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ENGINEERING DATA TRANSMITTAL

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16. KEY

Approval Designator (F)	Reason for Transmittal (G)	Disposition (H) & (I)
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1	1	Design Authority AG Westra	Per telecom DM Squier	6-1-99	R3-86	1	1	CA Petersen	CA Petersen	5/26/99	H0-34
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K-Basin Sludge Treatment Facility Pump Test Report

D. M. Squier
Numatec Hanford
Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

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Abstract: Tests of a disc pump and a dual diaphragm pump are stymied by pumping a metal laden fluid. Auxiliary systems added to a diaphragm pump might enable the transfer of such fluids, but the additional system complexity is not desirable for remotely operated and maintained systems.

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K-Basin Sludge Treatment Facility Pump Test Report

Introduction

The initial concepts for K-Basin sludge treatment delivered sludge batches to a processing facility. The facility required transfer pumps to move the sludge from one process vessel to another. The sludge contains mostly fine particles with some large heavy fuel particles. The difficult to pump fuel particles pose risks for a reliable sludge transfer system. This test effort was intended to identify the pump(s) most suitable for transferring untreated sludge for Sludge Treatment Project (A-13B).

Engineering study, HNF-3445, "Evaluation of Transfer Method and Instrumentation Applicable to Sludge Treatment Project" identified the disc pump, double diaphragm pump and eddy pump as pumps with promise for sludge transfer applications. The eddy pump vendor was adamant that they would perform all tests on the pump and were reluctant to sell a pump for the tests. The eddy pump was not included in the tests for this reason.

Test plan, HNF-3739, "K-Basin Sludge Treatment Facility Pump Test Plan" describes a series of tests on the three (two tested) pump types. The test plan included demonstrations of each pump's ability to transfer large heavy particles, measurement of pump damage to ion exchange resin beads and a pump endurance run. The flow rate that is required for transferring heavy particles defined the flow rate for the remaining tests. For this reason, the heavy particle transfer tests were performed first.

Many difficulties were experienced in efforts to pump the heavy particles. These efforts did not meet with successes that could be applied to remotely operated equipment. The test program was so stymied by these problems that the remaining measurements and demonstrations were not attempted. Alternate concepts for the sludge treatment process negated the need for completing the pump tests.

Fuel Particle Simulant

The K basin West canister removal and fuel wash station will produce a feed stream with the greatest concentration of fuel particles. The baseline concept collected large fuel particles in a knockout pot and delivered them to the treatment facility in a segregated batch. Appendix D of HNF-2735, "K Basin Sludge Treatment Process Description", gives a uranium metal concentration of 121.5 g/l for this feed stream. The fuel particle simulant was made from 6.35 mm ($^1/_4$ inch) diameter tungsten welding electrodes that were broken into pieces small enough to pass through a metal screen with 6.35 mm square openings but larger than 420 μm (0.0165 inch) square openings. Tungsten, with a density of 19,250 Kg/m^3, is a close match to the metallic uranium fuel having a density of 19,050 Kg/m^3.

Disc Pump Tests

A disc pump is comprised of two or more discs rotating within a case. The pump case looks similar to a centrifugal pump with the inlet located on the pump motor's centerline and the discharge located on a tangent to the circular rotor housing. The discs have a hole in the center to admit fluid from the suction inlet. Energy is imparted to the fluid by viscous drag between the rotating discs and the fluid.

The tests used a Discflo™,[1] model 2015-8, disc pack style 2HHD-8, serial number 3670, 1491 watt (2 hp) pump. This pump has a stainless steel pump body close coupled to the motor. The disc pack was constructed of two discs with low profile radial ribs on the opposing disc faces.

The disc pump's suction was fitted with a bell reducer to reduce the five cm (two inch) diameter inlet to a 2.54 cm (one inch) diameter. The pump was oriented vertically in a cone bottomed holding tank so that the suction inlet was 0.95 cm ($^3/_8$ inch) above the tank bottom. The bell reducer increases the suction velocity so that heavy particles could be drawn into the pump. This arrangement simulates the early treatment facility concept of submerged pumps within the tanks. The test system's holding tank could be filled with water to provide 23.3 cm (9.19 inches) of water head at the pump's reduced inlet.

[1] Discflo is a trademark of Discflo Corporation.

The pump discharge was fitted with a pressure gauge and a throttle valve. A pump curve was developed by incrementing the throttle valve and recording the pressures and water flow rates. The volume captured in a measured amount of time yielded the flow rates. These measurements suggested that the pump would not produce high enough velocities in the tubing to lift the fuel particles.

The pump vendor did not supply complete documentation with the equipment. Late arriving information indicated the pump needed a Net Positive Suction Head (NPSH) of 91 cm (three feet). The test system was reconfigured to provide the required NPSH as shown in Figure 1. The test system is shown as configured to collect pump curve data with a throttle valve and hose mounted pressure gauge. The pump suction was initially a 2 inch pipe from the tank to the pump inlet, but the flow velocity was too low to move the simulated fuel particles through the pipe and into the pump. The image shows a later modification with a 1 inch tubing sweep leading into the pump to increase the fluid velocity.

Figure 2 is a plot of the pump curves for both the in tank and external to tank pump configurations. Calculations have estimated a water flow rate in excess of 29.5 liters per minute (7.8 GPM) are required to lift the large heavy fuel particles in the 1.9 cm ($^3/_4$ inch) tubing. Flows above the figure's horizontal dashed line exceed the minimum volume flow rate threshold. Eight meters is the maximum pumped height requirement for the treatment facility. The vertical dashed line represents the pressure produced by an eight meter high water column or the minimum pump pressure. Traces in the upper right quadrant of the plot fall within the estimated operating parameters.

Figure 1 Disc Pump Test System

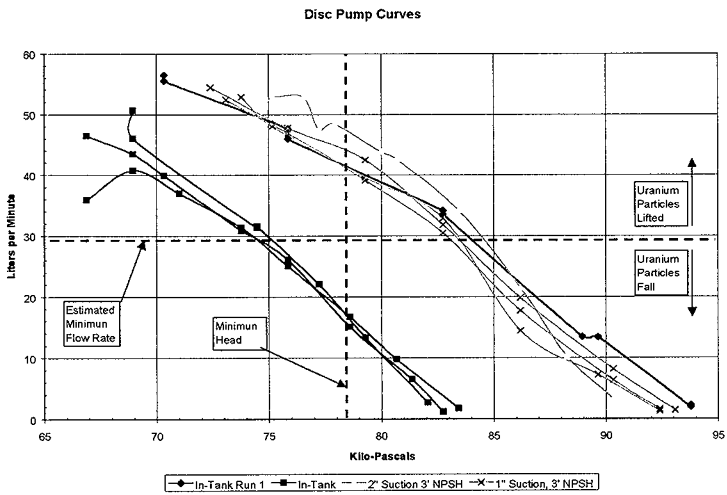

Figure 2 Disc Pump Curves

The first set of pump curve data (In-Tank Run 1) collected with the pump in tank configuration falls in the same operating range as the curves generated with the system configured for a 0.9 meter (three foot) NPSH. This result was not duplicated in three other in-tank pump curve runs. The lower performance in-tank curves were made under three different conditions. One was made with the bell reducer removed; the remaining two were made with the bell reducer installed, but with a 7 cm (2.75 inch) difference in water elevation to investigate the effect of changes in NPSH. The difference between these curves does not warrant distinguishing them on the plot.

Figure 2 also shows a decrease in flow rates when the suction line was changed from a 2 inch schedule 40 pipe to a 1 inch tube. Tungsten particles dropped into the tank fell to the lowest part of the 2 inch 90° elbow and remained there. The suction line was changed to a 2.2 cm inside diameter (1 inch, 0.065 wall) tube so that tungsten particles would be drawn into the pump. Three pump curves were generated with the 1 inch tube suction to serve as a baseline to detect if the pump suffered degradation from the test series.

A pump test loop was constructed of 1.7 cm inside diameter ($^3/_4$ inch, 0.035 wall) tubing. The tubing up flow leg is topped by a U bend that directs the flow down. The open end of the U bend is eight meters (26 ft) above the floor to match the treatment facility's maximum elevation change. The fluid is discharged from the U bend into a two inch PVC pipe that returns the fluid to a holding tank and pump at the floor elevation. An air gap between the tubing and pipe provides a siphon break between the test loop's up flowing and down flowing legs.

The water flow rate through the test system was measured as 25.9 liters per minute (6.9 gal/min). Tubing losses through the test system could account for the increased pressure requirements and reduced flow rates from the idealized values presented in Figure 2. Individual tungsten particles were thrown into the holding tank and lifted through the test loop via the pump. This result shows that the estimated minimum required flow rate exceeds the actual minimum value.

The holding tank was filled with 20 liters of water and 2400 grams of tungsten to simulate the 120g/l uranium laden feed stream. A fine screen placed between the return piping and the holding tank collected the tungsten that had made the trip through the test loop. The first run did not produce any tungsten movement through the test loop. The tungsten had jammed in the 1 inch suction tube as it was poured into the holding tank.

Greater success was obtained by installing a plug in the bottom of the tank and attaching an air powered vibrator to the suction line. The vibrator was set to provide lower frequency vibrations. The plug is pulled while simultaneously starting the pump. It was possible to move tungsten quantities through the loop, but the pump made coffee grinder sounds or stalled due to tungsten chunks wedged between the housing and the radial ribs. The sharp edges were worn off the tungsten particles collected in the screen. These characteristics were judged unacceptable and further disc pump tests were abandoned.

Dual Diaphragm Pump Tests

A Warren Rupp, Sandpiper model SA1-A, type DI4SS, dual diaphragm air powered pump was the second pump subjected to the tungsten particle pumping tests. The pump has a diaphragm at each end of a common shaft. A chamber encloses both sides of each diaphragm. One side of each diaphragm is subjected to pressurized air that displaces the diaphragm into the fluid chamber on the opposite side. This forces the pumped fluid from the chamber. The diaphragms are alternately pressurized by air so that the common shaft will pull the unpressurized diaphragm out of a fluid chamber to drawn in additional fluid. One fluid chamber expels fluid while the other chamber draws in fluid.

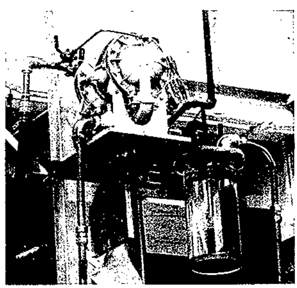

Figure 3 Dual Diaphragm Pump

Each fluid chamber is connected to a valve body that contains inlet and outlet flapper valves. The two valve bodies are adjacent to each other on the pump underside. Common inlet and outlet plenums direct the flow into and out of the valve bodies.

The sludge treatment facility's pump installation concept had changed from a pump within a vessel to a pump above a vessel. This arrangement placed the pumps in a separate room 5.2 meters (seventeen feet) above the room containing the process vessels. The elevated pumps would allow fluid to drain back into the vessels and possibly permit hands on replacement or service should a pump fail.

A new test system was constructed to elevate the double diaphragm pump 5.2 meters above the floor. The fluid was pumped from a cone bottomed holding tank on the floor elevation. The pump must be primed to draw fluid from the tank. Figure 3 shows the tubing modifications required for priming. Water is supplied to the fluid chambers though existing threaded ports. Two isolation valves are necessary, one must separate the fluid chambers from the water source and the other must isolate the fluid chambers from each other. Separate valves isolate the fluid chambers from the water supply in this installation. The isolation valves are opened and water fills the fluid chambers and valve bodies while discharging excess water from the outlet tubing. Air pressure is applied to the pump while the water isolation valves are closed to begin the pumping process. This is also an effective means to flush most particles out of the pump. Particles lodged in the inlet flapper valves or in the inlet plenum are not flushed by the priming system.

The pump works quite well for lifting tungsten particles from the tank. The large internal pump volumes reduce the local flow rates so that the tungsten collects in the pump cavities. The pump soon becomes filled and plugged with the heavy particles. As a result, very few particles are delivered out the pump discharge port.

Figure 3 also shows the pump with a clear knock out pot installed in the suction line. The knock out pot excludes the heavy particles from the pump internals. It was envisioned that the collected particles could be transferred from the knock out pot to the next vessel by gravity feed. The pump would not run reliably with this arrangement. As a pump run progressed, the tungsten content increased to a point the pump could not move the denser fluid.

Efforts were made to measure the maximum height the pump could reliably transfer the tungsten particles. The pump was tested in two foot elevation increments, starting with the pump three feet above the holding tank to the maximum height of seventeen feet. Inconsistent methodology doomed this effort to identify the maximum reliable pumping height. The tungsten was held in a beaker under the pump's suction tubing. If the pump were fed small slugs of tungsten then the metal would be carried to the knock out pot, otherwise the metal laden fluid would overwhelm the pump. The fluid's metallic content must be controlled and limited to reliably draw the heavy particles up the tested elevations.

Conclusions and Observations

The disc pump required a six to eight week procurement lead time. The disc pump was specified for a flow that would lift the heavy particles in 1.27 cm ($^1/_2$ inch) tubing. A test system change to 1.7 cm tubing was made to minimize plugging late in the procurement cycle. This resulted in the use of a pump that produced marginal tubing velocities for lifting the heavy particles.

The disc pump's radial rib ends created a source of interference with the pump body and hard particles passing through the pump. The ribs are intended to increase the pump's output head. If the treatment facility's pump head requirements are reduced, a rib less disc pump may warrant consideration.

The tested disc pump required a NPSH of 91 cm. This particular pump is not suitable for use in an application that elevates the pump above the fluid vessel.

Heavy particle transport in a fluid medium requires a high velocity. The heavy particles will settle and collect, possibly forming plugs, where the velocities are low. Flow paths with large cross sections create low velocity areas. In this test series, the larger cross sections were contained within the pump bodies. For systems that pass all particles through the pump, the pump body velocity is likely to be the velocity that controls the ability to move large heavy particles through the transport system.

A uranium metal concentration of 121.5 g/l requires liquid recirculation to carry away a batch's total metal content. Large metal particles traveling through metal tubing makes a characteristic sound that might be monitored to determine when all the metal is extracted from the pumped vessel.

DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	Engineering Laboratories	Date 5/26/99
Project Title/Work Order		EDT No. 157836
K-Basin Sludge Treatment Facility Pump Test Report		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
AG Westra	R3-86	x			
DM Squier	L6-13	x			
MJ Schliebe	L6-13	x			
CA Petersen	H0-34	x			
WW Rutherford	H0-34	x			
FW Moore	H0-34	x			
KL Pearce	H0-34	x			
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