TASK 11 FY09 YEAR END TECHNICAL REPORT
In-Tank Solids Monitor Development

EXECUTIVE SUMMARY

The U.S. DOE Hanford site has a need for remote monitors that can improve monitoring processes during HLW retrieval, separation and processing. These remote monitor technologies must help improve operational efficiencies and provide accurate information on the waste characteristics. As part of FIU's research efforts, the development of technologies to improve sensing of HLW has been an on-going effort for several years. This performance period, FIU began the design of an in-tank solids monitor (ITSM). This report highlights the results from this effort.

As part of improving efficiency for HLW waste transfer processes, accurate and precise measurement of the undissolved particulate concentration in a two-phase liquid-solid slurry is extremely important. The undissolved particulate concentration is the single most important parameter that determines plugging potential during slurry transport. Successful slurry transport is crucial for the disposition of millions of gallons of HLW at the DOE sites. During FY09, FIU designed, fabricated and tested a real-time particulate concentration monitor that uses two Coriolis flow meters and a crossflow filter. The in-tank solids monitor is capable of providing real-time measurement of particulate concentrations in liquid-solid slurries, despite dynamic disturbances during waste retrieval from tanks at the Hanford site. The ITSM design focused on providing a monitor that could be deployed through an eight-inch riser pipe on a Hanford HLW tank. This system will be ready for cold testing at Hanford within FY10.

INTRODUCTION

The U.S. DOE Hanford site has the largest number of HLW storage tanks and the largest volume of HLW in the United States. The safe storage, retrieval, treatment and disposal of approximately 53 million gallons of highly toxic, high-level radioactive waste stored in Hanford's 177 underground tanks is a priority. Retrieval and treatment of waste from these tanks pose a considerable challenge.

During retrieval of waste over the years, there have been several transfer pipelines that have been plugged. Costs exceeding $3M dollars have been generated to deal with issues related to the plugged line and to install a single, new pipeline section next to the plugged line. It is critical to continuously monitor the weight-percent solids in the pipeline to ensure that pipeline pressures and flow can maintain slurries above their critical velocities. This monitoring can mitigate the potential for pipeline plugging by providing operators with real-time measurements on weight-percent solids, allowing them to adjust transfer parameters as needed.

Presently, all weight percent estimates are performed via laboratory analysis of samples taken from a tank, or via an in-line, commercially-available ultrasonic sensor for weight percent measurement in real-time. The laboratory use is a costly process that requires transfer delays while samples are analyzed. The commercial technology suffers from inaccurate measurements; the inability of the ultrasonic unit to completely penetrate some slurries (dependant on slurry composition) results in inaccuracies of the weight percent measurement.

Hanford site personnel have identified the need for a more accurate measurement system. FIU determined that an ITSM system could be designed, and would provide more accurate real-time results than attainable with the existing technologies. FIU worked on the system design and fabrication during FY09, with an expected cold-test at the Hanford site in FY10.

EXPERIMENTAL

Design

System Requirements

During the preparation of HLW slurry for retrieval, measurement of the density and weight percent solids is crucial to verify sufficient mixing. The data determines uniform slurry within the tank, is used to calculate the slurry effectiveness and determines the rheological properties that impact the waste transfer. In order for an alternative system to be useful, the measurements must match the accuracy of a lab scale system, while providing the data in real-time to retrieval operators. In order to achieve these goals, the system design requirements were discussed between site and FIU engineers. The list of requirements is as follows:

- The sampling device shall be inserted into the sludge tank through one of the existing 8-in (203 mm) inspection ports available on the tank.
- The system must be positioned at various elevations in the tank.
- The system controls and data collection should be performed via remote methods.
- Minimum slurry flow rate of 6 feet per second (1.83 m/sec) is necessary to assure flow without segregation.
- Filtrate flow rate must be maintained above 0.5 feet per second (0.15 m/sec).
- The system must be capable of measuring the weight percent solids in a slurry range of 2-18 weight percent solids.
- Operational temperature range should be 10 – 85°C (50 – 185°F).
- Storage temperature for all equipment up to 250°F.
- Continuously monitor a waste slurry within the following fluid parameters:

Table 1. Slurry Parameters

Parameter	Value	Unit	Source
Particle Size	0.7-700	um	RPP-5346, (Julyk, 2002)
Viscosity	1.0-5.0	cP	RPP-5346, (Julyk, 2002)/Site Communication
Percent Solids	≤10	vol%	RPP-5346, (Julyk, 2002)
Temperature	50-185	F	HNF - SD-WM-TSR-006 (Cash, 2000)/Site Communication
Specific Gravity	1.0-2.0	-	RPP-5346, (Julyk, 2002)/ Site Communication
pH	≥9	-	Site Communication
Gamma Radiation	1000	R/hr	WHC-SD-W236A-ES-003, (W.C. Carlos, 1994)
Critical Velocity	6	ft/s	RPP-5346, (Julyk, 2002)

These technical & functional requirements were used in the design of a dual-Coriolis based in-tank solids monitor.

System Description

The ITSM was designed to accomplish slurry weight percent monitoring in real-time, with improved reliability and accuracy over current technologies and methods. The ITSM measures the slurry and liquid content density by pumping the tank slurry through a sampling loop. With the two measurements and the known undissolved solids density, the solid weight percent can be calculated using the following equation:

$$Wt\% = 100 \times \frac{\rho_s(\rho_{sl} - \rho_f)}{\rho_{sl}(\rho_s - \rho_f)} \tag{1}$$

where

$Wt\%$ = Weight percent of undissolved solids in the slurry

ρ_s = Density of the dried undissolved solids

ρ_{sl} = Density of the slurry

ρ_f = Density of the filtrate

The sampling loop (Figure 1) consists of a pump, two Coriolis meters, a cross-flow filter and a flow control valve. The operating principle behind the Coriolis meter is that a fluid entering a vibrating tube will accelerate/decelerate as it reaches/leaves the central point of the tube. The force applied as a result of the acceleration causes a deflection, or twist, that is directly proportional to the mass flow (Webster, 1999). These meters are known for their improved accuracy and the ability to handle corrosive and highly abrasive slurries. The HLW slurry is pumped from the tank by the pump (PCP-1) through the first Coriolis meter (FM-1) where the slurry's density, mass flow, viscosity and temperature is measured. The slurry then flows through the cross-flow filter (F-1), which separates a portion of the carrier fluid from the slurry. This allows a density measurement of the carrier fluid, or filtrate, by the second Coriolis meter (FM-2). The valve (V-1) regulates the flows by slightly restricting the slurry flow.

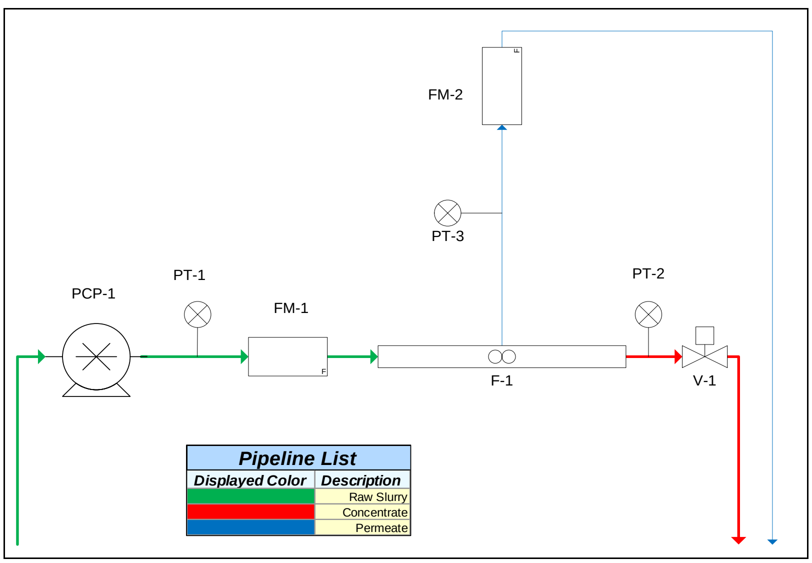

Figure 1. Dual-Coriolis flow loop.

Slurry pump and drive

A positive displacement pump (PCP-1) with associated drive motor drives the slurry into the sampling loop. This pump is custom-built to fit within the pod and drive the slurry without causing segregation. The pump selected is a Netzsch® progressive cavity type pump with double mechanical seals, (model # NM021BY01L06F) which is coupled to a NORD® ½ horsepower helical gear motor (model # SK172F 71L/4). The pump is designed to provide a flow rate of 3 gallons per minute at a 30 PSI head. This flow rate will maintain the minimum flow velocity within the system above the critical velocity for the slurry and the filtrate. The pump is coupled to a ½ horsepower 3-phase AC motor with a reduction gearbox that rotates the pump at 256 revolutions per minute. The motor is controlled through a variable frequency drive (VFD) located in the control center.

Coriolis meters

Two Coriolis mass flow sensors are incorporated into the design: one measures the composite slurry, and another measures the filtrate after separation. Flow meter 1 (FM-1) is where the flow rate, density and temperature of the bulk slurry is measured. The unit selected is an Endress+Hauser® Promass Coriolis meter with ½" ports (model # 83F15-ACVSAAADBAAQ) it can measure the density to an accuracy of ±0.0005 g/cc. Flow meter 2 (FM-2) is a smaller Endress+Hauser® Promass Coriolis meter with 3/8" ports (model # 83F08-ACVSAAADBAAQ) that is used to measure the flow rate, density and temperature of the carrier fluid, or filtrate. Both of these meters communicate sample measurements as well as meter system status through a Modbus (RS-485).

Cross-flow filter

To extract a sample of the carrier fluid of the slurry, a cross-flow filter (F-1) is used. This filter configuration removes liquid from the slurry stream with minimal pressure drop along the slurry line. In addition, the design of the cross flow filter allows for self cleaning such that as the particles flow within the main stream, they collide with the particles that are being deposited on the filter membrane and release them. The filter is where a portion of the transport fluid (filtrate) is removed from the slurry. The filter selected is a Mott cross-flow filter (model # 7610450-005). It has a 0.5 micron sintered metal filter media that is 24" long with an inner diameter of ½" and a media thickness of 0.0625".

Flow control valve

In order to maintain the filtrate flow rate from the filter above 0.5 ft/s, enough back pressure must be generated inside the filter. This is accomplished by the flow control valve (V-1). The valve selected for this application is an electronically actuated ball valve. The valve selected is a ½ in full port ball valve by Assured Automation (model # C26NRXN), which is coupled to an electronic actuator (model # EV1S1V1-V92) with a NEMA 4 rated enclosure.

The entire above mentioned sampling loop components are housed within a "sampling pod" that is lowered into the waste tank via a deployment platform. The entire sampling process is automated and can be initiated remotely via a computer program on the same data network. The details of the sampling pod, deployment platform and control system that make up the ITSM are detailed in the sections below.

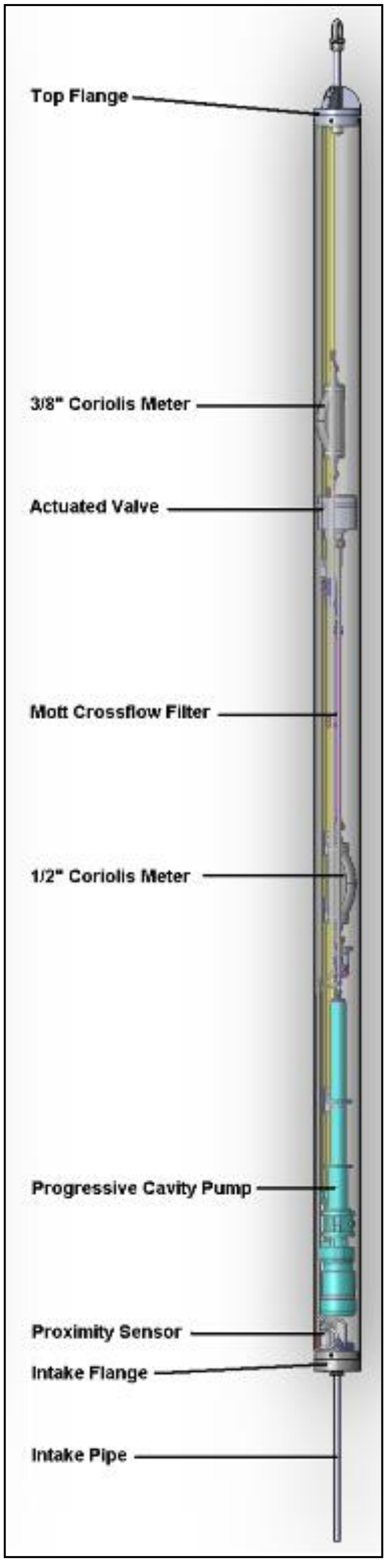

Figure 2. Sampling pod.

Sampling pod

In order to perform the solids weight percent measurement, the sampling loop must be lowered to varying depths in the HLW tank. This is accomplished by having all of the functional components housed in a pod (**Figure 2**). The functions of this pod are to provide:

- Isolation to reduce equipment exposure to the environment within the tanks
- Containment to prevent equipment from being damaged as it is deployed
- Support and rigidity for the internal equipment and process loop

Housing

The housing forms the containment for the fluid handling and instrumentation components of the ITSM. The housing is sized to allow entry through a tank inspection port of 8 in, schedule 40 pipe (203 mm), and it contains one inlet probe and two slurry/filtrate drain ports at the bottom end. Housing specifications are:

- Stainless steel tube body, 6.625 in. (168.3 mm) O.D.; 6.065 in. (154 mm) I.D.
- Housing length is 15 ft (4.57 m).
- Upper concentric port for power/control/instrument cable bundle (umbilical) as well as coupling to the deployment platform.
- Intake probe for sampling.
- Exposed capacitive proximity sensor for detection of liquid immersion.

Intake Probe

The intake probe is an external extension of the sampling loop that allows slurry sampling at various depths without the need to submerge the ITSM pod into the slurry. It has an inside diameter consistent with the sampling loop to maintain the minimum flow velocity, and it is durable enough to survive minor mishandling and contact with the tank or other structures. Probe specifications are:

- Basic construction is of stainless steel 0.5 in, schedule 80 pipe with an internal diameter of 0.546-in (14 mm) and an outer diameter of 0.84 in (21.34 mm).
- Nominal overall length extending out of the sampling pod is 42 in (1.07 m) to ensure that it will operate within the desired operating temperatures. If the selected tank environment is known to be within a narrower temperature range (lower in the scale), this probe can be replaced with a longer version, according to the graph in Figure 3 (based on NPSHa calculations).
- Multiple (3 nominally @ 0.19 in. (4.8 mm dia.)) cross-drilled entrances provide transverse sampling immediately above a welded plug at the extreme end of the tube.

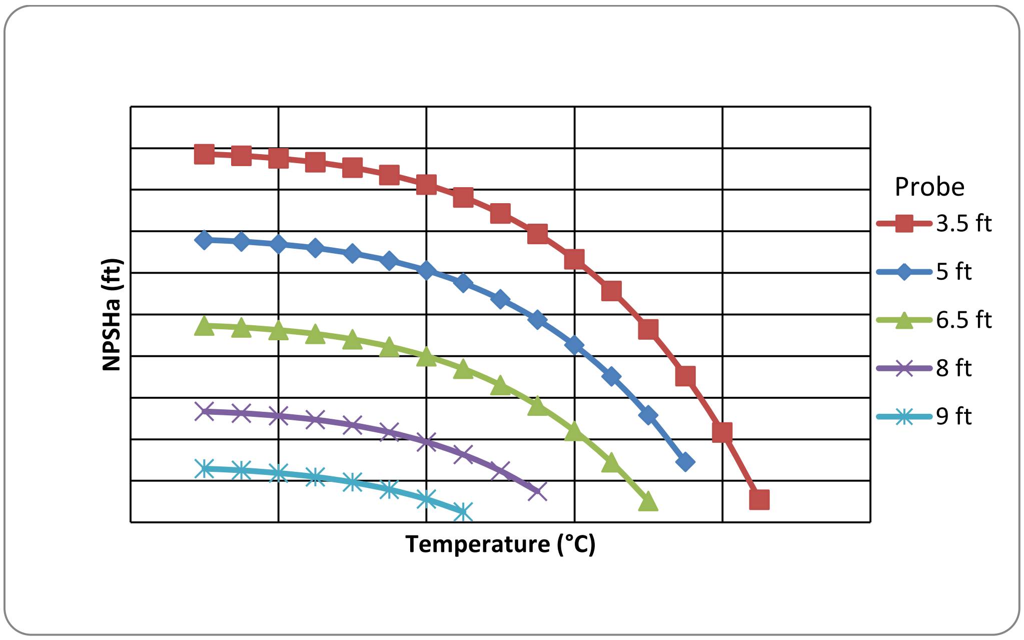

Figure 3. NPSHa vs. Temperature for various probe lengths.

Other ancillary components procured include pressure transducers, proximity sensor and all the process connections. Pressure transducers (PT-1, 2, 3) are located throughout the system and are used to monitor if the system is operating properly. The proximity sensor is located on the bottom of the pod and will indicate when the ITSM has reached the proper level within the fluid. The process connections are Parker CPI® compression fittings whose wetted parts are made of 316SS and the nuts are coated with molybdenum sulfate.

Deployment Platform

The deployment platform for the sampling pod has several requirements: sustain the pod weight while in the tank environment, remove any potential for contamination from tank waste to outside environment, control the depth of the sampling pod and support it in a retracted position within the tank riser. Specifically, the mechanism for strata adjustment of the pod by an adjustable distance into the slurry pool requires tank-specific information such as neighboring equipment, height requirements, slurry level, etc. Without a specific tank selected for deployment, the general requirements yielded the following basic conceptual design (Figure 4). The design is characterized by the use of a winch for positioning the ITSM and a gantry as a framed support to reduce applied loads onto the riser during operation. In addition, this design utilizes a flexible containment membrane to isolate both the deployment mechanism and the ITSM from exposure to the atmosphere. The system is relatively inexpensive due the low cost of materials and allows for more site-adaptability when deployed. The main components of this concept are the containment membrane, gantry and winch. As a preventative measure, there is a mechanical locking mechanism to secure the pod within the riser.

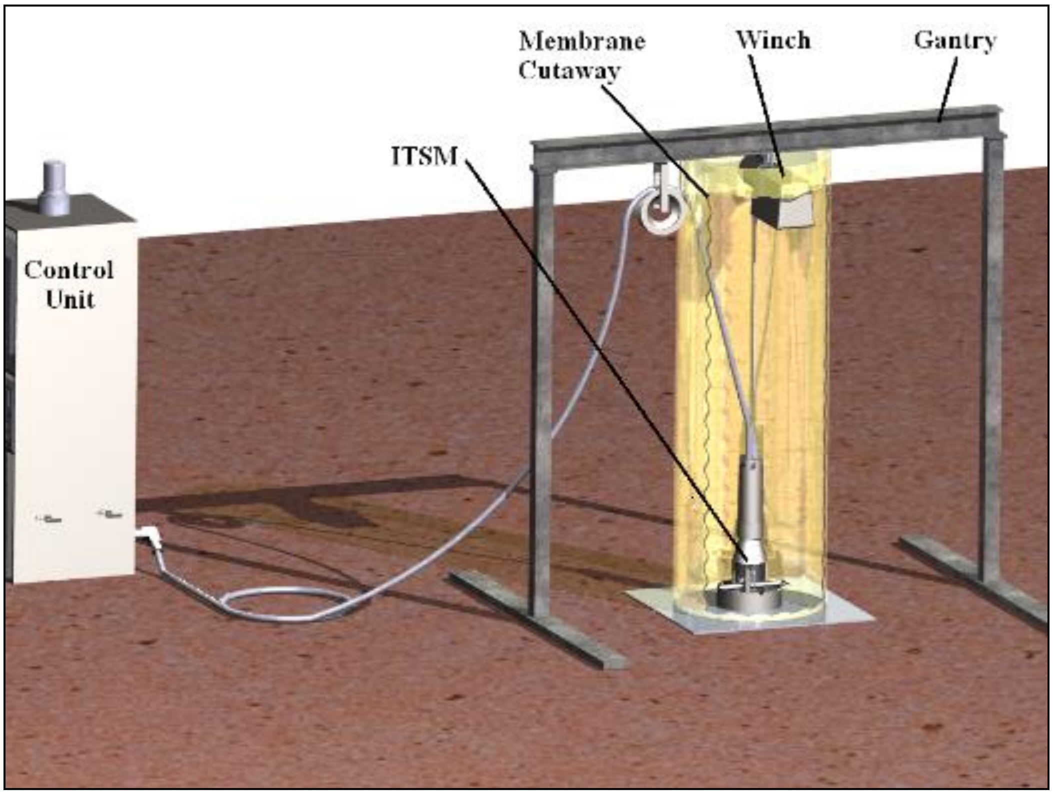

Figure 4. Deployment platform.

Locking Mechanism

The locking mechanism is one of the most critical components of the deployment platform. It is located on top of the tank riser and is used to secure the pod in the retracted/stored position in the tank riser. Figure 5 shows a rendering of the ITSM locking mechanism with the pod attached. The mechanism shown in **Error! Reference source not found.** is comprised of two 2 in thick steel jaws that each pivot on a 1 in diameter shaft. The jaws are free to move up but lock against each other when lowered. This design allows the pod to self lock; when fully retracted a linear actuator is utilized to release jaws so that the pod can be deployed. Even though the ITSM weighs just over 1000 lbs., the locking mechanism is designed to have a capacity of 4000 lbs.

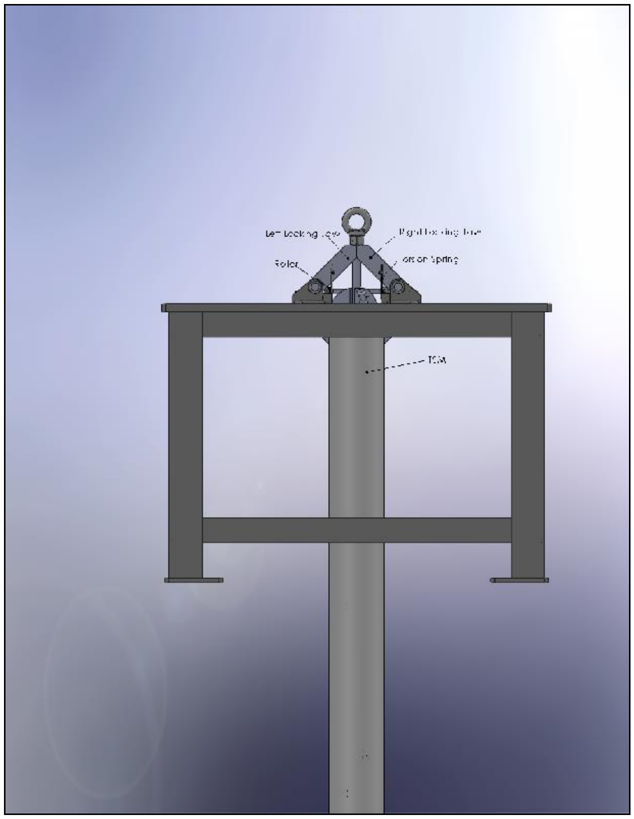

Figure 5. Locking mechanism.

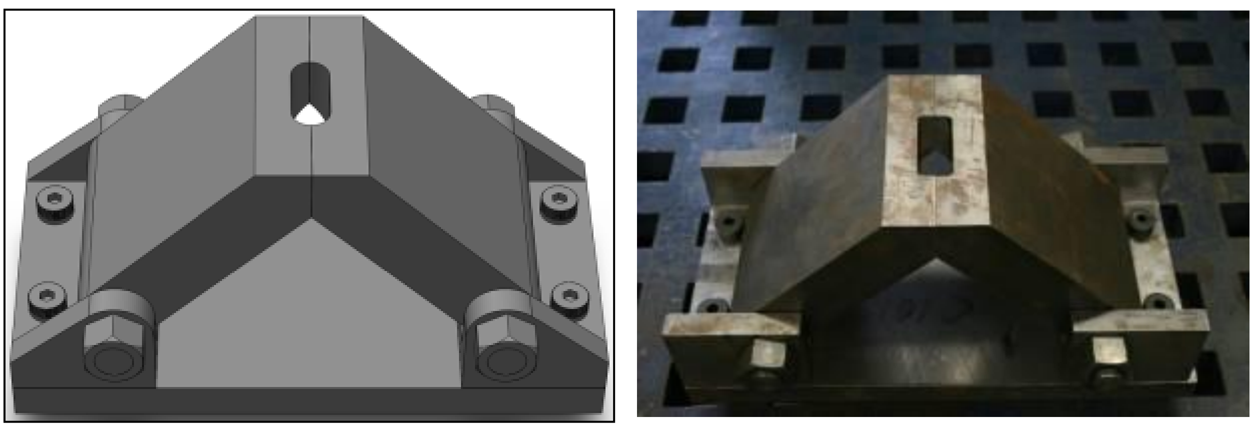

Figure 6. Locking mechanism jaws.

System control and interface

In order for the system to be deployed in a HLW tank, all control, communication and data acquisition must be performed remotely, and system operation must be fully automated. In order to implement the required functionality with the deployment constraints, the control sub-system was designed using a controller and scheme that allows for PLC-like functionality, while providing remote operation/web server capabilities. The ITSM control sub-system major components are highlighted in Figure 7 below.

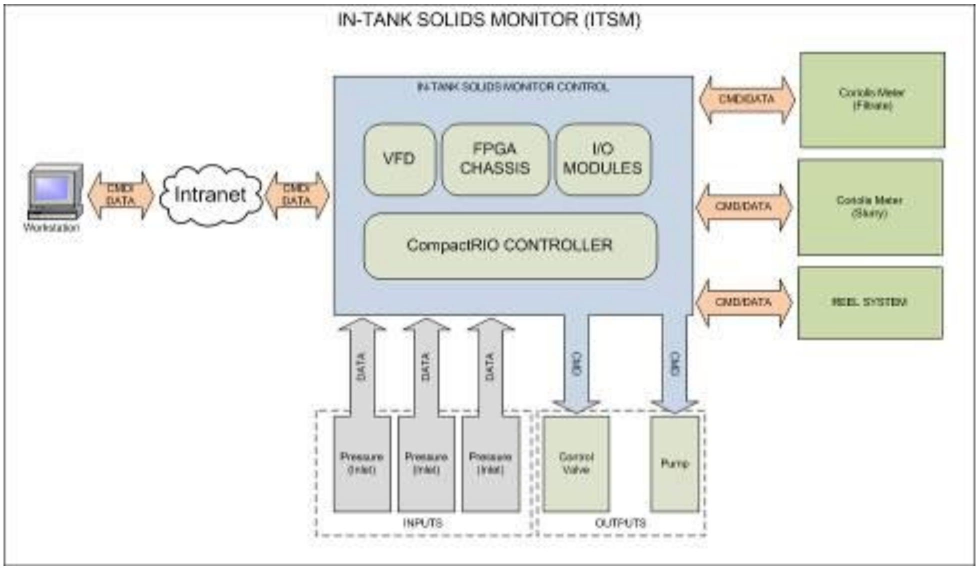

Figure 7. ITSM Control sub-system components and data flow.

The sub-system consists of three pressure inputs, providing data to determine optimal pump operation, assess over/under pressure faults and determine the amount of crossflow filter plugging. Several outputs control the flow pattern of the system; pump and control valves limit slurry flow to ensure the appropriate residence time between slurry and sampling calculation, while maintaining the slurry above the defined critical velocity. The Coriolis meters provide the temperature, mass flow and density data, which are used to calculate the weight-percent solids. This data is also used for calculating flow velocity, which allows for verification of system functions and helps determine any errors in operation. They are controlled via a RS-485 port using Modbus. The reel/winch system for deployment is controlled by driving the motor drive control, with feedback from quadrature encoders for position. The system control is a CompactRIO from National Instruments (NI) of Austin, TX. This unit consists of a controller running a Vxworks real-time operating system (RTOS). The controller is coupled to a chassis that includes a Xilinx Virtex-5 FPGA and allows up to 8 I/O modules to be attached to the system. A variable-frequency drive (VFD) is used to control pump operation via an RS-485 using Modbus. Communication between the user/operator is done using TCP/IP protocol via the local tank farms intranet. This will avoid any outside user from accessing the system. In addition, the user will have to provide credentials to access system controls/data.

In order to automate the ITSM process, the system is implemented as a state machine with several low-level control processes, or “thread,” handling IO and analysis. The system state diagram is provided in the figure below. The default state is labeled “IDLE;” this state awaits user input for transition, while allowing high-level controller maintenance “threads” to run. The web and variable engine servers are running continuously on the system. A data log can be accessed by a user with appropriate credentials at any time. When the “START” command is sent to the controller, the system will transition into the “SAMPLE” state; this high-level nested loop has two sub-states (not shown): “SAMPLE HERE” and “RE-POSITION.” The sub-state “SAMPLE-HERE” controls the PID loop that handles pump and valve control depending on calculated critical velocity, while calculating and logging the Coriolis meter parameters at 1 s intervals. The sub-state “RE-POSITION” controls the pod position by controlling the reel system. Both of these sub-states have pre-defined parameters that cannot be adjusted without recompiling FPGA code. Finally, the “SELF-TEST” state runs through several low-level troubleshooting functions to assess system health; if an error above a pre-defined value occurs during the “SAMPLE” state, the system will transition into the “SELF-TEST” state for error-checking. A self-test log will be available to the user, and notification of a system error will display on the user front panel.

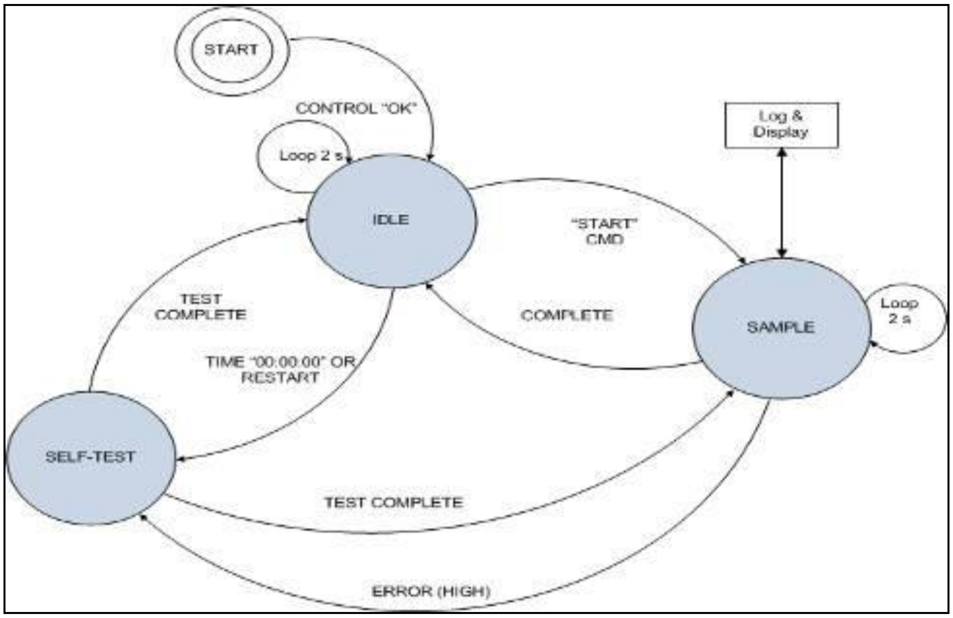

Figure 8. ITSM High-level control state diagram.

The control system will be located outside the pod in a remote panel accessible for setup, troubleshooting and decommissioning. All cabling between the system and remote panel will be included in an umbilical bundle that will be guided via the reel/winch. The bundle will provide power and communication between components and the control sub-system. All cabling voltage drops and overcurrent protection to components will be in accordance with National Electric Code (NEC) guidelines (as applicable). All cabling will provide adequate shielding to limit cross-talk and RFI/EMI effects.

Fabrication

Upon completion of design, fabrication commenced. Figure 9 shows the stainless steel top flange with the alignment fins, which center the pod within the riser during retraction along with the port where the lifting eye nut is attached.

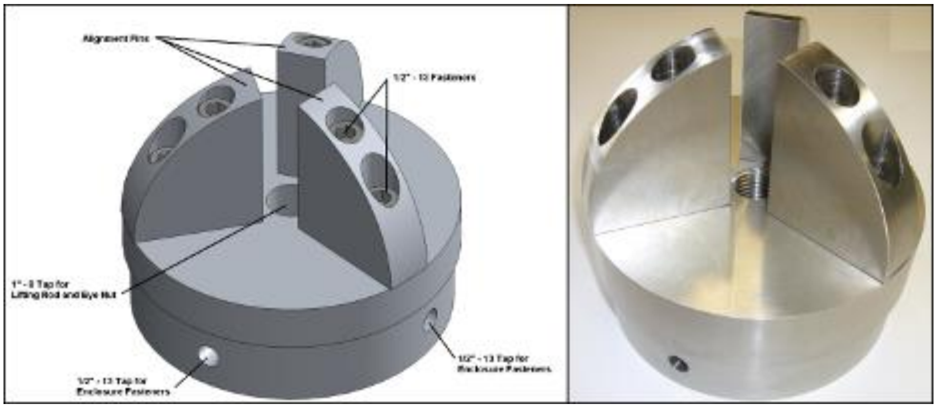

Figure 9. Top flange.

Figure 10 shows the stainless steel bottom flange with ports for the proximity sensor, intake probe and two discharge ports.

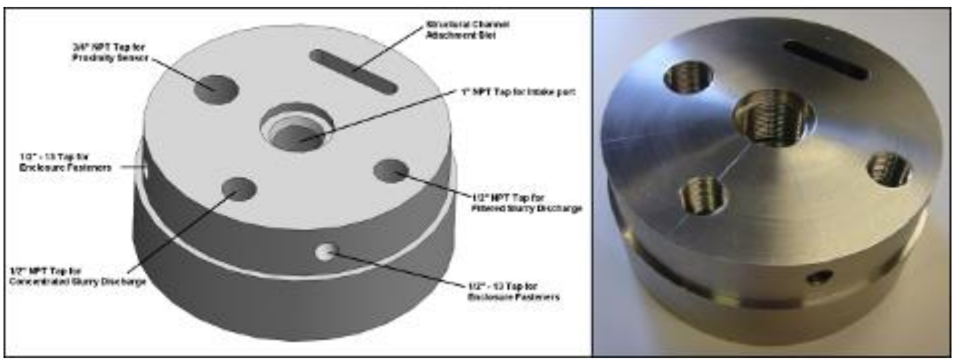

Figure 10. Bottom flange.

Figure 11 shows a subassembly comprised of both Coriolis meters, the control valve and the pressure transducers.

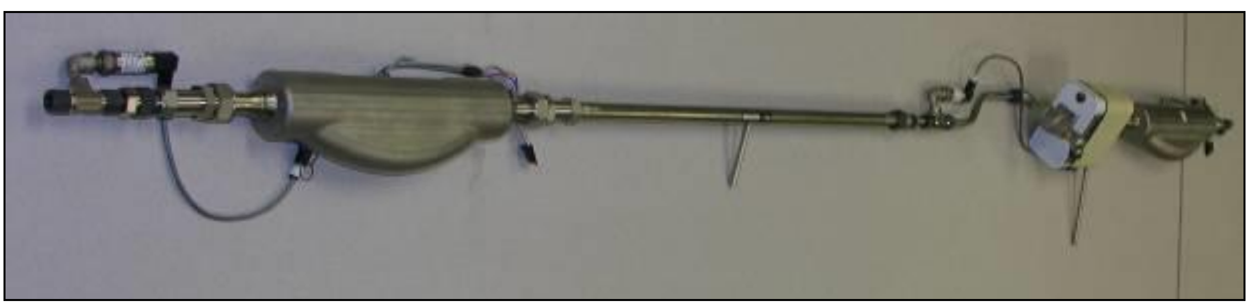

Figure 11. Subassembly of major components.

The ITSM control panel shown in Figure 12 houses the pump motor speed controller, both Coriolis meter control boards, along with all the control relays for the ancillary systems. **Error! Reference source not found.** shows the ITSM pod in the open configuration, and **Error! Reference source not found.** shows the top and bottom of the fully assembled pod.

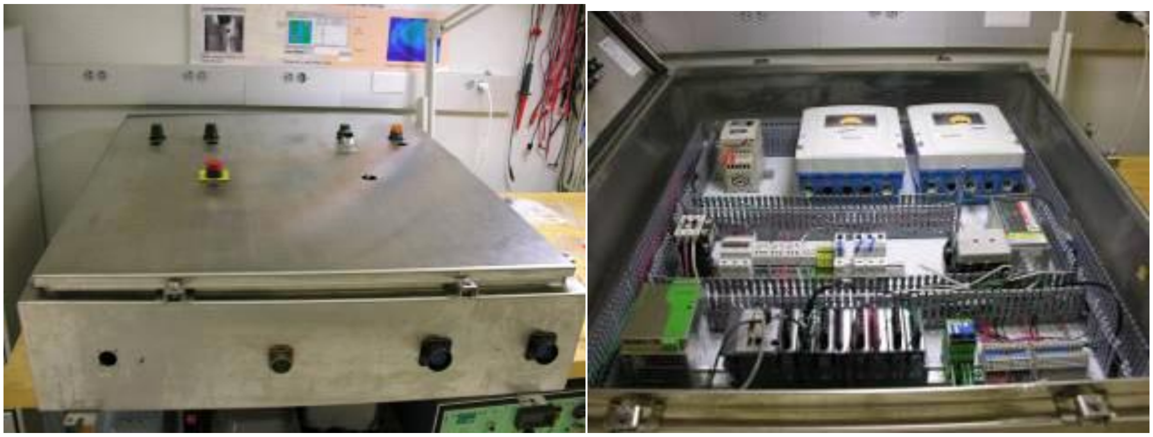

Figure 12. ITSM control panel.

Figure 13. Open ITSM pod showing the pump and first Coriolis meter.

Figure 14. Top and bottom of the closed pod.

Testing

Verification test program aimed to verify that the ITSM was capable of operating in accordance with the specified requirements. The ITSM was operated under various conditions that it may encounter within the Hanford HLW tanks and where probability for faults is highest. In order to verify the performance of the ITSM system, a small-scale tank environment was simulated, with waste conditions expected and fault-testing of components and procedures. The test program concentrated on parametric testing which included procedures, equipment accuracy and repeatability. Deployment tests were not conducted since the deployment system design and procedures are tank specific. At the time this document was written, no Hanford HLW tank where the ITSM could be deployed had been identified. The test program focused on collecting data provided in the sections below.

The ITSM testing required that the system to be suspended as it would during full-scale operations. Due to the height of the system this required that the system be suspended at 18 ft above ground level. A telescoping boom forklift was utilized for this (Figure 15). In addition to providing adequate suspension, the issue of equipment accuracy dictated that a test matrix of various simulated slurries was prepared. Since the main focus was the measurement of percent solids, this was the main variable in which the concentrations were altered. The other variable that was changed is the viscosity of the slurry. The pH of the slurry did not affect the readings from the Coriolis meter; however, it was maintained high (>9) for equipment testing and environment simulation.

Figure 15. ITSM supported by a forklift.

Two sets of parameter testing were conducted using steady state slurry and unsteady state slurry test matrices.

Steady State Slurry: To conduct tests for in-tank monitoring of weight percent suspended solids and under conditions anticipated in the real HLW tank.

Table 2 describes the parameters of the slurry that was used for testing.

Table 2. Slurry Test Matrix

Set Parameter	Details
Carrier Fluid Composition	$NaNO_3$ – Water Solution to achieve the required density. NaOH will be added to raise pH to >9
Undissolved Solids	Glass Beads (53 micron particle size)
Density of Carrier Fluid	1.25 g/cc
Weight Percent of Undissolved Solids	1%, 5%, 10%, 15%, 18%
Temperature of Slurry	40°C

Unsteady State Slurry Test Matrix: To study the dynamic response to changes in solid weight-percent and carrier fluid density changes by imposing a step change in weight percent solids and density of carrier fluid, respectively.

The imposed step change in weight percent solids was from 5% (Slurry 1) to 15% (Slurry 2). This is detailed in Table 3. The system was allowed to achieve a steady state with Slurry 1. Then a step change was achieved by adding more solids to the slurry at a certain recorded time in order to achieve Slurry 2. All time-varying data was recorded until the ITSM reached this new steady state.

Table 3. Slurry Compositions for the Step Change in Solid Weight Percent

Set Parameter	Details
Slurry 1	
Carrier Fluid Composition	$NaNO_3$ – Water Solution to achieve the required density. NaOH will be added to raise pH to >9
Undissolved Solids	Glass Beads (53 micron particle size)
Density of Carrier Fluid	1.25 g/cc
Weight Percent of Undissolved Solids	5%
Temperature of Slurry	40°C
Slurry 2	
Carrier Fluid Composition	$NaNO_3$ – Water Solution to achieve the required density. NaOH will be added to raise pH to >9
Undissolved Solids	Glass Beads (53 micron particle size)
Density of Carrier Fluid	1.25 g/cc
Weight Percent of Undissolved Solids	15%
Temperature of Slurry	40°C

The imposed step change in carrier fluid density solids was from 1.25 g/cc (Slurry 2) to 1.20 g/cc (Slurry 3). This is detailed in Table 4. The system was allowed to achieve a steady state with Slurry 2. Then a step change was achieved by adding water to the slurry at a certain recorded time in order to achieve Slurry 3. All time-varying data was recorded until the ITSM reaches this new steady state.

Table 4. Slurry Compositions for the Step Change in Carrier Fluid Density

Set Parameter	Details
Slurry 3	
Carrier Fluid Composition	$NaNO_3$ – Water Solution to achieve the required density. NaOH will be added to raise pH to >9
Undissolved Solids	Glass Beads (53 micron particle size)
Density of Carrier Fluid	1.20 g/cc
Weight Percent of Undissolved Solids	~12 % (This is not a set value – this value results from the effect of dilution and is not controlled)
Temperature of Slurry	40°C

Incorporating the simulated slurry with the suspended ITSM dictated that a container (Figure 16) capable of withstanding the high temperatures as well as the high pH had to be used. In addition, all the necessary spill containment equipment was also utilized in accordance with health and safety procedures. Since the test requires that the solids be suspended, agitators were integrated into the container design.

Figure 16. 30-gallon test vessel with sodium nitrate and glass beads.

During the testing it became apparent that the cross flow filter was becoming clogged. To resolve this issue, a reverse pulsing system comprised of an electronically controlled three-way valve and an air compressor was integrated into the ITSM downstream of the second Coriolis meter. Figure 17 shows the valve, which is activated for a 100 millisecond duration pulse when the controller detects that filtrate flow has dropped below a preset value. This forces a portion of the filtrate back through the filter and thus cleaning the filter media.

Figure 17. Reverse pulsing valve and air line (blue hose).

RESULTS

Steady State Slurry

Steady state slurry experiments were conducted on 15 gallons of slurry in a 30 gallon container consisting of a mixture of sodium nitrate ($NaNO_3$) and water. 720, 3020, 4160, 4640 and 3040 grams of glass beads with an average particle size of 53 micron were added to create ratios of 1, 5, 10, 15 and 18 weight percent solids, respectively. Figure 18 shows the raw data results for the steady state slurry. The spikes in the data are due to micro bubbles in the filtrate stream that are a result of the pressure drop across the filter. Figure 19 shows the modified weight percent data using a 10 second moving average; this is the reading that is displayed on the user interface. To eliminate error due to incomplete mixing of the test vessel, grab samples were taken at the same location as the inlet of the ITSM's pickup tube. A peristaltic pump attached the black hose in Figure 20 was used to take the grab sample.

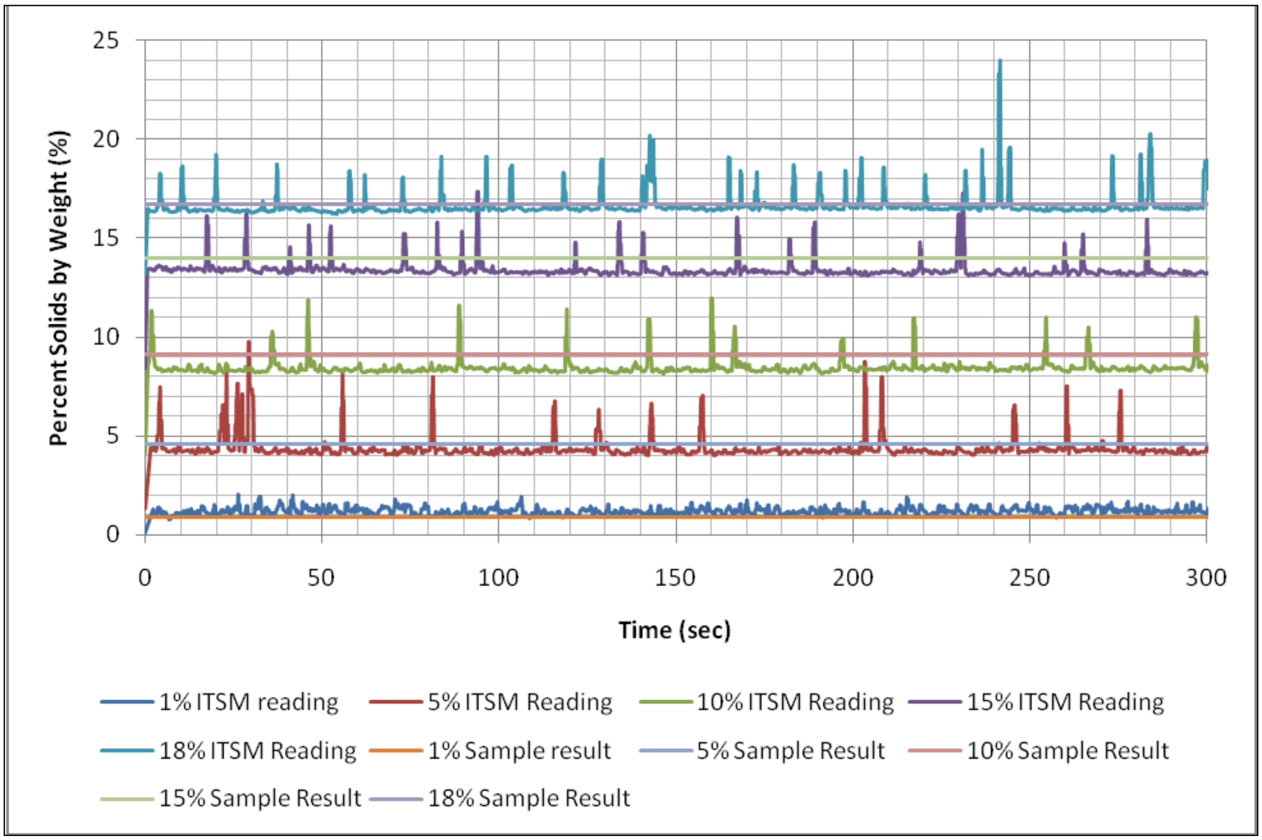

Figure 18. Steady state slurry raw data results.

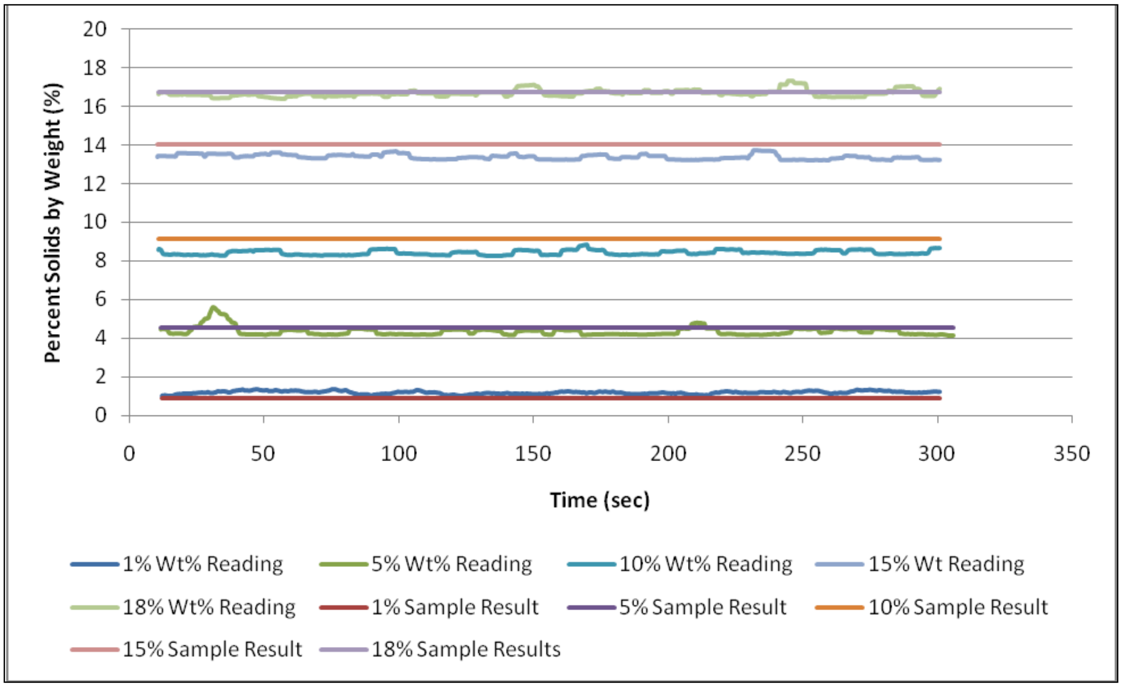

Figure 19. Steady state slurry modified results.

Figure 20. Grab sample hose.

In order to determine the accuracy of the ITSM, the ITSM readings were compared to the laboratory analysis of the grab samples. Table 5 shows the average ITSM weight percent reading compared to the measured weight percent of the grab sample for each of the five experiments. The variation between the ITSM reading and the measured value grab sample ranged between 0.05% - 0.71%.

Table 5. ITSM and Grab Sample Results Comparison

Beaker #	Wt of Beaker (g)	Wt of beaker + Slurry (g)	Wt of Slurry (g)	Vol of Slurry (mL)	Wt of Filter Paper (g)	Wt of Filter + Glass (g)	Wt of Sample	Wt% of Sample	ITSM Avg WT% Reading	Variation
11	53	136	*83*	73	0.3253	1.0796	0.7543	***0.908795***	***1.19112***	0.282325
12	55	143	*88*	78	0.3791	4.4049	4.0258	***4.574773***	***4.371452***	-0.20332
13	49	132	*83*	70	0.3723	7.9602	7.5879	***9.142048***	***8.434451***	-0.7076
14	53	143	*90*	73	0.3815	12.9785	12.597	***13.99667***	***13.36713***	-0.62954
15	49	138	*89*	70	0.3758	15.2581	14.8823	***16.72169***	***16.67048***	-0.05121

Unsteady State Slurry

In order to determine the dynamic response time of the ITSM to changes in solid weight-percent and carrier fluid density changes, additional experiments were conducted on unsteady state slurry. These experiments involved imposing a step changes to the weight-percent solids as well as the density of the carrier fluid. The slurry consisted of a 15 gallon mixture of sodium nitrate ($NaNO_3$), water and glass beads. The slurry had an initial weight percent solids concentration of 5% solids. The readings were allowed to stabilize for 5 minutes before 8.8 kg of glass beads were added to increase the slurry's weight percent solids concentration to 15% solids. The readings were allowed to stabilize for another 5 minutes before 3 gallons of water was added to reduce the percent solids concentration to approximately 12.4% solids. The findings of the unsteady state slurry are presented graphically in Figure 21. After analyzing the results, it clear that the ITSM has an average response lag of 30 seconds. This is due to the time required by the filtrate to pass through the filtrate loop including the filtrate Coriolis meter.

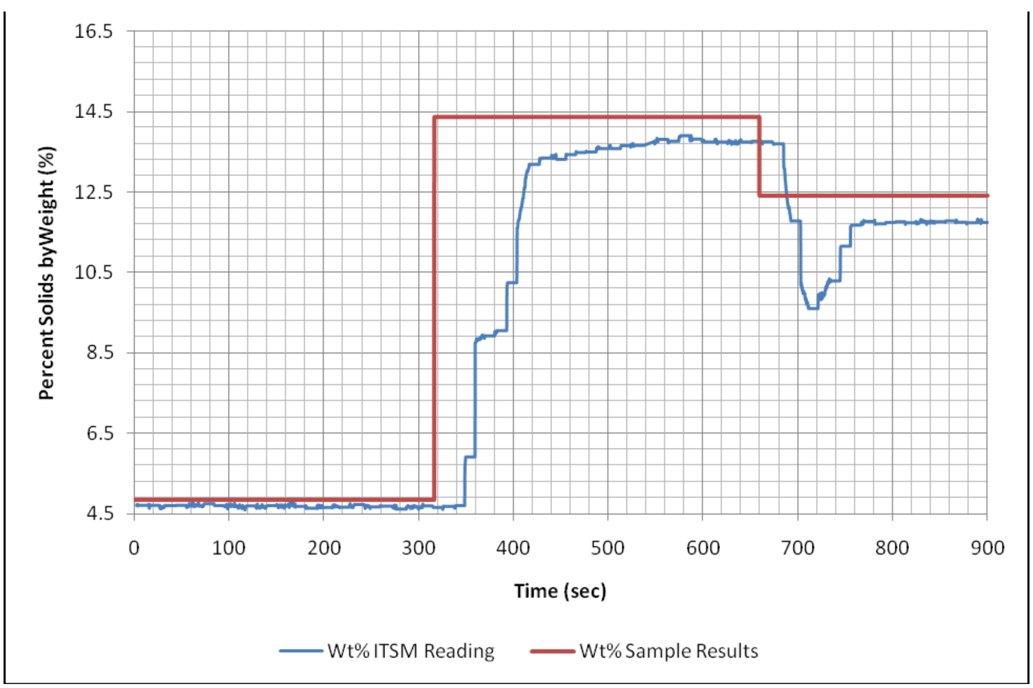

Figure 21. Unsteady slurry results.

OVERALL PROJECT CONCLUSIONS

An in-tank solids monitor system has been designed, fabricated and tested at FIU. The system is capable of deployment through an existing 8 inch tank inspection port, can be positioned at various elevations within the tank, can withstand operating temperatures up to 85^{o}C and is remotely controlled. The verification tests demonstrated that the system is capable of providing accurate weight percent solids concentration measurements of slurry with the same rheological properties as the slurry found in the Hanford HLW tanks. During the tests the ITSM provided accurate measurements that ranged between 0.05% - 0.71% of the actual weight percent solids of the slurry. The system also demonstrated it was capable of detecting changes in the slurry concentration within 30 seconds. Upon identification of a HLW tank at Hanford to deploy the ITSM, a deployment system will be designed and fabricated.