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Cold Test Loop Integrated Test Loop Results

September 2003

Prepared by

T. J. Abraham
The Providence Group Applied Technologies, Inc.

J. F. Walker, Jr.
Oak Ridge National Laboratory

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Nuclear Science and Technology Division

Cold Test Loop Integrated Test Loop Results

T. J. Abraham*
J. F. Walker, Jr.

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[*] The Providence Group Applied Technologies, Inc., Knoxville, Tennessee

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EXECUTIVE SUMMARY

A testing facility (Cold Test Loop) was constructed and operated to demonstrate the efficacy of the Accelerated Waste Retrieval (AWR) Project's planned sluicing approach to the remediation of Silos 1 and 2 at the Fernald Environmental Management Project near Cincinnati, Ohio. The two silos contain almost 10,000 tons of radium-bearing low-level waste, which consists primarily of solids of raffinates from processing performed on ores from the Democratic Republic of Congo (commonly referred to as "Belgium Congo ores") for the recovery of uranium. These silos are 80 ft in diameter, 36 ft high to the center of the dome, and 26.75 ft to the top of the vertical side walls.

The test facility contained two test systems, each designed for a specific purpose. The first system, the Integrated Test Loop (ITL), a near-full-scale plant including the actual equipment to be installed at the Fernald Site, was designed to demonstrate the sluicing operation and confirm the selection of a slurry pump, the optimal sluicing nozzle operation, and the preliminary design material balance. The second system, the Component Test Loop (CTL), was designed to evaluate many of the key individual components of the waste retrieval system over an extended run.

The major results of the initial testing performed during July and August 2002 confirmed that the AWR approach to sluicing was feasible. The ITL testing confirmed the following:

- The selected slurry pump (Hazleton 3-20 type SHW) performed well and is suitable for AWR application. However, the pump's motor should be upgraded to a 200-hp model and be driven by a 150-hp variable-frequency drive (VFD). A 200-hp VFD is not much more expensive and would allow the pump to operate at full speed.
- The best nozzle performance was achieved by using 15/16-in. nozzles operated alternately. This configuration appeared to most effectively mine the surrogate.
- The Solartron densitometer, which was tested as an alternative mass flow measurement device, did not operate effectively. Consequently, it is not suitable for application to the AWR process.
- Initially, the spray ring (operated at approximately 2300 psi) and the nozzles provided by the pump vendor did not perform acceptably. The nozzles were replaced with a more robust model, and the performance was then acceptable.
- The average solids concentration achieved in the slurry before Bentogrout addition was approximately 16% by weight. The solids concentration of the slurry after Bentogrout addition ranged from 26% to approximately 40%. The slurry pump and ITL system performed well at every concentration. No line plugging or other problems were noted.

The results of the CTL runs and later ITL testing are summarized in an appendix to this report.

1. BACKGROUND

Operable Unit 4 at the U.S. Department of Energy (DOE) Fernald Environmental Management Project near Cincinnati, Ohio, includes two domed silos that contain almost 10,000 tons of radium-bearing low-level waste. The waste, known as K-65 waste, consists primarily of solids of raffinates from processing operations performed on ores from the Democratic Republic of Congo (commonly referred to as “Belgium Congo ores”) for the recovery of uranium. These silos are 80 ft in diameter, 36 ft high to the center of the dome, and 26.75 ft to the top of the vertical side walls. The silos were constructed in 1951 and 1952 of concrete wrapped with steel post-tensioning wires, and the sides were covered with gunite. The silos are also equipped with an underdrain system and decant sump tank to collect any potential liquid leakage through the base of the silos. Earthen berms have been placed around the outside silo walls and a radon collection system installed to reduce exposure levels to workers and release to the environment. Details on the construction of the silos and the radon treatment system have been documented in a Fernald report.[1]

Waste materials were originally transferred to Silos 1 and 2 by pumping the wastes in the form of a slurry. The waste solids settled, and the slurry liquid was removed by decant ports located in two vertical lines on diametrically opposed sides of each silo, with the lowest port located 1 ft from the bottom. Silo 1 contains 115,900 ft^3 of K-65 waste and 12,600 ft^3 of a commercial grade of bentonite clay know as Bentogrout. Silo 2 contains 100,400 ft^3 of K-65 waste and 11,100 ft^3 of Bentogrout. The Bentogrout was added to both silos in 1991 to form a layer over the existing K-65 waste to reduce the potential for radioactive emissions to the environment. Details on the waste materials in the silos have been documented in a Fernald report.[1]

The purpose of the Accelerated Waste Retrieval (AWR) Project is to extract the material from Silos 1 and 2, transfer the material to interim storage tanks for staging before final remediation, reduce the radon concentration in the silo headspaces, provide radon control during retrieval and material storage, clean the silos and equipment for system closure, and handle secondary waste generated during the AWR Project. Design of the bulk waste retrieval system for the silos was prepared by Foster Wheeler in 1999–2000 and calls for hydraulic sluicing of the waste into four 750,000-gal interim storage tanks. Information on the Foster Wheeler design has been previously documented.[2]

DOE Fernald requested that the DOE Office of Science and Technology provide assistance in organizing a technical working meeting to discuss lessons learned from prior experiences at DOE sites with sluicing of material from large tanks. A technical working meeting, which included experts from industry, DOE facilities, and universities, was held on October 10 and 11, 2001. The experts felt that the most critical item of concern was the waste retrieval. Recommendations were made on modifying the sluicing design in terms of the number and locations of sluice nozzles, the pump specified to retrieve the K-65 waste, and the pump location. The team of experts also recommended that a demonstration system be developed and operated with a physical surrogate material to demonstrate the efficacy of the proposed system in the sluicing of K-65 waste from the silos. Furthermore, the test system should provide critical information concerning system and component operation and maintenance as well as nozzle operation and optimization of the sluicing system characteristics. This report presents the results of the first series of tests conducted to meet these objectives.

2. DESIGNATION OF CORE TEAM AND KEY RESPONSIBILITIES

This demonstration project was a collaboration of a broad team of experts, designers, and operators. Members of the team included Fluor-Fernald (project oversight and guidance); Jacobs Engineering Group (pump selection, component selection, and process engineering input); Oak Ridge National Laboratory (ORNL) (preparation of the test plan with input from the core team, data collection and analysis, and test oversight); TPG Applied Technology (TPG) (system design, system construction, system operation, and report preparation); and Pacific Northwest National Laboratory (PNNL) (surrogate specification).

3. TEST FACILITY AND SYSTEMS

Two test systems, each designed for a specific purpose, were installed to perform a series of tests. The first system, the Integrated Test Loop (ITL) was designed to demonstrate the operation of the waste retrieval process as a whole. The second system, the Component Test Loop (CTL), was designed to evaluate many of the key individual components of the waste retrieval system. Each system is described in detail in the following sections.

3.1 THE INTEGRATED TEST LOOP

The objective of the ITL, as stated above, was to demonstrate and evaluate the AWR sluicing operation at near full scale. The ITL utilized many of the actual operating modules and other components (i.e., pumps, valves, and instrumentation) that will be used in the sluicing operation at Fernald. A piping and instrument diagram for the ITL is presented in Fig. 3.1. The primary components of the ITL, as shown in Fig. 3.1, are the surrogate tank, a slurry pump (utilized to provide sluice water) and sluicer module, a slurry pump and slurry module, sluice water tanks, and slurry collection tanks. This system is designed for multiple short runs of about 1 h in duration.

During testing, water from the decant water supply tanks is pumped to the sluice nozzles. The sluice water then forms a slurry when it contacts the surrogate and mobilizes the surrogate to the slurry pump. The slurry is then pumped from the surrogate tank to the slurry receipt tank, where it is allowed to settle. Next, the supernatant is recovered and pumped to the decant water supply tanks, where it is used for the next test. The following sections provide details concerning some of the individual components in the ITL.

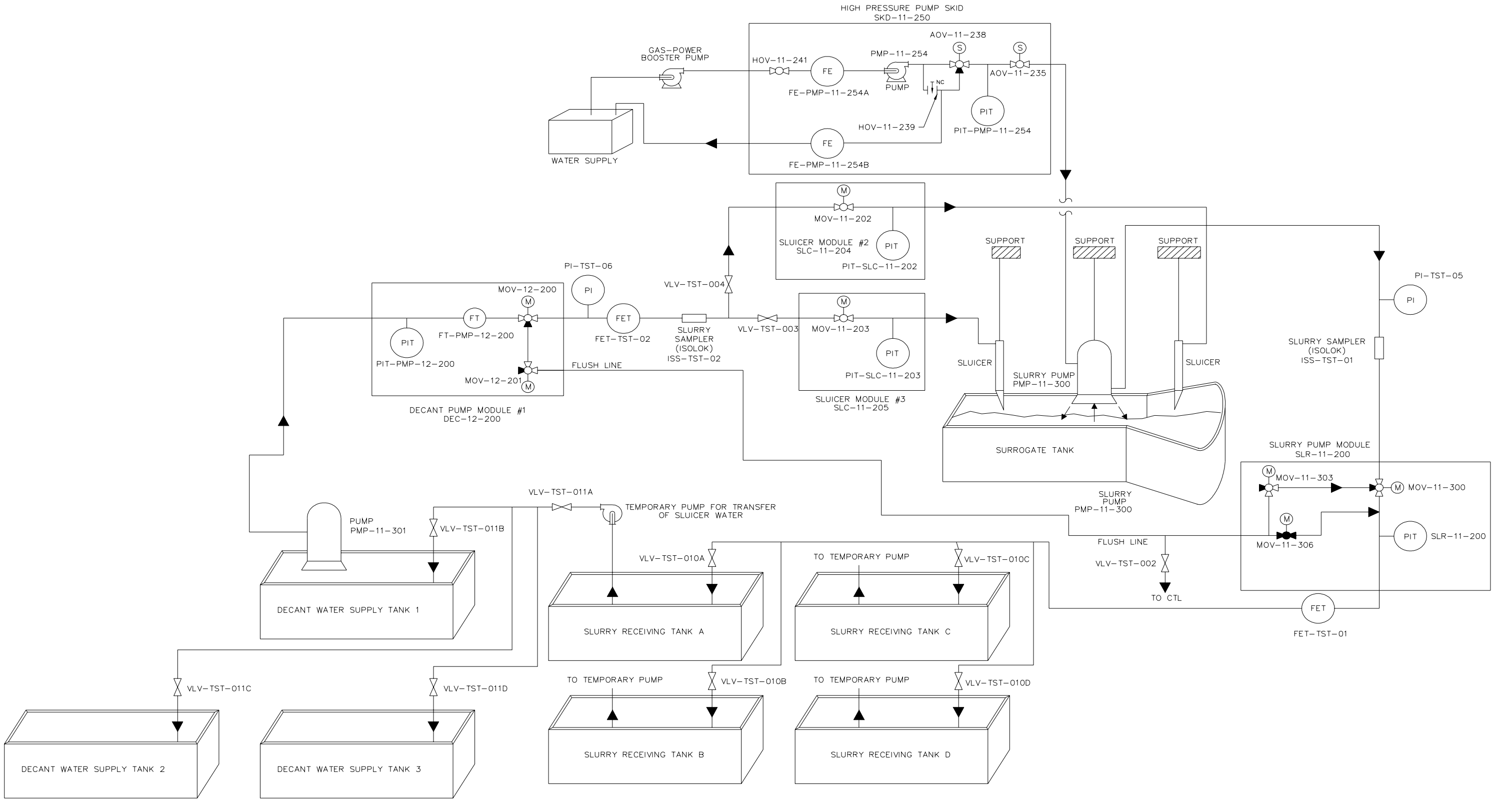

Fig. 3.1. Piping and instrument diagram for the ITL.

3.1.1 Surrogate Tank

The surrogate tank (a photograph is shown in Fig. 3.2) was designed to represent the actual silo diameter. The tank is approximately 70 ft long by 15 ft wide by 8 ft deep, with an arc section on one end to represent the silo wall. The tank has been equipped with two sluicer nozzles and a slurry pump, which are positioned to simulate the distances between the nozzles, the pump, and the silo wall in the actual bulk waste retrieval system planned for deployment in the silos. The nozzles and slurry pump are full scale and identical to those planned for deployment at Fernald. The surrogate material tank also has standpipes for determining the depth of any free liquid in the tank.

Fig. 3.2. View of the surrogate tank prior to testing.

3.1.2 Slurry and Sluice Pumps

One of the most important components tested in the ITL was the slurry pump. A pump selection process was undertaken prior to the testing and is documented in another report.[3] The pump chosen for testing is by Hazelton Pumps, Inc. The specific model is a series 3-20 type SHW pump. Initial (as-tested) specifications for the selected Hazelton pumps are as follows:

- The Hazelton SHW will pump 350 gal/min.
- The total dynamic head for the pump is 208 ft at 1350 rpm and 450 ft at 1975 rpm.
- The pump has an efficiency of 52%.
- The pump has a 3-in. discharge flange (150# ANSI), flat faced.
- The maximum size of spherical solids through the impeller is 1.25 in.
- A 20-in. minimum submergence over the suction inlet is required for full flow.
- The normal pump operating temperature is ambient.
- The impeller has a design diameter of 18 in.

A photograph of the pump is shown in Fig. 3.3.

Fig. 3.3. The slurry pump.

The Hazelton SHW had several key features that made it the pump of choice. First, the pump was delivered with an oversized motor that allows it to be run indefinitely without external cooling. Secondly, the pump can develop enough head to allow it to serve as both a slurry pump and a sluice water pump. Three pumps were tested during the cold testing. One, delivered with a high-pressure spray ring, was used as the ITL slurry pump. The other two, the same pump model without the spray ring, were either used as a sluice water pump in the ITL or tested in the CTL. The slurry pump and the pump tested in the CTL were powered by a 50-hp variable-frequency drive (VFD), and the sluice water pump was powered by a 100-hp VFD.

3.1.3 Other Components

The ITL has several other components worth noting, including two Isolok sampling devices and two mass flow measurement devices (one of each device in the sluice water and slurry lines). The Isolok samplers are designed to sample a slurry stream in situ by inserting a “thief” into a flowing stream of slurry. The Isolok can be programmed to take a sample periodically, which allows automated composite sampling.

The other component of note is an instrument assembly designed to measure mass flow of the slurry. This mass flow assembly is a combination of two independent instruments. One is a magnetic flowmeter (a technology that is well demonstrated in slurry service), and the other is a Solartron liquid density transducer. The magnetic flowmeter measures the volumetric flow of the slurry. The densitometer, which operates on the vibrating element principle with the element being a tuning fork, is immersed in the liquid being measured and measures the density. Readings from these two elements are used to calculate the solids concentration in the slurry. This assembly was tested in both the slurry streams and the sluice water streams.

3.2 THE COMPONENT TEST LOOP

A piping and instrument diagram for the CTL is presented in Fig. 3.4. A photograph of the CTL is shown in Fig. 3.5. The CTL was operated around the clock for extended periods of time to gather data on individual components that are planned for use in the remediation of the Fernald silos.

A slurry surrogate, similar to the physical surrogate used in the ITL, was prepared and placed in the feed tank. The target concentration of solids in the surrogate was 15% by weight. The slurry pump, which is identical to the pumps used in the ITL, circulated the slurry at flows of approximately 350 gal/min through the test loop and back to the feed tank. The pressure, flow, solids concentration, and the temperature on the pump discharge were logged, and an Isolok sampler on the slurry pump effluent line was included for taking grab samples. The CTL contains a valve for adjusting the back-pressure on the slurry pump to verify pump curves, as well as clear sections of pipe to determine the critical velocity at which the solids in the surrogate begin to settle. The various components of particular interest that were evaluated during these extended runs included a DeZurik brand plug valve, an Everlasting brand diverter valve, an RF brand pinch valve, a full-port two-way ball valve, full-port three-way ball valves, a standard long radius elbow, a bend on a 40-in. radius, a mass flowmeter, a magnetic flowmeter, a densitometer, and an Isolok sampler.

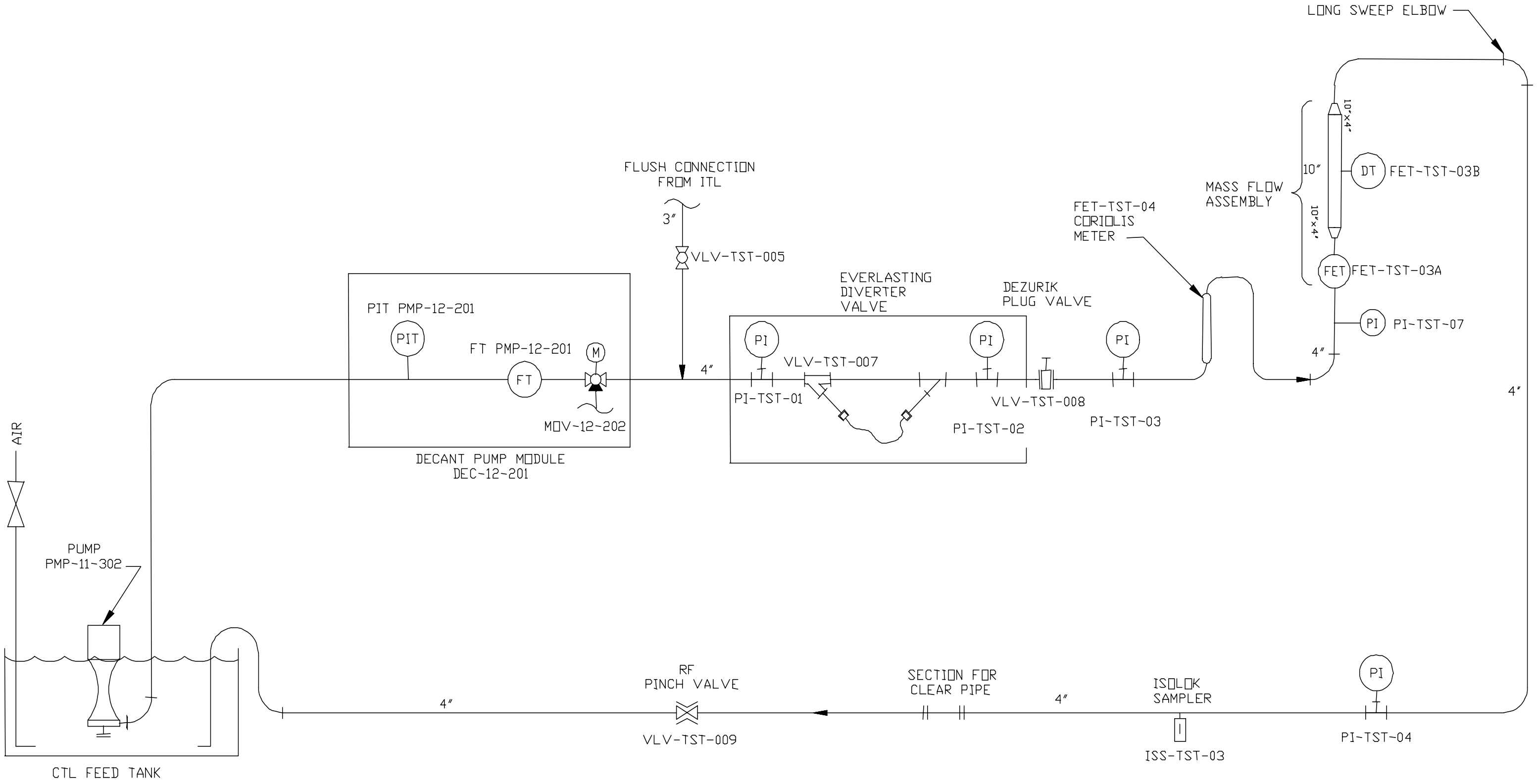

Fig. 3.4. Piping and instrument diagram for the CTL.

Fig. 3.5. The CTL.

3.3 SURROGATE

The K-65 waste consists primarily of solids of raffinates from processing operations on Belgian Congo ores for the recovery of uranium. The K-65 material contains a significant amount of lead (8.9%), iron (4.1%), and barium (4.4%). Therefore, this material is slightly denser, with a higher specific gravity (average 2.97, standard deviation of 0.13) than that of typical sands or minerals (specific gravity of 2.65). Personnel from PNNL, who have an expertise in surrogate development and specification based on previous work with similar wastes, studied the characterization data from the silos and developed a specification for the K-65 surrogate. Information on the surrogate and its development has been summarized in a PNNL report.[4]

The specifications for a physical surrogate developed by PNNL staff were met by combining 23% of a crushed block material with 77% of a crushed limestone material from a local vendor. The PNNL report discusses the issues associated with the variation in the surrogate and the specification requirements. A comparison of the surrogate and the specification is provided in Table 3.1.

Table 3.1. Comparison of surrogate and specification requirements[a]

Screen size (mesh no.)	Block material	Limestone material [a]	Combined material [b]	Fernald specifications
4	99	100.0	99.8	100.0
8	73	99.9	93.7	97.3
16	50	99.0	87.7	93
30	35	98.0	83.5	87.5
50	26	95.9	79.8	79.5
100	19	87.2	71.5	66.5
200	14	67.4	55.1	54.0

[a] Values listed indicate the percent passing through the screen size indicated but not the next-finer one. Specific gravities are 2.82 for the combined surrogate and 2.97 for the Fernald specification.

[b] Contains 23% block material and 77% limestone.

The block and limestone materials were mixed using a procedure developed by TPG. The mixing procedure is also referenced in a PNNL report.[4]

An adjustment to the above surrogate formula was made late in the program to support CTL operations. A vendor was located that offered graded silica sand, novaculite and TiO_2. PNNL staff were able to more closely match the K-65 material by formulating a blend of the block material, crushed limestone, and the new materials.

One important aspect of the silo material that will influence its behavior is the bentonite cover that was placed on the material in 1991. The material, Bentogrout, was added to reduce the potential for radioactive emissions to the environment. Consequently, a Bentogrout cap was placed over the K-65 surrogate during a portion of the ITL testing to simulate the waste condition in Silos 1 and 2. Testing was also conducted in the CTL with different combinations of K-65/Bentogrout to bound the range of compositions expected to be encountered during the actual remediation of the silos. In addition, debris (e.g., plastic bags) was added to the surrogate tank to determine how the slurry pump would handle this material.

4. INTEGRATED TEST LOOP RESULTS

A total of 13 documented runs have been completed in the ITL. The test plan initially called for eight runs; however, another five runs were included to more completely explore sluicing operations. General results and conclusions of initial ITL testing are summarized in the following sections. Run-specific data of results and summaries are included in the appendix.

4.1 SLUICING PERFORMANCE

4.1.1 Nozzle and Configuration

Two nozzle configurations were tested in the ITL. One configuration was two nozzles (15/16-in. orifice and/or 7/8-in. orifice) operating alternately at a sluice water flow of approximately 280 gal/min, and the other consisted of two smaller nozzles (5/8-in. orifice) operating concurrently at approximately 140 gal/min each. In each configuration, the sluice water pressure in the sluice module was approximately 150 psig.

The test results indicate that the preferred configuration is the use of the higher-flow nozzles operating alternately. Although the solids concentration in the slurry was approximately equal for each nozzle size (see Fig. 4.1), this conclusion was based primarily on observations of the depth profile in the surrogate bed after several ITL runs.

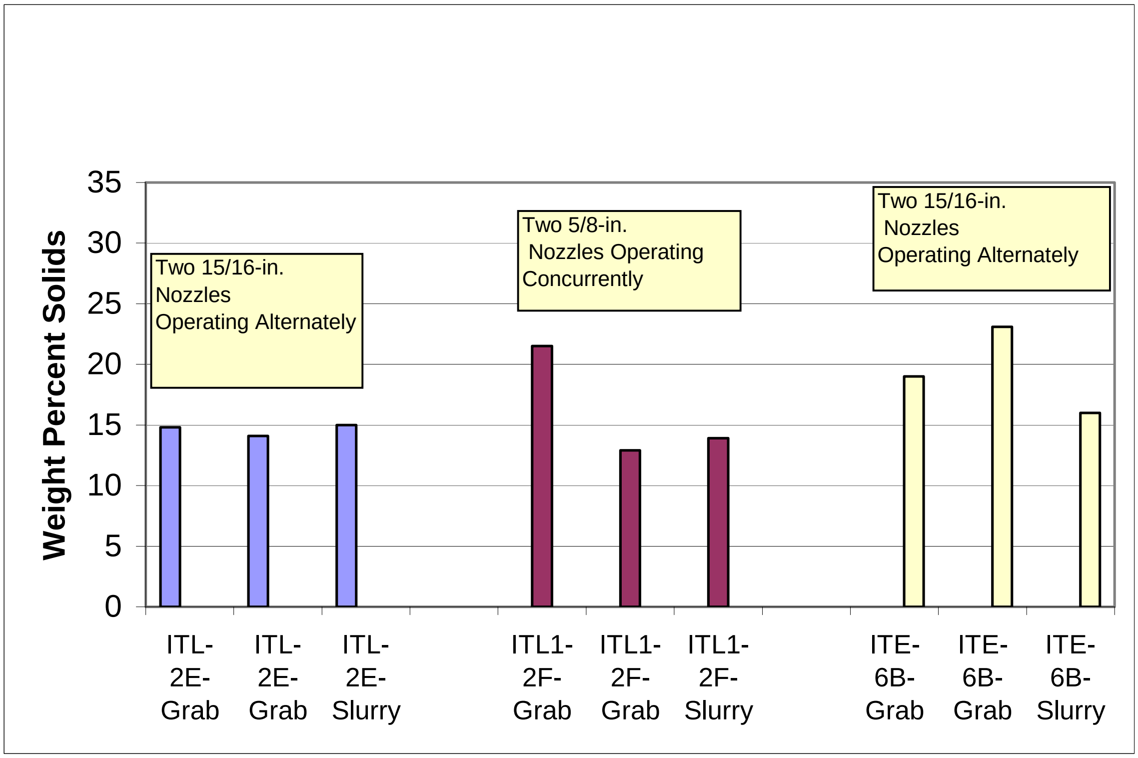

Fig. 4.1. Comparison of the performance of different nozzle configurations.

Upon completing the Series 1 tests, preliminary indications were that concurrent operation of two nozzles was preferred. However, after several more runs, it was observed that the surrogate bed developed a depth profile in which the area of the bed directly under and in close proximity to the pump was elevated with respect to the rest of the bed when the lower-flow nozzles were used simultaneously. Moreover, the profile could not be altered by adjusting the volumes of sluice water available when the lower-volume nozzles were used. When the higher-flow nozzles were installed and run alternately, sufficient sluice water flow was present to consistently move the material directly under the pump and develop a bed profile that was evenly depressed under the pump.

4.1.2 Spray Ring Configuration and Operation

The high-pressure spray ring, as delivered from Hazelton, was ineffective. The nozzles that were initially installed provided only a small direct water stream and did not impact the surrogate significantly. The initial nozzles were replaced with a set of adjustable nozzles, which showed significant wear after only two tests (approximately 1 h of operating time). Finally, the ring was modified and Viper Turbo nozzles were tested in the system. These nozzles appeared to effectively impact the surrogate bed (see Fig. 4.2) and performed reliably during testing.

Fig. 4.2. Nozzle pattern for the Viper Turbo nozzles.

The testing of the spray ring resulted in two important observations. First, water flow must be maintained to the nozzles whenever they are submerged in the surrogate. In every case, if water flow to the nozzles was interrupted during a run, the nozzles plugged and had to be either cleaned or replaced.

The other major observation concerned operation with the Bentogrout cap covering the surrogate. When the testing was initiated with the cap in place, the spray ring was operated for several minutes prior to turning on the sluicers. The high-pressure spray readily cut through the cap, removing a small amount of the Bentogrout under the nozzles. When the sluicing was started, however, the sluice water stream readily removed the Bentogrout cap almost immediately upon contact. Consequently, the large flow of water available from the sluicing nozzles is far more effective in mobilizing the Bentogrout cap than is the operation of the spray ring.

4.1.3 Pump Performance and Operation

The Hazelton pumps performed quite well during the testing. The pumps were taken through a variety of run conditions and speeds in the various runs. The following summarizes the significant results and observations concerning the pump and associated process equipment.

- The sluicing operation is quite dynamic. Consequently, the slurry pump operates over a wide range of speed, flow, and pressure. In many of the ITL tests, the slurry pump was operated both dry (i.e., the pump was running but there was no flow of slurry established) and while pumping slurry. In many instances, the pump would be started, several minutes would elapse before the slurry depth was sufficient for slurry flow to be established, pump flow would be established for a period of time, and the pump would then lose suction and run dry until the flow was reestablished. The pump appeared to handle this type of operation well without cavitating or pulsing.
- The sluice pump operated consistently throughout the testing; however, the 100-hp VFD was insufficient to allow the pump to run at 1975 rpm and 280 gal/min. Operation at these levels requires a 125-hp VFD.
- During the Bentogrout runs, the pump screen was blinded with surrogate. Figure 4.3 is a photograph of the pump screen after a Bentogrout run. Initially, the pumping rate was similar to that of the surrogate runs without Bentogrout. At times, however, the slurry flow would be dramatically reduced. The screen could be readily cleaned by raising the pump above the surrogate bed and cleaning it with one of the sluice nozzles.
- Debris was added to the system as part of Run 6. The debris included angle iron, a cinder block, plastic gloves, several sample bottles, a two-by-four, and a plastic bag of debris. The results of the runs were uneventful. The debris could be easily manipulated with the spray nozzles and kept away from the slurry pump. The Hazelton representative did have a concern with the external agitator potentially becoming entangled with a glove or piece of wire and recommended operating without the agitator.

Fig. 4.3. Pump screen after an ITL run with Bentogrout added to the surrogate.

4.2 PERFORMANCE OF SOLATRON UNIT

One of the key equipment assemblies tested in the ITL was the combination of a Solartron model 7826 insertion density transducer and a magnetic flowmeter. As previously indicated, this assembly was designed to allow the measurement of solids concentration in the slurry. The density transducer is used to measure the density of the flowing slurry. When combined with a volumetric flow measurement taken by the magnetic flowmeter, a mass flow (i.e., pounds per hour) is calculated. Furthermore, the equations provided with the Solartron flow computer can also be used to correlate the slurry density to the solids concentration (percent solids by weight) and an estimate of solids flow can then be calculated.

This system has not performed acceptably in either the ITL or CTL. The installation, calibration, and programming directions provided in the Solartron manual were followed to install and program the Solartron units. Initially, the flow computers were programmed using a water density of 8.34 lb/gal. However, after initial measurements were taken in each of the three densitometers, the following water density readings were recorded for the three Solartron units:

Sluice water loop in the ITL – 8.17 lb/gal (an error of 2%)

Slurry loop in the ITL – 8.2 lb/gal (an error of 1.7%), current reading: 7.7 lb/gal (an error of 8%)

CTL loop – 8.0 lb/gal, drifting to 7.8 lb/gal (an error of 2.4 to 6.5%)

While these errors appear to be relatively small, the difference in the density of water and that of a slurry of 10% solids concentration is approximately 5%—a value that is well within the measurement error.

Several other problems occurred with the use of the Solartron units.

- Calculation of the mass or volume concentration in the slurry requires that the average particle density of the solids be known. In other words, to predict solids concentration, the composition of solids must remain fixed. If the composition of the solids changes, the particle density also changes (e.g., solids-rich Bentogrout vs solids containing little or no Bentogrout) and significant error is introduced in the calculation of the solids concentration.
- The Solartron unit operates using a tuning fork arrangement. During the first ITL run, the Solartron unit failed to give any readings. When the unit was removed from the ITL, a piece of gravel was observed to be lodged in the tuning fork, causing the unit to fail. Solids similar to the gravel are expected in the K-65 material; consequently, this type of failure is probable in full-scale operation.
- The Solartron did not perform consistently in our testing. Constant recalibration will be required to reduce error.

Based on their performance in testing, it was concluded that the Solartron units are not suitable for inclusion in the AWR design or operation. However, the magnetic flowmeters appear to give very accurate and reproducible measurements. Practically, the operator will be able to use a combination of pump performance (e.g., torque, rpm, amperage requirements) and volumetric flow measurements from the magnetic flowmeters to run and control sluicing operations.

4.3 SOLIDS CONCENTRATION IN THE EFFLUENT

Slurry solids concentration is a very important parameter for both the design and operation of the AWR system. In earlier designs, significant attention was paid to carefully controlling the solids concentration to minimize the wear on components as well as eliminate the potential for plugging the equipment.

The concentration of solids in the ITL slurry effluent varied considerably throughout the testing. There were several contributing factors such as the state of the surrogate (e.g., early in the testing it had not been saturated and packed), the specific test being run, and the skill of the operator. However, the concentrations did appear to become more consistent in the later runs.

Table 4.1 summarizes the solids concentrations of the ITL slurry effluent for several ITL runs conducted prior to the addition of Bentogrout. Two types of samples were taken: grab and composite samples. The grab samples were taken directly from the discharge piping at the discharge tank, and the composite samples were taken by the Isolok sampler throughout the run. Also, in these runs, the Isolok sampler was operated only while the slurry flow was established. Earlier testing had indicated that if the Isolok sampler was operated during periods of no slurry flow, a stagnant stream would be sampled, potentially biasing the data.

The average solids concentration of all of the samples shown in Table 4.1 is 16.3%. The average concentration for the grab samples is 16.4%, and that for the composite samples is 15.9%. Quite a range of values (5.6 to 30.3%) was observed, primarily in the grab samples, resulting from the dynamic nature of the operation. Three sources of variability are possible: the operator is constantly moving the sluice nozzle and fanning the surrogate tank, which moves material to the pump at differing rates; the pump may be on the surrogate surface or above the surface, depending on the time of the sample; or the flow from the pump may be either steady, just starting, or even decreasing, depending on the pool depth around the pump.

After Bentogrout was added to the system, the solids concentration increased dramatically. The solids concentrations are shown in Table 4.2. The average solids concentration in Run ITL-4 was 33.8%, with the grab samples averaging 36.4%. The only composite sample had a solids concentration of 26%. The reason for this increase in solids concentration is likely twofold: (1) the Bentogrout itself as a solids contributor and (2) suspended (colloidal) Bentogrout acting to increase the density and viscosity of the sluice water and enhance the mobilization of solids. More tests need to be run in order to confirm the solids concentration with Bentogrout in the system.

Table 4.1. Summary of solids concentrations in several of the ITL runs prior to Bentogrout addition

Sample identification	Description of sample	Specific gravity	Solids concentration (percent by weight)
ITL-2C-Grab	Slurry receipt line (grab)	1.03	5.6
ITL-2C-Grab	Slurry receipt line (grab)	1.65	30.3
ITL-2C-Slurry	ISS-TST-002 (composite)	1.09	17.5
ITL-6-Grab	Slurry receipt line (grab)	1.13	13.8
ITL-6-Grab	Slurry receipt line (grab)	1.06	11
ITL-6-Slurry	ISS-TST-002 (composite)	1.04	16.3
ITL-2E-Grab	Slurry receipt line (grab)	1.11	14.8
ITL-2E-Grab	Slurry receipt line (grab)	1.09	14.1
ITL-2E-Slurry	Slurry receipt line (grab)	1.00	15
ITE-6B-Grab	Slurry receipt line (grab)	1.14	19
ITE-6B-Grab	Slurry receipt line (grab)	1.17	23.1
ITE-6B-Slurry	Slurry receipt line (grab)	1.09	16
ITL1-2F-Slurry	ISS-TST-002 (composite)	1.05	13.9
ITL1-2F-Grab1	Slurry receipt line (grab)	1.15	21.5
ITL1-2F-Grab2	Slurry receipt line (grab)	1.07	12.9

Table 4.2. Summary of solids concentrations in Run ITL-4 with Bentogrout

Sample identification	Description of sample	Specific gravity	Solids concentration (percent by weight)
ITL4-Slurry	Slurry receipt line (composite)	1.16	26.0
ITL4-Grab	Slurry receipt line (grab)	1.32	39.8
ITL4-Grab	Slurry receipt line (grab)	1.29	37.1
ITL4-Grab	Slurry receipt line (grab)	1.23	32.3

4.4 PARTICLE SIZE DISTRIBUTION

An appendix to this report, including the CTL data, provides a thorough review of this topic.

5. DESIGN RECOMMENDATIONS

The previous sections of this report have detailed the results and conclusions from the ITL testing. The objective of this section is to summarize recommended design changes resulting from the initial ITL testing.

- The Hazelton series 3-20 type SHW pump is an appropriate choice for both the slurry and sluice pumps. The pumps tested in the cold test program performed consistently, and no problems were observed with their operation. The VFDs used in cold testing were undersized and did not allow complete utilization of the pump.
- Upon observing the cold test operation, a Hazelton representative recommended that the pump be modified by removing the external agitator (removal of the agitator is not expected to degrade the performance of the pump); replacing the 125-hp motor with a 200-hp motor to allow higher delivery pressures for sluicing; and replacing the 18-in. impeller with a 19.5-in. impeller, also to allow higher delivery pressures.
- The VFD supplying the pumps should be 150 hp.
- The Solartron densitometer did not perform well in our testing and should not be used in full-scale operation.
- Cold testing used visual means to determine when the pump was on the surrogate surface. However, observation of the pump in the silos may become obscured during operation. A load cell should be installed on the pump hoist to give a remote indication of when the pump is on the surrogate.
- The dilution line in the slurry module, designed to allow the control of solids concentration in the slurry, is unnecessary and should be removed. Cold testing has clearly shown that the pump and piping can readily handle solids concentrations as high as 40% by weight. Thus, solids control is unnecessary.
- The sluicers should employ 15/16-in. nozzles in alternate operation.
- The Viper Turbo nozzles are the nozzles of choice for the spray ring.

6. RECOMMENDATIONS FOR FUTURE WORK

Several questions remain unanswered from the initial testing. The following items summarize recommendations for follow-up work.

- The pump screen should be redesigned and tested because of problems with blinding during runs with Bentogrout. The screen should then be tested in a Bentogrout-rich surrogate.
- Because the representative from Hazelton Pumps, Inc., expressed concerns regarding entanglement of the agitator at the base of the pump with debris, additional testing without the agitator is recommended. Removal of the agitator will allow the pump inlet screen to be redesigned to minimize the possibility of debris getting into the pump.
- Approximately six to eight replicate runs should be conducted to quantify the concentration of solids in the slurry and thus allow an accurate prediction of a material balance in silo operations.

- Three to five replicate runs are needed to determine the minimum flow necessary to prevent the spray ring nozzles from plugging. A continuous flow of water to the spray rings will contribute negatively to the AWR water balance. Minimization of the flow to the spray rings is necessary.
- The Coriolis meter should be installed and tested in the ITL sluice water stream during all of the above-mentioned runs.
- A longer run of steel pipe (200 to 400 ft) should be installed in the slurry pump outlet with a pinch valve or orifice plate to provide flow resistance and allow the slurry pump to be tested near expected full-scale discharge pressure requirements.
- Because of the problems in mobilization of the larger-particle-size materials, the CTL should be operated for approximately 2 weeks in continuous operation with the pump agitator removed. This will allow the CTL to be used to determine the ability of the valves, instruments, and fittings to withstand the abrasion and wear from the higher concentration of solids and from the larger particles. Removal of the agitator is also expected to enhance the mobilization of larger particles in the ITL.

7. REFERENCES

1. *Final Operable Unit 4 Remedial Investiation Report,* Fernald Environment Management Project, Fernald, Ohio, Nov. 3, 1993.

2. *System Design Descriptions for the Silos 1 & 2 Accelerated Waste Retrieval Project,* Document Number 624-P622-30, Rev. 1, Foster Wheeler Environmental Corporation, Contract No. FSC-624, submitted to Fluor Fernald, Inc., Nov. 16, 2000.

3. *Selection of a Slurry Pump for the Accelerated Waste Retrieval Project,* Document Number 40710-RP-0013, Jacobs Engineering Group, April 23, 2002.

4. *Surrogate Development for Fernald Silos 1 & 2 Accelerated Waste Retrieval Project,* PNNL-13996, Pacific Northwest National Laboratory, Sept. 4, 2002.

Appendix

RUN SUMMARIES

A.1 ITL SERIES 1 RUNS

A.1.1 Objectives

The primary objectives of the ITL Series 1 runs were to (1) determine the nozzle configuration that is most effective in mining the K-65 surrogate material, (2) determine the effective radius of the nozzles being tested with K-65 surrogate, and (3) determine the effectiveness of the nozzles in forming a sump around the slurry pump with the K-65 surrogate.

A.1.2 Summary of Results

- The initial conclusions from this set of runs indicated that two nozzles operating simultaneously at approximately 150 gal/min each were more effective than two nozzles operating alternately at approximately 280 gal/min. The initial observations during the runs seemed to indicate that more material was being moved to the slurry pump when two nozzles were run simultaneously. However, a "sump" was not observed under the pump in either configuration. The next series of runs, Runs ITL-2-A and ITL-2-B, were conducted with the two 150-gal/min nozzles operated simultaneously.
- Approximately 30 min elapsed between the start of the sluice water flow and the start of slurry pumping. An adequate amount of water had to be added to the surrogate to allow the pump to prime itself.
- Directing the sluice spray directly to the intake of the pump would interrupt slurry flow.
- Both nozzles were able to direct the sluice water to the far end of the ITL storage tank. In addition, the nozzle nearest the curved end of the surrogate tank was able to effectively mine the surrogate in the curved portion of the tank directly behind the nozzle.

Photographs of the apparatus are included as Figs. A.1–A.5. Process and analytical data are provided in Tables A.1 and A.2, respectively.

Fig. A.1. Surrogate tank prior to the start of the ITL-1 series runs.

Fig. A.2. Surrogate tank after Run ITL-1-A.

Fig. A.3. Area just under slurry pump before Run ITL-1-A.

Fig. A.4. Area immediately under the slurry pump after Run ITL-1-A.

Fig. A.5. One of the receiving tanks after Run ITL-1A.

Table A.1. Process data from the ITL Series 1 runs

Run: ITL 1A: Two 300 gpm nozzles operating alternately, no spray ring.

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-202	PIT-SLC-11-203	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
07/09/02 15:57	40	136	0	0	36	0	49	50	939		0	0		0	0	0		
07/09/02 15:59	58	163	0	0	50	0	56	67	1107		0	0		0	0	0		
07/09/02 16:09	5	2	0	0		0	0	0	0		0	0		0	0	0		
07/09/02 16:14	100	219	0	0	89	0	79	114	1461		0	0		0	0	0		
07/09/02 16:19	122	241	0	0	104	0	91	135	1591		718	1		0	0	0		
07/09/02 16:24	117	240	1	2	106	0	91	137	1591		0	1		0	0	0		
07/09/02 16:29	131	254	1	6	119	0	101	153	1683		0	1		0	0	0		
07/09/02 16:35	137	255	1	11	119	0	102	153	1683		894	16		0	0	0		
07/09/02 16:39	132	253	1	14	119	0	102	153	1683		894	16		0	0	0		
07/09/02 16:44	121	445	1	20	90	0	115	176	1680		897	3		0	0	0		
07/09/02 16:49	114	237	1	23	5	103	91	132	1572			2		0	0	0		

Run: ITL 1B: Two 150 gpm nozzles operating simultaneously, spray ring used to form initial sump and turned off.

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-202	PIT-SLC-11-203	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
07/11/02 14:29	0		1	0	0	0	0	0	0		0	1	1	0	0	17.6	218	3
07/11/02 14:43	0	0	1	0	0	0	0	0	0		0	1	1	0	0	18.6	371	1456
07/11/02 14:46	23	101	1	2	21	22	41	32	715		0	1	1	0	0	18.6	425	1458
07/11/02 14:51	144	261	1	6	135	136	106	162	1758		1005	3	1	0	0	16.2	513	1458
07/11/02 15:13	0	0	1	8	0	0	0	0	0		1366	1	1	0	0	0	611	3
07/11/02 15:16	0	0	1	8	0	0	0	0	0		1348	1	1	0	0	0	611	0
07/11/02 15:21	73	182	0	8	68	68	63	85	1257		1347	2	40	0	0	17.3	659	1545
07/11/02 15:26	132	251	0	74	124	125	99	149	1684		1347	2	122	0	0	17.1	745	1565
07/11/02 15:31	132	250	0	165	124	124	99	149	1684		1336	37	413	0	0	17.5	831	1531
07/11/02 15:36	132	250	44	316	123	124	99	150	1684		1162	19	97	0	0	17.8	916	1560
07/11/02 15:41	132	251	0	543	124	125	100	150	1684		1324	15	84	0	0	16.3	1002	1560
07/11/02 15:46	132	250	1	547	124	125	100	150	1684		1023	9	277	0	0	0	1084	3
07/11/02 15:51	115	233	1	550	107	108	89	131	1572		1021	7	112	0	0	0	1084	9
07/11/02 15:56	86	204	1	554	80	80	73	101	1368		1245	22	618	0	0	0	1084	3
07/11/02 16:03	1	0	1	559	1	0	0	0	0		1015	14	499	0	0	0	1084	0

Table A.2. Analytical data from the ITL Series 1 runs

Sample no.	Date/Time	Sample point	Density (g/mL)	Solids (wt %)
ITL-1A-1	07/09/02 16:16	Slurry receipt line (grab)	1.22	29.1
ITL-1A-2	07/09/02 16:38	Slurry receipt line (grab)	1.06	9.0
ITL-1B-1	07/11/02 15:25	Slurry receipt line (grab)	1.04	-
ITL-1B-2	07/11/02 15:42	Slurry receipt line (grab)	1.09	-

A.2 ITL SERIES 2 RUNS

A.2.1 Objectives

The primary objectives of the ITL Series 2 runs were to (1) determine the effectiveness of the spray ring in forming a sump around the slurry pump with the K-65 surrogate, (2) perform an integrated test using the parameters from the ITL Series 1 runs that were most effective in mobilizing the K-65 surrogate, (3) test the operation of the Isolok samplers, (4) determine variability in system parameters (e.g., flow, pressure) during integrated testing, and (5) close the water/solids material balance during the integrated test.

A.2.2 Summary of Results

Initially, only two runs were scheduled for the ITL Series 2 tests. However, based on observations of the subsequent runs (ITL-3, -5, -6, and -7), several additional ITL-2 series runs were scheduled to test the two 280-gal/min nozzles operating alternately.

ITL Runs 2A and 2B

- The operating conditions for ITL Runs ITL-2A and ITL-2B were chosen based on the results of Runs ITL-1A and ITL-1B.
- After Run ITL-2A, the surrogate bed was observed to be depressed in an 8- to 10-ft area around the slurry pump. However, the area just under the pump remained elevated. It was thought that the slurry operators were mining around the pump, not directly under the pump itself. The situation could not be readily corrected with the 150-gal/min nozzles.
- The slurry was observed to be either flowing smoothly at full flow or not flowing at all. Pump cavitation or pulsing was not observed. The pump was either deep enough to have been primed, or it simply ran dry.
- ITL Runs 2C–2F (all performed with the larger-flow nozzles operated alternately) demonstrated that with the 280-gal/min nozzles, the area under the pump could be effectively mined and a depression could be formed that could advance into a trough for the slurry pump. Based on this observation, it is recommended that two 280-gal/min nozzles operating alternately is the best configuration for silo sluicing. This nozzle configuration was chosen for Run ITL-4. Process and analytical data are provided in Tables A.3 and A.4, respectively.

Table A.3. Process data from the ITL Series 2 runs

Run: ITL 2A: Two 160 gpm nozzles operating simultaneously, spray ring used, continuously

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200 (psig)	FT-PMP-12-200 (gpm)	FET-TST-02A/B (lb/min)	FET-TST-02-Cumm (lbs)	PIT-SLC-11-204 (psig)	PIT-SLC-11-205 (psig)	Load-PMP-301 (amps)	%T (%T)	RPM-PMP-301 (rpm)	Load-PMP-300 (amps)	RPM-PMP-300 (rpm)	PIT-SLR-11-200 (psig)	FET-TST-01A (gpm)	FET-TST-01B (lb/min)	FET-TST-1B-Cumm (lbs)	FE-To-Spray Ring (gpm)	FE-Cumm (gal)	PE-To-Spray Ring (psig)
07/15/02 10:49	0	0	15	0	0	0	0	0	0	0	0	1	1	0	0	30.5	72	2364
07/15/02 10:54	142	259	5	22	133	135	104	160	1740	39	1008	1	1	0	0	29.6	224	2378
07/15/02 10:59	49	151	0	36	45	47	54	61	1032	65	990	11	34	0	0	30.8	376	2387
07/15/02 11:04	142	259	0	36	132	132	105	159	1740	43	954	5	6	0	0	30.8	562	2402
07/15/02 11:14	135	253	0	565	127	127	102	153	1701	42	954	2	6	0	0	26.5	770	1351
07/15/02 11:19	136	253	0	565	127	127	102	152	1701	41	954	3	8	0	0	27.6	909	1762
07/15/02 11:24	39	134	0	565	35	36	49	51	919	64	954	11	32	0	0	28.2	1054	1739
07/15/02 11:29	142	259	528	1092	132	133	104	159	1738	43	954	4	63	0	0	22.5	1171	625
07/15/02 11:34	142	258	528	3732	133	134	105	160	1738	65	954	11	530	0	0	22.3	1285	625
07/15/02 11:39	141	259	528	6373	133	134	104	160	1738	62	954	11	514	0	0	0	1307	0

Run: ITL 2B: Two 160 gpm nozzles operating simultaneously, spray ring used, continuously

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200 (psig)	FT-PMP-12-200 (gpm)	FET-TST-02A/B (lb/min)	FET-TST-02-Cumm (lbs)	PIT-SLC-11-204 (psig)	PIT-SLC-11-205 (psig)	Load-PMP-301 (amps)	%T (%T)	RPM-PMP-301 (rpm)	Load-PMP-300 (amps)	RPM-PMP-300 (rpm)	PIT-SLR-11-200 (psig)	FET-TST-01A (gpm)	FET-TST-01B (lb/min)	FET-TST-1B-Cumm (lbs)	FE-To-Spray Ring (gpm)	FE-Cumm (gal)	PE-To-Spray Ring (psig)
07/17/02 09:45	142	259	6	8533	133	134	103	153	1740	0	0	1	0	30	0	32	1495	2399
07/17/02 09:49	142	258	5	8561	133	132	105	160	1740	0	0	1	0	30	91	30.7	1588	2404
07/17/02 09:54	136	253	108	8764	127	127	102	153	1701	65	1026	12	553	30	242	31.5	1777	2373
07/17/02 10:04	136	255	106	8899	127	126	101	153	1701	65	1026	13	554	31	477	30.8	2054	2393
07/17/02 10:09	135	253	131	9454	127	128	102	153	1701	65	1026	11	531	2	601	31	2209	2376
07/17/02 10:15	164	278	7	9707	154	153	124	186	1866	43	1044	1	36	4	617	31.9	2396	2358
07/17/02 10:19	83	199	2	9738	77	79	69	95	1332	63	1008	11	549	2	628	30.6	2521	2416
07/17/02 10:24	135	253	22	9758	127	128	101	152	1701	40	1026	2	51	3	647	30.7	2705	2393
07/17/02 10:29	136	253	90		127	127	101	153	1701	68	1026	12	536	3	664	0	2800	0
07/17/02 10:34	135	253	0		127	127	101	152	1701	43	1026	4	54	4	679	0	2800	0

Run: ITL 2C: Two 300 gpm nozzles operating simultaneously, spray ring not used

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200 (psig)	FT-PMP-12-200 (gpm)	FET-TST-02A/B (lb/min)	FET-TST-02-Cumm (lbs)	PIT-SLC-11-204 (psig)	PIT-SLC-11-205 (psig)	Load-PMP-301 (amps)	%T (%T)	RPM-PMP-301 (rpm)	Load-PMP-300 (amps)	RPM-PMP-300 (rpm)	PIT-SLR-11-200 (psig)	FET-TST-01A (gpm)	FET-TST-01B (lb/min)	FET-TST-1B-Cumm (lbs)	FE-To-Spray Ring (gpm)	FE-Cumm (gal)	PE-To-Spray Ring (psig)
07/24/02 10:01	150	238	0		0	139	104	158	1777	53	864	8	419	1	748	0	3365	3
07/24/02 10:06	150	238	27		0	139	104	160	1777	45	702	3	100	2	757	0	3365	0
07/24/02 10:11	147	237	71		135	6	102	156	1758	47	702	5	389	4	770	0	3365	0
07/24/02 10:14	147	237	0		135	6	103	156	1758	46	702	5	112	4	777	0	3365	3
07/24/02 15:09	150	237	158		0	137	104	158	1779	50	774	7	412	5	833	0	3365	0
07/24/02 15:12	150	238	0		0	139	104	160	1779	51	738	7	390	5	855	0	3365	0
07/24/02 15:17	0	0	0		0	0	0	0	0	0	0	1	0	0	860	0	3365	0

Table A.3. (Continued)

Run: ITL 2E: Two 15/16" Nozzles Run Alternating, Spray Ring Run Continuously

Date/Time	Inlet Line To Nozzles PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Slurry Pump Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	Spray Ring FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
08/05/02 10:47	143	264	1		128		99	151	1740	0	0	1	1	0	902	32.6	6376	2283
08/05/02 10:52	142	265	0		128		102	154	1740	40	972	1	1	0	901	31.7	6536	2289
08/05/02 10:56	16	59	15		3		42	33	655	42	972	3	37	0	901	33.5	6699	2347
08/05/02 11:02	137	257	0		5		98	147	1702	41	936	3	77	1	904	28.1	6861	1345
08/05/02 11:07	134	254	131		5		95	143	1684	52	810	7	449	1	908	26.7	6999	1146
08/05/02 11:12	134	253	124		5		96	144	1684	51	792	7	418	2	913	31.3	7140	2173
08/05/02 11:17	143	259	0		128		101	151	1740	40	792	1	59	1	918	30.9	7295	2199
08/05/02 11:22	43	161	81		39		46	44	915	50	792	7	417	1	925	32	7455	2173
08/05/02 11:27	0	2	62		-2		0	0	0	63	1026	12	544	0	926	30.5	7611	2187

Run: ITL 2F: Two 5/8" Nozzles Operating Concurrently, 8 ea. TurboViper #4.5 Operating Continuously

Date/Time	Inlet Line To Nozzles PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Slurry Pump Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	Spray Ring FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
08/09/02 10:46	146	262	1		137	138	100	152	1758	0	0	1	0	0	977	34.6	9142	2286
08/09/02 10:50	146	262	0		137		102	156	1758	42	936	4	52	0	975	34.2	9275	2292
08/09/02 10:52	146	252	0		137	136	103	156	1758	43	936	1	80	0	973	33.6	9340	2271
08/09/02 10:53	146	262	0		137		104	156	1758	41	936	3	69	0	973	33.7	9373	2306
08/09/02 10:54	146	262	0		136		103	155	1758	42	936	3	74	0	972	34.5	9405	2283
08/09/02 10:56	145	262	0		136		103	156	1726	41	936	3	75	0	970	33.2	9474	2292
08/09/02 10:58	146	262	0		136		103	157	1758	60	936	12	454	0	968	33.9	9542	2274
08/09/02 10:59	146	262	129		136		103	156	1758	56	900	10	470	0	965	32.7	9575	2292
08/09/02 11:00	145	262	81		136		103	154	1758	48	882	3	242	0	964	33.1	9609	2312
08/09/02 11:01	146	262	0		136	137	104	155	1758	56	882	10	453	0	962	32.7	9642	2257
08/09/02 11:03	143	259	95		134		101	154	1740	56	882	9	470	0	958	32.7	9708	2268
08/09/02 11:05	143	259	135		134		102	155	1740	56	882	9	471	0	954	34.4	9775	2300
08/09/02 11:08	143	259	137		134		102	153	1740	57	882	9	469	0	946	32.3	9877	2306
08/09/02 11:10	143	259	0		134		101	156	1740	55	882	9	429	0	941	34.2	9944	2300
08/09/02 11:11	143	259	0		134	134	101	153	1740	56	882	9	473	0	938	33.4	9978	2297
08/09/02 11:12	143	259	0		134		102	154	1740	40	882	3	84	0	935	33.9	10011	2300
08/09/02 11:13	2	39	0		1		0	0	0	54	882	9	471	0	932	33.3	10046	2297
08/09/02 11:14	0	0	0		0		0	0	0	55	882	9	474	0	932	29.5	10075	1464
08/09/02 11:16	0	0	0		0		0	0	0	54	882	8	475	0	933	28.7	10135	1421
08/09/02 11:17	0	0	0		0		0	0	0	46	882	4	330	0	933	30	10164	1435

Table A.4. Analytical data from the ITL Series 2 runs

Sample no.	Date/Time	Sample point	Density (g/mL)	Solids (wt %)
ITL-2A-Grab-11:13	07/15/02 11:13	Slurry receipt line (grab)	1.31	36.8
ITL-2A-Grab-11:21	07/15/02 11:21	Slurry receipt line (grab)	1.23	28.4
ITL-2A-Sluice	07/15/02 11:21	ISS-TST-001(composite)	1.00	0.004
ITL-2A-Slurry	07/15/02 11:21	ISS-TST-002 (composite)	1.18	30.4
ITL-2B-Grab-10:05	07/17/02 10:05	Slurry receipt line (grab)	1.13	17.1
ITL-2B-Grab-10:23	07/17/02 10:23	Slurry receipt line (grab)	1.11	17.4
ITL-2B-Grab-10:34	07/17/02 10:34	Slurry receipt line (grab)	1.25	31.7
ITL-2B-Sluice	07/17/02 09:43	ISS-TST-001(composite)	1.00	0.006
ITL-2B-Slurry	07/17/02 09:43	ISS-TST-002 (composite)	1.09	14.1
ITL-2C-Grab-10:10	07/24/02 10:10	Slurry receipt line (grab)	1.03	5.6
ITL-2C-Grab-15:12	07/24/02 15:12	Slurry receipt line (grab)	1.65	30.3
ITL-2C-Slurry	07/24/02 15:12	ISS-TST-002 (composite)	1.09	17.5
ITL-2E-Grab-11:07	08/05/02 11:07	Slurry receipt line (grab)	1.11	14.8
ITL-2E-Grab-11:21	08/05/02 11:21	Slurry receipt line (grab)	1.09	14.1
ITL-2E-Slurry	08/05/02 11:10	Slurry receipt line (grab)	1.00	15.0
ITL-2E-Sluice	08/05/02 11:10	ISS-TST-001(composite)	0.94	0.0055
ITL1-2F-Slurry	08/09/02 11:00	ISS-TST-002 (composite)	1.05	13.9
ITL1-2F-Grab1	08/09/02 11:02	Slurry receipt line (grab)	1.15	21.5
ITL1-2F-Grab2	08/09/02 11:10	Slurry receipt line (grab)	1.07	12.9

A.3 ITL SERIES 3 RUNS

A.3.1 Objectives

The primary objective of the Series 3 runs was to determine the effects of reduced flow on the slurry pump. The pump flow was decreased in 50-gal/min (~400-lb/min) increments from an initial setting of 350 gal/min (~3000 lb/min) to a minimum of 200 gal/min (~1700 lb/min), and the effectiveness of the pump in handling the slurries was noted. After each reduction, the system was allowed to reach steady-state operation, and data were taken before the next flow reduction was made. Operating personnel noted any visible differences in the effectiveness of the pump in handling the slurry at the reduced flows during the integrated tests.

A.3.2 Summary of Results

Run ITL-3 demonstrated that there does appear to be a relationship between flow and electrical load to the pump (see Fig. A.6). This relationship could prove of value during full-scale silo operation. However, the load/flow relationship will need to be determined during start-up of the AWR system (as installed) to account for system pressure drop and desired operating pump speed. Process and analytical data are provided in Tables A.5 and A.6, respectively.

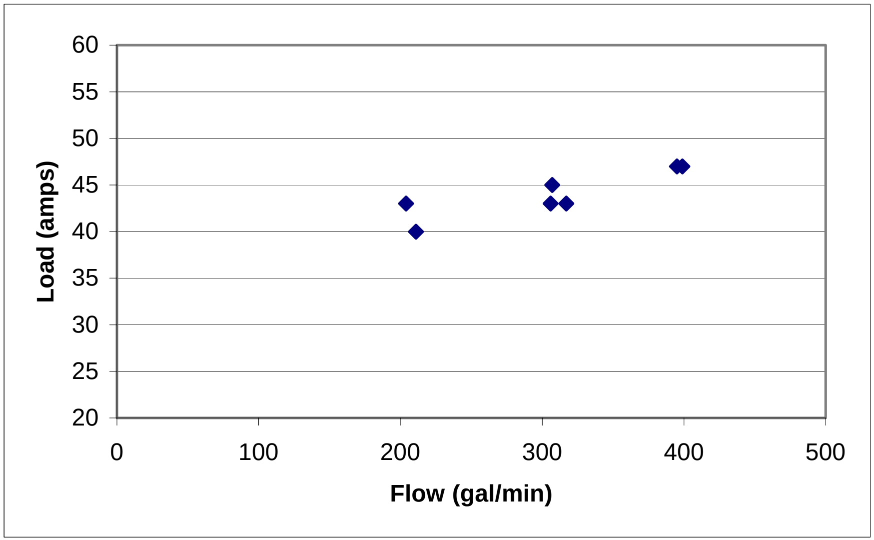

Fig. A.6. Pump load as a function of flow at approximately 670 rpm.

Table A.5 Process data from the ITL Series 3 runs

Run: ITL-3: Two 150 g nozzles operating simultaneously, spray ring used continuously.

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
07/19/02 11:58	145	262	1		136	136	105	159	1758	0	0	1	0	0	693	26	2817	1319
07/19/02 12:03	139	256	1		130	131	102	155	1720	39	882	1	1	1	694	30.8	2971	2494
07/19/02 12:05	139	256	1		130	130	102	154	1716	0	0	0	-1	1	695	30.1	3035	2448
07/19/02 12:08	139	257	40		130		102	155	1720	40	738	1	211	1	696	33.4	3130	2465
07/19/02 12:12	139	257	56		130	132	102	155	1720	47	738	6	395	1	699	32.1	3258	2451
07/19/02 12:13	57	178	61		52		54	59	1059	47	738	6	399	0	699	32.2	3290	2471
07/19/02 12:18	18	86	23		15	16	40	25	621	43	576	4	306	0	698	0	3353	0
07/19/02 12:23	139	256	1		130	129	101	156	1720	40	576	1	1	1	699	0	3365	0
07/19/02 12:28	139	256	1		130	131	102	154	1720	41	576	1	10	1	703	0	3365	3
07/19/02 12:34	49	152	35		45	47	52	60	1032	45	576	4	307	0	706	0	3365	3
07/19/02 12:38	50	152	25		45	47	51	59	1033	43	396	2	204	0	705	0	3365	0
07/19/02 12:43	142	259	11		133	134	103	156	1740	40	612	1	72	1	705	0	3365	-3
07/19/02 12:48	46	146	23		41	43	51	55	996	43	612	5	317	0	706	0	3365	-3

Table A.6. Analytical data from the ITL Series 3 Runs

Sample no.	Date/Time	Sample point	Density (g/mL)	Solids (wt %)
ITL-3-Sluice	07/19/02 12:05	ISS-TST-001 (composite)	1.00	0.0053
ITL-3-Slurry	07/19/02 12:05	ISS-TST-002 (composite)	1.02	4.1
ITL-3-Grab:12:13	07/19/02 12:13	Slurry Receipt Line (grab)	1.04	2.4
ITL-3-Grab:12:15	07/19/02 12:15	Slurry Receipt Line (grab)	1.02	5.2
ITL-3-Grab:12:35	07/19/02 12:35	Slurry Receipt Line (grab)	1.04	6.0
ITL-3-Grab:12:41	07/19/02 12:41	Slurry Receipt Line (grab)	1.01	3.2

A.4 ITL Series 4 Run

A.4.1 Objectives

A Bentogrout cap was placed over the K-65 surrogate in the surrogate material tank for the ITL Series 4 runs to simulate the Bentogrout cap in the silos. The K-65/Bentogrout ratio in the surrogate material tank was similar to that found in the top 15 ft of the silos. To simulate the actual conditions of the solids in the silos, the cap will vary from ~1 ft thick at the rounded end of the Tank to a few inches thick under the pump. The manufacturer's recommendations were followed to form a hard Bentogrout crust prior to starting the ITL Series 4 runs. The primary objectives of this series of runs were to (1) determine if the nozzle and pump configurations that proved effective in mobilizing the K-65 surrogate are effective in mobilizing the K-65/Bentogrout combination, (2) determine if the nozzle and pump configurations that proved effective in mobilizing the K-65 surrogate are effective in breaking up the Bentogrout cap, (3) verify the operation of the mass flowmeters and Isolok samplers on the K-65/Bentogrout combination, (4) determine the density and percent solids handled by the slurry pump during an integrated run with the K-65/Bentogrout combination from composite samples taken over the entire duration of the runs, (5) close the solids/water material balance for the Series 4 runs, and (6) verify the load on the slurry pump while operating with the K-65/Bentogrout combination.

A.4.2 Summary of Results

The Bentogrout cap was added to the surrogate tank the week of August 12, 2002. First, most of the free water was removed from the surface of the surrogate tank. Then, Bentogrout was mixed in the approximate proportion of 50 lbs of dry Bentogrout material to 14 gal of water. The Bentogrout mixture was then pumped onto the surface of the surrogate tank and allowed to cure for approximately 3 days. Also, a 2- to 3-ft mound of surrogate was placed under the pump and covered with Bentogrout to simulate the actual surface topography of the silos. Figure A.7 is a photograph of the surrogate tank surface prior to initiating Run ITL-4.

Fig. A.7. Surrogate tank covered with Bentogrout prior to Run ITL-4.

As described in the results of the ITL Series 2 Runs, the nozzle configuration chosen was to run two 280-gal/min (15/16-in.) nozzles operated alternately. Run ITL-4 was initiated by lowering the pump to within a few feet of the surrogate surface, starting the spray nozzles at a supply pressure of approximately 2300 psi, and observing the effect on the mound of surrogate under the pump. The spray nozzles appeared to readily cut through the Bentogrout cap.

The sluice water flow was then started and almost immediately cut through the Bentogrout cap and mobilized it to the sluice pump, demonstrating that this configuration should be very effective in handling the Bentogrout cap in the AWR application.

Most of the Bentogrout material in close proximity to the pump was removed in this one test (see Fig. A.8).

Fig. A.8. Surrogate tank covered with Bentogrout after to Run ITL-4.

One other major observation was noted during this test. The pump screen appeared to blind (see Fig. 4.3 in the body of this report). During the test, the slurry flow unexpectedly decreased and did not recover when by the pump speed was changed. The pump was lifted from below the water surface, and the screen appeared to be blinded with surrogate. The surrogate was readily removed with the sluice water flow. Process and analytical data are provided in Tables A.7 and A.8, respectively.

Table A.7. Process data from the ITL Series 4 runs

Run: ITL-4: Two 150 gpm nozzles operating simultaneously, spray ring used continuously. First run wiith Bentogrout.

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
08/20/02 14:30	146	266	1		0	132	101	152	1758	0	0	2	0	0	934	30.9	10336	2271
08/20/02 14:35	146	266	0		0	132	104	155	1758	41	882	3	94	0	928	32.3	10494	2312
08/20/02 14:38	146	266	0		0	132	103	155	1758	56	828	10	398	0	921	30.5	10593	2283
08/20/02 14:40	104	207	0		92	5	84	123	1524	55	846	10	426	0	917	32.4	10655	2289
08/20/02 14:46	143	265	0		129	5	101	153	1740	56	846	10	403	0	904	32.6	10844	2292
08/20/02 14:50	143	265	0		129	6	102	153	1740	56	846	9	419	0	896	30.8	10970	2283
08/20/02 14:55	22	116	0		18	5	40	22	627	56	846	9	434	0	887	31.8	11124	2315
08/20/02 15:01	134	254	0		4	121	96	143	1684	40	846	1	47	0	877	0	11247	0
08/20/02 15:06	146	266	0		4	132	103	156	1758	59	990	7	369	0	870	30	11334	2043
08/20/02 15:11	146	266	0		4	133	101	154	1758	57	990	7	376	0	864	30.1	11484	2043
08/20/02 15:15	0	0	97		4	1	0	0	0	56	990	7	384	1	858	28.5	11599	1664
08/20/02 15:20	0	0	67		4	0	0	0	0	63	1116	8	428	1	861	26.9	11737	1319

Table A.8.   Analytical data from the ITL Series 4 runs

Sample no.	Date/Time	Sample point	Density (g/mL)	Solids (wt %)
ITL4-Slurry	8/20/2002 14:20	Slurry receipt line (grab)	1.16	26.0
ITL4-Grab-14:34	8/20/2002 14:34	Slurry receipt line (grab)	1.32	39.8
ITL4-Grab-14:49	8/20/2002 14:49	Slurry receipt line (grab)	1.29	37.1
ITL4-Grab-14:56	8/20/2002 14:56	Slurry receipt line (grab)	1.23	32.3

A.5 ITL SERIES 5 RUNS

A.5.1 Objectives

The primary objective of the Series 5 run was to determine operational parameters typical of what would happen if the line on the discharge of the slurry pump becomes partially or fully blocked. In this test, VLV-TST-01 was closed in increments, the ITL system allowed to reach steady state, and the process parameters determined at each of the valve VLV-TST-01 positions.

A.5.2 Summary of Results

The Series 5 ITL run was conducted in conjunction with the ITL Series 7A run. Therefore, no process and analytical data for the ITL Series 5 runs are included here. The data for this series are included in the ITL Series 7A run data (see Sect. A.7).

A.6 ITL SERIES 6 RUNS

A.6.1 Objectives

The primary objective of the ITL Series 6 runs was to determine if the pump can handle debris that might be located in the site and that cannot be removed by long-handled tools.

A.6.2 Summary of Results

The debris added to the system included angle iron, a cinder block, plastic gloves, several sample bottles, a two-by-four, and a plastic bag of debris (see Fig. A.9). The results of the runs were uneventful. The debris could be easily manipulated with the spray nozzles and kept away from the slurry pump. The Hazelton representative did have a concern with the agitator potentially becoming entangled with a glove or piece of wire and recommended operating without the agitator. Process and analytical data are provided in Tables A.9 and A.10, respectively.

Fig. A.9. Debris added to the surrogate tank for Run ITL-6.

Table A.9. Process data from the ITL Series 6 runs

Run: ITL-6: Two 300 gpm nozzles operating alternately, spray ring used continuously (new nozzles). How is debris handled?

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
07/31/02 10:19	145	265	0		0	130	103	156	1758	0	0	1	0	2	882	33.7	5249	2297
07/31/02 10:24	142	262	0		0	128	103	154	1740	50	756	8	400	1	887	34.4	5416	2303
07/31/02 10:29	142	262	0		0	129	103	155	1740	40	756	1	60	2	893	34.7	5586	2283
08/01/02 10:34	142	264	0		128	6	102	153	1740	40	756	0	40	2	900	34.9	5765	2277
07/31/02 10:39	142	264	0		128	6	102	154	1740	49	756	7	395	2	909	33.9	5942	2300

Run: ITL-6B: Two 15/16" nozzles operating alternately, spray ring used continuously (new nozzles-Turbo Viper). How is debris handled?

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
08/07/02 09:17	0	0	1		0		0	0	0	0	0	1	1	0	928	30.1	7814	2225
08/07/02 09:20	145	268	1		131		101	153	1758	0	0	1	0	1	928	30.7	7908	2240
08/07/02 09:24	145	268	1		131		103	151	1758	0	0	1	0	0	928	29.9	8034	2260
08/07/02 09:25	145	267	1		131		104	157	1755	0	0	1	1	1	928	30	8065	2274
08/07/02 09:26	145	267	4		131		103	157	1758	43	936	3	21	0	928	32.4	8097	2277
08/07/02 09:27	145	267	0		131		104	156	1758	44	936	3	53	1	928	31	8129	2277
08/07/02 09:30	145	267	19		131		103	157	1758	41	936	2	75	1	930	31.4	8223	2260
08/07/02 09:31	145	267	21		131		104	157	1758	40	936	1	86	1	931	30.7	8254	2271
08/07/02 09:32	145	267	18		131		103	157	1758	41	936	1	91	1	932	31	8286	2286
08/07/02 09:34	145	267	0		130		103	156	1758	51	810	8	430	2	935	30.3	8349	2271
08/07/02 09:35	145	267	0		130		103	159	1758	49	792	8	406	2	937	31.5	8380	2283
08/07/02 09:36	145	267	0		130		103	159	1758	50	792	8	398	2	939	31.7	8412	2303
08/07/02 09:37	7	83	69		5		39	11	376	50	792	8	421	1	941	31.9	8443	2315
08/07/02 09:38	107	208	52		4		80	121	1531	50	792	7	424	1	942	31.6	8475	2260
08/07/02 09:39	145	265	88		5		103	155	1758	49	756	7	403	3	944	30.5	8507	2268
08/07/02 09:40	145	265	79		5		102	156	1758	49	756	7	397	2	946	31.7	8537	2286
08/07/02 09:42	145	265	0		5		103	155	1758	49	756	7	362	2	951	31.8	8601	2286
08/07/02 09:44	145	264	142		5		103	156	1758	49	756	7	402	3	957	30.8	8663	2303
08/07/02 09:45	145	265	118		5		102	155	1758	49	756	7	403	3	960	30.9	8694	2303
08/07/02 09:46	145	265	170		5		103	156	1758	49	756	7	395	3	963	32	8725	2283
08/07/02 09:47	12	84	128		5		39	13	462	50	756	7	404	1	966	30.6	8756	2289
08/07/02 09:52	108	229	244		97		80	116	1516	50	756	8	394	2	976	31.3	8941	2292
08/07/02 09:53	108	229	272		97		80	116	1516	51	756	8	393	2	976	30.7	8941	2254
08/07/02 09:54	0	0	341		0		0	0	0	50	756	8	381	0	977	26.7	8968	1453

Table A.10. Analytical data from the ITL Series 6 runs

Sample no.	Date/Time	Sample point	Density (g/mL)	Solids (wt %)
ITL-6-Grab-10:25	07/31/02 10:25	Slurry receipt line (grab)	1.13	13.8
ITL-6-Grab-10:40	07/31/02 10:40	Slurry receipt line (grab)	1.06	11.0
ITL-6-Sluice	07/31/02 10:20	ISS-TST-001 (composite)	0.92	0.0009
ITL-6-Slurry	07/31/02 10:20	ISS-TST-002 (composite)	1.04	16.3
ITE-6B-Grab-9:39	08/07/02 09:39	Slurry receipt line (grab)	1.14	19.0
ITE-6B-Grab-9:50	08/07/02 09:50	Slurry receipt line (grab)	1.17	23.1
ITE-6B-Sluice	08/07/02 09:40	ISS-TST-001 (composite)	0.95	0.0007
ITE-6B-Slurry	08/07/02 09:40	Slurry receipt line (grab)	1.09	16.0

A.7 ITL SERIES 7 RUNS

A.7.1 Objectives

The primary objective of the Series 7 runs was to cut the power to the ITL system during operation and determine how the system reacts to restarting after an uncontrolled shutdown. Two shutdowns were performed. The first was conducted after the ITL Series 5 runs, while the system contained K-65 surrogate only. The second shutdown was conducted after the ITL Series 4 runs, while the system contained a combination of K-65 surrogate and Bentogrout.

A.7.2 Summary of Results

In these runs, the system was operated to a point where the slurry flow was fully established (300–450 gal/min). In the case of Run ITL-5, the discharge valves to the collections were then incrementally closed. In the case of Runs ITL-7A and B, the slurry and sluice pumps were then stopped and the system allowed to sit idle for 15 min. These runs were noneventful. In the case of ITL Runs-7A and B, the system restarted immediately and no plugging or other problems were observed. In Run ITL-5, the discharge valve was slowly closed and other than a corresponding decrease in flow and an increase in discharge pressure, there were no other remarkable observations. Process and analytical data are provided in Tables A.11 and A.12, respectively.

Table A.11. Process data from the ITL Series 7 runs

Run: ITL-7A (Startup Following Off Normal Shutdown) and ITL-5 (Line Blockage Simulation): Two 300 gpm nozzles operating alternately, no spray ring.

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
07/22/02 10:03	150	238	1		0		104	157	1777	0	0	1	0	0	708	0	3365	0
07/22/02 10:06	50	134	1		0	46	51	58	1033	0	0	1	1	0	708	0	3365	0
07/22/02 10:11	150	238	25		0	139	105	159	1777	48	756	6	405	1	712	0	3365	0
07/22/02 10:11	150	238	27		0	139	104	160	1777	47	756	4	405	1	712	0	3365	0
07/22/02 10:11	94	202	111		0	139	74	99	1405	46	0	1	337	0	712	0	3365	0
07/22/02 10:26	0	1	1		0	139	53	4	136	0	0	0	0	0	712	0	3365	0
07/22/02 10:27	150	238	43		0	139	101	154	1755	48	756	7	178	1	712	0	3365	0
07/22/02 10:29	150	238	0		0	139	102	156	1777	40	756	0	253	1	713	0	3365	0
07/22/02 10:36	150	239	60		138		103	158	1777	49	756	6	406	1	722	0	3365	0
07/22/02 10:36	150	240	63		138		103	156	1777	46	666	5	356	2	724	0	3365	0
07/22/02 10:38	150	239	157		138		106	159	1777	48	666	6	352	2	728	0	3365	0
07/22/02 10:41	150	239	38		138		105	159	1777	43	666	11	124	2	732	0	3365	0
07/22/02 10:42	150	239	1		138		106	161	1777	43	666	12	1	2	737	0	3365	0
07/22/02 10:46	150	239	108		138		105	160	1777	51	828	8	436	2	741	0	3365	0
07/22/02 10:51	0	0	72		0		0	0	0	53	864	9	458	0	744	0	3365	0

Run: ITL-7B (Startup Following Off Normal Shutdown), Two 300 gpm nozzles operating alternately, no spray ring, bentogrout + K65.

	Inlet Line To Nozzles									Slurry Pump						Spray Ring		
Date/Time	PIT-PMP-12-200	FT-PMP-12-200	FET-TST-02A/B	FET-TST-02-Cumm	PIT-SLC-11-204	PIT-SLC-11-205	Load-PMP-301	%T	RPM-PMP-301	Load-PMP-300	RPM-PMP-300	PIT-SLR-11-200	FET-TST-01A	FET-TST-01B	FET-TST-1B-Cumm	FE-To-Spray Ring	FE-Cumm	PE-To-Spray Ring
	(psig)	(gpm)	(lb/min)	(lbs)	(psig)	(psig)	(amps)	(%T)	(rpm)	(amps)	(rpm)	(psig)	(gpm)	(lb/min)	(lbs)	(gpm)	(gal)	(psig)
08/22/02 14:21	147	268	0		132		101	153	1758	45	1044	2	84	31	897	32.3	11950	2306
08/22/02 14:22	147	268	35		132		102	156	1758	44	1044	2	111	23	927	31.9	11982	2268
08/22/02 14:28	2	34	8		1	132	39	19	312	40	1044	1	36	1	1123	31.4	12174	2283
08/22/02 14:31	149	265	4		5	132	104	159	1758	41	1044	1	25	65	1255	33.4	12267	2292
08/22/02 14:33	149	265	5		4	132	105	159	1758	41	1224	2	33	73	1391	30.7	12332	2277
08/22/02 14:44	0	0	1		4		0	0	0	0	0	1	0	0	1753	0	12576	6
08/22/02 14:47	149	264	59		4	132	103	156	1758	48	1044	3	237	86	1794	29.8	12609	1664
08/22/02 14:48	149	264	0		4	132	104	153	1758	56	1170	5	256	85	1879	29.5	12638	1649
08/22/02 14:50	149	265	0		4	132	104	159	1758	54	1170	4	253	85	2048	29.4	12696	1655
08/22/02 14:52	149	265	0		4	132	106	160	1758	53	1368	3	220	87	2220	29.6	12755	1675
08/22/02 15:11										60	1134	5	348					
08/22/02 15:15										60	1134	5	355					
08/22/02 15:16										0	0	0	0					
08/22/02 15:19										63	1134	7	404					
08/22/02 15:21										0	0	0	0					

Table A.12. Analytical data from the ITL Series 7 runs

Sample no.	Date/Time	Sample point	Density (g/mL)	Solids (wt %)
ITL-7A-Sluice	07/22/02 10:00	ISS-TST-001 (composite)	0.98	0.0018
ITL-7A-Slurry	07/22/02 10:00	ISS-TST-002 (composite)	1.04	6.4
ITL-7A-Grab-10:30	07/22/02 10:30	Slurry receipt line (grab)	1.07	9.2
ITL-7A-Grab-10:36	07/22/02 10:36	Slurry receipt line (grab)	1.08	12.3
ITL-7A-Grab-10:50	07/22/02 10:50	Slurry receipt line (grab)	1.01	2.2

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