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AZ-101 MIXER PUMP DEMONSTRATION AND TESTS: DATA MANAGEMENT (ANALYSIS) PLAN

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For

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Abstract: Two 300 horsepower mixer pumps that were installed in the AZ-101 tank as part of the W-151 project are scheduled to be tested to demonstrate their ability to mobilize waste. This document provides a plan for the analysis of the data collected during the test.

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AZ-101 MIXER PUMP DEMONSTRATION AND TESTS: DATA MANAGEMENT (ANALYSIS) PLAN

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Acronyms and Other Terms

ALC	Air lift circulator
ALCT	Air lift circulator thermocouple
CAM	Continuous air monitor
CCTV	Closed-circuit television
DAS	Data Acquisition System
DP	Differential pressure
ECR	Effective cleaning radius
HEGA	High-efficiency gas adsorber
HEME	High-efficiency mist eliminator
HEPA	High-efficiency particulate air
PTA	Profile thermocouple assembly
PUMP	Pump sensors • Column pressure • filter DP • bearing temperature • current • voltage • speed • orientation • vibration
SDS	Sensor data summary
SHMS	Standard hydrogen monitoring system
SSP	Suspended solids profiler
ST	Sludge thermocouple
STRAG	Strain gauge
SW	Sludge weight
TBT	Tank bottom thermocouple
TGAC	Gamma probe
URSILLA	Ultrasonic interface level analyzer
VENT	Ventilation system sensors • radiation (CAM) • VOCs • DP across HEPA, HEGA and HEME filters
VOCs	Volatile organic compounds
Sludge	Particulates that have settled at the bottom of the tank
Slurry	Mixture of particulates suspended in liquid that is created when the pumps mix the supernatant liquid with the underlying sludge

AZ-101 MIXER PUMP DEMONSTRATION AND TESTS: DATA MANAGEMENT (ANALYSIS) PLAN

1 INTRODUCTION

This document provides a plan for the analysis of the data collected during the AZ-101 Mixer Pump Demonstration and Tests. This document was prepared after a review of the AZ-101 Mixer Pump Test Plan (Revision 4) [1] and other materials. The plan emphasizes a structured and well-ordered approach towards handling and examining the data. This plan presumes that the data will be collected and organized into a unified body of data, well annotated and bearing the date and time of each record. The analysis of this data will follow a methodical series of steps that are focused on well-defined objectives.

Section 2 of this plan describes how the data analysis will proceed from the real-time monitoring of some of the key sensor data to the final analysis of the three-dimensional distribution of suspended solids. This section also identifies the various sensors or sensor systems and associates them with the various functions they serve during the test program.

Section 3 provides an overview of the objectives of the AZ-101 test program and describes the data that will be analyzed to support that test. The objectives are: (1) to demonstrate that the mixer pumps can be operated within the operating requirements; (2) to demonstrate that the mixer pumps can mobilize the sludge in sufficient quantities to provide feed to the private contractor facility, and (3) to determine if the in-tank instrumentation is sufficient to monitor sludge mobilization and mixer pump operation. Section 3 also describes the interim analysis that organizes the data during the test, so the analysis can be more readily accomplished.

Section 4 describes the spatial orientation of the various sensors in the tank. This section is useful in visualizing the relationship of the sensors in terms of their location in the tank and how the data from these sensors may be related to the data from other sensors. Section 5 provides a summary of the various analyses that will be performed on the data during the test program. Finally, an appendix reviews the technical aspects of the key sensor systems that will be used in the program. This review focuses on the performance capabilities and limits of the sensing systems.

Table 1 provides an overview of the data management (analysis) plan. It illustrates the various objectives, the primary- and secondary-priority sensors to be used to gather data related to each objective, and the essential end-product analysis that will achieve the specified objective. For example, one of the test objectives is to measure the mobilization of the solids afforded by the mixer pumps. A sub-objective is to calculate the percentage of the total solids suspended three-dimensionally in the slurry. Table 1 shows that, for this objective to be accomplished, data from three sources are essential: grab samples, the gamma probe, and the suspended solids profiler. The ultrasonic interface sensor (URSILLA) is a secondary sensor. By calibrating the sensor data using the grab sample data, the analysis will produce quantitative 3-D estimates of the slurry density. Each of the entries in Table 1 is explained in detail in the sections that follow. A description of each of the sensors to be used during this program is provided in the appendix.

Table 1. Objectives of Mixer Pump Test, Showing Analysis Method for Each Objective

Objective	**Sub-Objective**	**Primary Sensor(s)**	**Secondary Sensor(s)**		**Analysis Method**
Mixer Pump Operations	• pump operations	Pump		*Real-Time:* *Post-Test:*	Comparison to fixed thresholds. Time series analysis and comparison to parameter maximums.
	• in-tank structures	CCTV	STRAG	*Real-Time:* *Post-Test:*	Comparison to fixed thresholds. Calculation of stress and loads on structures; plots and extrapolation to other objects. Comparison to models.
	• Slurry temperature	PTA	ALCT TBT ST SW	*Real-Time:* *Post-Test:*	Comparison to fixed thresholds. Temperature growth as f(jet time); extrapolation to maximum allowed. Comparison to models
	• Ventilation and vapor space	VENT (& Vapor-Space Samples)	SHMS	*Real-Time:* *Post-Test:*	Comparison to fixed thresholds. Time series analysis and comparison to parameter maximums. Comparison to compliance limits.
Sludge mobilization	• Effective cleaning radius	ALCT TBT PTA ST PUMP	URSILLA TGAC	*Real-Time:* *Post-Test:*	Run-time guidance. Time rate-of-change of spatial map of temperature distribution. Calculated distance from jets where T (sludge) is significantly reduced; comparison to models.
	• Suspension	GRAB SSP TGAC	PUMP URSILLA	*Real-Time:* *Post-Test:*	None Time series plots; comparison to models.
	• Settling	GRAB URSILLA TGAC SSP	SW	*Real-Time:* *Post-Test:*	None. Time series plots; comparison to models.
Sensor Evaluation	• Quantitative utility	GRAB URSILLA TGAC SSP	PUMP	*Real-Time:* *Post-Test:*	None. Scatterplots; calculate calibration coefficients from grab samples; re-interpret sensor data in terms of physical parameters; hindcast to other times. Compare results to other grab samples estimate accuracy and utility of sensor(s).

Acronyms:

ALCT	Air lift circulator thermocouples	ST	Sludge thermocouple
CCTV	Closed circuit television	STRAG	Strain gauge
GRAB	Grab samples	SW	Sludge weights
PTA	Profile thermocouple assemblies	TBT	Tank bottom thermocouples
PUMP	Pump sensors	TGAC	Gamma probe
SHMS	Standard hydrogen monitoring system	URSILLA	Ultrasonic interface level analyzers
SSP	Suspended solids profiler	Vent	Ventilation system sensors (radiation [CAM], VOCs, HEPA, HEGA, HEME filters DP)

2 DATA PHASES AND DOCUMENTATION

It is expected there will be three distinct phases in the handling, examination and interpretation of the data from the AZ-101 test. First, there will be a real-time aspect of the test. Real-time monitoring of some key sensor data serves to ensure safe operation of the tank and pump systems and is of crucial importance to the continuation and successful outcome of the test. This phase of the test will utilize real-time outputs displayed to the operators of the various sensors. These outputs, together with pre-determined limiting thresholds on some of the outputs, will provide safety- and operations-related information about the pumps and in-tank components to the test director and other test personnel. This allows the test director to conduct each test sequence in a progressive manner, with the assurance provided by the real-time measurement of critical parameters.

The second phase in the data handling is the organization, cataloging, formatting and archiving of the data from each sensor, and the preparation of sensor data summaries (SDSs). These SDSs will summarize the operation of each of the sensors (or sensor systems) that are pertinent to the objectives of the demonstration and test. Each sensor team will prepare the SDSs daily (to the extent possible), and will provide them to the AZ-101 mixer pump project team. The systems for which SDSs will be prepared include: mixer pump and pump motor sensors (PUMP), ventilation systems (VENT), closed circuit television (CCTV), ultrasonic interface level analyzers (URSILLA), suspended solids profiler (SSP), and gamma probe (TGAC). A SDS will also be prepared for the thermocouple suite data recorded by the Data Acquisition System (DAS): air-lift circulator thermocouples (ALCT), tank bottom thermocouples (TBT), profile thermocouple assemblies (PTA), the sludge thermocouples (ST), and the concrete temperature thermocouples (CT). In addition, data summaries will be prepared for the sludge weight (SW), strain gauges (STRAG), and the standard hydrogen monitoring system (SHMS). The ENRAF level gauge will not require a data summary. This is because, while this liquid level measurement system is currently installed in the tank and used daily, the ENRAF data is not considered relevant or important to the specific objectives of the measurements described in this plan.

There are four central objectives for the sensor data summaries. First, for the demonstration of pump-safe and tank-safe operations, the SDS will document the operations aspects of the mixer pump program (e.g., pump parameters, in-tank structures, ventilation system) Second, for all of the sensors (or sensor systems) the SDS will serve to document the operation and performance of each of the sensor systems over the period of the test program. (This includes a "baseline" data period prior to the actual start of the pump phase of the demonstration and test.) Third, the SDS process will regularly document a preliminary qualitative interpretation of the data as the test program evolves. Fourth, the SDSs will form the basis of the "Test Data" deliverable, required by the FY 2000 Performance Incentive document [2].

The SDS will be prepared in the following format: a description and summary listing of the various data files comprising the record, including the start and end date/time identifier for each separate file; a description of the format of each file, including sample frequency and number of records in the file; a time serial assessment of the data quality within each file, including annotation and comment regarding anomalies or the absence of data; time series plots of selected data; and a qualitative (or quantitative) description of the observations or preliminary results obtained by that sensor. The SDS may or may not provide definitive results, but it *is* expected to validate the operation of the sensors, describe and illustrate the data that were collected during each sequence of the testing, and summarize the quality of the data that are available for analysis.

After the data from the test program become available to the analyst community, a detailed analysis will be performed. This analysis will focus on the technical objectives of the mixer pump tests that are not discernable from the real-time data, and validate the findings of the real-time portion of the tests. The detailed analysis is expected to include a comparison of the measured data to various models, and a time-series analysis (including statistical parameters) of the data from individual sensors. The analysis will also include calibration of the sensors with reference to the grab samples (where applicable), and a subsequent quantitative re-interpretation of those data as they relate to the objectives. There will also be a focus on an integrated analysis of data from several sensors taken together, where this is both possible and practical.

While the various sensors will be functionally and operationally checked before beginning the mixer pump tests, a calibration of each sensor against the actual slurry to be measured will not be possible. Accordingly, this plan assumes that grab sample-to-sensor comparisons will be done as part of the final analysis. Grab samples and the subsequent quantitative analyses of these samples are a fundamental part of the analysis and interpretation described below. It is *the* means by which the measures from one sensor can be (quantitatively) related to the measures from another sensor. This "hindcast" analysis will allow measurement of the tank and slurry parameters during periods between the grab sample events.

If grab samples cannot be obtained, or are not obtained in sufficient quantity or quality, or are not adequately synchronized with the other needed measures, the analysis may still proceed. There will, however, be a significant loss of accuracy and a loss of quantitative information regarding the growth and settling of the mobilized slurry.

A thorough discussion of the grab samples and grab sampling procedures and timing is given in [3]. The Data Quality Objectives for the AZ-101 MPT are described in [4].

3 REVIEW OF OBJECTIVES AND DATA TO BE ANALYZED

As noted above, the AZ-101 mixer pump test has numerous technical objectives. The tank instrumentation necessary to accomplish these objectives is shown in Table 2; this table shows that, depending upon the particular objective during the test, the various sensors take on primary or secondary roles (or are not needed). For example, to assess the effective cleaning radius, the thermocouple and the pump data are the primary measures, and the URSILLA and TGAC are secondary or back-up sensors. The type of analysis that will be performed for each objective is what drives the priorities.

In support of the objectives described below, other sensors *may* be used to collect data during the test program, depending upon the availability of the instruments and personnel. While these data may serve an ancillary function, they will not be required in support of the test objectives.

The sections below describe how the data to be collected is used as input to the data analysis.

Table 2. Objectives of Mixer Pump Test, Showing Primary and Secondary Sensors

Objective	**Sub-Objective**	**Sensor/Sensor System**													
		GRAB	PUMP	SHMS	VENT	CCTV	URSILLA	STRAG	TGAC	SSP	ALCT	TBT	PTA	ST	SW
Mixer Pump Operations	• pump operations		P												
	• in-tank structures					P		S							
	• ventilation and vapor space			S	P										
	• thermal limits										S	S	P	S	S
Sludge Mobilization	• Effective cleaning radius		P				S		S		P	P	P	P	
	• Suspension at min/max speeds	P	S				S		P	P					
	• Settling Rates	P					P		P	P					S
Sensor Evaluation	• Quantitative utility	P	S				P		P	P					

Key: S = Secondary sensor; P = Primary sensor (shaded box)

Acronyms:

ALCT	Air lift circulator thermocouples
CCTV	Closed circuit television
GRAB	Grab samples
PTA	Profile thermocouple assemblies
PUMP	Pump sensors (column pressure, filter DP, bearing temperature, current, voltage, speed, orientation)
SHMS	Standard hydrogen monitoring system
SSP	Suspended solids profiler
ST	Sludge thermocouple
STRAG	Strain gauge
SW	Sludge weights
TBT	Tank bottom thermocouples
TGAC	Gamma probe
URSILLA	Ultrasonic interface level analyzers
VENT	Ventilation system sensors (radiation [CAM], VOCs, HEPA, HEGA, HEME filters DP)

3.1 Mixer Pump Operations

First and foremost, there is an operational objective in this plan to show that the mixer pumps can be successfully operated in the Hanford tanks. This includes a *demonstration* that the mixer pumps can be operated within the allowable range of temperature, speed, and current, in a thick-sludge starting condition, without being damaged. It also includes a *demonstration* that the in-tank forces exerted by the pump jets will not damage in-tank structures. This operational objective will also determine whether or not the increased motion of the wastes caused by the pumps—including the potential to roil the surface of the wastes—will cause an unacceptable or unmanageable increase in the vented products. Since relevant results of this mixer pump test will be applicable to future mixer pump operations, a clear and unambiguous resolution of these fundamentals is important. Accordingly, these three operational objectives are given the highest priority in this analysis plan. To this end, the data analysis will initially concentrate on interpretation of data from the pumps, from the ventilation system, and from sensors installed in the tank to measure the forces applied to in-tank components.

Much of the analysis of the data in support of the operational demonstration objective will be contemporaneous with the test. This will include real-time monitoring of various parameters such as pump voltage and current, pump bearing temperatures, ventilation system performance, the displacement of in-tank structures, and so on. In addition, since the pumps may run for protracted periods of time during the test, it will be necessary to monitor the temperature of the mobilized slurry in real-time to ensure that the temperature limits in the tank are not exceeded. Most of these parameters will have threshold values associated with the measurements that specify the maximum allowable value. Real-time monitoring with pre-determined threshold values allows immediate action to be taken if one or more of the threshold indicators [1] exceeds allowable values, to prevent damage to in-tank components, or to prevent the release of airborne contaminants. For example, a CCTV camera will be calibrated to make real-time on-screen measurements of the displacement of certain structures in the tank as the pump jet is directed towards the object [1].

Based upon the geometry of the CCTV viewing system and the allowable displacements calculated for various selected in-tank structures, a displacement threshold value has been established that is based on 66% of the yield displacement[1] [1]. As the jet is directed towards particular structures, the operator will monitor the images and compare the observed displacement (in inches or centimeters) to the pre-determined threshold value. As the displacement reaches the threshold value, the operator will notify the test director, at which time the jet forces will be reduced or re-directed, or both.

Subsequent analysis will use snapshots of the video data (in this sample case) to document the displacement(s) at various times. A more detailed analysis of these data, with plots of measured displacement as a function of jet angle (or speed), for example, will be accomplished and will be included in a final data analysis report.

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[1] 66% is based on standards established by the American Institute of Steel Construction (AISC)

3.2 Sludge Mobilization

Second in analysis priority are the data collected to assess the mobilization capabilities of the mixer pumps in AZ-101. This portion of the test estimates how far from the jet nozzles the sludge will be moved, first by one pump and then by both pumps—that is, the "cleaning radius" of the pump(s). By extension, these results would be applicable to tanks that have sludge and supernatant like those in AZ-101, but they may not be applicable to other sludge forms. Nonetheless, the results are important because they can be employed, with models, to scale future mixer pump installations in terms of pump capacity and number. Another element of the mobilization objective is to determine the volume and concentration of the sludge mobilized by the pumps, as a function of the pump speed, and the minimum pump speed necessary to maintain the slurry in suspension. A third element is to determine the settling rate of the sludge. These are key objectives related to the transfer of the AZ-101 slurry from AZ-101 to the vitrification contractor.

Most of the analysis in support of the pump effectiveness objective depends upon measuring and quantifying the *change* and *rate of change* in conditions in the tank before and after the pump(s) are run (and to some degree, during the operation of the pumps). As a consequence, it will be important to determine the conditions in the tank before a test is initiated, and again after each phase of the testing. The data analysis in support of this objective focuses on the thermocouples that will measure the change in temperature as the sludge is swept off the bottom and mixed with the supernatant liquid to form the slurry. Additional sensors that will provide back-up or supporting data include the URSILLA, SSP and TGAC.

Another test priority is to make an estimate of the volume, mass, or density of the suspended solids in the slurry. In this objective, the test will also estimate the rate of growth of the mobilization and the rate of settling of the sludge. This is an important objective because it allows the project team to demonstrate that the pump-produced slurry meets (or does not meet) the physical properties described in the Interface Control Document [5]. The analysis to achieve this objective will utilize the grab sample data, primarily. When the grab sample results become available, the data analysis will use that information to measure and assess the physical, chemical, and radiological properties described in [3] and the Data Quality Objectives document [4]. Finally, the test addresses the settling time of the sludge—the period following the shutdown of the mixer pumps during which sludge continues to be suspended in the slurry, and the rate at which it settles.

3.3 Equipment Evaluation

In addition to the grab samples, the data analysis will incorporate data from the URSILLA, the SSP, and the TGAC probes. Essential to a quantitative resolution of this objective is the simultaneous collection of grab samples with the data collected by the other sensors. This will allow each of the other sensors to be calibrated to the lab-measured quantities rather than some individual and arbitrary "standard" that may or may not have a direct relation to the quantities actually being measured in the tank. A detailed description of the grab sample operations and laboratory analysis of these data is given in [5]. Thus, to the extent that good-quality grab sample data have been collected simultaneously with the SSP, TGAC, and URSILLA sensors, the sample data ("truth") will be used to establish a quantitative relationship between the lab-measured particle density and the sensor-measured data. These "calibration coefficients" will allow quantitative results to be inferred from each sensor, and will allow the data from multiple sensors to be analyzed together. An analysis of the calibration coefficients will provide information about the utility of using the remote sensors to make quantitative measurements without relying on the grab samples. If grab samples cannot be obtained, or are not obtained in sufficient quantity or quality, or are not adequately synchronized with the other needed measures, there will be a significant loss in the quantitative nature of the results, and a loss in the ability to analyze disparate sensor data as a set of common values.

4 LOCATION OF SENSORS

Tank AZ-101 is currently instrumented with a broad range of measurement systems. Figures 1, 2 and 3 show a plan view of AZ-101, with the various sensor systems overlaid on the tank drawing in their respective spatial (planar) locations. These are grouped by demonstration or test priority, as described in Section 3. Figure 1 shows the key instruments and locations used to support the *mixer pump operations* objectives. These include the CCTV data, strain gauge data, motor parameter data (voltage, current, bearing temperatures, speed, vibration), standard hydrogen monitoring system (SHMS) data, continuous air monitor (CAM) data, and various ventilation system data.

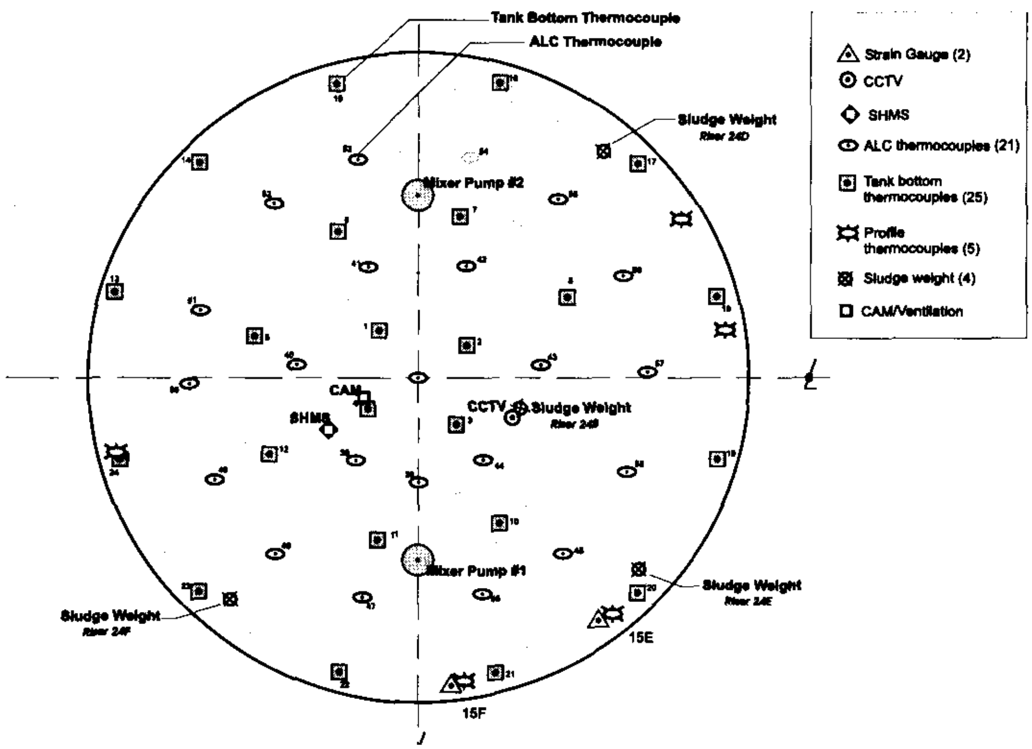

Figure 1. Data needed for pump operations objective.

Figure 2 shows the locations of the sensors whose data will be analyzed to achieve the effective cleaning radius portion of the *sludge mobilization* objective. In addition to grab samples, the primary sensors to be analyzed for this objective include the ALC, tank-bottom, profile and sludge thermocouples. The profile thermocouples will also serve for monitoring the slurry temperature. This figure shows that there is a dense matrix of thermocouples available for the sludge mobilization objective. The large number of sample points available and the distribution of those sensors around the tank should allow the analysis of the temperature data to be accomplished in a relatively straightforward manner.

Figure 3 shows the locations of the sensors needed to accomplish the suspension and settling portion of the *sludge mobilization* objective. These sensors include the URSILLA slurry interface profiler, the suspended solids profiler, and the gamma probes. Grab sample

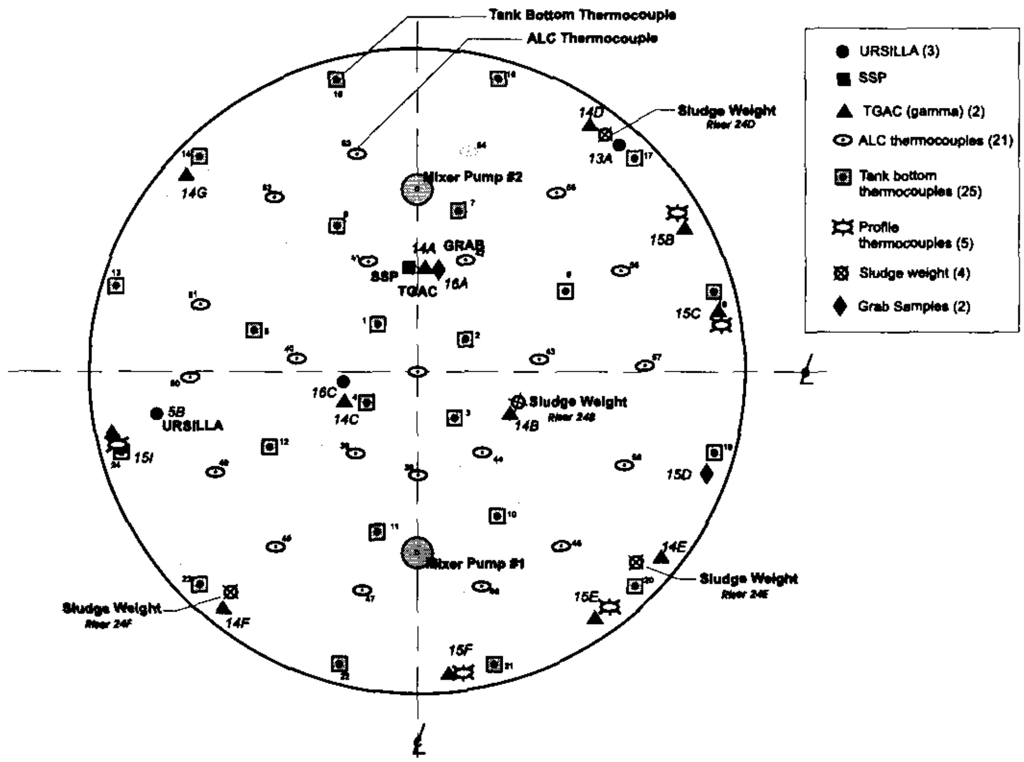

Figure 2. Data needed for sludge mobilization objective.

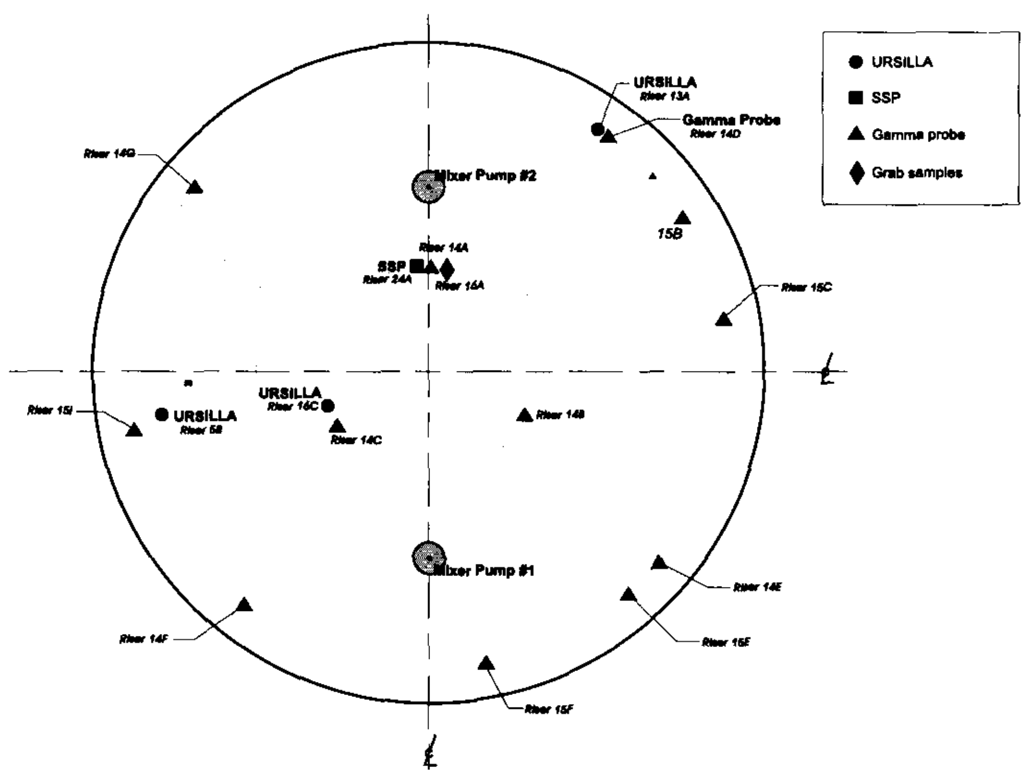

Figure 3. Data needed for sensor evaluation objective.

analysis will also be used for a quantitative assessment of the slurry using other sensor data. Although the URSILLA, SSP, and grab samples will provide good sampling of the vertical column, the (x,y) spatial distribution of the data is poor. Accordingly, the analysis will utilize the spatial diversity that can be achieved with the TGAC carts to sample the tank in a variety of locations. Using this data and the grab sample results, the data will be interpolated between sensors to infer the three-dimensional distribution.

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5 ANALYSIS PLAN

5.1 General Approach

As noted above, it is expected that the data from most of the sensor systems will undergo three separate analyses. First, any sensor system providing real-time data that can help assess the conduct of the operation(s) being undertaken will be utilized in that mode. Predetermined thresholds will be established in the OTP [6] for these systems so that the test director can be kept informed of any effects that are detrimental to the tank system or test objectives. A sensor data summary will be prepared daily or generally following the conclusion of the individual phases that comprise the demonstration and test. In this SDS, the test engineers (or designee) will examine their data, make representative time-series plots of pertinent data, identify anomalies in the data, format the data, and archive it for subsequent analyses. In the third phase, the various sensor data will be analyzed and interpreted qualitatively, and in quantitative terms, related to the objectives of each demonstration and test conducted.

The following example illustrates these phases. It is expected that the real-time output of the CCTV system, which images the in-tank components at the air/supernatant-liquid interface in support of the operational safety objective, would be monitored for specified displacement. During the test, the Test Director will be notified of measured displacements that exceed a specified threshold. Following the test, the SDS will document, qualify, and catalog the available data. Selected "snapshots" of the video data may be included to illustrate the extent of the deflections observed. In a preliminary analysis, selected portions of the video data will be analyzed on a frame-by-frame basis to measure the amplitude and variability of the displacement of the imaged pipes. In this analysis, the deflection measured in the video data will be plotted as a function of time. A plot of *simulated* video displacement data is shown in Figure 4, along with hypothetical AISC and yield displacement values. These data visualize the displacement data and document the test results.

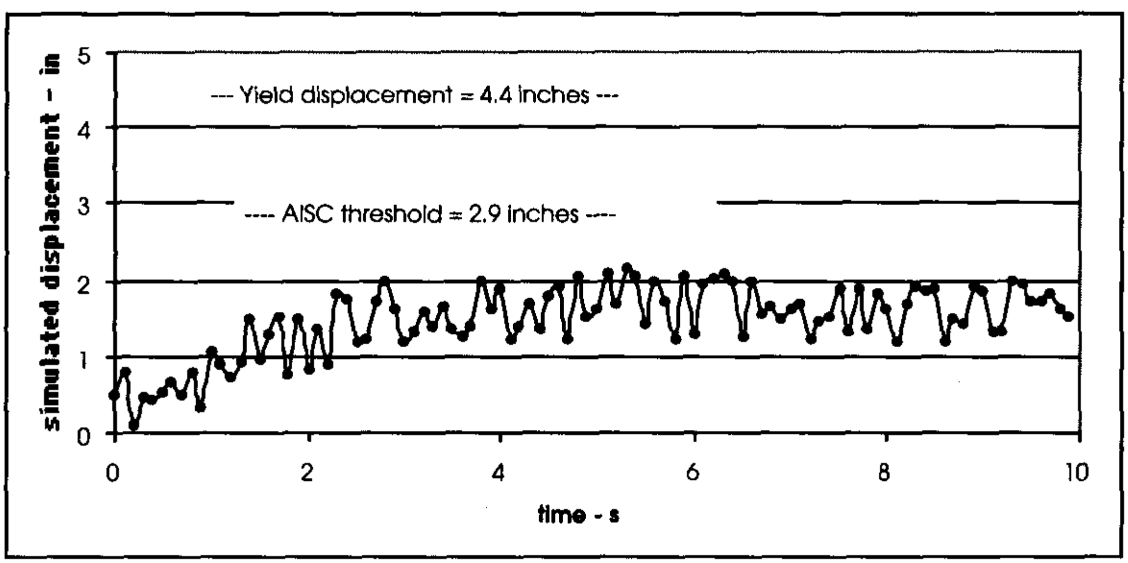

Figure 4. *Simulated* displacement data obtained from hypothetical CCTV data.

In a subsequent and more comprehensive analysis, the displacement data shown in Figure 4 would be used together with the Yield Stress models prepared for the various ALC and profile assemblies in AZ-101 [1]. The analysis would compare the measured data to the forces applied to various objects as a function of time, inferred from the pump speed and modeled fluid properties. The applied forces analysis would be interpreted as the applied loads compared to the yield loads for each object and would (statistically) describe the safety margins that were available (if any) for the various motor speeds, as a function of distance from the jet nozzle.

As another example, it is expected that the pump effectiveness analyses would examine the space-time behavior of the thermocouple data. The real-time data would focus on monitoring the temperature in the tank so as not to exceed the limiting values. The SDS would document the available data, make plots of representative data, and assess the maximum tank temperatures. A representative plot of thermocouple data is shown in Figure 5. This figure shows a plot of temperature as a function of time from 21 of the 22 ALC thermocouples in AZ-101 during a test of the air lift circulators in December 1999. These data illustrate how a change in temperature on all of the ALCs was observed at about 20 hours after the ALCs were turned on, shortly after the airflow through the ALCs was increased from 5 to 7 cfm.

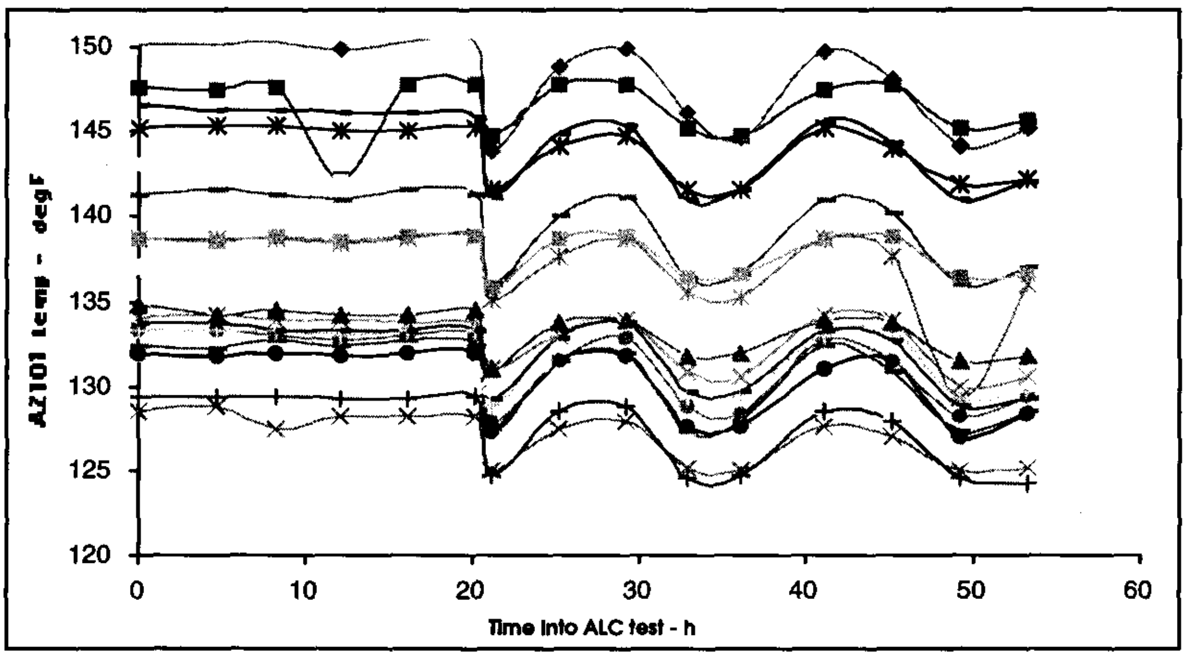

Figure 5. A time series plot of ALC thermocouple data recorded during ALC test in Dec 1999.

The subsequent detailed analysis would calculate the rate of change of temperature in the tank and relate those data to other factors such as pump speed. The effectiveness of the pump can be assessed in terms of distance as a function of motor rpm—for example, by defining and analyzing the area swept by the pump's jets, as measured by the thermocouple (or TGAC) data. By calculating the "swept area" and comparing these data to existing models that predict the effectiveness of the pump, the models can be validated and/or improved.

The pump effectiveness and solids mobilization objectives will be achieved by analyzing a *set* of sensor data, such as illustrated in Figure 5, with an interpretation of the result in terms of the *rate of change* of the measured quantities. In this example, the measured quantities might be the set of data recorded by the array of ALC thermocouples, for example. Here, a space-time analysis of the profile thermocouple data could result in an assessment of the horizontal or vertical growth of the suspended slurry. Or it could be sets of TGAC data recorded in (x,y,z) that showed the spatial and temporal evolution of the radionuclide particles that comprise the sludge. Or, it could be a combination of these two (or other) sensor data.[2] Where possible, a joint analysis will be used whereby the data from two or more sensors are combined using a common reference calibration such as will be determined from the grab sample data.

Another analysis technique that can be used with the time-series data is to create a "waterfall" plot and examine the ensemble of the data for observable features. In this analysis, "features" that cannot be found, or are difficult to find, in the single realizations are identified and tracked over time and associated with other events in the tank. An example of this analysis, using a set of *simulated* URSILLA data, is shown below. Applied to the AZ-101 Mixer Pump Demonstration and Test program, sequential time-series returns from the URSILLA or TGAC may be subjected to this analysis.

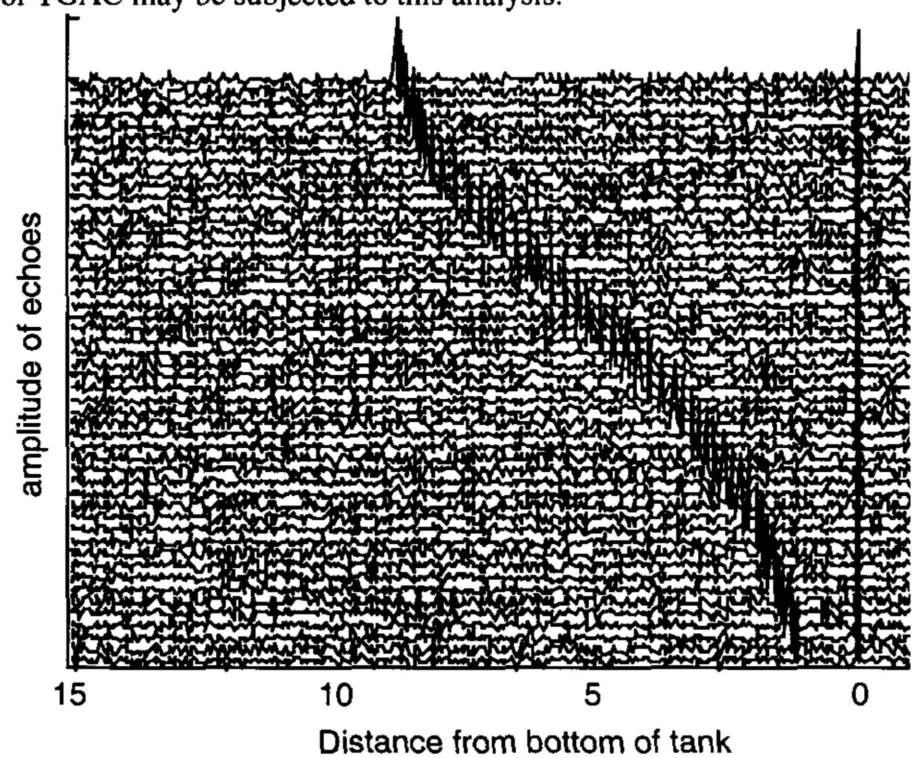

Figure 6. An example of a waterfall plot of simulated URSILLA data.

[2] So that different sensor data may be used in a joint analysis, the grab sample data collected simultaneously with the data from other sensors will be used to interpret the sensor data in terms of particle density or solids content, as a function of (x,y,z,t).

5.2 Data Analysis by Objective

This section of the analysis plan summarizes the steps that are expected to be taken in the analysis of the data collected in support of the AZ-101 Mixer Pump Demonstration and Tests program. Detailed test plan information is provided in [1]. The analysis outlined here is keyed to the test objectives, discussed in Section 1.2 of [1], and the test sequences (see Appendix A of [1]) that will provide the data to achieve the objectives.

Table 3 A Table Showing the Relationship Between Test Objective, Test Sequence, and Data Analysis

Test Objective (See Section 1.2)	Test Sequence(s)	Analysis
1.2.1.1 (pump operations)	1.1.1 through 2.6.3	*Real-Time*: Monitor pump parameters; alert TD to threshold exceedances; make logbook entries. *Post-Test*: Make time-series plots of parameters; compare to threshold values. Make parametric plots (e.g., rate of bearing temperature increase versus motor speed) as necessary.
1.2.1.2 (in-tank structural limits)	1.1.1 through 1.6.3	*Real-Time*: Monitor CCTV and strain gauge; alert TD to threshold exceedances; make logbook entries. *Post-Test*: Make time series plots of displacement of objects as function of pump speed for selected objects. Calculate and plot stress as function of pump speed and compare to models (Julyk 1997, Waters 1993). Plot strain gauge output as f(time) and compare to CCTV-measured displacements; correlate data.
1.2.1.3 (tank operating limits) 1.2.1.4 (air permit compliance)	1.1.1 through 2.6.3	*Real-Time*: Monitor ventilation parameters; alert TD to threshold exceedances; make logbook entries. *Post-Test*: Make time series plots of sampled data and compare to aerosol and radioactive vapor models (Waters 1994); compare to hydrogen gas release models (Hodgson 1996); plot hydrogen concentration in head space as f(time). Determine compliance with air permits.
1.2.1.3 (tank operating limits)	1.1.1 through 3.6	*Real-Time*: Monitor thermocouple data; alert TD to threshold exceedances; make logbook entries. Post-Test: Make time series plots of selected thermocouple data; compare • $T(t)_{measured}$ to • $T(t)_{predicted}$, based upon model for heat input from pump operation (Sathyanarayana 1994); extrapolate to estimate pump operation time to reach maximum-allowed temperatures. Make recommendation regarding pump operations in terms of temperature growth.
1.1.2.1 effective cleaning radius	2.1.1 through 2.6.3	*Real-Time*: monitor selected sludge and tank-bottom thermocouples to provide run-time guidance. *Post-Test*: Make time series plots of selected thermocouple data; assess • T as f(time, distance from nozzle, pump speed, location in tank); compare to empirical models. Make 3D (x,y,t) contour plots of swept area; estimate volume of sludge mobilized. Make 4D (x,y,z,t) estimates of vertical growth of

		slurry. Make recommendations regarding pump operations in terms of ECR.
1.2.2.2 (sludge mobilization) 1.2.2.3 (minimum pump speed)	2.1 through 3.6	*Real-Time*: None *Post-Test*: Make time series plots of URSILLA, TGAC and SSP data; estimate slurry growth. Determine minimum speed needed to maintain suspension. Using grab sample analysis, re-interpret URSILLA, TGAC and SSP data in terms of solids loading. Using baseline sludge volume and density, estimate solids loading as f(time, pump speed, configuration); compare inferred solids estimates to measured data at grab sample times. "Hindcast" to estimate solids estimates at other times and pump speeds. Make 3D (x,y, t) and 4D (x,y,z,t) estimates of growth and suspension rates of slurry; compare estimates to ICD-20 as f(z). Make recommendations regarding mobilization in terms of time, pump speed, and number of pumps.
1.2.2.4 (settling rates)	4.1 through 4.6	*Real-Time*: None *Post-Test*: Extend the analysis described above (objective 1.2.2.2) to periods after pump operations have been suspended to assess how the once-mobilized solids settle back onto the bottom. Estimate the settling rate as a function of the mobilized condition and compare to models (MacLean 1998). Make recommendations regarding waste feed transfers to the vitrification contractor in terms of pumping (source depth and duration) after the pumps have been turned off.
1.2.3.1 (sensor evaluation)	all	*Real-Time*: None *Post-Test*: Make x-y scatterplots between grab-sampled data (independent axis) and other sensed data (e.g., TGAC, SSP); estimate calibration coefficients; re-interpret sensor data in terms of physical parameters (e.g., mass density) and "hindcast" to estimate solids estimates at other times and pump speeds (see 1.2.2.2 above). Compare the repeatability of the calibration coefficients with other grab samples; estimate accuracy of various instruments for making in situ measurements. Make recommendations regarding the use of the tested sensors for measuring waste parameters in AZ-101 and other tanks.

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6 SUMMARY AND CONCLUSION

This analysis plan has described an efficient and practical means to accomplish the difficult task of assessing and quantifying the performance of mixer pumps placed into Tank AZ-101. The overall measurement program comprehends three distinct objectives, related to (1) mixer pump operations, (2) sludge mobilization, and (3) an evaluation of the quantitative performance of remote sensing instruments installed in the tank. The analysis of the data obtained in this test will allow the vitrification contractor to plan for the first waste feeds. It will also allow River Protection Project personnel to more confidently retrieve other tanks at Hanford. The plan presented here provides the means and methods to achieve the stated objectives in an ordered manner—in a way that places the emphasis on operational safety, followed by the technical objectives.

Successful accomplishment of this plan requires a cohesive team comprised of test personnel, sensor operators, and analysts. The development of the analysis program described herein should be initiated well before the mixer pump test program is ready to turn on the pumps for the first time.

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11. G. T. MacLean to R. A. Kirkbride, "The Settling and Compaction of Sludge in a 30-foot High Column, COGEMA-98-851, COGEMA Engineering Corp., Richland, Washington, (1998)

Appendix

KEY SENSORS / SENSOR SYSTEMS
AZ-101 MIXER PUMP TEST

A brief description of the various sensors/sensors systems that will be used during the AZ-101 Mixer Pump Test, and the data they will generate, is provided below.

A.1 Pump Instrumentation

Each of the mixer pumps will be instrumented with sensors that monitor the state of the pump. The data from each of the sensors will be recorded on a computer located in the 241-AZ-156 Building. This instrumentation includes:

A.1.1 *Motor Bearing Temperature.* Each motor will have a thermocouple installed on both the upper and lower motor bearings. Alarm points will be established to ensure that the motor bearing temperature does not exceed to operating limits. A warning set point will be established and a shutdown setpoint will be established.

A.1.2 *Pump Current / Voltage.* The current drawn by the pump is a function of the load on the pump motor and the speed of the pump. Both voltage and current will be monitored and a real-time threshold established.

A.1.3 *Pump Speed.* The operating range of the pumps, which varies from 700 to 1200 rpm, is set by means of a voltage-to-frequency device (VFD). The rotational speed limits are set in the VFD, and pump shutdown will occur if the limits are exceeded.

A.1.4 *Column Pressure.* The pressure across the pump impeller and across the column supply filter is measured to ensure the operating limits of the pump mechanism are not exceeded.

A.1.5 *Pump Orientation.* The pointing angle of the pump's jet nozzle is measured and recorded.

A.1.6 *Pump Runtime.* The operating time for each pump is recorded.

A.1.7 *Pump Vibration.* The vibration of the pump caused by shaft and load imbalances will be measured at each of the upper and lower motor bearings using a "Vibraswitch". In addition, motor vibration will be measured with an accelerometer attached to the housing. The acoustic noise produced by each pump will be monitored with a hand-held noise meter and recorded in a logbook.

Figures A-1 and A-2 show "dumps" of two of the many screens presented to the operator by the Data Acquisition System (DAS). These screens show the real-time data on which decisions can be made. The DAS records these data (and more) on disk for later analysis.

TANK 241-AZ-101 RETRIEVAL DAS SYSTEM DESCRIPTION

APPENDIX S – OPERATOR INTERFACE SCREENS

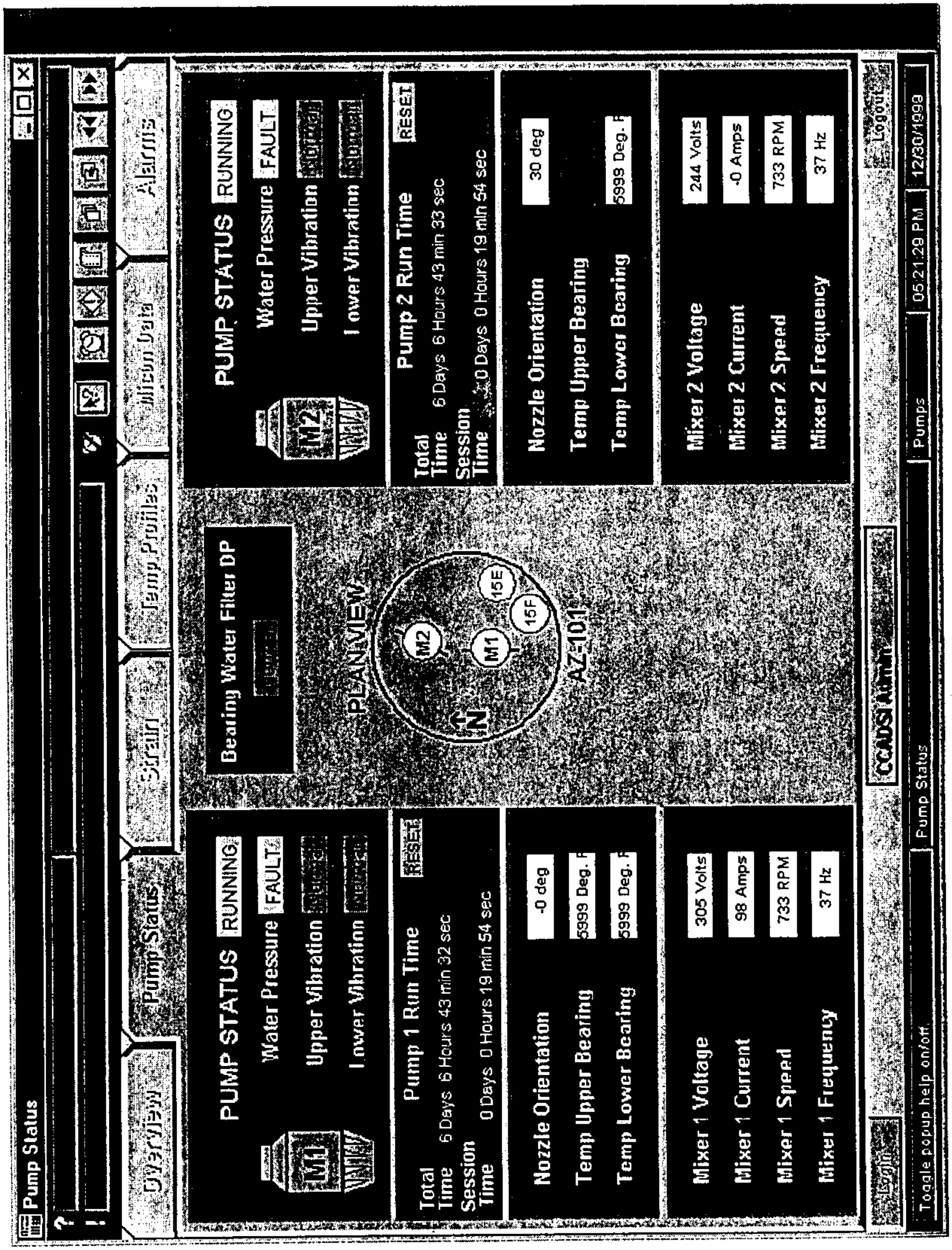

Figure A-1. A typical DAS screen display, showing Pump Status.

TANK 241-AZ-101 RETRIEVAL DAS SYSTEM DESCRIPTION

APPENDIX S – OPERATOR INTERFACE SCREENS

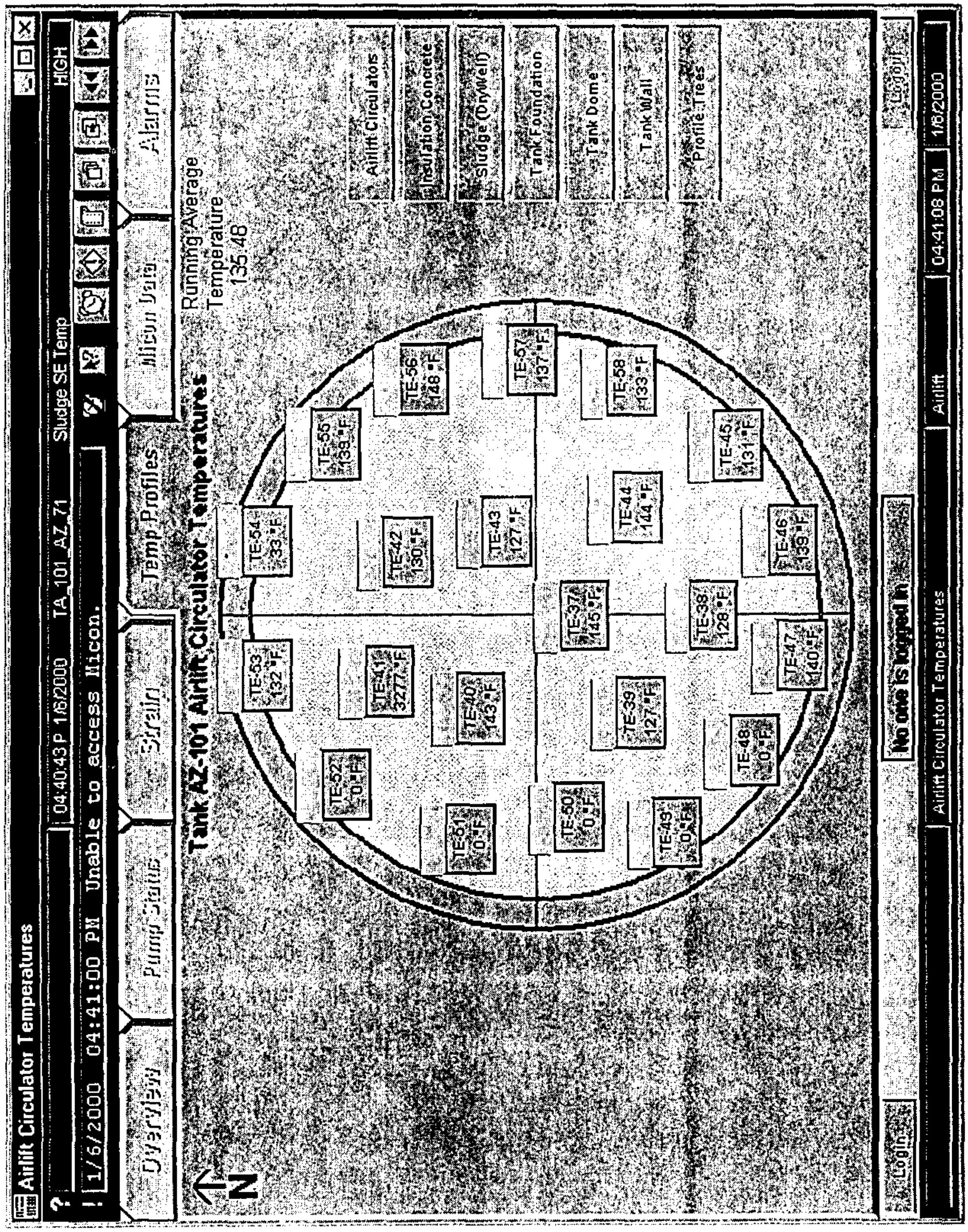

Figure A-2. A typical DAS screen display, showing Airlift Circulator Thermocouple Temperatures.

A.2 Air Emissions (SHMS, VOC, HEPA)

The emissions resulting from the operation of the mixer pumps will be measured with the Standard Hydrogen Monitoring System (SHMS) and with instrumentation located in the 241-AZ-702 Ventilation Building. The 241-AZ-702 instrumentation includes volatile-organic-compound (VOC) sensors, radiation sensors, and differential pressure sensors.

A.3 Closed Circuit Television Camera (CCTV)

A RJ Electronics model RCS-551 television camera will be installed in the tank at Riser 16B. This camera, on a motorized pan-tilt mount, has a lighting system built into the mount and can be pointed and zoomed at various objects in the tank. The video output of the camera is input to a Colorado Video Model 305 Video Micrometer, where the camera's data is scaled to metric units by means of an internal fiducial reference measurement system. Objects in the field of view of the camera are presented to the operator along with a video scale capable of measuring the actual size of the objects (or displacements). The camera uses a 0.5 inch sensor and images at 460 lines of horizontal resolution. Since the TV camera is located above the air-supernatant interface, the camera can be used throughout the entire test program; its use is not limited by pump operation. Radiation from the tank contents may degrade operation of the camera over time, however.

The CCTV system will serve three functions during the AZ-101 Mixer Pump Test program. First, it will be used as a general surveillance tool to observe the in-tank environment. Second, by observing bubbles rising to the surface, it will be used to confirm operation of the Air Lift Circulators (ALCs), if those devices are activated. Third, it will be used to measure the deflection of in-tank structures to assess the stress placed on these structures by the jet forces of the pump. This third purpose will require the CCTV system to reliably measure small fractions of an inch displacement at distances of up to about 40 feet.

It is noted that the CCTV is the *only* instrument in the present sensor matrix that can reliably be used to provide information about the forces on in-tank objects. The discussion below is focussed on interpreting the CCTV image data in terms of the displacement of various objects observed at or near the air-liquid interface in the tank.

There are five key ingredients to the successful use of the CCTV for measuring the forces on the in-tank structures caused by the pumps: 1) adequate illumination, 2) adequate spatial resolution, 3) adequate contrast, 4) proper object identification, and 5) compensation for "apparent deflection".

A.3.1 *Illumination.* For most TV systems, the electronic gain of the system is inversely proportional to brightness of the scene; the camera tries to maintain an appropriate "exposure" value. As the scene illumination is decreased, the electronic noise in the image is also amplified and at low levels of illumination, the noise begins to dominate the image. The resulting image appears muddled and "grainy"; in this case, the ability of the camera system to accurately measure the displacement of an object in the scene is greatly reduced. Based upon the signal-to-noise ratios (SNRs) required for other detection problems (e.g., radar or sonar) a minimum SNR of 10dB to 20dB is expected to be needed for the AZ-101 CCTV to allow good-quality measurements to be made. An image with a 10dB SNR would be mostly clear with only a slight indication of graininess; a 20dB SNR image would be clear and free of observable "graininess".

A.3.2 *Contrast.* Adequate illumination and adequate contrast are both required for an object to be "seen". To observe the displacement of an ALC, for example, it will be necessary to see some part or feature of the ALC, and watch that part or feature change. To see the part or feature requires that that part or feature be distinguished from other parts of the scene. If, for example, the position of the visible edge of the ALC is to be observed, the edge must be clearly distinguished from the background. Since the reflection coefficient of a cylindrical object decreases as the optical geometry approaches grazing incidence, and since the backgrounds of the AZ-101 images are likely to be either amorphous dark voids or dark, reddish areas similar to the object to be tracked, defining the "edge" of an ALC may be difficult unless there is sufficient illumination. Similarly, tracking the displacement or motion of a fleck of rust on an ALC is possible only if the contrast between the fleck and the surrounding area is sufficiently high. A scene in AZ-101 with adequate contrast would allow the boundary of the edge or fleck to be optically defined within a single resolution element (pixel).

A.3.3 *Spatial Resolution.* The CCTV system will see the deflection of an in-tank object as the change in position of an image point from one pixel to another. The resolution of the system must be adequate to measure the movement. To measure finely, the focus must be sharp, and the optical and geometrical configurations must be stable and well known.

One aspect of resolution that needs to be addressed is the rigidity of the camera mount. If the CCTV camera isn't mounted securely and rigidly, vibration or shaking of the camera can be incorrectly interpreted as object motion. At best, a shaking camera will degrade the performance of the measurement system. This shaking, observed during the shop tests of the CCTV equipment, should be quantified in the tank for every pump speed and geometry.

A.3.4 *Other Factors.* It is possible that a mist or fog could form in the tank during the tests. Condensation, water droplets, or evaporated salts on the lens are also possible. These phenomena, together with the noise caused by the gamma radiation in the tank, will degrade the measurement accuracy by lowering the contrast of the image or blurring the image, or both. The presence of these factors should be monitored as part of the operation of the CCTV system.

A.3.5 Object Identification. The location of in-tank objects in terms of their geometrical relationship to the camera installation is shown in Figure 1 in the main text. An important aspect of the MP tests is unambiguous identification of the various in-tank objects to be measured by the CCTV system.

A.3.6 *Apparent Deflection.* An imaging system sees change only in directions that are transverse to the look direction. For changes occurring out of the transverse plane, the imaging system projects the motion into the transverse plane and shows only the "apparent" motion. For AZ-101, the CCTV system will most often see only the "apparent" deflection of in-tank structures because the viewing angle to most of the objects is oblique. The actual deflection of the structures can be simply calculated from the apparent deflection by dividing the imaged deflection by the sine of the angle between the look direction and the deflection direction.

A.3.7 *Shop Test Data.* Figure A-3 shows a frame of CCTV data recorded during tests of the system performed in December 1999. This frame shows a simulated in-tank object (at a range of about 25 feet) against a simulated tank-wall background. This figure shows the in-frame reticule that allows the displacement of an object to be measured, as determined by the locations of user-selectable starting and ending cursor positions.

Figure A-4 shows a plot of the minimum detectable displacement, as determined during the December 1999 shop tests. To obtain this data, pipes were positioned at various distances from the camera, and then moved in (about) 1/32" increments transverse to the look angle. The smallest lateral displacement that could be observed was recorded. Allowing for operator error and other image-degrading factors, this data suggests that (apparent) displacements as small as 1/8" to 1/4" can be reliably detected by the CCTV system in AZ-101.

A.3.8 *Displacement Thresholds.* Displacement limits will be applied to the CCTV measurements of every object whose displacement will be measured. A threshold based upon standards established by the American Institute of Steel Construction (AISC) will be used as the maximum allowable displacement and will be monitored in real-time. The AISC threshold is based upon 66% of the yield displacement. To make metric measurements with high confidence, it is desirable to have at least 5 to 10 resolution intervals between the nominal rest position and the threshold. This says that the CCTV system must have a sampling interval of 0.8 inches to 0.4 inches in the object plane. These values are consistent with the shop test results described above.

A.3.9 *Data.* Based upon the yield displacement data shown the Test Plan, the tank geometry for the CCTV and other objects, the AISC allowable displacements will be calculated for the images of the in-tank objects that are displayed on the CCTV monitor, and used for the real-time monitoring and analysis. The minimum detectable displacement determined during the shop tests indicates that these measurements can be made relatively easily in the tank. The post-test analysis will examine the CCTV data on a frame by frame basis, as described in the text.

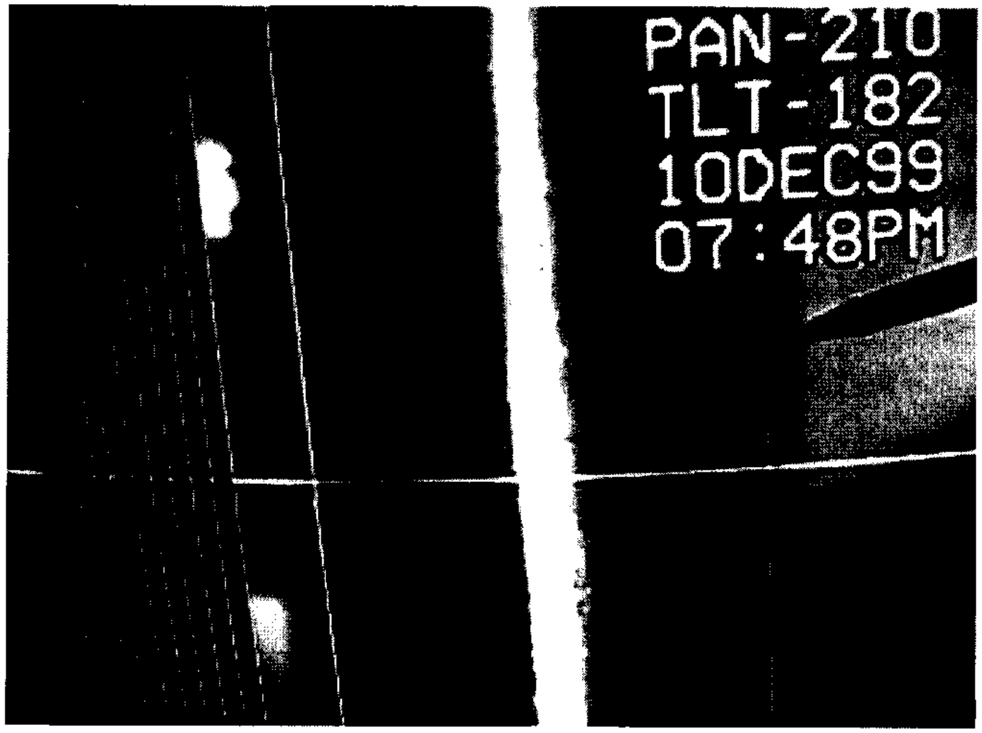

Figure A-3. A frame of CCTV data from the shop tests at Hanford.

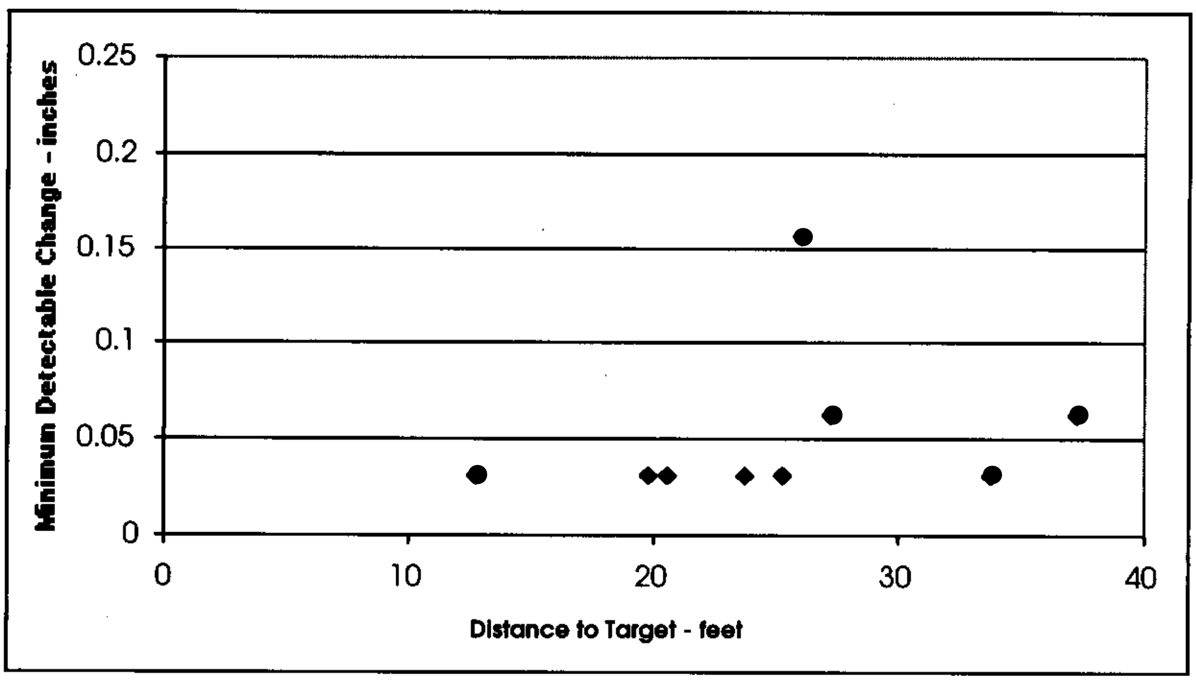

Figure A-4. A plot of the minimum CCTV-detectable displacement, as a function of object distance.

A.4 Ultrasonic Level Analyzer (URSILLA)

Three Royce Instrument Corporation, Model 2511 Interface Level Analyzers (URSILLA) will be used to measure the growth of the slurry layer as the pumps mobilize the wastes in AZ-101. Each URSILLA is comprised of a piezoelectric transducer and a receiver/analyzer unit. The transducers are installed at the ends of pipes that extend from the top of the tank at Risers 5B, 13A, and 16C. A user-provided data recording system (a PC) completes the system in terms of data collection for archival purposes and subsequent analysis. Taken together, URSILLA is an ultrasonic device that acts much like a sonar or a "fish finder". That is, URSILLA transmits an ultrasonic pulse signal. Echo(es) from the transmitted pulse are returned to the transducer as a result of scattering from objects or discrete changes within the acoustic path. These echoes are detected and--using a measured or assumed speed of sound--interpreted by the analyzer unit in terms of distance from the transducer.

Unlike a simple bottom finding sonar that returns only a single value to the user (the depth to the bottom or other strong scatterer), the URSILLA averages and integrates the received data and records both the arrival-time profile and the amplitude of the integrated return. The display processes a quasi-continuous time series so that all of the (resolved) detected returns are displayed. This allows the URSILLA to "see" and vertically measure the location of multiple layers of differing sludge density as the mixer pump(s) mobilizes the sludge in the tank.

The piezoelectric transducer is used for both transmitting and receiving. The transmitted signal is a 200KHz pulse. This frequency, together with the diameter of emitting surface of the transducer (~2 inches), results in a beamwidth of about 8 to 10 degrees. Thus, assuming an installation in AZ-101 where the transducer is placed immediately beneath the liquid surface (about 300 inches above the tank bottom), the transmitted beam illuminates a spot that is about 42 inches in diameter at the bottom of the tank. A detected return at this distance (the bottom of the tank) is therefore averaged over this area. Correspondingly smaller "spot" sizes are averaged as the scattering is moved closer to the transducer.

The range resolution of the URSILLA is about 0.2 feet, or 2-3 inches. This means that echoes from scatterers that are more than this separation can be discriminated. If closer, the echoes will merge and will not be "resolved". Taken with the spot size, the data from each URSILLA can be considered as from a cone of discrete slabs that are each 2-3 inches thick and whose diameter increases with depth. Each of these volume elements can be called "voxels".

Like any acoustic device, URSILLA requires a discrete change in the acoustic impedance of the propagation medium (the supernate /sludge /slurry, or some combination thereof) in order to "detect" the echo. More specifically, unless there is a discrete change in impedance, no echo (acoustic scattering) will be created, and as a result, no echo will be detected. Further, to be detected, the echo must be sufficiently strong to exceed some detection threshold in the analyzer. In discussions with the vendor[1], the minimum detectable scattering change corresponds to a solids loading of about 200 mg/L. This value is based on standard industrial/municipal sludge forms. With the smaller and denser particles likely in AZ-101, the minimum detectable change in solids loading will be somewhat greater. For discussion purposes here, however, 200 mg/L will be used as the expected lower limit during AZ-101 mixer pump tests.

There are significant expectations that can be deduced from this minimum detectable solids loading. For example, consider the case where the mixer pumps are beginning to mobilize the sludge. As the slurry-supernatant interface level rises in the tank as a result of the "fluffing" that is occurring, the interface will be detected as long as the solids loading of the top-most portion of the slurry layer is ~200 mg/L or greater. This should be the case early in the mobilization phase. However, if the slurry becomes thinned to less than 200mg/L, the slurry interface echo will be lost to the data system. That is, the "location" of the slurry-supernatant interface will not be determined for weak slurries.

Subsequently deeper and denser layers may or may not be detected, depending on the value of the incremental changes in the solids loading as a function of depth. In the extreme of a smooth and continuously changing solids loading from some small value (<200mg/L) to some much greater value, there might not be *any* detected returns whatsoever. Layers, or discrete changes on solids loading that exceed the minimum detectable level within two range bins (say a few inches) will be detected.

A solids loading range of from 200mg/L to about 200g/L requires a dynamic range of about 1000:1 or 60dB. Based upon dynamic ranges commonly achieved in ultrasonic equipment, 60dB is a reasonable expectation for the URSILLA. Since the expected solids loading in AZ-101 is not inconsistent with the URSILLA dynamic range, URSILLA is expected to detect scattering from AZ-101—as long as the changes in solids loading exceeds the minimum detectable value.

The intensity of the echo is measured by URSILLA. Since the strength of the echo will be proportional to the value of the incremental solids loading, the URSILLA has the *potential* for quantitative calibration—within the detectable limits.

Figure A-5 shows a plot of URSILLA data collected during the field tests of the system just before it was installed in AZ-101. This data shows two echoes coming from targets placed in the test tank. By examining repeated profiles, it will be possible to construct a "waterfall" display, illustrated in Figure A-6. To the extent the waterfall display shows discrete slurry layer information, it will allow the growth rate of the layer to be graphically illustrated and quantified. This is done by fitting tracking lines to the feature that is seen to change with time. Growth and settling rate data is easily obtained in this manner.

[1] Telecom with Rich Davis 10/25/99, Royce Instruments, New Orleans, LA, 1-800-347-3505

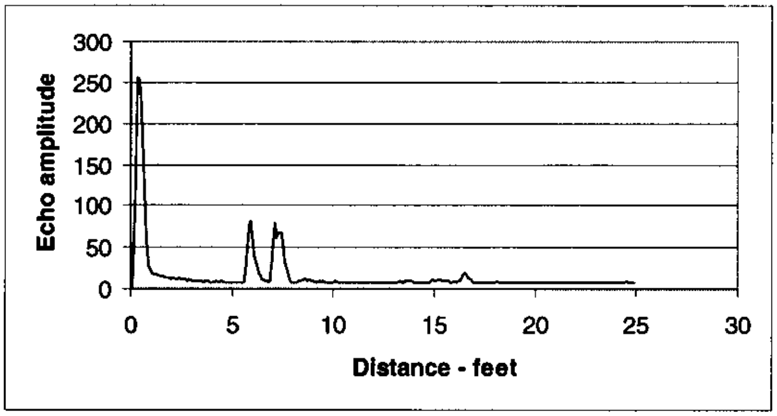

Figure A.5. A plot of URSILLA data collected in field tests (December 1999).

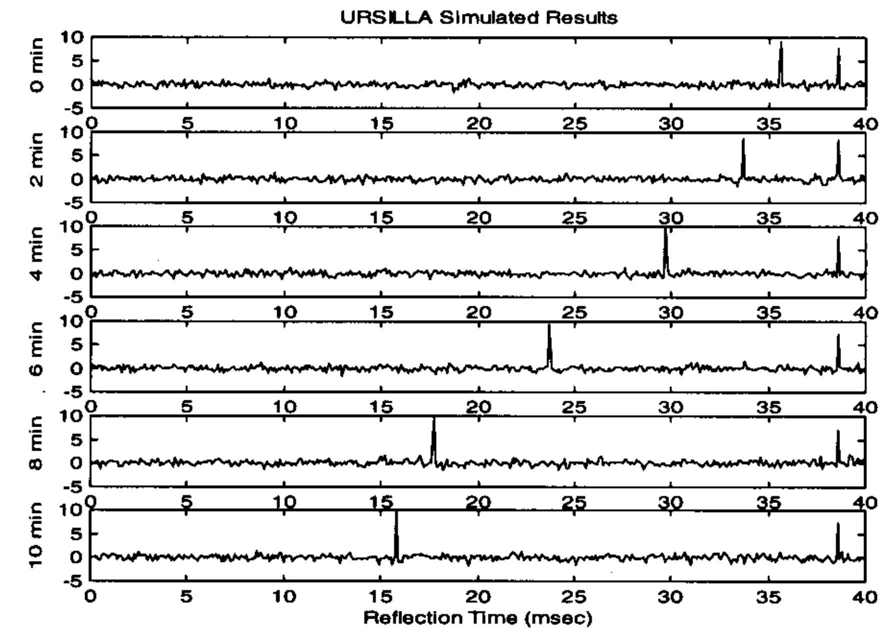

Figure A-6. Simulated URSILLA data, showing a moving "feature".

The following points are made with regard to the use of the URSILLAs in the AZ-101 MPT. First, incremental layering of solids density at intervals >200mg/L will be necessary for the URSILLA to "see" the mobilization that is taking place. Second, even the top interface could be lost if the solids density falls below the minimum detectable level. There are two additional points: 1) under the proper circumstances, the URSILLA data may lend itself to quantitative interpretation, and 2) the expected dynamic range of the URSILLA is roughly consistent with the expected range of solids loading expected from the mobilization program.

Based on the foregoing, the use of the URSILLA data to quantify the solids loading in the slurry represents a moderate technical risk of not obtaining the desired information. The use of the URSILLA data for measuring the height of the mobilized layer(s) and the changes in height with time represents a low technical risk to the project of not obtaining the desired information, provided that the layer(s) are distinct and that the solids loading differential between each layer is >200 mg/L.

A.5 Strain Gauges (STRAG)

Strain gauges will be mounted on the profile thermocouple mast at Risers 15E and 15F. The strain gauges will sense the strain on the masts caused by the flow of slurry jetting from the pump nozzle. Because of the considerable technical difficulties in converting strain to displacement, the use of these sensors for measuring the forces on the in-tank structures represents a significant technical risk to the project of not obtaining the desired information.

A.6 Gamma Probe (TGAC)

A Hanford-fabricated radiation probe will be used to monitor the growth and settling of the sludge during the mixer pump tests. This probe, termed the Total Gamma Above Cesium (TGAC), uses a shielded cadmium telluride detector to measure the slurry layer. The TGAC is deployed into the tank at various Liquid Observation Wells (LOWs), or "dry wells". Since the dry well isolates the probe from the jet forces, the TGAC can be used while the mixer pumps are running. The principle of operation of the TGAC is based on a characterization of the sludge and supernate which shows that the sludge is rich in TRU isotopes, uranium isotopes, Eu-152, Eu-154, and Sr-90, while the supernatant liquid is deficient in those radionuclides but rich in cesium. The sludge-borne materials radiate strongly at gamma energies greater than the Cs-137 energy of about 662KeV. The TGAC operates by measuring a wide range of energies above and below 662KeV. By examining the characteristic of the supernatant and then measuring the intensity of the excess energy, the sludge component of the slurry can be measured. By comparing the TGAC-measured slurry with the grab-sampled slurry taken from a nearby riser, it is expected that the TGAC can be calibrated in terms of the solids loading from the sludge.

Figure A-7 shows data collected from the TGAC using a few laboratory sources to simulate the tank-borne materials: Ba-133 and Eu-152. This figure illustrates the spectral differences that might be observed in AZ-101 from the radionuclides in the supernatant (illustrated here using the Ba-133 spectrum) and the sludge (using the Eu-152 spectrum). To the extent this figure is representative of the TGAC data from AZ-101, this data can be used to show how the differing spectral characters can be used to estimate the sludge mobilized by the pumps. As mobilization occurs, more and more of the sludge will mix with the supernatant. The gamma probe will measure the concentration of the slurry as the sum of the sludge spectrum and the supernatant spectrum. For a specified integration time, the change in both the intensity and the location of peaks in the spectral data will reflect these differences.

The data will be analyzed using a variety of standard tools (totals, partial totals, ratios, coherence, correlation, and so on), to extract the data that is sought. By calibrating the TGAC from the grab sample data, a quantitative interpretation of the TGAC may be possible. Since the TGAC can collect data while the pumps are running, such a calibration and interpretation would allow the effectiveness of the mixer pump to be measured in situ. These data would reduce the number of grab samples that were needed in future tank mixing and retrieval operations.

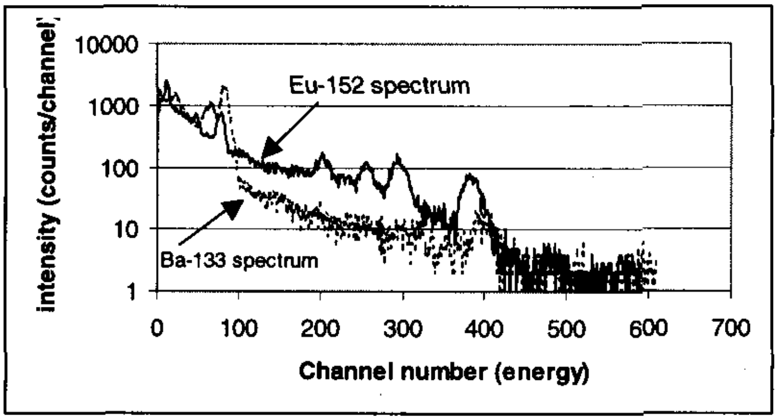

Figure A-7. A plot of gamma intensity as a function of energy for two laboratory sources.

A.7 Suspended Solids Profiler (SSP)

A Mt. Fury Company, Inc. Profiler, a sludge blanket level and suspended solids monitor (SSP), will be used to measure the solids content of the AZ-101 waste slurry. The SSP, a microprocessor-based turbidity sensor, is comprised of a sensor head, a stepper motor-driven cable reel, and an electronics module. The device operates by emitting infrared (IR) light and detecting that portion of the light that is scattered back into the IR detector in the sensor head. The more dense the particulate, the greater the backscatter and the greater the output of the device. The backscattered IR intensity data, along with the length of cable reeled out for each measurement, are digitized and recorded on a computer in the 241-AZ-156 Building for subsequent analysis.

The cable reel and electronics module will be installed on top of AZ-101 Riser 24A. The sensor, located at the end of the cable on the reel, is lowered into the tank as determined by the programming of the unit. This programming allows up to 20 discrete sample depths to be recorded over a programmable range. In the case of AZ-101, the first sample will be taken from just beneath the liquid surface (at about 320 inches off the bottom), and the 20th sample will be taken from just above the tank bottom (at about 6 inches.) As a result, the SSP will record the suspended solids data at (approximately) 16-inch intervals. Since the TGAC and Grab Samples will be collected at (approximately) 42-inch depth intervals (8 samples from top to bottom) the SSP sampling interval is adequate to allow vertical density profiles to be determined after calibrating the SSP from the grab sample data. The manufacturer quotes the accuracy of the vertical position data (reel length) as 0.1 in per foot. For a total data length of 50 feet, this corresponds to a vertical position accuracy of about 0.5 feet. Shop tests at Hanford in December 1999 showed that an accuracy of about 0.2 feet was obtained, but the precision of the measurements was only about 1-foot.

Each measurement cycle, 20 discrete samples at (about) 16-inch intervals, will require about 5 minutes to complete. Since each run sequence may take an hour or more to complete, the SSP will be programmed to make 10 measurement cycles per hour. This will improve the precision of the data because of the averaging that will be possible from the data.

The Mt. Fury SSP has a measurement range of 0.0005% solids to 6% solids (5 ppm to 60,000 ppm), with a resolution of 1% of the reading. This solids contents range favors dilute slurries, and the output may saturate for the thicker slurries expected to be found near the bottom of the tank. Figure A-8 shows a plot of SSP calibration data obtained during the mid-December tests at Hanford. This plot shows the output of the SSP as a function of the total suspended solids in the test slurry, as determined by a laboratory

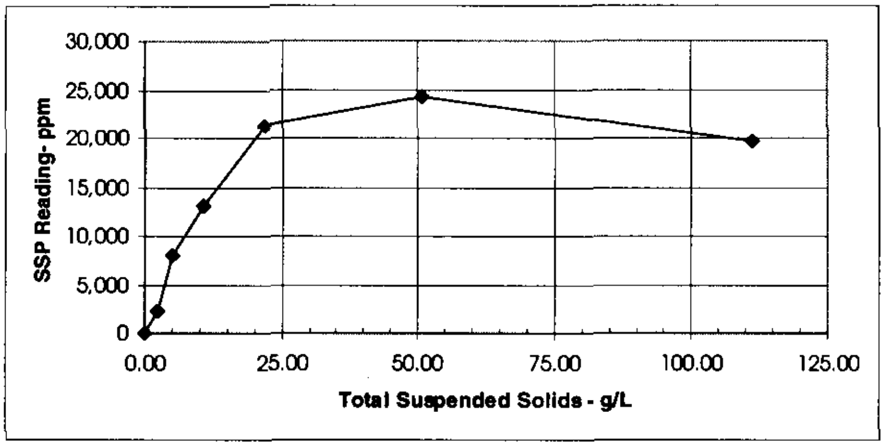

Figure A-8. SSP calibration curve, determined from Hanford shop tests.

analysis. At the low end of the scale--0 to 50 g/L, the plot illustrates how the calibrated SSP data will be used to infer the solids loading of the sampled slurry. The SSP output will be plotted against the solids loading in AZ-101 determined from a series of SSP-grab sample calibration runs (Sequence 4). After that calibration, the solids density for any set of SSP data can be determined by entering the (example) plot above on the y-axis with the SSP reading (assuming the data in Figure A-8 was properly calibrated), and reading the solids loading by dropping from the curve down to the x-axis.

Discussions with the manufacturer revealed that the "rollover" in Figure A-8 is due to a test procedure that didn't allow the SSP to "color correct" itself properly. The manufacturer described that the SSP processor has two gain channels: a high-gain channel for low concentration samples and a low-gain channel for high concentrations. The sensor uses the data from several repeated measures at concentrations above and below (about 7500 ppm) to determine a gain factor for the high-gain channel. To allow the SSP to preserve the calibration factor--once it has been determined, it is necessary to keep the SSP powered up at all times. If the power is turned off, the calibration data will have to be re-determined, at the cost of several otherwise useful measurements.

The SSP is an important sensor for quantifying the solids loading in the slurry during the AZ-101 MPT. Its use for this purpose represents a moderate technical risk to the project of not obtaining the desired information since there were calibration issues that could not be fully resolved in the lab before the sensor was deployed in AZ-101.

A.8 Thermocouples (ALCT, TBT, PTA, ST, CT)

For purposes of the AZ-101 MPT, there are four arrays of thermocouples that are installed in the tank. There are 22 thermocouples located 4 inches above the bottom of the tank, at the bottom of each air lift circulator (ALCT). There are also seven "sludge" thermocouples (ST) located at various places in the tank; these are also at 4 inches above the bottom of the tank. In addition to the ALCTs and STs, there are 24 thermocouples located at the bottom of the tank (TBT), between the steel liner and the concrete tank shell. There are also five "mast" assemblies (PTA) at Risers 15B, 15I, 15C, 15E, and 5F, with each mast supporting three thermocouples located vertically at 4, 14, and 140 inches off the bottom of the tank. There are an additional 22 thermocouples buried in the insulating concrete shell (CT). While the ALCT, TBT, PTA, and ST data (except for 4 STs and 1 PTA which are read manually) will be recorded on Westronics system computer in Building 241-AY-801G during the MPT, the CT thermocouple data will be manually read and the temperature data recorded in a log book.

Figure A-9 shows a plot of temperature data from 20 of the 22 ALCT thermocouples in AZ-101 recorded during an ALC test in November and December 1999[2]. (ALCTs #5 and #18 were not working.) This data shows the variance of the readings throughout the tank, as well as the expected temporal variance (at low flow rate conditions in the first eight hours of the test. These data suggest that every thermocouple in the tank (at least on the ALCs) is sufficiently different in characteristic that each will have to handled individually before analyzing the ensemble of data.

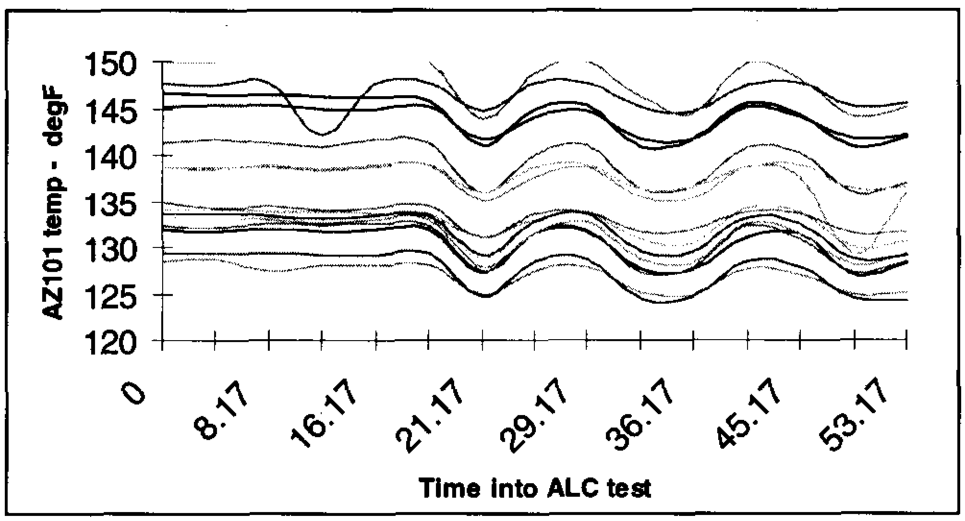

Figure A-9. ALCT data from 241-AZ-101: November 1999 ALC test.

[2] Tardiff, G, "241-AZ-101 Air Lift Circulator Functional Test Report", RPP Internal Memorandum, DRAFT, (December 28, 1999).

Although there is a potential of 83 thermocouples in the tank, most are distributed at or near the bottom of the tank, with a poor vertical distribution. This lack of sufficient thermocouple data makes it necessary to couple the available thermocouple data with the thermal hydraulic analysis of the tank to provide a reasonable estimate of the volume of sludge that can be mobilized and retrieved. The thermocouple data combined with the thermal hydraulic analysis will also be utilized to determine the growth of the non-convective sludge layer when the mixer pumps are turned off. It is anticipated that the resettlement of retrieved solids will increase the sludge volume (through "fluffing") and hence increase peak sludge temperatures.

Sludge mobilization will be estimated through the volume of undisturbed sludge and the concentration of solids with heat sources in the mixed waste. If the volume of sludge retrieved is available from other instruments, then it will be utilized to confirm through the measured thermocouple data and thermal analysis. If it is necessary to use the thermocouple data to estimate the sludge volume that could be retrieved, an iterative procedure will be required between sludge volume estimation and the thermal analysis. In order to perform these calculations, the thermal analysis includes the following steps:

- Collect and monitor waste, insulating concrete and ventilation flow temperature data before, during and after the mixer pump test. The data before the test includes for the year 1999 to understand and evaluate the temperature variations due to changes in ambient temperature conditions. This will provide information to baseline the model predictions as well as provide data to compare for the effects of waste retrieval with mixer pumps operation.
- Thermal Hydraulic Analysis using the current operating conditions of 702-AZ ventilation system and the above temperature data to baseline the Thermal Model.
- Estimation of volume of wastes mobilized and a calculation of the ECR based on the temperature data and data from other instruments, as applicable.

The data from the ALCT and ST arrays are likely to have comparable characteristics, and can likely be used together. The data from the TBT array and CT thermocouples are expected to be different from the ALCT and ST data in that their temporal response will be poorer due to the thermal time constant of the associated tank structure. The data from the five PTA arrays will likely be different altogether, since these thermocouples are located within a dry well.

The use of the thermocouple data in the AZ-101 MPT to monitor the waste temperatures represents a low technical risk to the project in terms of not obtaining the desired information since these sensors are currently in place and their functionality has been verified. The use of the thermocouple data for estimating the ECR or the volume of sludge that has been mobilized and available for retrieval represents a greater technical risk to the project of not obtaining the desired information. This is because the evolution from the current well-settled state to the maximally mobilized state is comprised of a series of pump runs at various azimuths and durations, rather than an orderly and more-easily-modeled run-stop scenario. Thus, the mobilization itself is likely to be difficult to model from the thermocouple data alone.

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