evolution of the test sequence. In the next evolution of the test sequence the starting condition will be altered in accordance with the test matrix and sample collection shall be repeated. The test conditions evolve to gain the additional data under similar operating conditions without having to prepare new simulant batches for each test evolution. It is anticipated that each test sequence will have two or three test evolutions each furnishing three Isolok® samples (replicates) and one full diversion sample. If during testing, conditions warrant that the testing duration must be reduced, it is preferred to reduce the number of Isolok® samples collected in each test evolution rather than eliminate a test evolution.

One condition to be varied through test evolutions during a test sequence is the weight percent of the base simulant. For testing performed without a base simulant (i.e., water testing), the mass of the spike particles should be equated to a test that includes a base simulant and the test evolution should be based on particle size instead of mass loading. For water testing the particle size of the spikes should be varied in the test evolution beginning with the largest size and adding smaller sizes for each evolution. For testing performed with a base simulant, test sequences evaluating the effects of the weight percent of the base simulant shall increase the mass loading of the base simulant from 5 wt % to 15 wt % in 5 wt % increments (i.e., 5% 10%, and 15%). Another acceptable approach is to use the SSMD mass loading values of 9 and 15 wt % (Section 3.2.1.3).

A second identified condition for the test evolution is the liquid supernatant properties. Test sequences evaluating the effects of the liquid supernatant density and viscosity shall increase the density and viscosity through test evolutions. In the first evolution the liquid density and viscosity shall be targeted to achieve 1.1 g/ml and 1cP using the composition listed in Table 3-2. In the second and third evolutions of the test sequence, the liquid density and viscosity shall be targeted to achieve 1.37 g/ml and 15 cP by adding additional sodium salt and glycerol. The required accuracy on the targeted values depends on the number of constituents needed to achieve the targeted value. If the targeted values can be achieved using a single sodium salt (e.g., sodium thiosulfate or sodium bromide), then the density must be attained to within 5% of the targeted value and the viscosity must be within 0.5 cP of the targeted value. If a second constituent (e.g., glycerol) is needed to achieve the desired consistency, then the density must be within 5% of the targeted value and viscosity must be attained to within 20% of the targeted values at the testing temperature.

For RSD Limits of Performance tests with a non-Newtonian slurry, the variable for the test evolution is the Bingham yield stress of the base simulant. Test sequences evaluating the effects of the yield stress shall increase the yield stress from 3 Pa to 10 Pa. Due to the time varying nature of the non-Newtonian slurry and anticipated difficulty in preparing the simulant, only two evolutions of the yield stress runs will be performed. Based on the necessary accuracy needed to resolve the effect of the yield stress on the capability to transfer large and dense particles and time varying nature of a non-Newtonian simulant, Kaolin slurries with a targeted yield stress of 3 Pa are determined to be acceptable in the range of 2 to 4.5 Pa and slurries with a targeted yield stress of 10 Pa are determined to be acceptable in the range of 7 to 13 Pa. The tests shall be performed at the prevailing density for the kaolin slurry. Table 3-1 provides kaolin composition needed to achieve the targeted Bingham yield stress values.

Initially test sequences are performed with an aqueous phase to determine the capability to collect different sized particles of different densities. These tests should be conducted with a single component spike using the largest and most dense particle to determine whether or not the Isolok® Sampler performs adequately. Acceptable performance is defined as simulant spike recovery in the collected sample without plugging the sample needle. Indications of poor performance include low total volume recoveries (less than 475 ml) and a lack of spike material in the collected sample. If unacceptable performance is observed, then the particle size shall be reduced and the tests shall be repeated until acceptable performance is observed. The particle size that has acceptable performance will be used with the complex simulant to quantify the performance of the Isolok® Sampler in the presence of the large and dense particles.

The test matrix for the RSD Limits of Performance testing is provided in Table 3-8. For RSD Limits of Performance testing, the variations in the tests included the base simulant composition and the spike particulate composition. Additional variations in the base simulant loading and supernatant composition are accounted for using test evolutions. For the non-Newtonian simulant, the test evolution accounts for variations in yield stress. Due to the relative simplicity of the test variables and the capability to collect additional data over test evolutions, the design was constrained to 10 tests.

Table 3-8: RSD Limits of Performance Test Matrix

Test Sequence	Base Simulant Constituents	Spike Simulant Composition	Test Evolution
1	Water	Stainless Steel	Spike Particle Size
2	Water	Soda Lime Glass	Spike Particle Size
3	Water	Tungsten Carbide	Spike Particle Size
4	High	Stainless Steel	Supernatant Composition
5	Low	Soda Lime Glass	Base Simulant Mass Loading
6	High	Tungsten Carbide	Supernatant Composition
7	Low	Stainless Steel	Base Simulant Mass Loading
8	non-Newtonian	Stainless Steel	Slurry Rheology
9	non-Newtonian	Soda Lime Glass	Slurry Rheology
10	non-Newtonian	Tungsten Carbide	Slurry Rheology

3.2.2.4 Sample Collection and Analysis

RSD Limits of Performance testing shall establish the particle size limit for acceptable performance of the Isolok® Sampler. However, chemical analysis is not always required to determine unacceptable performance. Unacceptable performance is observed when no solids are collected in the retrieved sample or there is an obvious fault in sampler operations during sample collection. Unacceptable performance is also observed when the collected slurry volume is outside of the 5% error (expressed as a relative percent difference) specified for the Isolok® Sampler during Phase I testing (RPP-RPT-51796). Low collection volumes (e.g., less than 475 ml for a 500 ml sample) would indicate that the sampler is partially or completely plugged. Initially these three criteria will be used to evaluate whether or not acceptable performance is attained for a simple simulant consisting of a spiking compound with a well-defined particle size. These criteria shall also be used to evaluate the behavior of the system with the complex simulant.

Three 500 ml Isolok® samples and a full diversion sample shall be collected for each evolution of a test sequence. In general there are two or three evolutions in a test sequence as discussed in Section 3.2.2.3 for 8 to 12 samples collected per test sequence. Unlike previous RSD testing activities, Isolok® samples are not expected to require off-site analysis to quantify the amount of large and dense particles collected in each sample; therefore, no laboratory control samples or archive samples will be collected. The collected Isolok® samples shall be analyzed for total slurry volume, total slurry mass and the mass (or count) of each spike particle. Spike mass shall be collected for each particle size and density when the spike is composed of multiple sets of uniformly sized particles. The mass of each sized particle collected in each Isolok® sample shall be reported.

Separation of the spike material will be based on size exclusion. Based on the glass sphere sizes proposed, the glass spikes could be separated from the base material using a No. 20 sieve but testing with the base material will be performed to ensure that sample throughput through the sieve can be maintained. The metal sphere spikes will be separated from the base material using a No. 14 sieve (1410 micron). The largest particles 3000-micron glass and 3175-micron metal spheres, a No. 7 sieve (2830 micron) will be adequate to separate the spikes from the base material. For the intermediate sized spheres of each type (2,000-micron glass and 2380-micron metal) a No. 12 sieve (1680 micron) will be adequate to separate the glass spikes from the base material and a No. 10 sieve (2000 micron) will be adequate to separate the metal spikes. The smallest sized spheres of each type should be retained on the screen used to separate the spikes from the base material (No.20 sieve for glass and No. 14 for metal spikes).

The spikes retained by the sieves will be washed, dried and weighed. The spike particle sizes are selected such that the separation of spikes is performed using sieves that are at least two sizes apart. The particles are also manufactured as spheres so that separation by sieving is expected to be readily accomplished. This should minimize the error associated with separating the different sized particles and an error tolerance of <1% is assigned to particle separation. The quantification error also includes the accuracy of weighing the washed and dried material. The accuracy of the scale for weighing the recovered spikes is ±0.1%. The sorting error is expected to be the largest source of error for quantification of the recovered spikes.

The mass of the base constituents does not need to be determined during RSD Limits of Performance testing. The entire volume of the full diversion sample shall also be analyzed for total slurry volume and the mass (or count) of each spike particle. Collected data shall be reported consistent with the Isolok® data reporting.

The full diversion sample provides the evidence that the spike particles are present in the flow loop and provides an estimate for the concentration of the spike particles in the flow loop. Differences between the concentration of the spike particles in the full diversion sample and the initial spike concentration will be attributed to settling in the transfer line and/or inadequate mixing in the mixing tank. Differences between the concentration of the spike particles in the Isolok® samples and the Full Diversion samples are attributed to the capability of the Isolok®

system to sample the spike particles. The difference between the Isolok® sample concentrations and the Full Diversion sample concentration will be expressed as a percent error (bias). In addition, correlations between the percent errors and the test properties that were changed will be analyzed for correlations.

3.2.3 Full-Scale Transfer Pump Limits of Performance

Full-Scale Transfer Pump Limits of Performance test activities documented in Section 3.2.3 are performed by CEES for WRPS. The Full-Scale Transfer Pump Limits of Performance test platform has not been constructed; therefore in the sections that follow the description of the test platform is brief compared to the descriptions of the test platforms discussed for other testing activities.

3.2.3.1 Test Equipment and Instrumentation

Full-Scale Transfer Pump Limits of Performance testing is being performed to determine the largest size of particles with densities characteristic of Hanford tank waste that can be transported out of a DST. Two mixing modes are evaluated, a quiescent condition when no mixing is performed and a mixed condition, when non-prototypic, mechanical mixing is performed. During quiescent testing, the transfer pump inlet is lowered from a starting position and the mobilization of spike particles introduced near the pump inlet is observed. Observations at different distances from the tank bottom are compared. Quiescent mixing determines the capability of the pump to mobilize particles from the bottom of the tank without the benefit of particle suspension using the mixer jet pumps. . During mixing tests, the transfer pump inlet is stationary at the full-scale height and the slurry is agitated to suspend the spike particles in the tank. The mobilization of spike particles from the tank is observed. Observations at different operating conditions are compared. Mixing tests determines the capability of the pump to mobilize suspended particles from the tank at the prototypic height of the pump suction inlet.

The major equipment included in the Full-Scale Transfer Pump Limits of Performance testing include a submersible centrifugal pump, a large test tank, mechanical agitator(s), a flush tank, a flush pump, a re-use tank, a flush receipt tank, a disposal basin, 3-inch diameter Schedule 40 pipe and fittings, and an instrument panel. The submersible transfer pump has a pump suction inlet diameter of 2.40", and is capable of processing 90 to 140 gallons of slurry per minute and developing 100 feet of head. With the exception of the reduced head requirement, these flow characteristics are consistent with the slurry transfer pump that is sought by the TOC to transfer HLW feed from a DST to the WTP. The flow rate and the inlet opening geometry set the capture zone around the pump inlet, which determines what particles can be entrained in the pumpage to be transported from the tank. The transfer pump inlet should be screened with a screen that is consistent with on-going DST transfer pump design (currently assumed to be 3/8-inch). The inlet shall initially be set at a distance of 6-inches above the tank bottom. The 6-inch height parameter is equivalent to the expected operating condition in the first waste feed staging tank, 241-AY-102. The height of the transfer pump inlet, relative to the tank bottom, is adjustable.

The mixing tank shall have transparent observation ports in the side and bottom of the vessel so that mixing can be observed. The mechanical agitator(s) shall have the capability to suspend the candidate spike materials, including 1/4-inch diameter particles of tungsten carbide (density approximately 14.2 g/cm^3) in a supernatant phase having a specific gravity of 1.1 and a viscosity of 1 cP. For sizing the mechanical agitators, suspend is defined as off-bottom suspension, the complete motion of all particles with no particle remaining on the base of the vessel for more than 1-2 seconds. This constraint may be relaxed if suspension of the most challenging spike particle causes mixing conditions that are extremely violent and compromises the integrity of the test to collect meaningful data for the other spike particles. Relaxation of this requirement requires concurrence of the TOC technical lead prior to proceeding.

Off-bottom particle suspension shall be visually verified through the tanks observation ports. The pump discharge shall be oriented vertically to transfer the mixed slurry up a vertical distance of 55 feet through a 90° elbow and across a horizontal distance of 20 feet. The distance from the bottom of the DST to the top of an access riser in AY-102 is about 55 feet. The horizontal distance needed to obtain stable flow for the Ultrasonic PulseEcho system was approximately 80 pipe diameters and this same criterion was applied to determine the horizontal flow length in the test platform. After 20 feet of horizontal flow, the slurry will be diverted to sample collection, recycled back to the mixing tank, or discharged to a waste collection. The discharge shall be screened to collect the large spike particles transferred beyond the 20-foot of horizontal piping.

Pump speed should be controlled so that the slurry flow is maintained at 140 gpm. The condition of the pump should be monitored by recording the pump speed or equivalent performance metric (e.g., hydraulic fluid flow rate). The specific gravity of the discharge should be monitored using a Coriolis meter. Transfer flow rates and pressures shall be monitored and recorded.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted, and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented.

3.2.3.2 Test Simulants

The Full-Scale Transfer Pump Limits of Performance simulants shall include spikes particles in a supernatant simulant when quiescent tests are performed and shall be a complex simulant containing base particulates and spike particulates in a supernatant when Newtonian tests with mixing are performed. For all non-Newtonian testing, the simulant shall be kaolin slurry supplemented with spike particles.

The effect of the base simulant on the capability of the system to transfer large and dense particles has not been previously investigated using the recommended simulants discussed in Section 3.1.1.1. However, it is expected that the presence of solids in the slurry should hinder settling, which could enhance waste transfer if the spike particulates become suspended by the mechanical agitator(s). Figure 8-10 in RPP-PLAN-51625 provides the basis that changes in the base simulant will influence the movement of the spike particles. The basis for the metric shown in the figure is developed for impeller mixed tanks using the Zweitering correlation. The calculation suggests that the difference in the capability of the system to suspend large and dense particles, and hence increase the probability of transferring the particles, is greatest for the Low Conceptual simulant and for a specific power input there is very little difference in the capability of the Typical and High Conceptual simulants at two different mass loadings. However, if there is sufficient power in the system to suspend all the material, it is uncertain whether the Typical or High Conceptual simulants would be more likely to transfer large and dense particles. Consistent with SSMD Limits of Performance testing (Section 3.2.1.3) and RSD Limits of Performance testing (Section 3.2.2.2) Full Scale Transfer Pump Limits of Performance testing will use the Low Conceptual and High Conceptual simulants to quantify the effects of each on the capability of the pump to transfer large and dense particles. Conducting tests with the two limiting base simulants, Low Conceptual and High Conceptual, is also consistent with the high uncertainty in the characterization of Hanford tank waste, especially as it is blended and staged for WFD to the WTP. The two base simulants that have a broad distribution of Archimedes numbers and using these two is appropriate for Limits of Performance testing because much of the Hanford waste is uncharacterized with respect to particle size and density distributions and that which has been characterized suggests a wide distribution of Archimedes numbers for tank waste. Evaluating the effect of a broader distribution of Archimedes number reduces the risk that uncharacterized waste could have a capability that has not been quantified.

The effects of solids loading will be evaluated. The low base loading weight percent solids shall be 9% and is based on a solids loading of approximately 125 g/l. The high mass loading shall be 15 wt % solids. The 15 wt % is based on the ICD-19 allowable limit of 200 g/l. For the Low Conceptual simulant in the low-density (1.1 g/ml) supernatant the solids loading is approximately 180 g/l when 5 wt % spike solids are added to the base. For the High Conceptual simulant in the high-density supernatant (1.37 g/ml) the solids loading is approximately 227 g/l at the same spiking level. The resulting slurry density ranges between 1.16 g/l and 1.51 g/ml, the latter being above the action level identified in ICD-19.

The liquid density and viscosity of the fluid phase (supernatant simulant) should be adjusted to target values using soluble salts, with addition of glycerol as necessary. For adjusting the liquid rheology, sodium thiosulfate is the preferred sodium salt. Two supernatant compositions will be investigated, high and low. For the high supernatant, the targeted slurry density is 1.37 g/ml and the targeted liquid viscosity is 15 cP. The targeted values are consistent with the high density/high viscosity recommendation in Table 3-2 and have an acceptable tolerance of 5% on liquid density and 20% on viscosity. The high values for liquid density and liquid viscosity are selected because higher densities and higher viscosities are expected to increase the buoyancy effecting solid particles in the mixing tank and reduce critical suspension and settling velocities. Increasing buoyancy and subsequently reducing the critical suspension velocity and settling velocities is expected to promote particle suspension, facilitating the movement of large and dense particles to the transfer pump suction inlet. The increased buoyancy will also promote the movement of particles beyond the 20 feet of horizontal piping so that the spikes can be captured and quantified. To confirm this expected correlation, a second supernatant simulant with a low density and viscosity will be evaluated. The targeted slurry density for the low supernatant is 1.1 g/ml ±5% and the targeted liquid viscosity is 1 cP ± 0.5 cP. The selected quantities are consistent with the low density/low viscosity recommendation in Table 3-2. The 50% tolerance on the viscosity value for the low supernatant is due to the expectation that the values are achievable using a single sodium salt and therefore the density and viscosity cannot be specified independently. As described in Section 3.1.2.2, viscosity measurements are collected at the beginning of each test and at the completion of testing to identify any changes that occurred during testing. Supernatant compositions matching the targeted characteristics are provided in Table 3-2.

In addition, tests shall be performed using a non-Newtonian slurry with a Bingham yield stress of 3 Pa and 10 Pa. The value is consistent with the recommendations described in Section 3.1.1.1. A non-Newtonian test should be used to verify the expectation that slurries having a yield stress result in better batch transfer of spike particulates, as reported in SRNL-STI-2011-00278. For verification tests requiring a non-Newtonian, cohesive slurry kaolin clay shall be used to increase the yield stress of the simulant to values up to the target value. With the expectation that higher yield stresses should facilitate the movement of larger and denser particles, the 3 Pa and 10 Pa limits were selected because these are similar to values that have been used in mixing tests in the past. Based on the necessary accuracy needed to resolve the effect of the yield stress on the capability to transfer large and dense particles and slight time varying nature of a non-Newtonian simulant, Kaolin slurries with a targeted yield stress of 3 Pa are determined to be acceptable in the range of 2 to 4.5 Pa and slurries with a targeted yield stress of 10 Pa are acceptable in the range of 7 to 13 Pa. Non-Newtonian tests are also being conducted at two different slurry densities, approximately 1.2 g/ml and 1.37 g/ml. The lower density value uses the unmodified density of the kaolin slurry, expected to be about 1.16 g/ml and 1.22 g/ml for the slurries with Bingham yield stress values of 3 Pa and 10 Pa, respectively. For the higher density fluid, a sodium salt is added to the kaolin slurry to achieve a density within 5% of the targeted value. Slurry compositions matching the targeted characteristics are provided in Table 3-1.

The spike material representing the large and dense particles should be composed from solids having a very narrow distribution range so that all of the particles from a single lot are essentially the same size. Selected spikes for the capability test will only include particles that can fit through the openings in the pump screen. The spike particulates included in each test include multiple sizes of particles. The size increments are at least 1/32-inch (794 microns) so that the particles can be readily separated for on-site analysis by sieving. Having multiple sizes of particles allows for positive confirmation that smaller particles can be transferred when larger particles are not transferred. This allows for an estimation of the capability limit of the system. Spike particulates with different densities and sizes are included in each test. Particles with different sizes are separated by sieving; particles with different densities are separated manually. Particles with different sizes and densities are used together to assess the limits of the transfer system. Table 3-9 provides the composition and particle size range for the simulant spikes.

The quantity of the spike particles added to the test tank shall initially be 5 wt % of the solids and may need to be increased prior to the first transfer if the observed movement of the particles suggests that there is a very low probability of mobilizing the solids to the transfer pump suction inlet. The 5 weight percent value was selected so that an adequate number of particles are present in each test and does not reflect any expected condition in the uncharacterized waste. For non-Newtonian slurries, the spike levels are matched to a Newtonian test having similar density and mass loading criteria. Ideally, the mass distribution of particle sizes in the specified mass loading would represent the expected distribution of the waste. A review of the data reported in PNNL-20646 indicates that tank waste samples tend to have few very large particles (>1000 microns) and more moderate sized particles (10s to 100s of microns). Two allocation methods that obey this relationship would be to equate the masses of each represented size or distribute the masses in proportion to the ratio of the particle diameters. In the latter approach, a system with 1/16-inch, 2/16-inch, 3/16-inch, and 4/16-inch spike particles uses weight percentages of 10%, 20%, 30%, and 40% for the particles, respectively. Comparing the two techniques, the latter approach reduces the number of the smallest particles and increases the number of larger particles over the former. This method is preferred because it increases the number of the largest spike particles relative to the equal mass method, which increases the probability of mobilizing the larger particles to the pump inlet. If the mass of any readily mobilized particles results in greater tendency for quantification errors for the more challenging spike particles, the quantity of readily mobilized particles added to the tank may be reduced. Any changes to the initial loading amount would need concurrence from the TOC technical leads.

Table 3-9: Full-Scale Transfer Pump Limits of Performance Spike Simulant

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)
Soda Lime Glass	2.52	2000 3000 5000 7000
Stainless Steel (SS)	8.0	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")
Tungsten Carbide Grit (WC)	14.2	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")

3.2.3.3 Operating Parameters and Test Methods

The Full Scale Transfer Pump Limits of Performance test activities shall evaluate a surrogate transfer pump with similar capabilities to the slurry transfer pump sought for WFD to the WTP. For mixing tests, the simulant discussed in Section 3.2.3.2 shall be added to the mixing vessel and the tank shall be mixed so that the large and dense spike particles are suspended. The agitator speed is increased until off-bottom suspension is attained for the simulant solids. Verification of off-bottom suspension is performed by observing the movement of the solids in the tank through the observation ports in the side and bottom of the tank. Collection of the spike particles shall be performed so that transient conditions experienced during the startup of mixing and pump operations do not influence the test results.

The test platform shall be configured so that the mixing and transfer operates in a recycling mode at a transfer flow rate of 140 gpm. The specific gravity of the slurry in the transfer line shall be monitored using a Coriolis meter and the mixers shall be adjusted until the specific gravity in the transfer line stabilizes. When the monitored specific gravity has stabilized, spike particle recovery in the transferred slurry shall be initiated. Spike recovery should proceed while the tank is recirculating the slurry through the transfer line. The minimum duration for the spike recovery in a test evolution is 10 turnover volumes. The spikes in the transferred slurry are recovered by passing the pumpage through a screen at the inlet of a collection vessel. The duration and accumulated volume transferred during spike recovery shall be recorded so that the concentration of spikes particles transferred can be determined. The screen shall isolate the spike particles from the other slurry solids by size exclusion. A No.14 or No. 16 sieve has appropriate sized openings to retain the spike particles, but the surface area of the screened opening needs to be determined through developmental testing to ensure that adequate throughput through the screen can be maintained at the pumping rates required during testing. The base material passing though the screen shall gravity drain or be pumped back into the mixing tank until the test evolution is completed. The captured spike particles, or a representative sample(s) of the captured particles, shall then be separated by size using cascading sieves. If subsampling is performed, the error in the subsampling method shall be quantified. For each sieve size, the retained particles shall then be manually separated by particle type to separate different density particles. The resulting piles are then counted or washed, dried and weighed. The resulting counts or mass of each spike particle size shall be recorded.

Test should be conducted to minimize the collection of spike particles during transient conditions. The conditions for the next test evolution are established by adding the necessary components. Once the conditions for the next test evolution are readied, the system is operated in a recirculation mode until a stable state in the transfer line has been reestablished. Once the steady state condition is resumed, spike recovery for the next test evolution proceeds in the same manner as the first test evolution.

At the conclusion of the final test evolution, the test is terminated. The fluid in the transfer line is allowed to gravity drain back into the mixing tank. The solids in the horizontal piping are flushed into a collection vessel to recover the spike particulates that settled in the horizontal section of the transfer pipe network. The flushing flow rate will exceed the transfer flow rate of the test to ensure that the settled solids are removed from the pipe. Alternatively, a higher density fluid could be used to flush the transfer line. Visual confirmation will ensure that adequate flushing through the transparent section of piping has been achieved. The flushed material is screened similar to the transferred slurry to collect the spike particles that settled in the transfer line. The collected spike particles are separated by size and density and quantified using the same methods used to quantify the spike particles that were discharged from the transfer line. The discharge shall be diverted to waste collection so that residual slurry in the transfer line is not placed back into the mixing tank.

The mass of the spike particles remaining in the tank shall also be characterized. The distribution of the heel in the tank will be qualitatively described with specific emphasis on noting where in the tank the large and dense particles are found (e.g., within the pump screen, near the pump screen, along the edges of the tank). Particles that may collect inside the pump screen would indicate that the mixing energy provides sufficient velocity to move the particles near the pump screen and that the flow velocity through the screen is sufficient to pull the particles through the screen but the flow velocity inside the screen is insufficient to maintain the particles in suspension. Once the heel is documented, the mixing tank shall be emptied so that the next test can be conducted.

For non-mixing tests, no base simulant is necessary; the spike solids in a supernatant comprise the simulant for the tests. It was concluded that, in the absence of mixing a consistent base composition could not be maintained in the tank. Because the base composition is expected to influence the capability of the integrated system, an inconsistent base composition would interfere with data interpretation. During quiescent testing, the transfer pump is started with the system in a recirculating mode. Because of the limited tank size and volume of material, the non-mixing tests that vary the operational height must be operated in a re-circulation mode so that the contents of the tank are not emptied before reaching the full travel distance to the bottom of the tank. The recirculating fluid is added back to the tank using a distributor under a gravity drain to minimize mixing in the tank. Once a stabilized state has been established, assessed by a constant specific gravity on a Coriolis meter monitoring the transfer line, spike particles are added to the test tank. The spike particles are dispersed on the bottom of the tank near the pump inlet. Spike particles that are transferred up the vertical section of piping and across the horizontal piping are captured and quantified using the same methods for the mixing tests. After a minimum of 10 turnover volumes have passed through the pump, the distance between the bottom of the tank and the suction inlet of the transfer pump is reduced by 1-inch so that particle capture as a function of suction height under quiescent conditions can be quantified. The test is repeated until the pump screen rests of the bottom of the tank. The duration at each elevation should be consistent. The flow condition shall be monitored using a Coriolis meter in the transfer line. The specific gravity of the slurry in the transfer line shall be monitored. The mass of the spike particles transferred by the pump at each height shall be quantified as described previously, and the transferred material shall be returned to the tank for the next height interval. Once all of the data has been collected, the mixing tank shall be emptied and the transfer lines shall be flushed and the settled particles quantified so that the next test can be conducted.

The test matrix for the Full-Scale Transfer Pump Limits of Performance testing is provided in Table 3-10. The tests included in the test matrix should be performed in a random order to minimize experimental error. For Full-Scale Transfer Pump Limits of Performance, the specified design factors include the mixing condition, the base simulant composition, the spike particulate composition, and the supernatant composition. The variation in properties was selected based on properties that are expected to have large effects on the performance of the system so that variability introduced by experimental error would be small enough to allow for performance correlations to the design factors. The test matrix was designed with separate test activities for two mixing conditions, mixing, and no mixing. Currently the design has been constrained to 14-18 tests. Designing 14-18 tests was based on conducting an appropriate number of tests to characterize the variability over the test variables while minimizing the test schedule and associated costs. In selecting the appropriate test matrix that is constrained to a specified number of tests, test replication has been sacrificed to test additional variations of the design factors. Test replication allows for the separate quantification of experimental error and inherent variability. By selecting the design factors that attempt to minimize experimental error, performing replicates, although still desirable, becomes less critical to evaluating the data.

Table 3-10: Full-Scale Transfer Pump Limits of Performance Test Matrix

Test Number	Base Simulant Constituents (Table 3-1)	Mass Loading[a]	Liquid Simulant Properties[b]	Mixing Condition
1	High	Low	Low	Mix
2	High	Low	High	Mix
3	High	High	Low	Mix
4	High	High	High	Mix
5	Low	Low	Low	Mix
6	Low	Low	High	Mix
7	Low	High	Low	Mix
8	Low	High	High	Mix
9	non-Newtonian	3 Pa	High	Mix
10	non-Newtonian	3 Pa	Low	Mix
11[c]	non-Newtonian	10 Pa	High	Mix
12[c]	non-Newtonian	10 Pa	Low	Mix
13	None	High	High	No Mix
14	None	High	Low	No Mix
15	non-Newtonian	3 Pa	Low	No Mix
16	non-Newtonian	3 Pa	High	No Mix
17[c]	non-Newtonian	10 Pa	Low	No Mix
18[c]	non-Newtonian	10 Pa	High	No Mix

[a] For non-Newtonian tests, increasing the mass loading of kaolin clay increases the yield stress of the slurry

[b] High supernatant properties: density = 1.37 g/ml, viscosity = 15 cP; Low supernatant properties: density = 1.1 g/ml, viscosity = 1 cP; non-Newtonian supernatant properties match the density of the Newtonian supernatant

[c] To reduce testing, it may be possible to combine testing into one test sequence by performing one test at a yield stress of 3 Pa and then add kaolin to increase the yield stress to 10 Pa before repeating the test.

3.2.3.4 Sample Collection and Analysis

Prior to operating the test platform, mixing shall be evaluated and determined to be adequate for the intended purposes of collecting the limit of performance data. To the extent that the simulant allows, mixing in the vicinity of the transfer pump should be observed to determine if the spike particles are delivered to the vicinity of the inlet. It is acknowledged that some slurries will obscure tank visibility and visual observation will be limited. In the event that the spike particles are collected downstream of the transfer pump discharge it can be concluded that the pump is capable of capturing and transferring the collected particles. If particles of a certain size and density are not collected downstream of the transfer pump then it can only be concluded that the pump is not capable of conveying the particles if it can be demonstrated that the particles were delivered to the pump inlet. Furthermore, being delivered to the pump inlet is not the only requirement for transfer, the momentum of the particle imparted by the non-prototypic mixing cannot be too high that the particle is carried past the inlet. A high concentration of large and dense particles within the pump screen would indicate that the particles were delivered to the vicinity of the pump inlet but that the pump was not capable of mobilizing the particles from the tank. An absence of the large and dense particles from the vicinity of the pump screen would indicate that the mixing system was inadequate to deliver the particles to the inlet.

Sample collection is similar for mixing and non-mixing test conditions; however, the frequency of data collection is increased in the non-mixing tests. The pumpage shall be collected and the spike particles separated from the base simulant solids using screens or filters. Spike particles in the recycled slurry are collected by screening the discharge from the horizontal transfer line using a basket screen. The slurry that passes through the screen is captured in a collection tank that gravity drains back into the mixing tank. The largest particles in the base material are smaller than the smallest spike particle so the base material should not be removed from the process stream if the proper screen size is selected. An No. 16 sieve should separate all of the spike particles from the base material. Once the pumping volume, defined as a certain number of turnover volumes when operated in recirculation mode, has been processed, the pump shall be turned off and the collected samples on the discharge end of the horizontal transfer line shall be quantified.

The volume of the slurry diverted to sample collection shall be monitored and recorded. The mass of the spike particles in the diverted volume shall be determined for each particle size and density included in the test. The presence of any spike particles in the collected sample indicates that the system is capable of transferring the particles to the sample location. Differences between the concentration of the spike in the collected sample and the initial concentration may be reflective of either the mixing condition in the tank or the capability of the transfer system.

Separation of the spike material will be based on size exclusion. The captured spike particles, or a representative sample(s) of the captured particles, shall then be separated by size using cascading sieves. If subsampling is performed, the number of required subsamples and the error in the subsampling method shall be quantified. Based on the sizes proposed, the spikes could be separated from the base material using a No. 14 or No. 16 sieve, but testing with the base material will be performed to ensure that slurry throughput through the sieve can be maintained. The largest particles (7000 micron glass and 6350 micron metal spheres will be separated using a No. 3.5 sieve (5660 micron). For the next largest size particles 5000-micron glass and 4762.5-micron metal spheres, a No. 5 sieve (4000 micron) will be adequate. For the next largest size particles 3000 micron glass and 3175 micron metal spheres, a No. 7 sieve (2830 micron) will be adequate. For the smallest sized spheres of each type (2,000-micron glass and 1587.5-micron metal) a No. 14 sieve (1410 micron) will be adequate to separate this material. All of the segregated material will be washed, dried, and weighed.

The spike particle sizes are selected such that the separation of spikes is performed using sieves that are at least two sizes apart. The particles are also manufactured as spheres so that separation by sieving is expected to be readily accomplished. This should minimize the error associated with separating the different sized particles and an error tolerance of ±1% is assigned to particle separation. The quantification error also includes the accuracy of weighing the washed and dried material. The accuracy of the scale for weighing the recovered spikes is ±0.1%, which, at the planned loadings, represents hundreds of smallest glass spheres, tens of the largest stainless steel spheres and several of the largest tungsten carbide spheres. The subsampling error is expected to be the largest source of error for quantification.

In addition to quantifying the mass of each spike particle that is successfully transferred from the horizontal transfer line, the mass of solids retained in the horizontal section of the transfer line at the end of the test shall also be determined. Particles that settle in the transfer line during mixing tests are also expected to settle in the transfer line during non-mixing tests. Spike particles that settle in the horizontal section of the transfer line are expected to be larger and denser than particles that do not settle out in the transfer line. The presence of smaller spike particles in the transfer line does not indicate that the particles settled, but could indicate that the particles were in the process of moving through the transfer line at the end of the test. Higher concentrations of large and dense particles in the transfer line at the end of the test compared to the collected samples does suggest that those particles did settle out in the transfer line.

Once all tests are completed, the capability of the transfer pump will be correlated to parameters that were varied during testing, particle size, base simulant composition, liquid density, and liquid viscosity.

3.3 SOLIDS ACCUMULATION

3.3.1 Scouting Studies

Test requirements for the SSMD Solids Accumulation Scouting Studies documented in Section 3.3.1 are performed by SRNL for WRPS. This test plan does not govern any development work that is performed to evaluate simulant compatibility with the test equipment, including the initial development of sampling and measurement techniques.

3.3.1.1 Test Equipment and Instrumentation

The SSMD Solids Accumulation Scouting Studies shall use the 1:22-scale MDT test platform at the SRNL test facility. The 1:22-scale MDT test platform has been used for previous test activities and will continue to be used to address uncertainties in the WFD Mixing and Sampling Program.

The main components of the MDT test platform include: a 120-gallon acrylic test tank (40.4-inch diameter), two rotating mixer jet pumps and a slurry transfer pump. Ancillary equipment, such as motors, controllers, and encoders to rotate and monitor the position of the mixer jets, the flexible tubing and rigid stainless tubing, and seven partially transparent PVC receipt tanks are also part of the test platform. The MDT test system shall be configured similarly to previous MDT test activities, making necessary modifications to accomplish the new scope and improve on past problems, (e.g., air leakage in the jet pump seals). Mixing shall be performed using two rotating mixer jets, each having two opposing nozzles placed near the tank bottom. Mixer jet rotation and nozzle velocities should be programmatically controlled and the nozzle position should be monitored using encoders. The transfer pump suction inlet shall be placed consistent with the location of Riser-012 in DST AW-105 (see Table 1-1), which would place it in-line with the two mixer jet pumps 0.29 feet from the center of the tank. The scaled height of the transfer pump suction inlet should be equivalent to the height of the transfer pump inlet in the full-scale DST transfer system (6-inches above tank bottom), which is approximately ¼-inch. For Solids Accumulation Scouting Studies testing, a separate mixing vessel will be required; the Feed Prep Tank will be used to mix the next round of simulant that will be used to refill the MDT. The Feed Prep Tank and associated transfer system will be used as the simulant source for each refill operation.

The transfer system piping, valving, and instrumentation (e.g., magnetic flow meters) should replicate the transfer system from previous testing reported in SRNL-STI-2011-00278. The test configuration shall include the capability to sample the very fast settling solids from the transferred slurry. Flow control should be automated using programmable logic controllers connected to a human–machine interface. System data, including flow conditions, should be monitored and recorded using a data acquisition system.

The accumulation of solids in the test tank shall be quantified by measuring the volume of solids remaining in the tank in between a series of slurry transfer and refill operations. The measurement technique (e.g., volume displacement) is being developed by the investigators as part of the test activity. The accuracy of the instrumentation used for solids measurement shall be quantified. An accuracy range of ±20% is comparable to liquid displacement or visual estimation techniques performed for quantifying residual wastes in Hanford single-shell tanks.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted, and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented.

3.3.1.2 Test Simulants

The base simulants used in the SSMD Solids Accumulation Scouting Studies shall be selected in accordance with the recommendations in RPP-PLAN-51625 and Section 3.1.1.1. The base simulants shall be a complex simulant containing slow settling, fast settling, and very fast settling solids. The base simulants should be sufficiently different so that separation and sampling techniques can be used to quantify the concentration of each particle type. For Solids Accumulation Scouting Studies the complex simulant will be the Typical Conceptual simulant presented in Table 3-1. The Typical Conceptual simulant is appropriate for use because multiple fill and empty operations will be performed and it is expected that understanding typical behavior is more appropriate for future performance than testing a series of "low" or "high" conceptual simulants that represent low probability expectations. Gibbsite is appropriate as a slow settling solid because chemical analyses of the tank waste indicate gibbsite is a principal component. Furthermore, the light color of gibbsite allows it to be distinguished from the different colored solids that will represent the fast and very fast settling particles. Medium sand, due its higher density and larger particle size, will settle faster than gibbsite. With a density more than twice that of the sand or gibbsite but a particle size that is smaller than the sand and similar to the gibbsite, zirconium oxide is expected to settle slower than the sand, but much faster than the gibbsite. The selected compound for the very fast settling solid is stainless steel. The stainless steel is darker in color than the other constituents in the base simulant and it is magnetically attractive. Therefore, the distribution of the very fast settling solids in the tank can be characterized visually and magnetism could be used to isolate these particles for quantification.

The supernatant simulant should be adjusted using soluble salts to achieve a target density of 1.29 g/ml ±5% and a liquid viscosity of 3.3 cP ±20%. The targeted values are consistent with previous studies conducted at SRNL. The target density is an intermediate density between the low and high density values included in Table 3-2. The targeted viscosity is consistent with the density-viscosity relationship shown in Figure 6-2 of RPP-PLAN-51625.

Unlike Limits of Performance testing, the capability of the system to transfer large and dense particles is not being evaluated in the MDT; therefore, the complex simulant shall not be spiked with large, dense particles. The very fast settling solids are represented by the stainless steel in the base simulant.

3.3.1.3 Operating Parameters and Test Methods

The operating conditions for the MDT test platform should be consistent with previous performance testing. The mixer jets shall be operated with no rotational offset, the streams will be synchronized to meet in the center of the tank. The rotational speed of the jets shall be determined in accordance with Equation 1-3. The accumulation of solids is studied using two different nozzle velocities. The nozzle velocities used in the capability testing shall be scaled equivalents of the full-scale mixer pumps. The two different nozzle velocities should be determined using recommended values for the scale factors exponents (i.e., 0.2 and 0.33). The appropriate nozzle velocities to use during the Solids Accumulation Scouting Studies testing should result in "dead zones" within the tank. If the jet nozzle velocity is high enough to prevent build-up in the MDT, then the accumulation of solids will not be adequately quantified. Previous MDT studies conducted with less challenging simulants at lower nozzle velocities than that resulting from a scale factor exponent of 0.33 prevented "dead zones". Therefore, the selection of the second nozzle velocity will be reevaluated at the time of testing to ensure that accumulation data can be collected.

The MDT test platform should be operated in a recirculation mode until a stable state mixing condition is established. Once the tank reaches the stable state, the batch transfer should be initiated. The batch volume should be pumped to the receipt tanks, utilizing a different tank for each of the different transfers. During each transfer, the very fast settling particles will be removed from the base material. Magnetics will be used to separate and retain the stainless steel particles from the other solids. After each transfer is completed, a description and quantification of the solids remaining in tank, including a photographic or video record, should be prepared. Solid samples shall be collected from the solid mounds left in the tank after the 1st, 5th, and 10th (or last) tank volume transfers. Solid samples shall be collected with minimal disturbance to the mounds. In addition, quantification of the settled solids in each receipt vessel shall also be documented. After the last tank volume transfer is completed, a description and accurate quantification of the solids remaining in the tank, including a photographic or video record, should be prepared. A description and accurate quantification of the solids remaining in the tank, including a photographic or video record, should also be prepared after the 5th and last tank volume transfers are completed.

After the solids from the first tank volume transfer operation have been characterized a new round of simulant shall be added to the MDT. The new slurry should be well mixed prior to and during the transfer. Refilling the MDT should not significantly disturb the piles of solids left behind after the previous transfer. The transfer from an auxiliary mixing tank into the MDT mixing tank should replicate the DST process that is expected to add the new slurry to the center of the tank.

A series of transfer and refill operations shall be performed. The volume of solids remaining in the MDT shall be characterized before the tank is refilled. Solids characterization can include length, depth, and width measurements of the mounds coupled with photographs that show the mound topography. Additionally, qualitative descriptions of the residual solids should be documented to augment the photographic records. Successive transfer and refill operations, up to ten, will evaluate whether or not the solid volume left in the tank continues to increase after each transfer. Ten tank volume transfers represent about one-half of the number of tank volume transfers that will originate from DST 241-AW-105, the tank with the greatest number of planned transfers to the WTP. Fewer tank volume transfers may be performed if it is demonstrated that the volume of solids left in the tank after successive transfers stabilizes.

The Solids Accumulation Scouting Studies operating parameters are shown in Table 3-11.

Table 3-11: Solids Accumulation Scouting Study Operating Parameters

Parameter	Value(s)	Parameter	Value(s)
Mixer Jet Synchronization	360° Rotation with no offset.	Test Volume	Approximately 104 gallons
Mixer Jet Rotational Velocity[1]	a=0.33: 1.6 rpm a = 0.2: 2.4rpm	Number of Batch Transfers to be Performed	6.5
Mixer Jet Nozzle Velocity[1]	a=0.33: 21 ft/s a = 0.2: 31.7 ft/s	Batch Transfer Size	13.1 gallons
Transfer Pump Flow Rate	0.58 gallons per minute	Tank Volume Transferred per Cycle	85 gallons

[1] The parameter ‘a’ denotes the scale factor exponent in Equations 1-2 and 1-3

3.3.1.4 Sample Collection and Analysis

Solid samples shall be collected from the MDT following the 1st, 5th, and 10th tank volume transfers. Solids samples shall be collected in place to provide a spatial characterization of the very fast settling solids. Samples should be collected from the two mounds formed in the "dead zone" in the tank and in the settled material that is deposited as a layer in the tank when the mixers are turned off. The mass of very fast settling solids in the settled layer distributed throughout the tank is characteristic of the mass that is suspended during mixing. The shape of the settled solids will be used to guide where the 3/8-inch outer diameter core samples are to be taken, but several samples will be taken at low, medium, and high pile depth locations to obtain a good representation of the location of the stainless steel particles in the mounds. Only one mound will be chosen for sampling after the 1st and 5th cycles. The second mound will not be sampled until the final cycle is completed. After the last cycle, both mounds will be sampled. The number of samples collected after the 1st and 5th cycles should not destroy the integrity of the mound. The stainless steel in each core sample will be extracted from the core using strong magnets, then dried, and weighed. The mass of the very fast settling solids in each sample shall be quantified and recorded in a test log. Solid samples shall be collected prior to re-filling the tank for the next tank volume transfer. If supplemental removal of tank liquids is necessary to collect the samples, the liquid shall be withdrawn with minimal disturbance to the residual solids and then be stored temporarily. The stored liquid should be added back to the tank after the samples are collected but before the tank is re-filled for the next round of transfers. The spatial location of the collected samples shall be recorded in the test log. The sample collection technique shall be documented in a photographic record or recorded on video. The collected samples shall be analyzed for the composition of the very fast settling particles so that a spatial distribution of the very fast settling solids in the accumulated material can be qualitatively described.

To estimate a mass balance, the mass of the very fast settling solids removed during each transfer shall be quantified. The discharge from the tank will flow through a magnetic separator to extract the stainless steel from the slurry. The recovered stainless steel shall be dried and weighed to quantify the amount transferred in each batch. An estimation of the sample error for the very fast settling solids in the tank residual and transfer batches should be quantified during developmental work to test the magnetic separator. A qualitative description of the sand, gibbsite, and zirconium oxide transferred in each batch shall also be reported by measuring the heights of the settled layers in the receipt tanks and calculating the resulting volumes of the settled layers using the known geometry of the vessels. Precise quantification of the sand, gibbsite, and zirconium oxide in the heel is not required for this test activity. More precise evaluations will be performed using the SSMD test platform in a separate test activity.

The volume of solids remaining in the tank shall be estimated using a technique developed during developmental testing. The methods that will be tested include laser height measurements of the solid piles, liquid displacement, and 3-D topographical mapping. For laser height measuring the distance from a known point to the surface of the mounds is measured using a laser measurement instrument. Several measurements are collected to map the topography of the surface. For the liquid displacement measurement technique, residual liquid is withdrawn from the tank in known height increments and the amount of liquid withdrawn is compared to the expected volume for that height. The liquid retained in the pores of the residual solids is estimated based on developmental work so that the difference in the expected liquid volume and measured liquid volume, accounting for the wetted pores, approximates the volume of solids in that height interval. After each incremental lowering of the liquid level, photographs of the surface will be captured and combined to form a topography map of the residual solids. The volume of the residual solids is estimated from the surface topography. The accuracy of the measurement technique shall be reported and comparable or better than ±20%, the approximate level of accuracy for existing tank solids volume estimation techniques. The mass of the very fast settling solids remaining in the tank after the transfer campaign shall be estimated by subtracting the total mass of very fast settling solids measured in the batch transfers from the total mass added to the tank during the testing campaign.

3.3.2 Solids Accumulation Performance Evaluation

SSMD Solids Accumulation Performance Evaluation test activities documented in Section 3.3.2 are performed by Energy*Solutions* for WRPS.

The SSMD Solids Accumulation Performance Evaluation activities will characterize the accumulation of solids in the prototypic test tanks at two scales (1:21 and 1:8). Data analysis will evaluate scaling relationships for different performance metrics related to the accumulation of solids as well as mixing and transfer performance. The test requirements, including requirements for platform configuration, operating parameters, test methods, simulants, and sample and analysis for these activities will be informed from the activities described in this test plan and will be developed and documented in a separate test plan.

3.4 SCALED/SYSTEM PERFORMANCE

3.4.1 Small Scale Mixing Demonstration

The SSMD Scaled Performance test activities documented in Section 3.4.1 are performed by Energy*Solutions* for WRPS.

The SSMD Scaled Performance test activities will evaluate scaling relationships for different performance metrics related to mixing and transfer performance, as well as the accumulation of solids. The test requirements, including requirements for platform configuration, operating parameters, test methods, simulants, and sample and analysis for these activities will be informed from the activities described in this test plan and will be developed and documented in a separate test plan.

3.4.2 Remote Sampler Demonstration

RSD system performance test activities documented in Section 3.4.2 are performed by Energy*Solutions* for WRPS.

The RSD system performance test activities will collect system performance data with the vertical piping configuration and the Ultrasonic PulseEcho system. The test requirements, including requirements for platform configuration, operating parameters, test methods, simulants, and sample and analysis for these activities will be informed from the activities described in this test plan and will be developed and documented in a separate test plan.

4.0 TEST COORDINATION

All testing equipment operation is performed by trained and qualified subcontracted personal under the supervision of a Test Director. An operations plan, including test run sheets, will be prepared that describes the precautions and limitation, the sequence of testing, testing prerequisites, startup conditions, and test procedures in stepwise detail. The TOC technical representative(s) must concur with the operations plan. The Test Director coordinates testing activities including ensuring that all test conditions required for the startup of testing have been performed and all test records (e.g., Test Log, Test Deficiency Reports, Test Change Requests, etc.) are maintained. The Test Director is also responsible for coordinating test activities with the Quality Assurance representative to ensure testing is performed in accordance with the approved quality assurance plan. While tests are conducted, the Test Director will also determine which changes are considered "inconsequential" and approves these test changes. All other changes require the concurrence with the TOC technical representative(s) before the change(s) is/are implemented.

4.1 PRECAUTIONS AND LIMITATIONS

The Job Hazards Analysis is the process for identifying, evaluating, controlling, and communicating potential hazards associated with the work being performed, including modifications to test facilities and test equipment. Testing for the Limits of Performance and Solids Accumulation Scouting Studies are being performed in test facilities constructed to perform the testing. Each test facility is governed by a facility specific Job Hazards Analysis documented in a Job Hazards Analysis checklist or equivalent document. Changing conditions that modify the test facility or equipment to accommodate testing will be evaluated in a revision to the Job Hazards Analysis before the modifications to the facility or equipment are performed. Workers performing work in the test facility governed by the Job Hazards Analysis shall review the document hazards and acknowledge that they understand the hazards associated with the work being performed and will abide by controls (e.g., don required personal protective equipment, obey posted signs and placards) put in place to mitigate or eliminate the hazards.

Any special precautions that must be taken or test limitations will be documented in the operations plan specifically prepared for each activity and will communicated to workers before the start of work during a Pre-Job briefing.

4.2 SEQUENCE OF TESTING

Any special requirements for the testing sequence that are not identified in Section 3.0 will be documented in the operations plan specifically prepared for each activity.

4.3 PLANT CONDITIONS

Any special requirements for the plant conditions, including connecting to site utilities and site restoration, that is not identified in Section 3.0 will be documented in the operations plan specifically prepared for each activity.

4.4 SPECIAL EQUIPMENT

Any special equipment required to conduct the tests that is not identified in Section 3.0 will be documented in the operations plan specifically prepared for each activity.

5.0 DATA COLLECTION AND TEST RESULTS REPORTING

Testing shall be conducted in accordance with an approved operations plan that is prepared in accordance with this test plan. All test activities shall be performed according to test run sheets. All major testing activities shall be documented in a test log. Test deficiencies shall be reported in a Test Deficiency record.

Test data identified in Section 3.0 , including test durations and test conditions, shall be recorded in the test log. Applicable data not recorded by a data acquisition system shall be recorded on the run sheet or recorded in the test log. All electronic data collected by a data acquisition system shall be content reviewed for error and anomalies. Electronic records shall be submitted to the TOC for evaluation.

All laboratory analysis results shall be accompanied by a chain of custody report that was prepared when the samples were collected. The chain of custody shall identify the samples by a unique name, describe the sample type and list the analyses to be performed. The chain of custody shall also document the preparers name and shall acknowledge receipt at the analytical laboratory. All laboratory analysis results shall be submitted to the TOC technical representative in an MS Excel compatible format.

Test result reports shall be prepared for each test activity. Test activities conducted by SRNL shall be documented in a test report prepared by SRNL. Test activities conducted by CEES shall be documented in a test report prepared by CEES. Test activities conducted by Energy*Solutions* shall be documented in a test data package that is submitted to the TOC. The TOC shall perform the required analysis and document the findings in a test report that is reviewed by Energy*Solutions*.

6.0 REFERENCES

American Society for Testing and Materials Standard E11, 2009e1, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves,* ASTM International, West Conshohocken, PA, 2009, DOI: 10.1520/E0011-09E01, www.astm.org.

American Society of Mechanical Engineers (ASME), NQA-1-2004, *Quality Assurance Requirements for Nuclear Facility Applications* (including NQA-1-a-2005 and NQA-1b-2007 Addenda), New York City, New York.

24590-WTP-ICD-MG-01-019, 2011, *ICD 19 – Interface Control Document for Waste Feed*, Rev. 5, Bechtel National, Inc., Richland, Washington.

24590-WTP-RPT-MGT-04-001, 2004, *Regulatory Data Quality Optimization Report,* Rev. 0, Bechtel National, Inc., Richland, Washington.

24590-WTP-RPT-MGT-11-014, 2011, *Initial Data Quality Objectives for WTP Feed Acceptance Criteria*, Rev. 0, Bechtel National, Inc., Richland, Washington.

24590-WTP-PL-PR-04-0001, 2008, *Integrated Sampling and Analysis Requirements Document (ISARD)*, Rev. 2, Bechtel National, Inc., Richland, Washington.

DNFSB Rec. 2010-2, Rev. 0, November 10, 2011, *Department of Energy Plan to Address Waste Treatment and Immobilization Plant Vessel Mixing Issues – Implementation Plan for the Defense Nuclear Safety Board Recommendation 2010-2*, U.S. Department of Energy, Washington D.C.

ORP-11242, 2011, *River Protection Project System Plan,* Rev. 6, U.S. Department of Energy, Office of River Protection, Richland, Washington.

PNNL-14443, 2003, *Recommendations for Advanced Design Mixer Pump Operation in Savannah River Site Tank 18F*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19441, 2010, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20637, 2011, *Comparison of Waste Feed Delivery Small Scale Mixing Demonstration Simulant to Hanford Waste*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20350, 2011, *Hanford Tank Farms Waste Certification Flow Loop Phase IV: PulseEcho Sensor Evaluation*, Pacific Northwest National Laboratory, Richland, Washington.

RPP-47557, 2010, *SSMD Test Platform – Small Scale Mixing Demonstration Initial Results Report*, Rev. 0,Washington River Protection Solutions, LLC, Richland, Washington.

RPP-49740, 2011, *Small Scale Mixing Demonstration Sampling and Batch Transfers Results Report*, Rev. 0, Washington River Protection Solutions, Richland, Washington.

RPP-50557, 2012, *Tank Waste Mixing and Sampling Update*, Rev 0B, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-41807, 2012, *Waste Feed Delivery Mixing and Sampling Program Plan and Test Requirements*, Rev. 01A, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-51625, 2012, *Waste Feed Delivery Mixing and Sampling Program Simulant Definition for Tank Farm Performance Testing,* Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-48233, 2011, *Independent Analysis of Small Scale Mixing Demonstration Test*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-48681, 2011, *Hanford Tank Waste Operations Simulator Model Data Package for the River Protection Project System Plan Rev. 6 Cases,* Rev. 6,Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-51796, 2012, *Remote Sampler Demonstration (RSD) Phase I Sampling Results Report*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

SRNL-STI-2010-00521, 2010, *Demonstration of Mixer Jet Pump Rotational Sensitivity on Mixing and Transfers of the AY-102 Tank*, Rev. 0, Savannah River National Laboratory, Aiken, South Carolina.

SRNL-STI-2011-00278, 2011, *Demonstration of Mixing and Transferring Settling Cohesive Slurry Simulants in the AY-102 Tank*, Rev. 0, Savannah River National Laboratory, Aiken, South Carolina.

SRNL-STI-2012-00062, 2012, *Properties Important to Mixing for WTP Large Scale Integrated Testing,* Rev. 0, Savannah River National Laboratory, Aiken, South Carolina.

SVF-2110, 2011, *TRANSFER_PLOTS_4MINTIMESTEP(6MELTERS)-MMR-11-031-6.5-8.3R1-2011-03-18-AT-01-31-58_V7.XLSM*, Revision 1, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ENG-DESIGN-C-18, "Testing Practices", Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ESHQ-Q_ADM-C-01, "Graded Quality Assurance", Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLAN-26, "Test Program Plan", Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLAN-39, "Risk Management Plan", Rev. G, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLAN-90, "Technology Development Management Plan", Rev. G, Washington River Protection Solutions, LLC, Richland, Washington.

WRPS-1105293, 2011, "Small Scale Mixing Demonstration Optimization Workshop Meeting Minutes", November 16, 2011, Washington River Protection Solutions, LLC, Richland, Washington.

APPENDIX A. SMALL SCALE MIXING TANK SCALING RELATIONSHIPS

A.1 Mixer Jet Pump Nozzle Velocity Scaling

The power, required to mix a tank with a jet, P_{mix}, can be determined from the kinetic energy supplied by the jet, as shown in Equation A-1,

$$P_{mix} = \left(\frac{\pi}{4} d_{jet}^2 U_{jet}\right)\left(\frac{1}{2}\rho U_{jet}^2\right) = \frac{\pi}{8}\rho d_{jet}^2 U_{jet}^3$$

Equation A-1

where, ρ is the fluid density, U_{jet} is the nozzle velocity of the jet and d_{jet} is the jet nozzle diameter.

For the equal power-per-volume scaling relationship, the power computed by Equation A-1 is divided by the mixing volume, V, as shown in Equation A-2. Note: the mixing volume is the waste simulant slurry volume, not the capacity of the tank. The mixing volume is characterized by the tank diameter, d_{tank}, and the height, h_{slurry},of the slurry in the tank as it is mixed.

$$\frac{P_{mix}}{V} = \frac{\frac{\pi}{8}\rho d_{jet}^2 U_{jet}^3}{\frac{\pi}{4} d_{tank}^2 h_{slurry}}$$

Equation A-2

For two scaled mixing systems with similar geometric properties mixing the same simulant, the nozzle diameter, tank diameter and slurry height from one tank are scaled from the other tank using the scaling factor, SF. The scaling factor is the ratio of the scaled tank diameter and the full-scale tank diameter. Setting the power-per-volume equation equal for the two scales, denoted with subscripts 1 and 2, and substituting in the scaling relationship ($SF=d_{tank2}/d_{tank1}$) is shown in Equation A-3. The simplification of Equation 1-3 is shown in Equation A-4.

$$\frac{P_{mix1}}{V_{tank1}} = \frac{\frac{\pi}{8}\rho d_{jet1}^2 U_{jet1}^3}{\frac{\pi}{4} d_{tank1}^2 h_{slurry1}} = \frac{P_{mix2}}{V_{tank2}} = \frac{\frac{\pi}{8}\rho d_{jet2}^2 U_{jet2}^3}{\frac{\pi}{4} d_{tank2}^2 h_{slurry2}} = \frac{\frac{\pi}{8}\rho SF^2 d_{jet1}^2 U_{jet2}^3}{\frac{\pi}{4} SF^2 d_{tank1}^2 SF h_{slurry1}}$$

Equation A-3

$$U_{jet1}^3 = \frac{U_{jet2}^3}{SF}$$

Equation A-4

The scaling factor exponent for equal power per volume conditions in the SSMD test platform is 1/3, as shown in Equation A-5.

$$U_{jet2} = U_{jet1}\left(\frac{d_{tank2}}{d_{tank1}}\right)^{\frac{1}{3}}$$

Equation A-5

A.2 Mixer Jet Pump Rotational Rate Scaling

The rotation rate for the mixer jet pump, ω, is also a scaled property of the integrated system. The scaling parameter for the mixer jet pump rotational rate equates the number of revolutions that occur in the time required to circulate an entire tank volume through the mixer jet pump inlet (PNNL-14443 Section 2.1.2).

Because the tank diameter and tank height are geometrically scaled from the full-scale, the volume of the scaled tanks, V, are related as shown in Equation A-6.

$$V_{tank2} = \frac{\pi}{4} d_{tank2}^2 h_{slurry2} = \frac{\pi}{4}(SF\ d_{tank1})^2 SF\ h_{slurry1} = SF^3 V_{tank1}$$

Equation A-6

The time required to circulate an entire tank volume through the mixer jet pump inlet, the turnover time (Θ), is the ratio of the tank volume and the mixer jet pump volumetric flow rate, which is itself a function of the nozzle velocity that is determined from a separate scaling relationship (see Equation 1-2). Equation A-7 shows this relationship.

$$\Theta_{tank1} = \frac{V_{tank1}}{Q_{tank1}} = \frac{V_{tank1}}{A_{nozzle1} U_{jet1}} \qquad \text{Equation A-7}$$

If the nozzle velocity through the two tanks are scaled according to Equation 1-2, the turnover times are also related as shown in Equation A-8.

$$\Theta_{tank2} = \frac{V_{tank2}}{Q_{tank2}} = \frac{SF^3 V_{tank1}}{A_{nozzle,2} U_{jet2}} = \frac{SF^3 V_{tank1}}{SF^2 A_{nozzle1} U_{jet1} SF^a} = SF^{1-a} \Theta_{tank1} \qquad \text{Equation A-8}$$

Setting the scaling condition ($\omega\Theta$) equal between the two tanks yields the angular velocity scaling relationship (Equations A-9 and A-10).

$$\omega_{tank1} \theta_{tank1} = \omega_{tank2} \theta_{tank2} = \omega_{tank2} SF^{1-a} \Theta_{tank1} \qquad \text{Equation A-9}$$

Therefore,

$$\omega_{tank2} = \frac{\omega_{tank1}}{SF^{1-a}} \qquad \text{Equation A-10}$$

DISTRIBUTION SHEET

To Document Control	From Kearn Patrick Lee	Page 1 of 1
Project Title/Work Order One System Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan		Date May 15, 2012 EDT No. NA ECN No. NA

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Ben Harp (ORP)	H6-60	X			
Mike Thien	B1-55	X			
Kearn Patrick Lee	B1-55	X			
Ted Wooley	B1-55	X			
Tamika Pirtle Moore	B1-55	X			
Jerry Heaney	H3-20	X			
Steve Kelly	B1-55	X			

WRPS-1202074-OS

ENCLOSURE 2

ERT-16 Feed Test Plan

Large-Scale Integrated Mixing System Expert Review Team

(L. Peurrung, Chair; R. Calabrese, R. Grenville, E. Hansen, R. Hemrajani)

To: Tom Fletcher, Tank Farms Federal Project Director; Michael D. Johnson, WRPS President and Project Manager, Tank Operations Contract

Cc: Ray Skwarek, One System IPT Manager; Mike Thien, WRPS; ERT Members

Subject: ***Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan*** (ERT-16)

Date: April 27, 2012

The Large-Scale Integrated Mixing System Expert Review Team (ERT) was asked to review "Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan" (RPP-PLAN-52005 Rev 0A). This document is meant to satisfy (in part) Commitment 5.5.3.6 in the Implementation Plan for DNFSB Recommendation 2010-2, "Test Plan to establish Tank Farm performance capability." Per the commitment, WRPS will "conduct testing to determine the range of waste physical properties that can be retrieved and transferred to WTP and determine the capability of tank farm staging tank sampling systems to provide samples that will characterize waste and determine compliance with the [Waste Acceptance Criteria]. This work will include development of a test plan." Per the test plan itself, "This test plan is one of multiple test plan documents that will be prepared to address [the commitment] and addresses the technical approach and test requirements for Limits of Performance test activities and developmental Solids Accumulation testing...For each test activity covered in this test plan, the test objectives along with success criteria are identified and described. The simulants that are appropriate for testing are identified and qualified in accordance with [the Simulant Definition document, RPP-PLAN-51625]."

The lines of inquiry for the ERT's review were:

- Are the major points of the document communicated well to the intended audience?
- Does the document provide a clear set of test objectives and requirements?
- Are the proposed approaches to testing sufficiently defined and technically defensible?
- Is simulant selection appropriate? Does the document meet its intent of "qualifying" the simulants proposed?

The ERT first observes that the level of detail in the document as a test plan is less than what the ERT has seen and reviewed in Waste Treatment Plant's (WTP's) test planning process for validation and verification of its computational fluid dynamics code. While the general objectives of testing and the measurements to be made are clear, there is relatively little on the specifics of how some of the measurements will be made and to what precision, particularly in the area of sample collection and analysis such as the sieving approach and heel estimation and sampling. Statements such as "It is anticipated that an aqueous solution of sodium thiosulfate will produce a supernatant with these characteristics" and "a temperature correlation will be developed [for viscosity as a function of temperature]", for example, fall somewhat short of the mark we might have expected for qualifying the simulant per the document's stated objectives. Presumably there will be follow-on documents with a higher level of detail. The ERT would like to see those documents as they become available.

The test plan describes scaled testing at 1:7.5 scale involving very large particles as simulant spikes. The ERT understands that it is problematic to scale a tank waste simulant to achieve full similitude in scaled testing. The ERT also understands why WRPS would like to evaluate particles of such large diameter to determine the limits of system performance. However, in these scaled tests, the un-scaled spike particles approach the scaled dimensions of the transfer pump suction inlet diameter. By general rule of thumb, particles that approach one-tenth to one-quarter of the diameter of the line have the potential to cause plugging. Moreover, the use of particles that approach the dimensions of the geometrically scaled system has the potential for complicating the interpretation of the results; that is, one should not use a simple scaling factor that assumes the same physics and deem the projection fully quantitative. The ERT recommends caution in interpreting these results.

In the same vein, the ERT questions whether it is appropriate to use the full-scale transfer pump suction inlet velocity for scaled testing. WTP took a somewhat different approach to scaling the suction inlet based on an argument that geometrically scaled the size of the capture zone for particles. For Small Scale Mixing Demonstration testing, the suction inlet nozzle is a fraction of an inch from the bottom of the vessel, and the inlet velocity is at its full-scale value of either 6.4 or 11.3 feet per second. The inlet diameter has been reduced, though not quite geometrically for the 1:21 scale testing to retain the ability to admit the largest particles in the test. At constant velocity but with a scaled offset from the bottom, there is no particular reason to believe, a priori, that the volume of influence around the suction line will have the same shape or extend radially by a geometrically scaled distance, which could significantly affect the data. The ERT recommends that this approach be re-examined or at least justified within the document.

Finally, the ERT has two observations related to the mixer jet pump rotational speed. The scaling approach in Equation 1-11 is based in part on constant power per unit volume, yet the appropriateness of that scaling approach is part of what scaled testing is trying to establish. The document acknowledges on pages 1-8 to 1-9 the "need to evaluate the impact of both mixer jet rotational rate and nozzle velocity", but there is no indication in the test plan that rotational rate will be a variable in testing.

Comments from individual ERT members are attached. The ERT hopes you find this review helpful, and we look forward to your response per the ERT Charter.

ERT-16 Feed Test Plan

Review Participants:

April 19, 2012: Rich Calabrese, Erich Hansen, Ramesh Hemrajani, Richard Grenville, Loni Peurrung

April 20, 2012: Rich Calabrese, Ramesh Hemrajani, Richard Grenville, Loni Peurrung, Mike Thien, Pat Lee

April 25, 2012: Rich Calabrese, Erich Hansen, Ramesh Hemrajani, Richard Grenville, Loni Peurrung

WRPS-1202074-OS

ENCLOSURE 3

FROM THE DESK OF

Raymond J. Skwarek
Manager, One System IPT

Date: May 10, 2012 WRPS-1201884-OS

To: L. M. Peurrung, Chair
Large-Scale Integrated Mixing System Expert Review Team

Subject: ONE SYSTEM TECHNICAL TEAM RESPONSE TO REVIEW OF WASTE FEED DELIVERY MIXING AND SAMPLING PROGRAM LIMITS OF PERFORMANCE AND SOLIDS ACCUMULATION SCOUTING STUDIES TEST PLAN (ERT-16)

Reference: Letter, C. A. Simpson, WRPS, to S. E. Bechtol, ORP, "Contract Number DE-AC27-08RV14800 – One System – Washington River Protection Solutions LLC Transmittal of the Large Scale Integrated Mixing System External Review Team Review Letter for the Tank Operations Contract Owned Commitment 5.5.3.6, 'Test Plan to Establish Tank Farm Performance Capability,'" WRPS-1201797-OS, dated May 2, 2012.

The One System Technical Team appreciates the Large-Scale Integrated Mixing System Expert Review Team (ERT) review (Reference) of the subject document. This response letter addresses the four areas of one general observation and the three specific technical comments identified by the ERT. The one specific technical concern is identified below followed by the One System response.

1. *"The ERT first observes that the level of detail in the document as a test plan is less than what the ERT has seen and reviewed in Waste Treatment Plant's (WTP's) test planning process for validation and verification of its computational fluid dynamics code. While the general objectives of testing and the measurements to be made are clear, there is relatively little on the specifics of how some of the measurements will be made and to what precision, particularly in the area of sample collection and analysis such as the sieving approach and heel estimation and sampling..."*

We understand and agree with the ERT's observation that the level of detail is not consistent with WTP test documentation. This difference is partly due to the different level of testing necessary to validate the computational fluid dynamic modeling and design of WTP systems contrasted with the limits of performance testing which is probing the extremes of tank farms equipment capabilities. We also recognize that the draft document included open-ended statements related to simulant formulation and performance. Laboratory testing to demonstrate specific simulant formulations that meet the targets identified in the Simulant Definition Document (RPP-PLAN-51625) was in progress during document review thereby causing the need to be less precise than desired. You will find that additional details regarding simulant formulation, sampling, and analytical techniques have been added to the updated document that incorporates review comments. We believe the level of detail is now appropriate for the initial solids accumulation testing and the limits of performance testing which is intended to qualitatively identify the most difficult particulates (spikes) the mixing, sampling, and transfer systems can accommodate.

The three specific technical comments are identified below followed by the One System response.

1. *"The test plan describes scaled testing at 1:7.5 scale involving very large particles as simulant spikes. The ERT understands that it is problematic to scale a tank waste simulant to achieve full similitude in scaled testing... By general rule of thumb, particles that approach one-tenth to one-quarter of the diameter of the line have the potential to cause plugging. Moreover, the use of particles that approach the dimensions of the geometrically scaled system has the potential for complicating the interpretation of the results; that is, one should not use a simple scaling factor that assumes the same physics and deem the projection fully quantitative. The ERT recommends caution in interpreting these results."*

The One System project team shares the ERT's concern that as particle sizes approach the size of the scaled test equipment, departure from scaled similitude and equipment performance problems (e.g., line plugging) become a larger risk. To address the equipment performance risks, we have performed developmental testing with the scaled equipment to demonstrate functionality of the equipment with the planned extreme particles. Scaled system design changes have been identified and completed as a result of these developmental tests to ensure necessary data can be collected without damage or malfunction to the test equipment. The physics uncertainty and complexity of testing these extreme particles in scaled equipment was the primary driver for initiating the full-scale transfer pump testing activity as it is recognized the scaled results with extreme particles may be difficult to interpret. The planned One System results analysis process includes workshops with our team of external experts to discuss interpretation of test results. In order to maintain independence, the ERT is not chartered with providing project direction or guidance; however, we will be happy to include the ERT in an observer role in the results evaluation workshops.

2. *In the same vein, the ERT questions whether it is appropriate to use the full-scale transfer pump suction inlet velocity for scaled testing. WTP took a somewhat different approach to scaling the suction inlet based on an argument that geometrically scaled the size of the capture zone for particles. For Small Scale Mixing Demonstration testing, the suction inlet nozzle is a fraction of an inch from the bottom of the vessel, and the inlet velocity is at its full-scale value of either 6.4 or 11.3 feet per second. The inlet diameter has been reduced, though not quite geometrically for the 1:21 scale testing to retain the ability to admit the largest particles in the test. At constant velocity but with a scaled offset from the bottom, there is no particular reason to believe, a priori, that the volume of influence around the suction line will have the same shape or extend radially by a geometrically scaled distance, which could significantly affect the data. The ERT recommends that this approach be re-examined or at least justified within the document.*

Scaling of the transfer pump system parameters has been a topic of much discussion from the beginning of testing as there are multiple phenomena to consider that all potentially interact with overall batch transfer performance. The original batch transfer demonstrations performed at SRNL considered preserving both scaled time and volume relationships and probed the impact of alternate flow rates to support more efficient test scheduling. The results (SRNL-STI-2009-00717) demonstrated the system is insensitive to capture velocity as long as the velocity is maintained above critical velocity to prevent plugging of system piping. These results were considered in setting test parameters for the multi-scaled tank testing (RPP-48061) where consensus was reached that matching transfer pump inlet velocity provides an equivalent opportunity in the scaled environment for the larger, more dense particles to be transferred. The test plan did note that results analysis should be cautious of the different relative suction zone of influence created by matching suction velocity. As with the early SRNL testing, SSMD results (RPP-49740) showed the system's insensitivity to lower capture velocity with slightly reduced solids transferred and slightly improved batch-to-batch consistency. We have discussed the WTP approach to scaling the capture velocity with the WTP subject matter experts. The WTP approach has moved away from defining an equivalent capture zone concept which does not account for the continuously changing mixing and settling characteristics experienced near the suction nozzle. The new approach (24590-WTP-TSP-RT-11-008) focuses on targeting a critical velocity for expected simulant properties. We believe that because of the extreme particles we will be testing, matching the full-scale transfer pump capture velocity, provides the best opportunity to determine the limits of performance. Based on previous test results exploring lower capture velocities, we also believe other performance attributes that may not be precisely scaled, such as relative zone of influence, will not significantly bias the test results with respect to the amount of solids transferred.

3. *Finally, the ERT has two observations related to the mixer jet pump rotational speed. The scaling approach in Equation 1-11 is based in part on constant power per unit volume, yet the appropriateness of that scaling approach is part of what scaled testing is trying to establish. The document acknowledges on pages 1-8 to 1-9 the "need to evaluate the impact of both mixer jet rotational rate and nozzle velocity," but there is no indication in the test plan that rotational rate will be a variable in testing.*

The rotation rate scaling equation (Equation 1-11) was presented as an example using a one-third scaling factor exponent and was not intended to apply for mixer jet velocities derived with different scale factor exponents. While the dominant contributor to solid particulate behavior in the mixed system is mixer pump jet velocity, the mixer pump rotational speed does contribute to tank mixing, sampling, and transfer performance and is considered a test variable. The Test Plan has been modified to clarify these points.

In addition to the specific responses highlighted above, the One System Technical Team has reviewed the ERT document suggestions provided on a separate document review record and modified the DNFSB commitment document. The updated draft document incorporating comments received from all reviewers is enclosed (Enclosure 1), as well as the disposition of the ERT individual review comments (Enclosure 2).

Please feel free to contact me at 372-9117, or Mike Thien at 372-3665 if you have any further questions regarding our response to the ERT review.

Sincerely,

R Skwarek

R. J. Skwarek, Project Manager
One System Integrated Project Team

MGT:MEH

Enclosure(s):
1. RPP-PLAN-52005, Rev. 0B, Draft, "Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan" (91 pages)
2. LSIMS ERT Document Review Record (27 pages)

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ERT-16
Consolidated Comment Resolution
(updated)

LSIMS ERT
DOCUMENT REVIEW RECORD

REVIEW NUMBER:	ERT-16 Feed Test Plan
DOCUMENT NUMBER:	RPP-PLAN-52005 Rev 0A
DOCUMENT TITLE:	Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan

Comment			Comments and Recommendations:	Resolution:
Number	Reviewer	Type*		
1	LMP	E	Page 1-4, top: It would be helpful to the reader to explain briefly what aspects of Phase I sampler testing suggested the need for further testing.	Added mention to high bias sampling of high density and large particles as concluded in RPP-RPT-51796.
2	LMP	**M**	Section 1.3: It is not clear a priori that equating the fluid velocity through the pump suction inlet in a geometrically scaled system is appropriate. No justification for this approach is provided. WTP used an argument that created a geometrically scaled zone of capture.	The new WTP approach focuses on targeting a critical velocity for expected simulant properties. Because of the extreme particles being tested, matching the full-scale transfer pump capture velocity provides the best opportunity to determine the limits of performance. See ERT-16 Review Response letter for additional details.
3	LMP	**M**	The largest particles in Table 3-3 (6350 um) are large compared to those dimensions in the 1:8 system. This leads to a number of potential problems as described in the review letter.	Developmental testing with the scaled equipment to demonstrate functionality of the equipment with the planned extreme particles has been performed and scaled system design changes have been identified and completed as a result of these developmental tests to ensure necessary data can be collected without damage or malfunction to the test equipment. See ERT-16 Review Response letter for additional details.
4	LMP	**A:M** B:O	Page 1-9, toward the bottom: "Equal performance between scales is determined when the chemical compositions at both scales are similar." A) Will samples be collected over multiple rotations of the jets, since otherwise composition is highly time-dependent? B) What is "similar"?	A. For scaled performance testing in the 1:8 scale tank, samples will be collected over integer values for the number of mixer jet rotations to minimize any influence of the position of the mixer jet during sampling. Furthermore, four samples will be taken during a transfer. These four samples will be combined and mixed and composite samples will be withdrawn and sent for chemical analysis. For the 1:21 scale tank, the entire transfer volume is collected and subsampled. B. Similar means equivalent within allowable tolerances. However, the text is more a method than a scaling basis and was deleted. It will be discussed further in the forthcoming technical details of the SSMD Scaled Performance

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***Type:** E – Editorial, addresses word processing errors that do not adversely impact the integrity of the document.
O – Optional, comment resolution would provide clarification, but does not impact the integrity of the document
M – Mandatory, comment shall be resolved, reviewer identifies impact on the integrity of the document

LSIMS ERT DOCUMENT REVIEW RECORD	**REVIEW NUMBER:**	ERT-16 Feed Test Plan
	DOCUMENT NUMBER:	RPP-PLAN-52005 Rev 0A
	DOCUMENT TITLE:	Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan

				test plan.
5	LMP	I	Page 2-3: Is the SSMD transfer system prototypic? If particle sizes approach the line diameter, is it still prototypic?	The SSMD transfer system is prototypic. The particles sizes only approach the line diameter for LOP testing, in all other SSMD testing particle sizes are at least 10 times smaller than the line diameter and transfer inlet diameter.
6	LMP	**M**	Section 2.1.3.2: Basis for dimensions of the system (45-55 ft vertical, 20 ft horizontal) are not clear. Is 20 ft enough to demonstrate the effect you're looking for?	Vertical rise has been changed to 55 ft, the approximate depth to the bottom a DST from the surface. 20 ft is the distance included in the waste certification flow loop (based on the positions of the Ultrasonic PulseEcho system) and as serves as the basis for our testing. The real effect we are looking for is what is captured by the pump and less on how particles settle in the horizontal section of the flow line as the Ultrasonic PulseEcho will be used to evaluate critical velocity and solid settling.
7	LMP	**M**	Page 2-9: How will the slurry retained in the transfer line be extracted (quantitatively?) for screening?	Added discussion. Settled slurry in the transfer line will be extracted using a flush pump that generates a greater flow than the test pump. Discharge will be basket screened and spikes will be collected for sieving.
8	LMP	O	Page 3-22: Are you confident you can find a mechanical agitator that can mix 3/8" tungsten particles?	Requirement has been reduced to ¼-inch tungsten carbide. Design is in process.
9	LMP	O	Page 3-30: Approach to accurate quantification of remaining solids is unspecified.	Requirement has been eliminated. Quantification of heel solids will be done by mass balance. Qualitative observations of how the spike solids are distributed in the heel will be reported.
10	LMP	O	Page 3-31: Sample collection approach and the size of the sample volume relative to the volume of heel are unspecified.	Added detail. "The shape of the settled solids will be used to guide where the 3/8-inch outer diameter core samples are to be taken, but several samples will be taken at low, medium and high pile depth locations to obtain a good representation of the location of the stainless steel particles in the mounds. The number of samples collected should not destroy the integrity of the mound. Only one mound will be chosen for

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***Type:** **E** – Editorial, addresses word processing errors that do not adversely impact the integrity of the document.
O – Optional, comment resolution would provide clarification, but does not impact the integrity of the document
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LSIMS ERT DOCUMENT REVIEW RECORD		
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				sampling after the 1st and 5th cycles. The second mound will be left intact until the final cycle is completed. After the last cycle, the second mound both mounds will be sampled."
11	RRH	O	Page 1-1, second bullet: "understand the behavior of remaining solids" – please define the behavior.	Changed behavior to accumulation and distribution.
12	RRH	O	Page 1-2, Background: It appears that similar studies have been carried out for material in AY-102, and this study expands the objectives to cover other Tank Farm materials.	This is correct.
13	RRH	O	Page 1-3, third paragraph: The objective of delivering consistent 145 kgal batches may be difficult, because Pump Jet Mixers may not be capable of providing complete homogeneity of solids at all liquid levels. Is this absolutely important?	It is desirable to reduce sampling of the waste prior to delivery. Pre-samples are collected to determine is waste meets acceptance criteria. Desire is to have samples representative of the entire tank. The number of required samples is fewer if the tank can be well mixed.
14	RRH	O	Page 1-6, Table 1-1: Diameters of transfer pump suction inlets for 1:8 scale and 1:21 scale may be too small for spike particles being considered in the test plans. Industrial experiences indicate that ratio of inlet dia. to particle dia. should be a minimum of 4 and preferably 10. Using small diameter inlet may cause plugging and possibly divert large particles away and cause bias in the results.	See comment response letter.
15	RRH	O	Page 1-6, Table 1-1: Use of poly tubing may make the transfer erratic due to flexing of tubing which can be caused by pumping and/or flow patterns in the vessel. This does not apply if tubing is supported rigidly.	Acknowledged. The operators state that the tube is not supported along its length but does not move during a transfer. There is enough structure near the tube to secure it if erratic motion is observed.
16	RRH	O	Page 1-7, third paragraph, last sentence: Since limited data indicated that the scale factor exponent may be 0.39, the test conditions should be designed to include this value.	0.39 was provided as an example calculation for a simple simulant (zirconium oxide slurry). The discussion has been updated to clarify this.
17	RRH	O	Page 1-8, Equation 1-11: Use of SF^2/3 for rotation rate of mixer jet pump is not convincing. Since particle size and density are not scaled down, settling rates in the test units would be the same as in full scale vessels. Therefore faster rotation of pump jet mixers would reduce settling of particles.	Acknowledged. Scaled relationship will be honored based on the selected scale factor and Scaled Performance testing will evaluate the rotational rate scaling relationship.

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18	RRH	O	Page 1-9, top: It is understandable that ECR decreases as mixer jet rotational velocity increases. This could be caused by relative propagation of jets as the pump mixer rotates. I suggest calculating relative time for jet propagation to the tank wall.	We will follow up for more information on relative jet propagation. This may prove useful for future analysis of test results and scaling evaluations.
19	RRH	O	Page 1-9: I agree with the approach of determining the scale factor exponent 'a' from the data.	Acknowledged.
20	RRH	O	Page 2-4, Table 2-1: In the 'Success Criteria' column, it is mentioned that large and dense particles that can be mobilized to a sample location. Is mobilization sufficient or suspension is desired.	For Limits of Performance testing, mobilization under expected operating conditions is the objective as it couples the need to deliver a particle to the transfer pump inlet using the mixer jets and then the pump must be able to capture and transfer it down the line.
21	RRH	O	Page 2-7, Table 2-2: The design of agitator in the test tank is not provided. It should be specified if the agitator is designed to provide capability to suspend solids having particle size/density of material to be spiked. In addition, a definition of desired suspension quality should be provided, e.g., 'Just Suspension' or 'Complete Homogeneity'.	The vendor is being consulted on the capability of the mixer to suspend the spike particles (1/4-inch WC). The tests will not be allowed to proceed until the agitator is determined to be adequate. This is a project management control.
22	RRH	O	Page 2-9, last paragraph: It is not clear how slurry retained in the transfer line upstream of the sample location will be captured.	Added discussion. Settled slurry in the transfer line will be extracted using a flush pump that generates a greater flow than the test pump. Discharge will be basket screened and spikes will be collected for sieving.
23	RRH	O	Page 2-11: In the conference call on 4/20/12 Mike explained how solids sample from the heel will be collected by decanting the liquid and using a 'sample thief'. This technique is likely to provide a qualitative assessment of solids distribution, because settling may not be homogeneous on the tank floor.	Agreed. Quantitative measurements of the very fast settling solids will be performed by mass balance because the amount withdrawn from the tank will be known. Collected samples will be used to describe how the very fast settling solids are distributed in the mounds.
24	RRH	O	Page 2-14, Table 2-5: It is mentioned that mixing and transfer demonstration are performed at two different jet nozzle velocities. Are two velocities enough? – Should consider using 3 or more velocities. Also it is planned to use 100 micron dense particles to represent fissile material. The 6-part simulant in the WTP program uses	Work follows scaled performance testing, which should result in a better understanding of scale and help determine the two best velocities to use. Schedule and budget drive the number of tests that will be performed. Differences between WTP testing and TOC testing will be reconciled as DNFSB work

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			10 micron dense particles.	progresses.
25	RRH	O	Page 3-5, Table 3-3: With ½" poly tubing in 1:8 scale vessel, spike particles should be <1270 microns based on industrial experience. Similarly with ¼" poly tubing in 1:21 scale, spike particles should be <635 microns.	See comment response letter. And response to LMP #5.
26	RRH	O	Page 3-7, first paragraph: There is a mention of "drill mixing". Please define and explain.	Clarified. "Mixing in the auxiliary vessel was implemented using different methods including no mixing, mixing using a paint mixer <u>attached to a portable drill</u> and mixing using simulated jets. "
27	RRH	O	Page 3-11, 3.2.1.4: It is mentioned that there will be no rotational offset between mixer jet pumps. I was wondering if some offset would be beneficial for enhancing solids suspension and increasing ECR.	SRNL-STI-2010-00521 demonstrated nearly equivalent transfer under different mixer jet rotation configurations, but this will be a consideration for a Scaled Performance testing that will evaluate different rotational rates.
28	RRH	O	Page 3-11, 3.2.1.4: Values of scale factor exponents of 1/3 and 1/5 are mentioned. These values seem to vary at other locations in the document. I understand that there are two values under consideration, 0.18 based on Poreh correlation and 1/3 based on constant P/V scale-up. Although a value of 0.39 is mentioned earlier based on limited data.	1/3 and 1/5 are recommended starting points. 0.39 is the value when the 1:21 and 1:8-scale tanks had equal solids distribution (no transfer). Tests at other velocities will be considered as described for SSMD LOP. SSMD Scaled Performance will evaluate a third velocity, as yet to be defined.
29	RRH	O	Page 3-13, Table 3-6: There is no column for "Fill Height". On page 3-12 (third paragraph) it is mentioned that effect of fill height should be investigated.	Fill height will be examined as the fill height decreases when batches are transferred. The fill height will be considered in the analysis of the data, which will have samples from each batch transfer.
30	RRH	O	Page 3-14, first paragraph: It appears that some of methodologies for sampling and analyses have not been finalized. Some of these proposed techniques may not be feasible, e.g., separation of different density particles. Also measurement of solids remaining in the tank using photographic method seems to be qualitative.	Acknowledged. The text has been updated. The process of separating the materials is now better understood and are being demonstrated.
31	RRH	**M**	Page 3-15, 3.2.2.1, second paragraph: Since capability of mechanical agitator has not been evaluated, it is possible that existing agitator may need to be upgraded. This should be done soon since delivery time for	Acknowledged. The vendor is being consulted on the capability of the mixer to suspend the spike particles (1/4-inch WC). The tests will not be allowed to proceed until the agitator is determined

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			mixing equipment may be long. This mixer evaluation and possible upgrading of mechanical agitator should be documented for review.	to be adequate. Note, that homogeneous distribution is not required but rather a consistent distribution in the flow loop piping emerging from the bottom of the tank.
32	RRH	O	Page 3-16, second paragraph: Level of maximum pressure should be specified for the RSD flow loop.	The operating pressure range of the equipment has been added.
33	RRH	O	Page 3-18, Table 3-7: Similar to previous comments, the particle sizes planned for spike material seem to be very large and may cause plugging at the entrance of transfer line.	See comment response letter. And response to LMP #5.
34	RRH	O	Page 3-19, third paragraph: I believe time dependent rheological properties do not apply to these solid/liquid slurries.	Kaolin is slightly rheopectic and a slight variation in the yield stress as mixing progresses will be accommodated.
35	RRH	O	Page 3-21, first paragraph: It is not clear how particle density and size will be measured. Please provide a brief description.	Added discussion of sieving and counting or weighing of separated particles.
36	RRH	**M**	Page 3-22, first paragraph: A system of suspending 3/8" dia. 19.3 g/cc particles appears to be highly demanding for mechanical agitators. The mixer design should be evaluated for determining if an upgrade is needed and if it is feasible for this size tank.	The mixing requirement has been reduced to ¼-inch tungsten carbide. The mixer is not existing equipment so this sets the design basis.
37	RRH	O	Page 3-24, last paragraph: Mixing tank is planned to be emptied after each test. It is a common experience that all solids may not be removable by draining. Some washing may be required to completely empty the tank.	Acknowledged. Sluicing the tank clean has been discussed with the subcontractors performing the work.
38	RRH	O	Page 3-30, first paragraph: Scale factor exponent of 0.25 and 0.33 are listed. As commented earlier, the range of exponents should be 0.18 to 0.33 and possibly a maximum of 0.39 as indicated by limited data.	Acknowledged. The initial work is consistent with previous work done by SRNL. There is concern that 0.2 may be too high a velocity to result in solids accumulation. The test plan builds in the flexibility to use a different velocity.
39	RRH	O	Page 3-30, paragraphs 2 and 4: Please describe clearly the methodology proposed for quantifying solids in the heel, with any evidence to support viability of the technique.	Added discussion of the concepts being developed and tested. The technique is being developed as part of this testing activity.
40	EKH	O	Page i, first paragraph, second sentence: "...and determine the capability of the tank	Deleted "Appropriately" to make the sentence match the DNFSB 2010-2

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			farm staging tank sampling systems to provide samples that will appropriately characterize the tank waste and determine compliance with the WAC." Not clear what this sentence means; the word "appropriately" is not definitive and would the results from this testing make changes to the WAC or will it show sampling being compliance to the WAC requirements? Are these tests to provide input in the development of the WAC requirements and/or tolerances?	Implementation Plan. This work, in conjunction with other work, will provide input an Initial Gap Analysis that will define the initial WAC, define the characteristics of the tank waste, define the capability of the TOC to characterize the tank waste and identify whether TOC can characterize samples in accordance with requirements and has waste that exceeds the requirements in the WAC. The WAC will be then be refined by the WTP based on LSIT testing.
41	EKH	O	Page i, second paragraph, third sentence: Are you only demonstrating or are you going to perform "tests" to quantify the full scale slurry transfer pump performance? This statement seems that you're only going to demonstrate. Figure 2-1 states otherwise. Clarify.	Proper terminology is "test" and the document has been updated to clarify the distinction between the "demonstration platforms" where the tests are performed. – Note that demonstration is a legacy term carried forward to maintain connection with earlier tests.
42	EKH	O	Page i: Should scaling relationships be captured prior to performing any additional tests using the scaled systems (paragraph 4)? Shouldn't this test be performed prior to the limits and solids accumulations tests so as to use the appropriate scaling parameter(s)?	Limits of Performance testing to identify the capability of the system will be performed consistent with recommendations from experts providing us guidance. Scaling up to full scale will not be done for Limits of Performance so the work can proceed refinement of the scaling velocity. However, because of this some additional testing is being conducted, a nozzle velocity evaluation is being performed to determine if different nozzle velocities influence the capability of the integrated system.
43	EKH	O	Page 1-1, last paragraph: See comment 40 above on the use of appropriately.	Same change as EKH #40.
44	EKH	E	Page 1-2, second paragraph, second to last sentence: This seems to indicate that this testing may input the WAC requirements, e.g., may change the requirements? Does this support how you would address comment 40?	See response to EKH #40.
45	EKH	E	Page 1-2, Section 1.2: State that ICD-19 is the WAC, if this is correct.	Currently, the waste feed criteria are defined in waste feed specifications, WTP permits, the WTP safety authorization basis and ICD-19 and are summarized in an Initial Data Quality

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				Objectives for WTP Feed Acceptance Criteria report.
46	EKH	O	Page 1-3, second burger dot: The word "fissile" starts in this paragraph and is then used for buildup, mixing, transfer and sampling throughout this document. Which of the particles defined in this task is considered the fissile particles?	Solids accumulation uses stainless steel with a median particle size of ~112 microns to represent fissile material.
47	EKH	E	Page 1-3, third paragraph: "…145,000 gallon batch has the same solids composition." Recommend using "...same solids chemical composition..." Does this assume that the supernate phase has little significance or that it will be removed in the WTP?	Changed to "…has the same solids chemical composition and physical attributes (e.g., mass loading) as the …"
48	EKH	O	Page 1-3, fourth paragraph, second sentence: This response does not have to be in the report. Question, how were the samples pulled to make the statement that "…equivalent mixing performance, from a solids distribution perspective…"? I'm assuming the sampling locations were geometrically similar as well to support this statement. I just don't have the time to look back into these documents.	Monitored specific gravity at multiple equivalently scaled heights and compared the data from each velocity test.
49	EKH	O	Page 1-3, fourth paragraph: (e.g., bottom clearing, mixing homogeneity, etc.) Was the homogeneity case for a Newtonian or non-Newtonian fluid? Homogeneity is very hard to achieve and an impossibility for a fast settling slurry with a Newtonian carrier fluid, especially for rotating jets. Please clarify where homogeneity was observed (e.g., fluid/particle condition).	Fluid was Newtonian. Homogeneous was incorrectly used. Text changed to "(e.g., bottom clearing, solids distribution, batch-to-batch consistency, etc.)"
50	EKH	O	Page 1-4, first paragraph: Not clear; did the full-scale sampling show that chemically, the undissolved solids (UDS) contents in the tank were "similar" to those of the UDS contents in the samples in the condition where WAC sampling is to take place? Was this shown to be the case?	Added discussion that initial results tended to be biased high for high density (>8 g/ml) particles with sizes >50 microns). System changes showed improved performance but additional testing was recommended to confirm that the configuration change is adequate for field conditions.
51	EKH	M	Section 1.3: Scaling philosophy must also include the discussion that the flow regime (turbulent for instance, Reynolds numbers) must be the same in all scales to allow for proper scaling. Calculations do not have to	Based on previous scaled testing of jet mixed tank performance, it is assumed that equivalent flow regimes are maintained across scales. As results are analyzed and performance anomalies

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			be performed in this document showing that such is the case given the various physical properties (density/rheology) listed in this document, but it should be stated that flow regime calculations to support scaling between scales. This can be a harder problem for non-Newtonian fluids or particles that are on the same order of magnitude as that of the jet nozzle.	identified between scales, the impact of potentially operating under different flow regimes will be considered. This consideration has been added into the scaled performance section.
51A	EKH	O	Section 1.3: No discussion about scaling of non-Newtonian slurries and/or their matrices. Add some discussion. I didn't state this clearly (and I didn't expect physical properties to be scaled, I haven't seen this in any of the WTP or ORP testing to date and it has its own challenges.). It seems that you're going to be using the same scaling exponent for the non-Newtonian case (vessel containing NN fluid) as that of the Newtonian case. I would not expect that the scaling exponents to be the same for both the NN and Newtonian cases. For example, there is a relationship between Bingham Plastic yield stress and ECR which is different for a fluid that has no yield stress and it's ECR. So, what I'm saying is that there is no discussion in this document saying how the scaling exponent for the N is acceptable for the NN, other than its used. Please provide why the same scaling exponents are used for both NN and N fluids and provide references why such is the case.	Basic discussion of simulant scaling has been added to describe that our simulants are not scaled. The program is beginning to look at NN slurries in the SSMD. At this point we have not done any testing to allow us to defend the validity of applying the same scaling relationship to N and NN slurries. We are just beginning to use NN slurries and will continue to include them in Scaled Performance testing. We acknowledge this comment by adding a test plan statement that we need to evaluate the appropriateness of applying the same scaling relationships to N and NN slurries. It is an interesting comment, I recognize that there would be a performance difference with NN slurries but had not considered that different scales might mix NN slurries differently.
52	EKH	O	Table 1-1: Transfer pump suction inlet for the 1:8 scale is 0.3125 inches. Is this correct? Either this number is wrong or the data in Table 1-2 for the 1:8 scale is incorrect. For an inlet velocity of 6.4 ft/sec and suction inlet diameter of 0.3125 inches, I get the following: D = 0.02604 ft, Suction Area = 0.000533 ft^2, Q = 0.003409 ft3/sec = 1.53GPM.	The tabulated values for the 1:8 scale were not presented in the units cited. The table has been corrected.
53	EKH	E	Page 1-6: Add "performance" after" equivalent mixing". I assume this is for having the same solids distributions between scales as described earlier in comment 48.	Clarified that equal mixing performance is in regards to the distribution of solids throughout the mixed volume.

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54	EKH	O	Page 1-8, pump rotation speed: 1) Why is constant per unit volume scale used? Should Equation 1-6 be used rather than P/V, using the metric of interest or just an unknown power for a given metric (though it may be different than the metric)? This would support the conclusion made on Page 1-9, top paragraph, that scaled rotation speed needs to be further evaluated. 2) The statement made about jet mixing in tank 18F at SRS clearly shows that the ECR decrease with increasing jet rotational velocity (I'm assuming this is for a fixed jet velocity), hence would the scaled tests be impacted by rotating at a fast speed if dead zones are of interest (or ECR determination)?	Scale relationship has been revised to reflect generic (i.e., Equation 1-6 in Rev0A) velocity relationship. Clearly there is a dynamic that has not been well studied between the benefit of the increased nozzle velocity and the detriment of the lower ECR. This will be a consideration for follow-on testing.
55	EKH	E	Page 1-9, second paragraph: What does "similar" mean? Within +/- ?%? Clarify.	Similar means equivalent within allowable tolerances. Previously a metric, such as SpG at equivalently scaled heights in both scaled tanks were compared so the sum of the squares of the density differences at each scaled height was a minimum.
56	EKH	E	Page 2-2, Section 2.1, second sentence: I thought that providing a "representative" sample for the WTP prequalification program was one of the most important mixing/sampling evolutions that need to be considered. Transfers to the WTP could be monitored, but the WAC depends on the samples used for the prequalification program. Should such wording be added?	The intro and background discuss the objectives of the program.
57	EKH	O	Page 2-2, last sentence: Who at SRNL is doing this work and whom at WTP is supporting this effort? After reading your statement on page 3-6 of the SRNL literature survey on irregular shaped particles, not sure you can make the conclusions your making based on the SRNL document. Such as "...creating a greater challenge to mix, transfer and sample." There are no statements made in the SRNL document that such is the case, other than settling of non-spherical particles are slower than spherical. If you have literature to support the other statements about the spherical particles in	This refers to SRNL-STI-2012-00062 which is recently released and can be cited. The authors are Koopman, Martino and Poirier. We recognize that spherical particles settle faster and therefore are more challenging to keep suspended in the tank. LOP testing will indicate whether large and dense spherical particles can be transferred with the expectation that larger non-spherical particles could also be transferred. We will not be able to make conclusions about the ability to

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			this report, please provide them.	transfer non-spherical particles based on observations that a similarly sized spherical particle was not transferred. The gap analysis will constrain the capability results to the context of what could be in the tanks.
58	EKH	E	Page 2-3, Section 2.1.1.2, first paragraph: Don't remember any bench scale discussion in this document. Is the bench scale the full scale pump tests? I'm assuming that the scaled and prototypic test tanks are the 1/21 and 1/8 scales. Clarify; this does not make sense.	Discussion is in 3.2.1.1.
59	EKH	O	Table 2-1 (and there could be others, such as Table 2-2…). I thought chemical composition, not PSD, was the most appropriate matrix for SSMD test platform. See Page 1-9. Please correct.	For limits of performance testing, the focus is finding the largest size of different density particles that can be transferred. Chemical composition of the large spikes is important only from the standpoint of understanding the size and density of the material transferred.
60	EKH	E	Page 2-5, top paragraph: Question: is the 1/8th and 1/21st scale mixer jet pump of similar design (e.g., concentric flow). If so, could particles get trapped or logged in the concentric section of the pump leading to the jet nozzles or is the flow tapered in this section such that there are areas where large particles cannot settle out? This is only a question, does not have to be addressed in the report.	Mixer is concentric and operates at very high flow velocities. Spike particle sizes have been selected to be smaller than the passages and additional steps are being taken to prevent the largest particles from entering the MJPs.
61	EKH	O	Page 2-6, Section 2.1.2.1: What is meant by "consistently" sampled? Pulling consistent samples does not mean that the sampler is a good sampler. It could be pulling a low or high quantity of large particles constantly, not what is in the process. You would have to do a lot of tests to determine if this consistent response is the same for various conditions.	RSD LOP is trying to determine the largest particle that can be sampled by the sampler without causing poor performance, as indicated by complete or partial plugging. Consistently means replication without plugging. Supplemental testing will investigate sampler performance.
62	EKH	O	Page 2-6, Section 2.1.2.1: Provide additional information on what you mean by "flow properties" that influence the sampler.	This is a hypothesis proposed in Section 11.3 of RSD Phase I test report (RPP-RPT-51796) that says that the lower inertia of the lightest particles may be allowing them to be diverted with the flow that goes around the Isolok sample plunger as it is inserted into the stream.

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				The heavier particles may have too much inertia to flow around the plunger and tend to be captured by the plunger. Additional testing is needed to confirm this hypothesis so it has been deleted from the text.
63	EKH	O	Table 2-2: Questions. Test Objective: Are different transfer velocities to be tested as well? Success Criteria: 1) Is there a time for how long the sampler stays open or the number of times it is cycled into the stream to pull the collected sample volumes? No sampling philosophy is provided in this section of the text. 2) What method is going to be used to separate the materials, since chemical seems to be out of the picture?	Added text. "The Isolok sampler will collect 500 ml samples in increments of 5.3 ml per sample plunger actuation. Collecting the sample takes approximately 40 minutes. Once the sample is collected, the collected volume will be sieved to separate the different sizes of spike particles. "
64	EKH	O	Page 2-9, Section 2.1.3.2, first paragraph: Define what you mean by "flow properties" in this case (these must be different from the sampler flow properties). There seems to be some important pump characteristics.	Changed to "flow capability and inlet velocity"
65	EKH	O	Table 2-3. Objective. Is varying flowrate an operating mode that needs to be considered? Success Criteria: How will the information of the ratio of what is captured to what is batch going to be used in assessing the technology?	It is expected that the largest, most dense particle will be transferred at the highest flow velocity; therefore only the highest flow velocity will be tested. The most important determination is a Yes/No on whether or not particles of a specified size and density can be transferred. The amount transferred will inform the reliability of the results, high recoveries, high confidence the particle can be transferred, low recoveries, low confidence the particle can be transferred.
66	EKH	O	Page 2-9, Section 2.1.3.2: Give the length of piping (horizontal) to be tested. Do you expect that the results in this test can be extrapolated to a pipe that over a few miles long? Or there is no intent to use this data for such activities?	Accepted. Horizontal pipe length is 20 feet. A technique (Ultrasonic PulseEcho system) for monitoring critical settling velocity is developed and tested and will be implanted in the waste feed delivery sampling flow loop. This test is interested in lengths that are characteristic of the waste feed delivery sampling flow loop.
67	EKH	E	Page 2-9, second paragraph: Statement is made that replicating particle movement around the pump inlet is desirable, but if so,	Because of similar comments, this sentence has been deleted.

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			how would it be measured and what would it be compared against? Such statements that have no means of comparison or validation are typically meaningless.	
68	EKH	O	Page 2-9, second paragraph: 1) Why is it important to pump 45 to 55 feet vertically? What would this buy you? 2) Details, is the 90 degree a long, short or custom build elbow? 3) Is the 20 feet adequate to obtain flow stability? Should sampling occur at two horizontal distances to show solids capture is consistent? 4) It states that the slurry upstream of the sample location in the horizontal section and in the tank will be analyzed. Is this to occur after each sampling sequence? 5) The line after the sampling location, if recycled, will it also be screened for large particles or will this line be designed such that large particles will not settle out?	1. Added "Simulant, including large diameter spike particles, will be mixed and pumped through a network of pipes that mimic the flow from the bottom of a DST to the location of the Ultrasonic PulseEcho system in the waste feed delivery characterization flow loop." 2. The design of the bend is not completed yet. 3. The criteria is based on recommendations for placement of the Ultrasonic PulseEcho system in the WFD certification flow loop. 4.Yes, solids in the horizontal section will be quantified after each test. 5. Initial design has flow passing through a screen to capture the spikes but allow the base material to pass though and drain back into the mixing tank.
69	EKH	O	Page 2-10, Section 2.2.1.1: How will subsequent batches be added to the DST? Provide some description. Seems that sampling of the mound and mound volume determination are to be developed? If so, state it. (OK I found this statement on Page 2-12 about sampling and analysis methods are to be developed.)	Subsequent batches are added to a DST by pumping the material through a drop leg at the top center of the tank or through a slurry distributor. Not all DSTs have a slurry distributor. Moved text up in the discussion.
69A	EKH	O	Page 2-10, Section 2.2.1.1: Will sampling be representative of the mound composition and could this sampling affect the test results due to it disturbing the mound contour?	Yes, sampling will change the mound. In the details section it has been added that the second mound will only be sampled after the last transfer is a campaign is performed so that it remains intact.

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69B	EKH	O	Table 2-4: Objective: Should rotational speed be considered? Success: 1) By sampling the mound, can you use this data to determine the quantity of very fast settling particles that have accumulated inside the MDT? Or by measuring what is transferred out of the DST a better means of determining what is left in the tank? I find it hard to subsample a mount (and where do you do it) and then making a conclusion based on that sample on mound composition. 2) What is it meant by "The relative quantities of solid in each transfer batch are estimated."?	1. For this development work, the rotational rate will not be considered. For more precise quantitative work performed later, the rotational rate may be considered if preceding work for SSMD Scaled Performance indicates it should be. The mass taken out will be measured and heel contents will be largely determined by mass balance. Heel samples will provide indications of where material is settling. 2. For Scouting Studies, the other solids will not be quantified with great precision, the heights of the settled solid layers in the receipt tanks will be measured, and a volume transferred will be determined by the height and geometric of the receipt tanks. However, it is known that, although the particles settle in distinct layers, perfect settling into layers does not happen so the volumes in each batch will be estimates that can be compared relative to one another.
70	EKH	O	Page 2-11, Section 2.2.1.2: 1) Will the mixer pumps be turned off at the same height in the MDT as that in the DST (scaled accordingly)? 2) Last sentence states the solids remaining in the MDT will be characterized. Do you mean subsampled and characterized?	1. Yes, batch volumes are scaled geometrically so that the waste heights after a full batch transfer will also be scaled. 2. Text has been deleted as it is was determined to be too much detail for this section and is repeated in more detail in Section 3.0, but characterized means heel volume is determined by measuring (different techniques are used during development), heel shape is described (or photographed) and the spatial distribution of very fast settling solids in the heel is described from heel subsampling and quantification.
71	EKH	O	Page 2-12, first paragraph: I would expect it to be easier to quantify the transferred material and that this testing could be used to determine if the sampling method(s) used to determine the mound composition are adequate in characterizing its composition.	This is a consistent approach with what is planned.
72	EKH	O	Table 2-5: 1) See comment 69B. 2) What	This testing will be informed by all

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			about rotational speed? Could solids accumulation also be a function of rotational speed?	previously conducted work, which may include conclusions on rotational velocity.
73	EKH	E	2.2.2 and 2.3: I will place more thought in this objective when I see their test plans. I expect changes will occur and that there should not be a lot of effort spent on these sections.	Acknowledged.
74	EKH	E	Page 3-2, first paragraph: Will the performance metrics be calculated using the physical properties of the actual Newtonian fluids used in this task as well? This may provide additional insight on the effect these physical properties have on these performance metrics.	Yes.
75	EKH	O	Page 3-3, first paragraph: I do not believe you will be calibrating the instrument (e.g., the rheometer). NIST oil standards are used to verify the operability of the instrument and either flow curves or single points are used to verify that the calculate viscosity is within +/- 10% of the NIST standard viscosity. Calibrations are much more complicated, where applied torque is measured and speed is verified independently.	Correct. Provided clarification that the instrument would be calibrated in accordance with NQA-1 requirements.
76	EKH	O	Table 3-2: 1) A 1.1 density sodium bromide solution will not provide a liquid viscosity of 8 cP. What also will be added. 2) Don't know how you're going to achieve high density/low viscosity using only glycerol. Please clarify.	Table entries pertaining to comments were reversed. Updated table with compositions determined in the lab.
77	EKH	E	Page 3-3, Section 3.1.2.1, second paragraph: This paragraph is not clear on its intent. Is $Na_2S_2O_3$ to be used in supernatant? Where does this typical supernatant properties come from (reference)?	Clarified that it pertains to Solids Accumulation and provided discussion of the selected values.
78	EKH	O	Page 3-4, first paragraph: 1) The low density and low viscosity fluid in this paragraph does not match up with that specified in Table 3-2. Which one is correct? 2) Note about calibration, see comment 75 above or the rheometer/viscometer.	1. 5 cP in text was incorrect, Table value is correct. 2. Made similar change as EKH #75.
79	EKH	O	Page 3-4, Section 3.1.3: What properties of the spiked particle will be measured and how? For instance, the typical method of	The spike particles listed are commercially available items that have an industrial purpose and are

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			using light scattering to determine PSD may be captured for the smallest particle listed on Table 3-3, but will be challenged on the others.	manufactured to size tolerances that exceed the tolerances necessary to distinguish the different sized spike particles by sieving. Qualification of the spike particles is limited to demonstrating that 99.9% of a one pound sample taken from each delivered lot is retained on the sieve used to separate that size from the other particles.
80	EKH	E	Page 3-4, Section 3.1.3, second paragraph: Given the 1/8 scale, how would these very large particles impact jet performance if these large particles are captured and transferred in the jet system? Has this been considered?	This is currently being evaluated and steps to prevent the particles from entering (a 3/16-inch wire mesh) the 1:8 scale mixer jets are being considered.
81	EKH	E	Page 3-6, first paragraph: This data is not consistent with Table 1-2 for the 1:8 scale transfer pump flowrate. Correct table or text.	Table 1-2 has been corrected and is now consistent.
82	EKH	O	Section 3.2.1.1: Are these same types of tests and simulants going to be used when testing the full scale pump? The zone of suction (ZOS) could be better quantified between scales.	Testing will be similar, LOP testing is using consistent simulants and spike particles. The zone of suction will not be measured directly during testing because of the impracticality of measurement in the chaotic mixing environment.
83	EKH	E	Page 3-7, first paragraph: What are the limits for tungsten? Testing was performed and there seemed to be some conclusion, but it was not stated.	The conclusion is that if slow moving large and dense particles (even 7200 micon W) get close enough to the pump (~0.3 inches), the pump can capture them and that fast (velocity was not measured) moving particles are not transferred at operational heights. Large and dense particles will be used in the 1:8-scale system.
84	EKH	O	Page 3-8, last paragraph: Show how you obtained these density values for the lower density supernatant. For instance, when I start with a 1.1 sg supernatant and blend solids resulting in 15 wt% UDS (200 g/liter) slurry, I can only achieve a density of 1.30, assuming I was not considering the volume of the solids themselves, hence a maximum density. The same goes for the 9 wt% UDS (125 g/l) for the low density supernate. The high density (1.37 sg) calc seems reasonable. I must have not stated this correctly.	The low density value is the density of the supernatant without the UDS, when the UDS are added to form a slurry, the slurry density ranges from 1.38 to 1.51 g/ml depending on which simulant characteristics are used in the calculation (UDS loading, UDS composition, liquid density). The calculations for the density and solid levels were corrected. It appears as though I failed to include the low density supernatant in my ranges as described in the text. Low Base / Low Density

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			Example: For a 1.1 sg supernate (continuous phase), containing 15 wt% UDS and using volume additivity ($\frac{1}{\rho_{slurry}} = \frac{f_{solids}}{\rho_{solids}} + \frac{1 - f_{solids}}{\rho_{supernate}}$), I can never reach the 1.37sg value stated in this document (nor can you reach the 200g UDS/L limit for this case). Show me the calc on how you obtained the density of the slurries given the constraints you provided.	Supernatant @ 15% = 180 g/l, slurry density = 1.2 g/ml, @ 9% the density is 1.16 g/ml. For all possible combinations the slurry density ranges between 1.16 and 1.51 g.ml.
85	EKH	O	Page 3-9, second paragraph: 1) Isn't sodium thiosulfate and sodium bromide used for density adjustments, not rheology? 2) For the low density/viscosity supernate, shouldn't the viscosity tolerance be +/- 0.1 cP rather than +/- 0.5 cP and for density it should be +/- 0.055 g/ml rather than 0.05 g/ml? 3) Provide tolerances for the higher density/viscosity supernate or provide table of tolerance for the supernate density and viscosity.	1. Sodium salts are used to adjust density. The viscosity of the solutions is then set by the composition needed to attain the density, both properties cannot be adjusted independently with a simple salt. Higher viscosity solutions will use mixtures with glycerol to attain the required viscosity. 2. When using a simple sodium salt to adjust the supernatant properties, density and viscosity cannot be specified independently, thus there is a wide tolerance on the viscosity because it will depend on the salt used to attain the density. I'll check text for 5% calculations to make them consistent. 3. Tolerances have been added.
86	EKH	O	Page 3-9, third paragraph: 1) Is there a limit on what the wt% of kaolin and/or kaolin/bentonite that can be used to provide the targeted yield stresses? There should at least be an upper limit not to exceed 15 wt%, since these are UDS, not soluble solids. Interesting, these are UDS and there is a limit on what can be transferred (thought I personnel think this is the incorrect why of processing sludges, since other physical properties are more limiting on transfer). 2) Last paragraph should state flow curve measurements rather than yield stress measurements. The Bingham yield stress is then obtained from the flow curve by regression of the data. Recommend that you report the Bingham yield stress, plastic viscosity, R^2, and range in which the data	1. Kaolin wt % range from 15 to 30 wt % depending on slurry properties. No upper limit is imposed. 2. The critical parameter is the yield stress. How the yield stress is calculated and reported will depend on the instrument that is being procured for testing. I will recommend to the operators that this information be captured if possible. This is a good point and one that will need to be considered in the gap analysis and WAC revisions. At 30 wt% kaolin for the 10 Pa slurry, solids loadings are 2-2.5x the 200 g/l action level, but we are also 10x over the 1 Pa action level for the yield stress. Although 30 wt%

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			was fitted. I recommend you clearly specify how the yield stress is calculated and measured. You will obtain different results using a vane method as compared to a flow curve method. Both are yield stresses, but both can have very different results.	solids may not represent a slurry that meets the WAC, it is included to test the expected relationship between yield stress and the capability to move particles. Added discussion about the rheometer being procured and measurement method to take rheological measurements.
87	EKH	E	Page 3-9, fourth paragraph: This sentence seems out of place?	Agreed. Moved to a more relevant location (3.1.1.1).
88	EKH	O	Page 3-9 to 3-10, fifth paragraph: 1) How is PSD and density going to be determined for the spike materials? 2) How with different density materials be separated if at least two different spike materials are used?	1. Added to discussion in 3.1.3 per Comment EKH #79. 2. Different sieves can be used to separate glass and metal spheres which are incremented according to mm and 1-16 inches, respectively. Otherwise, the two subcontractors are still evaluating most efficient methods that will be documented in their operating procedures.
89	EKH	O	Page 3-10, second paragraph: Is this paragraph stating that the spikes should be blended with the NN slurry prior to adding the slurry to the test vessel? Or are the spikes to be added to the test vessel containing the NN slurry? Not clear.	This is a detail level reserved for the operating procedure but discussions with the subcontractors encourage them to prepare and measure the slurry first and then add the spikes.
90	EKH	O	Page 3-10, third paragraph: 1) How is spike addition going to be added to the NN simulants? Is the wt% UDS of the NN simulant going to be used as the basis for adding the spike materials? Not clear on how you plan on handling the NN case. Are the spikes going to be added to the Kaolin before it is added to the test tank or blended after the kaolin has been added to the tank? Two very different conditions. 2) I haven't placed much thought in the two allocation methods, but not sure if it will work for the NN simulants. 3) The discussion on mass distribution is not clear. Maybe an example would help.	1. Changed text to "For tests including a non-Newtonian simulant, kaolin clay is spiked with the same particle types and masses used in comparable Newtonian tests." 2. Allocation method is based on the mass or size of the spikes that are added and is not dependent on the base. 3. Clarified with example. Current plans call to blend the spikes to a tank containing the slurry meeting the yield stress tolerance.
91	EKH	E/0	Page 3-11, second paragraph: 1) Second sentence makes no sense. 2) Is rotational speed going to be set or is it going to be a	1. Clarified. 2. Rotational speed will be set for a specified velocity in accordance with the

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			variable? It also states that a number of revolutions could be used, but does not specify the number.	scaling relationship. Number of revolutions specified based on previous operating experience to attain heel stability with other simulants.
92	EKH	E	Page 3-11, third paragraph: How do you plan on managing this for the NN simulant?	Sieving the discharge so that the spikes are collected but the base material passes though the sieve back into the tank. This has yet to be demonstrated though.
93	EKH	O	Page 3-12, second paragraph, last sentence: What does intermediate conditions mean? First time this term has come up.	There are only two conditions, high and low. This text has been deleted.
94	EKH	O	Page 3-12, third paragraph: Table 1-2 needs to be checked for suction flow rate. Do you expect cyclic behavior when testing the NN fluid? The last sentence does not make sense.	Table 1-2 suction flow rates have been corrected. Cyclical variations may not occur in NN slurries when the jet sweeps past the transfer pump inlet. Duration changed to sufficient to collect a representative sample, currently the plan is to screen the entire transfer volume.
96	EKH	O	Table 3-5: You've got supernate simulant properties for the non-Newtonian simulants. Please correct. Are the nozzle velocity scaling factor exponent correct for the NN fluids? See 51A for clarification to question.	Table has been corrected. Yes NN tests will be done at two nozzle velocities. See response to 51A.
96	EKH	E	Page 3-16, second paragraph: What is the maximum pressure?	Isolok is rated for pressures up to 275 psi.
97	EKH	E	Page 3-16, Section 3.2.2.2, second paragraph, last sentence: "The liquid phase shall be a supernatant simulant?" Is this for Newtonian slurries only? If so, state it.	Added.
98	EKH	E	Page 3-17, third paragraph: Not clear. Is only a 10 Pa Bingham plastic yield stress cohesive slurry going to be tested (why not a 3 Pa as described in SSMD limits of performance testing being used)? If 10 Pa, should there be a wt% limit on what can be used? See previous comments on the NN simulant.	Text clarified. 3Pa and 10 Pa will be tested.
99	EKH	O	Page 3-18, second paragraph: What is considered "acceptable performance"?	Moved statement to discussions on performance "Acceptable performance is defined as simulant spike recovery in the collected sample without plugging the sample needle. Indications of poor performance include low total volume recoveries (less than 475 ml) and a lack of spike material in the collected sample."

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100	EKH	**M**	Page 3-18, Section 3.2.2.3: Given a +/-5% of theoretical density value, what error could we see with wt% solids concentration and is this acceptable? For instance, a 1.45 g/ml would have a range of 1.378 to 1.523 g/ml range and this would incorporate a very large wt% solids range.	With the new simulant, the 5% level may not be attainable so this requirement has been removed until it can be demonstrated. Stability is defined as stable specific gravity as reported by the Coriolis meter. As long as the spike particles are in the transfer line, which will be measured by a full diversion line sample, having a well mixed mixing tank is not a requirement. All Isolok samples will be compared to full diversion samples which measure what is in the pipe at the sample location.
101	EKH	O	Table 3-7: Noted on few pages back that conventional agitation will be used. It may be very hard to adequately mix the dense and large particles shown on this table given the mixing system. Is the mixing system going to be re-designed to properly handle these larger particles to provide a well mixed tank, if that is the intent? Good luck.	Ideally the tank will be well mixed but as long as the spike particles are in the transfer line, which will be measured by a full diversion line sample, having a well mixed mixing tank is not a requirement. All Isolok samples will be compared to full diversion samples which measure what is in the pipe at the sample location.
102	EKH	O	Page 3-19, fourth paragraph: Acceptable performance is defined loosely. What is considered acceptable as compared to batched conditions?	Limits of performance is trying to determine what sized particles can be sampled without plugging the sample needle, thus acceptable performance for these tests is simply the ability to sample particles without plugging. More quantitative performance will be evaluated in System Performance tests to be performed in the future.
103	EKH	O	Page 3-20: Is line pressure going to be considered as one of the inputs into potential plugging issue or has this already been discredited? Discussions of increasing pressure were discussed earlier in the text.	Line pressure fluctuates minimally when the plunger is inserted into the pipe such that variations in pressure are even encountered under normal operations. How the system responds with a plugged needle will be tracked. The discussions for increasing the pressure were to test the system near its operating pressure limit, which is 275 psi, but the system is benchmarked to 600 psi.
104	EKH	E	Page 3-21, second paragraph: "…transfer line or inadequate mixing...", change or to and/or.	Accepted.

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105	EKH	E	Page 3-24, Section 3.2.3.3, first paragraph: When you say "…dense spike particles are suspended…", do you just off bottom suspension requirements only?	Yes. Off-bottom suspension of the spike particles is the metric.
106	EKH	O	Section 3.2.3.2: For the NN simulant, how is mixing defined when blending in the spike particles.	Mixing will have to be confirmed by visual observation. It will have to be proven that off-bottom suspension of the spike particles can be visually verified in the tank portals.
107	RKG	**M**	Page 1-1, last paragraph: When will the tank contents be sampled and tested so that their properties can be related to those of the simulants to be tested? When will we know what the "broader spectrum" looks like?	RPP-PLAN-51625 has comparisons of the simulant to characterized tank waste. However, the tanks that have been sampled and characterized only represent of small fraction of the tank waste. Furthermore, the feed to the WTP will be highly blended before it is staged for delivery. Therefore our simulants represent the best information we have and expect to have in the near term.
108	RKG	**M**	Page 1-7, paragraph 4: What is the standard error of the 0.39 exponent? How is "mixing performance" defined in this case?	Added discussion. The test compared tests done at nine velocities performed at two scales and picked the slowest velocities that had similar vertical distributions of slurry SpG. Well mixed was not a criterion.
109	RKG	E	Table 1-2: Residence Time implies a CSTR. I think you mean Internal Circulation Time.	Changed to turnover time.
110	RKG	O	Section 2.1: Are particles large **and** dense? I thought that the dense particles were small and the larger particles less dense.	We are using large particles with average particle density (~2.5 g/ml) and higher densities (>8 g/ml).
111	RKG	O	Section 2.1.1.1: I would like more clarity on density and particle size. Are you planning to fix the density and keep increasing particle size until the system fails?	Spike particles having a uniform size will be added to the tank. To evaluate size and density four different groups of uniformly sized particles will be included at two different densities. Sizes will be incremented by at least 1000 microns so that sieving can be used to separate the particles for quantification. The particles that are transferred by the transfer pump will be quantified. The capability of the system to transfer the different density particles will be based on the four sizes tested.
112	RKG	**M**	Section 2.1.1.2: How will the velocity in the 1/8 scale transfer line be scaled down?	Transfer line velocity is not scaled but set above a critical velocity value (<4.0 ft/s) to prevent deposition of particles

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				between the transfer suction nozzle and the batch receipt tank..
113	RKG	**M**	Page 2-5: Data to determine the scaling of the 1/8 and 1/21 scale transfer lines should collected with particles which will not create blockages. There are literature references on transfer line design which can be used to relate particle properties to velocity.	Scaled Performance testing will use particles smaller than 700 microns, it is only LOP testing in the 1:8 scale tank that is using the large spike particles.
114	RKG	**M**	Section 2.1.2.1: What is the largest particle that we expect to remove from the tanks? How does this compare to the 3.4 mm sampling limit on the Isolock?	Information on what sized particles are in the tanks is still being collected. Hanford waste is not fully characterized. Therefore, LOP testing is being performed without limits to the particle size that does not impose a size constraint beyond the physical limits imposed by the equipment. LOP testing would be constrained to the limits if they were known, but because the sizes are not known with great certainty, there is no defendable constraint on particle size. Full-scale pump testing will provide an indication of what can be transferred.
115	RKG	**M**	Section 2.1.3.2: Is there a contingency plan should a customized pump not be feasible?	A commercially available pump has been identified.
116	RKG	O	Figure 2.3: What is the design basis for the mixing tank and agitator? What basic data have been given to the vendor?	The vendor is being consulted on the capability of the mixer to suspend the spike particles (1/4-inch WC). The tests will not be allowed to proceed until the agitator is determined to be adequate. This is a project management control.
117	RKG	O	Page 2-12: Won't the fastest settling particles (most difficult to suspend) leave the vessel first? Unless they cannot be fluidized in the outlet pipe? The particles left behind will be the easiest to suspend that follow the flow patterns?	Historical testing shows that the earliest samples do have a higher fraction of faster settling particles but also that, because of the rotating nature of the mixing the heaviest particles are also swept up by the jets but settle in the area that is furthest away from the jets and the pump. The tank is operated to achieve solids distribution, not bottom clearing so piles are left behind.
118	RKG	**M**	Table 2-6: Are two scales sufficient to develop a scaling rule with confidence?	Two scales were determined to be sufficient by the mixing experts consulted by the program. Results analysis will identify uncertainties and potential need for data from additional scales.

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119	RKG	O	Table 3-1: How do the simulant characteristics compare with those proposed for WTP? Where they are different, why?	This is addressed in Section 4.0 of RPP-PLAN-51625. One example is that LOP simulants are different because tank farms is exploring the capability of the system to transfer large and dense particles without size constraints. It is not appropriate for WTP to test with these simulants because tank farms may not be able to transfer them if they are in the waste or tank farms may show that there is very low probability of these particles being in the waste or have little risk to the WTP (e.g., inert material). In addition, the WTP has not begun an evaluation of simulants for tests using received waste but it is planned that the simulants for these activities will converge.
120	RKG	**M**	Section 3.1.3: If the waste characteristics are described in Table 3-1, why are you considering spiking with a particle of 7 mm? This cannot be detected in the IsoLock.	Because most of the tank waste has not been characterized there is no defendable basis for constraining sizes. Work is being done to develop a basis but it is not completed. LOP testing will determine whether large and dense particles could be transferred and sampled IF they are present in the tank waste.
121	RKG	**M**	Table 3-3: What is the minimum transport velocity for these particles in the 3 inch transfer line? Add two more columns to this table with Archimedes number and the velocity.	Added.
122	RKG	**M**	Table 3-4: See comment 121 above applied to SSMD.	Added.
123	RKG	**M**	Page 3-10, paragraph 3: The Yield Stress should also be measured after the experiment to determine if the work of the mixers and pumps has changed the rheology.	Added.
124	RKG	O	Page 3-12, paragraph 2: Why 10 turnovers? Has this been fixed or still open to discussion?	Text changed to 20 mixer jet rotations, which has historically been the point where operators see stabilization of the heel mounds.
125	RKG	O	Table 3-6: What values of velocity do the two scaling factors represent?	Added to Table 1-2. a=1/3 is 30 ft/s, a = 1/5 is 39.4 ft/s.
126	RKG	O	Section 3.2.2.1: Based on the simulant characteristics what are their minimum transport velocities in the 3 inch pipe?	Critical settling velocities for the base material are below 4 ft/s.

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127	RKG	**M**	Section 3.2.2.2: How and where will be kaolin / clay slurry be prepared?	Kaolin slurry will be prepared in the mixing tank. Preparation is an operating detail but usually SSMD operators added solids to water while agitating. Others have added water to solids.
128	RKG	E	Page 3-18: Is the "(larger the individual spikes)" correct?	Corrected "…, which is larger than the individual spikes,…"
129	RKG	O	Table 3-7 and Section 3.2.3.2: According to my calculations, the WC particles will not be transported in a 3 inch diameter pipe at 140 GPM flow rate. This seems unrealistic compared to Table 3-1.	Having particles that fail to be transferred is part of defining the capability of the system as both successes and failures are needed to define the capability.
130	RKG	O	Page 3-20, paragraph 2: Have you demonstrated time dependency of the kaolin slurries? What is the source of this behavior?	Kaolin slurries are slightly rheopectic so they may thicken as they are mixed.
131	RKG	O	Page 3-22, paragraph 2: Will you be able to demonstrate how many samples need to be taken to obtain a representative measure of the waste's true composition?	All spike solids that are discharged from the system (either during operations or when flushing the lines) will be collected in a basket screen.
132	RKG	**M**	Page 3-23, paragraph 1: Have you determined what size the agitator will need to be if it can suspend 3/8 inch tungsten particles? Is the agitator required to just suspend the particles or distribute them uniformly throughout the liquid? What size do you anticipate this vessel will be?	Design has been changed to ¼-inch WC. The design for off-bottom suspension is in development to procure an adequate mixer. Currently expect an 8-foot diameter tank capable of holding 700 gallons of slurry.
133	RKG	O	Table 3-10: Could we include two other velocities; one above and one below these values?	The values are initial starting points and held for 10 empty and fills. This is development work that must be completed to perform more quantitative analyses. More quantitative analysis will be performed at two scales later in the year but only two velocities are targeted for the tests. If the initial work shows that accumulation ceases after only several fills, there may be additional testing capacity to test additional velocities. This later work will be done after the scaled testing work so more information will be known for those tests.
134	RVC	O	Page 1-4: To what extent are the scale-up relations well established and confirmed?	The scale up relationship for sampling and batch transfer performance of mixed double shell tanks are not established. One purpose of this testing is to collect

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LSIMS ERT DOCUMENT REVIEW RECORD		
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				performance data at two scales in order to develop scale-up relationships that will allow estimation of full-scale performance.
135	RVC	O	Pages 1-5 and 1-6, Table 1-1: Fill volume - 1,100,00?-typo? Define reference angle for mixer jet pump location. What is the Reynolds number in the transfer lines?	The operating capacity of AW-105 is 1,144,000 gallons. Reference angle is footnote 2 of Table 1-1. At 140 gpm in a 3-inch diameter Sch 40 pipe, a 1.37 g/ml slurry with a viscosity of 15 cP has a Re of ~13500 and stays turbulent at the lower end of 90 gpm.
136	RVC	O	Table 1-1 General: To avoid confusion, exactly which tests will be performed at each scale should be clearly stated/discussed in the accompanying text.	Acknowledged. Text changd to make sure this is described in the Scope of each test. SSMD LOP is performed at 1:8 scale because the LOP particles are too large for the 1:21 scale transfer lines. SRNL only has a 1:22-scale tank so Solids Accumulation Scouting Studies are performed at 1:22 scale. All other SSMD testing is done at both 1:8 and 1:21 scales.
137	RVC	O	Page 1-6: Is Power per volume sacred; that is, is it validated at large scales?	The experts consulted for our mixing program recommend power-per-unit volume as a starting point for evaluating scaling relationships.
138	RVC	O	Page 1-6, Eq. 1-1: Is this completely true; that is, are there no friction losses across the nozzle contributing to the pressure drop?	This is not a precise calculation that accounts for all factors but is used as an estimate to define a starting point from which to begin operating the tanks and collecting test data.
139	RVC	O	Page 1-7: Be careful – the waste simulant slurry volume may not be the proper volume for P/V scaling. Most of the energy is dissipated close to the vessel bottom, so ability to suspend, etc. is less than proportional to fill height. Eq. 1-2 would only be valid for vessels that are geometrically similar in all respects.	Acknowledged. With respect to mixing, the tanks are geometrically similar.
140	RVC	O	Page 1-7: Eqs. 1-4 and 1-5 are redundant.	Acknowledged. The derivation has been moved to an appendix and the important equations have been retained in the main text.
141	RVC	O	Page 1-7: A scaling exponent of 0.39 is closer to n = 1/5 than n = 1/3. Which is it? If 0.30 is about 1/3 than 59 ft/s is about 60 ft/s. Should be ft/s – not ft/sec.	The experts consulted for our mixing program recommend 1/3 and 1/5 as a starting point for evaluating scaling relationships and these will be during

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				scaled performance testing.
142	RVC	O	Page 1-8, Eq. 1-6: Please explain more clearly. How can **a** be < 0.39 for the integrated system? Why is the value of **a** not controlled by the limiting (most demanding) operation?	Added detail, the test conditions for the experiment and the metric for the 0.39 scale factor were not clearly communicated. Lower values will result in better solids distribution in the tank. The value of a will be controlled by a limiting step.
143	RVC	O	Page 1-8, Eqs. 1-10 and 11: Will the scaling criteria for jet pump rotation rate be confirmed. Why isn't ω a testing variable? What proof do you have that it does not need to be parameterized?	Based on extensive review comments on the topic, the rotational rate scaling will be evaluated during SSMD Scaled Performance testing.
144	RVC	O	Pages 1-7 and 1-8: There are more equations than are needed, making it difficult to appreciate the most important ideas.	The derivation has been moved to an appendix and the important equations have been retained in the main text.
145	RVC	O	Page 1-9, Table 1-2: It would be useful to report U_{jet}.	Agreed. The detail has been added.
146	RVC	O	Page 1-9: Do you mean chemical composition or particle concentration? There is no explanation of why chemical composition is the most appropriate metric.	The text was determined to be too much detail for the section discussing it and has been deleted.
147	RVC	O	Pages 2-1 and 2-2: Why do you say on page 2-1 that scaled/system performance is one of the 3 major testing areas and then say on page 2-2 that it will not be considered in this test plan? Figure 2-1 implies that there will be 3 separate test plans.	A separate and future test plan will be prepared for Scaled/System testing.
148	RVC	O	Page 2-2: I would be interested to know how SNRL will put the particle shape issue to bed. This also arises at WTP. Why are you confident that shape will not be an issue? Are there data to substantiate this?	The SRNL report states that for Limits of Performance spherical particles shall be considered when challenging particles are desired and recommends the use of both spherical and irregularly shaped particles. We use both in our testing and will use mostly spherical particles for spikes, but some irregular shaped WC will be used.
149	RVC	O	Page 2-5: You state that the 1:21 scale is too small to use with the largest particles. It is implied that the 1/2 inch line at 1:8 scale is of sufficient diameter to capture the largest particles in a representative fashion. Can you justify this?	Plugging maybe an issue and we may need to reevaluate of spike selection. Preliminary testing showed that, under controlled conditions, the large particles could move though the inlet and tubing. We are also conducting full scale experiments to understand real particle size limitations.
150	RVC	O	Section 2.1.2.1, Page 2-6: States that	The collected samples are compared to

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			sampling needle diameter determines limiting particle. How does ability of the transfer pipe inlet to capture a representative sample compare?	full diversion samples that are withdrawn from the pipe near the sample location. If the large particles are in the full diversion sample, then the mixing in the tank and pump capability are adequate to get the particles to the Isolok. The ability of the pump to capture particles is not relevant to Isolok performance because the sample is trying to quantify what is transferred and thus is must be captured by the pump to be sampled in the flow loop.
151	RVC	O	Section 2.1.3.2, Page 2-9: What evidence is there that the commercially available pump will mimic actual pump performance? How does the described test procedure ensure this?	The commercially available pump mimics the flow rate and capture velocity of the proposed WFD delivery transfer pump, as such the hydraulics around the pump inlet are being replicated to the extent practicable. Test requirements specify the flow rate and inlet geometry. This approach is necessary to collect initial performance data prior to completion of final pump design and procurement.
152	RVC	O	Section 2.2.1.1, Page 2-10: How can scalable transfer and refill operations be performed at 1:22 scale if the largest particles are only slightly smaller than the inlet pipe diameter?	Solids Accumulation does not use the large spike particles describe for LOP testing, the largest particles are several hundred microns.
153	RVC	O	Table 2-4, Page 2-11: Why 2 jet velocities as opposed to 1, 3, 4, etc.?	This is driven by economics and schedule to complete the work so that it can inform follow-on work to be performed later in the year.
154	RVC	O	Section 2.3.1.1, Page 2-16 and Table 2-6: You never state the specific objectives of the scaled performance tests, but you state that they are subject to change. Why now do 100 μm particles represent the hard to transfer fraction to WTP?	Because there is uncertainty with what is in the waste, LOP testing will determine if a particle or a certain size and density can be transferred to the WTP, other work being performed (specifically DNFSB 2010-2 Commitment 5.5.3.2) will provide information on what is in the waste, including uncertainties. All this feeds the Initial Gap Analysis that is being prepared to guide the program testing needs. Solids Accumulation particles are based on what is already known about the waste.
155	RVC	O	Section 2.3.1.2, Page 2-17: It is now stated	Rotational rate will be set by the scaling

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			that rotational speed may be varied. In Section 1, it is said that results are not sensitive to ω. Which is it?	relationship in Section 1.3 and Scaled Performance testing will evaluate the relationship.
156	RVC	O	Section 2, General: Detailed test procedures are described in words, but very little quantitative information is given. As a result, it is difficult to assess if these procedures can realistically accomplish the test goals.	Additional details and quantitative info has been added to Section 3.0.
157	RVC	O	Section 2, General: The discussions are often repetitive. Points could be made more efficiently by drawing from (or referring to) previous material, rather than repeating it in its entirety.	Acknowledged. The test plan is written for a broad audience, including the subcontractors performing the work who tend to only read the text that is applicable to them.
158	RVC	O	Section 3, General: Since Section 2 it somewhat more balanced, it really does not hit home until here that Solids Accumulation & Scaled Performance are mostly discussed in future reports. However, selected topics are presented here. This seems somewhat arbitrary (like this report contains what we are prepared to talk about and we will put the rest in future reports) rather than strategic. Rationale and justification for this approach should be given in the Introduction.	This is addressed in the last paragraph of Section 1.1.
159	RVC	O	Section 3.1: Can you say more about the non-Newtonian simulant or provide a reference with some of the details? In Table 3-1, what is meant by the median size? Is this d_{50} by volume? Can you provide a measure of the distribution? Can you say more about how you will distinguish and measure spiked particles?	More discussion on the non-Newtonian simulant has been added. Median size is d50 by volume as described, along with PSDs in RPP-PLAN-51625. Additional information on spike quantification has been added.
160	RVC	O	Page 3-5, last sentence: The words "*economically favorable conditions*" are not an appropriate euphemism to describe crude preliminary experiments.	The text has been changed.
161	RVC	O	Section 3.2.1: I do not see how the Coriolis meter can discriminate spiked particles. It is a mass flow meter. How can it detect a few spiked particles passing through? How do you relate its reading to what you find later in the separated spiked particle analysis?	The Coriolis meter is used to monitor slurry mass flow and specific gravity, stabilized readings of specific gravity suggest that transient conditions experienced during startup have stabilized. The Coriolis meter is not used to quantify results.
162	RVC	O	Section 3, General: The general comments made above about Section 2 also apply here.	The level of detail has been expanded in Section 3.

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RPP-PLAN-52005
One System Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan

DRAFT

RPP-PLAN-52005
Rev. 0B

Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan

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Abstract: This plan addresses the technical approach and test requirements for the Small-Scale Mixing Demonstration Limits of Performance, Remote Sampler Demonstration Limits of Performance, Full-Scale Transfer Pump Limits of Performance and Solids Accumulation Scouting Studies being performed under the Mixing and Sampling Program to support waste feed delivery to the Hanford Waste Treatment and Immobilization Plant. The program will include activities to determine the range of waste physical properties that can be retrieved and transferred based on testing and analysis and determine the capability of the tank farm staging tank sampling and transfer systems to obtain samples that can be characterized to assess the bounding physical properties important for the Waste Acceptance Criteria based on testing and analysis.

Release Approval

Date

Release Stamp

DRAFT

RPP-PLAN-52005
Rev. 0B

WASTE FEED DELIVERY MIXING AND SAMPLING PROGRAM LIMITS OF PERFORMANCE AND SOLIDS ACCUMULATION SCOUTING STUDIES TEST PLAN

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EXECUTIVE SUMMARY

The primary purpose of the Tank Operations Contractor Mixing and Sampling Program is to mitigate the technical risks associated with the ability of the tank farms feed delivery systems to adequately mix and sample High Level Waste feed in order to meet the Hanford Waste Treatment and Immobilization Plant Waste Acceptance Criteria. The Tank Operations Contractor will conduct tests to determine the range of waste physical properties that can be retrieved and transferred to Hanford Waste Treatment and Immobilization Plant and determine the capability of tank farm staging tank sampling systems to provide samples that will characterize the tank waste to determine compliance with the Waste Acceptance Criteria. The tests being conducted to define the capabilities of the mixing, sampling, and transfer system are focused on three areas: Limits of Performance, Solids Accumulation and Scaled Performance.

Limits of performance testing will be conducted to determine the range of waste physical properties that can be mixed, sampled, and transported under varying modes of operation. These tests will use both the Remote Sampler Demonstration platform and the Small Scale Mixing Demonstration platform. In addition, a test using a full-scale slurry transfer pump will be performed. Testing will evaluate the capabilities of the systems to mix, sample, and transfer large and dense particulate solids in simulant slurries that are characteristic of Hanford tank waste. With the exception of the full-scale transfer pump testing, Limits of Performance testing will utilize the Small Scale Mixing Demonstration and Remote Sampler Demonstration test platforms used in previous Waste Feed Delivery Mixing and Sampling Program test activities; however, the operating conditions and simulants tested will be expanded to allow evaluation of each system's capabilities.

Solids accumulation scaled testing will be conducted to understand the behavior of remaining solids in a double-shell tank during multiple fill, mix, and transfer operations that are typical of the feed delivery mission. Testing will evaluate the propensity of the mixing and transfer system to accumulate fast settling particulate solids in simulant slurries that are characteristic of Hanford tank waste by simulating the multiple fill and transfer operations that is planned for a feed staging tank. Solids accumulation testing will utilize the Savannah River National Labs Mixing Demonstration Tank to develop appropriate test methods that will be executed at both scales in the Small Scale Mixing Demonstration test platform.

Scaled performance testing will be conducted to demonstrate mixing, sampling, and transfer performance using a realistic simulant representing a broad spectrum of Hanford waste. These tests will use both the Small Scale Mixing Demonstration and Remote Sampler Demonstration test platforms used in previous Waste Feed Delivery Mixing and Sampling Program test activities; however, the operating conditions and simulants tested will be expanded to collect additional performance data. Small Scale Mixing Demonstration data will be collected to increase the confidence in the scale up relationship for mixing, sampling and transfer. Remote Sampler Demonstration test data will be collected and analyzed to provide additional confidence in the systems capabilities to sample a wider range of Hanford waste characteristics.

This test plan is one of multiple test plan documents that will be prepared to address DNFSB 2010-2 Sub-Recommendation 5 Commitment 5.5.3.6, "Test Plan to establish Tank Farm performance capability", and addresses the technical approach and test requirements for the Limits of Performance test activities and developmental Solids Accumulation testing being performed to support waste feed delivery. For each test activity covered in this test plan, the test objectives along with success criteria are identified. The necessary equipment to conduct the tests and collect the necessary data is identified and described. The simulants that are appropriate for testing are identified and qualified in accordance with the recommendations in RPP-PLAN-51625, *Waste Feed Delivery Mixing and Sampling Program Simulant Definition for Tank Farm Performance Testing*. Different simulants are proposed for the different tests to explore the capabilities of the individual systems. Because the test objectives for all Limits of Performance activities are similar, the test matrices evaluate similar test conditions (e.g., base simulant components, spike components, supernatant properties, and mass loadings). The most important properties that have been identified for Limits of Performance work include variations to: Mixer Jet Nozzle Velocity (Small Scale Mixing Demonstration only), Newtonian slurry solids simulant composition, spike particle characteristics (size and density), supernatant density and viscosity, Newtonian solid simulant mass loading, spike particle mass loading, and the yield strength of a non-Newtonian slurry simulant.

This test plan also identifies and describes supplemental testing activities that will be performed to address the technical risks associated with the Waste Feed Delivery Mixing and Sampling Program. The testing requirements and test plan for the supplemental work will be prepared separately so that the test activities can be informed by the results of the test activities described in this test plan.

CONTENTS

FIGURES

TABLES

TERMS

Abbreviations and Acronyms

ASME	American Society of Mechanical Engineers
BNI	Bechtel National, Inc.
CEES	Columbia Energy and Environmental Services, Inc
DOE	U.S. Department of Energy
DNFSB	Defense Nuclear Facilities Safety Board
DST	double-shell tank
DQO	data quality objective
FBRM	Focus Beam Reflectance Measurement
HLW	high-level waste
ICD	Interface Control Document
LSIT	Large-Scale Integrated Testing
MDT	SRNL mixing demonstration tank
ORP	Office of River Protection
RPP	River Protection Project
RSD	Remote Sampler Demonstration
SRNL	Savannah River National Laboratory
SSMD	Small-Scale Mixing Demonstration
TOC	Tank Operations Contract
WC	Tungsten carbide grit
WAC	waste acceptance criteria
WFD	Waste Feed Delivery
WRPS	Washington River Protection Solutions, LLC
WTP	Hanford Waste Treatment and Immobilization Plant

Units

cP	centipoise
ft	feet
in	inch
gpm	gallons per minute
Pa	Pascal
s	second

1.0 INTRODUCTION

1.1 INTRODUCTION

The primary purpose of the Tank Operations Contractor (TOC) Waste Feed Delivery (WFD) Mixing and Sampling Program is to mitigate the technical risks associated with the ability of the tank farms feed delivery systems to adequately mix and sample High Level Waste (HLW) feed in order to meet the Hanford Waste Treatment and Immobilization Plant (WTP) Waste Acceptance Criteria (WAC). The TOC has identified two critical risks TOC-12-64 and TOC-12-65 per the TFC-PLN-39 (Risk Management Plan, Rev. G) which address sampling method and emerging WAC requirements. In addition, in November 2011, U.S. Department of Energy (DOE) issued the Implementation Plan for the Defense Nuclear Facility Safety Board Recommendation (DNFSB) 2010-2 (DOE Rec. 2010-2, Rev. 0, *Implementation Plan for Defense Nuclear Safety Board Recommendation 2010-2*) which addresses safety concerns associated with the ability of the WTP to mix, sample, and transfer fast settling particles.

Report RPP-PLAN-41807, *Waste Feed Delivery Mixing and Sampling Program Plan and Test Requirements* defines the three test requirements for continued WFD Mixing and Sampling Program testing as follows:

- Limits of performance - determine the range of waste physical properties that can be mixed, sampled, and transported under varying modes of operation. These tests will use both the Remote Sampler Demonstration (RSD) platform and the Small Scale Mixing Demonstration (SSMD) platform. In addition, a test using a full-scale slurry transfer pump will be performed.
- Solids accumulation - perform scaled testing to understand the accumulation and distribution of remaining solids in a double-shell tank (DST) during multiple fill, mix, and transfer operations that are typical of the HLW feed delivery mission. These tests include activities at the Savannah River National Laboratory (SRNL) Mixing Demonstration Tank (MDT) and the SSMD platform.
- Scaled/system performance - demonstrate mixing, sampling, and transfer performance using a realistic simulant representing a broad spectrum of Hanford waste to meet WTP waste acceptance criteria Data Quality Objectives (DQO) sampling confidence requirements. These tests will use both the SSMD and the RSD platforms. The RSD platform is full scale; therefore, RSD system performance testing activities will collect additional system performance data at full scale.

This represents a broadening of objectives from earlier SSMD and RSD testing. The simulants and operating conditions in this earlier testing were intended to simulate the particle size and density distribution and operating configuration of Hanford DST 241-AY-102, the first tank waste to be delivered to WTP. Simulants and operating conditions will now need to be developed to represent the complete range of physical properties for the broader spectrum of Hanford waste tanks, and to address specific testing requirements summarized above.

The TOC will conduct tests to determine the range of waste physical properties that can be retrieved and transferred to WTP and determine the capability of tank farm staging tank sampling systems to provide samples that will characterize the tank waste to determine compliance with the WAC. These tests will reduce the technical risk associated with the overall mixing, sampling, and transferring of HLW feed to WTP so that all WAC requirements are met.

This test plan is one of multiple test plan documents that will be prepared to address DNFSB 2010-2 Sub-Recommendation Commitment 5.5.3.6, "Test Plan to establish Tank Farm performance capability", and addresses the technical approach and test requirements for the SSMD Limits of Performance, RSD Limits of Performance, Full-Scale Transfer Pump Limits of Performance and SSMD Solids Accumulation Scouting Studies being performed to support waste feed delivery to the Hanford WTP. This test plan also identifies and describes supplemental testing activities that will be performed to address the technical risks associated with the WFD Mixing and Sampling Program. The testing requirements and test plan for the supplemental work will be prepared separately so that the test activities can be informed by the results of the test activities described in this test plan. Also, additional information will be generated as part of parallel work that may result in further refinements to the test requirements. This parallel work includes Commitment 5.5.3.2, which estimates, based on current information, the range of waste physical properties that can be transferred to WTP and Commitments 5.7.3.1 and 5.7.3.4 which identify potential new WAC requirements based on preliminary documented safety analyses coupled with projections of potential WAC requirements based on recent assessments. Decisions on how to adjust test requirements based on these evolving requirements will be made and documented in updates to the issued test plans.

1.2 BACKGROUND

The Office of River Protection (ORP) has defined the interface between the two prime River Protection Project (RPP) contractors, Bechtel National, Inc. (BNI) and Washington River Protection Solutions (WRPS), in a series of interface control documents (ICDs). The primary waste interface document is 24590-WTP-ICD-MG-01-019, *ICD-19-Interface Control Document for Waste Feed* (ICD-19). Iterative updates to ICD-19 are anticipated as new information is generated. ICD-19 identifies a significant incompatibility between the TOC baseline equipment configuration and capabilities and the WTP baseline design and regulatory assumptions requirements for tank WFD to WTP. Section 2.3 states that the TOC baseline sampling plans and capabilities are not currently compatible with WTP sample and analysis requirements as described in *Integrated Sampling and Analysis Requirements Document (ISARD)* (24590-WTP-PL-PR-04-0001), the *Initial Data Quality Objectives for WTP Feed Acceptance Criteria* (24590-WTP-RPT-MGT-11-014), and the *Regulatory Data Quality Optimization Report* (24590-WTP-RPT-MGT-04-001).

The original objective of the WFD Mixing and Sampling Program was to mitigate the technical risks associated with the ability of the tank farms WFD systems to mix and sample HLW feed adequately to meet the WTP waste acceptance criteria. These risks address emerging waste acceptance criteria and sampling method requirements. The focus of the original testing was to model the particle size and density distribution of DST 241-AY-102; future testing will expand the range of waste physical properties considered in testing. Historically, testing performed by WTP used simulants consistent with the WTP design basis and is further discussed in Appendix A of RPP-PLAN-51625, *Waste Feed Delivery Mixing and Sampling Program Simulant Definition for Tank Farm Performance Testing.*

In November 2011, the DOE issued the Implementation Plan for the DNFSB 2010-2, DOE Rec. 2010-2, Rev. 0, *Implementation Plan for Defense Nuclear Safety Board Recommendation 2010-2*, which addresses safety concerns associated with the ability of the WTP to mix, sample, and transfer fast settling particles.

To ensure tank farms and WTP mixing and sampling systems are integrated and compatible (i.e., execution of the One System approach) and the uncertainties identified by testing to date are addressed, the WFD Mixing and Sampling Program has been expanded to include the following:

- Define DST mixing, sampling, and transfer system limits of performance with respect to the ability to transfer waste to the WTP with varying physical properties, solid particulates sizes and densities, and under various modes of operation (i.e., defining the expected range of particle size and density and consideration of data uncertainty).
- Define propensity of solid particulates to build up, and the potential for concentration of fissile material over time in DSTs during the multiple fill, mix, and transfer operations expected to occur over the life of the mission.
- Define ability of DST sampling system to collect representative slurry samples and in-line critical velocity measurements from a fully mixed waste feed staging tank.
- Develop sufficient data and methodology to predict confidently full-scale DST mixing, sampling, and transfer system performance; such that a gap analysis against WTP feed receipt system performance can be adequately completed.

The WTP dynamic processing analysis and batch processing planning currently assumes each staged HLW feed tank is mixed and delivered in consistent feed delivery batches of up to 145,000 gallons (ICD-19). Consistent, as used here is intended to mean that the first 145,000 gallon batch has the same solids chemical composition and physical attributes (e.g., mass loading) as the last 145,000 gallon batch. Small scale testing completed to date (RPP-50557, *Tank Waste Mixing and Sampling Update* , Rev. 0B) concludes that the first feed tank (241-AY-102) can likely be adequately mixed and sampled using DST mixing systems, but that additional uncertainties related to data uncertainty, optimizing system performance, applicability to all feed tanks, and understanding emerging WTP solids handling risks still need to be addressed.

The WFD Mixing and Sampling Program has focused on the first HLW planned for transfer to WTP, (241-AY-102) and now will apply knowledge gained to the remaining planned feed delivery DSTs. Initial SSMD project results documented in RPP-47557, *SSMD Test Platform – Small Scale Mixing Demonstration Initial Results Report*, RPP-49740, *SSMD Test Platform – Small Scale Mixing Demonstration Sampling & Batch Transfers Results Report,* and RPP-RPT-48233, *Independent Analysis of Small Scale Mixing Demonstration Test*, have demonstrated that equivalent mixing performance, from a solids distribution perspective, can be achieved at approximately 1:21-scale (43.2-inch diameter) and 1:8-scale (120-inch diameter). The scaling factors derived for equivalent performance for varying nozzle velocities ranged from 0.18 to 0.33, and varied for different performance objectives (e.g., bottom clearing, solids distribution, batch-to-batch consistency, etc.). These results provide a foundation for beginning to explore other performance parameters which were investigated in the sampling and batch transfer phase. Using a simulant that is characteristic of the first HLW feed that will be delivered to the WTP, the sampling and batch transfer testing results have indicated the feasibility of mixing the tanks adequately to provide a representative sample to the transfer system. The results indicated that more difficult and fastest settling particles can be delivered to the transfer system.

Initial RSD project results conducted using a full-scale sampling system determined that the tank waste could be sampled from the transfer piping, but that additional testing was needed to optimize the configuration to improve the performance of the system, which when oriented horizontally tended to collect samples that were biased high (measured more than expected) for particles that have high densities and particles sizes (>8.0 g/ml and >50 microns) (RPP-RPT-51796, *Remote Sampler Demonstration (RSD) Phase I Sampling Results Report*). When oriented vertically, the performance of the sampler improved, but additional testing in the vertical configuration was recommended.

While the initial work for the SSMD and RSD projects has demonstrated the concept functionality for the first feed tank, uncertainties remain that must be addressed. Uncertainties remain to be resolved by the WFD Sampling and Mixing Program related to optimizing system performance, the applicability of data to all tank waste, and understanding emerging WTP solids handling risks.

DNFSB Recommendation 2010-2 has raised WTP safety issues related to tank farms ability to mix, sample, and transfer solids. In response, DOE developed an implementation plan to resolve these issues (DOE Rev. 0 2010-2). As discussed in Section 1.0, this test plan is one of multiple test plan documents that will be prepared to address Commitment 5.5.3.6 of the Implementation Plan. This test plan also is being prepared to address the outstanding key uncertainties pertaining to the bounds of the SSMD and RSD equipment performance identified during the TOC Mixing and Sampling workshop held in Richland, Washington between October 10 – 12, 2011 (WRPS-1105293, *Small Scale Mixing Demonstration Optimization Workshop Meeting Minutes)*. Other test plans are being prepared to address the remaining priorities identified by the workshop participants.

1.3 SCALING PHILOSOPHY

The WFD Mixing and Sampling Program is performing both full-scale and small scale tests in order to evaluate mixing, sampling and transfer performance between the Hanford HLW feed staging tanks and the receipt tanks at the WTP. Full scale tests using prototypic equipment and operating conditions are being used to demonstrate the performance capabilities of the HLW sampling and transfer system that will be used to characterize the waste prior to transferring it to the WTP. Full-scale testing of components provides experimental data that can be used to evaluate the performance of the integrated system without the need to consider scale. Sampling and transfer testing at full-scale is manageable both fiscally and operationally. However, performing full-scale tests of the mixing system was not practical with considerations of economics, schedule and operating complexity. Therefore, it has been determined that mixing tests would be performed at small scales and full scale performance would be evaluated using scale-up relationships. Operating at smaller scales is desirable because it reduces the cost of materials (i.e. simulants), labor, and time necessary to perform tests. For example, a full-scale transfer of 950,000 gallons of HLW at the maximum transfer flow rate (140 gpm) would take nearly five days of continuous operation. Using smaller scales, the transfer could be completed in a single work shift. However, operating at smaller scales also requires that scaling relationships be understood in order to adequately predict full-scale performance.

The SSMD test platform contains two scaled systems that are geometrically similar to the DST and transfer system that will be used for first delivery to the WTP. The scaled properties are provided in Table 1-1. Full-scale DST properties are provided for 241-AY-102 and 241-AW-105. The SSMD test platform was constructed according to scale from 241-AY-102, the first DST staging tank to supply feed to the WTP. According to the System Plan documented in ORP-11242 Revision 6, *River Protection Project System Plan*, 241-AW-105 will participate in numerous feed transfers to the WTP receipt tank, accounting for about 24% of the total waste volume that will be transferred to the WTP from the 13 feed staging tanks (SVF-2110, *TRANSFER_PLOTS_4MINTIMESTEP(6MELTERS)-MMR-11-031-6.5-8.3R1-2011-03-18-AT-01-31-58_V7.XLSM*). Therefore, DST 241-AW-105 has been selected as the model tank for investigating solids accumulation.

The dimensions of the scaled test tanks and placement of the mixing and transfer equipment (e.g., tank diameter, bottom configuration, waste volume, mixer jet and transfer pump spatial locations, mixer jet nozzle diameter, mixer jet pump suction diameter and general tank obstructions) are directly scaled (i.e., proportional) to a full-scale DST filled with actual or anticipated volumes of waste. However, scaling is not full similitude. Consistent with general industry practice for mixing studies, simulant properties, including particle sizes are not scaled. Scaling of simulant properties such as viscosity, particle size, and particle/liquid density can change the controlling physical mechanisms of the processes, such as changing the flow regime in which particles are settling. In addition, to mitigate line plugging with the unscaled simulant, the scaled dimensions for the transfer pump suction inlet diameter and transfer line conduit diameter are also not in direct proportion to a full-scale system. To avoid plugging, the diameter of the pipe should be 3 to 10 times the size of the particles being transferred. Hanford waste simulants are 10s to 100s of microns in size; therefore, the smallest diameter piping that was considered for the scaled systems was ¼-inch, which is much larger than would be used if the pipe diameter was proportionally scaled.

Similarly, scaling the flow rate through a proportionally scaled transfer pump inlet was also not practical for flow hydraulic concerns. For the 1:8 scale system, a proportionally scaled system would pump 12 – 19 gallons of slurry per minute through an approximate 0.3-inch diameter inlet yielding a transfer velocity of at least 54 ft/s, well above the expected capture velocities in the full scale system. Therefore, the range for the transfer pump flow rates at each scale are specified to equate the fluid velocity through the inlet. The size and shape of the inlet and the fluid velocity through the inlet establish the velocity gradient into the pump inlet. Particles that enter the area of influence of the pump suction will only be captured by the pump if the pump suction, together with any upward motion induced by mixing, is sufficient to overcome any opposing motion due to particle settling and mixing. For the anticipated range of 90 – 140 gallons per minute, the fluid velocity through the 2.25 to 2.4 inch diameter inlet ranges between 6.4 and 11.3 feet per second. The transfer rates for the scaled systems are equated to this rate to establish a similar gradient. The transfer pump flow rate is calculated as the product of the fluid velocity, 6.4 and 11.3 feet per second, and the pump suction inlet area in the scaled system.

Table 1-1: SSMD Tank Geometrically Scaled Properties

Property	Full-Scale DST(AY-102)	Full-Scale DST(AW-105)	1:8 Scale	1:21 Scale
Diameter (in)	900	900	120	43.2
Scale Factor	1	1	0.1333	0.048
Bottom Geometry	Flat w/12-inch corner radius	Flat	Flat w/1.6-inch corner radius	Flat w/0.6-inch corner radius
Fill Volume[1] (gallons)	944,620	~1,100,00	~2,200	~100
Mixer Jet Pump 1 Location[2]	Riser-001 0°, 22 feet	Riser-007 270°, 20 feet	90°, 2.9 feet	90°, 0.96 feet (12.7 in as-built)
Mixer Jet Pump 2 Location[2]	Riser-003 180°, 22 feet	Riser-008 85°, 20 feet	270°, 2.9 feet	270°, 0.96 feet (12.7 in as-built)
Mixer Jet Pump Suction Elevation[3] (in)	5±1	5±1	0.67±0.13	0.24±0.05
Mixer Jet Pump Suction Diameter (in)	11	11	1.47	0.53
Mixer Jet Pump Nozzle Diameter (in)	6	6	0.80	0.29
Mixer Jet Pump Nozzle Elevation[3] (in)	18	18	2.4	0.86
Transfer Pump Location[2]	Riser-030 90°, 6 feet	Riser-012 270°, 3 feet	0°, 0.8 feet	0°, 0.29 feet
Transfer Pump Suction Inlet Diameter (in)[4]	2.25-2.40	2.25-2.40	0.3125	0.25
Transfer Pump Suction Inlet Height (in)[4]	6	6	0.8	0.28
Transfer Line Diameter (in)	3.07 (3-inch Schedule 40)	3.07 (3-inch Schedule 40)	½"-poly tubing	¼"-poly tubing
Tank Obstructions	Air Lift Circulators (ALCs)	None	Simulated ALCs (removable)	Simulated ALCs (removable)

[1] Fill volume is determined by linear scaling of the tank diameter and sludge volume height.

[2] The reference point for DST locations presented in this table defines 0° as the top (241-AY-102) or bottom (241-AW-105) of the tank in a plan view drawing of the tank. Provided distances are design distances from the center of the riser to the center of the tank.

[3] Elevation is relative to the tank bottom.

[4] The pump suction inlet diameter of the full-scale transfer pump is underdevelopment and the tabulated value is based on similar transfer pumps used on the Hanford site to convey waste. The inlet size on the 1:21 scale tank is not geometrically scaled. The resulting inlet size was too small to accommodate the particle sizes targeted.

Data collection from small scale experiments performed at two or more different scales can be used to predict full-scale performance if the scaling relationship is known. Scaled performance experiments can be conducted at multiple scales to establish or refine scaling relationships. In order to develop scaling relationships, equivalent performance within the scaled systems must be established for known operating conditions. Developing the scaling relationship is performed by using generally accepted scaling relationships, which can be theoretically based or empirically determined from similar experiments, to establish a test matrix for the scales of interest. For SSMD scaled performance testing, the generally accepted scaling relationship used for equivalent mixing among scales, as relates to the distribution of solids throughout the mixed volume, is the equal power-per-unit-volume relationship (see Equation 1-1). The derivation of the relationship is provided in Appendix A. $U_{jet2} = U_{jet1}\left(\frac{d_{tank2}}{d_{tank1}}\right)^{\frac{1}{3}}$

Equation 1-1

Equation 1-1 assumes that equal performance is attained when the applied power to mix is directly proportional to the volume to be mixed. The mixer jet pumps are being designed to sustain a flow rate of 5,200 gallons per minute from each of two 6-inch diameter nozzles on each mixer jet. The nozzle velocity exiting the full scale pump is about 59 ft/s. Using a 1/3 scale factor exponent, nozzle velocities of approximately 30 ft/s and 21 ft/s are determined for the 1:8 and 1:21 scale systems, respectively.

Initially scaling between the two scales in the SSMD test platform was performed to demonstrate that the scaled tanks could be scaled from the full scale system using the equal power-per-volume scale factor exponent. While this relationship is suitable for mixing, it may not be suitable for other performance metrics, such as the effective cleaning radius, off-bottom suspension, or particle transfer. Equal performance between scales is not just limited to mixing, it could also consider the transfer pumps ability to capture and convey the slurry solids. Therefore, the equal power per unit volume relationship with a scale factor exponent of 1/3 may not be the best relationship to use to scale the integrated system. Equation 1-2 replaces the 1/3 scale factor exponent with an unknown value, a, that can be determined for different performance metrics.

$$U_{jet2} = U_{jet1}\left(\frac{d_{tank2}}{d_{tank1}}\right)^{a} \qquad \text{Equation 1-2}$$

The scale factor exponent can be determined through scaled testing. As an example, in RPP-RPT-48233 the mixing data using nine mixer jet pump flow rates at 1:8-scale and 1:21-scale determined that equal mixing performance of zirconium oxide in water, as defined by equivalent slurry densities at equal scaled heights, was attained with flow rates of 102.0 gallons per minute (32.6 ft/s) and 9.0 gallons per minute (21.9 ft/s), respectively. The scale factor exponent for point where mixing performance at the two scales became equal was determined to be 0.39. It should be noted that the metric evaluated equal mixing, not adequate mixing as defined by a consistent density at all heights within the tank. The latter was achieved at higher nozzle velocities and equivalent mixing between the scales was maintained at the higher velocities. At the identified flow rates the specific gravity of the zirconium oxide slurry was higher at lower heights in both tanks, indicating that the solids (presumably the larger particles in prepared batch) were not being dispersed throughout the entire tank volume. The results also indicate that with increasing nozzle velocities (decreasing scale factor exponent values), mixing performance becomes adequate and plateaus.

Because there is uncertainty in the appropriate scale factor for the performance of the integrated system with simulants characteristic of other Hanford tanks, future tests will be performed using two scales and a range of different mixer jet pump nozzles velocities. Equal performance, as measured by a specific performance metric (e.g., distribution of solids, effective cleaning radius, off-bottom suspension, or particle transfer), will be used to refine previous scaling work.

The rotation rate for the mixer jet pump, ω, is also a scaled property of the integrated system. The scaling parameter for the mixer jet pump rotational rate equates the number of revolutions that occur in the time required to circulate an entire tank volume through the mixer jet pump inlet (PNNL-14443 Section 2.1.2). Equation 1-3 provides the relationship, the derivation of which is provided in Appendix A.

$$\omega_{tank2} = \frac{\omega_{tank1}}{SF^{1-a}} \qquad \text{Equation 1-3}$$

In SRNL-STI-2010-00521, *Demonstration of Mixer Jet Pump Rotational Sensitivity on Mixing and Transfers of the AY-102 Tank*, the effect of the rotational velocity of the mixer jets was evaluated at 1:22-scale and shown to have little effect on the amount of solids transferred in each transfer batch. However, it is noted that the nozzle velocity of the mixer jet was selected so that no "dead zones" were observed in the tank during testing; the testing did not assess whether or not the rotational rate would influence the amount of solids transferred if solids were allowed to accumulate in "dead zones". PNNL-14443, *Recommendations for Advanced Design Mixer Pump Operation in Savannah River Site Tank 18F* showed that the effective cleaning radius of a mixer jet decreased with increasing mixer jet rotational velocity and decreasing mixer jet nozzle velocity. It can be reasoned that performance metrics aimed at bottom cleaning or metrics that are strongly influenced by the solids on the bottom of the tank would need to evaluate the impact of both mixer jet rotational rate and nozzle velocity.

These scaling relationships set the initial conditions for Limits of Performance and Solids Accumulation Scouting Studies test activities, but the relationships will be refined in accordance with performance data developed at multiple scales during Scaled Performance testing.

Table 1-2 lists the properties and scaling basis for initial test conditions.

Table 1-2: Initial SSMD Tank Non-Geometrically Scaled Properties

Property	**Scaling Basis**	**Full-Scale DST**	**1:8 Scale**	**1:21 Scale**
Transfer Pump Flow Rate (gpm)	Equivalent inlet velocity (6.4 – 11.3 ft/s)	90-140	1.5-2.7	0.98-1.7
Initial Mixer Jet Pump Nozzle Flow Rate (gpm) (two per pump)	Nozzle velocities determined using Eq 1-2 (a=1/3)	~5200 (59 ft/s)	47.0 (30 ft/s)	4.3 (21 ft/s)
Initial Mixer Jet Pump Nozzle Flow Rate (gpm) (two per pump)	Nozzle velocities determined using Eq 1-2 (a=1/5)	~5200 (59 ft/s)	61.7 (39.4 ft/s)	6.6 (32.1 ft/s)
Mixer Jet Rotation Rate (rpm)	Equivalent number of rotations per tank turnover time (mixer jet pump basis) ($\omega\Theta$); (a=1/3)	0.2	0.77	1.5
Mixer Jet Rotation Rate (rpm)	Equivalent number of rotations per tank turnover time (mixer jet pump basis) ($\omega\Theta$); (a=1/5)	0.2	1.0	2.3

2.0 SCOPE

The original objective of the WFD Mixing and Sampling Program was to mitigate the technical risks associated with the ability of the tank farms feed delivery systems to adequately mix and sample HLW feed in order to meet the WTP WAC. Testing focused on the ability to achieve adequate mixing and representative sampling, minimizing variability between batches transferred to WTP. Testing to date (RPP-49740) has demonstrated the potential ability to adequately mix, deliver and sample 241-AY-102 simulated waste using prototypic DST mixing and transfer systems.

While several uncertainties remain regarding the ability to adequately characterize DST waste, larger mission uncertainties related to the compatibility of tank farms feed systems with the WTP receipt systems remain to be addressed. The current WFD Mixing and Sampling Program being executed to address the issues is being performed in a phased approach which will:

- Optimize requirements
- Demonstrate the viability of systems to meet those requirements in small-scale or full-scale environments, and upon successful demonstration
- Exhibit system capability in a full-scale DST (i.e., DST which will be providing hot commissioning feed to WTP)

This plan is one of multiple test plans being prepared to define test requirements to address tank farm feed mixing, sampling, characterization and transfer system capability, in order to meet the expanded requirements associated with DNFSB Recommendation 2010-2. This test plan documents planned activities that will be performed to support a gap analysis of capabilities to sample characterize and transfer waste to WTP that conforms with ICD-19. As described in RPP-PLAN-41807 the objectives of the test activities are to determine the range of waste physical properties that can be retrieved and transferred to the WTP and determine the capability of the tank farm staging, tank sampling systems to obtain samples that can be characterized to assess the bounding physical properties important for the WAC. The three major areas of testing that will be executed by the WFD Mixing and Sampling Program include Limits of Performance, Solids Accumulation, and Scaled/System Performance. Specifically seven testing activities are planned:

- SSMD Limits of Performance (performed by Energy*Solutions*)
- RSD Limits of Performance (performed by Energy*Solutions*)
- Full-Scale Transfer Pump Limits of Performance (performed by Columbia Energy and Environmental Services (CEES))
- SSMD Solids Accumulation Scouting Studies (performed by SRNL)
- SSMD Solids Accumulation Performance Evaluation (performed by Energy*Solutions*)
- SSMD Scaled Performance (performed by Energy*Solutions*)
- RSD System Performance (performed by Energy*Solutions*)

This plan defines test requirements to address the first four test activities, including all Limits of Performance scope and the initial Solids Accumulation development work. Subsequent test plans will provide the test requirements for SSMD Solids Accumulation Performance Evaluation scope and the two scaled/system performance activities. Figure 2-1 shows test sequence and portrays how information learned from early testing activities is used to develop the test plans for subsequent scope.

WFD Mixing and Sampling Program testing is performed in accordance with Phase I testing described in TFC-PLAN-90, *Technology Development Management Plan* and implements a graded application of the quality assurance program requirements. While not specifically required for Phase I testing, WFD Mixing and Sampling Program test planning, test review, test control and test results reporting are guided by testing principles described in TFC-ENG-DESIGN-C-18, *Testing Practices*. WFD Mixing and Sampling Program testing falls outside the scope of TFC-PLAN-26, *Test Program Plan*, which defines additional requirements for oversight, development, and the conduct of factory acceptance, construction acceptance, and operational acceptance tests for demonstrating the operability and integrity of new or modified tank farm facilities and systems.

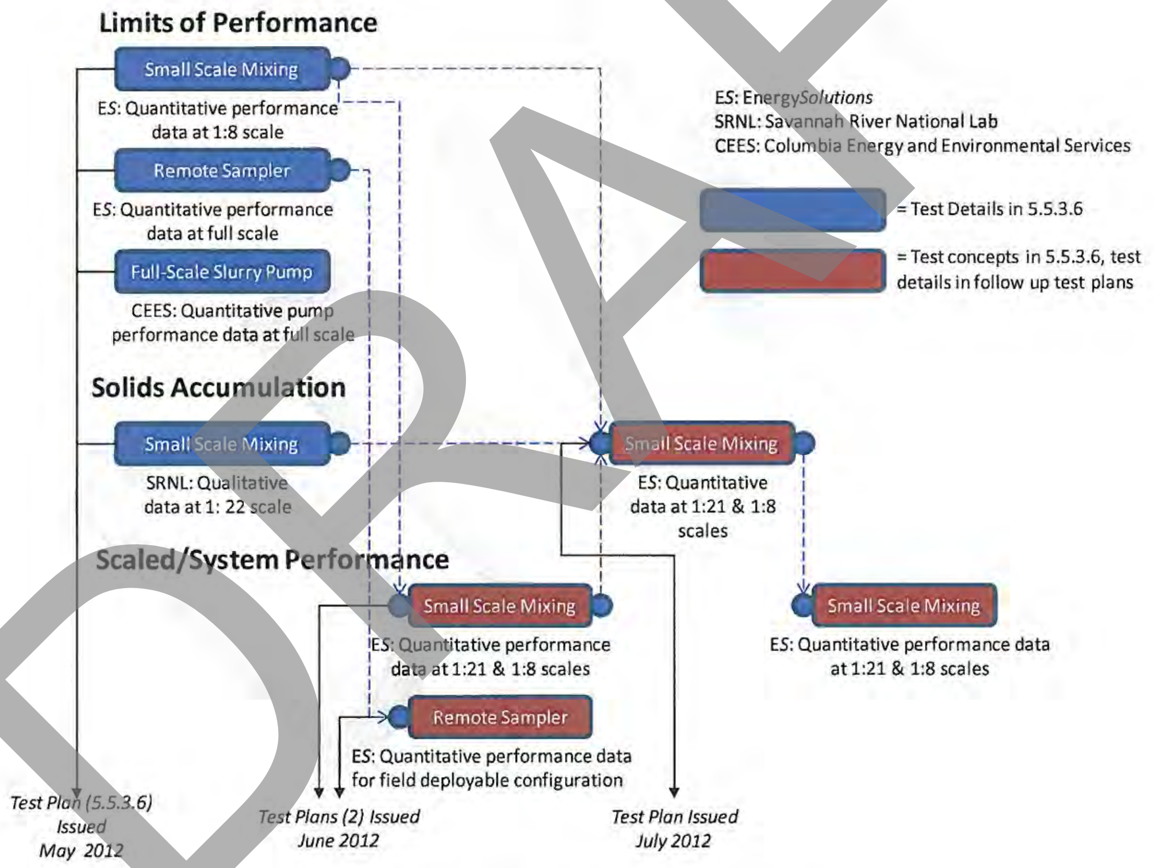

Figure 2-1 WFD Mixing and Sampling Program Test Sequence

2.1 LIMITS OF PERFORMANCE

The objective of Limits of Performance activities is to determine the range of waste physical properties that can be mixed, sampled and transported under varying modes of operation. The capability gap between the TOC and the WTP is defined by the capability of the TOC's capability to mix, sample and transfer large and dense particles and the WTP's capability to process these particles. Therefore, integral with defining the gap in capabilities is the selection of appropriately complex simulants, integrated with WTP simulant selection and supported by accurate analytical techniques to characterize the material of interest. As detailed in RPP-PLAN-51625 particle size and density are expected to be the most important solids properties and liquid density and viscosity are expected to be important liquid phase properties. Particle shape is being considered consistent with recommendations in SRNL-STI-2012-00062, *Properties Important to Mixing for WTP Large Scale Integrated Testing*, which recommends that simulants for pulse jet mixer limits of performance testing should include a variety of particle shapes and that spherical particles should be considered for at least a portion of the particles at the high end of the Archimedes number distribution. Particle hardness, which is important for understanding the longevity of the plant equipment, is not considered an important factor for accessing the capability of the WFD system to mix, sample and transfer HLW slurry.

2.1.1 Small Scale Mixing Demonstration

SSMD Limits of Performance test activities documented in Section 2.1.1 are performed by Energy*Solutions* for WRPS.

2.1.1.1 Objective

The objective of SSMD Limits of Performance activities is to determine the range of waste physical properties that can be mixed and transported by the SSMD test platform under varying modes of operation. Testing will be performed at 1:8-scale to determine the capability of the scaled test system to transfer large and dense particles that are characteristic of the to-be-delivered tank waste. Testing will also identify whether the capability of the SSMD 1:8-scale test system is limited by the mixing system or the waste transfer system. Understanding the limits of the test system will provide insight into understanding the performance of the fully-integrated scaled system. Specifically SSMD Limits of Performance testing will identify the capability of operating rotating mixer jet pumps to deliver large and dense particles to the area of influence of the transfer system so that the transfer pump can mobilize the particles from the tank.

Using spike particulates with densities that are representative of the average density solids in the Hanford tank waste, including uncertainties, successful testing will identify the largest waste particle size that can be transferred by the 1:8-scale tank waste transfer system. In addition, using spike particulates with densities that are representative of the high density fissile material, successful testing will also identify the largest particle that can be transferred by the 1:8-scale tank waste transfer system. Successful testing will also identify whether or not the large and dense particles can be suspended inside the mixing tank and delivered to the waste transfer pump suction inlet.

The test objectives are summarized in Table 2-1.

2.1.1.2 Technical Approach

The SSMD Limits of Performance activities described in this test plan will use the SSMD test platform (Figure 2-2) located at Monarch Machine & Tool Company, Inc. in Pasco, WA to determine whether large and dense particles can be mixed and transferred by the prototypic mixing and transfer system. Preliminary testing was performed to identify suitable spike particles to be used in fully integrated testing in a scaled and prototypic test tank. Testing in this manner was being performed to determine the capability of the scaled test system to transfer large and dense particles. To date, SSMD performance testing has focused on developing the SSMD test platform and then demonstrating that the scaled system is capable of adequately mixing and sampling a simulant that is characteristic of the first HLW feed batch that will be delivered to the WTP. The SSMD work scope has not specifically addressed the capability of the system to evaluate simulants characteristic of other tanks that may contain other dense fissile material.

Testing will be designed to bound system performance without taking into account the uncertainty of known waste characteristics. Scale-up of the performance limits to full scale is not anticipated from the tests, which are only being performed at one scale. Preliminary work will be performed to evaluate the capability of the SSMD test platform 1:8-scale tank transfer system to convey large and dense particles. Once the capability of the transfer system is known, then the 1:8-scale integrated system will be used to determine the capability of the mixing system to deliver the large and dense particles to the transfer pump suction inlet. Supplemental testing described in Section 2.1.3 will be performed to evaluate the capability of a full-scale slurry transfer pump to convey large and dense particles out of a tank.

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis are provided in Section 3.2.1.

Table 2-1: SSMD Limits of Performance Test Objective

Objective	Success Criteria
Demonstrate the capability of the 1:8-scale mixing and transfer system to transfer large and dense particles.	Mixing and transfer tests are performed at different operating conditions in the 120-inch diameter SSMD mixing tank with a base simulant, a supernatant simulant and spike particles that are distinguishable in collected samples by size and another physical property (color, density, etc). Large and dense particles that can be mobilized to a sample location downstream of the transfer pump discharge are identified and quantified according to fraction of each particle size and density transferred in each transfer batch relative to the starting composition. Correlations relating the fraction of particles of each size and density transferred are evaluated with respect to the changes in the operating conditions.
Demonstrate whether the mobilization of large and dense particles is constrained by the mixing system or the transfer system.	Mixing and transfer limitations of the integrated SSMD test platform are identified.

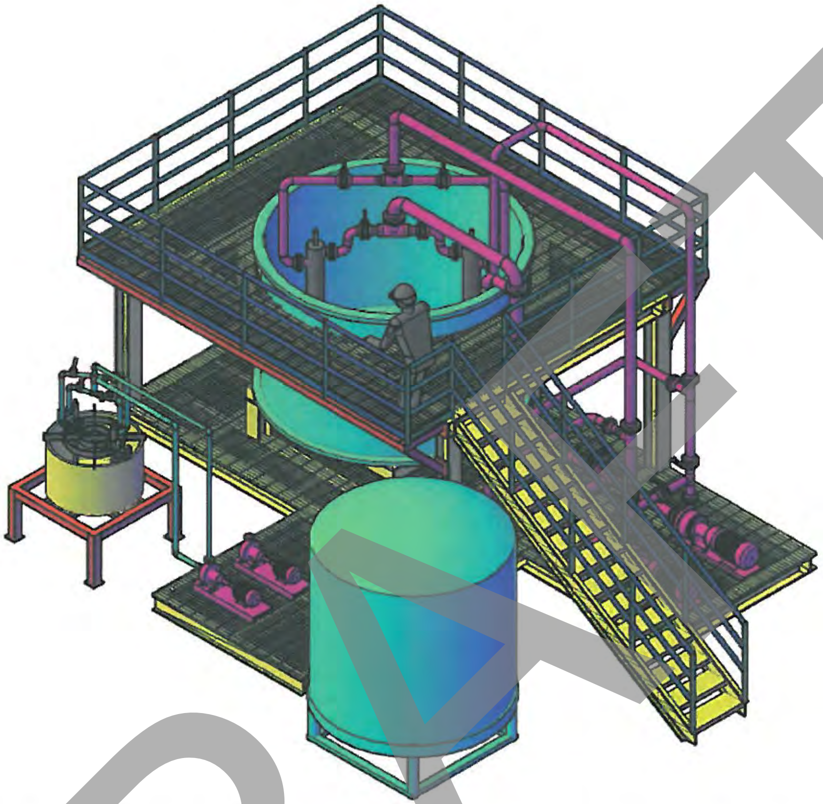

Figure 2-2 Schematic of Small Scale Mixing Demonstration Test Platform

2.1.2 Remote Sampler Demonstration

RSD Limits of Performance test activities documented in Section 2.1.2 are performed by Energy*Solutions* for WRPS.

2.1.2.1 Objective

The objective of RSD Limits of Performance activities is to determine the range of waste physical properties that can be sampled by the RSD test platform under varying modes of operation. Testing will determine the capability of the Isolok®[1] sampling system to sample large and dense particles that are characteristic of the to-be-delivered tank waste. RSD Limits of Performance testing will emphasize the capability of the Isolok sampler; the simulants used in testing are selected to challenge the sampler.

Using spike particulates with densities that are representative of the average density solids in the Hanford tank waste, including uncertainties, successful testing will identify the largest waste particle size that can be consistently sampled by the Isolok sampler without plugging. In addition, successful testing will also identify the largest particle with a density characteristic of fissile material that can be consistently sampled by the Isolok sampler without plugging.

The test objectives are summarized in Table 2-2.

2.1.2.2 Technical Approach

The testing described in this test plan will use the RSD test platform (Figure 2-3) located at Monarch Machine & Tool Company, Inc. in Pasco, WA to test progressively larger particle sizes and densities to identify the largest size and density particle that can be sampled consistently by the Isolok sampler. The Isolok sampler will collect 500 ml samples in increments of 5.3 ml per sample plunger actuation. Collecting the sample takes approximately 40 minutes. Once the sample is collected, the collected volume will be sieved to separate the different sizes of spike particles. Testing in this manner is being performed to determine the capability of the full-scale sampler system to sample large, dense particles that may be characteristic of the to-be-delivered tank waste. The largest size that can be consistently sampled by the sampler is constrained by the diameter of the internal sampling needle (approximately 3,400 micron). To date, RSD performance testing has focused on developing the RSD test platform and then demonstrating that the system is capable of adequately sampling a simulant that is characteristic of the first HLW feed batch that will be delivered to the WTP. The RSD work scope has not specifically addressed the capability of the system to evaluate simulants characteristic of other tanks that may contain larger and denser material. RSD Limits of Performance testing is being conducted to address the uncertainty in the capability of the Isolok sampler (shown in red in Figure 2-3). Testing the capability of the Isolok sampler will be designed to bound system performance without taking into account the uncertainty of known waste characteristics. RSD Limits of Performance testing will utilize a simulant that is consistent with the SSMD Limits of Performance testing, with the exception that spike particles will be restricted to a size less than the internal sampling needle.

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[1] Isolok is a registered trademark of Sentry Equipment Corp. of Oconomowoc, WI

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis are provided in Section 3.2.2.

Although Figure 2-3 includes the Ultrasonic PulseEcho system (shown in blue in Figure 2-3), this system has been previously evaluated, as reported in PNNL-19441, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments*, and is not being evaluated for limits of performance. The Ultrasonic PulseEcho system will be further evaluated during RSD System Performance testing.

Table 2-2: RSD Limits of Performance Test Objective

Objective	Success Criteria
Demonstrate the capability of the Isolok Sampler to sample large and dense particles in different simulant compositions (using both cohesive and non-cohesive simulants).	Isolok sampling tests are performed in the RSD flow loop with a base simulant, a supernatant simulant and spike particles that are distinguishable in collected samples by size and another physical property (color, density, etc). Large and dense particles that can be sampled by the Isolok sampler without degrading equipment performance are identified and quantified according to fraction of each particle size and density sampled relative to a full diversion sample. Collected sample volumes are within 5% of the expected volume. The sampled concentration of large and dense particles collected by the Isolok sampler is within 5% of the concentration determined from comparable full diversion samples taken from the flow loop. Correlations relating the fraction of particles of each size and density captured in the Isolok sample are evaluated with respect to the changes in the testing conditions (e.g., simulant variations and loadings).

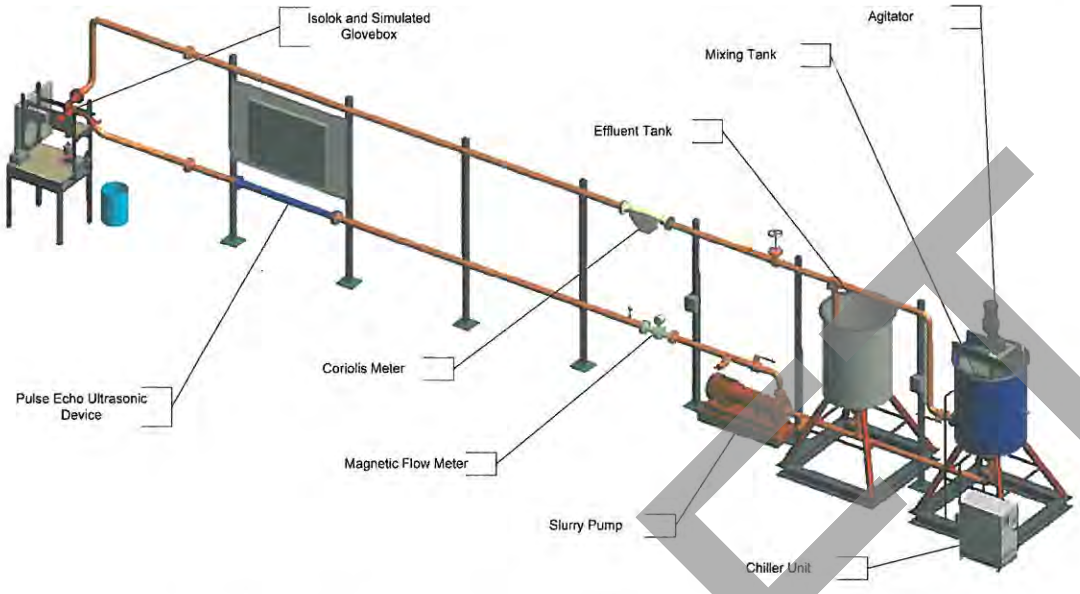

Figure 2-3 Schematic of Remote Sampler Demonstration Test Platform

2.1.3 Full-Scale Transfer Pump Limits of Performance

Full-Scale Transfer Pump Limits of Performance test activities documented in Section 2.1.3 are performed by CEES for WRPS.

2.1.3.1 Objective

The objective of Full-Scale Transfer Pump Limits of Performance activity is to determine the range of waste physical properties that can be transferred from a mixed DST to the WTP receipt tanks. Testing will determine the capability of the WFD transfer pump to capture and convey large and dense particles in a configuration that is similar to the transfer configuration planned for the WFD feed staging tanks. Testing will also evaluate the capability of the transfer pump to mobilize solids in an unmixed tank at different transfer pump suction inlet heights.

Using spike particulates with densities that are representative of the average density solids in the Hanford tank waste, including uncertainties, successful testing will identify the largest waste particle size that can be transferred by a full-scale slurry transfer pump. Testing will also identify the largest particle with a density characteristic of fissile material that can be transferred by the pump.

The test objective is summarized in Table 2-3.

Table 2-3: Full-Scale Transfer Pump Limits of Performance Test Objective

Objective	Success Criteria
Demonstrate the capability of the full-scale WFD slurry transfer pump to transfer large and dense slurry particles in different simulant compositions and under different operating modes (semi-quiescent tank, mixed tank, variable pump suction height).	Transfer tests are performed at different operating conditions with a base simulant, a supernatant simulant and average density and high density spike particles that are distinguishable by size and density. Large and dense particles that can be mobilized to a sample location downstream of the transfer pump discharge under mixing and quiescent conditions are identified and quantified according to fraction of each particle size and density transferred relative to the starting composition. Correlations relating the fraction of particles of each size and density transferred are evaluated with respect to the changes in the operating conditions.

2.1.3.2 Technical Approach

The testing described in this test plan will procure a commercially available submersible slurry pump that has hydraulic properties similar to the next generation transfer pump sought by the TOC to convey HLW slurry between the DST feed staging tank and the WTP receipt tank. The TOC has evaluated commercially available pumps and has determined that a submersible slurry pump that is capable of conveying the HLW slurry from the bottom of the DST to the WTP receipt tank without an intermittent booster pump or exceeding the pressure limits of the transfer piping is not available. The TOC is pursuing the development of a customized pump to meet WFD requirements, but development of this pump will not be completed in time to support Limits of Performance testing and the initial gap analysis. Therefore, a commercially available pump that has the flow capability and inlet velocity of the proposed pump without the high head requirements will be used for Full-Scale Transfer Pump Limits of Performance test activities.

The procured transfer pump will be placed into a mixing tank such that the pump inlet is located consistently with the DST 241-AY-102 transfer system configuration. Simulant, including large diameter spike particles, will be mixed and pumped through a network of pipes that mimic the flow from the bottom of a DST to the location of the Ultrasonic PulseEcho system in the waste feed delivery characterization flow loop. The slurry will be pumped vertically through55 feet of 3-inch diameter Schedule 40 piping, through a 90° bend and then horizontally through 20 feet of 3-inch diameter, transparent Schedule 40 plastic piping so that the flow can be observed. The spike particulates in the mobilized slurry will be collected and quantified from the end of the horizontal run. so that the capability of the pump to transfer large and dense particles out of the DST can be assessed. After testing is completed, the horizontal transfer line will be flushed (>140 gpm) and the discharge will be screened to collect the large and dense particles that were captured by the pump but settled out in the transfer line prior to reaching the sample location. The screened material will then be sieved to separate the different particle sizes. The spatial distribution of the large and dense particles remaining in the mixing tank will also be reported so that the mixing systems capability to deliver the large and dense particles to the area of influence of the pump can be considered in the analysis of the pumps capabilities.

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis are provided in Section 3.2.3.

2.2 SOLIDS ACCUMULATION

The objective of Solids Accumulation activities is to perform scaled testing to understand the behavior of remaining solids in a DST during multiple fill, mix, and transfer operations that are typical of the HLW feed delivery mission. Testing will focus on accumulation of total solids over time and the propensity for simulated fissile material to concentrate over time.

2.2.1 Scouting Studies

SSMD Solids Accumulation Scouting studies documented in Section 2.2.1 are performed by SRNL for WRPS.

2.2.1.1 Objective

SSMD project testing activities to date have developed two scaled test platforms to evaluate the baseline design for mixing and transferring slurry from DST 241-AY-102, the first staged HLW feed to the WTP. SRNL constructed a 1:22-scale Mixing Demonstration Tank (MDT) to perform mixing and transfer studies. Energy*Solutions* has also constructed a test platform that includes both a 1:21-scale and a 1:8–scale mixing tank and transfer system. The objective of the SSMD Solids Accumulation Scouting studies is to simulate a series of full WFD to WTP transfer and refill operations using the 1:22-scale MDT and evaluate the bulk material that remains in the tank after the series of pump-out and refill operations are performed. Testing will determine the amount of bulk solids remaining and the concentration and approximate locations where the fastest settling particles accumulate in the tank heel and estimate the error associated with the collected measurements. Providing insight into how fast settling particles are distributed in a WFD feed staging tank is important to criticality evaluations that include the accumulation of dense plutonium and uranium containing solids. The scope of the work is limited to preliminary scoping studies, the results of which will be used to define supplemental test work that will be performed using the test platform operated by Energy*Solutions*.

Integral with this activity is the selection of appropriately complex simulants that are integrated with WTP simulant selection and supported by accurate analytical techniques to characterize the material of interest. Using simulants characteristic of high density solids in the Hanford tank waste, including uncertainties, successful testing will identify a simulant that can be readily characterized by standard analytical techniques, a sampling technique for characterizing the residual tank waste solids that accumulate in the tank after a series of transfer and refill operations are performed, and a technique for quantifying the residual solids in the tank after each transfer and refill operation is completed.

The test objectives are summarized in Table 2-4.

Table 2-4: Solids Accumulation Scouting Studies Test Objectives

Objective	Success Criteria
Demonstrate at two jet nozzle velocities the potential accumulation of solids in the DST after several transfer and re-fill operations are conducted.	Mixing and transfer tests are performed at two different jet nozzle velocities with a base simulant that contains moderately sized (approximately 100 microns), dense particles to represent fissile material in the Hanford tank waste. The spike particles are distinguishable in collected samples by a physical property that can be exploited for quantification. Very fast settling particles that can accumulate inside a DST used for several staged feeds are quantified relative to the amount of the solids added to the tank. The relative quantities of solids in each transfer batch are estimated. The accumulation of heel solids is evaluated after each tank volume transfer by observing changes in the heel volume. The accumulation of heel solids is quantified after the 1st, 5th and last (e.g., 10th) tank volume transfer by measuring the volume of heel in the tank. The distribution of the very fast settling solids in the heel is described using quantitative results from collected heel samples. Correlations relating the fraction of very fast settling solids transferred and remaining in the tank are evaluated with respect to each transfer batch and after multiple tank volume transfers.
Develop and demonstrate quantification techniques to characterize the residual tank waste in-situ.	Techniques to sample and quantify the volume of residual solids are identified and documented. Different heel volume measurement techniques are compared.

2.2.1.2 Technical Approach

The SSMD Solids Accumulation Scouting studies described in this test plan will use the MDT platform (Figure 2-4) at SRNL to simulate a DST transfer campaign to characterize the solids that remain in the tank after a series of tank transfers have been performed. A DST transfer campaign includes a series of transfer and refill operations that fill the MDT mixing tank with simulant and then pump-out the material to one or more receipt tanks using 6.5 consecutive batch transfers. This number reflects the anticipated number of transfers needed to reduce the tank contents in a full feed DST to 72-inches using 145,000 gallon batches. The residual volume of 72-inches of solids and supernatant is an operating limitation to avoid cavitation when the mixer jet pumps are operating at full speed. A tank volume transfer operation is completed when 6.5 batches of slurry are transferred from the MDT to the receipt tank(s). Following a successful tank volume transfer, the solids remaining in the MDT, the heel, will be characterized and additional simulant will be added to refill the mixing tank. A series of tank volume transfers with subsequent refills, up to ten, will be performed in a campaign. Fewer tank volume transfers may be performed if it is demonstrated that the heel volume stabilizes despite performing additional fill and transfer cycles. The solids remaining in the tank after each transfer campaign will be characterized and compared to the total solids that are added during testing. Quantification in the heel and in each transfer batch will specifically target the very fast settling particles. However, the volume of the other solids constituents will also be measured. Once a campaign is completed, a second campaign will be performed at a different mixer jet nozzle velocity to evaluate the effect of the mixer jet nozzle velocity on the accumulation of very fast settling particles.

Solids Accumulation Scouting Studies will investigate and develop techniques to sample the heel solids with minimal disturbance, measure the heel volume, and refill the tank after each transfer operation. Testing in this manner is being performed to determine the location of the very fast settling solids that remain in a tank after several transfer and refill operations in order to evaluate the potential to accumulate fissile material in the tank heels. To date, SSMD performance testing has focused on developing the SSMD test platform and then demonstrating that the scaled system is capable of adequately mixing and sampling a simulant that is characteristic of the first HLW feed batch that will be delivered to the WTP. Although some effort has begun to understand the accumulation of solids in the tank, the SSMD work scope has not specifically addressed the accumulation of material in the tank after successive transfer operations are performed from a feed stage tank.

Once adequate sampling and analysis methods are developed through these scoping studies, the SSMD test platform 1:21-scale and a 1:8–scale mixing tanks will be used to perform more precise evaluations (see Section 2.2.2).

Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis are provided in Section 3.3.1.

Figure 2-4 Mixing Demonstration Tank Test Platform

2.2.2 Performance Evaluation

SSMD Solids Accumulation Performance Evaluation test activities documented in Section 2.2.2 are performed by Energy*Solutions* for WRPS.

SSMD Solids Accumulation Performance Evaluation testing is introduced in this test plan because it is being conducted to address DNFSB 2010-2 work scope; however, a separate test plan will document the tests that will be performed to further evaluate the accumulation of solids in the scaled systems. Developing appropriate tests details to evaluate solids accumulation will be informed from the SSMD Limits of Performance test results and SRNL Solids Accumulation Scouting Studies test results.

2.2.2.1 Objective

The objective of the SSMD Solids Accumulation Performance Evaluation testing is to perform a series of full WFD to WTP transfer and refill operations using the 1:21-scale and a 1:8–scale mixing tank and transfer systems at Monarch Machine and Tool Company, Inc in Pasco, WA to evaluate the bulk material that remains in the tanks after a series of pump-out and refill operations are performed. Testing will be conducted at two nozzle velocities for each of two scales and the results will be compared using the scaling relationship for waste transfer and other performance metrics (e.g., bottom cleaning). The scaling relationship for waste transfer will be developed/refined during SSMD Scaled Performance test activities (see Section 2.3.1) prior to the start of this work scope. Testing will determine the amount of bulk solids remaining and the concentration and approximate locations where the fastest settling particles accumulate in the tank heel. Providing insight into how fast settling particles are distributed in a WFD feed staging tank is important to criticality evaluations that include the accumulation of dense plutonium and uranium containing solids. The work that will be performed is expected to use methods refined by SRNL during the SSMD Solids Accumulation Scouting studies (Section 2.2.1). The work will build on the work performed by SRNL by expanding the scope to include the larger scale.

The test objectives are summarized in Table 2-5. The objective(s) of SSMD Solids Accumulation Performance Evaluation testing are subject to change as on-going and planned work being performed by the WFD Mixing and Sampling Program is completed.

Table 2-5: Solids Accumulation Performance Evaluation Test Objectives

Objective	Success Criteria
Demonstrate, at two scales, the potential accumulation of solids in the DST after several transfer and re-fill operations are conducted.	Mixing and transfer tests are performed at two different jet nozzle velocities and at two different scales with a base simulant that contains moderately sized (approximately 100 microns), dense particles to represent fissile material in the Hanford tank waste. The spike particles are distinguishable in collected samples by a physical or chemical property that can be exploited for quantification. Very fast settling particles that can accumulate inside a DST used for several staged feeds are identified and quantified relative to the amount of the solids added to the tank. The relative quantities of typical solids in each transfer batch are quantified. The accumulation of heel solids is evaluated after each tank volume transfer by estimating the volume of heel in the tank after each tank volume transfer. The accumulation of heel solids is quantified after the 1st, 5th and last (e.g., 10th) tank volume transfer by measuring the volume of heel in the tank. Correlations relating the fraction of solids transferred and remaining in the tank are evaluated with respect to each transfer batch and after multiple tank volume transfers. The spatial distribution of the residual solids after several transfer and re-fill operations are characterized.
Evaluate solids accumulation at two scales and compare the tests results to the scaling relationship for waste transfer.	Solids accumulation data at two nozzle velocities for each of two scales is collected. Comparisons using the scaling relationship for waste transfer and bottom cleaning are performed.

2.2.2.2 Technical Approach

The SSMD Solids Accumulation Performance Evaluation testing will use the 1:21-scale and a 1:8–scale mixing tank and transfer systems to perform multiple DST transfer campaigns to characterize the solids that remain in the tank after a series of tank transfer and refill operations have been performed. A DST transfer campaign includes a series of tank volume transfers and refill operations that fill the mixing tanks with simulant and then pump-out the material to one or more receipt tanks using 6.5 consecutive batch transfers. This number reflects the anticipated number of transfers needed to reduce the tank contents in a full feed DST to 72-inches using 145,000 gallon batches. The residual volume of 72-inches of solids and supernatant is an operating limitation to avoid cavitation when the mixer jet pumps are operating at full speed. A tank volume transfer is completed when 6.5 batches of slurry are transferred from the mixing tanks to the receipt tank(s). Following a successful tank volume transfer operation, the solids remaining in the mixing tanks, the heel, will be characterized and additional simulant will be added to refill the mixing tanks. A series of transfer and refill operations, up to ten, will be performed in a campaign. The solids remaining in the tanks after each transfer campaign will be characterized and compared to the total solids that are added during testing.

Testing in this manner is being performed to determine the composition and location of the solids that remain in the tanks after several transfer and refill operations are performed in order to evaluate the potential to accumulate fissile material in the tank heels. The SSMD work scope continues the work conducted by SRNL to address the accumulation of material in the tank after successive transfer operations are performed. Unlike SRNL scouting studies that only quantified the very fast settling solids, the performance evaluation will quantify all solids in the transfer batches and heel.

Solids Accumulation Performance Evaluation testing will use a complex simulant recommended by previous testing activities that include but are not limited to the Solids Accumulation Scouting studies, SSMD Limits of Performance and SSMD Scaled Performance test activities. The SRNL method to characterize the quantity of very fast settling solids that are and are not transferred will be used or refined so that monitoring the accumulation of very fast settling particles can be performed as successive transfer and refill operations are performed.

The technical approach for SSMD Solids Accumulation Performance Evaluation testing will be refined as on-going and planned SSMD test activities and other related work (e.g., simulant development) are completed. Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis will be provided in a future test plan.

2.3 SCALED/SYSTEM PERFORMANCE

While test data collected to date has provided some insight to mixing, sampling, and transfer performance (e.g., RPP-50557), more data is needed to confidently predict full-scale performance that covers the range of physical properties of Hanford waste. The objective of SSMD Scaled Performance activities is to test mixing and transfer performance at two scales using a realistic simulant representing a broad spectrum of Hanford waste to meet WTP WAC DQO sampling confidence requirements. The objective of RSD System Performance activities is to evaluate the performance of the RSD, including the Ultrasonic PulseEcho system, in a configuration that addresses field deployment constraints.

2.3.1 Small Scale Mixing Demonstration

SSMD Scaled Performance test activities documented in Section 2.3.1 are performed by Energy*Solutions* for WRPS.

SSMD Scaled Performance testing is introduced in this test plan because it is being conducted to address DNFSB 2010-2 work scope; however, a separate test plan will document the tests that will be performed to further evaluate the performance of the scaled system. Developing appropriate tests details to evaluate SSMD Scaled Performance will be informed from the SSMD Limits of Performance test results and SSMD Solids Accumulation Scouting Studies test results.

2.3.1.1 Objective

The objective of SSMD Scaled Performance testing is to further improve the knowledge and understanding of the scaled mixing systems by conducting additional mixing tests. The SSMD Scaled Performance testing will extend previous work using simulants that are representative of other tank wastes. SSMD testing will be performed using three nozzle velocities at both the 1:21 and 1:8-scale test systems to build confidence in the scaling models that are used to predict full-scale performance.

The objective of SSMD Scaled Performance testing is subject to change as on-going and planned work being performed by the WFD Mixing and Sampling Program is completed. The on-going and planned work is being performed to identify the gaps that exist between the WFD's capability to deliver consistent HLW waste slurry batches and the WTP's capability to accept and process any variations in batch consistency and any potential deviation from the WAC.

The test objective is summarized in Table 2-6.

Table 2-6: SSMD Scaled Performance Test Objectives

Objective	Success Criteria
Use the 1:8- and 1:21-scale SSMD platforms to build confidence in the pre-transfer sampling representativeness and the predictions of full-scale performance.	Mixing and transfer tests are performed at multiple jet nozzle velocities with a base simulant that contains moderately sized (approximately 100 microns), dense particles to represent hard to transfer waste particles in the Hanford tank waste. The spike particles are distinguishable in collected samples by a physical or chemical property that can be exploited for quantification. Performance data (i.e., sample composition of each transfer batch) is collected at two scales and is used to refine the scaling relationship for the integrated mixer jet pump and slurry transfer system. The scaling relationship is refined and used to predict waste transfer performance at full-scale.

2.3.1.2 Technical Approach

The testing described in this test plan will use the SSMD test platform located at Monarch Machine & Tool Company, Inc. in Pasco, WA to evaluate the system performance when operating parameters for mixing and transfer are varied. The operating parameters that may be varied during testing include: the mixer jet nozzle velocity, the mixer jet rotational velocity and the transfer pump capture velocity. The selection of the appropriate test configuration will be informed from SSMD Limits of Performance testing and SRNL Solids Accumulation Scouting studies. Equivalent tests will be performed in the 1:21- and 1:8-scale test systems. The SSMD platform will be modified in accordance with any recommendations from previous work. Evaluating the effect of transfer pump capture velocity and mixer jet rotational velocity would provide additional scale-up data for evaluating full-scale performance. To date, SSMD performance testing has focused on developing the SSMD test platform and then demonstrating that the scaled system is capable of adequately mixing and sampling a simulant that is characteristic of the first HLW feed batch that will be delivered to the WTP. On-going SSMD work scope will evaluate the capability of the system to mix and transfer simulants characteristic of other tanks that may contain other dense fissile material. SSMD Scaled Performance work will perform additional performance evaluations with simulants that are characteristic of other tank wastes operating under different conditions.

The technical approach for SSMD Scaled Performance testing will be refined as on-going and planned SSMD test activities and related work (e.g., simulant development) are completed. Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis will be provided in a future test plan.

Based on previous scaled testing of jet mixed tank performance, it is assumed that equivalent flow regimes are maintained across scales. As results are analyzed and performance anomalies identified between scale are founds, the impact of potentially operating under different flow regimes will be considered.

2.3.2 Remote Sampler Demonstration

RSD System Performance test activities documented in Section 2.3.2 are performed by Energy*Solutions* for WRPS. Evaluating the RSD and Ultrasonic PulseEcho system has previously been classified as RSD Scaled Performance. The activities are now referred to as RSD System Performance because the RSD flow loop (i.e., the Isolok, PulseEcho, and piping) is not a scaled system, it is full-scale.

RSD System Performance testing is introduced in this test plan because it is being conducted to address DNFSB 2010-2 work scope; however, a separate test plan will document the tests that will be performed to further evaluate the performance of the RSD system. Developing appropriate test details to evaluate RSD System Performance will be informed from the SSMD Limits of Performance test results and RSD Limits of Performance test results.

2.3.2.1 Objective

The objective of RSD System Performance test activities is to continue to optimize the configuration of the Isolok sampler system to improve the performance of the sampler to obtain reliable samples from the waste characterization flow loop. Operating parameters that will be investigated include variations in simulant composition (base solids, supernatant and spike particles), simulant mass loading and flow velocity. Additionally, RSD System Performance testing will utilize the Ultrasonic PulseEcho system for monitoring solid settling (i.e., the onset of Critical Velocity) in the flow loop. Critical velocity evaluations will expand upon any testing performed during RSD Limits of Performance testing (Section 2.1.2). In addition, the system design will be evaluated against field deployable constraints and limitations.

The objectives of RSD System Performance testing are subject to change as on-going and planned work being performed by the WFD Mixing and Sampling Program is completed. The on-going and planned work is being performed to identify the gaps that exist between the WFD's capability to deliver consistent HLW waste slurry batches and the WTP's capability to accept and process any variations in batch consistency and any potential deviation from the WAC.

The test objectives are summarized in Table 2-7.

2.3.2.2 Technical Approach

RSD System Performance testing will continue to use the RSD test platform developed at Monarch Machine and Tool Company, Inc in Pasco, WA. The RSD test platform was constructed using a full-scale Isolok sampler and Ultrasonic PulseEcho system and the pipe diameter in the flow loop was also full-scale. Supplemental performance testing that is performed as part of the RSD System Performance effort will be informed by the previous RSD test results and incorporate any recommendations from previous testing, which includes RSD Phase I development testing, RSD Phase II mechanical handling testing and RSD Limits of Performance testing. For instance, System Performance testing will evaluate whether the presence of challenging particles, as identified during RSD Limits of Performance testing, affect the reliability of the sampler to quantify other solids in the flow loop. Additionally, the RSD platform will utilize the Ultrasonic PulseEcho system to measure critical slurry velocities between 2 ft/s and 6 ft/s. PulseEcho testing at RSD is follow-on to previous testing performed by PNNL at their PDL-East facility in Richland WA. Results of this testing can be found in PNNL-20350 *Hanford Tank Farms Waste Certification Flow Loop Phase IV: PulseEcho Sensor Evaluation.*

The technical approach for RSD System Performance testing will be refined as on-going and planned RSD test activities and other related work (e.g., simulant development) are completed. Additional test plan details, including an expanded discussion of the requirements for test equipment, simulants, operating parameters, test matrix, sample collection and data analysis will be provided in a future test plan.

Table 2-7: RSD System Performance Test Objectives

Objective	Success Criteria
Demonstrate, with different simulant compositions, the capability of the Isolok sampler to collect representative samples in the vertical configuration.	Isolok sampling tests in the vertical configuration are performed in the RSD flow loop with a base simulant that contains moderately sized (approximately 100 microns), dense particles to represent hard to transfer waste particles in the Hanford tank waste, a supernatant simulant and some challenging spike particles that are distinguishable in collected samples by size and another physical property (color, density, etc). Collected samples are analyzed for chemical composition and quantified relative to a full diversion sample. Sampler performance is evaluated against a 5% relative difference criteria. Correlations relating the relative difference between the Isolok samples and full diversion samples are evaluated with respect to the changes in the operating conditions.
Continue the evaluation of the Ultrasonic PulseEcho system for monitoring solid movement in the flow loop.	Identify critical velocity of simulants as measured with the PNNL Ultrasonic PulseEcho system to be within 0.1 feet per second (2.3 gallons per minute) of the critical velocity value determined through visual monitoring of the settled slurry.
Define operational steps for the Isolok sampler and describe functional requirement for supporting systems necessary for field deployment.	Develop operational protocols for the Isolok sampler system that allow consistent and integrated sample collection of HLW slurries coming from a mixed DST, and document results in a report. Identify field deployment considerations for the remote sampling system, based on the experience gained during the RSD activities.

3.0 TEST REQUIREMENTS

Test requirements and test guidance have been developed to meet the SSMD Solids Accumulation Scouting studies, SSMD Limits of Performance, RSD Limits of Performance, and Full-Scale Transfer Pump Limits of Performance test objectives and technical approach identified in Section 2.0. Test requirements and test guidance has not been developed for SSMD Scaled Performance, RSD System Performance and SSMD Solids Accumulation Performance Evaluation as the test conditions for these activities will be determined by on-going test activities or other activities that are under development. Separate test plans will be developed for these activities at a later date.

In addition to this and future test plans, each testing contractor will develop operational procedures that include or reference the test configuration, test objectives, test requirements and provisions for assuring that prerequisites and suitable environmental conditions are met, adequate instrumentation is available and operational, and that necessary monitoring is performed.

3.1 TEST SIMULANTS

The simulants used for WFD Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies test activities are based upon guidance documented in RPP-PLAN-51625. Simulant selection considers parameters (e.g., particle size, density, viscosity and yield stress) important to solids accumulation and mixing, sampling and transfer performance. Simulant properties, such as hardness, that are important to evaluating erosion and wear of the tank and pipe walls and the mixing and transfer equipment are not primary considerations for understanding the capability of the system to accumulate solids and mix, sample and transfer large and dense particles. However, simulant selection does favor materials that result in less wear on the test equipment when alternatives that match the critical characteristics are available.

Simulant procurement, preparation and simulant property data collection are performed to enhanced quality assurance standards as defined in TFC-ESHQ-Q_ADM-C-01, *Graded Quality Assurance*. As such, additional level of controls beyond the providers published or stated attributes of the item, service, or process are needed to verify critical attributes of the simulants. Simulant materials procured as commercial grade items shall be prepared and qualified to match the critical characteristics of the simulants. The critical characteristics for the Newtonian base simulant and spike materials are the particle size distribution and density of the materials. The particle size distributions and densities of the components in the composite slurry are used to calculate performance metrics (e.g., distribution of Archimedes numbers) for the composite to qualify the simulant for use. For the supernatant, the critical characteristics are the liquid density and liquid viscosity. For Non-Newtonian simulants the critical characteristics are yield stress and density. To qualify the supernatant and non-Newtonian slurry for use, the critical characteristics will be measured when the simulant batches are prepared.

Newtonian simulant batches of base material, spikes and supernatant are prepared according to prepared recipes. By specifying the mass fraction of each solid component (base and spikes), the density of each solid component, the density of the supernatant, the solids loading and the batch volume, the required amounts of each solid component are fully defined. Supernatant and non-

Newtonian slurry recipes are determined from test batches prepared to match the critical characteristics.

3.1.1 The base simulant, supernatant simulant and spike particles for Newtonian simulants and the non-Newtonian simulant described in this test plan are described below. Selection and justification of the simulants to be used in each test activity are provided in the test requirements for each test activity. Base Simulant

3.1.1.1 Base Simulant Description

The base simulant is the mixture of solid particles in the Newtonian slurry representing the Hanford tank waste. RPP-PLAN-51625 recommends three base simulants for WFD Mixing and Sampling Program test activities, Low Conceptual, Typical Conceptual, and High Conceptual. The Low Conceptual base simulant is a single component base composed of gibbsite particles. The Typical Conceptual and High Conceptual base simulants are complex simulants composed of gibbsite particles, sand particles, zirconium oxide particles, and stainless steel particles. Differences in recommended particle sizes of gibbsite and sand, as well as, differences in the mass fractions of each component mixture distinguish the Typical and High Conceptual simulants. Table 3-1 provides the composition of the base simulants recommended in RPP-PLAN-51625. The selected base simulant used in each test is specific to the objective of the test and justified in the Test Simulants section of the test plan.

In addition, following the recommendations in RPP-PLAN-51625, tests will also be performed using a non-Newtonian slurry with a Bingham yield stress between 3 and 10 Pa. Tests requiring a non-Newtonian, cohesive slurry will be made from EPK kaolin clay. Based on initial laboratory work performed to develop simulant recipes at lab scale quantities, a non-Newtonian slurry with a yield stress of 3 Pa and a density of about 1.2 g/ml is obtained by adding 20-22 weight percent Kaolin to tap water. A non-Newtonian slurry with a yield stress of 10 Pa and a density of about 1.2 g/ml is obtained by adding 28-30 weight percent Kaolin to tap water. Test samples shall be prepared to confirm these quantities and the critical properties (i.e., the yield stress and density) of the test batch shall be confirmed prior to testing. Table 3-1 includes the properties for the non-Newtonian simulant. For a non-Newtonian slurry with a yield stress of 3 Pa and a higher density, sodium thiosulfate at 28 weight percent can be added to 16 weight percent Kaolin in tap water.

Based on the necessary accuracy needed to resolve the effect of the yield stress on the capability to transfer large and dense particles and time varying nature of a non-Newtonian simulant, Kaolin slurries with a targeted yield stress of 3 Pa are determined to be acceptable in the range of 2 to 4.5 Pa and slurries with a targeted yield stress of 10 Pa are determined to be acceptable in the range of 7 to 13 Pa.

Table 3-1: Base Particulate Simulant Characteristics

Newtonian Base					
Compound	Solid Density (g/cm^3)	Median Particle Size (micron)	Mass Fraction		
			Low	Typical	High
Small Gibbsite	2.42	1.3	1.00	0.27	0
Large Gibbsite	2.42	10	0	0.44	0.03
Small Sand	2.65	57	0	0	0.35
Medium Sand	2.65	148	0	0.13	0
Large Sand	2.65	382	0	0	0.21
Zirconium Oxide	5.7	6	0	0.10	0.08
Stainless Steel	8.0	112	0	0.06	0.33
Non-Newtonian Base					
				Yield Stress	
			Slurry Density (g/cm^3)	3 Pa	10 Pa
Kaolin clay	NA	NA	1.2	20 wt%	28 wt%
Kaolin clay w/ sodium thiosulfate	NA	NA	1.37	16 wt% Kaolin 28 wt% sodium thiosulfate	TBD

3.1.1.2 Base Simulant Qualification

As described in RPP-PLAN-51625, particle size distributions, particle density and mass fractions of the components in the composite simulant can be used to determine the distributions of Archimedes numbers and jet velocities needed to achieve a certain degree of solid suspension for the composite simulant. As discussed in PNNL-20637, the Archimedes number is closely related to the settling velocity and is also a parameter in other mixing and transfer metrics such as pump intake, jet suspension velocity, critical shear stress for erosion, critical suspension velocity, suspended particle cloud height and pipeline critical velocity. The jet velocity needed to achieve a certain degree of solid suspension comparison correlates the particle size and density to the jet velocity of a radial wall jet needed to suspend solids in a tank. Base simulant qualification is performed by comparing the distribution of Archimedes numbers and jet velocities needed to achieve a certain degree of solid suspension calculated for the procured simulants to the distributions documented in Figures 8-1 and 8-2 in RPP-PLAN-51625. To provide comparable results, performance metrics are calculated using the same assumptions used to calculate the metrics for the three conceptual simulants. Metrics are calculated using particle densities and particle size distributions obtained on samples from each procured lot. The particle size distribution provided by the vendor is not adequate for simulant qualification. Appendix C of RPP-PLAN-51625 includes additional performance metrics, such as the critical shear stress for erosion of non-cohesive particles, just suspended impeller speed, pulse jet mixer critical suspension velocity for non-cohesive solids, pulse jet mixer cloud height for non-cohesive solids and pipeline critical transport velocity. The procured material will also be compared to the conceptual simulants using these metrics.

The metrics calculated for the conceptual simulants in RPP-PLAN-51625 include typical distributions for some of the components. Therefore, the calculated values represent target values and deviations from the conceptual simulants are anticipated. The appropriateness of candidate material will be evaluated before simulant procurement. For procurement purposes, in absence of samples from actual lots, vendor supplied information (e.g., particle size distributions and particle density) and targeted mass fractions can be used to calculate the performance metrics for comparison to the conceptual simulants. For simulant qualification, calculations will be based on laboratory analysis of samples taken from the procured material and actual weight measurements recorded during testing.

Tests using a non-Newtonian slurry with a Bingham yield stress between 3 and 10 Pa will be made from EPK kaolin clay. The yield stress will be measured to be within 0.5 Pa of the target value prior to testing. The yield stress measurements will be performed on-site with a rheometer calibrated in accordance with Requirement 12, Control of Measuring and Test Equipment, in ASME NQA-1-2004 including addenda, or a later version. Data collection shall be performed in accordance with Requirement 11, Test Control in ASME NQA-1-2004 including addenda, or a later version. Yield stress measurements will be collected prior to the start of testing to ensure that the time varying qualities of the non-Newtonian slurry do not change significantly before testing is initiated. In addition, yield stress will also be measured at the completion of testing, and during testing if necessary, to assess rheological changes that may occurring during the course of testing.

3.1.2 Supernatant Simulant

3.1.2.1 Supernatant Simulant Description

The supernatant simulant is the liquid phase of the simulant slurry. For WFD Mixing and Sampling Program test activities, RPP-PLAN-51625 recommends four supernatant simulants, which are characterized by liquid density and liquid viscosity. The four supernatant characteristics are taken from Table 6-1 in RPP-PLAN-51625, which is summarized in Table 3-2. Table 3-2 also provides the weight percentages of the components that can be used to produce the targeted characteristics. These compositions are informed from chemical handbooks and previous testing and were confirmed by preparing test batches at a laboratory scale. The tabulated supernatant simulants are limiting supernatants and were developed for testing activities that attempt to mobilize large and dense particles. The selected supernatant simulant used in each test is specific to the objective of the test and justified in the Test Simulants section of the test plan. The target density and viscosity will be achieved by adding sodium thiosulfate, or other readily available sodium salt (e.g., sodium bromide), to water to achieve the targeted density. Glycerol will be added as necessary to increase the viscosity to the targeted value required for testing.

A typical supernatant is also considered to represent when it is not necessary to evaluate the capability of the test system to mobilize large and dense particles (i.e., Solids Accumulation Scouting Studies). The liquid density for the Typical supernatant is the median density from the same dataset used to derive the low and high density values in RPP-PLAN-51625. The dataset is the liquid density of the feed batches to the WTP calculated using the Hanford Tank Waste Operations Simulator model (RPP-RPT-48681, *Hanford Tank Waste Operations Simulator Model Data Package for the River Protection Project System Plan Rev. 6 Cases*). The typical supernatant is characterized as having a liquid density of about 1.29 g/ml ±5% and a liquid viscosity of 3.3 ±1 cP. The viscosity of the supernatant is determined by the salt used to attain the desired density and is comparable to the value determined using the relationship in Figure 6-2 of RPP-PLAN-51625. An aqueous solution of 31.5 weight percent sodium thiosulfate will produce a supernatant with these characteristics.

Table 3-2: Newtonian Liquid Supernatant Simulant Characteristics

Supernatant	Liquid Density (g/ml)	Liquid Viscosity (cP) @ 20°C	Aqueous Solutions
Low Density / Low Viscosity	1.1	1	12 wt% Sodium bromide or Sodium Thiosulfate
Low Density / High Viscosity	1.1	8	55wt% glycerol
High Density / Low Viscosity	1.37	1	37 wt% sodium bromide
High Density / High Viscosity	1.37	15	33.5 wt% sodium thiosulfate and 19.9 wt% glycerol
Typical Density and Viscosity	1.29	3.3	31.5 wt% sodium thiosulfate

3.1.2.2 Supernatant Simulant Qualification

The simulant recipe for the supernatant simulant was developed in the laboratory but will need to be scaled to the volume needed for each test. Small test batches will be prepared to confirm the relative amounts of each constituent needed to achieve the targeted results using the procured materials at testing conditions. Test batches shall be within 5% of the target density and within 20% of the target viscosity. Then scale up to testing volumes will be performed and the liquid density and liquid viscosity will be measured to confirm that the prepared batch is within the required range for liquid density and viscosity. For low density and low viscosity fluids, 1.1 g/ml and 1 cP, respectively, the acceptable range of liquid densities is ±5% and 0.5 cP. The low density and low viscosity liquid will be attained using sodium thiosulfate and the two properties cannot be adjusted independently using the single component so a broader tolerance is allowable for liquid viscosity. For higher density and viscosity fluids the acceptable range for the density is ±5%. The tolerance on the liquid viscosity at levels above 5 cP is ±20% when the measurement is determined at testing temperatures. High viscosities will be attained by adding glycerol. The viscosity of glycerol is dependent on concentration and temperature, increasing as concentration increases and temperature decreases. For a specified concentration, a temperature correlation will be developed so that the viscosity at the measured temperature can be used to evaluate the viscosity at the testing temperature to determine if the prepared simulant meets the 20% tolerance on viscosity. The liquid property measurements will be measured on-site with the appropriate instrumentation (e.g., hydrometer, viscometer, rheometer) calibrated in accordance with Requirement 12, Control of Measuring and Test Equipment, in ASME NQA-1-2004 including addenda, or a later version. Data collection shall be performed in accordance with Requirement 11, Test Control in ASME NQA-1-2004 including addenda, or a later version. To ensure that the prepared simulant is appropriate for use, liquid properties will be measured prior to adding base simulant solids and therefore will be performed at the start of testing.

3.1.3 Spike Particulates

For Limits of Performance test activities, additional particles will be added (spiked) to the simulant slurry consisting of the base simulant and the liquid supernatant. For Solids Accumulation Scouting Studies, the very fast settling solids are accounted for in the stainless steel base material and no supplemental spiking material is necessary. RPP-PLAN-51625 recommends four materials for the spike particulates, sand, stainless steel, tungsten carbide grit (WC), and tungsten grit. Sand is a simulant for large particles that have a density comparable to the average density of Hanford waste particles. Stainless steel, tungsten carbide and tungsten, which have densities of approximately 8 g/ml, 14 g/ml and 19 g/ml, respectively, are simulants for high density plutonium containing compounds (e.g., plutonium oxide (~11 g/ml)) in the Hanford tank waste. The sand and stainless steel spike particulates are chemically similar to the components in the base simulant and therefore must be distinguishable from the base materials in order to be quantified. The spike materials will be distinguishable by particle size; size exclusion (e.g., sieving) will be used to separate the spike particles from the chemically similar base material.

Table 3-3 identifies the spike materials for Limits of Performance testing. Procured samples of very large sand material (>7000 microns silica) were irregularly shaped and had a broad particle size distribution despite being classified by sieving to a single sieve size. Borosilicate glass or soda-lime glass spheres will used as a surrogate for very large sand particles. The glass spheres are chemically inert, have a density similar to sand but have consistent sizes in 1,000 micron increments because they are manufactured products. Having a consistent shape will facilitate separation of the spike particles by sieving.

The sizes of the glass, stainless steel and tungsten carbide spike particulates are for spheres, which are readily available in the sizes listed. Consistent with recommendations in SRNL-STI-2012-00062, spherical particles are considered because, compared to irregularly shaped particles with more surface area per volume, spherical particles would settle faster from suspensions, creating a greater challenge to mix, transfer and sample challenging particles. The spike particles listed are commercially available items that have an industrial purpose and are manufactured to size tolerances that exceed the tolerances necessary to distinguish the different sized spike particles by sieving. Commercial sources for the listed particles manufacture the particles in either 1/32-inch or 1/16-inch increments for metal spheres and 1mm increments for glass spheres with size variations that typically do not exceed a several microns. Qualification of the spike particles is limited to demonstrating that 99.9% of a one pound sample taken from each delivered lot is retained on the sieve used to separate that size from the other particles.

The spike materials listed in Table 3-3 have densities characteristic of Hanford tank waste and are provided for test planning purposes; the densities of procured spike materials may be different due to differences in manufacturing processes. Table 3-3 also includes two properties that are relevant to mixing, the Archimedes number and the free settling velocity. The tabulated Archimedes numbers, Ar, are calculated according to Equation 2-1. The Archimedes number indicates general settling characteristic, particles with higher Archimedes values tend to settle faster than particles with lower Archimedes values. The reported values are calculated for the high density (1.37 g/ml) and high viscosity (15 cP) supernatant. The tabulated free settling velocity, V_t, is calculated in the same supernatant liquid according to Equation 2-2. The free settling velocities result in Reynolds numbers, Re, (Equation 2-3) in the Intermediate Law regime (between 0.3 and 1000).

$$Ar = \frac{\left(\frac{\rho_s}{\rho_l} - 1\right) g d^3}{\upsilon^2} \qquad \text{Equation 2-1}$$

$$V_t = \left(\frac{4gd(\rho_s - \rho_l)}{3\rho_l \left(\frac{18.5}{Re^{0.6}} \right)} \right)^{0.5} \qquad \text{Equation 2-2}$$

$$Re = \frac{\rho_l V_t d}{\mu} \qquad \text{Equation 2-3}$$

where ρ_s is the particle density, ρ_l is the liquid density, g is the gravitational constant, d is the particle diameter, ν is the kinematic viscosity of the liquid and μ is the dynamic viscosity of the liquid. The selected spike particulates, including particle size and spike concentration, used in each test are specific to the objective of the test and justified in the Test Simulants section of the test plan. Alternatives to the spike materials require the concurrence with the TOC technical representative(s) before the material is procured.

Table 3-3: Limits of Performance Simulant Spike Candidates

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)	Archimedes Number [1]	Free Settling Velocity (ft/s) [1]
Very Large Sand or Gravel	2.65	1500-9510	258-65,700	0.24-1.0
Borosilicate Glass	2.23	1000 2000 3000 5000 7000	51.4 411 1390 6420 17,600	0.14 0.25 0.34 0.51 0.67
Soda-Lime Glass	2.52	1000 2000 3000 5000 7000	68.7 540 1820 8430 23,100	0.16 0.28 0.39 0.59 0.77
Stainless Steel (SS)	8.0	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")	1580 12,700 42,800 101,000	0.58 1.0 1.4 1.7
Tungsten Carbide (WC)	14.2	1587.5 (1/16") 2380 (3/32") 3175 (1/8") 4762.5 (3/16") 6350 (1/4")	3070 10,300 24,500 82,800 196,000	0.80 1.1 1.4 1.9 2.4

[1] Calculated for a fluid having a liquid density of 1/37 g/ml and a viscosity of 15 cP.

3.2 LIMITS OF PERFORMANCE

3.2.1 Small Scale Mixing Demonstration

SSMD Limits of Performance test activities documented in Section 3.2.1 are performed by Energy*Solutions* for WRPS. This test plan does not identify specific test requirements for development work that has been performed to investigate appropriate spike particulates to use for testing; however, a description of the preliminary work is provided for information in Section 3.2.1.1.

3.2.1.1 Development Activities

Preliminary studies have been performed with particles having very high values for particle size and density in a non-prototypic mixing environment to determine the capability of the SSMD 1:8-scale transfer pump to deliver large and dense solids to a sample location downstream of the transfer pump. Although this transfer pump is not prototypic of the submersible pump anticipated to be used to transfer waste to the WTP, understanding the limits of the current transfer pump can be used to assess the limits of the entire 1:8-scale mixing platform. In the event that large and dense particles included in the mixing test are not recovered in transfer batch samples withdrawn from the mixing tank, it can only be concluded that the mixing performance is inadequate to deliver these particles to the transfer system if it is known that the transfer system is capable of conveying the particles to the sample collection location.

Evaluating the capability of the transfer pump from the 1:8-scale system was performed using a simplistic test set up (i.e., without filling the SSMD platform 120-inch diameter mixing tank). The transfer system of the 120-inch diameter mixing tank in the SSMD test platform at the Monarch Machine and Tool facility in Pasco, Washington was placed into an auxiliary vessel and operated at approximately 2.8 gpm, the scaled transfer rate for the 1:8-scale system. The operating flow rate resulted in a flow velocity of approximately 11.7 ft/s through the 5/16-inch diameter pump suction inlet, which was mounted at the scaled height of 0.8 inches above the tank bottom.

For developmental testing, the spikes were added to a vessel filled with water and the transfer pump suction was brought to operating conditions. Table 3-4 lists the spike materials that were included in the preliminary tests. The Archimedes Number and free settling velocity are calculated using Equations 2-1 through 2-3 for a supernatant having a density of 1.37 g/ml and a viscosity of 15 cP. All particle settling occurs in the Intermediate Law regime. The list of spike particles tested exceeded what is recommended as spike particulates in RPP-PLAN-51625, but evaluating multiple components built confidence that the right particles would be selected for testing. With the exception of the sand/silica, which was irregularly shaped, the spike particles were spherically shaped. Mixing was started and the particles that were entrained in the pumpage were captured in a trap and quantified.

Mixing in the auxiliary vessel was implemented using different methods including no mixing, mixing using a paint mixer attached to a portable drill and mixing using simulated jets. Testing progressed from the no mixing condition, to the paint mixer condition, to the simulated jet mixing condition. The static condition resulted in very few large particles being transferred when the transfer pump suction inlet height was set at the scaled height. Mixing using paint mixer resulted in vortexing and was not prototypic. Mixing using the simulated jets attempted to result in a "representatively mixed" conditions within the vessel. In this usage, "representatively mixed" means that the particles in the vicinity of the transfer pump suction should have had a velocity and direction that is similar to that anticipated in the 120-inch diameter test tank. For static conditions, the pump suction inlet height was lowered until particle transfer occurred and the height at the time of transfer was recorded.

Table 3-4: Preliminary SSMD Limits of Performance Simulant Spike Candidates

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)	Archimedes Number[1]	Free Settling Velocity[1]
Very Large Sand / Silica	2.7	7000 8000	27,200 40,700	0.83 0.93
Borosilicate	2.23	3175 (1/8")	1640	0.36

Glass		4762.5 (3/16")	5550	0.49
		6350 (1/4")	13,200	0.62
Stainless Steel	8.0	1587.5 (1/16")	1580	0.58
		3175 (1/8")	12,700	1.0
		4500	36,100	1.3
		4762 (3/16")	42,800	1.4
		6350 (1/4")	101,000	1.7
		7938 (5/16")	198,000	2.8
Tungsten	19.0	7200	393,000	3.1
		7800	500,000	3.3
Copper	8.9	4500	41,000	1.4
Aluminum	2.7	2381.25 (3/32")	1070	0.35
		3175 (1/8")	2540	0.443

[1] Calculated for a fluid having a liquid density of 1/37 g/ml and a viscosity of 15 cP.

The results of the static tests showed that even the largest, most dense particle tested, 7800 micron tungsten spheres, could be entrained in the pump suction if the pump suction was close enough to the particle (approximately 0.3 inches) but that no particle larger than ¼-inch in diameter was transferred when the transfer pump suction inlet height was equal to the scaled height of 0.8 inches. Smaller particles with densities up to 9 g/ml were transferred at the scaled height. Using drill mixing, the large silica could be transferred when the pump suction inlet was placed at the scaled height. When jet mixing was used to create a representatively mixed tank, no transfer of ¼-inch stainless steel or tungsten spheres was observed when the pump suction inlet was placed at the scaled height. The preliminary test results suggest that the largest stainless steel sphere to be used in the SSMD Limits of Performance testing should be ¼--inch spheres and that tungsten sizes could be constrained to even smaller diameters.

Once the capability of the transfer system was established, with respect to simulant spike particle size and density, the transfer system can be used to assess the capability of the fully-integrated 1:8-scale mixing and transfer system.

3.2.1.2 Test Equipment and Instrumentation

Fully integrated 1:8-scale testing will be performed using the SSMD test platform at the Monarch Machine and Tool facility in Pasco, Washington. A schematic of the SSMD test platform is shown in Figure 2-2. The SSMD test platform has been used for previous test activities and will continue to be used to address uncertainties in the WFD Mixing and Sampling Program. The SSMD test platform was constructed to perform mixer jet pump testing at two different scales, approximately 1:21 (43.2-inch diameter tank) and 1:8 (120-inch diameter tank). The 1:8-scale tank is appropriate for limits of performance testing. Due to much smaller transfer pipe diameters (1/4" as shown in Table 1-1), which are likely to be smaller than the largest particle that can be transferred, the smaller scale tank is not appropriate for limits of performance testing to determine the largest size of a dense particle that can be transported from the mixing tank.

The SSMD test platform has been used previously for SSMD testing work and will continue to be used without significant modifications to assess the capability of the system to mix tank waste simulants and deliver the solids to a receipt tank. SSMD Limits of Performance testing shall utilize the 1:8-scale system. The main components of the test platform include: a 3,000 gallon flush tank, a 2,358 gallon clear acrylic test tank (TK-301), the dual rotating mixer jet pump assembly and the slurry transfer pump. The slurry transfer pump is not a submersible pump located inside TK-301. The slurry transfer pump is a progressive cavity pump located outside of the test tank; the inlet of the pump is connected to a suction line that is placed within the tank. The end of the suction line inside the tank is fitted with a machined orifice matching the requirements in Table 1-1. Scaled dimensions for TK-301 are also provided in Table 1-1. Ancillary equipment, such as the support structure, the control system, video monitoring and simulated piping to transfer the material from the tank are also part of the test platform. The test system shall be configured similarly to previous SSMD test activities using the 241-AY-102 configuration. Mixing in TK-301 shall be performed using two rotating mixer jets, each having two opposing nozzles placed near the tank bottom. The transfer pump suction inlet shall be placed consistent with the location of Riser 30 and the scaled height of the pump suction inlet should be equivalent to the height of the transfer pump inlet in the full-scale DST transfer system, 0.8 inches (see Table 1-1).

The transfer system piping, valving, and instrumentation (e.g., in-line Coriolis meters, and magnetic flow meters) should replicate the transfer system from previous testing reported in RPP-49740. The test configuration shall include a closed recirculation loop from the tank. The recirculation loop shall accommodate sample collection. Flow control shall be automated using programmable logic controllers connected to a human–machine interface. System data, including flow conditions and specific gravity measurements, shall be monitored and recorded using a data acquisition system.

The internal passage way of the transfer pump is larger than the transfer line; therefore, large and dense particles that can be captured and transferred may settle in the pump because the velocity through the pump is reduced below the critical velocity of the particles. To prevent the buildup of large and dense particles in the pump, the transfer line upstream of the pump inlet shall be modified to include a particle collection trap. The trap will increase the cross sectional area of the transfer line to reduce the transfer velocity through the trap, allowing the large and dense particles to settle to the bottom of the trap. The trap shall accommodate emptying without requiring that the transfer operation be stopped. Downstream of the transfer pump, slurry shall be discharged through a No. 14 or No. 16 screen to separate the spike particles from the base material. When operating in a recycling mode, the base material that passes through the screen shall be discharged back into the tank. When operating in batch transfer mode, the base material that passes through the screen is sent to waste collection. The spike particles retained by the screen shall be collected and segregated by cascading sieves (see Section 3.2.1.5) to separate the different sized particles. The particles collected in the trap shall also be introduced to the cascading sieves for quantification. The amount of each spike transferred shall be quantified by counting or by weighing the separated material after it has been washed and dried. The quantity of the transferred spikes shall be recorded.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented in a test log.

3.2.1.3 Test Simulants

The simulants used in the SSMD Limits of Performance testing are selected in accordance with the recommendations in RPP-PLAN-51625. Simulant properties and qualification is described in Section 3.1. Selecting particular simulants for SSMD Limits of Performance test activities is discussed below. The test matrix showing the combinations of base simulant, liquid supernatant and spike particulates is discussed in Section 3.2.1.4.

The SSMD Limits of Performance simulants shall include Newtonian and non-Newtonian simulants spiked with large and dense particles. The Newtonian simulant shall be a complex simulant containing base particulates and spike particulates. The liquid phase shall be a supernatant simulant. The non-Newtonian simulant will be kaolin clay with spike particulates. Sodium thiosulfate will be added to increase the density of the non-Newtonian slurry when required in the test matrix. Recipes for the simulants discussed below are tabulated in Table 3-1 and Table 3-2.

The effect of the base simulant on the capability of the system to transfer large and dense particles has not been previously investigated using the recommended simulants; however, it is expected that the presence of solids in the slurry should hinder settling which could enhance waste transfer if the spike particulates become suspended by the rotating mixer jets. Two base simulants are selected for evaluating the effect of the base simulant on the capability of the system to transfer large and dense particles. Figure 8-10 in RPP-PLAN-51625 provides for selecting two of the three conceptual simulants recommended in RPP-PLAN-51625. The figure suggests that changes in the base simulant composition will influence the movement of the spike particles. Although the basis for the metric shown in the figure is developed for impeller mixed tanks using the Zweitering correlation, the functional form for similar metrics for jet mixed systems (i.e., the jet velocity needed to achieve a certain degree of solid suspension (Equation 2.9 in PNNL-20637)). Excluding the properties of the tank or mixing system, the exponential dependence on the fluid properties (kinematic viscosity, liquid density) and particle properties (density, size and mass loading) are similar; when the two equations are compared to one another, the exponents on these terms vary by 0.13 or less. The calculation provided in Figure 8-10 of RPP-PLAN-51625 suggests that the Low Conceptual simulant should have the greatest capability to transfer large and dense particles and that for a specific power input there is very little difference in the spike transfer capability of the Typical and High Conceptual simulants. If there is sufficient mixing energy introduced into the tank to suspend all the material, the additional large sized base material in the High Conceptual simulant may hinder settling of the spike particles, which could promote spike particle transfer over the other simulant bases. On these bases, SSMD Limits of Performance testing will utilize the Low Conceptual and High Conceptual simulants to quantify the effects of each on the capability of the system.

Conducting tests with the Low and High Conceptual simulants is also consistent with the high uncertainty in the characterization of Hanford tank waste, especially as it is blended and staged for waste feed delivery to the WTP. The two base simulants that have a broad distribution of Archimedes numbers and using these two limiting cases is appropriate for Limits of Performance testing because much of the Hanford waste is uncharacterized with respect to particle size and density distributions and that which has been characterized suggests a wide distribution of Archimedes numbers for tank waste. Evaluating the effect of the limiting cases reduces the risk that uncharacterized waste could have a capability that has not been quantified.

To investigate the effects of solids loading, two base simulant loadings, high and low, will be investigated during SSMD Limits of Performance testing. For the high loading, the weight percent shall be 15% and is based on the ICD-19 allowable limit of 200 g/l. For the Low Conceptual simulant in the Low density supernatant the solids loading is approximately 207 g/l when 5 weight percent spike solids are added to the base. For the High Conceptual simulant in the High density supernatant the solids loading is approximately 227 g/l at the same spiking level. The resulting slurry density ranges between 1.38 g/l and 1.51 g/ml, the latter being slightly above the action level identified in ICD-19. A second, low loading weight percentage is based on a feed solids composition of 125 g/l. A mass loading of 9 weight percent yields a solids concentration between 120 and 130 g/l, depending on the base simulant and supernatant composition selected. The resulting slurry density ranges between 1.34 g/l and 1.45 g/ml.

To investigate the effects of the supernatant density and viscosity, two supernatant compositions will be investigated, high and low. For the high supernatant, the targeted slurry density is 1.37 g/ml and the targeted liquid viscosity is 15 cP. The targeted values are consistent with the high density / high viscosity recommendation in Table 3-2 and have an acceptable tolerance of 5% for the liquid density and 20% for the liquid viscosity. Liquid viscosity tolerance is evaluated at the operating temperature of the test tank if the temperature of the sampled material differs from the bulk volume. The high values for liquid density and liquid viscosity are selected because higher densities and higher viscosities are expected to increase the buoyancy effecting solid particles in the mixing tank and reduce critical suspension and settling velocities. Increasing buoyancy and subsequently reducing the critical suspension velocity and settling velocities is expected to promote particle suspension, facilitating the movement of large and dense particles to the transfer pump suction inlet. To confirm this expected correlation, a second supernatant simulant with a lower density and viscosity will be evaluated. The targeted slurry density for the low supernatant is 1.1 g/ml and the targeted liquid viscosity is 1 cP. The selected quantities are equivalent to the Low Density / Low Viscosity supernatant listed in Table 3-2. For the Low supernatant, the acceptable tolerance on the density is ±5% and the acceptable tolerance on the viscosity is 0.5 cP.

In addition, tests shall be performed using a non-Newtonian slurry with a Bingham yield stress of 3 Pa ±50%. A high tolerance is added to the yield stress measurement because of dynamic changes in the slurry viscosity as it is prepared and mixed. A non-Newtonian test should be used to verify the expectation that slurries having a yield stress result in better batch transfer of spike particulates, as reported in SRNL-STI-2011-00278, *Demonstration of Mixing and Transferring Settling Cohesive Slurry Simulants in the AY-102 Tank.* For verification tests requiring a non-Newtonian, cohesive slurry kaolin clay shall be used to increase the yield stress of the simulant to values up to 3 Pa, as measured at the beginning of testing. Supplemental measurements should be taken to monitor changes in the slurry as mixing progresses. With the expectation that higher yield stresses should facilitate the movement of larger and denser particles, the 3 Pa limit was selected because it is similar to values that have been used in mixing tests in the past and is expected to be manageable in the 120-inch diameter tank. A 3 Pa kaolin mixture has a density around 1.15 g/ml, which means that the fluid density would be comparable to the Newtonian low density supernatant. For comparisons to higher density, Newtonian supernatants, sodium thiosulfate will be added to a kaolin slurry to increase the slurry density, without spikes, to 1.37 g/ml ±5%. Yield stress measurements should be performed prior to testing and at subsequent startups if the slurry is idle for more than 8 hours in between testing.

The spike material representing the large and dense particles should be composed from lots of solids having a very narrow distribution range so that all of the particles from a single lot are essentially the same size. The spike particulates included in each test include multiple sizes of particles at two different densities. The size increments for each particle type are at least 1000 microns so that the particles can be readily separated by sieving on-site. Having multiple sizes of particles allows for positive confirmation that smaller particles can be transferred when larger particles are not transferred. This allows for an estimation of the capability limit of the system. Furthermore, to reduce the number of tests that need to be conducted, two different density materials (of multiple sizes) shall be included in each test. The spike particulates added in each test have a different density so that differences in density and differences in sizes transferred can be used together to assess the limits of the integrated mixing and transfer system. Differences in particle density may also facilitate the separation of the spike particulates for quantification. The largest particles of high spike particulates are those that could be conveyed during preliminary test activities. Smaller particles are also be included. Table 3-5 provides the composition and particle sizes for the simulant spikes. Soda-lime glass is selected as a spike material instead of sand, one of the recommended spike materials in RPP-PLAN-51625, because it has a comparable density to sand and the spherical shape will facilitate separation of the different sized particles by sieving. Furthermore, glass spheres are available in size increments that are different from the stainless steel or tungsten carbide spheres so that different sieve sizes can be used to segregate the material (see Section 3.2.1.5).For tests including a non-Newtonian simulant, kaolin clay is spiked with the same particle types and masses used in comparable Newtonian tests .

The quantity of the spike particles added to the test tank shall initially be 5 weight percent (total) of the solids and may need to be increased prior to the first transfer if the observed movement of the particles suggests that there is a very low probability of mobilizing the solids to the transfer pump suction inlet. Figure 8-10 in RPP-PLAN-51625 provides the basis for choosing a spike loading between 1 and 10%. The result suggests that for impeller mixed systems, or similarly jet mixed systems as described previously, the mixing power necessary to suspend a certain sized particle does not change significantly when the spike loading is changed from 1% to 10%. Although the required energy changes for different base materials and different sized spike particles, a spike loading between 1 and 10% does not change the dynamics of the system considerably. Ideally, the mass distribution of particle sizes in the specified mass loading would represent the expected distribution of the waste. A review of the data reported in PNNL-20646 indicates that tank waste samples tend to have few very large particles (>1000 microns) and more moderate sized particles (10s to 100s of microns). Two allocation methods that result in greater number of smaller spike particles compared to the largest spike particles would be to equate the masses of each represented size or distribute the masses in proportion to the ratio of the particle diameters. In the latter approach, a system with 1/16-inch, 2/16-inch, 3/16-inch and 4/16-inch spike particles uses weight percentages of 10%, 20%, 30% and 40% for the particles, respectively. Comparing the two techniques, the latter approach reduces the number of the smallest particles and increases the number of larger particles over the former. This method is preferred because it increases the number of the largest spike particles relative to the equal mass method. Increasing the number of the largest spike particles increases the probability capturing a representative number of the larger particles. Using the preferred method 2.5% weight percent tungsten at the lowest solids loading level (9%) and four size particles places more than 5000 ¼-inch diameter, tungsten carbide spheres into the tank during each test. The number of ¼-inch diameter spheres included in each test increases for the less dense materials.

Table 3-5: SSMD Limits of Performance Spike Simulant

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)
Soda Lime Glass	2.52	200030005000 7000
Stainless Steel (SS)	8.0	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")
Tungsten Carbide Grit (WC)	14.2	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")

3.2.1.4 Operating Parameters and Test Methods

The operating conditions for the SSMD Limits of Performance testing should be consistent with previous SSMD performance testing. The mixer jets shall rotate continuously with no rotational offset between mixer jet pumps, the streams will be synchronized to meet in the center of the tank. The rotational speed of the jets (ω) shall be set in accordance with Equation 1-3, but mixing performance using two different nozzle velocities shall be evaluated. The nozzle velocities used in the capability testing shall be scaled according to the Full-Scale flow rate of 5,200 gallons per minute per nozzle using Equation 1-2. The values for the scale factor exponents (1/3 and 1/5) are the consensus path forward recommendations for the starting point for Scale-Up testing from the SSMD Workshop held in Richland, WA in October 2011 (Table 3.0 WRPS-1105293, *Small Scale Mixing Demonstration Optimization Workshop Meeting Minutes*). The scale factor exponents are the selected values to be used to determine the nozzle velocities during batch transfers. Prior to performing batch transfers the system will be operated in a recirculation mode to gather limit of performance data under different operating conditions that include nozzle velocity variations.

It is anticipated that the very fast settling spike particulates may collect in the "dead zones" that are formed if the nozzle velocity is insufficient to clear the bottom. If all of the spike particles are stuck in the accumulating piles, then it would indicate that the operating conditions would not promote the transfer of the spike particulates even though it may be possible for the transfer pump to capture and convey the spikes. Previous experience shows that pile dynamics (i.e., formation of "dead zones") is highly dependent on the nozzle velocity and whether or not the rotation of the mixer jets is synchronized, offset or fixed. For Limits of Performance testing, piles could trap the spike particles rendering them unavailable for transport. In order to evaluate the role of pile dynamics, different pile conditions will be evaluated. Pile formation for the Low Conceptual simulant is expected to be minimal because the base material is small, low density gibbsite particles which are readily suspended in the tank. For the High Conceptual simulant the effect of pile dynamics will be investigated by changing the size of the piles through changes in the nozzle velocity of the mixer jets. Prior to performing batch transfers that remove material from the tank, the system shall be operated in a recirculation mode and the nozzle velocity shall be varied to determine which spike particulates are conveyed by the integrated system at the prevailing nozzle velocities. Nozzle velocities shall initially be set according to a scale factor exponent value of 1/3 and then be gradually increased, allowing time for mixing to distribute the solids throughout the tank. Previous operator experience indicates that approximately 10-20 rotations of the mixer jets pumps is sufficient to result in a stabilized state, therefore the minimum number of revolutions of the mixer jets to collect particles at each velocity shall be 20 rotations.

As discussed previously in Section 3.2.1.2, the particles shall be collected downstream of the transfer pump suction inlet. The capture system shall be operated to minimize the amount of the base simulant withdrawn from the system during spike particulate collection in the recirculation mode. After the minimum number of mixer jet rotations have been realized, the number of spike particles transferred of each size and density shall be separated using the cascading sieves and quantified by either counting the recovered particles or washing, drying and weighing the collected particles. After the material is quantified, the material shall be returned to the tank for testing at the next nozzle velocity. The quantity of each particulate size and density shall be recorded in a test log along with the operating conditions and duration allowed for data collection. The nozzle velocity shall be incremented and the quantity of spike particulates should be similarly quantified over an equivalent duration. The test is repeated at higher velocities until the largest and most dense particles are transferred or until no "dead zones" are observed during operations. If necessary, the transfer pump should be turned off to allow the tank to achieve a stable state before testing resumes.

In addition to evaluating the effects of changing the nozzle velocity, the effects of increasing the mass loading of the spike particles shall also be investigated in the recirculation mode. The weight percent of the spike particles shall start at 1/4 the targeted value (5 weight percent) and be incrementally increased until the targeted weight percent is attained. Similar to the velocity testing, transferred particles at each mass loading shall be quantified when a minimum of 20 mixer jet rotations is reached. The collected particulates shall be quantified as previously described and returned to the tank. Then the weight percent of the spike particles shall be increased and the system shall be allowed to reach the stable state before particle collection is resumed. When evaluating the effects of mass loading and nozzle velocity in the same test, the nozzle velocities shall be varied for each mass loading. Once the data for spike particulate transport for each nozzle velocity variation has been collected, the nozzle velocity is returned to the lowest setting and the mass loading is incremented for the next set of nozzle velocity observations. The cycle is repeated until the range of nozzle velocities is evaluated over the range of mass loadings.

The test activities investigating the correlation between nozzle velocity and mass loading does not need to be replicated for each Limit of Performance test and to the extent described. At a minimum, the nozzle velocity and mass loading investigation should be performed with the high density / high viscosity supernatant and the Low Conceptual simulant, these two properties are expected to be the most capable of transporting the most challenging particles. The extended testing is not necessary when the testing is replicated at a second nozzle velocity. Extended testing in recirculation mode can also be eliminated by concurrence from the technical representatives from Energy*Solutions* and the TOC. An example of when tests can be curtailed is when the largest of the dense particles is captured at intermediate conditions.

Once the investigative tests at various nozzle velocities and mass loadings are completed, the effects of fill height shall be investigated by performing batch transfers and quantifying the spike particulates that are collected downstream of the transfer pump suction inlet. The SSMD test platform should be operated in a recirculation mode until a stable state is established. The stable state is indicated by a consistent mass flow rate reading from the Coriolis meter, after adjusting for cyclical variations caused by the rotating jets or a steady cloud height or mixer jet zone of influence. Once the tank reaches the stable condition, batch transfers are initiated at the maximum flow rate provided in

Table 1-2. The batch volume should be screened to separate the spike particles from the base material and the material passing through the screen should be discharged to a waste collection pond. The discharged volume should be passed through a screen or filter that facilitates isolation of the spikes particles from the rest of the discharge. If easily separated, the entire transfer volume should be screened for the large spike particles; otherwise the sample collection duration should be adequate to collect a representative sample.

The collection and separation of the transferred spike particles from the base simulant will be performed on-site using cascading sieves. A transfer sample may need to be collected if the spike simulant cannot be readily separated from the base particulates (e.g., segregated based on size exclusion, magnetism, etc.). The need for collecting and analyzing a transfer sample will be identified by technical representatives from the testing contractor, the TOC and the DOE. If necessary, previously established practices for collecting slurry samples from the SSMD test platform will be followed.

Replicate analyses have not been included in the test matrix but the design is such that estimates of variability can be determined. In addition, the reproducibility of the tests without performing replicates can be assessed because equivalent glass spheres are included in each of the 12 tests that are being performed. Data analysis using the test results from all 12 tests together will identify the capability of the system relative to the different operating conditions (see Section 3.2.1.5).

The data collected from each experimental run will consist of the mass of each of the spike particles transferred. These data from the entire experiment will then be analyzed, using multiple regression analysis, to determine the relationship between the spikes transferred and the specific factors which were manipulated in the experiment, i.e., jet nozzle velocity, base simulant composition, spike particulate composition, supernatant composition, and solids loading. Note that the actual response values used in the analysis may be some function of the measured mass, e.g., fraction of particles transferred, as appropriate. Note also that the regression model which will be fit will only include the linear (or main) effects of each of experiment factors, due to the resource constraints imposed on the experiment effort. Including all higher-order effects, e.g., interaction or quadratic, would have required more experimental runs than were available within the budget and time constraints. Given these constraints, the specific experiment design chosen was the most efficient design to allow estimation of the main effects of the design factors, while also providing some ability to check for the presence of the interactions. Evaluating higher-order effects would require an expanded test matrix in order to be able to estimate the interaction effects. The test matrix has been constrained to 12 tests in the 1:8-scale tank. Performing 12 tests was based on conducting an appropriate number of tests to characterize the variability over the test variables while minimizing the test schedule and associated costs.

Table 3-6Table 3-6 provides the test matrix for these tests. The test included in the test matrix should be performed in any order. The specific variations in the test conditions were selected using a computer algorithm. This method, known as a Bayesian D-optimal design algorithm, essentially selects the "best" test runs from the set of all possible combinations of the settings of the specified design factors, where "best" translates to small variability and small correlation of the coefficients in the design model. For SSMD Limits of Performance, the design model includes all of the linear (main) effects of the design factors. Additionally, the design algorithm includes the ability to provide a check for the presence of any of the two-factor interaction effects among the design factors. Note that a much larger experiment is required to actually estimate each of the two-factor effects. The design factors include the jet nozzle velocity, the base simulant composition, the spike particulate composition, the supernatant composition and the solids loading.

Replicate analyses have not been included in the test matrix but the design is such that estimates of variability can be determined. In addition, the reproducibility of the tests without performing replicates can be assessed because equivalent glass spheres are included in each of the 12 tests that are being performed. Data analysis using the test results from all 12 tests together will identify the capability of the system relative to the different operating conditions (see Section 3.2.1.5).

The data collected from each experimental run will consist of the mass of each of the spike particles transferred. These data from the entire experiment will then be analyzed, using multiple regression analysis, to determine the relationship between the spikes transferred and the specific factors which were manipulated in the experiment, i.e., jet nozzle velocity, base simulant composition, spike particulate composition, supernatant composition, and solids loading. Note that the actual response values used in the analysis may be some function of the measured mass, e.g., fraction of particles transferred, as appropriate. Note also that the regression model which will be fit will only include the linear (or main) effects of each of experiment factors, due to the resource constraints imposed on the experiment effort. Including all higher-order effects, e.g., interaction or quadratic, would have required more experimental runs than were available within the budget and time constraints. Given these constraints, the specific experiment design chosen was the most efficient design to allow estimation of the main effects of the design factors, while also providing some ability to check for the presence of the interactions. Evaluating higher-order effects would require an expanded test matrix in order to be able to estimate the interaction effects. The test matrix has been constrained to 12 tests in the 1:8-scale tank. Performing 12 tests was based on conducting an appropriate number of tests to characterize the variability over the test variables while minimizing the test schedule and associated costs.

Table 3-6: SSMD Limits of Performance Test Matrix

Test Number	Nozzle Velocity Scaling Factor Exponent (a)	Base Simulant Constituent	Spike Particulate	Supernatant Simulant Properties[1]	Solids Loading[2]
1	0.33	High	Glass/WC	High	Low
2	0.33	High	Glass/SS	High	High
3	0.33	Low	Glass/WC	Low	High
4	0.33	Low	Glass/SS	Low	Low
5	0.33	Non-Newtonian	Glass/WC	3 Pa, 1.37 g/ml	High
6	0.33	Non-Newtonian	Glass/SS	3 Pa, 1.1 g/ml	Low
7	0.2	High	Glass/WC	Low	Low

8	0.2	High	Glass/SS	Low	High
9	0.2	Low	Glass/WC	High	Low
10	0.2	Low	Glass/SS	High	High
11	0.2	Non-Newtonian	Glass/WC	3 Pa, 1.1 g/ml	High
12	0.2	Non-Newtonian	Glass/SS	3 Pa, 1.37 g/ml	Low

[1] High supernatant properties: density = 1.37 g/ml, viscosity = 15 cP; Low supernatant properties: density = 1.1 g/ml, viscosity = 1 cP; non-Newtonian slurry properties, yield strength = 3 Pa and density modified to be 1.1 g/ml or 1.37 g/ml as listed

[2] High solids loading is 15 weight percent; Low solids loading is 9 weight percent.

3.2.1.5 Sample Collection and Analysis

Test progress should be monitored using a Coriolis meter to monitor mass flow rate and specific gravity of the transferred slurry.. Monitoring the mass flow rate and slurry specific gravity will allow an assessment of the systems capability to mix and convey the complex simulant.

Samples shall be collected downstream of the transfer pump suction inlet at either the large particle trap upstream of the transfer pump, at the discharge back into the tank when operating in recirculation mode, or at waste collected. Samples shall collect the large and dense spike particulates but allow the smaller solids to be recirculated back into the tank or be discharged to the waste collection. During recirculation mode, the amount of each size and density spike particulate shall be separated (see below) and quantified (as a dried mass or count of particles). Results shall be recorded in the test log. The duration for collecting the samples, expressed as a number of tank turnover volumes or mixer jet rotations, shall also be recorded in the test log. It is anticipated that the spike particulates can be segregated from the base material using properly sized screens or sieves. An appropriately sized screen has a mesh opening smaller than the smallest size of the spike particles but larger than the largest constituent in the base simulant. For the spike particles identified a No.14 or No. 16 sieve size would capture all of the spike particulates. Screening the discharge will facilitate visual confirmation of the transferred material and allow for quantification of the amount of the spike particulate transferred. Different sized spikes shall be separated by appropriately sized sieves.

Separation of the spike material will be based on size exclusion and some manual selection. Based on the sizes proposed the spikes could be separated from the base material using a No. 14 or No. 16 sieve but testing with the base material will be performed to ensure that slurry throughput through the sieve can be maintained. The largest particles (7000 micron glass and 6350 micron metal spheres will be separated using a No. 3.5 sieve (5660 micron) and subsequent separation of the glass and metal spheres. Based on preliminary test results, the transfer of 6350 micron metal spheres is expected to be minimal so that manual separation of the metal spheres may be achievable with high accuracy. For the next largest size particles 5000um glass and 4762.5um metal spheres, a No. 5 sieve (4000 micron) will be adequate because the next largest sieve size, a No. 4 (4760um), would not be adequate to separate the two different sized materials. Based on preliminary test results, the transfer of 4762.5 micron metal spheres is expected to be minimal so that manual separation of the metal spheres may be achievable with high accuracy. For the next largest size particles 3000 micron glass and 3175 micron metal spheres, a No. 7 sieve (2830um) will be adequate because the next largest sieve size, a No. 6 (3360 micron), would not be adequate to separate the two different sized materials. Supplemental separation of the glass and metal spheres will need to be performed and exploiting the different settling velocities of the materials (0.4 ft/s vs. 1 ft/s) may be necessary if manual separation of the particles is not practical because of the quantity of each material recovered. Particles that are improperly sorted by the settling velocity method will be manually sorted into the correct category. For the smallest sized spheres of each type (2,000um glass and 1587.5um metal) a No. 12 sieve (1680um) may be adequate to separate the glass and metal spheres.

The spikes retained by the sieves will be washed dried and weighed. The spike particle sizes are selected such that the separation of spikes of differing size is performed using sieves that are at least two sizes apart. The particles are also manufactured as spheres so that separation by sieving is expected to be readily accomplished. For the two largest particles included in each test, manual separation of the particles is expected to be performed with high accuracy because of the different physical appearance of the glass and metal particles and the low recovery expected for the metal particles. For the smallest particles included in each test, separation of the particles is expected to be performed with high accuracy because sieves are available to separate the glass spheres from the metal spheres. The differences in the physical appearance of the particles will facilitate sorting error corrections prior to weighing the particles. However, separation of the 3000 micron glass particles from the 3175 micron metal particles is subject to additional error because the expected recovery of the metal spheres is unknown and there is not a sieve available to separate the glass spheres from the metal spheres. The acceptable error rate for manually misclassifying glass and metal spheres is 1 in 10,000 (0.1%) and is based on misclassifying one sphere per square foot of mesh in a No. 7 sieve. The error in quantifying the particulates also includes the accuracy of weighing the washed and dried material. The accuracy of the scale for weighing the recovered spikes is ±0.1%. The sorting error is expected to be additive for a total quantification tolerance of ±0.2%.

Segregation of different density particles retained by a sieve shall be at the discretion of the test director but could include separating similarly sized particles based on density methods (floating less dense material out of a sample container) or by manual methods based on other physical characteristics (e.g., color, magnetism, etc.). The segregated material should be cleaned, dried and weighed to quantify the mass of each large particulate type transferred in each batch. Alternatively, in lieu of weighing, particle counts are acceptable if the number of particles transferred is low and the particulates of a certain size are fairly uniform. The mass of the simulant spike shall be determined for each transfer batch. The segregated material shall be cleaned and dried before quantifying the mass of the transferred spike material.

If it is not practical to collect the transferred particles from an entire transfer batch, subsampling will be collected during each batch transfer. Similar to previous work, batch transfer samples should be diversion samples through diversion valves that are controlled programmatically and correlated to the position of the mixer jet nozzles using encoders. Samples shall be collected to avoid sample bias that could be introduced by the position of the rotating mixer jet nozzles. To avoid this bias and collect a sample that averages the highs and lows in the fluctuations, the sample shall be collected continuously over a duration that spans an integer value (e.g., 2, 4, 10) for the number of half rotations (there are two opposing nozzles on each mixer jet pump) of the mixer jet nozzles; for a full rotation approximately 9 gallons would be collected (transfer rate of 6.9 gallons per minute and 0.77 revolutions per minute). The sample should be collected and sieved to separate the large and dense particles from the base material for quantification.

After the sample is collected the remaining volume should be diverted back to the waste collection pond until the entire batch volume is transferred to either waste collection or a sample container. After the transfer, the system should be reconfigured to recirculate the waste until a stable state condition is re-established. Once the stable state condition is re-established, a second transfer and sampling operation should be initiated and will proceed like the first transfer and sampling operation. The process is repeated until the required number of transfers (i.e., 5 or 6) has occurred. After the last transfer is completed, a description of the solids remaining in tank, including a photographic or video record, should be prepared and then the tank should be emptied.

Assessing the capability of the mixer jets to deliver large and dense particles to the transfer system will be determined by comparing the fraction of each spike particulate transferred during each operating condition. Fractional information is expressed in terms of the initial loading of each particulate into the tank. For comparisons at different operating conditions (e.g., nozzle velocity variations, mass loadings, simulant characteristics), the amount of particles transferred over an equivalent duration can be directly compared to develop correlations between the operating conditions and the capability of the system. In addition, limits of the system will be assigned based upon observations where spikes of a certain size and density are not captured and transferred by the integrated system.

Data analysis shall compare how the distributions of the spike simulants varied in each transfer batch within a test and among tests with different test conditions. The objective of the data analysis is to develop correlations, whether quantitative or qualitative, to support findings on the systems capability to transfer large and dense particles.

3.2.2 RSD Limits of Performance

RSD Limits of Performance test activities documented in Section 3.2.2 are performed by Energy*Solutions* for WRPS.

3.2.2.1 Test Equipment and Instrumentation

Integrated testing for the Isolok Sampler evaluations shall be performed using the RSD test platform constructed at the Monarch Machine and Tool facility in Pasco, Washington. The RSD test platform includes a mixing tank and agitator, an effluent tank, a slurry pump, a Coriolis meter, the Isolok Sampler, the integrated mechanical handling system, the Ultrasonic PulseEcho system (not operational during RSD Limits of Performance testing), a simulated glove box and all associated piping to connect these components. A schematic of the flow loop is shown in Figure 2-3. The RSD test platform also includes a sampling valve to collect full diversion samples. Although it is not expected to be used during RSD Limits of Performance testing, the

Ultrasonic PulseEcho system will be used during RSD System Performance testing to measure critical velocity of the simulant.

The RSD test platform has been used previously for related testing work, including integrated testing using the mechanical handling system (in process at the time of development of this test plan). With the exception of adding the Ultrasonic PulseEcho system into the flow loop in anticipation of RSD System Performance testing, the RSD platform shall be used without significant modifications from previous work that demonstrated the mechanical handling component of the system. However, an evaluation shall be performed to confirm that the mechanical agitator in the mixing tank provides adequate mixing for the RSD Limits of Performance test simulants. The mechanical agitator was previously sized according to average waste characteristics and may not be appropriate for RSD Limits of Performance testing. With this confirmation, the RSD test platform is appropriate for Limits of Performance testing because it was constructed at full scale, with the exception of the mixing and transfer system, to demonstrate the capabilities of the Isolok sampler, the Mechanical Handling System, and the Ultrasonic PulseEcho system.

The RSD flow loop includes 3-inch diameter, schedule 40 pipe with a centrifugal pump capable of pumping at slurry velocities from 2 feet per second (ft/s) to 8 ft/s; below 2 ft/s pump cavitation is experienced.

To establish the proper flow conditions required to demonstrate the capability of the Ultrasonic PulseEcho system, the flow loop contains approximately 15-18 feet (60-70 pipe diameters) of straight horizontal pipe before the Ultrasonic PulseEcho system and approximately 4 feet (15 pipe diameters) of straight horizontal pipe after the device. The flow loop shall be equipped with a data acquisition system connected to a Coriolis meter to monitor and record the mass flow rate and the specific gravity of the slurry. The Ultrasonic PulseEcho system includes a separate data acquisition system to collect relevant data.

The flow loop shall contain the Isolok sampler oriented in the vertical configuration. The Ultrasonic PulseEcho system is not required to be operational during the Isolok Limits of Performance testing. For testing purposes, evaluating the capability of the Isolok system is independent of evaluating critical flow velocities. Actual in-field sampling of waste will require confirmation of critical velocity before slurry samples are collected so that resampling is minimized. Evaluating the capability of the Isolok system to collect representative samples of large and dense particles is independent of evaluating the mechanical handling of the collected samples. However for completeness testing should be performed with the fully integrated system including the Isolok sampler and the mechanical handling system to retrieve the prototypic sample containers.

The RSD flow loop shall also accommodate a mechanism to increase the pressure in the transfer line. Increasing the transfer pressure will establish the capability of the Isolok sampler to collect representative samples at elevated operating pressures up to the working range of the sampler, which is 275 psi.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented in a test log.

3.2.2.2 Test Simulants

The simulants used in the RSD Limits of Performance testing are selected in accordance with the recommendations in RPP-PLAN-51625. Simulant properties and qualification is described in Section 3.1. Selecting particular simulants for RSD Limits of Performance test activities is discussed below. The test matrix showing the combinations of base simulant, liquid supernatant and spike particulates is discussed in Section 3.2.2.3.

The simulants used in RSD Limits of Performance testing shall be a complex simulant containing base particulates and spike particulates to characterize the capability of the sampling system to sample large and dense particles.

For RSD Isolok performance evaluations, the Low and High Conceptual simulants presented in Table 3-1 will be used. The Typical and High Conceptual simulants are composed of similar particles, just in different proportions and so any interference with the large and dense particles would be similar using either base composition. The High Conceptual simulant was selected over the Typical Conceptual because it contains larger particles that could enhance plugging of the sample needle when the large spike particles are captured. The Low Conceptual simulant is a single component simulant comprised of small particles that are not expected to enhance plugging in the sample needle. Selecting the Low and High Conceptual simulants is also with the base simulants selected for SSMD Limits of Performance testing.

To investigate the effects of solids loading the weight percent of the base simulant shall reach a maximum value of 15 weight percent, but the base particulate shall be added incrementally as discussed in Section 3.2.2.3. The 15 weight percent is based on the ICD-19 allowable limit of 200 g/l. For the Low Conceptual simulant in the low density (1.1 g/ml) supernatant the solids loading is approximately 207 g/l when 5 weight percent spike solids are added to the base. For the High Conceptual simulant in the high density supernatant (1.37 g/ml) the solids loading is approximately 227 g/l at the same spiking level. The resulting slurry density ranges between 1.38 g/l and 1.51 g/ml, the latter being above the action level identified in ICD-19. Although the ICD-19 control value for solid content has an constraint of 200 g/L, successful testing with simulants that vary over the anticipated range will add confidence that the sampler can collect representative samples of the transferred material regardless of the slurry content.

To investigate the effects of the supernatant density and viscosity, two Newtonian supernatant compositions will be investigated, high and low. For the high supernatant, the targeted slurry density is 1.37 g/ml and the targeted liquid viscosity is 15 cP. The targeted values are consistent with the high density / high viscosity recommendation in Table 3-2 and have an acceptable tolerance of 5% for the liquid density and 20% for the liquid viscosity. Liquid viscosity tolerance is evaluated at the operating temperature of the test tank if the temperature of the sampled material differs from the bulk volume. The high values for liquid density and liquid viscosity are selected because higher densities and higher viscosities are expected to increase the buoyancy effecting solid particles in the flow loop, increasing the potential to capture the large and dense particles in the vertically oriented flow stream. To confirm this expected correlation, a second supernatant simulant with a lower density and viscosity will be evaluated. The targeted slurry density for the low supernatant is 1.1 g/ml and the targeted liquid viscosity is 1 cP. The selected quantities are equivalent to the Low Density / Low Viscosity supernatant listed in Table 3-2. For the Low supernatant, the acceptable tolerance on the density is ±5% and the acceptable tolerance on the viscosity is 0.5 cP. The initial properties of the supernatant will be lower than the target values, which will be reached at the end of the test evolution as discussed in Section 3.2.2.3. Sample measurements shall be collected from the mixing tank and the liquid density and viscosity should be measured and adjusted until the target range is attained before the next test evolution is performed. For adjusting the liquid rheology, sodium thiosulfate is the preferred sodium salt with glycerol being a secondary additive to increase the viscosity to the targeted values. Supernatant compositions matching the targeted characteristics are provided in Table 3-2.

In addition, tests shall be performed using a non-Newtonian slurry with a Bingham yield stress of up to 10 Pa. For test requiring a non-Newtonian, cohesive slurry, kaolin clay shall be used to increase the yield stress of the simulant to values up to 10 Pa The initial properties of the slurry will be lower than the maximum value of 10 Pa, which will be reached at the end of the test evolution as discussed in Section 3.2.2.3. Sample measurements shall be collected from the mixing tank and kaolin clay shall be added until the yield stress meets the acceptance criteria.

Small test batches should be prepared to determine the relative amounts of each constituent to achieve the targeted results at testing temperatures and using the procured materials.

The limits of performance of the Ultrasonic PulseEcho system are not being evaluated in this test activity; therefore, the size of the sample needle is the constraint for the upper particle size used during RSD Limits of Performance testing. The largest dense particle that results in acceptable performance during developmental testing will be added as a spike to a complex simulant. The simulant spikes may be different from the large and dense particles that can be transferred by the transfer system due to the size constraint of the Isolok sample needle. The spike material representing the large and dense particles should use the largest particles of high density solids that could be sampled through the internal needle in the samplers double needle (approximately 3,400 microns) or can be repeatedly sampled without plugging the sampler. Tests are also be conducted with particles of a smaller size to determine the capability of the system to reliably collect samples of large and dense particles. Table 3-7 provides the particle size range for the simulant spikes.

Note that although the Isolok needle size is approximately 3400 microns, which is larger than the individual spikes, it is assumed that some combination (aggregation) of large spikes and small particles (base simulant) will effectively plug the needle. Moreover the commercially available products tend to be produced in 1/32-inch (approximately 800 microns) increments so that the next available size for each spike listed in Table 3-7 is greater than 3400 microns, limiting the maximum spike size to below the target. Soda-lime glass is selected as a spike material instead of sand, one of the recommended spike materials in RPP-PLAN-51625, because it has a comparable density to sand and the spherical shape will facilitate separation of the different sized particles by sieving.

The quantity of the spike particle added to the test tank shall initially be 5 weight percent of the total solids added during a test sequence. Ideally, the distribution of different sized particles should represent the expected distribution of the waste. A review of the data reported in PNNL-20646 indicates that tank waste samples tend to have few very large particles (>1000 microns) and more moderate sized particles (10s to 100s of microns). However, in order to determine the capability of the system to sample very large particles, the sampler must have the opportunity to sample these particles. Therefore, the concentration of the large particles should be greater than the expected distribution of large particles in the tank waste to increase the probability that a large particle is present in the flow stream at the time that the Isolok sampler collects a sample. Two allocation methods that result in greater number of smaller spike particles compared to the largest spike particles would be to equate the masses of each represented size or distribute the masses in proportion to the ratio of the particle diameters. In the latter approach, a system with 1/16-inch, 2/16-inch, 3/16-inch and 4/16-inch spike particles uses weight percentages of 10%, 20%, 30% and 40% for the particles, respectively. Comparing the two techniques, the latter approach reduces the number of the smallest particles and increases the number of larger particles over the former. This method is preferred because it increases the number of the largest spike particles relative to the equal mass method, which increases the probability of collecting the larger particles in the sampler.

Table 3-7: RSD Limits of Performance Spike Simulant

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)
Soda Lime Glass	2.52	1000 2000 3000
Stainless Steel	8.0	1587.5 (1/16") 2380 (3/32") 3175 (1/8")
Tungsten Carbide (WC)	14.2	1587.5 (1/16") 2380 (3/32") 3175 (1/8")

3.2.2.3 Operating Parameters and Test Methods

The RSD platform shall be configured to adequately suspend the simulant in the mixing tank and transfer the contents to the inlet of the transfer pump. The speed of the mechanical agitators shall be increased until the specific gravity in the transfer line, monitored by a Coriolis meter, stabilizes. For Isolok sample collection in the vertical configuration, the transfer pump flow rate shall be set at 140 ± 5 gallons per minute.

Once the RSD flow loop has stabilized, as evidenced by stable mass flow rates and specific gravity readings from the Coriolis meter, the Isolok sampler shall be activated to collect three 500 ml samples. After the third sample, a full diversion sample shall be collected. The amount of each spike particle type in each sample collected shall be determined and recorded by size and density. Due to the small sample size and large particles it may be possible to count the number of particles of each size. If not the particles shall be separated by size using sieves, washed, dried and weighed to quantify the mass of each particle captured by the sampler. The amount can be expressed as a particle count or sampled mass. After characterization, the collected sample, including the slurry shall be returned to system for the next evolution of the test sequence. In the next evolution of the test sequence the starting condition will be altered in accordance with the test matrix and sample collection shall be repeated. The test conditions evolve to gain the additional data under similar operating conditions without having to prepare new simulant batches for each test evolution. It is anticipated that each test sequence will have two or three test evolutions each furnishing three Isolok samples (replicates) and one full diversion sample. If during testing, conditions warrant that the testing duration must be reduced, it is preferred to reduce the number of Isolok samples collected in each test evolution rather than eliminate a test evolution.

One condition to be varied through test evolutions during a test sequence is the weight percent of the base simulant. For testing performed without a base simulant (i.e., water testing), the mass of the spike particles should be equated to a test that includes a base simulant and the test evolution should be based on particle size instead of mass loading. For water testing the particle size of the spikes should be varied in the test evolution beginning with the largest size and adding smaller sizes for each evolution. For testing performed with a base simulant, test sequences evaluating the effects of the weight percent of the base simulant shall increase the mass loading of the base simulant from 5 weight percent to 15 weight percent in 5 weight percent increments (i.e., 5% 10%, and 15%).

A second identified condition for the test evolution is the liquid supernatant properties. Test sequences evaluating the effects of the liquid supernatant density and viscosity shall increase the density and viscosity through test evolutions. In the first evolution the liquid density and viscosity shall be targeted to achieve 1.1 g/ml and 1cP using the composition listed in Table 3-2. In the second and third evolutions of the test sequence, the liquid density and viscosity shall be targeted to achieve 1.37 g/ml and 15 cP by adding additional sodium salt and glycerol. The required accuracy on the targeted values depends on the number of constituents needed to achieve the targeted value. If the targeted values can be achieved using a single sodium salt (e.g., sodium thiosulfate or sodium bromide), then the density must be attained to within 5% of the targeted value and the viscosity must be within 0.5 cP of the targeted value. If a second constituent (e.g., glycerol) is needed to achieve the desired consistency, then the density must be within 5% of the targeted value and viscosity must be attained to within 20% of the targeted values at the testing temperature.

For RSD Limits of Performance tests with a non-Newtonian slurry, the variable for the test evolution is the Bingham yield stress of the base simulant. Test sequences evaluating the effects of the yield stress shall increase the yield stress from 3 Pa to 10 Pa. Due to the time varying nature of the non-Newtonian slurry and anticipated difficulty in preparing the simulant, only two evolutions of the yield stress runs will be performed. Based on the necessary accuracy needed to resolve the effect of the yield stress on the capability to transfer large and dense particles and time varying nature of a non-Newtonian simulant, Kaolin slurries with a targeted yield stress of 3 Pa are determined to be acceptable in the range of 2 to 4.5 Pa and slurries with a targeted yield stress of 10 Pa are determined to be acceptable in the range of 7 to 13 Pa. The tests shall be performed at the prevailing density for the kaolin slurry.

Initially test sequences are performed with an aqueous phase to determine the capability to collect different sized particles of different densities. These tests should be conducted with a single component spike using the largest and most dense particle to determine whether or not the Isolok sampler performs adequately (i.e., collects particles without plugging). Acceptable performance is defined as simulant spike recovery in the collected sample without plugging the sample needle. Indications of poor performance include low total volume recoveries (less than 475 ml) and a lack of spike material in the collected sample. If unacceptable performance is observed, then the particle size shall be reduced and the tests shall be repeated until acceptable performance is observed. The particle size that has acceptable performance will be used with the complex simulant to quantify the performance of the Isolok sampler in the presence of the large and dense particles.

The test matrix for the RSD Limits of Performance testing is provided in Table 3-8. For RSD Limits of Performance, the variations in the tests included the base simulant composition and the spike particulate composition. Additional variations in the base simulant loading and supernatant composition are accounted for using test evolutions. For the non-Newtonian simulant, the test evolution accounts for variations in yield stress. Due to the relative simplicity of the test variables and the capability to collect additional data over test evolutions, the design was constrained to 10 tests.

Table 3-8: RSD Limits of Performance Test Matrix

Test Sequence	Base Simulant Constituents	Spike Simulant Composition	Test Evolution
1	Water	Stainless Steel	Spike Particle Size
2	Water	Very Large Sand	Spike Particle Size
3	Water	Tungsten Carbide	Spike Particle Size
4	High	Stainless Steel	Supernatant Composition
5	Low	Very Large Sand	Base Simulant Mass Loading
6	High	Tungsten Carbide	Supernatant Composition
7	Low	Stainless Steel	Base Simulant Mass Loading
8	Non-Newtonian	Stainless Steel	Slurry Rheology
9	Non-Newtonian	Very Large Sand	Slurry Rheology
10	Non-Newtonian	Tungsten Carbide	Slurry Rheology

3.2.2.4 Sample Collection and Analysis

RSD Limits of Performance testing shall establish the particle size limit for acceptable performance of the Isolok sampler. However, chemical analysis is not always required to determine unacceptable performance. Unacceptable performance is observed when no solids are collected in the retrieved sample or there is an obvious fault in sampler operations during sample collection. Unacceptable performance is also observed when the collected slurry volume is outside of the 5% error (expressed as a relative percent difference) specified for the Isolok sampler during Phase I testing (RPP-RPT-51796). Low collection volumes (e.g., less than 475 ml for a 500 ml sample) would indicate that the sampler is partially or completely plugged. Initially these three criteria will be used to evaluate whether or not acceptable performance is attained for a simple simulant consisting of a spiking compound with a well-defined particle size. These criteria shall also be used to evaluate the behavior of the system with the complex simulant.

Three 500 ml Isolok samples and a full diversion sample shall be collected for each evolution of a test sequence. In general there are two or three evolutions in a test sequence as discussed in Section 3.2.2.3 for a total of 8 to 12 samples collected per test sequence. Unlike previous RSD testing activities, Isolok samples are not expected to require off-site analysis to quantify the amount of large and dense particles collected in each sample; therefore, no laboratory control samples or archive samples will be collected. The collected Isolok samples shall be analyzed for total slurry volume, total slurry mass and the mass (or count) of each spike particle. Spike mass shall be collected for each particle size and density when the spike is composed of multiple sets of uniformly sized particles. The mass of each sized particle collected in each Isolok sample shall be reported.

Separation of the spike material will be based on size exclusion. Based on the glass sphere sizes proposed, the glass spikes could be separated from the base material using a No. 20 sieve but testing with the base material will be performed to ensure that sample throughput through the sieve can be maintained. The metal sphere spikes will be separated from the base material using a No. 14 sieve (1410 micron). The largest particles 3000 micron glass and 3175 micron metal spheres, a No. 7 sieve (2830um) will be adequate to separate the spikes from the base material. For the intermediate sized spheres of each type (2,000 micron glass and 2380 micron metal) a No. 12 sieve (1680 micron) will be adequate to separate the glass spikes from the base material and a No. 10 sieve (2000 micron) will be adequate to separate the metal spikes. The smallest sized spheres of each type should be retained on the screen used to separate the spikes from the base material (No.20 sieve for glass and No. 14 for metal spikes).

The spikes retained by the sieves will be washed dried and weighed. The spike particle sizes are selected such that the separation of spikes is performed using sieves that are at least two sizes apart. The particles are also manufactured as spheres so that separation by sieving is expected to be readily accomplished. This should minimize the error associated with separating the different sized particles and an error tolerance of <1% is assigned to particle separation. The quantification error also includes the accuracy of weighing the washed and dried material. The accuracy of the scale for weighing the recovered spikes is ±0.1%. The sorting error is expected to be the largest source of error for quantification of the recovered spikes.

The mass of the base constituents does not need to be determined during RSD Limits of Performance testing. The entire volume of the full diversion sample shall also be analyzed for total slurry volume and the mass (or count) of each spike particle. Collected data shall be reported consistent with the Isolok data reporting.

The full diversion sample provides the evidence that the spike particles are present in the flow loop and provides an estimate for the concentration of the spike particles in the flow loop. Differences between the concentration of the spike particles in the full diversion sample and the initial spike concentration will be attributed to settling in the transfer line and/or inadequate mixing in the mixing tank. Differences between the concentration of the spike particles in the Isolok samples and the Full Diversion samples are attributed to the capability of the Isolok system to sample the spike particles. The difference between the Isolok sample concentrations and the Full Diversion sample concentration will be expressed as a percent error (bias). In addition, correlations between the percent errors and the test properties that were changed will be analyzed for correlations.

3.2.3 Full-Scale Transfer Pump Limits of Performance

Full-Scale Transfer Pump Limits of Performance test activities documented in Section 3.2.3 are performed by CEES for WRPS. The Full-Scale Transfer Pump Limits of Performance test platform has not been constructed; therefore in the sections that follow the description of the test platform is brief compared to the descriptions of the test platforms discussed for other testing activities.

3.2.3.1 Test Equipment and Instrumentation

Full-Scale Transfer Pump Limits of Performance testing is being performed to determine the largest size of particles with densities characteristic of Hanford tank waste that can be transported out of a DST. Two mixing modes are evaluated, a quiescent condition when no mixing is performed and a mixed condition, when mechanical mixing is performed. During quiescent testing, the transfer pump inlet is lowered from a starting position and the mobilization of spike particles introduced near the pump inlet is observed. Observations at different distances from the tank bottom are compared. Quiescent mixing determines the capability of the pump to mobilize particles from the bottom of the tank without the benefit of particle suspension using the mixer jet pumps. . During mixing tests, the transfer pump inlet is stationary at the full scale height and the slurry is agitated to suspend the spike particles in the tank. The mobilization of spike particles from the tank is observed. Observations at different operating conditions are compared. Mixing tests determines the capability of the pump to mobilize suspended particles from the tank at the prototypic height of the pump suction inlet.

The major equipment included in the Full-Scale Transfer Pump Limits of Performance testing include a submersible centrifugal pump, a large test tank, mechanical agitator(s), a flush tank, a flush pump, a re-use tank, a flush receipt tank, a disposal basin and 3-inch diameter Schedule 40 pipe and fittings. The submersible transfer pump has a pump suction inlet diameter of 2.40", is capable of processing 90 to 140 gallons of slurry per minute and develop 100 feet of head. With the exception of the reduced head requirement, these flow characteristics are consistent with the slurry transfer pump that is sought by the TOC to transfer HLW feed from a DST to the WTP. The flow rate and the inlet opening geometry set the capture zone around the pump inlet, which determines what particles can be entrained in the pumpage to be transported from the tank. The transfer pump inlet should be screened with a screen that is consistent with on-going DST transfer pump design (currently assumed to be 3/8-inch). The inlet shall initially be set at a distance of 6-inches above the tank bottom. The 6-inch height parameter is equivalent to the expected operating condition in the first waste feed staging tank, 241-AY-102. The height of the transfer pump inlet, relative to the tank bottom, shall be adjustable.

The mixing tank shall have transparent observation ports in the side and bottom of the vessel so that mixing can be observed. The mechanical agitator(s) shall have the capability to suspend the candidate spike materials, including 1/4-inch diameter particles of tungsten carbide (density approximately 14.2 g/cm^3) in a supernatant phase having a specific gravity of 1.1 and a viscosity of 1 cP. For sizing the mechanical agitators, suspend is defined as off-bottom suspension, the complete motion of all particles with no particle remaining on the base of the vessel for more than 1-2 seconds. Off-bottom particle suspension shall be visually verified through the tanks observation ports. The pump discharge shall be oriented vertically to transfer the mixed slurry up a vertical distance of 55 feet through a 90° elbow and across a horizontal distance of 20 feet.

The distance from the bottom of the DST to the top of an access riser in AY-102 is about 55 feet. The horizontal distance needed to obtain stable flow for the Ultrasonic PulseEcho system was approximately 80 pipe diameters and this same criterion was applied to determine the horizontal flow length in the test platform. After 20 feet of horizontal flow, the slurry will be diverted to sample collection, recycled back to the mixing tank or discharged to a waste collection. The discharge shall be screened to collect the large spike particles transferred beyond the 20-foot of horizontal piping.

Pump speed should be controlled so that the slurry flow is maintained at 140 gpm. The condition of the pump should be monitored by recording the pump speed or equivalent performance metric (e.g., hydraulic fluid flow rate). The specific gravity of the discharge should be monitored using a Coriolis meter. Transfer flow rates and pressures shall be monitored and recorded.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented.

3.2.3.2 Test Simulants

The Full-Scale Transfer Pump Limits of Performance simulants shall include spikes particles in a supernatant simulant when quiescent tests are performed and shall be a complex simulant containing base particulates and spike particulates in a supernatant when Newtonian tests with mixing are performed. For all non-Newtonian testing, the simulant shall be kaolin slurry supplemented with spike particles. .

The effect of the base simulant on the capability of the system to transfer large and dense particles has not been previously investigated using the recommended simulants discussed in Section 3.1.1; however, it is expected that the presence of solids in the slurry should hinder settling which could enhance waste transfer if the spike particulates become suspended by the mechanical agitator(s). Figure 8-10 in RPP-PLAN-51625 provides the basis that changes in the base simulant will influence the movement of the spike particles. The basis for the metric shown in the figure is developed for impeller mixed tanks using the Zweitering correlation. The calculation suggests that the difference in the capability of the system to suspend large and dense particles, and hence increase the probability of transferring the particles, is greatest for the Low Conceptual simulant and for a specific power input there is very little difference in the capability of the Typical and High Conceptual simulants at two different mass loadings. However, if there is sufficient power in the system to suspend all the material, the additional large sized base material in the High Conceptual simulant may hinder settling of the spike particles and facilitate capture and transfer. On these bases, Full Scale Transfer Pump Limits of Performance testing will utilize the Low Conceptual and High Conceptual simulants to quantify the effects of each on the capability of the pump to transfer large and dense particles. Conducting tests with the two limiting base simulants, Low Conceptual and High Conceptual, is also consistent with the high uncertainty in the characterization of Hanford tank waste, especially as it is blended and staged for waste feed delivery to the WTP. The two base simulants that have a broad distribution of Archimedes numbers and using these two is appropriate for Limits of Performance testing because much of the Hanford waste is uncharacterized with respect to particle size and density distributions and that which has been characterized suggests a wide distribution of Archimedes numbers for tank waste. Evaluating the effect of a broader distribution of Archimedes number reduces the risk that uncharacterized waste could have a capability that has not been quantified.

The effects of solids loading will be evaluated The low base loading weight percent solids shall be 9% and is based on a solids loading of approximately 125 g/l. The high mass loading shall be 15 weight percent solids. The 15 weight percent is based on the ICD-19 allowable limit of 200 g/l. For the Low Conceptual simulant in the low density (1.1 g/ml) supernatant the solids loading is approximately 207 g/l when 5 weight percent spike solids are added to the base. For the High Conceptual simulant in the high density supernatant (1.37 g/ml) the solids loading is approximately 227 g/l at the same spiking level. The resulting slurry density ranges between 1.38 g/l and 1.51 g/ml, the latter being above the action level identified in ICD-19.

The liquid density and viscosity of the fluid phase (supernatant simulant) should be adjusted to target values using soluble salts, with addition of glycerol as necessary. For adjusting the liquid rheology, sodium thiosulfate is the preferred sodium salt. Two supernatant compositions will be investigated, high and low. For the high supernatant, the targeted slurry density is 1.37 g/ml and the targeted liquid viscosity is 15 cP. The targeted values are consistent with the high density / high viscosity recommendation in Table 3-2 and have an acceptable tolerance of 5% on liquid density and 20% on viscosity. The high values for liquid density and liquid viscosity are selected because higher densities and higher viscosities are expected to increase the buoyancy effecting solid particles in the mixing tank and reduce critical suspension and settling velocities. Increasing buoyancy and subsequently reducing the critical suspension velocity and settling velocities is expected to promote particle suspension, facilitating the movement of large and dense particles to the transfer pump suction inlet. The increased buoyancy will also promote the movement of particles beyond the 20 feet of horizontal piping so that the spikes can be captured and quantified. To confirm this expected correlation, a second supernatant simulant with a low density and viscosity will be evaluated. The targeted slurry density for the low supernatant is 1.1 g/ml ±5% and the targeted liquid viscosity is 1 cP ± 0.5 cP. The selected quantities are consistent with the low density / low viscosity recommendation in Table 3-2. The acceptable tolerance on the lower density is ±5% and the acceptable tolerance on the low viscosity is 0.1 cP. The lower tolerance on the density values for the low supernatant is due to the expectation that the values are achievable using a sodium thiosulfate without the addition of other compounds. Supernatant compositions matching the targeted characteristics are provided in Table 3-2.

In addition, tests shall be performed using a non-Newtonian slurry with a Bingham yield stress of 3 Pa. The value is consistent with the recommendations described in Section 3.1.1. A non-Newtonian test should be used to verify the expectation that slurries having a yield stress result in better batch transfer of spike particulates, as reported in SRNL-STI-2011-00278. For verification tests requiring a non-Newtonian, cohesive slurry kaolin clay shall be used to increase the yield stress of the simulant to values up to the target value. With the expectation that higher yield stresses should facilitate the movement of larger and denser particles, the 3 Pa limit was selected because it is similar to values that have been used in mixing tests in the past. Based on the necessary accuracy needed to resolve the effect of the yield stress on the capability to transfer large and dense particles and slight time varying nature of a non-Newtonian simulant, Kaolin slurries with a targeted yield stress of 3 Pa are determined to be acceptable in the range of 2 to 4.5 Pa.

The spike material representing the large and dense particles should be composed from lots of solids having a very narrow distribution range so that all of the particles from a single lot are essentially the same size. Selected spikes for the capability test will only include particles that can fit through the openings in the pump screen. The spike particulates included in each test include multiple sizes of particles. The size increments are at least 1/32-inch so that the particles can be readily separated for on-site analysis by sieving. Having multiple sizes of particles allows for positive confirmation that smaller particles can be transferred when larger particles are not transferred. This allows for an estimation of the capability limit of the system. Spike particulates with different densities and sizes are included in each test. Particles with different sizes are separated by sieving, particles with different densities are separated manually. Particles with different sizes and densities are used together to assess the limits of the integrated mixing and transfer system. Table 3-9 provides the composition and particle size range for the simulant spikes.

The quantity of the spike particles added to the test tank shall initially be 5 weight percent of the solids and may need to be increased prior to the first transfer if the observed movement of the particles suggests that there is a very low probability of mobilizing the solids to the transfer pump suction inlet. Ideally, the mass distribution of particle sizes in the specified mass loading would represent the expected distribution of the waste. A review of the data reported in PNNL-20646 indicates that tank waste samples tend to have few very large particles (>1000 microns) and more moderate sized particles (10s to 100s of microns). Two allocation methods that obey this relationship would be to equate the masses of each represented size or distribute the masses in proportion to the ratio of the particle diameters. In the latter approach, a system with 1/16-inch, 2/16-inch, 3/16-inch and 4/16-inch spike particles uses weight percentages of 10%, 20%, 30% and 40% for the particles, respectively. Comparing the two techniques, the latter approach reduces the number of the smallest particles and increases the number of larger particles over the former. This method is preferred because it increases the number of the largest spike particles relative to the equal mass method, which increases the probability of mobilizing the larger particles to the pump inlet.

Table 3-9: Full-Scale Transfer Pump Limits of Performance Spike Simulant

Compound	Solid Density (g/cm^3)	Characteristic Particle Size (micron)
Soda Lime Glass	2.52	2000 3000 5000 7000
Stainless Steel (SS)	8.0	1587.5 (1/16") 3175 (1/8") 4762 (3/16") 6350 (1/4")
Tungsten Carbide Grit (WC)	14.2	1587.5 (1/16") 3175 (1/8") 4762 (3/16")

		6350 (1/4")

3.2.3.3 Operating Parameters and Test Methods

The Full Scale Transfer Pump Limits of Performance test activities shall evaluate a surrogate transfer pump with similar capabilities to the slurry transfer pump sought for waste feed delivery to the WTP. For mixing tests, the simulant discussed in Section 3.2.3.2 shall be added to the mixing vessel and the tank shall be mixed so that the large and dense spike particles are suspended. The agitator speed in increased until off-bottom suspension is attained for the simulant solids. Verification of off-bottom suspension is performed by observing the movement of the solids in the tank through the observation ports in the side and bottom of the tank. Collection of the spike particles shall be performed so that transient conditions experienced during the start up of mixing and pump operations do not influence the test results.

The test platform shall be configured so that the mixing and transfer operates in a recycling mode at a transfer flow rate of 140 gpm. The specific gravity of the slurry in the transfer line shall be monitored using a Coriolis meter and the mixers shall be adjusted until the specific gravity in the transfer line stabilizes. When the monitored specific gravity has stabilized, spike particle recovery in the transferred slurry shall be initiated. Spike recovery should proceed while the tank is recirculating the slurry through the transfer line. The minimum duration for the spike recovery in a test evolution is 10 turnover volumes. The spikes in the transferred slurry are recovered by passing the pumpage through a screen at the inlet of a collection vessel. The duration and accumulated volume transferred during spike recovery shall be recorded so that the concentration of spikes particles transferred can be determined. The screen shall isolate the spike particles from the other slurry solids by size exclusion. A No.14 or No. 16 sieve has appropriate sized openings to retain the spike particles, but the surface area of the screened opening needs to be determined through developmental testing to ensure that adequate throughput through the screen can be maintained at the pumping rates required during testing. The base material passing though the screen shall gravity drain or be pumped back into the mixing tank until the test evolution is completed. The captured spike particles shall then be separated by size using cascading sieves. For each sieve size, the retained particles shall then be manually separated by particle type to separate different density particles. The resulting piles are then counted or washed, dried and weighed. The resulting counts or mass of each spike particle size shall be recorded.

Prior to performing the next evolution, the transfer pump screen is removed so that the spike particles are not collected during the transient conditions between test evolutions. The conditions for the next test evolution are established by adding the necessary components. Once the conditions for the next test evolution are readied, the system is operated in a recirculation mode until a stable state in the transfer line has been reestablished. Once the steady state condition is resumed, spike recovery for the next test evolution proceeds in the same manner as the first test evolution.

At the conclusion of the final test evolution, the test is terminated. The fluid in the transfer line is allowed to gravity drain back into the mixing tank. The solids in the horizontal piping are flushed into a collection vessel to recover the spike particulates that settled in the horizontal section of the transfer pipe network. The flushing flow rate will exceed the transfer flow rate of the test to ensure that the settled solids are removed from the pipe. Visual confirmation will ensure that adequate flushing through the transparent section of piping has been achieved. The flushed material is screened similar to the transferred slurry to collect the spike particles that settled in the transfer line. The collected spike particles are separated by size and density and quantified by counting the particles in each pile or by washing, drying and weighing the particles. The discharge shall be diverted to waste collection so that particles in the transfer line are not placed back into the mixing tank.

The mass of the spike particles remaining in the tank shall also be characterized. The distribution of the heel in the tank will be qualitatively described with specific emphasis on noting where in the tank the large and dense particles are found (e.g., within the pump screen, near the pump screen, along the edges of the tank) Particles that may collect inside the pump screen would indicate that the mixing energy provides sufficient velocity to move the particles near the pump screen and that the flow velocity through the screen is sufficient to pull the particles through the reduced area through the screen but the flow velocity inside the screen is insufficient to maintain the particles in suspension. Once the heel is documented, the mixing tank shall be emptied so that the next test can be conducted.

For non-mixing tests, no base simulant is necessary, the spike solids in a supernatant comprise the simulant for the tests. It was concluded that, in the absence of mixing a consistent base composition could not be maintained in the tank. Because the base composition is expected to influence the capability of the integrated system, an inconsistent base composition would interfere with data interpretation. During quiescent testing, the transfer pump is started with the system in a recirculating mode. Because of the limited tank size and volume of material, the non-mixing tests that vary the operational height must be operated in a re-circulation mode so that the contents of the tank are not emptied before reaching the full travel distance to the bottom of the tank. The recirculating fluid is added back to the tank using a distributor under a gravity drain to minimize mixing in the tank. Once a stabilized state has been established, assessed by a constant specific gravity on a Coriolis meter monitoring the transfer line, spike particles are added to the test tank. The spike particles are dispersed on the bottom of the tank near the pump inlet. Spike particles that are transferred up the vertical section of piping and across the horizontal piping are captured and quantified using the same methods for the mixing tests. After a minimum of 10 turnover volumes have passed through the pump, the distance between the bottom of the tank and the suction inlet of the transfer pump is reduced by 1-inch so that particle capture as a function of suction height under quiescent conditions can be quantified. The test is repeated until the pump screen rests of the bottom of the tank. The duration at each elevation should be consistent . The flow condition shall be monitored using a Coriolis meter in the transfer line. The specific gravity of the slurry in the transfer line shall be monitored. The mass of the spike particles transferred by the pump at each height shall be quantified as described previously and the transferred material shall be returned to the tank for the next height interval. Once all of the data has been collected, the mixing tank shall be emptied and the transfer lines shall be flushed and the settled particles quantified so that the next test can be conducted.

The test matrix for the Full-Scale Transfer Pump Limits of Performance testing is provided in Table 3-10. The tests included in the test matrix should be performed in a random order to minimize experimental error. For Full-Scale Transfer Pump Limits of Performance, the specified design factors include the mixing condition, the base simulant composition, the spike particulate composition, and the supernatant composition. The variation in properties was selected based on properties that are expected to have large effects on the performance of the system so that variability introduced by experimental error would be small enough to allow for performance correlations to the design factors. The test matrix was designed with separate test activities for two mixing conditions, mixing and no mixing. Currently the design has been constrained to 14-18 tests. Designing 14-18 tests was based on conducting an appropriate number of tests to characterize the variability over the test variables while minimizing the test schedule and associated costs. In selecting the appropriate test matrix that is constrained to a specified number of tests, test replication has been sacrificed in order to test additional variations of the design factors. Test replication allows for the separate quantification of experimental error and inherent variability. By selecting the design factors that attempt to minimize experimental error, performing replicates, although still desirable, becomes less critical to evaluating the data.

Table 3-10: Full-Scale Transfer Pump Limits of Performance Test Matrix

Test Number	Base Simulant Constituents (Table 3-1)	Mass Loading[a]	Liquid Simulant Properties[b]	Mixing Condition
1	High	Low	Low	Mix
2	High	Low	High	Mix
3	High	High	Low	Mix
4	High	High	High	Mix
5	Low	Low	Low	Mix
6	Low	Low	High	Mix
7	Low	High	Low	Mix
8	Low	High	High	Mix
9	Non-Newtonian	3 Pa	High	Mix
10	Non-Newtonian	3 Pa	Low	Mix
11[c]	Non-Newtonian	10 Pa	High	Mix
12[c]	Non-Newtonian	10 Pa	Low	Mix
13	None	High	High	No Mix
14	None	High	Low	No Mix
15	Non-Newtonian	3 Pa	Low	No Mix
16	Non-Newtonian	3 Pa	High	No Mix

Test Number	Base Simulant Constituents (Table 3-1)	Mass Loading[a]	Liquid Simulant Properties[b]	Mixing Condition
17[c]	Non-Newtonian	10 Pa	Low	No Mix
18[c]	Non-Newtonian	10 Pa	High	No Mix

[a] For non-Newtonian tests, increasing the mass loading of kaolin clay increases the yield stress of the slurry

[b] High supernatant properties: density = 1.37 g/ml, viscosity = 15 cP; Low supernatant properties: density = 1.1 g/ml, viscosity = 1 cP; non-Newtonian supernatant properties match the density of the Newtonian supernatant

[c] To reduce testing, it may be possible to combine testing into one test sequence by performing one test at a yield stress of 3 Pa and then add kaolin to increase the yield stress to 10 Pa before repeating the test.

3.2.3.4 Sample Collection and Analysis

Sample collection is similar for mixing and non-mixing test conditions; however, the frequency of data collection is increased in the non-mixing tests. The pumpage shall be collected and the spike particles separated from the base simulant solids using screens or filters. Spike particles are collected by diverting the recycle loop into an collection vessel, which is screened to separate the spike particles from the base slurry. The largest particles in the base material are smaller than the smallest spike particle so the base material should not be removed from the process stream if the proper screen size is selected. An ASTM-11E Number 16 sieve should separate all of the spike particles from the base material. Once the pumping volume has been processed, defined as a certain number of turnover volumes when operated in recirculation mode, the pump shall be turned off and the collected samples on the discharge end of the horizontal transfer line shall be quantified. The volume of the slurry diverted to sample collection shall be monitored and recorded. The mass of the spike particles in the diverted volume shall be determined for each particle size and density included in the test. The presence of any spike particles in the collected sample indicates that the system is capable of transferring the particles to the sample location. Differences between the concentration of the spike in the collected sample and the initial concentration may be reflective of either the mixing condition in the tank or the capability of the transfer system.

Separation of the spike material will be based on size exclusion. Based on the sizes proposed the spikes could be separated from the base material using a No. 14 or No. 16 sieve but testing with the base material will be performed to ensure that slurry throughput through the sieve can be maintained. The largest particles (7000 micron glass and 6350 micron metal spheres will be separated using a No. 3.5 sieve (5660 micron). For the next largest size particles 5000um glass and 4762.5um metal spheres, a No. 5 sieve (4000 micron) will be adequate. For the next largest size particles 3000 micron glass and 3175 micron metal spheres, a No. 7 sieve (2830um) will be adequate. For the smallest sized spheres of each type (2,000um glass and 1587.5um metal) a No. 14 sieve (1410 micron) will be adequate to separate this material. All of the segregated material will be washed, dried and weighed. The spike particle sizes are selected such that the separation of spikes is performed using sieves that are at least two sizes apart. The particles are also manufactured as spheres so that separation by sieving is expected to be readily accomplished. This should minimize the error associated with separating the different sized particles and an error tolerance of ±0.1% is assigned to particle separation. The quantification error also includes the accuracy of weighing the washed and dried material. The accuracy of the scale for weighing the recovered spikes is ±0.1%, which, at the planned loadings, represents hundreds of smallest glass spheres, tens of the largest stainless steel spheres and several of the largest tungsten carbide spheres. The sorting error is expected to be the largest source of error for quantification.

In addition to quantifying the mass of each spike particle that is successfully transferred from the horizontal transfer line, the mass of solids retained in the horizontal section of the transfer line at the end of the test shall also be determined. Particles that settle in the transfer line during mixing tests are also expected to settle in the transfer line during non-mixing tests. Spike particles that settle in the horizontal section of the transfer line are expected to be larger and more dense than particles that do not settle out in the transfer line. The presence of smaller spike particles in the transfer line does not indicate that the particles settled, but could indicate that the particles were in the process of moving through the transfer line at the end of the test. Higher concentrations of large and dense particles in the transfer line at the end of the test compared to the collected samples does suggest that those particles did settle out in the transfer line.

Once all tests are completed, the capability of the transfer pump will be correlated to parameters that we varied during testing, particle size, base simulant composition, liquid density and liquid viscosity.

3.3 SOLIDS ACCUMULATION

3.3.1 Scouting Studies

Test requirements for the SSMD Solids Accumulation Scouting studies documented in Section 3.3.1 are performed by Savannah River National Laboratory for WRPS. This test plan does not govern any development work that is performed to evaluate simulant compatibility with the test equipment, including the initial development of sampling and measurement techniques.

3.3.1.1 Test Equipment and Instrumentation

SSMD Solids Accumulation Scouting studies shall use the 1:22-scale MDT test platform at the SRNL test facility. The 1:22-scale MDT test platform has been used for previous test activities and will continue to be used to address uncertainties in the WFD Mixing and Sampling Program.

The main components of the MDT test platform include: a 120 gallon acrylic test tank (40.4-inch diameter), two rotating mixer jet pumps and a slurry transfer pump. Ancillary equipment, such as motors, controllers and encoders to rotate and monitor position of the mixer jets, both flexible tubing and rigid stainless tubing and seven partially transparent PVC receipt tanks are also part of the test platform. The MDT test system shall be configured similarly to previous MDT test activities, making necessary modifications to accomplish the new scope and improve on past problems, e.g., air leakage in the jet pump seals. Mixing shall be performed using two rotating mixer jets, each having two opposing nozzles placed near the tank bottom. Mixer jet rotation and nozzle velocities should be programmatically controlled and the nozzle position should be monitored using encoders. The transfer pump suction inlet shall be placed consistent with the location of Riser-012 in DST AW-105 (see Table 1-1), which would place it in-line with the two mixer jet pumps 0.29 feet from the center of the tank. The scaled height of the transfer pump suction inlet should be equivalent to the height of the transfer pump inlet in the full-scale DST transfer system (6-inches above tank bottom), which is approximately ¼-inch. For Solids Accumulation Scouting Studies testing, a separate mixing vessel will be required; the Feed Prep Tank will be used to mix the next round of simulant that will be used to refill the MDT. The Feed Prep Tank and associated transfer system will be used as the simulant source for each refill operation.

The transfer system piping, valving, and instrumentation (e.g., magnetic flow meters) should replicate the transfer system from previous testing reported in SRNL-STI-2011-00278, *Demonstration of Mixing and Transferring Settling Cohesive Slurry Simulants in the AY-102 Tank*. The test configuration shall include the capability to sample the very fast settling solids from the transferred slurry. Flow control should be automated using programmable logic controllers connected to a human–machine interface. System data, including flow conditions, should be monitored and recorded using a data acquisition system.

Solids accumulation in the test tank shall be quantified by measuring the volume of solids remaining in the tank in between a series of slurry transfer and refill operations. The measurement technique (e.g., volume displacement) shall be at the discretion of the investigators but the accuracy of the instrumentation used for solids measurement shall be quantified. An accuracy range of ±20% is comparable to liquid displacement or visual estimation techniques performed for quantifying residual wastes in Hanford single-shell tanks.

All measuring and test equipment, including gauges and instrumentation, used for testing activities shall be controlled, calibrated under conditions typical of the test environment, adjusted and maintained to required accuracy limits. The condition and the reported accuracy of each instrument shall be documented in a test log.

3.3.1.2 Test Simulants

The base simulants used in the SSMD Solids Accumulation Scouting studies shall be selected in accordance with the recommendations in RPP-PLAN-51625 and Section 3.1.1. The base simulants shall be a complex simulant containing slow settling, fast settling, and very fast settling solids. The base simulants should be sufficiently different so that separation and sampling techniques can be used to quantify the concentration of each particle type in the tank heel. For Solids Accumulation Scouting Studies the complex simulant will be the "Typical" conceptual simulant presented in Table 3-1. The "Typical" simulant is appropriate for use because multiple fill and empty operations will be performed and it is expected that understanding the "typical" behavior is more appropriate for future performance than testing a series of "low" or "high" conceptual simulants which represent low probability expectations. Gibbsite is appropriate as a slow settling solid because chemical analyses of the tank waste indicate gibbsite is a principal component. Furthermore, the light color of gibbsite allows it to be distinguished from the different colored solids that will represent the fast and very fast settling particles. Medium sand, due its higher density and larger particle size, will settle faster than gibbsite. With a density more than twice that of the sand or gibbsite but a particle size that is smaller than the sand and similar to the gibbsite, zirconium oxide is expected to settle slower than the sand, but much faster than the gibbsite. The selected compound for the very fast settling solid is stainless steel. The stainless steel is darker in color than the other constituents in the base simulant and it is magnetically attractive. Therefore, the distribution of the very fast settling solids in the tank can be characterized visually and magnetism could be used to isolate these particles for quantification.

The supernatant simulant should be adjusted using soluble salts to achieve a target density of 1.29 g/ml and a liquid viscosity of 3.3 cP. The targeted values are consistent with previous studies conducted at SRNL. The target density is an intermediate density between the low and high density values included in Table 3-2. The targeted viscosity is consistent with the density-viscosity relationship shown in Figure 6-2 of RPP-PLAN-51625.

Unlike Limits of Performance testing, the capability of the system to transfer large and dense particles is not being evaluated in the MDT; therefore, the complex simulant shall not be spiked with large, dense particles. The very fast settling solids are represented by the stainless steel in the base simulant.

3.3.1.3 Operating Parameters and Test Methods

The operating conditions for the MDT test platform should be consistent with previous performance testing. The mixer jets shall be operated with no rotational offset, the streams will be synchronized to meet in the center of the tank. The rotational speed of the jets shall be maintained for all tests, but solids accumulation using two different nozzle velocities shall be evaluated. The nozzle velocities used in the capability testing shall be scaled equivalents of the full-scale mixer pumps. The two different nozzle velocities should be determined using recommended values for the scale factors exponents (i.e., 0.25 and 0.33). The appropriate nozzle velocities to use during solids accumulation should result in "dead zones" within the tank. If the jet nozzle velocity is high enough to prevent build-up in the MDT, then solids accumulation will not be adequately quantified. Previous MDT studies conducted with less challenging simulants at lower nozzle velocities than that resulting from a scale factor exponent of 0.25 prevented "dead zones". Therefore, the selection of the second nozzle velocity will be reevaluated at the time of testing to ensure that accumulation data can be collected.

The MDT test platform should be operated in a recirculation mode until a stable state mixing condition is established. Once the tank reaches the stable state, the batch transfer should be initiated. The batch volume should be pumped to the receipt tanks, utilizing a different tank for each of the different transfers. During each transfer, the very fast settling particles will be removed from the base material. Magnetics will be used to separate and retain the stainless steel particles from the other solids. After each transfer is completed, a description and quantification of the solids remaining in tank, including a photographic or video record, should be prepared. Heel samples shall be collected from the tank after the 1st, 5th and 10th tank volume transfers. Heel samples shall be collected with minimal disturbance to the remaining heel. In addition, quantification of the settled solids in each receipt vessel shall also be documented. After the last tank volume transfer is completed, a description and accurate quantification of the solids remaining in tank, including a photographic or video record, should be prepared. A description and accurate quantification of the solids remaining in tank, including a photographic or video record, should also be prepared after the 5th and last tank volume transfers are completed.

After the solids from the first tank volume transfer operation have been characterized a new round of simulant shall be added to the MDT. The new slurry should be well mixed prior to and during the transfer. Refilling the MDT should not significantly disturb the piles of solids left behind after the previous transfer. The transfer from an auxiliary mixing tank into the MDT mixing tank should replicate the DST process that is expected to add the new slurry to the center of the tank.

A series of transfer and refill operations shall be performed. The volume of solids remaining in the MDT shall be characterized before the tank is refilled. Solids characterization can include length, depth and width measurements of the mounds coupled with photographs that show the mound topography. Additionally, qualitative descriptions of the heel should be documented to augment the photographic records. Successive transfer and refill operations, up to ten, will evaluate whether or not the solid volume left in the tank continues to increase after each transfer. Ten tank volume transfers represent about one half of the number of tank volume transfers that will originate from DST 241-AW-105, the tank will the greatest number of planned transfers to the WTP. Fewer tank volume transfers may be performed if it is demonstrated that the heel volume stabilizes despite performing additional fill and transfer cycles.

The solids accumulation testing operating parameters are shown in Table 3-11.

Table 3-11: Solids Accumulation Scouting Study Operating Parameters

Parameter	Value(s)	Parameter	Value(s)
Mixer Jet Synchronization	360° Rotation with no offset.	Test Volume	Approximately 104 gallons
Mixer Jet Rotational Velocity[1]	SFE=0.33: 1.6 rpm SFE = 0.25: 2.1rpm	Number of Batch Transfers to be Performed	6.5
Mixer Jet Nozzle Velocity	SFE=0.33: 21 ft/s SFE = 0.25: 27 ft/s	Batch Transfer Size	13.1 gallons
Transfer Pump Flow Rate	0.58 gallons per minute	Tank Volume Transferred per Cycle	85 gallons

[1] Selected to be consistent with previous MDT studies.

3.3.1.4 Sample Collection and Analysis

Solid samples from the heel shall be collected from the MDT following the 1st, 5th and 10th tank volume transfers. Solids samples shall be collected in place to provide a spatial characterization of the heel. Heel samples should be collected from the mounds formed in the "dead zone" in the tank and in the settled material that is deposited as a layer in the tank when the mixers are turned off. The mass of very fast settling solids in the settled layer distributed throughout the tank is characteristic of the mass that is suspended during mixing. The shape of the settled solids will be used to guide where 3/8-inch outer diameter core samples are to taken, but several samples will be taken at low, medium and high pile depth locations to obtain a good representation of the location of the stainless steel particles in the mounds. Only one mound will be chosen for sampling after the 1st and 5th cycles. The second mound will be left intact until the final cycle is completed. After the last cycle, the second mound both mounds will be sampled. The number of samples collected after the 1st and 5th cycles should not destroy the integrity of the mound. The stainless steel in each core sample will be extracted from the core using strong magnets, dried and weighed. The mass of the very fast settling solids in each sample shall be quantified and recorded in a test log. Solid samples shall be collected prior to re-filling the tank for the next tank volume transfer. If supplemental removal of tank liquids is necessary to collect the samples, the liquid shall be withdrawn with minimal disturbance to the residual solids and then be stored temporarily. The stored liquid should be added back to the tank after the samples are collected but before the tank is re-filled for the next round of transfers. The spatial location of the collected samples shall be recorded in the test log. The sample collection technique shall be documented in a photographic record or video recorded. The collected samples shall be analyzed for the composition of the very fast settling particles so that a spatial distribution of the very fast settling solids in the accumulated material can be qualitatively described.

To estimate a mass balance, the mass of the very fast settling solids removed during each transfer shall be also quantified. The discharge from the tank will flow through a magnetic separator to extract the stainless steel from the slurry. The recovered stainless steel shall be dried and weighed to quantify the amount transferred in each batch. An estimation of the sample error for the very fast settling solids in the heel and transfer batches should be quantified during developmental work to test the magnetic separator. A qualitative description of the sand, gibbsite and zirconium oxide transferred in each batch shall also be reported by measuring the heights of the settled layers in the receipt tanks and calculating the resulting volumes of the settled layers using the known geometry of the vessels. Precise quantification of the sand, gibbsite and zirconium oxide in the heel is not required for these scouting studies. More precise evaluations will be performed using the SSMD test platform in a separate test activity.

The volume of solids remaining in the tank shall be estimated using a technique developed during developmental testing. The methods that will be tested include laser height measurements of the heel piles, liquid displacement, and 3-D topographical mapping. For laser height measuring the distance from a known point to the surface of the heel is measured using a laser measurement instrument. Several measurements are collected to map the topography of the surface. For the liquid displacement measurement technique, heel liquid is withdrawn from the tank in know height increments and the amount of liquid withdrawn is compared to the expected volume for that height. The liquid retained in the pores of the heel is estimated based on developmental work so that the difference in the expected liquid volume and measured liquid volume, accounting for the wetted pores, approximates the volume of solids in that height interval. After each incremental lowering of the liquid level, photographs of the heel surface will be captured and combined to form a topography map of the heel surface. The volume of the heel is estimated from the heel topography. The accuracy of the measurement technique shall be reported and comparable or better than ±20%, the approximate level of accuracy for existing tank solids volume estimation techniques. The mass of the very fast settling solids remaining in the tank after the transfer campaign shall be estimated by subtracting the total mass of very fast settling solids measured in the batch transfers from the total mass added to the tank during the testing campaign.

3.3.2 Solids Accumulation Performance Evaluation

SSMD Solids Accumulation Performance Evaluation test activities documented in Section 3.3.2 are performed by Energy*Solutions* for WRPS.

The SSMD Solids Accumulation Performance Evaluation activities will characterize the accumulation of solids in the prototypic test tanks at two scales (1:21 and 1:8). Data analysis will evaluate scaling relationships for different performance metrics related to solids accumulation as well as mixing and transfer performance. The test requirements, including requirements for platform configuration, operating parameters, test methods, simulants, and sample and analysis for these activities will be informed from the activities described in this test plan and will be developed and documented in a separate test plan.

3.4 SCALED/SYSTEM PERFORMANCE

3.4.1 Small Scale Mixing Demonstration

SSMD Scaled Performance test activities documented in Section 3.4.1**Error! Reference source not found.** are performed by Energy*Solutions* for WRPS.

The SSMD Scaled Performance test activities will evaluate scaling relationships for different performance metrics related to mixing and transfer performance, as well as solids accumulation.

The test requirements, including requirements for platform configuration, operating parameters, test methods, simulants, and sample and analysis for these activities will be informed from the activities described in this test plan and will be developed and documented in a separate test plan.

3.4.2 Remote Sampler Demonstration

RSD System Performance test activities documented in Section **Error! Reference source not found.** are performed by Energy*Solutions* for WRPS.

The RSD System Performance test activities will collect system performance data with the vertical piping configuration. The test requirements, including requirements for platform configuration, operating parameters, test methods, simulants, and sample and analysis for these activities will be informed from the activities described in this test plan and will be developed and documented in a separate test plan.

4.0 TEST COORDINATION

All testing equipment operation is performed by trained and qualified subcontracted personal under the supervision of a Test Director. An operations plan, including test run sheets, will be prepared that describes the precautions and limitation, the sequence of testing, testing prerequisites, startup conditions, and test procedures in stepwise detail. The TOC technical representative(s) must concur with the operations plan. The Test Director coordinates testing activities including ensuring that all test conditions required for the start up of testing have been performed and all test records (e.g., Test Log, Test Deficiency Reports, Test Change Requests, etc.) are maintained. The Test Director is also responsible for coordinating test activities with the Quality Assurance representative to ensure testing is performed in accordance with the approved quality assurance plan. While tests are conducted, the Test Director will also determine which changes are considered "inconsequential" and approves these test changes. All other changes require the concurrence with the TOC technical representative(s) before the change(s) is/are implemented.

4.1 PRECAUTIONS AND LIMITATIONS

The Job Hazards Analysis is the process for identifying, evaluating, controlling, and communicating potential hazards associated with the work being performed, including modifications to test facilities and test equipment. Testing for the Limits of Performance and Solids Accumulation Scouting Studies are being performed in test facilities constructed to perform the testing. Each test facility is governed by a facility specific Job Hazards Analysis documented in a Job Hazards Analysis checklist or equivalent document. Changing conditions that modify the test facility or equipment to accommodate testing will be evaluated in a revision to the Job Hazards Analysis before the modifications to the facility or equipment are performed. Workers performing work in the test facility governed by the Job Hazards Analysis shall review the document hazards and acknowledge that they understand the hazards associated with the work being performed and will abide by controls (e.g., don required personal protective equipment, obey posted signs and placards) put in place to mitigate or eliminate the hazards.

Any special precautions that must be taken or test limitations will be documented in the operations plan specifically prepared for each activity and will communicated to workers before the start of work during a Pre-Job briefing.

4.2 SEQUENCE OF TESTING

Any special requirements for the testing sequence that are not identified in Section 3.0 will be documented in the operations plan specifically prepared for each activity.

4.3 PLANT CONDITIONS

Any special requirements for the plant conditions, including connecting to site utilities and site restoration, that is not identified in Section 3.0 will be documented in the operations plan specifically prepared for each activity.

4.4 SPECIAL EQUIPMENT

Any special equipment required to conduct the tests that is not identified in Section 3.0 will be documented in the operations plan specifically prepared for each activity.

5.0 DATA COLLECTION AND TEST RESULTS REPORTING

Testing shall be conducted in accordance with an approved operations plan that is prepared in accordance with this test plan. All test activities shall be performed according to test run sheets. All major testing activities shall be documented in a test log. Test deficiencies shall be reported in a Test Deficiency record.

Test data identified in Section 3.0 , including test durations and test conditions, shall be recorded in the test log. Applicable data not recorded by a data acquisition system shall be recorded on the run sheet or recorded in the test log. All electronic data collected by a data acquisition system shall be content reviewed for error and anomalies. Electronic records shall be submitted to the TOC for evaluation.

All laboratory analysis results shall be accompanied by a chain of custody report that was prepared when the samples were collected. The chain of custody shall identify the samples by a unique name, describe the sample type and list the analyses to be performed. The chain of custody shall also document the preparers name and shall acknowledge receipt at the analytical laboratory. All laboratory analysis results shall be submitted to the TOC technical representative in an MS Excel compatible format.

Test result reports shall be prepared for each test activity. Test activities conducted by SRNL shall be documented in a test report prepared by SRNL. Test activities conducted by CEES shall be documented in a test report prepared by CEES. Test activities conducted by Energy*Solutions* shall be documented in a test data package that is submitted to the TOC. The TOC shall perform the required analysis and document the findings in a test report that is reviewed by Energy*Solutions*.

6.0 REFERENCES

ASTM 11E

American Society of Mechanical Engineers (ASME), NQA-1-2004, *Quality Assurance Requirements for Nuclear Facility Applications* (including NQA-1-a-2005 and NQA-1b-2007 Addenda), New York City, New York.

24590-WTP-ICD-MG-01-019, 2011, *ICD 19 – Interface Control Document for Waste Feed*, Rev. 5, Bechtel National, Inc., Richland, Washington.

24590-WTP-RPT-MGT-04-001, 2004, *Regulatory Data Quality Optimization Report,* Rev. 0, Bechtel National, Inc., Richland, Washington.

24590-WTP-RPT-MGT-11-014, 2011, *Initial Data Quality Objectives for WTP Feed Acceptance Criteria*, Rev. 0, Bechtel National, Inc., Richland, Washington.

24590-WTP-PL-PR-04-0001, *Integrated Sampling and Analysis Requirements Document (ISARD)*, Rev. 2, Bechtel National, Inc., Richland, Washington.

DNFSB Rec. 2010-2, Rev. 0, November 10, 2011, *Department of Energy Plan to Address Waste Treatment and immobilization plant Vessel Mixing Issues – Implementation Plan for the Defense Nuclear Safety Board Recommendation 2010-2,* U.S. Department of Energy, Washington D.C.

ORP-11242, 2011, *River Protection Project System Plan,* Rev. 6, U.S. Department of Energy, Office of River Protection, Richland, Washington.

PNNL-14443, 2003, *Recommendations for Advanced Design Mixer Pump Operation in Savannah River Site Tank 18F*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-19441, 2010, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20637, 2011, *Comparison of Waste Feed Delivery Small Scale Mixing Demonstration Simulant to Hanford Waste*, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-20350, 2011, *Hanford Tank Farms Waste Certification Flow Loop Phase IV: PulseEcho Sensor Evaluation,* Pacific Northwest National Laboratory, Richland, Washington.

RPP-47557, Rev. 0, 2010, *SSMD Test Platform – Small Scale Mixing Demonstration Initial Results Report,* Washington River Protection Solutions, LLC, Richland, Washington.

RPP-49740, Rev. 0, 2011, *Small Scale Mixing Demonstration Sampling and Batch Transfers Results Report*, Energy Solutions, Richland, Washington.

RPP-50557, Rev 0B, *Tank Waste Mixing and Sampling Update*, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-41807, 2012, *Waste Feed Delivery Mixing and Sampling Program Plan and Test Requirements*, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-PLAN-51625, 2012, *Waste Feed Delivery Mixing and Sampling Program Simulant Definition for Tank Farm Performance Testing,* Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-48233, Rev. 0, 2011, *Independent Analysis of Small Scale Mixing Demonstration Test*, Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-48681, 2011, *Hanford Tank Waste Operations Simulator Model Data Package for the River Protection Project System Plan Rev. 6 Cases,* Washington River Protection Solutions, LLC, Richland, Washington.

RPP-RPT-51796, 2012, *Remote Sampler Demonstration (RSD) Phase I Sampling Results Report*, Washington River Protection Solutions, LLC, Richland, Washington.

SRNL-STI-2010-00521, 2010, *Demonstration of Mixer Jet Pump Rotational Sensitivity on Mixing and Transfers of the AY-102 Tank*, Savannah River National Laboratory, Aiken, South Carolina.

SRNL-STI-2011-00278, 2011, *Demonstration of Mixing and Transferring Settling Cohesive Slurry Simulants in the AY-102 Tank*, Savannah River National Laboratory, Aiken, South Carolina.

SRNL-STI-2012-00062, 2012, *Properties Important to Mixing for WTP Large Scale Integrated Testing,* , Savannah River National Laboratory, Aiken, South Carolina.

SVF-2110, 2011, *TRANSFER_PLOTS_4MINTIMESTEP(6MELTERS)-MMR-11-031-6.5-8.3R1-2011-03-18-AT-01-31-58_V7.XLSM*, Revision 1, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ENG-DESIGN-C-18, *Testing Practices,* Washington River Protection Solutions, LLC, Richland, Washington.

TFC-ESHQ-Q_ADM-C-01, *Graded Quality Assurance,* Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLAN-26, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLAN-39, 2011, *Risk Management Plan*, Rev. G, Washington River Protection Solutions, LLC, Richland, Washington.

TFC-PLAN-90, 2011, *Technology Development Management Plan,* Rev. G, Washington River Protection Solutions, LLC, Richland, Washington.

WRPS-1105293, *Small Scale Mixing Demonstration Optimization Workshop Meeting Minutes*, November 16, 2011, Washington River Protection Solutions, LLC, Richland, Washington.

APPENDIX A

SMALL SCALE MIXING TANK SCALING RELATIONSHIPS

A.1 Mixer Jet Pump Nozzle Velocity Scaling

The power, required to mix a tank with a jet, P_{mix}, can be determined from the kinetic energy supplied by the jet, as shown in Equation A-1,

$$P_{mix} = \left(\frac{\pi}{4} d_{jet}^2 U_{jet}\right)\left(\frac{1}{2}\rho U_{jet}^2\right) = \frac{\pi}{8}\rho d_{jet}^2 U_{jet}^3 \qquad \text{Equation A-1}$$

where, ρ is the fluid density, U_{jet} is the nozzle velocity of the jet and d_{jet} is the jet nozzle diameter.

For the equal power-per-volume scaling relationship, the power computed by Equation A-1 is divided by the mixing volume, V, as shown in Equation A-2. Note: the mixing volume is the waste simulant slurry volume, not the capacity of the tank. The mixing volume is characterized by the tank diameter, d_{tank}, and the height, h_{slurry}.of the slurry in the tank as it is mixed.

$$\frac{P_{mix}}{V} = \frac{\frac{\pi}{8}\rho d_{jet}^2 U_{jet}^3}{\frac{\pi}{4} d_{tank}^2 h_{slurry}} \qquad \text{Equation A-2}$$

For two scaled mixing systems with similar geometric properties mixing the same simulant, the nozzle diameter, tank diameter and slurry height from one tank are scaled from the other tank using the scaling factor, SF. The scaling factor is the ratio of the scaled tank diameter and the full-scale tank diameter. Setting the power-per-volume equation equal for the two scales, denoted with subscripts 1 and 2, and substituting in the scaling relationship ($SF=d_{tank2}/d_{tank1}$) is shown in Equation A-3. The simplification of Equation 1-3 is shown in Equation A-4.

$$\frac{P_{mix1}}{V_{tank1}} = \frac{\frac{\pi}{8}\rho d_{jet1}^2 U_{jet1}^3}{\frac{\pi}{4} d_{tank1}^2 h_{slurry1}} = \frac{P_{mix2}}{V_{tank2}} = \frac{\frac{\pi}{8}\rho d_{jet2}^2 U_{jet2}^3}{\frac{\pi}{4} d_{tank2}^2 h_{slurry2}} = \frac{\frac{\pi}{8}\rho SF^2 d_{jet1}^2 U_{jet2}^3}{\frac{\pi}{4} SF^2 d_{tank1}^2 SF h_{slurry1}} \qquad \text{Equation A-3}$$

$$U_{jet1}^3 = \frac{U_{jet2}^3}{SF} \qquad \text{Equation A-4}$$

The scaling factor exponent for equal power per volume conditions in the SSMD test platform is 1/3, as shown in Equation A-5.

$$U_{jet2} = U_{jet1}\left(\frac{d_{tank2}}{d_{tank1}}\right)^{\frac{1}{3}} \qquad \text{Equation A-5}$$

A.2 Mixer Jet Pump Rotational Rate Scaling

The rotation rate for the mixer jet pump, ω, is also a scaled property of the integrated system. The scaling parameter for the mixer jet pump rotational rate equates the number of revolutions that occur in the time required to circulate an entire tank volume through the mixer jet pump inlet (PNNL-14443 Section 2.1.2).

Because the tank diameter and tank height are geometrically scaled from the full-scale, the volume of the scaled tanks, V, are related as shown in Equation A-6.

$$V_{tank2} = \frac{\pi}{4} d_{tank2}^2 h_{slurry2} = \frac{\pi}{4}(SF\ d_{tank1})^2 SF\ h_{slurry1} = SF^3 V_{tank1} \qquad \text{Equation A-6}$$

The time required to circulate an entire tank volume through the mixer jet pump inlet, the turnover time (Θ), is the ratio of the tank volume and the mixer jet pump volumetric flow rate, which is itself a function of the nozzle velocity that is determined from a separate scaling relationship (see Equation 1-2). Equation A-7 shows this relationship.

$$\Theta_{tank1} = \frac{V_{tank1}}{Q_{tank1}} = \frac{V_{tank1}}{A_{nozzle1} U_{jet1}}$$

Equation A-7

If the nozzle velocity through the two tanks are scaled according to Equation 1-2, the turnover times are also related as shown in Equation A-8.

$$\Theta_{tank2} = \frac{V_{tank2}}{Q_{tank2}} = \frac{SF^3 V_{tank1}}{A_{nozzle,2} U_{jet2}} = \frac{SF^3 V_{tank1}}{SF^2 A_{nozzle1} U_{jet1} SF^a} = SF^{1-a} \Theta_{tank1}$$

Equation A-8

Setting the scaling condition (ωΘ) equal between the two tanks yields the angular velocity scaling relationship (Equations A-9 and A-10).

$$\omega_{tank1} \theta_{tank1} = \omega_{tank2} \theta_{tank2} = \omega_{tank2} SF^{1-a} \Theta_{tank1}$$

Equation A-9

Therefore,

$$\omega_{tank2} = \frac{\omega_{tank1}}{SF^{1-a}}$$

Equation A-10

WRPS-1202074-OS
Enclosure 4

LSIMS ERT DOCUMENT REVIEW RECORD	**REVIEW NUMBER:**	ERT-16 Feed Test Plan
	DOCUMENT NUMBER:	RPP-PLAN-52005 Rev 0A
	DOCUMENT TITLE:	Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan

Comment			Comments and Recommendations:	Resolution:
Number	Reviewer	Type*		
1	LMP	E	Page 1-4, top: It would be helpful to the reader to explain briefly what aspects of Phase I sampler testing suggested the need for further testing.	Added mention to high bias sampling of high density and large particles as concluded in RPP-RPT-51796.
2	LMP	**M**	Section 1.3: It is not clear a priori that equating the fluid velocity through the pump suction inlet in a geometrically scaled system is appropriate. No justification for this approach is provided. WTP used an argument that created a geometrically scaled zone of capture.	The new WTP approach focuses on targeting a critical velocity for expected simulant properties. Because of the extreme particles being tested, matching the full-scale transfer pump capture velocity provides the best opportunity to determine the limits of performance. See ERT-16 Review Response letter for additional details.
3	LMP	**M**	The largest particles in Table 3-3 (6350 um) are large compared to those dimensions in the 1:8 system. This leads to a number of potential problems as described in the review letter.	Developmental testing with the scaled equipment to demonstrate functionality of the equipment with the planned extreme particles has been performed and scaled system design changes have been identified and completed as a result of these developmental tests to ensure necessary data can be collected without damage or malfunction to the test equipment. See ERT-16 Review Response letter for additional details.
4	LMP	**A:M** B:O	Page 1-9, toward the bottom: "Equal performance between scales is determined when the chemical compositions at both scales are similar." A) Will samples be collected over multiple rotations of the jets, since otherwise composition is highly time-dependent? B) What is "similar"?	A. For scaled performance testing in the 1:8 scale tank, samples will be collected over integer values for the number of mixer jet rotations to minimize any influence of the position of the mixer jet during sampling. Furthermore, four samples will be taken during a transfer. These four samples will be combined and mixed and composite samples will be withdrawn and sent for chemical analysis. For the 1:21 scale tank, the entire transfer volume is collected and subsampled. B. Similar means equivalent within allowable tolerances. However, the text is more a method than a scaling basis and was deleted. It will be discussed further in the forthcoming technical details of the SSMD Scaled Performance

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				test plan.
5	LMP	I	Page 2-3: Is the SSMD transfer system prototypic? If particle sizes approach the line diameter, is it still prototypic?	The SSMD transfer system is prototypic. The particles sizes only approach the line diameter for LOP testing, in all other SSMD testing particle sizes are at least 10 times smaller than the line diameter and transfer inlet diameter.
6	LMP	**M**	Section 2.1.3.2: Basis for dimensions of the system (45-55 ft vertical, 20 ft horizontal) are not clear. Is 20 ft enough to demonstrate the effect you're looking for?	Vertical rise has been changed to 55 ft, the approximate depth to the bottom a DST from the surface. 20 ft is the distance included in the waste certification flow loop (based on the positions of the Ultrasonic PulseEcho system) and as serves as the basis for our testing. The real effect we are looking for is what is captured by the pump and less on how particles settle in the horizontal section of the flow line as the Ultrasonic PulseEcho will be used to evaluate critical velocity and solid settling.
7	LMP	**M**	Page 2-9: How will the slurry retained in the transfer line be extracted (quantitatively?) for screening?	Added discussion. Settled slurry in the transfer line will be extracted using a flush pump that generates a greater flow than the test pump. Discharge will be basket screened and spikes will be collected for sieving.
8	LMP	O	Page 3-22: Are you confident you can find a mechanical agitator that can mix 3/8" tungsten particles?	Requirement has been reduced to ¼-inch tungsten carbide. Design is in process.
9	LMP	O	Page 3-30: Approach to accurate quantification of remaining solids is unspecified.	Requirement has been eliminated. Quantification of heel solids will be done by mass balance. Qualitative observations of how the spike solids are distributed in the heel will be reported.
10	LMP	O	Page 3-31: Sample collection approach and the size of the sample volume relative to the volume of heel are unspecified.	Added detail. "The shape of the settled solids will be used to guide where the 3/8-inch outer diameter core samples are to be taken, but several samples will be taken at low, medium and high pile depth locations to obtain a good representation of the location of the stainless steel particles in the mounds. The number of samples collected should not destroy the integrity of the mound. Only one mound will be chosen for

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				sampling after the 1st and 5th cycles. The second mound will be left intact until the final cycle is completed. After the last cycle, the second mound both mounds will be sampled."
11	RRH	O	Page 1-1, second bullet: "understand the behavior of remaining solids" – please define the behavior.	Changed behavior to accumulation and distribution.
12	RRH	O	Page 1-2, Background: It appears that similar studies have been carried out for material in AY-102, and this study expands the objectives to cover other Tank Farm materials.	This is correct.
13	RRH	O	Page 1-3, third paragraph: The objective of delivering consistent 145 kgal batches may be difficult, because Pump Jet Mixers may not be capable of providing complete homogeneity of solids at all liquid levels. Is this absolutely important?	It is desirable to reduce sampling of the waste prior to delivery. Pre-samples are collected to determine is waste meets acceptance criteria. Desire is to have samples representative of the entire tank. The number of required samples is fewer if the tank can be well mixed.
14	RRH	O	Page 1-6, Table 1-1: Diameters of transfer pump suction inlets for 1:8 scale and 1:21 scale may be too small for spike particles being considered in the test plans. Industrial experiences indicate that ratio of inlet dia. to particle dia. should be a minimum of 4 and preferably 10. Using small diameter inlet may cause plugging and possibly divert large particles away and cause bias in the results.	See comment response letter.
15	RRH	O	Page 1-6, Table 1-1: Use of poly tubing may make the transfer erratic due to flexing of tubing which can be caused by pumping and/or flow patterns in the vessel. This does not apply if tubing is supported rigidly.	Acknowledged. The operators state that the tube is not supported along its length but does not move during a transfer. There is enough structure near the tube to secure it if erratic motion is observed.
16	RRH	O	Page 1-7, third paragraph, last sentence: Since limited data indicated that the scale factor exponent may be 0.39, the test conditions should be designed to include this value.	0.39 was provided as an example calculation for a simple simulant (zirconium oxide slurry). The discussion has been updated to clarify this.
17	RRH	O	Page 1-8, Equation 1-11: Use of SF^2/3 for rotation rate of mixer jet pump is not convincing. Since particle size and density are not scaled down, settling rates in the test units would be the same as in full scale vessels. Therefore faster rotation of pump jet mixers would reduce settling of particles.	Acknowledged. Scaled relationship will be honored based on the selected scale factor and Scaled Performance testing will evaluate the rotational rate scaling relationship.

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18	RRH	O	Page 1-9, top: It is understandable that ECR decreases as mixer jet rotational velocity increases. This could be caused by relative propagation of jets as the pump mixer rotates. I suggest calculating relative time for jet propagation to the tank wall.	We will follow up for more information on relative jet propagation. This may prove useful for future analysis of test results and scaling evaluations.
19	RRH	O	Page 1-9: I agree with the approach of determining the scale factor exponent 'a' from the data.	Acknowledged.
20	RRH	O	Page 2-4, Table 2-1: In the 'Success Criteria' column, it is mentioned that large and dense particles that can be mobilized to a sample location. Is mobilization sufficient or suspension is desired.	For Limits of Performance testing, mobilization under expected operating conditions is the objective as it couples the need to deliver a particle to the transfer pump inlet using the mixer jets and then the pump must be able to capture and transfer it down the line.
21	RRH	O	Page 2-7, Table 2-2: The design of agitator in the test tank is not provided. It should be specified if the agitator is designed to provide capability to suspend solids having particle size/density of material to be spiked. In addition, a definition of desired suspension quality should be provided, e.g., 'Just Suspension' or 'Complete Homogeneity'.	The vendor is being consulted on the capability of the mixer to suspend the spike particles (1/4-inch WC). The tests will not be allowed to proceed until the agitator is determined to be adequate. This is a project management control.
22	RRH	O	Page 2-9, last paragraph: It is not clear how slurry retained in the transfer line upstream of the sample location will be captured.	Added discussion. Settled slurry in the transfer line will be extracted using a flush pump that generates a greater flow than the test pump. Discharge will be basket screened and spikes will be collected for sieving.
23	RRH	O	Page 2-11: In the conference call on 4/20/12 Mike explained how solids sample from the heel will be collected by decanting the liquid and using a 'sample thief'. This technique is likely to provide a qualitative assessment of solids distribution, because settling may not be homogeneous on the tank floor.	Agreed. Quantitative measurements of the very fast settling solids will be performed by mass balance because the amount withdrawn from the tank will be known. Collected samples will be used to describe how the very fast settling solids are distributed in the mounds.
24	RRH	O	Page 2-14, Table 2-5: It is mentioned that mixing and transfer demonstration are performed at two different jet nozzle velocities. Are two velocities enough? – Should consider using 3 or more velocities. Also it is planned to use 100 micron dense particles to represent fissile material. The 6-part simulant in the WTP program uses	Work follows scaled performance testing, which should result in a better understanding of scale and help determine the two best velocities to use. Schedule and budget drive the number of tests that will be performed. Differences between WTP testing and TOC testing will be reconciled as DNFSB work

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			10 micron dense particles.	progresses.
25	RRH	O	Page 3-5, Table 3-3: With ½" poly tubing in 1:8 scale vessel, spike particles should be <1270 microns based on industrial experience. Similarly with ¼" poly tubing in 1:21 scale, spike particles should be <635 microns.	See comment response letter. And response to LMP #5.
26	RRH	O	Page 3-7, first paragraph: There is a mention of "drill mixing". Please define and explain.	Clarified. "Mixing in the auxiliary vessel was implemented using different methods including no mixing, mixing using a paint mixer attached to a portable drill and mixing using simulated jets. "
27	RRH	O	Page 3-11, 3.2.1.4: It is mentioned that there will be no rotational offset between mixer jet pumps. I was wondering if some offset would be beneficial for enhancing solids suspension and increasing ECR.	SRNL-STI-2010-00521 demonstrated nearly equivalent transfer under different mixer jet rotation configurations, but this will be a consideration for a Scaled Performance testing that will evaluate different rotational rates.
28	RRH	O	Page 3-11, 3.2.1.4: Values of scale factor exponents of 1/3 and 1/5 are mentioned. These values seem to vary at other locations in the document. I understand that there are two values under consideration, 0.18 based on Poreh correlation and 1/3 based on constant P/V scale-up. Although a value of 0.39 is mentioned earlier based on limited data.	1/3 and 1/5 are recommended starting points. 0.39 is the value when the 1:21 and 1:8-scale tanks had equal solids distribution (no transfer). Tests at other velocities will be considered as described for SSMD LOP. SSMD Scaled Performance will evaluate a third velocity, as yet to be defined.
29	RRH	O	Page 3-13, Table 3-6: There is no column for "Fill Height". On page 3-12 (third paragraph) it is mentioned that effect of fill height should be investigated.	Fill height will be examined as the fill height decreases when batches are transferred. The fill height will be considered in the analysis of the data, which will have samples from each batch transfer.
30	RRH	O	Page 3-14, first paragraph: It appears that some of methodologies for sampling and analyses have not been finalized. Some of these proposed techniques may not be feasible, e.g., separation of different density particles. Also measurement of solids remaining in the tank using photographic method seems to be qualitative.	Acknowledged. The text has been updated. The process of separating the materials is now better understood and are being demonstrated.
31	RRH	**M**	Page 3-15, 3.2.2.1, second paragraph: Since capability of mechanical agitator has not been evaluated, it is possible that existing agitator may need to be upgraded. This should be done soon since delivery time for	Acknowledged. The vendor is being consulted on the capability of the mixer to suspend the spike particles (1/4-inch WC). The tests will not be allowed to proceed until the agitator is determined

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			mixing equipment may be long. This mixer evaluation and possible upgrading of mechanical agitator should be documented for review.	to be adequate. Note, that homogeneous distribution is not required but rather a consistent distribution in the flow loop piping emerging from the bottom of the tank.
32	RRH	O	Page 3-16, second paragraph: Level of maximum pressure should be specified for the RSD flow loop.	The operating pressure range of the equipment has been added.
33	RRH	O	Page 3-18, Table 3-7: Similar to previous comments, the particle sizes planned for spike material seem to be very large and may cause plugging at the entrance of transfer line.	See comment response letter. And response to LMP #5.
34	RRH	O	Page 3-19, third paragraph: I believe time dependent rheological properties do not apply to these solid/liquid slurries.	Kaolin is slightly rheopectic and a slight variation in the yield stress as mixing progresses will be accommodated.
35	RRH	O	Page 3-21, first paragraph: It is not clear how particle density and size will be measured. Please provide a brief description.	Added discussion of sieving and counting or weighing of separated particles.
36	RRH	**M**	Page 3-22, first paragraph: A system of suspending 3/8" dia. 19.3 g/cc particles appears to be highly demanding for mechanical agitators. The mixer design should be evaluated for determining if an upgrade is needed and if it is feasible for this size tank.	The mixing requirement has been reduced to ¼-inch tungsten carbide. The mixer is not existing equipment so this sets the design basis.
37	RRH	O	Page 3-24, last paragraph: Mixing tank is planned to be emptied after each test. It is a common experience that all solids may not be removable by draining. Some washing may be required to completely empty the tank.	Acknowledged. Sluicing the tank clean has been discussed with the subcontractors performing the work.
38	RRH	O	Page 3-30, first paragraph: Scale factor exponent of 0.25 and 0.33 are listed. As commented earlier, the range of exponents should be 0.18 to 0.33 and possibly a maximum of 0.39 as indicated by limited data.	Acknowledged. The initial work is consistent with previous work done by SRNL. There is concern that 0.2 may be too high a velocity to result in solids accumulation. The test plan builds in the flexibility to use a different velocity.
39	RRH	O	Page 3-30, paragraphs 2 and 4: Please describe clearly the methodology proposed for quantifying solids in the heel, with any evidence to support viability of the technique.	Added discussion of the concepts being developed and tested. The technique is being developed as part of this testing activity.
40	EKH	O	Page i, first paragraph, second sentence: "...and determine the capability of the tank	Deleted "Appropriately" to make the sentence match the DNFSB 2010-2

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			farm staging tank sampling systems to provide samples that will appropriately characterize the tank waste and determine compliance with the WAC." Not clear what this sentence means; the word "appropriately" is not definitive and would the results from this testing make changes to the WAC or will it show sampling being compliance to the WAC requirements? Are these tests to provide input in the development of the WAC requirements and/or tolerances?	Implementation Plan. This work, in conjunction with other work, will provide input an Initial Gap Analysis that will define the initial WAC, define the characteristics of the tank waste, define the capability of the TOC to characterize the tank waste and identify whether TOC can characterize samples in accordance with requirements and has waste that exceeds the requirements in the WAC. The WAC will be then be refined by the WTP based on LSIT testing.
41	EKH	O	Page i, second paragraph, third sentence: Are you only demonstrating or are you going to perform "tests" to quantify the full scale slurry transfer pump performance? This statement seems that you're only going to demonstrate. Figure 2-1 states otherwise. Clarify.	Proper terminology is "test" and the document has been updated to clarify the distinction between the "demonstration platforms" where the tests are performed. – Note that demonstration is a legacy term carried forward to maintain connection with earlier tests.
42	EKH	O	Page i: Should scaling relationships be captured prior to performing any additional tests using the scaled systems (paragraph 4)? Shouldn't this test be performed prior to the limits and solids accumulations tests so as to use the appropriate scaling parameter(s)?	Limits of Performance testing to identify the capability of the system will be performed consistent with recommendations from experts providing us guidance. Scaling up to full scale will not be done for Limits of Performance so the work can proceed refinement of the scaling velocity. However, because of this some additional testing is being conducted, a nozzle velocity evaluation is being performed to determine if different nozzle velocities influence the capability of the integrated system.
43	EKH	O	Page 1-1, last paragraph: See comment 40 above on the use of appropriately.	Same change as EKH #40.
44	EKH	E	Page 1-2, second paragraph, second to last sentence: This seems to indicate that this testing may input the WAC requirements, e.g., may change the requirements? Does this support how you would address comment 40?	See response to EKH #40.
45	EKH	E	Page 1-2, Section 1.2: State that ICD-19 is the WAC, if this is correct.	Currently, the waste feed criteria are defined in waste feed specifications, WTP permits, the WTP safety authorization basis and ICD-19 and are summarized in an Initial Data Quality

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				Objectives for WTP Feed Acceptance Criteria report.
46	EKH	O	Page 1-3, second burger dot: The word "fissile" starts in this paragraph and is then used for buildup, mixing, transfer and sampling throughout this document. Which of the particles defined in this task is considered the fissile particles?	Solids accumulation uses stainless steel with a median particle size of ~112 microns to represent fissile material.
47	EKH	E	Page 1-3, third paragraph: "…145,000 gallon batch has the same solids composition." Recommend using "...same solids chemical composition..." Does this assume that the supernate phase has little significance or that it will be removed in the WTP?	Changed to "…has the same solids chemical composition and physical attributes (e.g., mass loading) as the …"
48	EKH	O	Page 1-3, fourth paragraph, second sentence: This response does not have to be in the report. Question, how were the samples pulled to make the statement that "…equivalent mixing performance, from a solids distribution perspective…"? I'm assuming the sampling locations were geometrically similar as well to support this statement. I just don't have the time to look back into these documents.	Monitored specific gravity at multiple equivalently scaled heights and compared the data from each velocity test.
49	EKH	O	Page 1-3, fourth paragraph: (e.g., bottom clearing, mixing homogeneity, etc.) Was the homogeneity case for a Newtonian or non-Newtonian fluid? Homogeneity is very hard to achieve and an impossibility for a fast settling slurry with a Newtonian carrier fluid, especially for rotating jets. Please clarify where homogeneity was observed (e.g., fluid/particle condition).	Fluid was Newtonian. Homogeneous was incorrectly used. Text changed to "(e.g., bottom clearing, solids distribution, batch-to-batch consistency, etc.)"
50	EKH	O	Page 1-4, first paragraph: Not clear; did the full-scale sampling show that chemically, the undissolved solids (UDS) contents in the tank were "similar" to those of the UDS contents in the samples in the condition where WAC sampling is to take place? Was this shown to be the case?	Added discussion that initial results tended to be biased high for high density (>8 g/ml) particles with sizes >50 microns). System changes showed improved performance but additional testing was recommended to confirm that the configuration change is adequate for field conditions.
51	EKH	**M**	Section 1.3: Scaling philosophy must also include the discussion that the flow regime (turbulent for instance, Reynolds numbers) must be the same in all scales to allow for proper scaling. Calculations do not have to	Based on previous scaled testing of jet mixed tank performance, it is assumed that equivalent flow regimes are maintained across scales. As results are analyzed and performance anomalies

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			be performed in this document showing that such is the case given the various physical properties (density/rheology) listed in this document, but it should be stated that flow regime calculations to support scaling between scales. This can be a harder problem for non-Newtonian fluids or particles that are on the same order of magnitude as that of the jet nozzle.	identified between scales, the impact of potentially operating under different flow regimes will be considered. This consideration has been added into the scaled performance section.
51A	EKH	O	Section 1.3: No discussion about scaling of non-Newtonian slurries and/or their matrices. Add some discussion. I didn't state this clearly (and I didn't expect physical properties to be scaled, I haven't seen this in any of the WTP or ORP testing to date and it has its own challenges.). It seems that you're going to be using the same scaling exponent for the non-Newtonian case (vessel containing NN fluid) as that of the Newtonian case. I would not expect that the scaling exponents to be the same for both the NN and Newtonian cases. For example, there is a relationship between Bingham Plastic yield stress and ECR which is different for a fluid that has no yield stress and it's ECR. So, what I'm saying is that there is no discussion in this document saying how the scaling exponent for the N is acceptable for the NN, other than its used. Please provide why the same scaling exponents are used for both NN and N fluids and provide references why such is the case.	Basic discussion of simulant scaling has been added to describe that our simulants are not scaled. The program is beginning to look at NN slurries in the SSMD. At this point we have not done any testing to allow us to defend the validity of applying the same scaling relationship to N and NN slurries. We are just beginning to use NN slurries and will continue to include them in Scaled Performance testing. We acknowledge this comment by adding a test plan statement that we need to evaluate the appropriateness of applying the same scaling relationships to N and NN slurries. It is an interesting comment, I recognize that there would be a performance difference with NN slurries but had not considered that different scales might mix NN slurries differently.
52	EKH	O	Table 1-1: Transfer pump suction inlet for the 1:8 scale is 0.3125 inches. Is this correct? Either this number is wrong or the data in Table 1-2 for the 1:8 scale is incorrect. For an inlet velocity of 6.4 ft/sec and suction inlet diameter of 0.3125 inches, I get the following: D = 0.02604 ft, Suction Area = 0.000533 ft^2, Q = 0.003409 ft3/sec = 1.53GPM.	The tabulated values for the 1:8 scale were not presented in the units cited. The table has been corrected.
53	EKH	E	Page 1-6: Add "performance" after" equivalent mixing". I assume this is for having the same solids distributions between scales as described earlier in comment 48.	Clarified that equal mixing performance is in regards to the distribution of solids throughout the mixed volume.

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54	EKH	O	Page 1-8, pump rotation speed: 1) Why is constant per unit volume scale used? Should Equation 1-6 be used rather than P/V, using the metric of interest or just an unknown power for a given metric (though it may be different than the metric)? This would support the conclusion made on Page 1-9, top paragraph, that scaled rotation speed needs to be further evaluated. 2) The statement made about jet mixing in tank 18F at SRS clearly shows that the ECR decrease with increasing jet rotational velocity (I'm assuming this is for a fixed jet velocity), hence would the scaled tests be impacted by rotating at a fast speed if dead zones are of interest (or ECR determination)?	Scale relationship has been revised to reflect generic (i.e., Equation 1-6 in Rev0A) velocity relationship. Clearly there is a dynamic that has not been well studied between the benefit of the increased nozzle velocity and the detriment of the lower ECR. This will be a consideration for follow-on testing.
55	EKH	E	Page 1-9, second paragraph: What does "similar" mean? Within +/- ?%? Clarify.	Similar means equivalent within allowable tolerances. Previously a metric, such as SpG at equivalently scaled heights in both scaled tanks were compared so the sum of the squares of the density differences at each scaled height was a minimum.
56	EKH	E	Page 2-2, Section 2.1, second sentence: I thought that providing a "representative" sample for the WTP prequalification program was one of the most important mixing/sampling evolutions that need to be considered. Transfers to the WTP could be monitored, but the WAC depends on the samples used for the prequalification program. Should such wording be added?	The intro and background discuss the objectives of the program.
57	EKH	O	Page 2-2, last sentence: Who at SRNL is doing this work and whom at WTP is supporting this effort? After reading your statement on page 3-6 of the SRNL literature survey on irregular shaped particles, not sure you can make the conclusions your making based on the SRNL document. Such as "...creating a greater challenge to mix, transfer and sample." There are no statements made in the SRNL document that such is the case, other than settling of non-spherical particles are slower than spherical. If you have literature to support the other statements about the spherical particles in	This refers to SRNL-STI-2012-00062 which is recently released and can be cited. The authors are Koopman, Martino and Poirier. We recognize that spherical particles settle faster and therefore are more challenging to keep suspended in the tank. LOP testing will indicate whether large and dense spherical particles can be transferred with the expectation that larger non-spherical particles could also be transferred. We will not be able to make conclusions about the ability to

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			this report, please provide them.	transfer non-spherical particles based on observations that a similarly sized spherical particle was not transferred. The gap analysis will constrain the capability results to the context of what could be in the tanks.
58	EKH	E	Page 2-3, Section 2.1.1.2, first paragraph: Don't remember any bench scale discussion in this document. Is the bench scale the full scale pump tests? I'm assuming that the scaled and prototypic test tanks are the 1/21 and 1/8 scales. Clarify; this does not make sense.	Discussion is in 3.2.1.1.
59	EKH	O	Table 2-1 (and there could be others, such as Table 2-2…). I thought chemical composition, not PSD, was the most appropriate matrix for SSMD test platform. See Page 1-9. Please correct.	For limits of performance testing, the focus is finding the largest size of different density particles that can be transferred. Chemical composition of the large spikes is important only from the standpoint of understanding the size and density of the material transferred.
60	EKH	E	Page 2-5, top paragraph: Question: is the 1/8th and 1/21st scale mixer jet pump of similar design (e.g., concentric flow). If so, could particles get trapped or logged in the concentric section of the pump leading to the jet nozzles or is the flow tapered in this section such that there are areas where large particles cannot settle out? This is only a question, does not have to be addressed in the report.	Mixer is concentric and operates at very high flow velocities. Spike particle sizes have been selected to be smaller than the passages and additional steps are being taken to prevent the largest particles from entering the MJPs.
61	EKH	O	Page 2-6, Section 2.1.2.1: What is meant by "consistently" sampled? Pulling consistent samples does not mean that the sampler is a good sampler. It could be pulling a low or high quantity of large particles constantly, not what is in the process. You would have to do a lot of tests to determine if this consistent response is the same for various conditions.	RSD LOP is trying to determine the largest particle that can be sampled by the sampler without causing poor performance, as indicated by complete or partial plugging. Consistently means replication without plugging. Supplemental testing will investigate sampler performance.
62	EKH	O	Page 2-6, Section 2.1.2.1: Provide additional information on what you mean by "flow properties" that influence the sampler.	This is a hypothesis proposed in Section 11.3 of RSD Phase I test report (RPP-RPT-51796) that says that the lower inertia of the lightest particles may be allowing them to be diverted with the flow that goes around the Isolok sample plunger as it is inserted into the stream.

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				The heavier particles may have too much inertia to flow around the plunger and tend to be captured by the plunger. Additional testing is needed to confirm this hypothesis so it has been deleted from the text.
63	EKH	O	Table 2-2: Questions. Test Objective: Are different transfer velocities to be tested as well? Success Criteria: 1) Is there a time for how long the sampler stays open or the number of times it is cycled into the stream to pull the collected sample volumes? No sampling philosophy is provided in this section of the text. 2) What method is going to be used to separate the materials, since chemical seems to be out of the picture?	Added text. "The Isolok sampler will collect 500 ml samples in increments of 5.3 ml per sample plunger actuation. Collecting the sample takes approximately 40 minutes. Once the sample is collected, the collected volume will be sieved to separate the different sizes of spike particles. "
64	EKH	O	Page 2-9, Section 2.1.3.2, first paragraph: Define what you mean by "flow properties" in this case (these must be different from the sampler flow properties). There seems to be some important pump characteristics.	Changed to "flow capability and inlet velocity"
65	EKH	O	Table 2-3. Objective. Is varying flowrate an operating mode that needs to be considered? Success Criteria: How will the information of the ratio of what is captured to what is batch going to be used in assessing the technology?	It is expected that the largest, most dense particle will be transferred at the highest flow velocity; therefore only the highest flow velocity will be tested. The most important determination is a Yes/No on whether or not particles of a specified size and density can be transferred. The amount transferred will inform the reliability of the results, high recoveries, high confidence the particle can be transferred, low recoveries, low confidence the particle can be transferred.
66	EKH	O	Page 2-9, Section 2.1.3.2: Give the length of piping (horizontal) to be tested. Do you expect that the results in this test can be extrapolated to a pipe that over a few miles long? Or there is no intent to use this data for such activities?	Accepted. Horizontal pipe length is 20 feet. A technique (Ultrasonic PulseEcho system) for monitoring critical settling velocity is developed and tested and will be implanted in the waste feed delivery sampling flow loop. This test is interested in lengths that are characteristic of the waste feed delivery sampling flow loop.
67	EKH	E	Page 2-9, second paragraph: Statement is made that replicating particle movement around the pump inlet is desirable, but if so,	Because of similar comments, this sentence has been deleted.

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			how would it be measured and what would it be compared against? Such statements that have no means of comparison or validation are typically meaningless.	
68	EKH	O	Page 2-9, second paragraph: 1) Why is it important to pump 45 to 55 feet vertically? What would this buy you? 2) Details, is the 90 degree a long, short or custom build elbow? 3) Is the 20 feet adequate to obtain flow stability? Should sampling occur at two horizontal distances to show solids capture is consistent? 4) It states that the slurry upstream of the sample location in the horizontal section and in the tank will be analyzed. Is this to occur after each sampling sequence? 5) The line after the sampling location, if recycled, will it also be screened for large particles or will this line be designed such that large particles will not settle out?	1. Added "Simulant, including large diameter spike particles, will be mixed and pumped through a network of pipes that mimic the flow from the bottom of a DST to the location of the Ultrasonic PulseEcho system in the waste feed delivery characterization flow loop." 2. The design of the bend is not completed yet. 3. The criteria is based on recommendations for placement of the Ultrasonic PulseEcho system in the WFD certification flow loop. 4.Yes, solids in the horizontal section will be quantified after each test. 5. Initial design has flow passing through a screen to capture the spikes but allow the base material to pass though and drain back into the mixing tank.
69	EKH	O	Page 2-10, Section 2.2.1.1: How will subsequent batches be added to the DST? Provide some description. Seems that sampling of the mound and mound volume determination are to be developed? If so, state it. (OK I found this statement on Page 2-12 about sampling and analysis methods are to be developed.)	Subsequent batches are added to a DST by pumping the material through a drop leg at the top center of the tank or through a slurry distributor. Not all DSTs have a slurry distributor. Moved text up in the discussion.
69A	EKH	O	Page 2-10, Section 2.2.1.1: Will sampling be representative of the mound composition and could this sampling affect the test results due to it disturbing the mound contour?	Yes, sampling will change the mound. In the details section it has been added that the second mound will only be sampled after the last transfer is a campaign is performed so that it remains intact.

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69B	EKH	O	Table 2-4: Objective: Should rotational speed be considered? Success: 1) By sampling the mound, can you use this data to determine the quantity of very fast settling particles that have accumulated inside the MDT? Or by measuring what is transferred out of the DST a better means of determining what is left in the tank? I find it hard to subsample a mount (and where do you do it) and then making a conclusion based on that sample on mound composition. 2) What is it meant by "The relative quantities of solid in each transfer batch are estimated."?	1. For this development work, the rotational rate will not be considered. For more precise quantitative work performed later, the rotational rate may be considered if preceding work for SSMD Scaled Performance indicates it should be. The mass taken out will be measured and heel contents will be largely determined by mass balance. Heel samples will provide indications of where material is settling. 2. For Scouting Studies, the other solids will not be quantified with great precision, the heights of the settled solid layers in the receipt tanks will be measured, and a volume transferred will be determined by the height and geometric of the receipt tanks. However, it is known that, although the particles settle in distinct layers, perfect settling into layers does not happen so the volumes in each batch will be estimates that can be compared relative to one another.
70	EKH	O	Page 2-11, Section 2.2.1.2: 1) Will the mixer pumps be turned off at the same height in the MDT as that in the DST (scaled accordingly)? 2) Last sentence states the solids remaining in the MDT will be characterized. Do you mean subsampled and characterized?	1. Yes, batch volumes are scaled geometrically so that the waste heights after a full batch transfer will also be scaled. 2. Text has been deleted as it is was determined to be too much detail for this section and is repeated in more detail in Section 3.0, but characterized means heel volume is determined by measuring (different techniques are used during development), heel shape is described (or photographed) and the spatial distribution of very fast settling solids in the heel is described from heel subsampling and quantification.
71	EKH	O	Page 2-12, first paragraph: I would expect it to be easier to quantify the transferred material and that this testing could be used to determine if the sampling method(s) used to determine the mound composition are adequate in characterizing its composition.	This is a consistent approach with what is planned.
72	EKH	O	Table 2-5: 1) See comment 69B. 2) What	This testing will be informed by all

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			about rotational speed? Could solids accumulation also be a function of rotational speed?	previously conducted work, which may include conclusions on rotational velocity.
73	EKH	E	2.2.2 and 2.3: I will place more thought in this objective when I see their test plans. I expect changes will occur and that there should not be a lot of effort spent on these sections.	Acknowledged.
74	EKH	E	Page 3-2, first paragraph: Will the performance metrics be calculated using the physical properties of the actual Newtonian fluids used in this task as well? This may provide additional insight on the effect these physical properties have on these performance metrics.	Yes.
75	EKH	O	Page 3-3, first paragraph: I do not believe you will be calibrating the instrument (e.g., the rheometer). NIST oil standards are used to verify the operability of the instrument and either flow curves or single points are used to verify that the calculate viscosity is within +/- 10% of the NIST standard viscosity. Calibrations are much more complicated, where applied torque is measured and speed is verified independently.	Correct. Provided clarification that the instrument would be calibrated in accordance with NQA-1 requirements.
76	EKH	O	Table 3-2: 1) A 1.1 density sodium bromide solution will not provide a liquid viscosity of 8 cP. What also will be added. 2) Don't know how you're going to achieve high density/low viscosity using only glycerol. Please clarify.	Table entries pertaining to comments were reversed. Updated table with compositions determined in the lab.
77	EKH	E	Page 3-3, Section 3.1.2.1, second paragraph: This paragraph is not clear on its intent. Is $Na_2S_2O_3$ to be used in supernatant? Where does this typical supernatant properties come from (reference)?	Clarified that it pertains to Solids Accumulation and provided discussion of the selected values.
78	EKH	O	Page 3-4, first paragraph: 1) The low density and low viscosity fluid in this paragraph does not match up with that specified in Table 3-2. Which one is correct? 2) Note about calibration, see comment 75 above or the rheometer/viscometer.	1. 5 cP in text was incorrect, Table value is correct. 2. Made similar change as EKH #75.
79	EKH	O	Page 3-4, Section 3.1.3: What properties of the spiked particle will be measured and how? For instance, the typical method of	The spike particles listed are commercially available items that have an industrial purpose and are

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			using light scattering to determine PSD may be captured for the smallest particle listed on Table 3-3, but will be challenged on the others.	manufactured to size tolerances that exceed the tolerances necessary to distinguish the different sized spike particles by sieving. Qualification of the spike particles is limited to demonstrating that 99.9% of a one pound sample taken from each delivered lot is retained on the sieve used to separate that size from the other particles.
80	EKH	E	Page 3-4, Section 3.1.3, second paragraph: Given the 1/8 scale, how would these very large particles impact jet performance if these large particles are captured and transferred in the jet system? Has this been considered?	This is currently being evaluated and steps to prevent the particles from entering (a 3/16-inch wire mesh) the 1:8 scale mixer jets are being considered.
81	EKH	E	Page 3-6, first paragraph: This data is not consistent with Table 1-2 for the 1:8 scale transfer pump flowrate. Correct table or text.	Table 1-2 has been corrected and is now consistent.
82	EKH	O	Section 3.2.1.1: Are these same types of tests and simulants going to be used when testing the full scale pump? The zone of suction (ZOS) could be better quantified between scales.	Testing will be similar, LOP testing is using consistent simulants and spike particles. The zone of suction will not be measured directly during testing because of the impracticality of measurement in the chaotic mixing environment.
83	EKH	E	Page 3-7, first paragraph: What are the limits for tungsten? Testing was performed and there seemed to be some conclusion, but it was not stated.	The conclusion is that if slow moving large and dense particles (even 7200 micon W) get close enough to the pump (~0.3 inches), the pump can capture them and that fast (velocity was not measured) moving particles are not transferred at operational heights. Large and dense particles will be used in the 1:8-scale system.
84	EKH	O	Page 3-8, last paragraph: Show how you obtained these density values for the lower density supernatant. For instance, when I start with a 1.1 sg supernatant and blend solids resulting in 15 wt% UDS (200 g/liter) slurry, I can only achieve a density of 1.30, assuming I was not considering the volume of the solids themselves, hence a maximum density. The same goes for the 9 wt% UDS (125 g/l) for the low density supernate. The high density (1.37 sg) calc seems reasonable. I must have not stated this correctly.	The low density value is the density of the supernatant without the UDS, when the UDS are added to form a slurry, the slurry density ranges from 1.38 to 1.51 g/ml depending on which simulant characteristics are used in the calculation (UDS loading, UDS composition, liquid density). The calculations for the density and solid levels were corrected. It appears as though I failed to include the low density supernatant in my ranges as described in the text. Low Base / Low Density

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			Example: For a 1.1 sg supernate (continuous phase), containing 15 wt% UDS and using volume additivity ($\frac{1}{\rho_{slurry}} = \frac{f_{solids}}{\rho_{solids}} + \frac{1-f_{solids}}{\rho_{supernate}}$), I can never reach the 1.37sg value stated in this document (nor can you reach the 200g UDS/L limit for this case). Show me the calc on how you obtained the density of the slurries given the constraints you provided.	Supernatant @ 15% = 180 g/l, slurry density = 1.2 g/ml, @ 9% the density is 1.16 g/ml. For all possible combinations the slurry density ranges between 1.16 and 1.51 g.ml.
85	EKH	O	Page 3-9, second paragraph: 1) Isn't sodium thiosulfate and sodium bromide used for density adjustments, not rheology? 2) For the low density/viscosity supernate, shouldn't the viscosity tolerance be +/- 0.1 cP rather than +/- 0.5 cP and for density it should be +/- 0.055 g/ml rather than 0.05 g/ml? 3) Provide tolerances for the higher density/viscosity supernate or provide table of tolerance for the supernate density and viscosity.	1. Sodium salts are used to adjust density. The viscosity of the solutions is then set by the composition needed to attain the density, both properties cannot be adjusted independently with a simple salt. Higher viscosity solutions will use mixtures with glycerol to attain the required viscosity. 2. When using a simple sodium salt to adjust the supernatant properties, density and viscosity cannot be specified independently, thus there is a wide tolerance on the viscosity because it will depend on the salt used to attain the density. I'll check text for 5% calculations to make them consistent. 3. Tolerances have been added.
86	EKH	O	Page 3-9, third paragraph: 1) Is there a limit on what the wt% of kaolin and/or kaolin/bentonite that can be used to provide the targeted yield stresses? There should at least be an upper limit not to exceed 15 wt%, since these are UDS, not soluble solids. Interesting, these are UDS and there is a limit on what can be transferred (thought I personnel think this is the incorrect why of processing sludges, since other physical properties are more limiting on transfer). 2) Last paragraph should state flow curve measurements rather than yield stress measurements. The Bingham yield stress is then obtained from the flow curve by regression of the data. Recommend that you report the Bingham yield stress, plastic viscosity, R^2, and range in which the data	1. Kaolin wt % range from 15 to 30 wt % depending on slurry properties. No upper limit is imposed. 2. The critical parameter is the yield stress. How the yield stress is calculated and reported will depend on the instrument that is being procured for testing. I will recommend to the operators that this information be captured if possible. This is a good point and one that will need to be considered in the gap analysis and WAC revisions. At 30 wt% kaolin for the 10 Pa slurry, solids loadings are 2-2.5x the 200 g/l action level, but we are also 10x over the 1 Pa action level for the yield stress. Although 30 wt%

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			was fitted. I recommend you clearly specify how the yield stress is calculated and measured. You will obtain different results using a vane method as compared to a flow curve method. Both are yield stresses, but both can have very different results.	solids may not represent a slurry that meets the WAC, it is included to test the expected relationship between yield stress and the capability to move particles. Added discussion about the rheometer being procured and measurement method to take rheological measurements.
87	EKH	E	Page 3-9, fourth paragraph: This sentence seems out of place?	Agreed. Moved to a more relevant location (3.1.1.1).
88	EKH	O	Page 3-9 to 3-10, fifth paragraph: 1) How is PSD and density going to be determined for the spike materials? 2) How with different density materials be separated if at least two different spike materials are used?	1. Added to discussion in 3.1.3 per Comment EKH #79. 2. Different sieves can be used to separate glass and metal spheres which are incremented according to mm and 1-16 inches, respectively. Otherwise, the two subcontractors are still evaluating most efficient methods that will be documented in their operating procedures.
89	EKH	O	Page 3-10, second paragraph: Is this paragraph stating that the spikes should be blended with the NN slurry prior to adding the slurry to the test vessel? Or are the spikes to be added to the test vessel containing the NN slurry? Not clear.	This is a detail level reserved for the operating procedure but discussions with the subcontractors encourage them to prepare and measure the slurry first and then add the spikes.
90	EKH	O	Page 3-10, third paragraph: 1) How is spike addition going to be added to the NN simulants? Is the wt% UDS of the NN simulant going to be used as the basis for adding the spike materials? Not clear on how you plan on handling the NN case. Are the spikes going to be added to the Kaolin before it is added to the test tank or blended after the kaolin has been added to the tank? Two very different conditions. 2) I haven't placed much thought in the two allocation methods, but not sure if it will work for the NN simulants. 3) The discussion on mass distribution is not clear. Maybe an example would help.	1. Changed text to "For tests including a non-Newtonian simulant, kaolin clay is spiked with the same particle types and masses used in comparable Newtonian tests." 2. Allocation method is based on the mass or size of the spikes that are added and is not dependent on the base. 3. Clarified with example. Current plans call to blend the spikes to a tank containing the slurry meeting the yield stress tolerance.
91	EKH	E/0	Page 3-11, second paragraph: 1) Second sentence makes no sense. 2) Is rotational speed going to be set or is it going to be a	1. Clarified. 2. Rotational speed will be set for a specified velocity in accordance with the

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			variable? It also states that a number of revolutions could be used, but does not specify the number.	scaling relationship. Number of revolutions specified based on previous operating experience to attain heel stability with other simulants.
92	EKH	E	Page 3-11, third paragraph: How do you plan on managing this for the NN simulant?	Sieving the discharge so that the spikes are collected but the base material passes though the sieve back into the tank. This has yet to be demonstrated though.
93	EKH	O	Page 3-12, second paragraph, last sentence: What does intermediate conditions mean? First time this term has come up.	There are only two conditions, high and low. This text has been deleted.
94	EKH	O	Page 3-12, third paragraph: Table 1-2 needs to be checked for suction flow rate. Do you expect cyclic behavior when testing the NN fluid? The last sentence does not make sense.	Table 1-2 suction flow rates have been corrected. Cyclical variations may not occur in NN slurries when the jet sweeps past the transfer pump inlet. Duration changed to sufficient to collect a representative sample, currently the plan is to screen the entire transfer volume.
96	EKH	O	Table 3-5: You've got supernate simulant properties for the non-Newtonian simulants. Please correct. Are the nozzle velocity scaling factor exponent correct for the NN fluids? See 51A for clarification to question.	Table has been corrected. Yes NN tests will be done at two nozzle velocities. See response to 51A.
96	EKH	E	Page 3-16, second paragraph: What is the maximum pressure?	Isolok is rated for pressures up to 275 psi.
97	EKH	E	Page 3-16, Section 3.2.2.2, second paragraph, last sentence: "The liquid phase shall be a supernatant simulant?" Is this for Newtonian slurries only? If so, state it.	Added.
98	EKH	E	Page 3-17, third paragraph: Not clear. Is only a 10 Pa Bingham plastic yield stress cohesive slurry going to be tested (why not a 3 Pa as described in SSMD limits of performance testing being used)? If 10 Pa, should there be a wt% limit on what can be used? See previous comments on the NN simulant.	Text clarified. 3Pa and 10 Pa will be tested.
99	EKH	O	Page 3-18, second paragraph: What is considered "acceptable performance"?	Moved statement to discussions on performance "Acceptable performance is defined as simulant spike recovery in the collected sample without plugging the sample needle. Indications of poor performance include low total volume recoveries (less than 475 ml) and a lack of spike material in the collected sample."

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100	EKH	**M**	Page 3-18, Section 3.2.2.3: Given a +/-5% of theoretical density value, what error could we see with wt% solids concentration and is this acceptable? For instance, a 1.45 g/ml would have a range of 1.378 to 1.523 g/ml range and this would incorporate a very large wt% solids range.	With the new simulant, the 5% level may not be attainable so this requirement has been removed until it can be demonstrated. Stability is defined as stable specific gravity as reported by the Coriolis meter. As long as the spike particles are in the transfer line, which will be measured by a full diversion line sample, having a well mixed mixing tank is not a requirement. All Isolok samples will be compared to full diversion samples which measure what is in the pipe at the sample location.
101	EKH	O	Table 3-7: Noted on few pages back that conventional agitation will be used. It may be very hard to adequately mix the dense and large particles shown on this table given the mixing system. Is the mixing system going to be re-designed to properly handle these larger particles to provide a well mixed tank, if that is the intent? Good luck.	Ideally the tank will be well mixed but as long as the spike particles are in the transfer line, which will be measured by a full diversion line sample, having a well mixed mixing tank is not a requirement. All Isolok samples will be compared to full diversion samples which measure what is in the pipe at the sample location.
102	EKH	O	Page 3-19, fourth paragraph: Acceptable performance is defined loosely. What is considered acceptable as compared to batched conditions?	Limits of performance is trying to determine what sized particles can be sampled without plugging the sample needle, thus acceptable performance for these tests is simply the ability to sample particles without plugging. More quantitative performance will be evaluated in System Performance tests to be performed in the future.
103	EKH	O	Page 3-20: Is line pressure going to be considered as one of the inputs into potential plugging issue or has this already been discredited? Discussions of increasing pressure were discussed earlier in the text.	Line pressure fluctuates minimally when the plunger is inserted into the pipe such that variations in pressure are even encountered under normal operations. How the system responds with a plugged needle will be tracked. The discussions for increasing the pressure were to test the system near its operating pressure limit, which is 275 psi, but the system is benchmarked to 600 psi.
104	EKH	E	Page 3-21, second paragraph: "…transfer line or inadequate mixing...", change or to and/or.	Accepted.

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105	EKH	E	Page 3-24, Section 3.2.3.3, first paragraph: When you say "…dense spike particles are suspended…", do you just off bottom suspension requirements only?	Yes. Off-bottom suspension of the spike particles is the metric.
106	EKH	O	Section 3.2.3.2: For the NN simulant, how is mixing defined when blending in the spike particles.	Mixing will have to be confirmed by visual observation. It will have to be proven that off-bottom suspension of the spike particles can be visually verified in the tank portals.
107	RKG	**M**	Page 1-1, last paragraph: When will the tank contents be sampled and tested so that their properties can be related to those of the simulants to be tested? When will we know what the "broader spectrum" looks like?	RPP-PLAN-51625 has comparisons of the simulant to characterized tank waste. However, the tanks that have been sampled and characterized only represent of small fraction of the tank waste. Furthermore, the feed to the WTP will be highly blended before it is staged for delivery. Therefore our simulants represent the best information we have and expect to have in the near term.
108	RKG	**M**	Page 1-7, paragraph 4: What is the standard error of the 0.39 exponent? How is "mixing performance" defined in this case?	Added discussion. The test compared tests done at nine velocities performed at two scales and picked the slowest velocities that had similar vertical distributions of slurry SpG. Well mixed was not a criterion.
109	RKG	E	Table 1-2: Residence Time implies a CSTR. I think you mean Internal Circulation Time.	Changed to turnover time.
110	RKG	O	Section 2.1: Are particles large **and** dense? I thought that the dense particles were small and the larger particles less dense.	We are using large particles with average particle density (~2.5 g/ml) and higher densities (>8 g/ml).
111	RKG	O	Section 2.1.1.1: I would like more clarity on density and particle size. Are you planning to fix the density and keep increasing particle size until the system fails?	Spike particles having a uniform size will be added to the tank. To evaluate size and density four different groups of uniformly sized particles will be included at two different densities. Sizes will be incremented by at least 1000 microns so that sieving can be used to separate the particles for quantification. The particles that are transferred by the transfer pump will be quantified. The capability of the system to transfer the different density particles will be based on the four sizes tested.
112	RKG	**M**	Section 2.1.1.2: How will the velocity in the 1/8 scale transfer line be scaled down?	Transfer line velocity is not scaled but set above a critical velocity value (<4.0 ft/s) to prevent deposition of particles

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				between the transfer suction nozzle and the batch receipt tank..
113	RKG	**M**	Page 2-5: Data to determine the scaling of the 1/8 and 1/21 scale transfer lines should collected with particles which will not create blockages. There are literature references on transfer line design which can be used to relate particle properties to velocity.	Scaled Performance testing will use particles smaller than 700 microns, it is only LOP testing in the 1:8 scale tank that is using the large spike particles.
114	RKG	**M**	Section 2.1.2.1: What is the largest particle that we expect to remove from the tanks? How does this compare to the 3.4 mm sampling limit on the Isolock?	Information on what sized particles are in the tanks is still being collected. Hanford waste is not fully characterized. Therefore, LOP testing is being performed without limits to the particle size that does not impose a size constraint beyond the physical limits imposed by the equipment. LOP testing would be constrained to the limits if they were known, but because the sizes are not known with great certainty, there is no defendable constraint on particle size. Full-scale pump testing will provide an indication of what can be transferred.
115	RKG	**M**	Section 2.1.3.2: Is there a contingency plan should a customized pump not be feasible?	A commercially available pump has been identified.
116	RKG	O	Figure 2.3: What is the design basis for the mixing tank and agitator? What basic data have been given to the vendor?	The vendor is being consulted on the capability of the mixer to suspend the spike particles (1/4-inch WC). The tests will not be allowed to proceed until the agitator is determined to be adequate. This is a project management control.
117	RKG	O	Page 2-12: Won't the fastest settling particles (most difficult to suspend) leave the vessel first? Unless they cannot be fluidized in the outlet pipe? The particles left behind will be the easiest to suspend that follow the flow patterns?	Historical testing shows that the earliest samples do have a higher fraction of faster settling particles but also that, because of the rotating nature of the mixing the heaviest particles are also swept up by the jets but settle in the area that is furthest away from the jets and the pump. The tank is operated to achieve solids distribution, not bottom clearing so piles are left behind.
118	RKG	**M**	Table 2-6: Are two scales sufficient to develop a scaling rule with confidence?	Two scales were determined to be sufficient by the mixing experts consulted by the program. Results analysis will identify uncertainties and potential need for data from additional scales.

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119	RKG	O	Table 3-1: How do the simulant characteristics compare with those proposed for WTP? Where they are different, why?	This is addressed in Section 4.0 of RPP-PLAN-51625. One example is that LOP simulants are different because tank farms is exploring the capability of the system to transfer large and dense particles without size constraints. It is not appropriate for WTP to test with these simulants because tank farms may not be able to transfer them if they are in the waste or tank farms may show that there is very low probability of these particles being in the waste or have little risk to the WTP (e.g., inert material). In addition, the WTP has not begun an evaluation of simulants for tests using received waste but it is planned that the simulants for these activities will converge.
120	RKG	**M**	Section 3.1.3: If the waste characteristics are described in Table 3-1, why are you considering spiking with a particle of 7 mm? This cannot be detected in the IsoLock.	Because most of the tank waste has not been characterized there is no defendable basis for constraining sizes. Work is being done to develop a basis but it is not completed. LOP testing will determine whether large and dense particles could be transferred and sampled IF they are present in the tank waste.
121	RKG	**M**	Table 3-3: What is the minimum transport velocity for these particles in the 3 inch transfer line? Add two more columns to this table with Archimedes number and the velocity.	Added.
122	RKG	**M**	Table 3-4: See comment 121 above applied to SSMD.	Added.
123	RKG	**M**	Page 3-10, paragraph 3: The Yield Stress should also be measured after the experiment to determine if the work of the mixers and pumps has changed the rheology.	Added.
124	RKG	O	Page 3-12, paragraph 2: Why 10 turnovers? Has this been fixed or still open to discussion?	Text changed to 20 mixer jet rotations, which has historically been the point where operators see stabilization of the heel mounds.
125	RKG	O	Table 3-6: What values of velocity do the two scaling factors represent?	Added to Table 1-2. a=1/3 is 30 ft/s, a = 1/5 is 39.4 ft/s.
126	RKG	O	Section 3.2.2.1: Based on the simulant characteristics what are their minimum transport velocities in the 3 inch pipe?	Critical settling velocities for the base material are below 4 ft/s.

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127	RKG	**M**	Section 3.2.2.2: How and where will be kaolin / clay slurry be prepared?	Kaolin slurry will be prepared in the mixing tank. Preparation is an operating detail but usually SSMD operators added solids to water while agitating. Others have added water to solids.
128	RKG	E	Page 3-18: Is the "(larger the individual spikes)" correct?	Corrected "…, which is larger than the individual spikes,…"
129	RKG	O	Table 3-7 and Section 3.2.3.2: According to my calculations, the WC particles will not be transported in a 3 inch diameter pipe at 140 GPM flow rate. This seems unrealistic compared to Table 3-1.	Having particles that fail to be transferred is part of defining the capability of the system as both successes and failures are needed to define the capability.
130	RKG	O	Page 3-20, paragraph 2: Have you demonstrated time dependency of the kaolin slurries? What is the source of this behavior?	Kaolin slurries are slightly rheopectic so they may thicken as they are mixed.
131	RKG	O	Page 3-22, paragraph 2: Will you be able to demonstrate how many samples need to be taken to obtain a representative measure of the waste's true composition?	All spike solids that are discharged from the system (either during operations or when flushing the lines) will be collected in a basket screen.
132	RKG	**M**	Page 3-23, paragraph 1: Have you determined what size the agitator will need to be if it can suspend 3/8 inch tungsten particles? Is the agitator required to just suspend the particles or distribute them uniformly throughout the liquid? What size do you anticipate this vessel will be?	Design has been changed to ¼-inch WC. The design for off-bottom suspension is in development to procure an adequate mixer. Currently expect an 8-foot diameter tank capable of holding 700 gallons of slurry.
133	RKG	O	Table 3-10: Could we include two other velocities; one above and one below these values?	The values are initial starting points and held for 10 empty and fills. This is development work that must be completed to perform more quantitative analyses. More quantitative analysis will be performed at two scales later in the year but only two velocities are targeted for the tests. If the initial work shows that accumulation ceases after only several fills, there may be additional testing capacity to test additional velocities. This later work will be done after the scaled testing work so more information will be known for those tests.
134	RVC	O	Page 1-4: To what extent are the scale-up relations well established and confirmed?	The scale up relationship for sampling and batch transfer performance of mixed double shell tanks are not established. One purpose of this testing is to collect

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				performance data at two scales in order to develop scale-up relationships that will allow estimation of full-scale performance.
135	RVC	O	Pages 1-5 and 1-6, Table 1-1: Fill volume - 1,100,00?-typo? Define reference angle for mixer jet pump location. What is the Reynolds number in the transfer lines?	The operating capacity of AW-105 is 1,144,000 gallons. Reference angle is footnote 2 of Table 1-1. At 140 gpm in a 3-inch diameter Sch 40 pipe, a 1.37 g/ml slurry with a viscosity of 15 cP has a Re of ~13500 and stays turbulent at the lower end of 90 gpm.
136	RVC	O	Table 1-1 General: To avoid confusion, exactly which tests will be performed at each scale should be clearly stated/discussed in the accompanying text.	Acknowledged. Text changd to make sure this is described in the Scope of each test. SSMD LOP is performed at 1:8 scale because the LOP particles are too large for the 1:21 scale transfer lines. SRNL only has a 1:22-scale tank so Solids Accumulation Scouting Studies are performed at 1:22 scale. All other SSMD testing is done at both 1:8 and 1:21 scales.
137	RVC	O	Page 1-6: Is Power per volume sacred; that is, is it validated at large scales?	The experts consulted for our mixing program recommend power-per-unit volume as a starting point for evaluating scaling relationships.
138	RVC	O	Page 1-6, Eq. 1-1: Is this completely true; that is, are there no friction losses across the nozzle contributing to the pressure drop?	This is not a precise calculation that accounts for all factors but is used as an estimate to define a starting point from which to begin operating the tanks and collecting test data.
139	RVC	O	Page 1-7: Be careful – the waste simulant slurry volume may not be the proper volume for P/V scaling. Most of the energy is dissipated close to the vessel bottom, so ability to suspend, etc. is less than proportional to fill height. Eq. 1-2 would only be valid for vessels that are geometrically similar in all respects.	Acknowledged. With respect to mixing, the tanks are geometrically similar.
140	RVC	O	Page 1-7: Eqs. 1-4 and 1-5 are redundant.	Acknowledged. The derivation has been moved to an appendix and the important equations have been retained in the main text.
141	RVC	O	Page 1-7: A scaling exponent of 0.39 is closer to n = 1/5 than n = 1/3. Which is it? If 0.30 is about 1/3 than 59 ft/s is about 60 ft/s. Should be ft/s – not ft/sec.	The experts consulted for our mixing program recommend 1/3 and 1/5 as a starting point for evaluating scaling relationships and these will be during

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				scaled performance testing.
142	RVC	O	Page 1-8, Eq. 1-6: Please explain more clearly. How can **a** be < 0.39 for the integrated system? Why is the value of **a** not controlled by the limiting (most demanding) operation?	Added detail, the test conditions for the experiment and the metric for the 0.39 scale factor were not clearly communicated. Lower values will result in better solids distribution in the tank. The value of a will be controlled by a limiting step.
143	RVC	O	Page 1-8, Eqs. 1-10 and 11: Will the scaling criteria for jet pump rotation rate be confirmed. Why isn't ω a testing variable? What proof do you have that it does not need to be parameterized?	Based on extensive review comments on the topic, the rotational rate scaling will be evaluated during SSMD Scaled Performance testing.
144	RVC	O	Pages 1-7 and 1-8: There are more equations than are needed, making it difficult to appreciate the most important ideas.	The derivation has been moved to an appendix and the important equations have been retained in the main text.
145	RVC	O	Page 1-9, Table 1-2: It would be useful to report U_{jet}.	Agreed. The detail has been added.
146	RVC	O	Page 1-9: Do you mean chemical composition or particle concentration? There is no explanation of why chemical composition is the most appropriate metric.	The text was determined to be too much detail for the section discussing it and has been deleted.
147	RVC	O	Pages 2-1 and 2-2: Why do you say on page 2-1 that scaled/system performance is one of the 3 major testing areas and then say on page 2-2 that it will not be considered in this test plan? Figure 2-1 implies that there will be 3 separate test plans.	A separate and future test plan will be prepared for Scaled/System testing.
148	RVC	O	Page 2-2: I would be interested to know how SNRL will put the particle shape issue to bed. This also arises at WTP. Why are you confident that shape will not be an issue? Are there data to substantiate this?	The SRNL report states that for Limits of Performance spherical particles shall be considered when challenging particles are desired and recommends the use of both spherical and irregularly shaped particles. We use both in our testing and will use mostly spherical particles for spikes, but some irregular shaped WC will be used.
149	RVC	O	Page 2-5: You state that the 1:21 scale is too small to use with the largest particles. It is implied that the 1/2 inch line at 1:8 scale is of sufficient diameter to capture the largest particles in a representative fashion. Can you justify this?	Plugging maybe an issue and we may need to reevaluate of spike selection. Preliminary testing showed that, under controlled conditions, the large particles could move though the inlet and tubing. We are also conducting full scale experiments to understand real particle size limitations.
150	RVC	O	Section 2.1.2.1, Page 2-6: States that	The collected samples are compared to

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			sampling needle diameter determines limiting particle. How does ability of the transfer pipe inlet to capture a representative sample compare?	full diversion samples that are withdrawn from the pipe near the sample location. If the large particles are in the full diversion sample, then the mixing in the tank and pump capability are adequate to get the particles to the Isolok. The ability of the pump to capture particles is not relevant to Isolok performance because the sample is trying to quantify what is transferred and thus is must be captured by the pump to be sampled in the flow loop.
151	RVC	O	Section 2.1.3.2, Page 2-9: What evidence is there that the commercially available pump will mimic actual pump performance? How does the described test procedure ensure this?	The commercially available pump mimics the flow rate and capture velocity of the proposed WFD delivery transfer pump, as such the hydraulics around the pump inlet are being replicated to the extent practicable. Test requirements specify the flow rate and inlet geometry. This approach is necessary to collect initial performance data prior to completion of final pump design and procurement.
152	RVC	O	Section 2.2.1.1, Page 2-10: How can scalable transfer and refill operations be performed at 1:22 scale if the largest particles are only slightly smaller than the inlet pipe diameter?	Solids Accumulation does not use the large spike particles describe for LOP testing, the largest particles are several hundred microns.
153	RVC	O	Table 2-4, Page 2-11: Why 2 jet velocities as opposed to 1, 3, 4, etc.?	This is driven by economics and schedule to complete the work so that it can inform follow-on work to be performed later in the year.
154	RVC	O	Section 2.3.1.1, Page 2-16 and Table 2-6: You never state the specific objectives of the scaled performance tests, but you state that they are subject to change. Why now do 100 μm particles represent the hard to transfer fraction to WTP?	Because there is uncertainty with what is in the waste, LOP testing will determine if a particle or a certain size and density can be transferred to the WTP, other work being performed (specifically DNFSB 2010-2 Commitment 5.5.3.2) will provide information on what is in the waste, including uncertainties. All this feeds the Initial Gap Analysis that is being prepared to guide the program testing needs. Solids Accumulation particles are based on what is already known about the waste.
155	RVC	O	Section 2.3.1.2, Page 2-17: It is now stated	Rotational rate will be set by the scaling

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			that rotational speed may be varied. In Section 1, it is said that results are not sensitive to ω. Which is it?	relationship in Section 1.3 and Scaled Performance testing will evaluate the relationship.
156	RVC	O	Section 2, General: Detailed test procedures are described in words, but very little quantitative information is given. As a result, it is difficult to assess if these procedures can realistically accomplish the test goals.	Additional details and quantitative info has been added to Section 3.0.
157	RVC	O	Section 2, General: The discussions are often repetitive. Points could be made more efficiently by drawing from (or referring to) previous material, rather than repeating it in its entirety.	Acknowledged. The test plan is written for a broad audience, including the subcontractors performing the work who tend to only read the text that is applicable to them.
158	RVC	O	Section 3, General: Since Section 2 it somewhat more balanced, it really does not hit home until here that Solids Accumulation & Scaled Performance are mostly discussed in future reports. However, selected topics are presented here. This seems somewhat arbitrary (like this report contains what we are prepared to talk about and we will put the rest in future reports) rather than strategic. Rationale and justification for this approach should be given in the Introduction.	This is addressed in the last paragraph of Section 1.1.
159	RVC	O	Section 3.1: Can you say more about the non-Newtonian simulant or provide a reference with some of the details? In Table 3-1, what is meant by the median size? Is this d_{50} by volume? Can you provide a measure of the distribution? Can you say more about how you will distinguish and measure spiked particles?	More discussion on the non-Newtonian simulant has been added. Median size is d50 by volume as described, along with PSDs in RPP-PLAN-51625. Additional information on spike quantification has been added.
160	RVC	O	Page 3-5, last sentence: The words "*economically favorable conditions*" are not an appropriate euphemism to describe crude preliminary experiments.	The text has been changed.
161	RVC	O	Section 3.2.1: I do not see how the Coriolis meter can discriminate spiked particles. It is a mass flow meter. How can it detect a few spiked particles passing through? How do you relate its reading to what you find later in the separated spiked particle analysis?	The Coriolis meter is used to monitor slurry mass flow and specific gravity, stabilized readings of specific gravity suggest that transient conditions experienced during startup have stabilized. The Coriolis meter is not used to quantify results.
162	RVC	O	Section 3, General: The general comments made above about Section 2 also apply here.	The level of detail has been expanded in Section 3.

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WRPS-1202074-OS
Enclosure 5

ERT-16 Feed Test Plan

Large-Scale Integrated Mixing System Expert Review Team

(L. Peurrung, Chair; R. Calabrese, R. Grenville, E. Hansen, R. Hemrajani)

To: Ray Skwarek, One System IPT Manager

From: Loni Peurrung, Chair, Large-Scale Integrated Mixing System Expert Review Team

Subject: Concurrence on *Waste Feed Delivery Mixing and Sampling Program Limits of Performance and Solids Accumulation Scouting Studies Test Plan* (ERT-16)

Date: May 10, 2012

Dear Mr. Skwarek:

The Large-Scale Integrated Mixing System Expert Review Team (ERT) concurs with the disposition of ERT comments documented in ERT-16 Feed Test Plan (dated April 27, 2012) as described in your reponse WRPS-1201884-OS dated May 10, 2012.

This letter closes review ERT-16.