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Revision 0

Advanced Sluicing System Test Report for Single Shell Tank Waste Retrieval Integrated Testing

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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Los Alamos Technical Associates, Inc.

Date Published
April 1997

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ADVANCED SLUICING SYSTEM TEST REPORT FOR SINGLE SHELL TANK WASTE RETRIEVAL INTEGRATED TESTING

Prepared By:

LOS ALAMOS TECHNICAL ASSOCIATES, INC.
Richland, WA

Under Purchase Order MJS-SLD-C15104
Revision 1
April, 1997

ABSTRACT

This document describes the testing performed by ARD Environmental, Inc., and Los Alamos Technical Associates of the LATA/ARD Advanced Sluicing System, in support of ACTR Phase 1 activities. Testing was to measure the impact force and pressures of sluicing streams at three different distances, as measured by the Government supplied load cell. Simulated sluicing of large simulated salt cake and hard pan waste coupons was also performed.

Due to operational difficulties experienced with the Government supplied load cell, no meaningful results with respect to sluice stream impact pressure distribution or stream coherence were obtained. Sluice testing using 3000 psi salt cake simulants measured waste retrieval rates of approximately 12 m^3/day (17.6 ft^3/hr. Rates as high as 314 m^3/day (463 ft^3/hr) were measured against the lower strength salt cake simulants.

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1.0 INTRODUCTION

During the months of October, and November of 1996, testing in support of Track 1, Phase 1, of the Hanford Acquire Commercial Technology for Retrieval (ACTR) effort was conducted by ARD Environmental (ARD), Los Alamos Technical Associates (LATA), at ARD's facility in Laurel, Maryland. Pacific Northwest National Laboratories (PNNL) provided support for force testing of the nozzles using a government supplied load cell, with SGN Eurisys Services Corporation (SESC) in attendance for test observation. The testing performed established estimated rates of tank waste retrieval for the LATA/ARD Advanced Sluicing System (LAASS).

Testing was conducted in two phases. The first phase was to measure sluice stream impact (recoil) forces, pressures, and sluice stream coherence of the 1" and 1¼" nozzles proposed for use in the LAASS. In addition, baseline performance data for the past practice sluice nozzle was to be obtained. These data were to be acquired using the government supplied load cell. Based on the data obtained from the force testing, a determination was to be made as to which two nozzles to carry forward into simulated sluice testing. However, as a result of operational difficulties experienced with the load cell, no quantitative data of nozzle performance, or stream coherence were obtained.

The second phase of testing used the two nozzle configurations proposed for use with the LAASS, and used them to sluice large coupons of salt cake and hard pan waste matrix simulants. Based on the data obtained from these tests, estimated waste retrieval rates for the salt cake and hard pan waste simulants are established.

The second phase of testing also evaluated the effectiveness of a pump in keeping the surface of the waste exposed to the sluice stream, and conveying dislodged waste from the test container, while operating at discharge head pressures greater than those anticipated during operation in Hanford's aging waste tanks.

2.0 DESCRIPTION OF TEST

A diagram of the test logic is included as Appendix A.

A detailed description of the test methods, equipment, and system configuration is provided in Section 3.

2.1 NOZZLE FORCE TESTING

This testing was intended to evaluate the resulting impact pressure and total force applied to a target at various stand-off distances, by a stream flowing through the existing 1 in. Hanford sluice hardware, and a 1 in. diameter bore nozzle at 350 G.P.M. In addition, the resulting recoil force and pressure peaks for the stream from an 1 1/4 in. diameter bore nozzle operating at 500 G.P.M. was to be evaluated.

Data were to be obtained for each of the three systems at stand-off distances of 100 nozzle diameters, 35 ft, and at approximately 50 ft.

2.2 SIMULATED SLUICE TESTING

Testing was performed to evaluate the effectiveness of 1 in. and 1¼ in. diameter bore nozzles at dislodging, and mobilizing the waste in Hanford waste storage tanks. In addition, the ability of a pump to convey the mobilized waste from the tanks at flow rates in excess of sluice stream flow rates was assessed.

3.0 TEST METHOD AND EQUIPMENT

3.1 NOZZLE FORCE TESTING

The test hardware configuration for nozzle force testing using the government supplied load cell is shown in Figure 1. The methodology employed for force testing was to first, perform a gross "sighting-in" of the nozzle being tested on the load cell. The sluice pump was then brought on-line, and further positioning of the jet's point of impact on the load cell was performed, until the stream appeared centered on the target.

With the pump shut down, the load cell was then covered with a piece of pressure sensitive film. A "test shot" was then made, and the position of the stream relative to the center of the target determined. Final adjustments were then made to the relative position of the target and nozzle based on the measurements obtained from the pressure film.

Once the stream was verified to be located in the center of the target, the sluice pump was brought to speed, and allowed approximately 45 seconds to reach a steady-state operating condition. Impact force and pressure data were acquired from the load cell by PNNL on a lap top computer using Lab View software. Concurrently, data for nozzle flow rates were obtained from Doppler flow meters in the monitor supply line, and supply line pressure data from a pressure transducer, and recorded on an ARD computer using Lab View software.

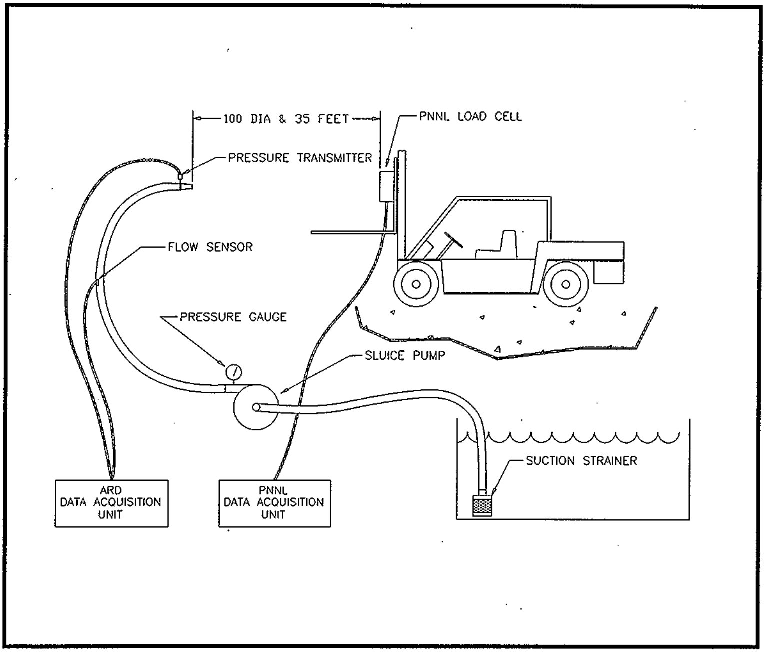


Figure 1. Force Test Configuration Using the Government Supplied Load Cell.

3.2 SIMULATED SLUICE TESTING

3.2.1 Prepare Test Coupons

Waste simulant test coupons were prepared in accordance with Hanford supplied recipes, and poured in place in dumpsters approximately 7 ft wide, and 22 ft long. Required cure times for all simulants used were observed, and a concerted effort made to limit evaporation until testing was initiated.

3.2.2 Establish Test Hardware Position

The test hardware configuration for the simulated sluice testing is shown in

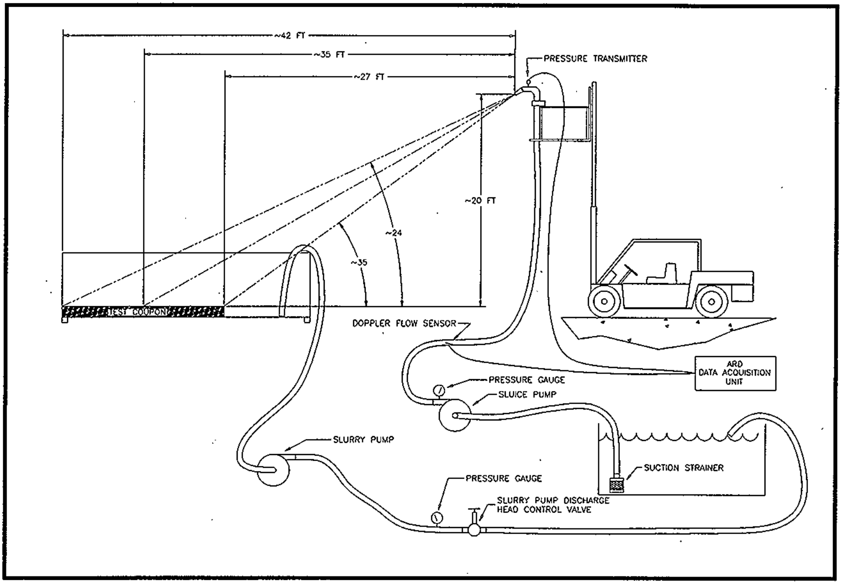


Figure 2. Simulated Sluice Testing Hardware Configuration.

Figures 2 , and 3 . The methodology employed for the simulated sluice testing was to establish the nozzle location relative to the centerline of the test coupon. This was accomplished by using a tape measure and positioning the nozzle (now mounted to the forklift) the required horizontal distance from the test coupon centerline. The forklift mast was then raised to its maximum elevation, and the distance from the nozzle tip to the ground determined. Finally, the change in elevation (a result of test location grade) between the center of the test coupon, and the nozzle tip was accounted for, to establish actual test configuration.

3.2.3 Determine Test Coupon Density and Dimensions

Using a 25 ft tape measure, the length and width of the simulated waste test coupon were measured. Similarly, a measurement of the nominal depth of the coupon was made. Using these data, a value for the total volume of the coupon was determined.

A sample of the coupon was then obtained from a top edge of the simulant. The sample was weighed, and its volume obtained by immersing it in a container of water, and

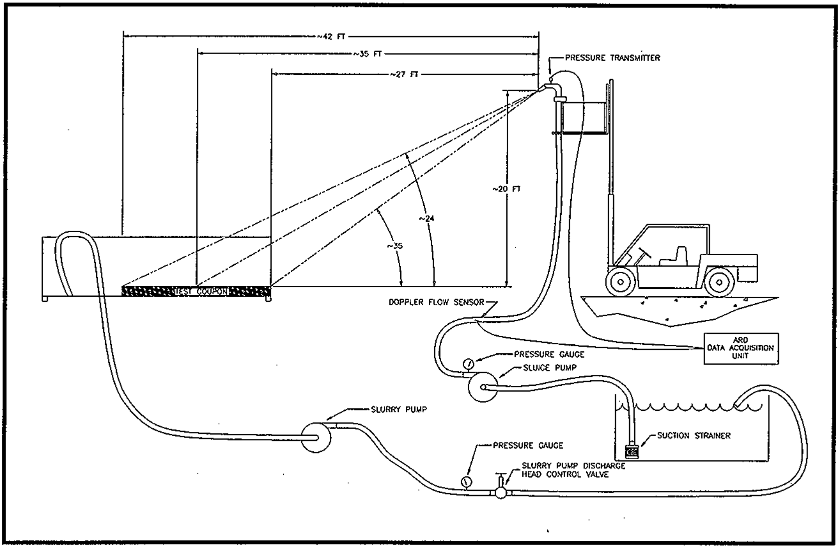


Figure 3. Simulated Sluice Testing Hardware Configuration.

measuring the change in water elevation. This was the only practical method of obtaining a volume for the prepared simulant test coupons, and worked well in most cases. Using the sample volume, and weight, the density could be calculated and compared against desired values. The measured and calculated values for the waste matrix simulants used are included as Appendix B.

3.2.4 Record Sluice Water Temperature/Totalizer Readings

Prior to the commencement of sluicing, sluice water temperature was measured, and the totalizer's initial reading were recorded as applicable.

3.2.5 Sluicing of Test Coupon

With all prerequisite information recorded, and the test configuration established, sluicing of the test coupon commenced. First, the sluice pump supplying the nozzle was brought to speed, and then the slurry pump used to remove water from the test coupon container. Start and stop times for sluicing were recorded using a wrist watch.

Once a steady state flow was established for the slurry pump, a gate valve in the discharge hose was closed sufficiently to establish a 150 psi back pressure (approximately 350 feet of head) in the line.

The ARD data acquisition system was used to record flow rates from the slurry and sluice pumps and the supply pressure to the nozzle. When available, a totalizing flow meter was used in the supply to the monitor to determine flow.

Sluicing of the test coupon continued until the coupon had been removed, or was interrupted to allow close inspection of the test coupon to make a subjective evaluation of sluicing performance.

3.2.6 Measurements and Observations at Conclusion

At the conclusion of sluice testing, final totalizer readings, recirculated sluice water temperature, and any other pertinent observations were recorded.

4.0 TEST RESULTS

4.1 FORCE TESTING

Due to difficulties experienced with the Government supplied load cell, the only impact force data obtained was for a 1 in. nozzle at 100 nozzle diameters. Test conditions and results are shown in Table 4-1 (data sheets pages D-2 through D-4). No other impact force or pressure data from the load cell for the nozzles and flow enhancement devices tested is available. Data sheets for the force testing performed using the supplied load cell are included in Appendix D.

Table 4-1. Measured Impact (Recoil) Force at 100 Nozzle Diameters.

NOZZLE DIAMETER (in)	NOZZLE PRESSURE (psi)	FLOW RATE (G.P.M.)*	IMPACT OR RECOIL FORCE (lb)
1	152	288	233.9

* Measured by doppler flow meters.

4.2 SIMULATED SLUICE TESTING

Simulated sluice testing began with the 1¼ in. nozzle and was run against the SC-3, SC-4, and HP-1 simulants, as prescribed by the test logic diagrams. Results for the testing are summarized in Table 4-2 for the 1¼ in., and for the 1 in. Observations, and other pertinent data are recorded by test below.

4.2.1 SC-1 Simulant, 1¼ in. Nozzle

4.2.1.1 Test Configuration. The pumping system was placed in front of the test coupon, and sluiced material would flow from the back of the dumpster toward the suction point, as shown in Figure 2. The nozzle elevation above the top of the simulant coupon was approximately 19 ft. The waste simulant coupon was poured into two different forms and allowed to cure, covered, inside the building.

4.2.1.2 Observations. (Data sheet pages E-2 and E-3). As sluicing commenced, rapid progress was made on removing the test coupon. Subjectively it appeared that the coupon volume was reduced by about half during each hour of operation. During the final 2 hours, sluicing effectiveness appeared to be more a function of test geometry. It was necessary to keep sufficient water in the dumpster to keep the slurry pump from air locking, which covered the remaining simulant, dissipating the energy imparted by the sluicing stream.

Testing was finally stopped with approximately 2 cubic feet of broken simulant pieces remaining in the container. Sluicing was not efficient as this point, as the sluicing stream forces rattled the remaining simulant chunks around like peas in a jar. At the conclusion of testing, the Slurry pump was able to pump the fluid level in the dumpster down to within approximately 1 in. of the bottom, or sufficient to meet presently required clean out levels assuming a uniform 1 in. distribution of waste remaining on the tank floor.

Finally, it appeared that the test coupons properties were stratified, as evidenced by retrieval rates and simulant appearance. Simulant farther from an air interface seemed to have much greater strength than that at the bottom of the coupon. A piece of simulant from the bottom of the coupon was compared with a sample of SC-1 (3000 psi compressive strength), and appeared similar. The prevailing theory is that during the 14 day cure required, moisture from the elevated regions of the coupon seeps down to the lower portions, reducing the grain size of the K-mag, and resulting in a more cohesive mixture.

4.2.2 SC-4 Simulant, 1¼ in. Nozzle

4.2.2.1 Test Configuration. For this test, the slurry pump was placed behind the coupon as shown in Figure 3, allowing the sluice nozzle to push the waste to the pump. The nozzle elevation above the top of the simulant was approximately 16 ft 3 in. A 4 in. in-line totalizing turbine flow meter was place in the supply line to the sluicing nozzle. Lumber (2 X 10) used to close off the front of the dumpster and retain water protected about 5 cubic feet of simulant from being washed to the slurry pump.

Table 4-2. Simulated Sluicing Test Results Summary.

SIMULANT	SIMULANT STRENGTH (psi)*	NOZZLE DIA. (in.)	NOZZLE PRESSURE (psi)	NOZZLE FLOW RATE (GPM)	WATER TEMP. (°F)	TOTAL LIQUID VOLUME DELIVERED TO TARGET (Gal)**	TOTAL OPERATING TIME (min)	WASTE VOLUME REMOVED (cu ft.)	OVERALL RETRIEVAL PRODUCTION RATE (ft³/hr)
SC-1	3000 C	1¼	90	440	58	140,800	320	93.75	17.58
SC-4	8 C	1¼	95	452	58	5,876	13	100.00	461.54
HP-1	4.6 S	1¼	97	455	60	25,480	56		
			77	405	60	6,885	17		
	TOTAL FOR	HP-1				32,365	73	59.90	49.23
HP-2	21.8 S	1¼	91	443	45	107,206	242	1.00	0.25
SC-1	3000 C	1	112	314	43	16,642	53	29.00	32.83
SC-3	1500 C	1	112	314	43	10,990	35	30.00	51.43
HP-2	21.8 S	1	110	312	45	74,880	240	6.00	1.50

Notes:

* Per ACTR Recipes, C=Compression, S = Shear

** Calculated from flow rate and operating times

See Figures 2 and 3 for test configuration.

4.2.2.2 Observations. (Data sheet page E-4). Once again, the water covering the test coupon to prevent the slurry pump from air locking, served to dissipate the energy of the sluicing stream, and prevented the sluice nozzle operator from working the sluicer in the most effective manner due to a lack of visability. At the conclusion of testing, the slurry pump was able to pump the fluid level in the dumpster down to within approximately 1 in. of the bottom, or sufficient to meet presently required clean out levels assuming a uniform 1 in. distribution of waste remaining on the tank floor.

4.2.3 HP-1 Simulant, 1¼ in. Nozzle

4.2.3.1 Test Configuration. For this test the slurry pump was placed behind the coupon, as shown in Figure 3, allowing the sluice nozzle to push the waste to the pump. The nozzle elevation above the top of the simulant was approximately 16 ft 9 in. A 4 in. in-line totalizing turbine flow meter was place in the supply line to the sluicing nozzle. Lumber (2 X 10) used to close off the front of the dumpster and retain water protected about 4.5 cubic ft of simulant from being washed to the slurry pump. Test coupon thickness was only 9 in. thick, the result of a shortage of plaster used to make up the simulant.

4.2.3.2 Observations. (Data sheet pages E-5 and E-6). At the conclusion of testing, the slurry pump was able to pump the fluid level in the dumpster down to within approximately 1 in. of the bottom, or sufficient to meet presently required clean out levels assuming a uniform 1 in. distribution of waste remaining on the tank floor.

4.2.4 HP-2 Simulant, 1¼ in. Nozzle

4.2.4.1 Test Configuration. The pumping system was placed in front of the test coupon, and sluiced material would flow from the back of the dumpster toward the suction point, as shown in Figure 2. The nozzle elevation above the top of the simulant coupon was approximately 17 ft 4 in. The waste simulant coupon was poured into two different forms and allowed to cure, covered, inside the building. Each form was 4 ft X 8 ft, and contained 32 cubic feet of simulant. These forms were set end to end in the dumpster. Lumber (2 x 10) were placed at the front of the dumpster to retain the water during testing.

4.2.4.2 Observations. (Data sheet page E-7). The water stream was directed into the test bed in a concentrated area for the first hour of testing. It did not appear that the water was having any significant effect on the material. The water stream would, from time to time, dislodge a large chunk of simulant from the coupon, creating an opportunity for the stream to be directed at a fissure in the material. This in turn enabled some of the material to be broken off in large pieces.

Once simulant had been dislodged however, it was not possible to trap the waste against the pump and further reduce the size of the waste sufficiently to allow its conveyance from the container by the slurry pump. The slurry pump was able to maintain water levels within the dumpster down to a maximum depth of approximately 1 in., with 1 inch of water remaining in the container at the conclusion of testing.

4.2.5 SC-1 Simulant, 1 in. Nozzle

4.2.5.1 Test Configuration. For this test, the equipment and test coupon were configured as shown in Figure 2. The nozzle elevation above the top of the simulant coupon was approximately 17 ft 5 in.

4.2.5.2 Observations. (Data sheet page E-9). The water stream was directed into the test bed in a concentrated area for the first five minutes of testing. During this time the water began to break-up and dislodge material from that point. This was observed by the change in the angle of the back spray leaving the coupon. Since the water appeared to break the material it was then directed onto various locations on the coupon to dislodge the material for conveyance. The water stream would, from time to time, dislodge a large chunk of simulant from the coupon and create an opportunity for the stream to be directed at a horizontal work face. When this occurred the water would break the material more effectively and efficiency increased. The entire coupon was dislodged from the form and additional time was spent attacking large pieces to aid conveyance. Upon completion of the testing, only small chunks of material remained, and these were tossed about by the force of the water.

The slurry pump was able to maintain water levels within the dumpster down to a maximum depth of approximately 1 in. , with 1 inch of water remaining in the container at the conclusion of testing.

4.2.6 SC-3 Simulant, 1 in. Nozzle

4.2.6.1 Test Configuration. For this test, the equipment and test coupon were configured as shown in Figure 2. The nozzle elevation above the top of the simulant coupon was approximately 17 ft 3 in.

4.2.6.2 Observations. (Data sheet page E-10). The water stream was directed into the test bed in a concentrated area for the first minute of testing. During this time the water began to break-up and dislodge material from that point. This was observed by the change in the angle of back spray leaving the coupon. Since the water appeared to break the material, it was then directed onto various locations on the coupon to dislodge the material for conveyance. The water stream would, from time to time, dislodge a large chunk of simulant from the coupon and create an opportunity for the stream to be directed at a horizontal work face. When this occurred, the water would break the material more effectively and efficiency increased. The entire coupon was dislodged from the form and additional time was spent attacking large pieces to aid conveyance. Upon completion of the testing only small chunks of material remained, and these were tossed about by the force of the water. The 1500 psi salt cake simulant was easily dislodged and conveyed.

The slurry pump was able to maintain water levels within the dumpster down to a maximum depth of approximately 1 in. , with 1 inch of water remaining in the container at the conclusion of testing.

4.2.7 HP-2 Simulant, 1 in. Nozzle

4.2.7.1 Test Configuration. For this test, the equipment and test coupon were configured as shown in Figure 2. The nozzle elevation above the top of the simulant coupon was approximately 17 ft 4 in.

4.2.7.2 Observations. (Data sheet pages E-8). The water stream was directed into the test bed in a concentrated area for the thirty minutes of testing. It did appear that the water was breaking some of the material by the fragments contained in the spray which left the dumpster. The water stream would, from time to time, dislodge a large chunk of simulant from the coupon and create an opportunity for the stream to be directed at a fissure in the material. This in turn enabled some of the material to be broken off in both large (>6 in. diameter) and smaller (<1 in. diameter) pieces.

Once simulant had been dislodged however, it was not possible to trap the waste against the pump and further reduce the size of the waste sufficiently to allow its conveyance from the container by the slurry pump. The slurry pump was able to maintain water levels within the dumpster down to a maximum depth of approximately 1 in., with 1 inch of water remaining in the container at the conclusion of testing.

4.3 ADDITIONAL OBSERVATIONS

During density measurements of the coupon, when cold water from the tap was used to measure the SC-1 coupon sample volume, it took overnight for the sample to break down sufficiently for disposal. A later test of a sample from the lower regions of the same coupon was made to determine if there was any measurable differences in density. Hot water from the tap was used and it was noted that the sample had completely broken down within a couple of hours.

This indicates that for the waste simulants, the water temperature used will have a significant effect on apparent retrieval rates. To what extent the solubility time constant for the simulants is affected by temperature is unknown. The testing performed at ARD did not attempt to evaluate it. However, based on the water temperature used for simulated sluicing, the retrieval rates, and the solids in the sluice pump supply tank (conveyed there via the slurry pump), the removal of the simulants during testing is believed to have been a result of the mechanical energy imparted by the stream, and not by dissolving of the waste.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Sluicing is an efficient and cost effective method of removing large amounts of waste from the single shell waste tanks. Against the "hardest" Salt Cake waste simulants, at the maximum stand-off distances, sluicing was able to dislodge, mobilize, and convey waste at rates greater than 7.2 m^3 per day , at sluicer flow rates and pressures considered to be less than optimal (maximum force and velocity intended). The inability to test the nozzles at full flow does not represent any inherent capacity limitations for the system, but is more a reflection of the condition of the rental hardware.

Results for testing against the Hard Pan simulants were mixed. Retrieval rates measured against the HP-2, strongest of the two simulants, were only about 1.5 ft^3/hr using the 1 in. nozzle, and 0.25 ft^3/ hr for the 1¼ in. Although the nozzle(s) were able to dislodge and mobilize the waste, the inability to reduce the waste chunks broken from the test coupon to sizes small enough to be accomdated by the slurry pump is believed to be the primary cause for the relatively low retrieval rates. Finally, the amount of material removed may have been affected to some extent by the test configuration, which placed the slurry pump between the sluicing stream and the test coupon. This prevented using the energy available in the sluicing stream to drive the waste simulant into the pump suction.

The LAASS slurry pump tested proved itself capable of removing liquids at a rate meeting or exceeding that of the sluice system flow rates, and handling solids, while pumping against a discharge head of 150 psi (~340 ft head). At the conclusion of each test, the slurry pump was able to remove all the water in the container, with the exception of the final 1", at which point the pump suction was exposed to air.

Adequate vision systems will significantly improve sluicing performance by allowing operators to direct the sluice streams within the tank as required to optimize waste retrieval rates. It will also allow operators to develop and implement a sluicing strategy based upon visual evidence of waste type, sluice system and waste tank configurations.

5.2 RECOMMENDATIONS

Phase 2 testing should focus on the following issues:

5.2.1 Slurry Pump Configuration/Selection

The most significant factor affecting the hard pan simulant retrieval rates was the inability to "trap" the waste in a location where it could be broken down sufficiently in size to allow its conveyance from the tank by the slurry pump. Design features could be provided as part of the slurry pump which would trap the waste, and provide for its mechanical size reduction using the energy of the sluicing stream as the motive force.

The other issue to be resolved is the selection of design features required to prevent the slurry pump from air locking during operation, thus keeping the surface of the waste exposed to the full impact of the sluicing stream.

5.2.2 Threshold pressures for waste mobilization

Testing during phase two should determine the minimum hydraulic pressure required for mobilization of the waste simulants. This information would be input into the design of the advanced sluicing system, and would effect not only nozzle flow rates and corresponding discharge pressuress, but also the configuration of the mast used for sluicer deployment.

5.2.3 Vision Systems

It is recommended that a contrast enhanced vision system be evaluated as part of phase two testing. The selection of a vision system which will provide operators with real time information regarding waste type, waste tank configuration, and sluicer performance will allow them to develop and implement a sluicing strategy that optimizes the systems retrieval rate.

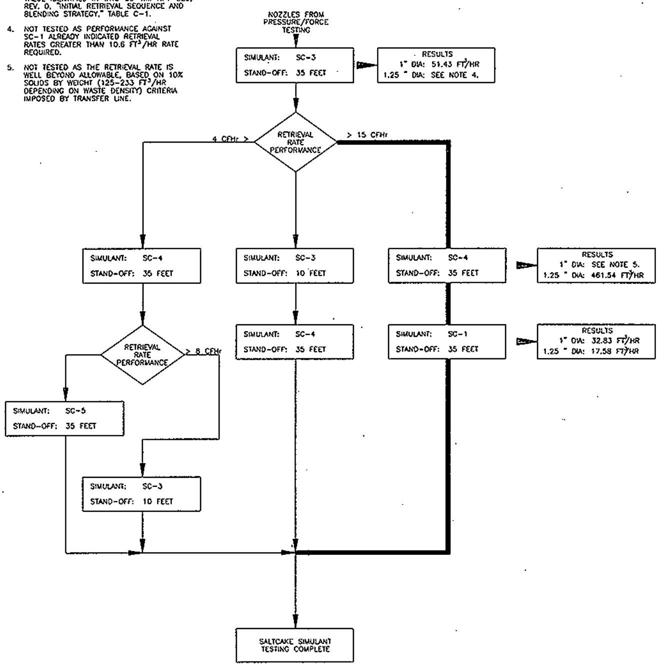
ATTACHMENT A

TEST LOGIC DIAGRAM

GENERAL TEST NOTES

1. FOR ALL SLUICE TESTING, FOR RETRIEVAL RATES GREATER THAN 8 CFHr, SLUICE COUPON TILL GONE. OTHERWISE, SLUICE 8 HOURS, AND MEASURE COUPON TO ESTIMATE RETRIEVAL RATE.
2. ALL TEST COUPONS TO BE 100 SQ FT BY 1 FOOT THICK.
3. RETRIEVAL RATE DECISION CRITERIA BASED ON 7.2 M^3 PER DAY (10.6 FT^3 PER HOUR) VALUE IDENTIFIED IN WHC-SD-WM-RPT-229, REV. 0, "INITIAL RETRIEVAL SEQUENCE AND BLENDING STRATEGY," TABLE C-1.
4. NOT TESTED AS PERFORMANCE AGAINST SC-1 ALREADY INDICATED RETRIEVAL RATES GREATER THAN 10.6 FT^3/HR RATE REQUIRED.
5. NOT TESTED AS THE RETRIEVAL RATE IS WELL BEYOND ALLOWABLE, BASED ON 10% SOLIDS BY WEIGHT (125-233 FT^3/HR DEPENDING ON WASTE DENSITY) CRITERIA IMPOSED BY TRANSFER LINE.

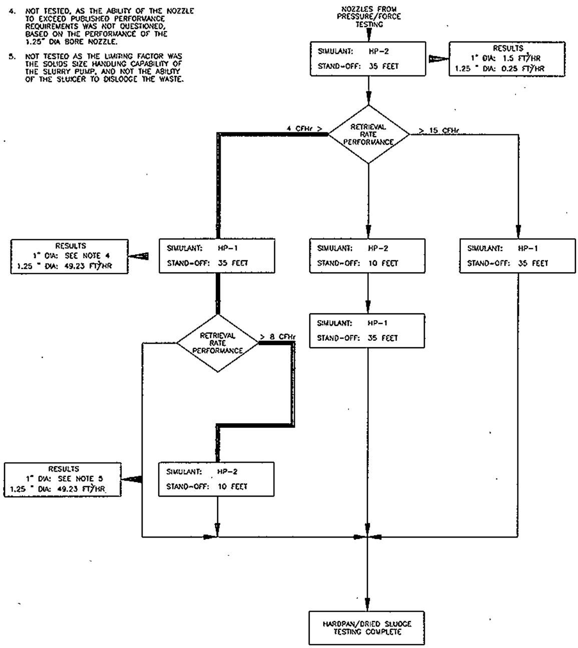
TEST LOGIC FOR SALTCAKE SIMULATED SLUICING



GENERAL TEST NOTES

1. FOR ALL SLUICE TESTING, FOR RETRIEVAL RATES GREATER THAN 8 CFHr, SLUICE COUPON TILL GONE. OTHERWISE, SLUICE 8 HOURS, AND MEASURE COUPON TO ESTIMATE RETRIEVAL RATE.
2. ALL TEST COUPONS TO BE 100 SQ FT BY 1 FOOT THICK.
3. RETRIEVAL RATE DECISION CRITERIA BASED ON 7.2 M^3 PER DAY (10.6 FT^3 PER HOUR) VALUE IDENTIFIED IN WHC-SD-WM-RPT-229, REV. 0, "INITIAL RETRIEVAL SEQUENCE AND BLENDING STRATEGY," TABLE C-1.
4. NOT TESTED, AS THE ABILITY OF THE NOZZLE TO EXCEED PUBLISHED PERFORMANCE REQUIREMENTS WAS NOT QUESTIONED, BASED ON THE PERFORMANCE OF THE 1.25" DIA BORE NOZZLE.
5. NOT TESTED AS THE LIMITING FACTOR WAS THE SOLIDS SIZE HANDLING CAPABILITY OF THE SLURRY PUMP, AND NOT THE ABILITY OF THE SLUICER TO DISLODGE THE WASTE.

TEST LOGIC FOR HARDPAN/DRIED SLUDGE SIMULATED SLUICING



ATTACHMENT B

WASTE SIMULANT TEST COUPON DENSITY CALCULATIONS

SIMULANT	WEIGHT (lbs)	INITIAL DEPTH (in ± 1/32)	FINAL DEPTH (in ± 1/32)	Δh (in)	WATER VOLUME DISPLACED (in^3)	DENSITY (lb/in^3)	DENSITY (lb/ft^3)	TARGET DENSITY (lb/ft^3)	NOTES
SC-1	0.90	4.375	4.9688	0.59	10.52	0.086	147.9	140	
SC-1	1.15	4.5938	5.375	0.78	13.84	0.083	143.6	140	
SC-4	0.75	4.2813	4.9063	0.63	11.07	0.068	117.1	74.9	Volume measurement does not account for intergranular voids in simulant.
SC-4	0.45	4.8125	5.0938	0.28	4.98	0.09	156.1	74.9	
HP-1	1.25	4.5	5.8125	1.31	23.24	0.054	92.9	92.4	
HP-2	1.27			0	21.00	0.06	104.5	103	
HP-2	.69			0	11.54	0.06	103.3	103	
SC-1	1.05			0	13.37	0.079	135.7	140	
SC-3	1.69			0	19.46	0.087	150.1	142	

APPENDIX C

TEST HARDWARE
VENDOR CATALOG DATA

(PROPRIETARY - Not included for Public Release)

The information in this Appendix is proprietary, and is not for public release.

APPENDIX D

FORCE TEST DATA SHEETS

DATA SHEET #1

DATE:	TIME:	TEST ID NUMBER:
10/31/96	11:53 Am	CANNON1.TXT

NOZZLE BORE DIAMETER: in.	DISTANCE FROM LOAD CELL:
1"	100 IN

TEST MEASUREMENTS AT NOZZLE:

PRESSURE: PSI	FLOW G.P.M.
152	288**

TEST MEASUREMENTS AT LOAD CELL:*

TOTAL FORCE:	PEAK PRESSURE:
STREAM AREA:	ANGLE OF INCIDENCE: (ESTIMATED) ~0

OBSERVATIONS

RETEST SAME AS CANNON.TXT

☐ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 11/1/93	[signature] 11/6/96
ARD TEST ENGINEER DATE	LATA TEST ENGINEER DATE

* To be provided by PNL @ conclusion of testing.

** Flow rate per doppler flow meters. See section 4.1.3 of test report.

Filename 1la10003.dat

Caption Test 1la10003: 1" Nozzle, 150 psi, 100 inch stand-off

Test	1la10003	
Nozzle Diameter	1.000 in	
Nozzle Pressure	150 psi	
Stand-off	0 ft	100.00 in
Stand-off	100.00 in	
Nozzle Diameters	100	
Total average force	233.90 lb	Total Recoil

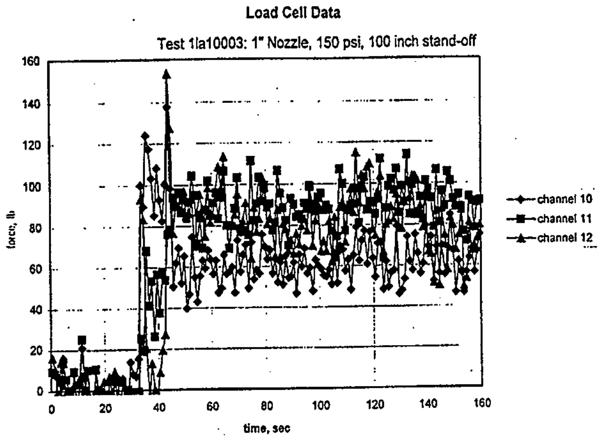
Maximum impact pressure

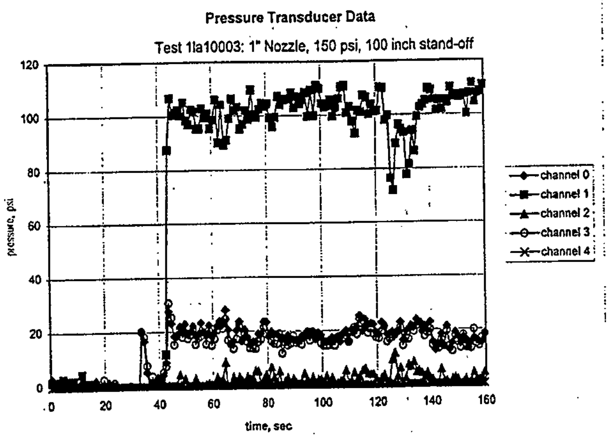
Channel	12	11	10	4	3	2	1	0
average	82.42	89.99	61.49	0.00	17.25	2.49	101.89	18.74
max	50.00	63.64	46.39	0.00	24.58	11.50	111.34	27.93
min	114.98	114.00	84.84	0.00	11.84	-4.07	71.89	12.55
sd	14.10	10.18	8.89	0.00	2.74	2.57	7.41	2.87
Offset	8.24E-04	-7.67E-03	-6.09E-03	-3.92E-04	9.97E-04	2.96E-03	-1.11E-03	1.01E-03
cal factor	44362	44362	44362	10494	9494	9178	10957	10001

David Ransome
H5-61

Steve Shaw
B1-49

"Data from one good test at ARD"


Load Cell Data
Test 1la10003: 1" Nozzle, 150 psi, 100 inch stand-off
force, lb
time, sec
channel 10
channel 11
channel 12


Pressure Transducer Data
Test 1la10003: 1" Nozzle, 150 psi, 100 inch stand-off
pressure, psi
time, sec
channel 0
channel 1
channel 2
channel 3
channel 4

APPENDIX E

SLUICE TEST DATA

Pg 1 of 2

DATA SHEET #2

DATE: Nov 4, 5 1996	TEST ID NUMBER: SCANNON.TXT

NOZZLE DATA

NOZZLE BORE DIAMETER: 1 1/4" in.	DISTANCE FROM TEST COUPON: 35'

TEST COUPON

TEST COUPON TYPE: SC-31	TEST COUPON DIMENSIONS: 95.75 ft³	TEST COUPON DENSITY: ~155 #/ft³

WATER TEMPERATURE

INITIAL: 58° °F	FINAL: ~58 °F

TOTALIZER READINGS

START: * NA	FINISH: NA	TOTAL: * 140,800 GAL.

TIME

START: ** 3:05 pm	FINISH: 6:30 pm	TOTAL: ** 320 MIN

NOZZLE DATA

FLOW: *** ~440 G.P.M.	PRESSURE: ~90 PSI

SLURRY PUMP

NOMINAL FLOW: **** ~440 G.P.M.

OBSERVATIONS

For *, **, ***, ****, see sheet 2.
~2 ft³ remaining, 50% small chunks, + 50% fines.

OTHER DATA FILES
SCANNON1.TXT
SCANNON2.TXT
SCANNON3.TXT

☑ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 11/6/96
ABD TEST ENGINEER DATE

[signature] 11/6/96
LATA TEST ENGINEER DATE

ARD ENVIRONMENTAL

Supp. Data Sheet
for SC-~~3~~1 Sluice Test

Pg 2 of 2

ARD Environmental, Inc.

Notes:

* Totalizer Data not available. Total volume estimated by multiplying hours (minutes) of pump operation by estimated flow rate.

** Actual run times for the SC-3 test:

	Nov 4		Nov 5			
	3:05 pm	Start	9:25 am	10:05	11:00	Total Run
	6:30	Stop	10:00	10:45	11:40	
minutes	205		35	40	40	320 minutes

*** Flow data is estimated from Akron Brass, Straight (Solid) Bore Nozzle Data Chart, for 1¼ Ø nozzle @ 90 PSI.

**** Pump flow estimated as no flow instrumentation data available. Pump had sufficient capacity to "keep up" with nozzle flow.

⇒ Test Coupon shows strength gradient, with compressive strength increasing from top to bottom of coupon. Corresponding affect on retrieval rate. 1st hour, about 50% coupon removed, 2nd hour, approx 50% of the remainder was removed, & so on.

[signature] 11/6/96

9115 Whiskey Bottom Road
Laurel, Maryland 20723
301/497-0477
Fax: 301/497-1645

DATA SHEET #2

DATE: Nov 5, 1996	TEST ID NUMBER: CANNON 1.TXT *

NOZZLE DATA

NOZZLE BORE DIAMETER: 1 1/4" in.	DISTANCE FROM TEST COUPON: 35'

TEST COUPON

TEST COUPON TYPE: SC-4	TEST COUPON DIMENSIONS: 84 x 180 x 12, 105 ft³	TEST COUPON DENSITY: 117 #/ft³

WATER TEMPERATURE

INITIAL: 58 °F	FINAL: 58 °F

TOTALIZER READINGS

START: 1	FINISH: 50	TOTAL: 4900 GAL.

TIME

START: 2:40 2:55	FINISH: 2:50 2:58	TOTAL: 13 MIN

NOZZLE DATA

FLOW: 400 G.P.M.	PRESSURE: 95 PSI

SLURRY PUMP

NOMINAL FLOW: 400 G.P.M. No Instrument Data Available. Slurry Pump kept up with Nozzle.

OBSERVATIONS

~5 ft³ of coupon remained, result of test geometry.

☐ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 11/6/96 — ARD TEST ENGINEER, DATE

[signature] 11/6/96 — LATA TEST ENGINEER, DATE

* Data also in Files Cannon 2.TXT, Cannon 3.TXT & Cannon 4.TXT

Page 1 of 2

DATA SHEET #2

DATE: 11/7/96	TEST ID NUMBER: PCANNON1.TXT [1]

NOZZLE DATA

NOZZLE BORE DIAMETER: 1 1/4 in.	DISTANCE FROM TEST COUPON: 35'

TEST COUPON

TEST COUPON TYPE: HP-1	TEST COUPON DIMENSIONS: 87x162x69" 73.4 ft³	TEST COUPON DENSITY: 92.9 #/ft³

WATER TEMPERATURE

INITIAL: 60 °F	FINAL: 60 °F

TOTALIZER READINGS

START: 55.5	FINISH: 356	TOTAL: 30,050 GAL.

TIME

START: 11:26*	FINISH: *	TOTAL: 73* MIN

NOZZLE DATA

FLOW: 400, 360** G.P.M.	PRESSURE: 97, 77** PSI

SLURRY PUMP

NOMINAL FLOW: *** ~400 G.P.M.

OBSERVATIONS

For Notes *, **, ***, see attached sheet(s).
Approx 1½ yd³ remaining @ completion of test. Approx ½ yd could not be sprayed because of test geometry.

☑ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 11/8/96 — ARD TEST ENGINEER, DATE

[signature] 11/8/96 — LATA TEST ENGINEER, DATE

[1] Data also in files PCANNON2.TXT, PCANNON3.TXT, & PCANNON4.TXT

Supp. Data Sheet for HP-1 Sluice Test

ARD ENVIRONMENTAL

SHEET 2 of 2

ARD Environmental, Inc.

NOTES:

* OPERATING PERIODS for HP-1 TEST

RUN TIMES	MINUTES	FLOW RATE	COMMENTS
11:26 - 11:50	24	400	INSPECTION
11:54 - 12:03	9	│	DRY/DE-FOG CAMERA LENS
12:12 - 12:23	11	│	SLURRY PUMP STOPPED
2:22 - 2:28	6	│	│
2:29 - 2:31	2	│	│
2:32 - 2:33	1	│	│
2:34 - 2:38	4	⊥	⊥
2:38 - 2:45	7	360	UNABLE TO ELEVATE MONITOR
~~2:45~~ 2:52 - 2:58	6	│	SLURRY PUMP STOPPED
2:59 - 3:03	4	⊥	⊥

TOTAL OPERATING TIME: 73 MIN

** Flow rate changed from 400 GPM to 360 GPM IN AN EFFORT to minimize flow disturbances around slurry pump to see if could prevent pump from "losing suction."

*** SLURRY pump flow estimated, as no pump flow instrumentation data available. Pump as sufficient capacity to keep up with "nozzle flow" & over come 150 psi head pressure.

[signature]

9115 Whiskey Bottom Road
Laurel, Maryland 20723
301/497-0477
Fax: 301/497-1645

DATA SHEET #2

DATE: 12/3/96 - 12/4/96	TEST ID NUMBER:

NOZZLE DATA

NOZZLE BORE DIAMETER: 1 1/4 in.	DISTANCE FROM TEST COUPON: 35 ft.

TEST COUPON

TEST COUPON TYPE: HP-2	TEST COUPON DIMENSIONS: 4' x 8'	TEST COUPON DENSITY:

WATER TEMPERATURE

INITIAL: 45 °F	FINAL: 45 °F

TOTALIZER READINGS

START:	FINISH:	TOTAL: 107,206 GAL.

TIME

START: 8:35 (12/3) 8:30 (12/4)	FINISH: 10:35 (12/3) 10:32 (12/4)	TOTAL: 242 MIN

NOZZLE DATA

FLOW: 443 G.P.M.	PRESSURE: 91 PSI

SLURRY PUMP

NOMINAL FLOW: 443 G.P.M.

OBSERVATIONS

☐ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 12-3-96
ARD TEST ENGINEER DATE

[signature] 12/16/96
LATA TEST ENGINEER DATE

DATA SHEET #2

DATE: 12/4/96	TEST ID NUMBER:

NOZZLE DATA

NOZZLE BORE DIAMETER: 1 in.	DISTANCE FROM TEST COUPON: 35 ft.

TEST COUPON

TEST COUPON TYPE:	TEST COUPON DIMENSIONS:	TEST COUPON DENSITY:
HP-2	4' x 8'	

WATER TEMPERATURE

INITIAL: 45 °F	FINAL: 45 °F

TOTALIZER READINGS

START:	FINISH:	TOTAL: 74,880 GAL.

TIME

START: 10:35 12:30	FINISH: 11:05 4:00	TOTAL: 240 MIN

NOZZLE DATA

FLOW: 312. G.P.M.	PRESSURE: 110 PSI

SLURRY PUMP

NOMINAL FLOW: 312 G.P.M.

OBSERVATIONS

☐ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 12-4-96
ARD TEST ENGINEER DATE

[signature] 12/16/96
LATA TEST ENGINEER DATE

DATA SHEET #2

DATE: 12/5/96	TEST ID NUMBER:

NOZZLE DATA

NOZZLE BORE DIAMETER: 1 in.	DISTANCE FROM TEST COUPON: 35 ft.

TEST COUPON

TEST COUPON TYPE: SC-1	TEST COUPON DIMENSIONS: 4' x 8'	TEST COUPON DENSITY:

WATER TEMPERATURE

INITIAL: 43 °F	FINAL: 43 °F

TOTALIZER READINGS

START:	FINISH:	TOTAL: 16,642 GAL.

TIME

START: 10:30	FINISH: 11:23	TOTAL: 53 MIN

NOZZLE DATA

FLOW: 314 G.P.M.	PRESSURE: 112 PSI

SLURRY PUMP

NOMINAL FLOW: 314 G.P.M.

OBSERVATIONS

☐ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 12-5-96 [signature] 12/16/96

ARD TEST ENGINEER DATE LATA TEST ENGINEER DATE

DATA SHEET #2

DATE: 12/5/96	TEST ID NUMBER:

NOZZLE DATA

NOZZLE BORE DIAMETER: 1 in.	DISTANCE FROM TEST COUPON: 35 ft.

TEST COUPON

TEST COUPON TYPE: SC-3	TEST COUPON DIMENSIONS: 4' x 8'	TEST COUPON DENSITY:

WATER TEMPERATURE

INITIAL: 43 °F	FINAL: 43 °F

TOTALIZER READINGS

START:	FINISH:	TOTAL: 10,990 GAL.

TIME

START: 1:35	FINISH: 2:00	TOTAL: 25 MIN

NOZZLE DATA

FLOW: 314 G.P.M.	PRESSURE: 112 PSI

SLURRY PUMP

NOMINAL FLOW: 314 G.P.M.

OBSERVATIONS

☐ CHECK HERE IF ADDITIONAL OBSERVATION SHEET ATTACHED.

[signature] 12-5-96 [signature] 12/16/96

ARD TEST ENGINEER DATE LATA TEST ENGINEER DATE

APPENDIX F

TEST PHOTOS

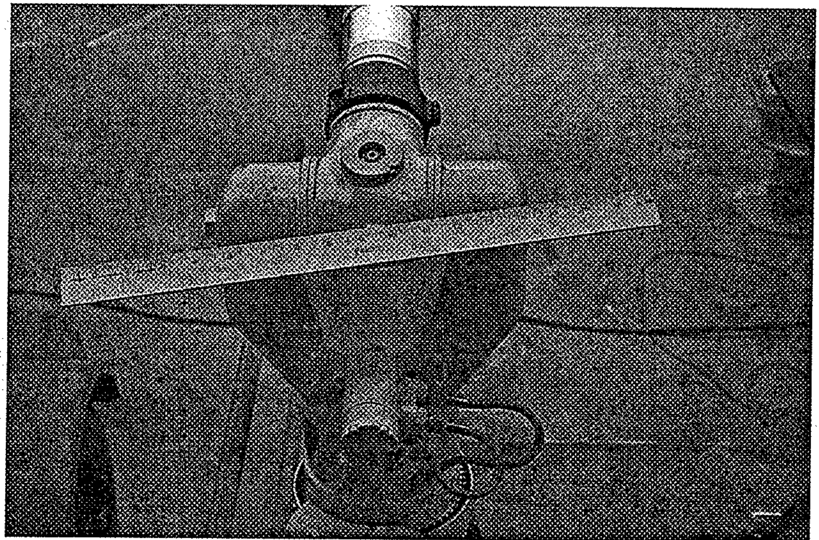


Figure 1 Hydraulic Monitor

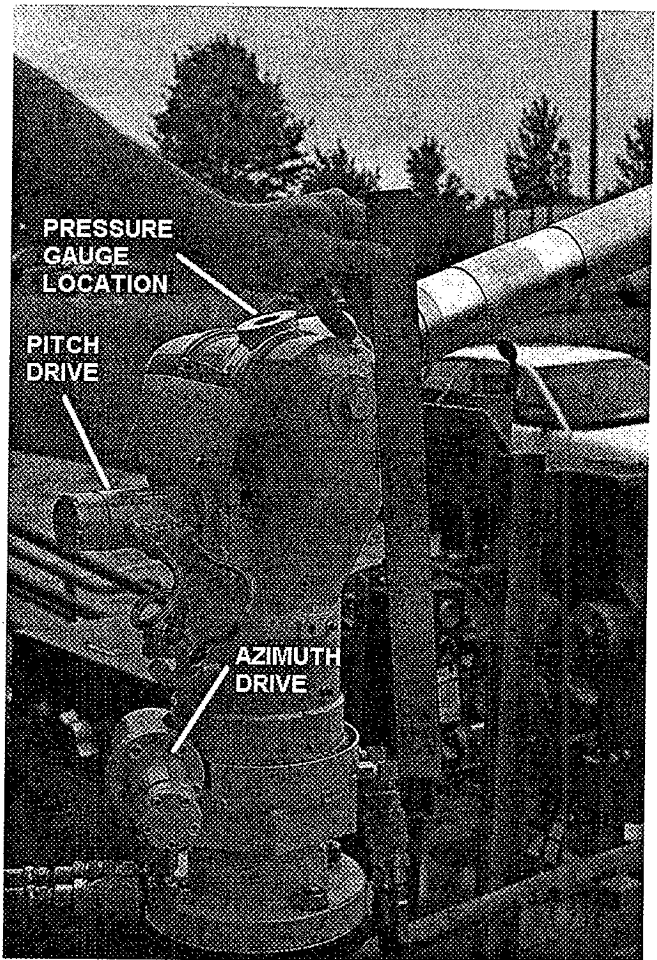


Figure 2 Hydraulic Monitor

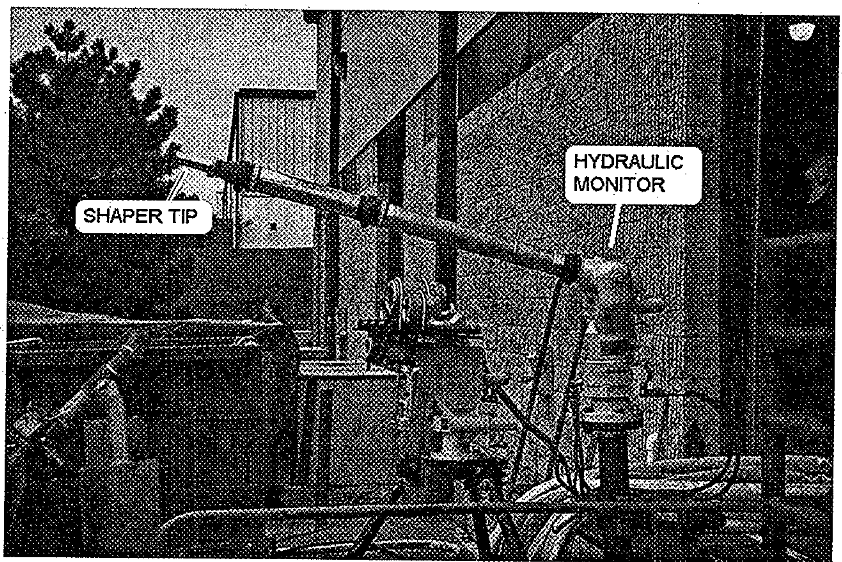


Figure 3 Sluicer Configuration for Nozzle Force and Simulated Sluice Testing

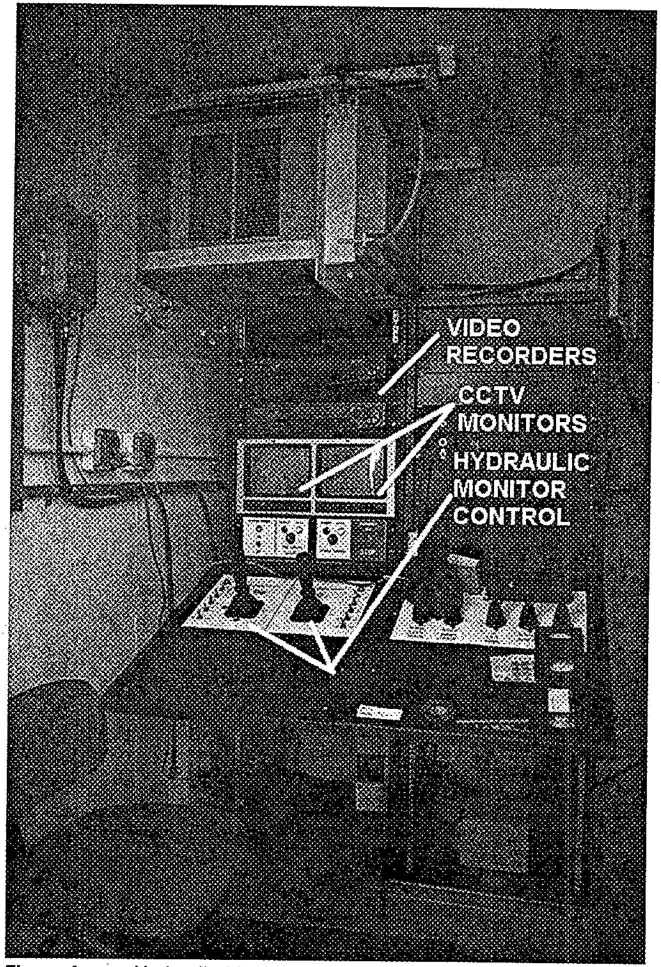


Figure 4 Hydraulic Monitor Control Station

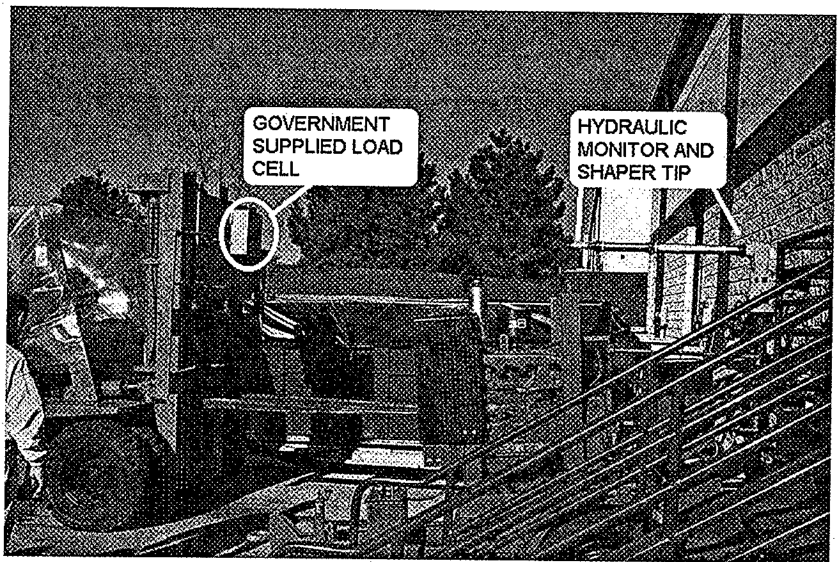


Figure 5 General Force Test Hardware Configuration

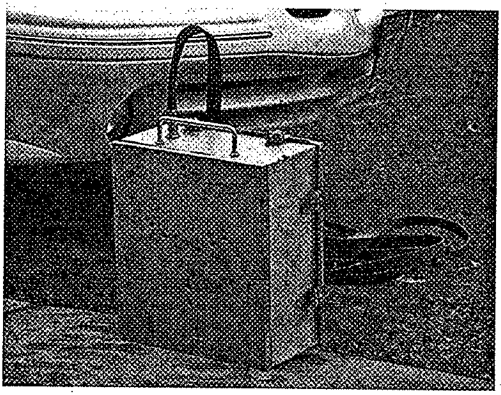


Figure 6 Government Load Cell

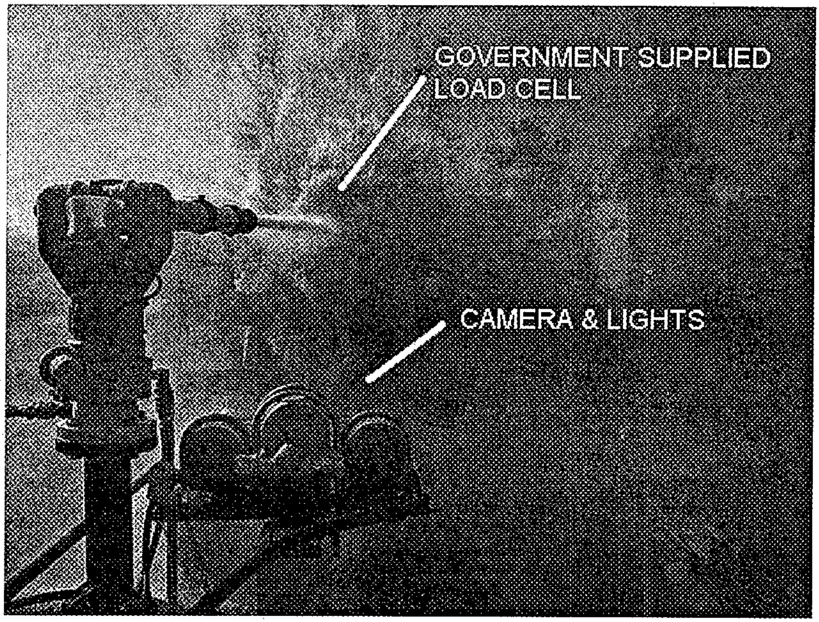


Figure 7 Nozzle Force Testing at 100 Diameters

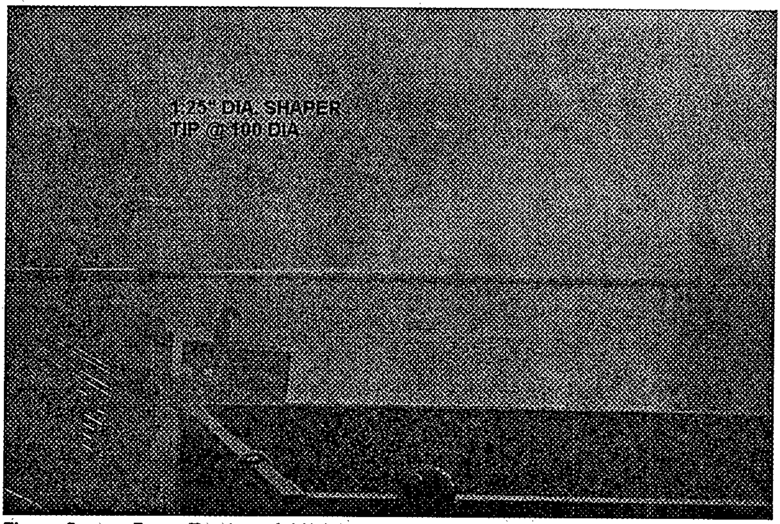


Figure 8 Force Testing of 1¼" Diamter Bore Nozzle at 100 Nozzle Diameters

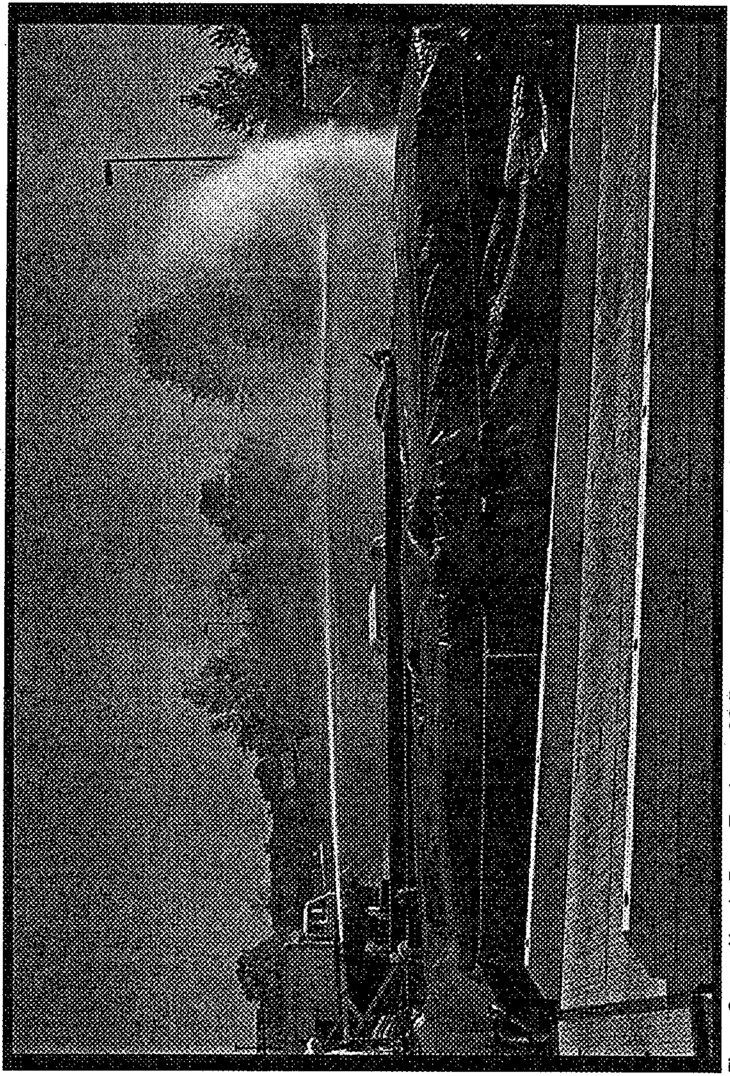


Figure 9 Nozzle Force Testing at 35 Feet

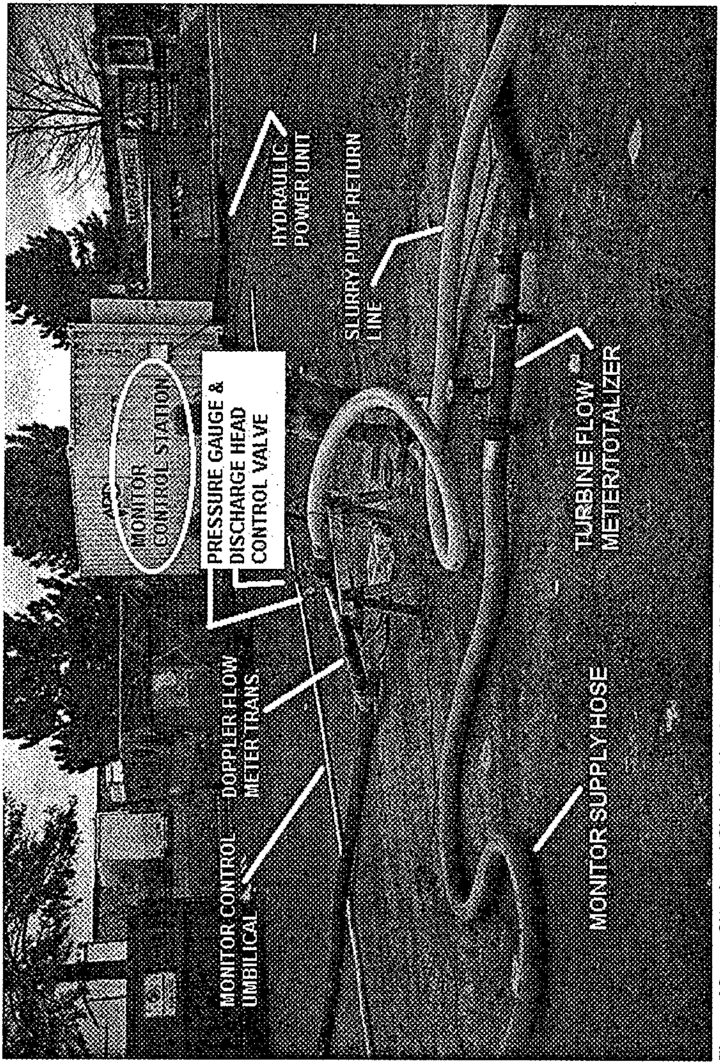


Figure 10 Simulated Sluicing Hardware Test Configuration

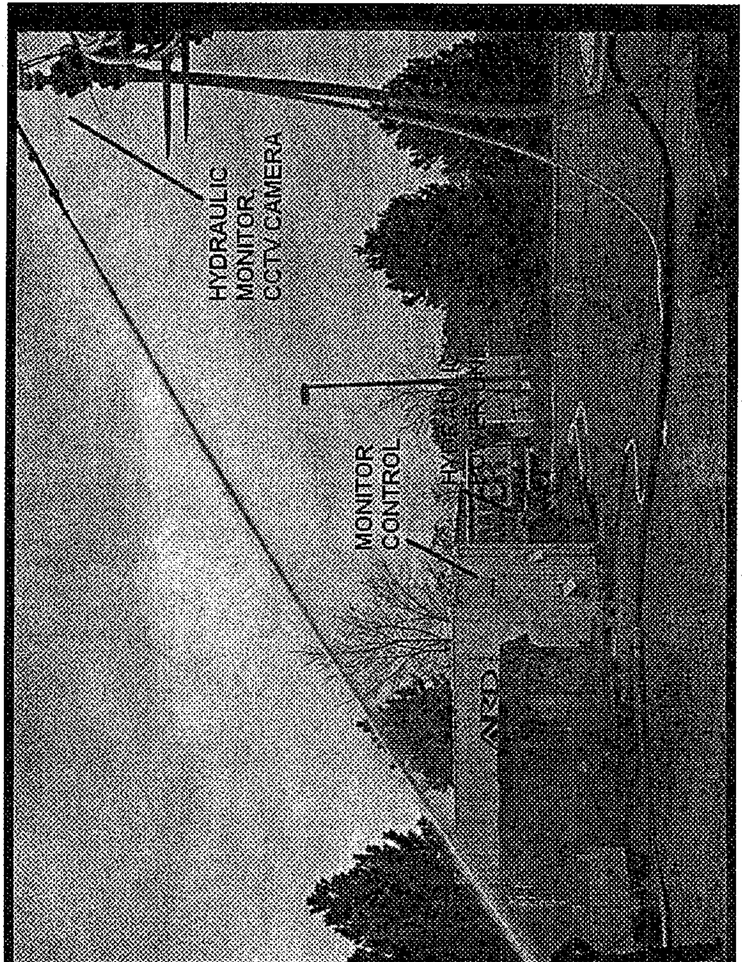


Figure 11 Simulated Sluice Testing Hardware Configuration

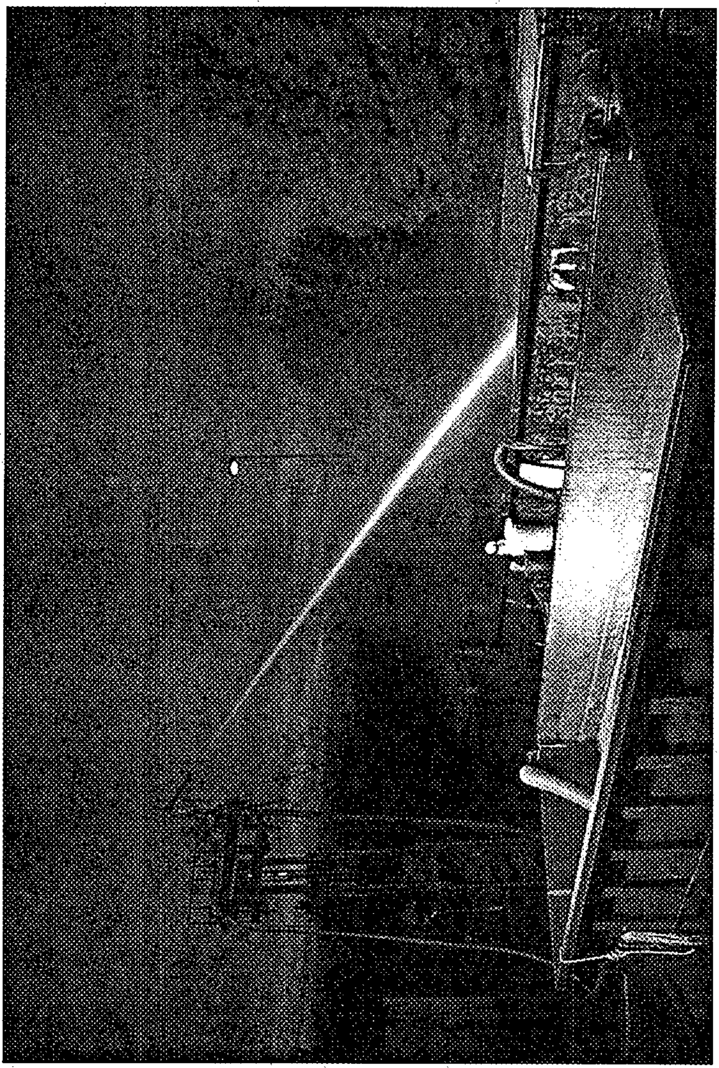


Figure 12 Sluice Testing Against SC-1 at 35 feet with 1¼" Diameter Solid Bore Nozzle

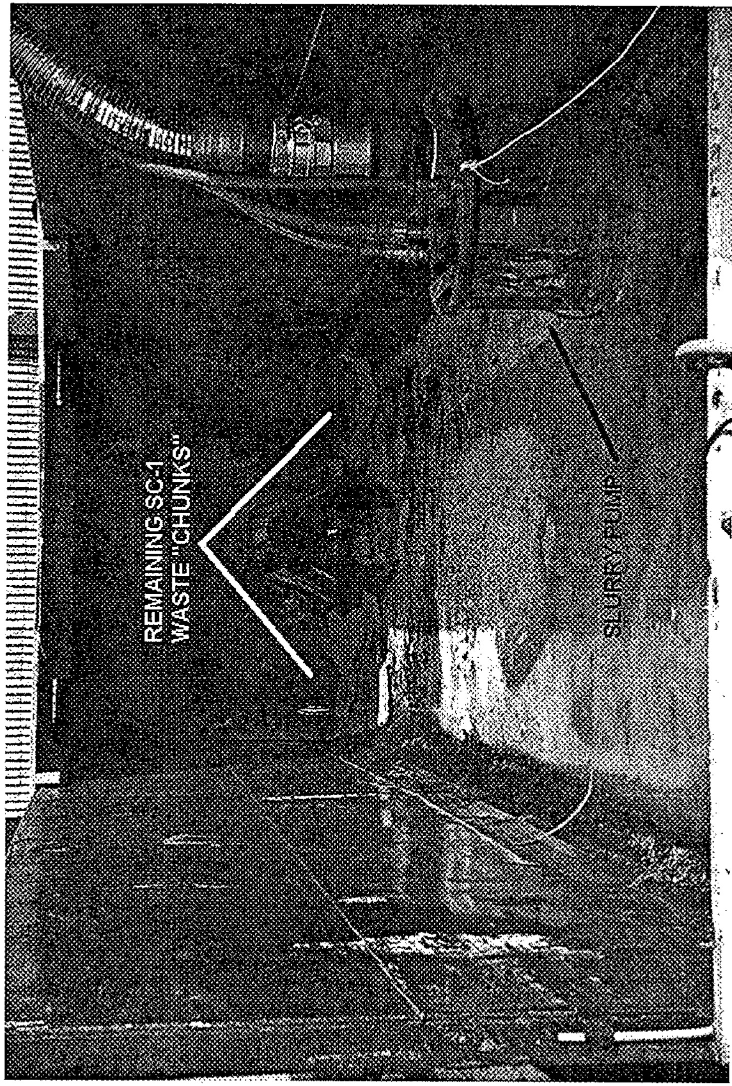


Figure 13 Conclusion of Simulated Sluice Testing Against SC-1

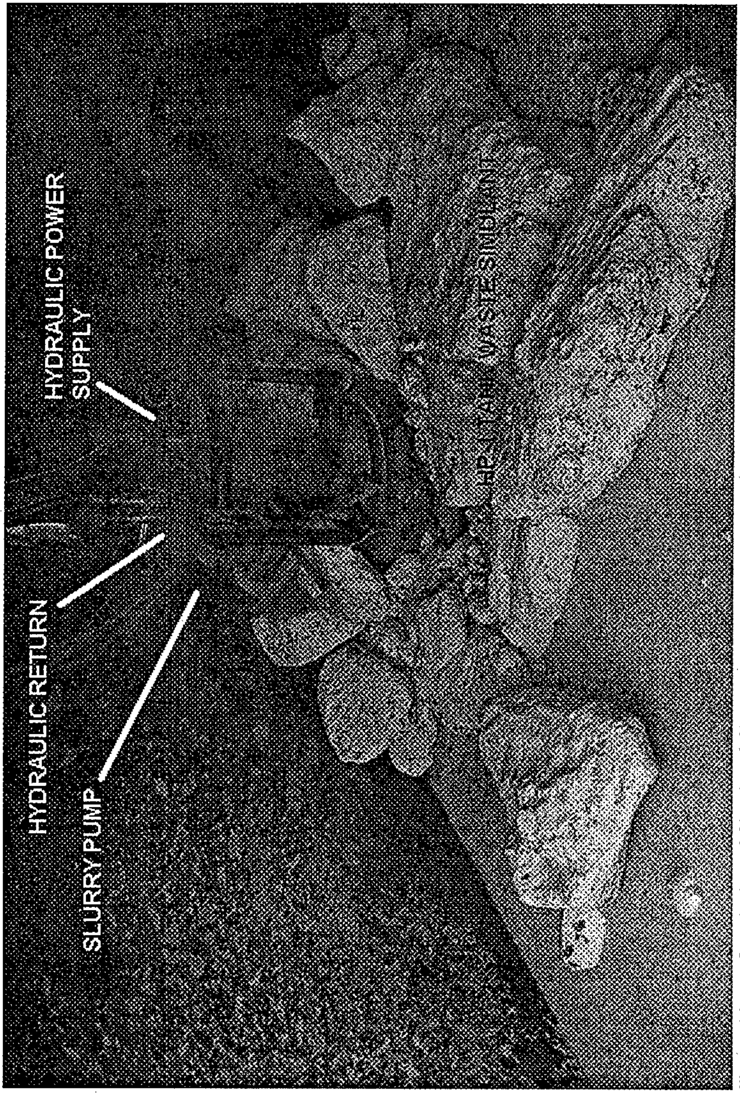


Figure 14 Conclusion of Simulated Sluice Testing Against HP-1 Waste Simulant

APPENDIX G

SAMPLE CALCULATIONS

The formulas performed for the preparation of this report are very basic, and are listed below:

1. Stream Velocity

$$v=\frac{Q}{A}$$

v: velocity (in/sec)
Q: Volume Flow Rate (in^3/sec)
A: Nozzle Area (in^2)

2. Waste Volume Retrieved

$$W_i - W_f = W_R$$

W_i: Initial Waste Volume (ft^3)
W_f: Final Waste Volume (ft^3)
W_R: Waste Volume Retrieved (ft^3)

3. Retrieval Rate

$$R_r=\frac{W_r}{t}$$

R_r: Retrieval Rate (ft^3/hr)
W_r: Waste Volume Retrieved (ft^3)
t : time (hr)

4. Density

$$\rho=\frac{Wgt}{V_s}$$

ρ: density (lb/in^3)
Wgt: Weight (lb)
V_s: Sample Volume (in^3)