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Sluicing Nozzle Test Report, Volume 1

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Abstract: The Westinghouse Hanford Company is exploring various options for retrieving waste materials from the underground storage tanks at the Hanford Site in Richland, Washington. One option under investigation is the use of a commercially available sluicing nozzle manufactured by Bristol Equipment Company.

Sluicing Nozzle Test Report, Volume I

July 1996

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Sluicing Nozzle Test Report, Volume I

1.0 INTRODUCTION

The Westinghouse Hanford Company (WHC) is exploring various options for retrieving waste materials from the underground storage tanks at the Hanford Site in Richland, Washington. One option under investigation is the use of a commercially available sluicing nozzle manufactured by Bristol Equipment Company (BEC).

A test program was recently conducted under Purchase Order Number MKJ-SVW-400385 to determine the performance of the sluicing nozzle against several waste simulants developed by WHC. The purpose of the test program was to establish a performance baseline against which to compare other competing technologies. The sluicing nozzle performance was determined as a function of nozzle diameter, nozzle pressure, and standoff.

The test program was divided into two test groups: Load Cell Tests and Waste Simulant Reaction Tests. The approved Work Plan is included in Appendix A and the approved Test Procedure is included in Appendix B for reference. A photograph log is included as a separate volume to this report (Volume II). Four videotapes have also been submitted as part of the test program documentation (Volume III).

2.0 TEST SETUP AND EQUIPMENT

The test setup and equipment were the same for the Load Cell Tests and Waste Simulant Reaction Tests. The equipment for the tests included the following: BEC nozzle, 125 hp pump, small submersible pump with 2 inch flexible hose, 200 KW generator, small generator, collection basin, target tank with fixture, 4900 gallon storage tank with two valves at the base, trailer, truck with hitch, 3 and 4 inch flexible hoses, 2 inch gate valve, and 3 inch globe valve. A schematic of the test setup is shown in Figure 1.

The BEC nozzle was secured to a fixture constructed from angle iron, and the angle iron fixture was attached to the back of the trailer. The 125 hp pump was positioned behind the nozzle on the front of the trailer.

The discharge from the pump was connected to the nozzle with 2 inch steel pipe. A bypass "tee" was located between the discharge and the nozzle. The gate valve and globe valve were on the bypass and nozzle sides, respectively. The four inch flexible hose connected the 4900 gallon storage tank to the inlet of the 125 hp pump. The 3 inch bypass line circulated the flow back to the inlet piping directly downstream of the valves at the base of the 4900 gallon storage tank.

Directly in line with the trailer and set in the ground was the 9 foot deep collection basin. The submersible pump was suspended in the collection basin and recirculated the water to the top of the 4900 gallon storage tank. The target tank was positioned in line and perpendicular to the collection basin, lying along the ground. The target tank overhung the lip of the collection basin a few inches. The fixture to hold the load cell and the pails was parallel with the ground. The fixture could be located either one foot or five feet from the front of the target tank.

The trailer holding the pump and nozzle apparatus was moved using the truck with the hitch. The hitch could be lowered or raised to provide a range of heights for the nozzle tip. The 200 KW generator (diesel) powered the motor for the 125 hp pump and the small generator (gasoline) powered the submersible pump.

3.0 DEVIATIONS FROM THE WORK PLAN

Changes to the work plan were made at different stages of the test program. The deviations were discussed with and approved by the WHC technical representative before, during, and after testing. The changes are listed below.

Load Cell Tests

1. A total of 59 tests were performed instead of 30 tests.
2. The nozzle flow rate was not measured.
3. Tests 1, 2, 26, and 27 were not performed.
4. Added Tests 66 - 75 at standoffs of 720, 900, 360, 450, 240, 300, 120, 150, 44, and 55, respectively, and nozzle pressures of 150 psig.
5. The jet geometry was not determined.
6. Only the maximum impact pressure and the maximum impact force were determined and reported.

Waste Simulant Reaction Tests

1. A total of 32 tests, including 5 screening tests, were performed instead of 35.
2. The nondimensional standoff distance for each test was 200 D_o instead of 100 D_o.
3. The nozzle flow rate was not measured.
4. The mass of the oversize material was not determined.
5. The threshold (minimum) impact pressure was not determined.
6. Tests 53 and 59 were not performed because the nozzle pressure of 75 psig was too low to have any affect on the waste simulant. The pails for Tests 53 and 59 (21 and 27) were used for Tests 51A and 57A at nozzle pressures of 300 psig.
7. Tests 63, 64, and 65 (Recipe 8 - saltcake) were not performed because of the high porosity and low strength of the simulant, and the results of Tests 60, 61, and 62 (Recipe 7 - saltcake).

4.0 LOAD CELL TEST RESULTS

The test conditions and test results for the 59 tests conducted are delineated in Tables 1 and 2, respectively. All pressures reported are gauge pressures. The load cell instrumentation was fabricated and operated by Pacific Northwest National Laboratories operated by Battelle. The pressure and force data were reduced and summarized by Batelle and provided to Packer Engineering.

The load cell consisted of nine pressure transducers and three load cells. The maximum impact pressure recorded from the nine transducers and the maximum impact force recorded from the three load cells were reported in Table 2. Plots of the maximum impact pressure versus standoff for each nozzle diameter and nozzle pressure are shown in Figures 2 (2A) and 3 (3A), respectively. The figures are shown both in English (Figures 2 and 3) and metric (Figures 2A and 3A).

The results are qualitatively consistent with the published literature. Figure 2 shows that impact pressure decreases with increasing standoff. The effect is similar for all nozzle pressures. Figure 3 shows that the impact pressure - standoff relationship is a weak function of nozzle diameter.

5.0 WASTE SIMULANT REACTION TEST RESULTS

A description of the waste simulants tested is shown below.

Waste Simulant Compositions and Properties

RecipeNo.	Description	Composition*	Density g/cm³ (lb./ft.³)	Strength kPa (psi)
1	Wet Sludge	66% clay/34% water	1.65 (103)	3.5 (0.51)
2	Hardpan/Dried Sludge	30% plaster/27.5% clay/42.5% water	1.48 (92.4)	32 (4.6)
3	Hardpan/Dried Sludge	40% plaster/22.5% clay/37.5% water	1.65 (103)	150 (21.8)
4	Saltcake	84% K-Mag/16% water	2.25 (140)	20,700 (3000)
5	Saltcake	88% K-Mag/12% water	1.94 (121)	10,300 (1500)
6	Saltcake	75% K-Mag/25% water	2.27 (142)	10,300 (1500)
7	Saltcake	86% salt/9.33% plaster/4.67% water	1.20 (74.9)	55 (8.0)
8	Saltcake	95% salt/3.33% plaster/1.67% water	1.20 (74.9)	10 (1.5)

* All compositions in weight percent.

clay	=	kaolin clay
plaster	=	plaster of Paris
K-Mag	=	potassium magnesium sulfate
salt	=	sodium chloride rock salt

The test conditions and test results for the 32 tests conducted are delineated in Tables 3 and 4, respectively. All pressures reported are gauge pressures. Waste simulant screening tests were performed with a water jet at 20 psi using a 0.25 inch brass hose barb at a standoff of 24 inches (96 nozzle diameters). Waste simulant recipes 1, 2, 3, 7, and 8 were tested. The screening tests demonstrated that the lower strength waste simulants would be easily sluiced at higher pressures (or larger standoffs). Waste simulant recipe 3 was unaffected by the screening test.

In the waste simulant reaction tests, the water jet immediately ejected the material from the pails in the tests that were conducted with waste simulant recipes 1, 2, and 7 (Tests 36 - 41, and 60 - 62). The tests with waste simulant recipe 8 were not performed, based on the screening test results. Remarkably, all three of the high strength saltcakes (recipes 4, 5 and 6) were sluiced by the 150 and 300 psi water jets, however, the sluicing time required was significantly longer on average to obtain measurable results. The mass loss rate spanned four orders of magnitude for the waste simulants tested, ranging from a low of 0.00556 lb/sec (0.00252 kg/sec) for recipe 3 to a high of 27.5 lb/sec (12.5 kg/sec) for recipe 2.

The water jet exhibited varying degrees of success at sluicing the surface of waste simulant recipes 3, 4, 5, and 6. The histograms of the mass loss rate (mass loss/length of test) versus nozzle pressure at fixed nozzle diameters for waste simulant recipes 1 - 7 are displayed in Figures 4 (4A) - 12 (12A). The figures are shown both in English (Figures 4 - 12) and metric (Figures 4A - 12A) units. For the most part, the figures exhibit increasing mass loss rates with increasing nozzle pressures. Waste simulant recipes 1 and 7 (Figures 4 and 12) did not follow this trend. The water jet was not stopped immediately after ejecting the material from the pails during Tests 36 and 38 (waste simulant recipe 1). The length of the test was greater than the time it took to eject all the material. The duration of the test could not be shortened due to concerns that this might result in damaging pressure transients. Therefore, the mass loss rates calculated are lower than the actual mass loss rates, and Figure 4 should realistically follow the overall trend. Similarly, the time to eject the material from the pails for Tests 60 - 61 (waste simulant recipe 7) was difficult to accurately determine because the effect was practically instantaneous.

The histogram of the mass loss rate versus nozzle diameter for waste simulant recipe 3 at nozzle pressures of 75 psi, 150 psi, and 300 psi is displayed in Figure 13 (13A). For a given nozzle pressure, the flow rate increases with the square of the nozzle diameter. The mass loss rate increased with increasing nozzle diameter for nozzle pressures of 150 psi and 300 psi. However, the mass loss rate decreased with increasing nozzle diameter for nozzle pressures of 75 psi.

The observed dislodging and mobilization mechanisms for the seven waste simulants tested are summarized in Table 5. The dislodging mechanism was characterized as dissolution, plastic flow, brittle fracture, no effect, or a combination of these. The mobilization mechanism was characterized as slurry flow, tumbling, immobile, or a combination of these.

6.0 CONCLUSIONS

The sluicing nozzle test program was successfully completed. The load cell tests confirmed trends reported in the published literature. The waste simulant reaction tests demonstrated that all waste simulant recipes can be sluiced by water jets with nozzle pressures in the 150 to 300 psi range. This result was unexpected for the high strength saltcake recipes.

LIST OF TABLES

Table 1: Test Conditions - Load Cell

Table 2: Test Results - Load Cell

Table 3: Test Conditions - Waste Simulants

Table 4: Test Results - Waste Simulants

Table 5: Dislodging and Mobilization Mechanisms

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
1	-	-	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	1'-3" (0.381 m)	30	-	-
2	-	-	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	1'-6 3/4" (0.476 m)	30	-	-
3	59	5/22/96	0.75 ($1.91*10^{-2}$)	75 (618)	146 (9.21)	1'-10 1/2" (0.572 m)	30	60	test3
4	57	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	1'-10 1/2" (0.572 m)	30	60	test4
4A	58	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	1'-10 1/2" (0.572 m)	30	60	test4A
5	56	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	1'-10 1/2" (0.572 m)	30	60	test5
6	15	5/21/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	4'-2" (1.27 m)	100	40	test6
6A	16	5/21/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	4'-2" (1.27 m)	100	40	test6A
7	14	5/21/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	5'-2 3/4" (1.59 m)	100	40	test7
7A	17	5/21/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	5'-2 3/4" (1.59 m)	100	40	test7A

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
8	20	5/21/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	6'-3" (1.91 m)	100	40	test8
8A	51	5/22/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	6'-3" (1.91 m)	100	60	test8A
9	19	5/21/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	6'-3" (1.91 m)	100	40	test9
9A	49	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	6'-3" (1.91 m)	100	60	test9A
9B	50	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	6'-3" (1.91 m)	100	60	test9B
10	18	5/21/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	6'-3" (1.91 m)	100	40	test10
10A	48	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	6'-3" (1.91 m)	100	60	test10A
11	21	5/21/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	8'-4" (2.54 m)	200	40	test11
12	22	5/21/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	10'-5 1/4" (3.18 m)	200	40	test12
13	13	5/21/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	12'-6" (3.81 m)	200	40	test13

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
13A	45	5/22/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	12'-6" (3.81 m)	200	60	test13A
14	12	5/21/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	12'-6" (3.81 m)	200	40	test14
14A	43	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	12'-6" (3.81 m)	200	60	test14A
14B	44	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	12'-6" (3.81 m)	200	60	test14B
15	11	5/21/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	12'-6" (3.81 m)	200	40	test15
15A	42	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	12'-6" (3.81 m)	200	60	test15A
16	10	5/21/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	12'-6" (3.81 m)	300	40	test16
17	9	5/21/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	15'-7 3/4" (4.77 m)	300	40	test17
18	8	5/21/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	18'-9 1/2" (5.73 m)	300	40	test18
18A	39	5/22/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	18'-9 1/2" (5.73 m)	300	60	test18A

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
19	7	5/21/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	18'-9 1/2" (5.73 m)	300	60	test19
19A	37	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	18'-9 1/2" (5.73 m)	300	60	test19A
19B	38	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	18'-9 1/2" (5.73 m)	300	60	test19B
20	6	5/21/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	18'-9 1/2" (5.73 m)	300	60	test20
20A	36	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	18'-9 1/2" (5.73 m)	300	60	test20A
21	5	5/21/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	25' (7.62 m)	600	60	test21
22	4	5/21/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	31'-3 1/2" (9.54 m)	600	60	test22
23	2	5/21/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	37'-7" (11.5 m)	600	60	test23
23A	30	5/22/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	37'-7" (11.5 m)	600	60	test23A
23B	33	5/22/96	0.75 ($1.91*10^{-2}$)	75 (517)	146 (9.21)	37'-7" (11.5 m)	600	60	test23B

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
24	1	5/20/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	37'-7" (11.5 m)	600	60	test24
24A	28	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	37'-7" (11.5 m)	600	60	test24A
24B	29	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	37'-7" (11.5 m)	600	60	test24B
24C	32	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	37'-7" (11.5 m)	600	60	test24C
25	3	5/21/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	37'-7" (11.5 m)	600	60	test25
25A	27	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	37'-7" (11.5 m)	600	60	test25A
25B	31	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	37'-7" (11.5 m)	600	60	test25B
26	-	-	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	41'-8" (12.7 m)	1000	-	-
27	-	-	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	52'-1 3/4" (15.9 m)	1000	-	-
28	26	5/22/96	0.75 ($1.91*10^{-2}$)	75 (618)	146 (9.21)	62'-7 3/4" (19.1 m)	1000	-	-

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
29	25	5/22/96	0.75 ($1.91*10^{-2}$)	150 (1034)	207 (13.1)	62'-7 3/4" (19.1 m)	1000	60	test29
30	23	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	62'-7 3/4" (19.1 m)	1000	60	test30
30A	24	5/22/96	0.75 ($1.91*10^{-2}$)	300 (2068)	292 (18.4)	62'-7 3/4" (19.1 m)	1000	60	test30A
66	34	5/22/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	37'-7" (11.5 m)	720	60	test66
67	35	5/22/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	37'-7" (11.5 m)	900	60	test67
68	40	5/22/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	18'-9" (5.72 m)	360	60	test68
69	41	5/22/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	18'-9" (5.72 m)	450	60	test69
70	46	5/22/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	12'-6" (3.81 m)	240	60	test70
71	47	5/22/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	12'-6" (3.81 m)	300	60	test71
72	52	5/22/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	6'-3" (1.91 m)	120	60	test72

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
73	53	5/22/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	6'-3" (1.91 m)	150	60	test73
74	54	5/22/96	0.5 ($1.27*10^{-2}$)	150 (1034)	92 (5.80)	1'-10" (0.559 m)	44	60	test74
75	55	5/22/96	0.625 ($1.59*10^{-2}$)	150 (1034)	144 (9.08)	1'-10" (0.559 m)	35	60	test75

* gauge pressure

TABLE 1: TEST CONDITIONS - LOAD CELL

TEST #	SEQ. #	DATE	NOZZLE DIA Inches (m)	NOZZLE PRESSURE psi (kPa)*	CALC. NOZZLE FLOW RATE gpm (L/sec)	STANDOFF DIMENSIONAL	STANDOFF NONDIM.	TEST DURATION seconds	FILE # file.dat
3	0.75 (1.91*10^{-2})	30	75 (517)	49.1 (339)	53.3 (237)	146 (9.21)	continuous		
4A	0.75 (1.91*10^{-2})	30	150 (1034)	100 (689)	132 (587)	207 (13.1)	continuous		
5	0.75 (1.91*10^{-2})	30	300 (2068)	192 (1324)	201 (894)	292 (18.4)	continuous		
8A	0.75 (1.91*10^{-2})	100	75 (517)	6.29 (43.4)	50.3 (224)	146 (9.21)	continuous		
9A	0.75 (1.91*10^{-2})	100	150 (1034)	13.7 (94.5)	123 (547)	207 (13.1)	continuous		
10A	0.75 (1.91*10^{-2})	100	300 (2068)	63.9 (441)	227 (1010)	292 (18.4)	continuous		
13A	0.75 (1.91*10^{-2})	200	75 (517)	13.5 (93.1)	56.7 (252)	146 (9.21)	broken		
14A	0.75 (1.91*10^{-2})	200	150 (1034)	17.1 (118)	107 (476)	207 (13.1)	broken		
15A	0.75 (1.91*10^{-2})	200	300 (2068)	40.0 (276)	184 (818)	292 (18.4)	broken		
18A	0.75 (1.91*10^{-2})	300	75 (517)	5.71 (39.4)	32.2 (143)	146 (9.21)	broken		
19A	0.75 (1.91*10^{-2})	300	150 (1034)	6.25 (43.1)	52.1 (232)	207 (13.1)	broken		
20A	0.75 (1.91*10^{-2})	300	300 (2068)	16.3 (112)	208 (925)	292 (18.4)	broken		
23B	0.75 (1.91*10^{-2})	600	75 (517)	3.68 (25.4)	34.1 (152)	146 (9.21)	broken		
24C	0.75 (1.91*10^{-2})	600	150 (1034)	19.5 (134)	73.5 (327)	207 (13.1)	broken		
25B	0.75 (1.91*10^{-2})	600	300 (2068)	2.09 (14.4)	89.2 (397)	292 (18.4)	broken		
66	0.625 (1.59*10^{-2})	720	150 (1034)	1.60 (11.0)	20.1 (89.4)	144 (9.08)	broken		

TABLE 2: TEST RESULTS - LOAD CELL

TEST #	NOZZLE DIA Inches (m)	STANDOFF NONDIM.	NOZZLE PRESS. psi (KPa)*	MAX. IMPACT PRESS. psi (KPa)*	MAX. IMPACT FORCE lb_f (N)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
67	0.5 ($1.27*10^{-2}$)	900	150 (1034)	2.11 (14.5)	28.8 (128)	92 (5.80)	broken
68	0.625 ($1.59*10^{-2}$)	360	150 (1034)	0.85 (5.86)	48.6 (216)	144 (9.08)	broken
69	0.5 ($1.27*10^{-2}$)	450	150 (1034)	5.95 (41.0)	62.9 (280)	92 (5.80)	broken
70	0.625 ($1.59*10^{-2}$)	240	150 (1034)	7.56 (52.1)	76.4 (340)	144 (9.08)	broken
71	0.5 ($1.27*10^{-2}$)	300	150 (1034)	4.47 (30.8)	61.8 (275)	92 (5.80)	broken
72	0.625 ($1.59*10^{-2}$)	120	150 (1034)	24.0 (165)	74.1 (330)	144 (9.08)	continuous
73	0.5 ($1.27*10^{-2}$)	150	150 (1034)	6.57 (45.3)	45.7 (203)	92 (5.80)	broken
74	0.5 ($1.27*10^{-2}$)	44	150 (1034)	27.2 (188)	43.7 (194)	92 (5.80)	continuous
75	0.625 ($1.59*10^{-2}$)	35	150 (1034)	86.4 (596)	77.2 (343)	144 (9.08)	continuous

* gauge pressure

TABLE 3: TEST CONDITIONS - WASTE SIMULANTS					
TEST#	SEQ.#	DATE	PAIL#	RECIPE#	STANDOFF (DIMENSIONAL
31	-	5/22/96	1	1	24" ($61.0*10^{-3}$ m)
32	-	5/22/96	5	2	24" ($61.0*10^{-3}$ m)
33	-	5/22/96	9	3	24" ($61.0*10^{-3}$ m)
34	-	5/22/96	28	7	24" ($61.0*10^{-3}$ m)
35	-	5/22/96	32	8	24" ($61.0*10^{-3}$ m)
36	60	5/29/96	2	1	12'-6" (3.81 m)
37	61	5/29/96	3	1	12'-6" (3.81 m)
38	62	5/29/96	4	1	12'-6" (3.81 m)
39	63	5/29/96	6	2	12'-6" (3.81 m)
40	64	5/29/96	7	2	12'-6" (3.81 m)
41	65	5/29/96	8	2	12'-6" (3.81 m)
42	81	5/31/96	10	3	8'-4" (1.93 m)
43	82	5/31/96	11	3	8'-4" (1.93 m)
44	83	5/31/96	12	3	8'-4" (1.93 m)
45	84	5/31/96	13	3	10'-5 ½" (3.24 m)
46	85	5/31/96	14	3	10'-5 ½" (3.24 m)
47	86	5/31/96	15	3	10'-5 ½" (3.24 m)
48	66	5/29/96	16	3	12'-6" (3.81 m)
49	67	5/29/96	17	3	12'-6" (3.81 m)
50	68	5/29/96	18	3	12'-6" (3.81 m)
51	69	5/29/96	19	4	12'-6" (3.81 m)
51A	75	5/30/96	21	4	12'-6" (3.81 m)
52	76	5/30/96	20	4	12'-6" (3.81 m)
54	70	5/29/96	22	5	12'-6" (3.81 m)
55	77	5/30/96	23	5	12'-6" (3.81 m)
56	78	5/30/96	24	5	12'-6" (3.81 m)
57	71	5/29/96	25	6	12'-6" (3.81 m)

TABLE 3: TEST CONDITIONS - WASTE SIMULANTS					
TEST#	SEQ.#	DATE	PAIL#	RECIPE#	STANDOFF (DIMENSIONAL
57A	80	5/30/96	27	6	12'-6" (3.81 m)
58	79	5/30/96	26	6	12'-6" (3.81 m)
60	-	-	29	7	12'-6" (3.81 m)
61	-	-	30	7	12'-6" (3.81 m)
62	-	-	31	7	12'-6" (3.81 m)
63	-	-	33	8	12'-6" (3.81 m)
64	-	-	34	8	12'-6" (3.81 m)
65	-	-	35	8	12'-6" (3.81 m)

TABLE 4: TEST RESULTS - WASTE SIMULANTS

TEST #	RECIPE DESCRIPTION	NOZZLE DIA inches (m)	NOZZLE PRESS. psi (kPa)*	TEST DURATION seconds	INTL WT lb (kg)	FINL WT lb (kg)	CHANGE lb (kg)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
31	1 Wet Sludge 0.51 psi (4 kPa)	garden hose 0.25 (6.35 $*10^{-3}$)	20 (138)	-	-	-	-	-	Jet created a crater with depth of 7.5 inches (0.191 m) and width of 2 inches (0.0508 m).
32	2 Hardpan/DS 4.6 psi (32 kPa)	garden hose 0.25 (6.35 $*10^{-3}$)	20 (138)	-	-	-	-	-	Jet created a crater with depth of 2 inches (0.0508 m)and a width of 1.75 inches (0.0445 m).
33	3 Hardpan/DS 21.8 psi (150 kPa)	garden hose 0.25 (6.35 $*10^{-3}$)	20 (138)	-	-	-	-	-	Jet had negligible effect on waste surface.
34	7 Saltcake 8.0 psi (55 kPa)	garden hose 0.25 (6.35 $*10^{-3}$)	20 (138)	-	-	-	-	-	Jet created a crater with a depth of 8 inches (0.203 m) and width of 1.5 inches (0.0381 m).
35	8 Saltcake 1.5 psi (10 kPa)	garden hose 0.25 (6.35 $*10^{-3}$)	20 (138)	-	-	-	-	-	Jet caused a mass failure of the plaster matrix. Pore space filled with water.

TABLE 4: TEST RESULTS - WASTE SIMULANTS

TEST #	RECIPE DESCRIPTION	NOZZLE DIA inches (m)	NOZZLE PRESS. psi (kPa)*	TEST DURATION seconds	INTL WT lb (kg)	FINL WT lb (kg)	CHANGE lb (kg)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
36	1 Wet Sludge 0.51 psi (4 kPa)	0.75 (1.91 $*10^{-2}$)	300 (2068)	37	64.0 (29.0)	3.06 (1.39)	60.9 (27.6)	292 (18.4)	Material ejected in one piece almost immediately.
37	1 Wet Sludge 0.51 psi (4 kPa)	0.75 (1.91 $*10^{-2}$)	150 (1034)	10	63.0 (28.6)	3.06 (1.39)	59.9 (27.2)	207 (13.1)	Material ejected in one piece almost immediately.
38	1 Wet Sludge 0.51 psi (4 kPa)	0.75 (1.91 $*10^{-2}$)	75 (517)	23	64.9 (29.4)	3.06 1.39)	61.8 (28.0)	146 (9.21)	Material ejected in one piece almost immediately.
39	2 Hardpan/DS 4.6 psi (32 kPa)	0.75 (1.91 $*10^{-2}$)	300 (2068)	2	58.1 (24.6)	3.06 (1.39)	55.1 (25.0)	292 (18.4)	Material ejected in one piece almost immediately.
40	2 Hardpan/DS 4.6 psi (32 kPa)	0.75 (1.91 $*10^{-2}$)	150 (1034)	2	57.3 (26.0)	3.13 (1.42)	54.1 (24.5)	207 (13.1)	Material ejected in one piece almost immediately.

TABLE 4: TEST RESULTS - WASTE SIMULANTS

TEST #	RECIPE DESCRIPTION	NOZZLE DIA inches (m)	NOZZLE PRESS. psi (kPa)*	TEST DURATION seconds	INTL WT lb (kg)	FINL WT lb (kg)	CHANGE lb (kg)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
41	2 Hardpan/DS 4.6 psi (32 kPa)	0.75 ($1.91 * 10^{-2}$)	75 (517)	5	59.3 (26.9)	3.06 (1.39)	56.2 (25.5)	146 (9.21)	Material ejected in one piece almost immediately.
42	3 Hardpan/DS 21.8 psi (150 kPa)	0.5 ($1.27 * 10^{-2}$)	300 (2068)	90	64.4 (29.2)	60.5 (27.4)	3.88 (1.76)	130 (8.20)	Jet created a crater 8.5 inches (0.216 m) deep with a 6 inch (0.152 m) diameter at the top.
43	3 Hardpan/DS 21.8 psi (150 kPa)	0.5 ($1.27 * 10^{-2}$)	150 (1034)	180	64.6 (29.3)	62.0 (28.1)	2.63 (1.19)	92 (5.80)	Jet created a crater 7 inches (0.178 m) deep with a 4.5 inch (0.114 m) diameter at the top.
44	3 Hardpan/DS 21.8 psi (150 kPa)	0.5 ($1.27 * 10^{-2}$)	75 (517)	300	67.1 (30.5)	64.5 (29.3)	3.08 (1.40)	65 (4.10)	Jet created a crater 4-5/8 inches (0.118 m) deep with a 5 inch (0.127 m) diameter at the top.
45	3 Hardpan/DS 21.8 psi (150 kPa)	0.625 ($1.59 * 10^{-2}$)	300 (2068)	10	66.9 (30.4)	44.5 (20.2)	22.4 (10.2)	203 (12.8)	Jet ejected a large chunk almost immediately upon impact.

TABLE 4: TEST RESULTS - WASTE SIMULANTS

TEST #	RECIPE DESCRIPTION	NOZZLE DIA inches (m)	NOZZLE PRESS. psi (kPa)*	TEST DURATION seconds	INTL WT lb (kg)	FINL WT lb (kg)	CHANGE lb (kg)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
46	3 Hardpan/DS 21.8 psi (150 kPa)	0.625 ($1.59 *10^{-2}$)	150 (1034)	90	61.8 (28.0)	58.9 (26.7)	2.87 (1.30)	144 (9.08)	Jet created a crater 5.75 inches (0.146 m) deep with a 6 inch (0.152 m) diameter at the top.
47	3 Hardpan/DS 21.8 psi (150 kPa)	0.625 ($1.59 *10^{-2}$)	75 (517)	240	64.0 (29.0)	62.0 (28.1)	2.0 (0.907)	101 (6.37)	Jet created a crater 6.25 inches (0.159 m) deep with a 4 inch (0.102 m) diameter at the top.
48	3 Hardpan/DS 21.8 psi (150 kPa)	0.75 ($1.91 *10^{-2}$)	300 (2068)	11.7	70.4 (31.9)	3.0 (1.36)	67.4 (30.6)	292 (18.4)	Material ejected in one piece.
49	3 Hardpan/DS 21.8 psi (150 kPa)	0.75 ($1.91 *10^{-2}$)	150 (1034)	50	68.9 (31.3)	3.0 (1.36)	65.9 (29.9)	207 (13.1)	Material ejected in one piece.
50	3 Hardpan/DS 21.8 psi (150 kPa)	0.75 ($1.91 *10^{-2}$)	75 (517)	540	67.5 (30.6)	64.5 (29.3)	3.0 (1.36)	146 (9.21)	Jet created a crater 4-7/8 inches (0.124 m) deep with a 4.5 inch (0.114 m) diameter at the top.

TABLE 4: TEST RESULTS - WASTE SIMULANTS

TEST #	RECIPE DESCRIPTION	NOZZLE DIA inches (m)	NOZZLE PRESS. psi (kPa)*	TEST DURATION seconds	INTL WT lb (kg)	FINL WT lb (kg)	CHANGE lb (kg)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
51	4 Saltcake 3000 psi (20,684 kPa)	0.75 ($1.91 * 10^{-2}$)	300 (2068)	299	92.8 (42.1)	48.7 (22.1)	44.1 (20.0)	292 (18.4)	Jet created a crater 13 inches (0.330 m) deep with a 7 inch (0.178 m) diameter at the top.
51A	4 Saltcake 3000 psi (20,684 kPa)	0.75 ($1.91 * 10^{-2}$)	300 (2068)	233	92.9 (42.1)	53.0 (24.0)	39.9 (18.1)	292 (18.4)	Jet created a crater 11-1/8 inches (0.283 m) deep with an 8.5 inch (0.216 m) diameter at the top.
52	4 Saltcake 3000 psi (20,684 kPa)	0.75 ($1.91 * 10^{-2}$)	150 (1034)	270	92.6 (42.0)	57.0 (25.9)	35.6 (16.2)	207 (13.1)	Jet created a crater 10.5 inches (0.267 m) deep with an 8 inch (0.203 m) diameter at the top.
54	5 Saltcake 1500 psi 0.0701 lb/in^3 (10,342 kPa) (1.94 g/cm^3)	0.75 ($1.91 * 10^{-2}$)	300 (2068)	288	80.6 (36.5)	56.5 (25.6)	24.0 (10.9)	292 (18.4)	Jet created a crater 11.5 inches (0.292 m) deep with a 7 inch (0.178 m) diameter at the top.
55	5 Saltcake 1500 psi 0.0701 lb/in^3 (10,342 kPa) (1.94 g/cm^3)	0.75 ($1.91 * 10^{-2}$)	150 (1034)	180	80.3 (36.4)	70.5 (32.0)	9.75 (4.42)	207 (13.1)	Jet created a crater 7.5 inches (0.191 m) deep with a 5.5 inch (0.140 m) diameter at the top.

TABLE 4: TEST RESULTS - WASTE SIMULANTS

TEST #	RECIPE DESCRIPTION	NOZZLE DIA inches (m)	NOZZLE PRESS. psi (kPa)*	TEST DURATION seconds	INTL WT lb (kg)	FINL WT lb (kg)	CHANGE lb (kg)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
56	5 Saltcake 1500 psi 0.0701 lb/in^3 (10,342 kPa) (1.94 g/cm^3)	0.75 (1.91 $*10^{-2}$)	75 (517)	300	79.9 (36.3)	70.0 (31.8)	9.94 (4.51)	146 (9.21)	Jet created a crater 9-1/8 inches (0.232 m) deep with a 5 inch (0.127 m) diameter at the top.
57	6 Saltcake 1500 psi 0.0820 lb/in^3 (10,342 kPa) (2.27 g/cm^3)	0.75 (1.91 $*10^{-2}$)	300 (2068)	600	89.3 (40.5)	64.5 (29.6)	24.8 (11.2)	292 (18.4)	Jet created a crater 3-3/8 inches (0.0859 m) deep with a 6.5 inch (0.165 m) diameter at the top.
57A	6 Saltcake 1500 psi 0.0820 lb/in^3 (10,342 kPa) (2.27 g/cm^3)	0.75 (1.91 $*10^{-2}$)	300 (2068)	900	88.3 (40.0)	45.9 (20.8)	42.3 (19.2)	292 (18.4)	Jet created a crater 7 inches (0.178 m) deep with a 6 inch (0.152 m) diameter at the top.
58	6 Saltcake 1500 psi 0.0820 lb/in^3 (10,342 kPa) (2.27 g/cm^3)	0.75 (1.91 $*10^{-2}$)	150 (1034)	1200	91.0 (41.3)	61.5 (32.6)	29.5 (13.4)	207 (13.1)	Jet created a crater 5 inches (0.127 m) deep with a 7 inch (0.178 m) diameter at the top.

TABLE 4: TEST RESULTS - WASTE SIMULANTS

TEST #	RECIPE DESCRIPTION	NOZZLE DIA inches (m)	NOZZLE PRESS. psi (kPa)*	TEST DURATION seconds	INTL WT lb (kg)	FINL WT lb (kg)	CHANGE lb (kg)	CALC. NOZZLE FLOW RATE gpm (L/sec)	OBSERVATIONS
60	7 Saltcake 8.0 psi (55 kPa)	0.75 ($1.91 *10^{-2}$)	300 (2068)	2	49.6 (21.2)	3.0 (1.36)	46.6 (21.2)	292 (18.4)	Material ejected immediately.
61	7 Saltcake 8.0 psi (55 kPa)	0.75 ($1.91 *10^{-2}$)	150 (1034)	3	49.8 (22.6)	3.0 (1.36)	46.8 (21.2)	207 (13.1)	Material ejected immediately.
62	7 Saltcake 8.0 psi (55 kPa)	0.75 ($1.91 *10^{-2}$)	75 (517)	2	50.5 (22.9)	3.0 (1.36)	47.5 (21.5)	146 (9.21)	Material ejected immediately.
63	8 Saltcake 1.5 psi (10 kPa)	0.75 ($1.91 *10^{-2}$)	300 (2068)	-	-	-	-	292 (18.4)	Not run.
64	8 Saltcake 1.5 psi (10 kPa)	0.75 ($1.91 *10^{-2}$)	150 (1034)	-	-	-	-	207 (13.1)	Not run.

TABLE 4: TEST RESULTS - WASTE SIMULANTS									
TEST #	RECIPE DESCRIPTION	NOZZLE DIA	NOZZLE PRESS.	TEST DURATION	INTL WT	FINL WT	CHANGE	CALC. NOZZLE FLOW RATE	OBSERVATIONS
		inches (m)	psi (kPa)*	seconds	lb (kg)	lb (kg)	lb (kg)	gpm (L/sec)	
65	8 Saltcake 1.5 psi (10 kPa)	0.75 ($1.91 * 10^{-2}$)	75 (517)	-	-		-	146 (9.21)	Not run.

* gauge pressure

TABLE 5: DISLODGING AND MOBILIZATION MECHANISMS		
Waste Simulant	**Dislodging Mechanism**	**Mobilization Mechanism**
1	plastic flow and dissolution	slurry flow and tumbling
2	plastic flow and dissolution	slurry flow and tumbling
3	dissolution	slurry flow
4	dissolution	slurry flow
5	dissolution	slurry flow
6	brittle fracture	slurry flow
7	brittle fracture	tumbling

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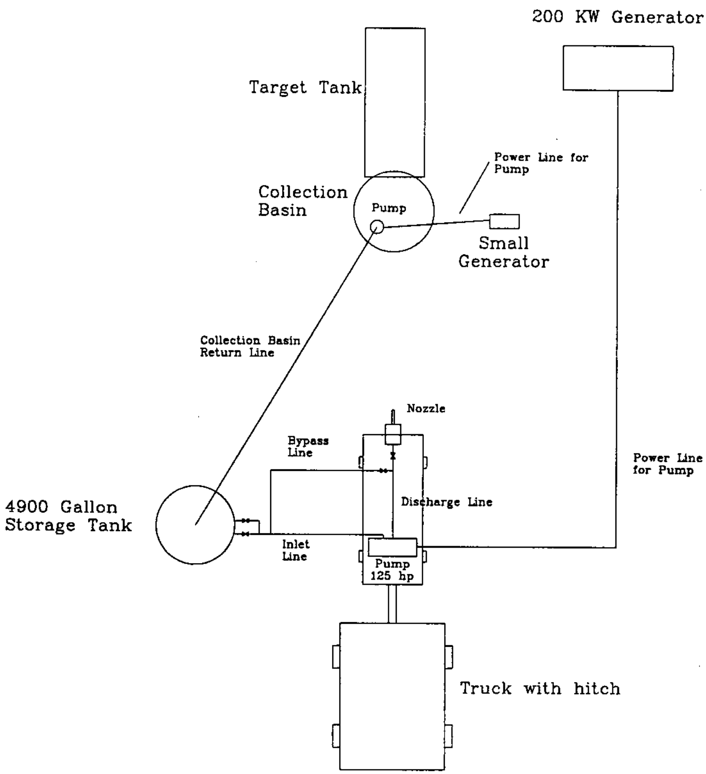
FIGURE 1: SCHEMATIC OF TEST SETUP



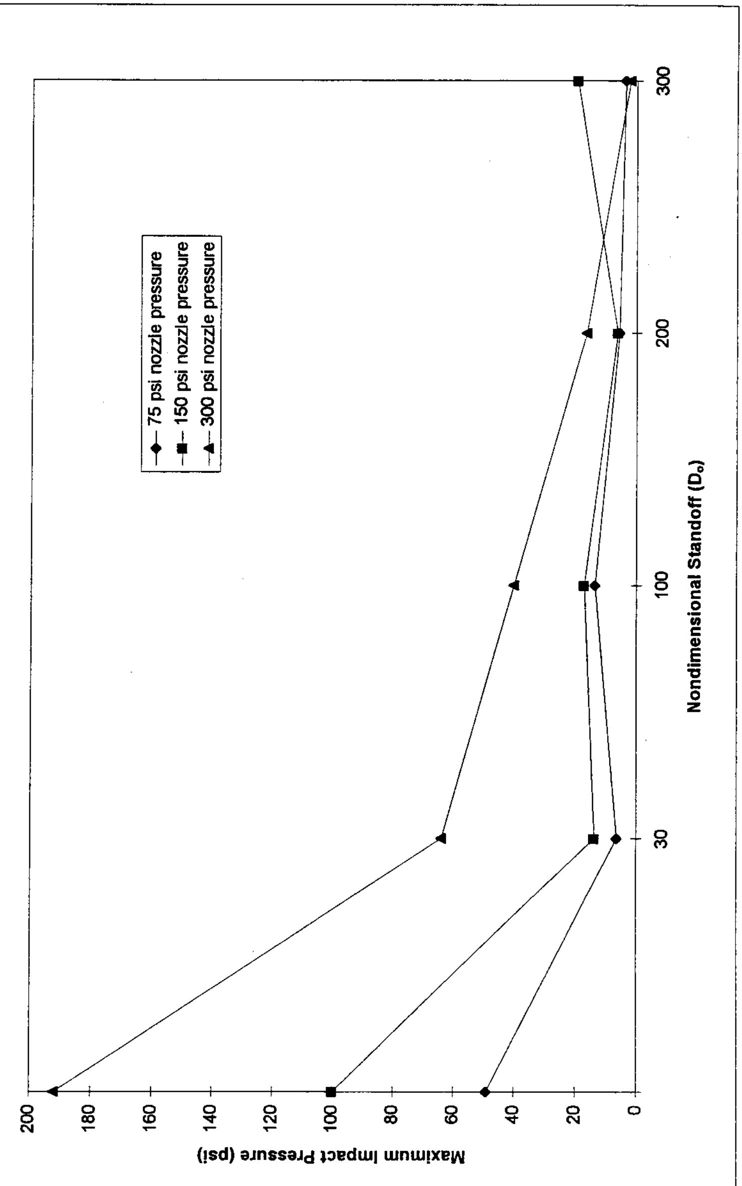


Figure 2. Maximum Impact Pressure vs Nondimensional Standoff 0.75 Inch Nozzle

Figure 2A. Maximum Impact Pressure vs Nondimensional Standoff
$1.91*10^{-2}$ Meter Nozzle

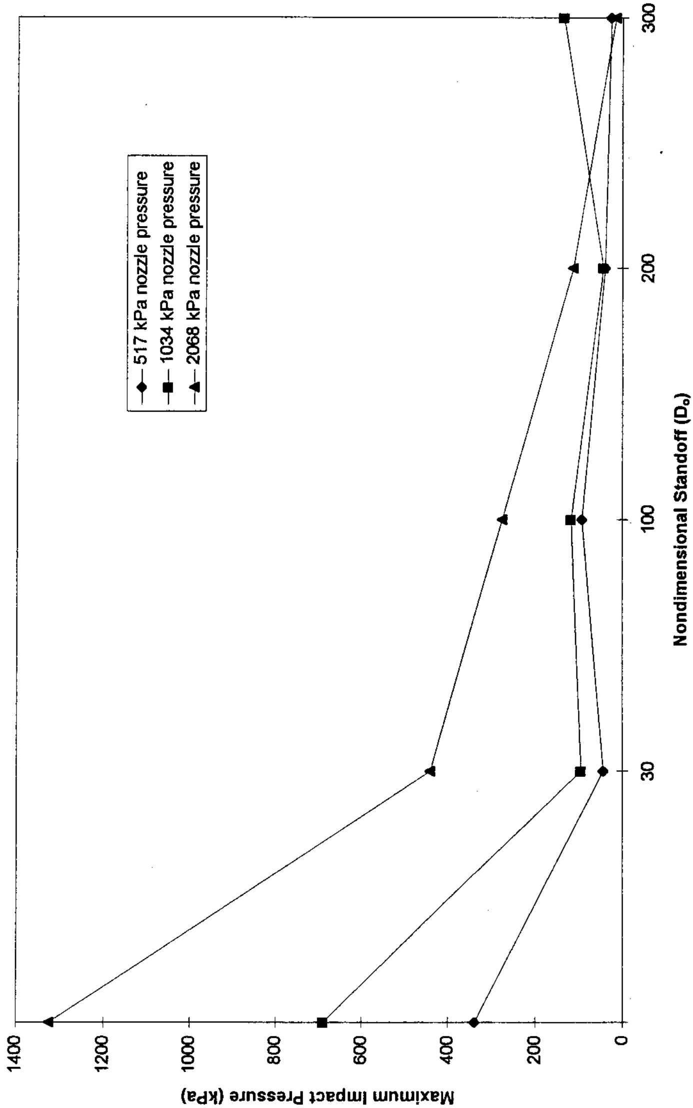
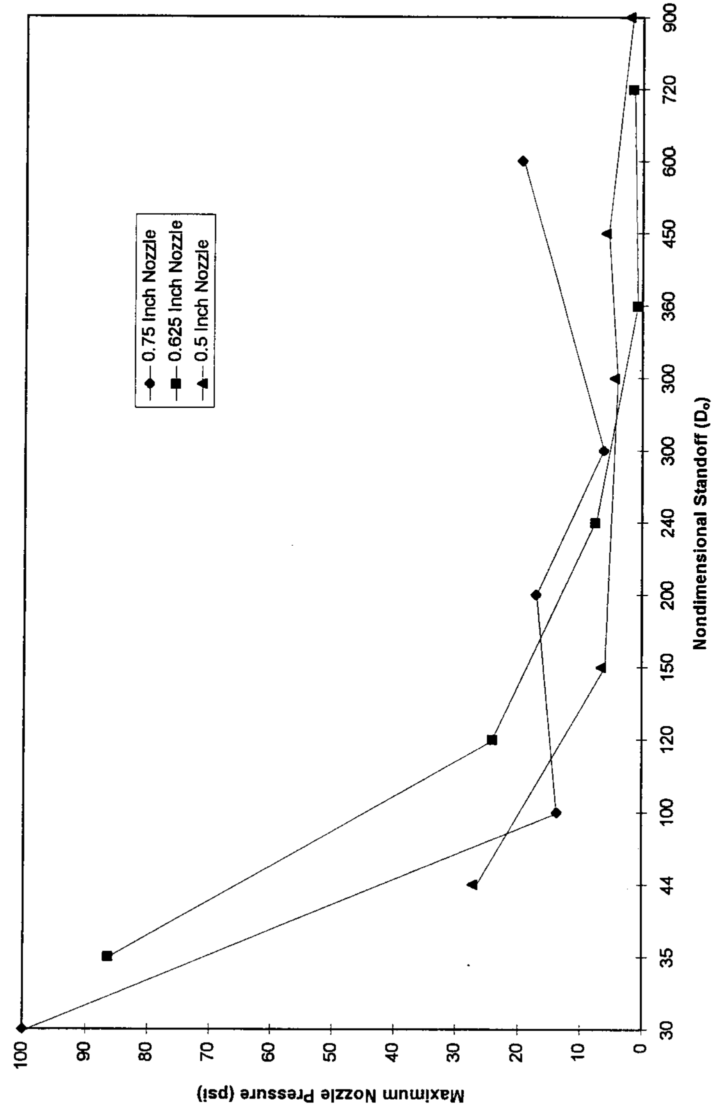


Figure 3. Maximum Impact Pressure vs Nondimensional Standoff 150 psi Nozzle Pressure



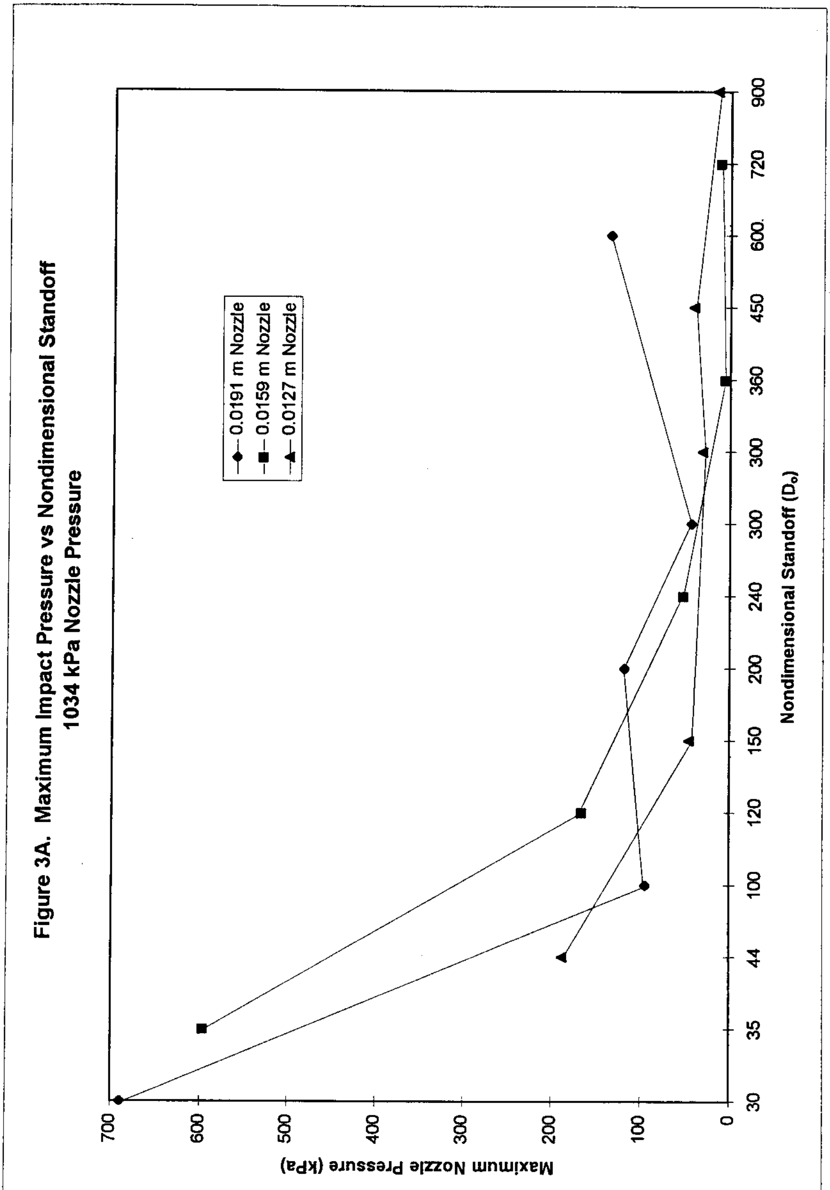
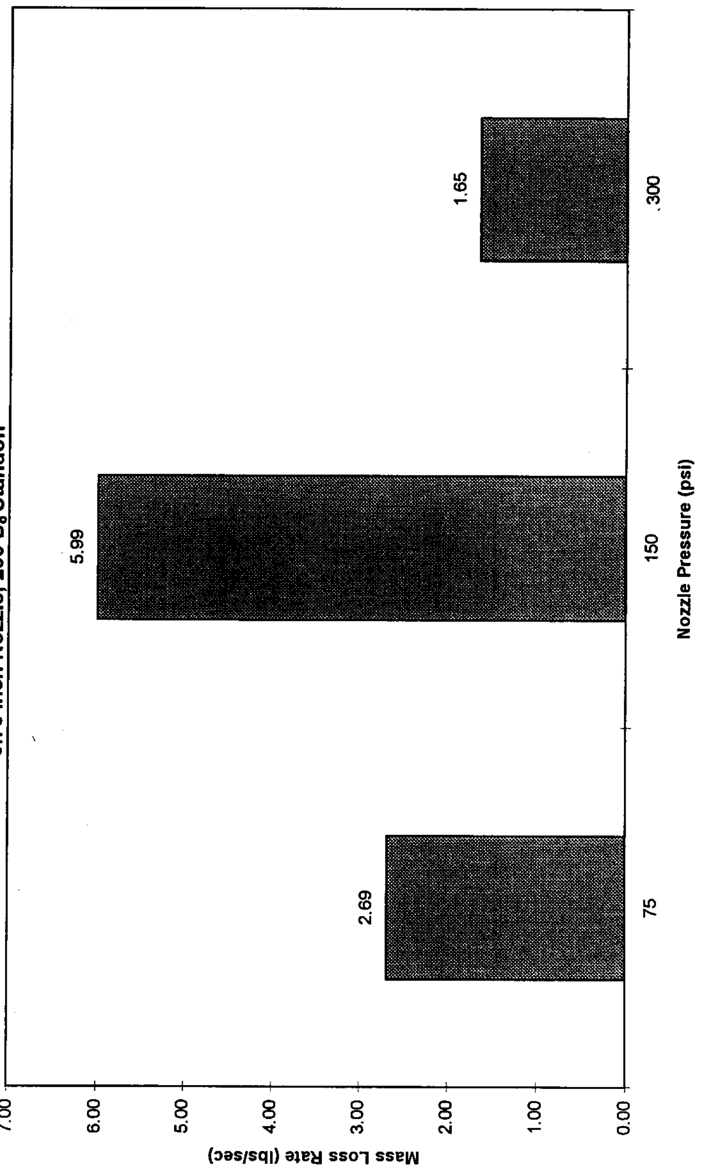


Figure 3A. Maximum Impact Pressure vs Nondimensional Standoff
1034 kPa Nozzle Pressure

Figure 4. Mass Loss Rate vs Nozzle Pressure Waste Simulant 1 (Wet Sludge, 0.51 psi) 0.75 Inch Nozzle, 200 D_o Standoff



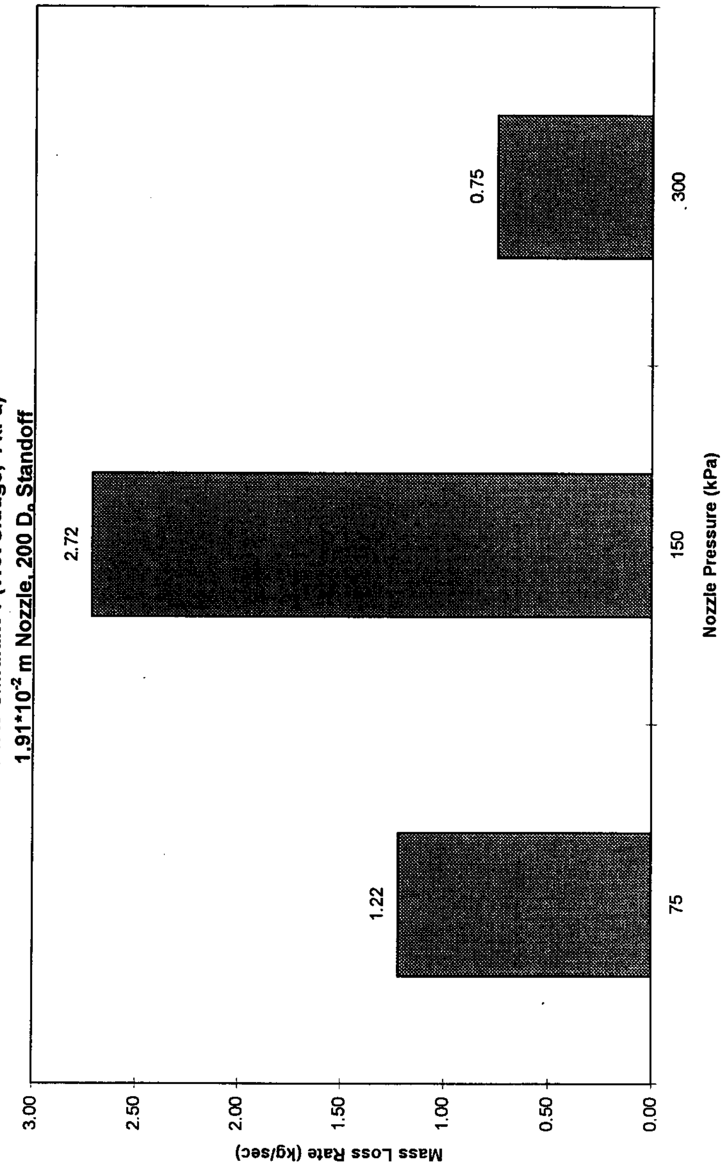


Figure 4A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 1 (Wet Sludge, 4 kPa)
$1.91*10^{-2}$ m Nozzle, 200 D_o Standoff

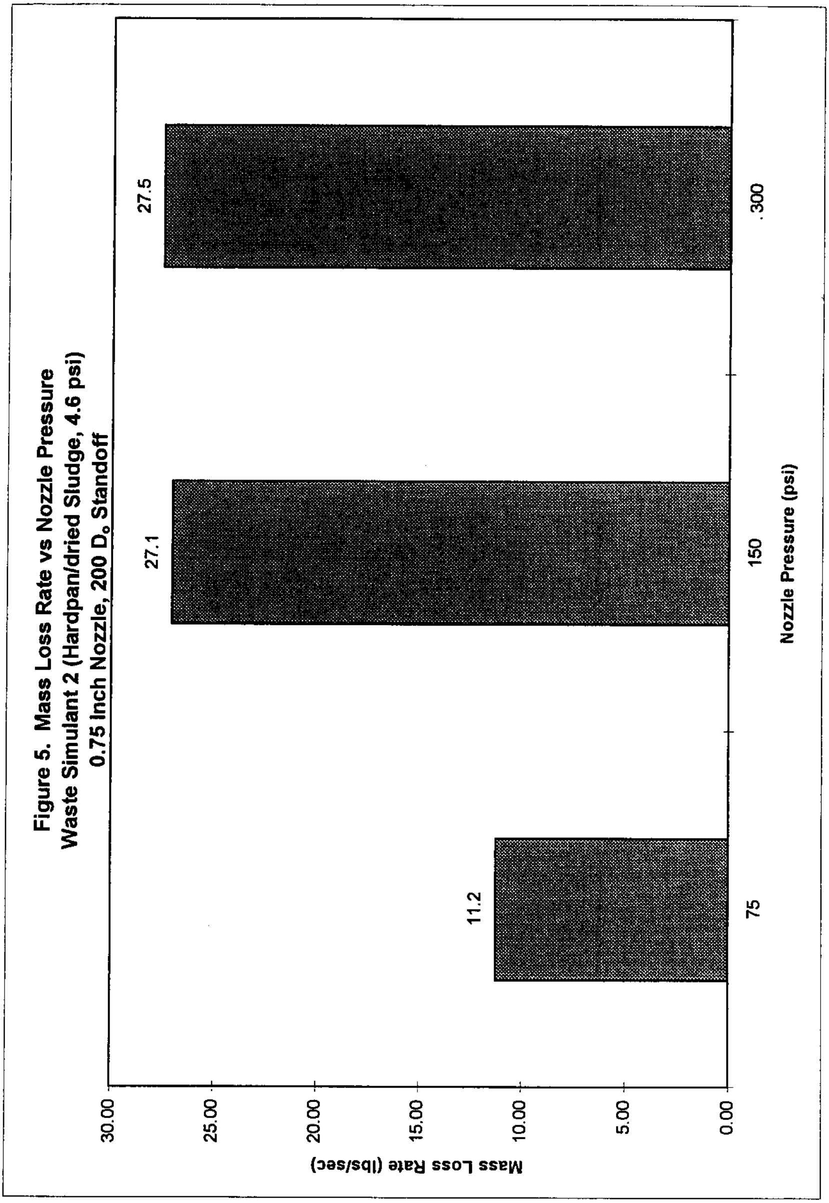


Figure 5. Mass Loss Rate vs Nozzle Pressure Waste Simulant 2 (Hardpan/dried Sludge, 4.6 psi) 0.75 Inch Nozzle, 200 D_o Standoff

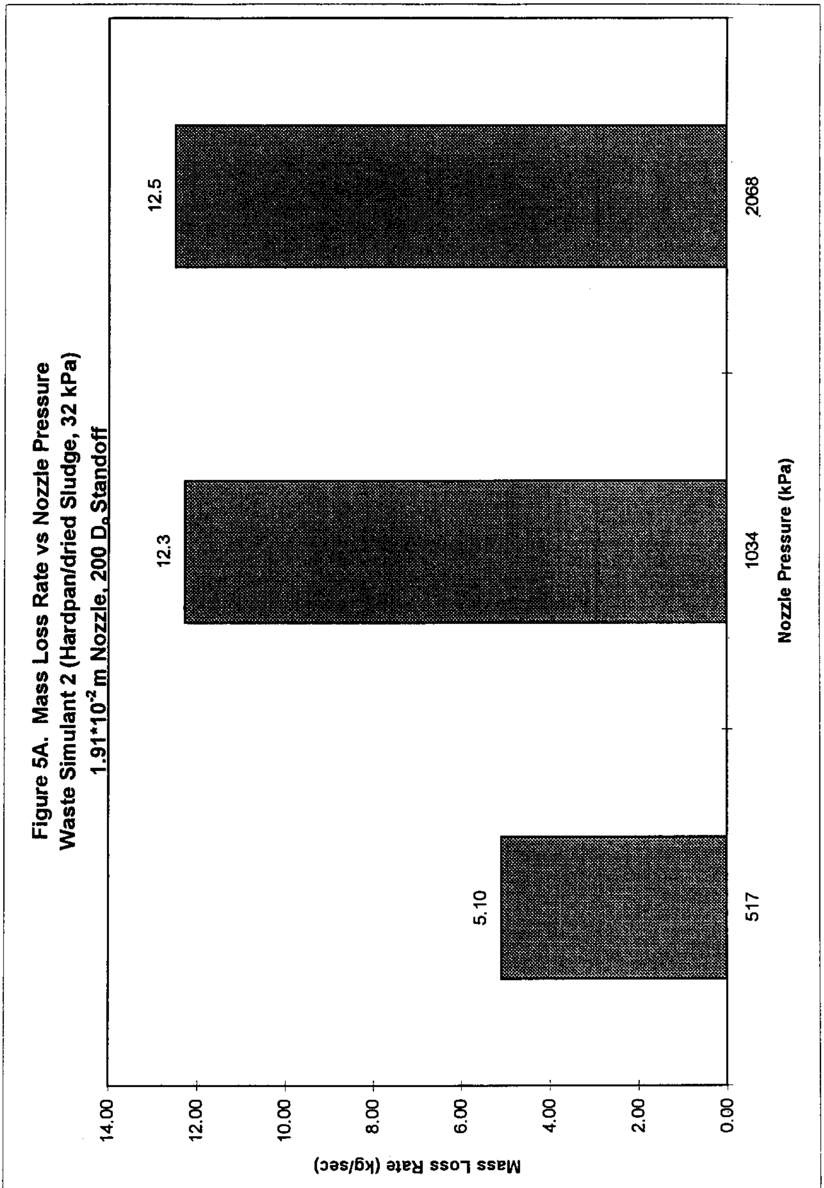


Figure 5A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 2 (Hardpan/dried Sludge, 32 kPa)
$1.91*10^{-2}$ m Nozzle, 200 D_o Standoff

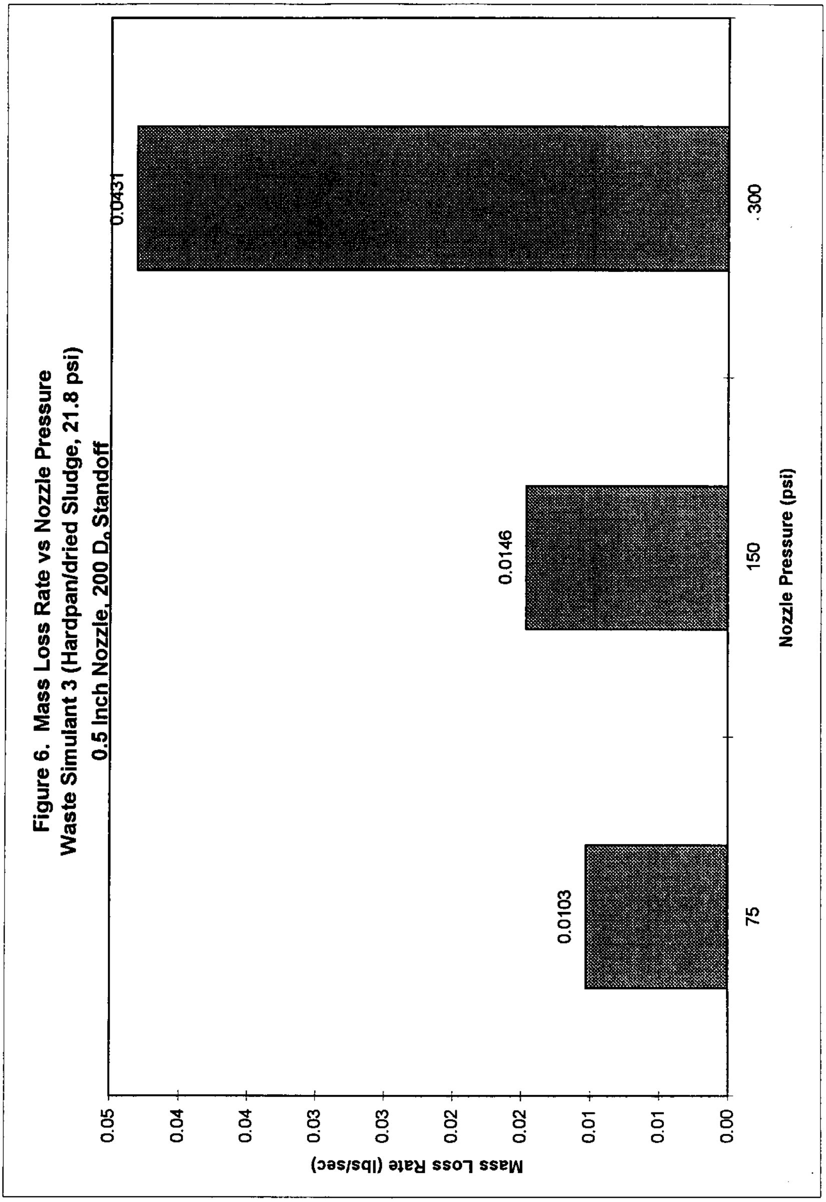


Figure 6. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 3 (Hardpan/dried Sludge, 21.8 psi)
0.5 Inch Nozzle, 200 D$_o$ Standoff

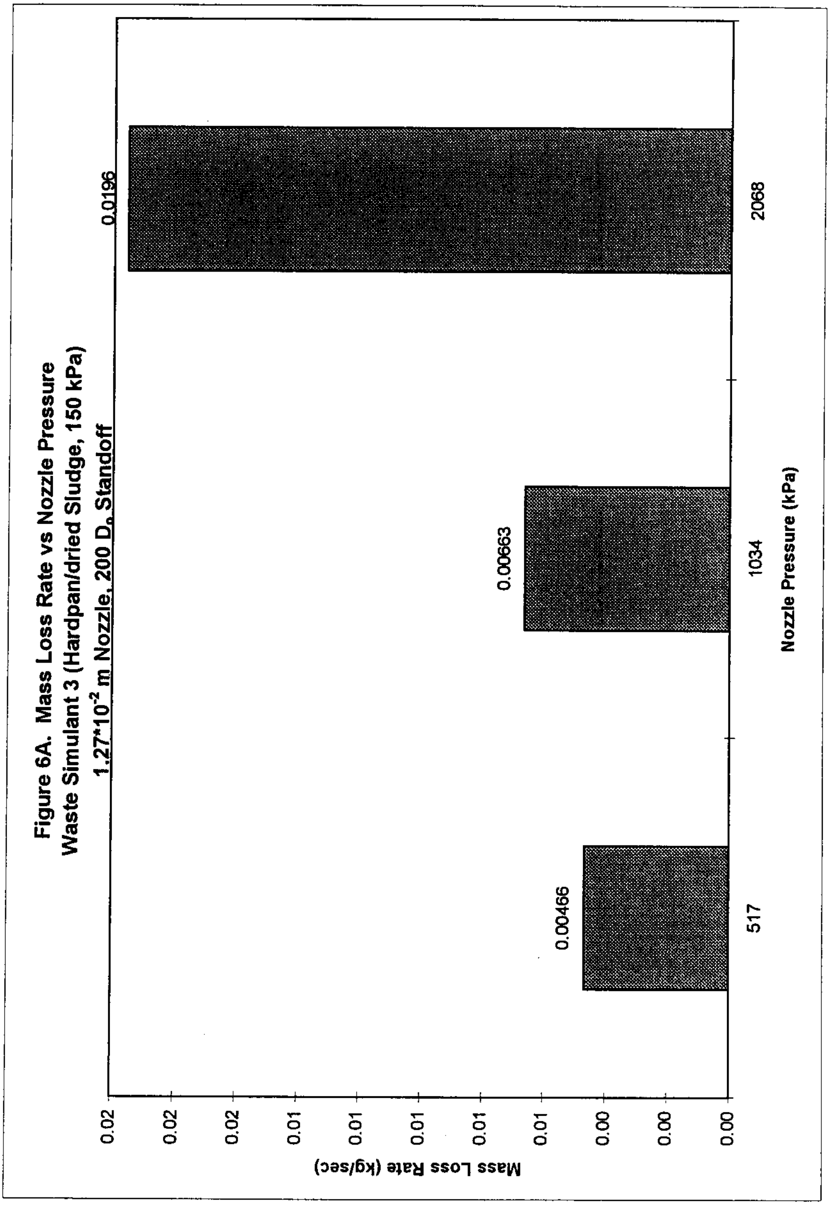


Figure 6A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 3 (Hardpan/dried Sludge, 150 kPa)
$1.27*10^{-2}$ m Nozzle, 200 D_o Standoff

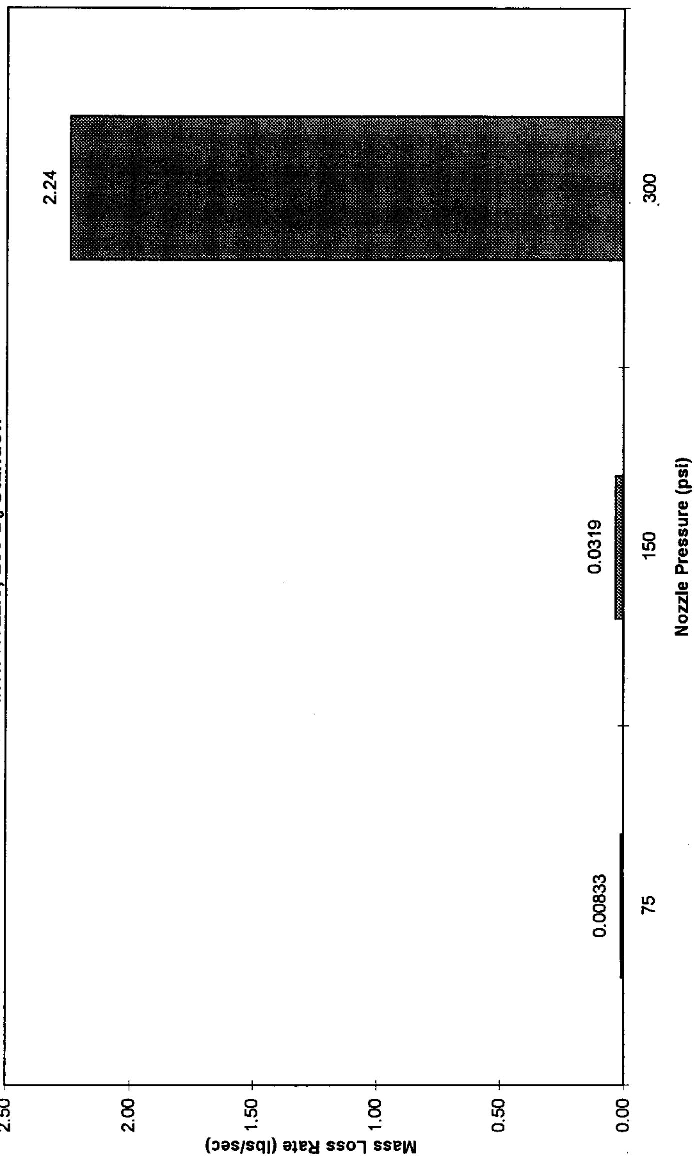


Figure 7. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 3 (Hardpan/dried Sludge, 21.8 psi)
0.625 Inch Nozzle, 200 D_o Standoff

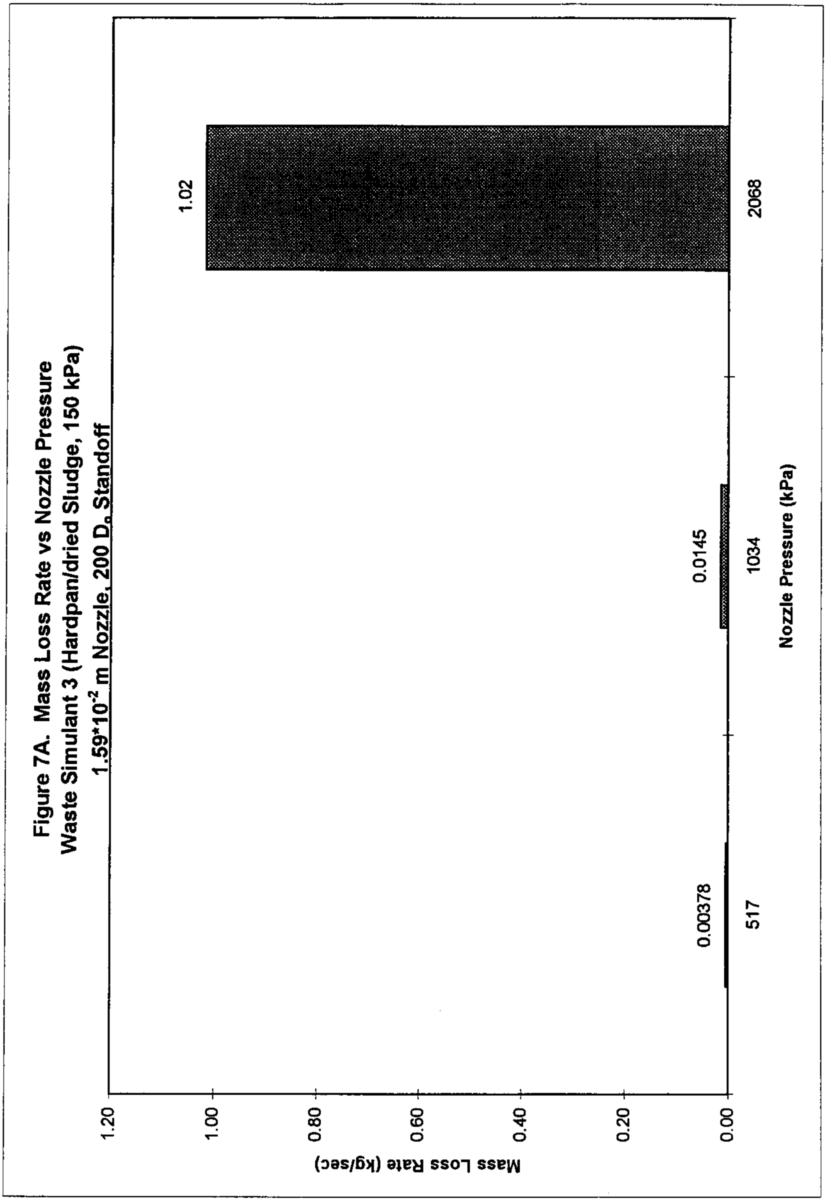


Figure 7A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 3 (Hardpan/dried Sludge, 150 kPa)
$1.59*10^{-2}$ m Nozzle, 200 D_o Standoff

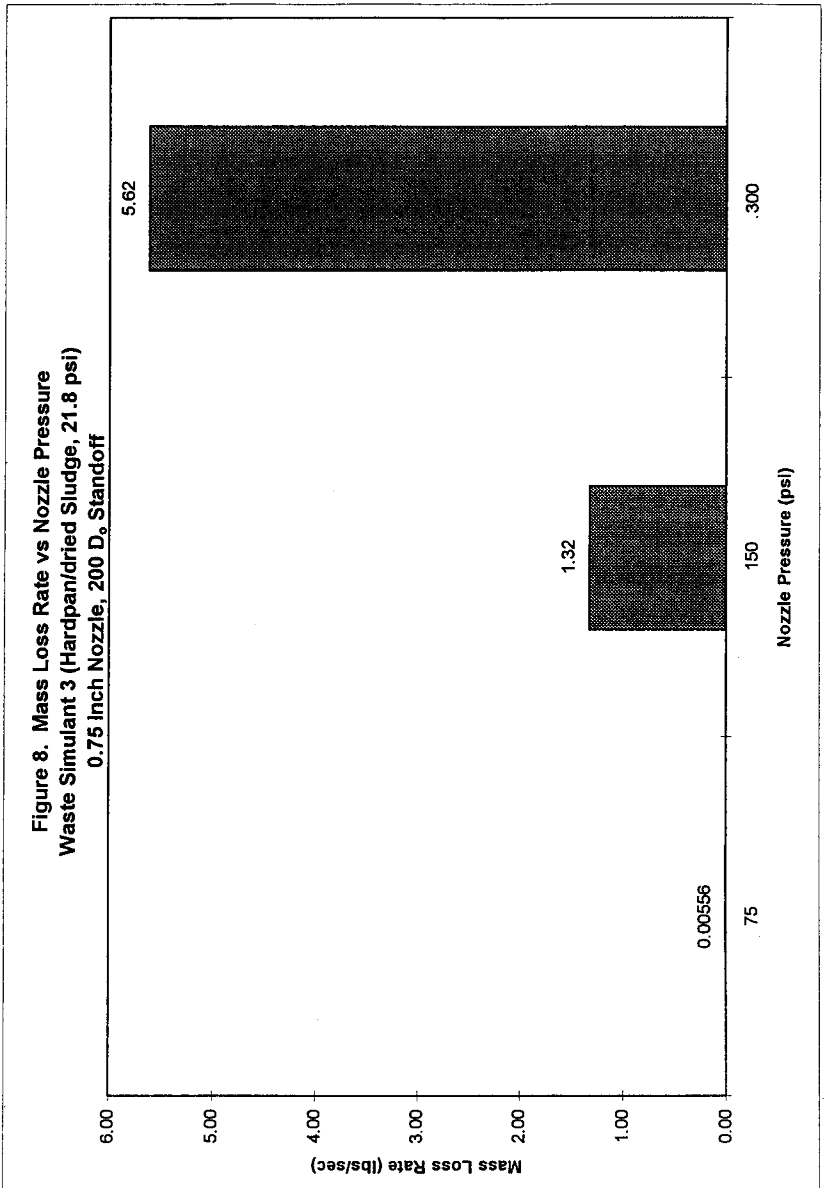
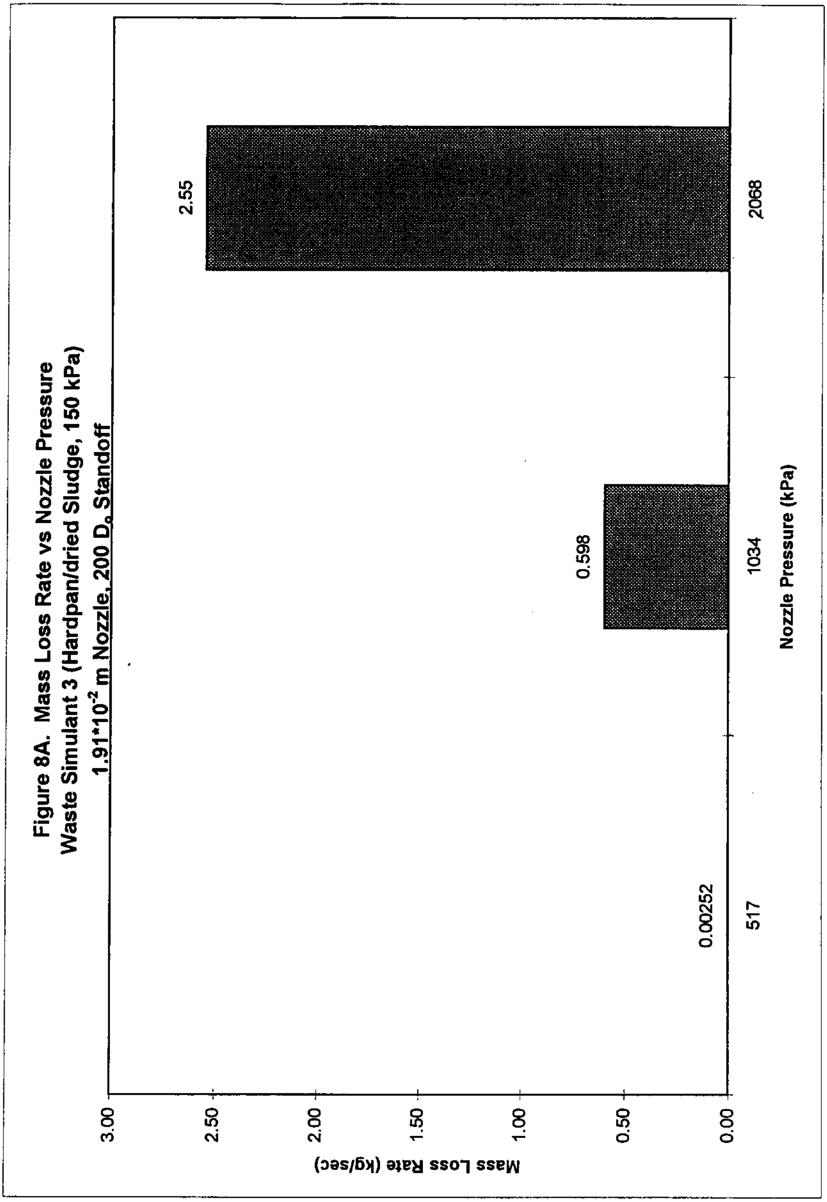


Figure 8. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 3 (Hardpan/dried Sludge, 21.8 psi)
0.75 Inch Nozzle, 200 D_o Standoff

Figure 8A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 3 (Hardpan/dried Sludge, 150 kPa)
$1.91*10^{-2}$ m Nozzle, 200 D_o Standoff



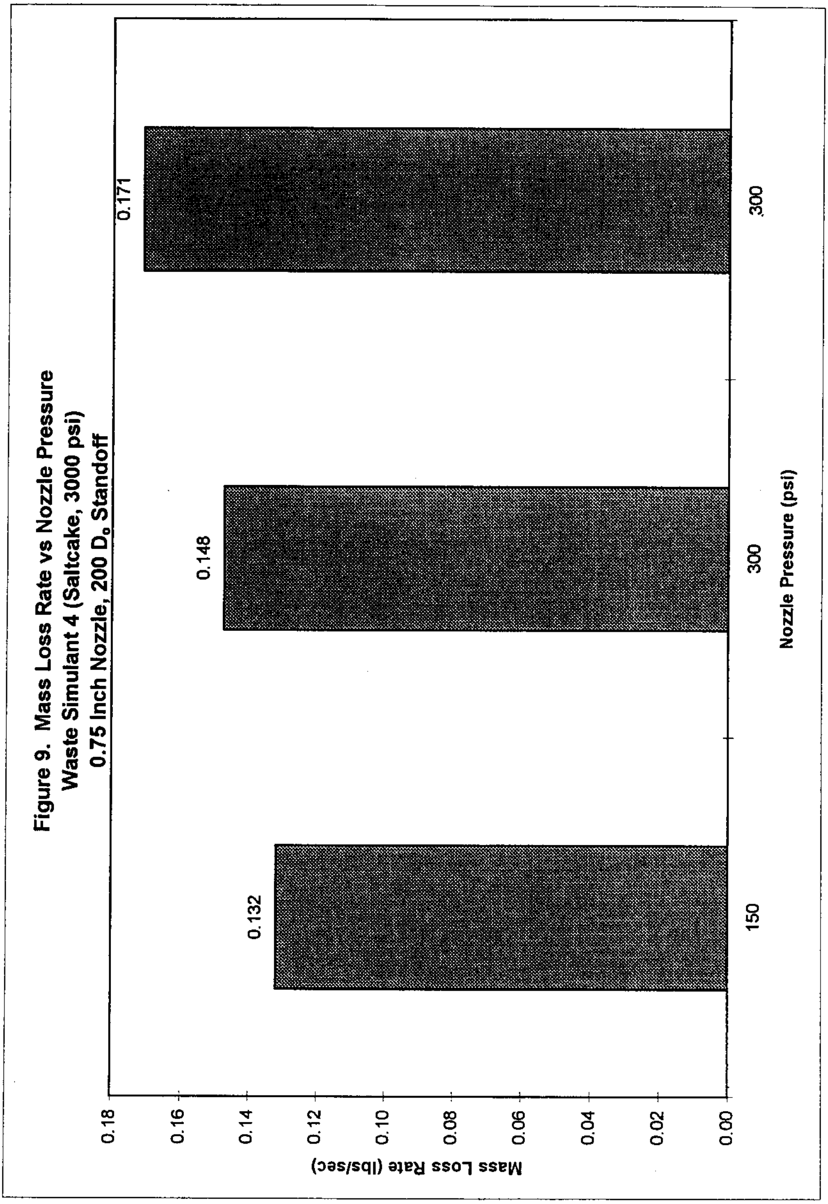


Figure 9. Mass Loss Rate vs Nozzle Pressure Waste Simulant 4 (Saltcake, 3000 psi) 0.75 Inch Nozzle, 200 D_o Standoff

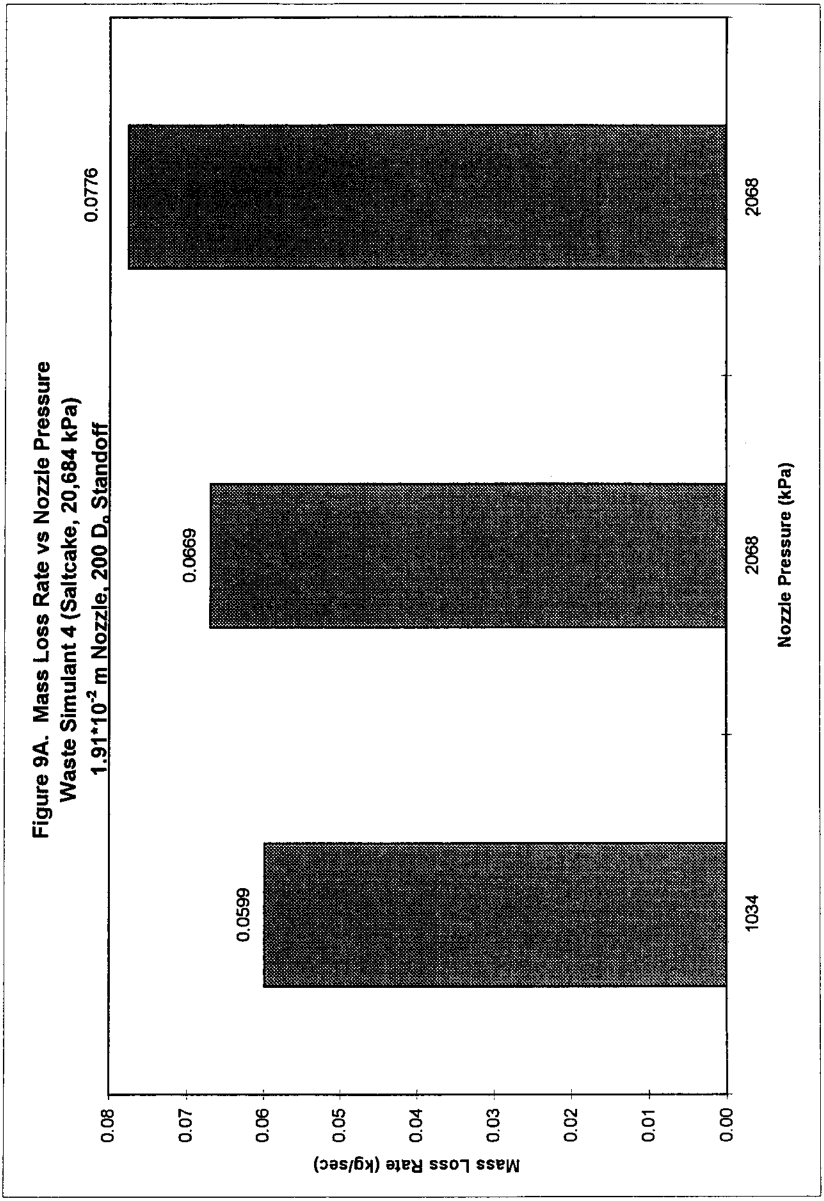


Figure 9A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 4 (Saltcake, 20,684 kPa)
$1.91*10^{-2}$ m Nozzle, 200 D_o Standoff

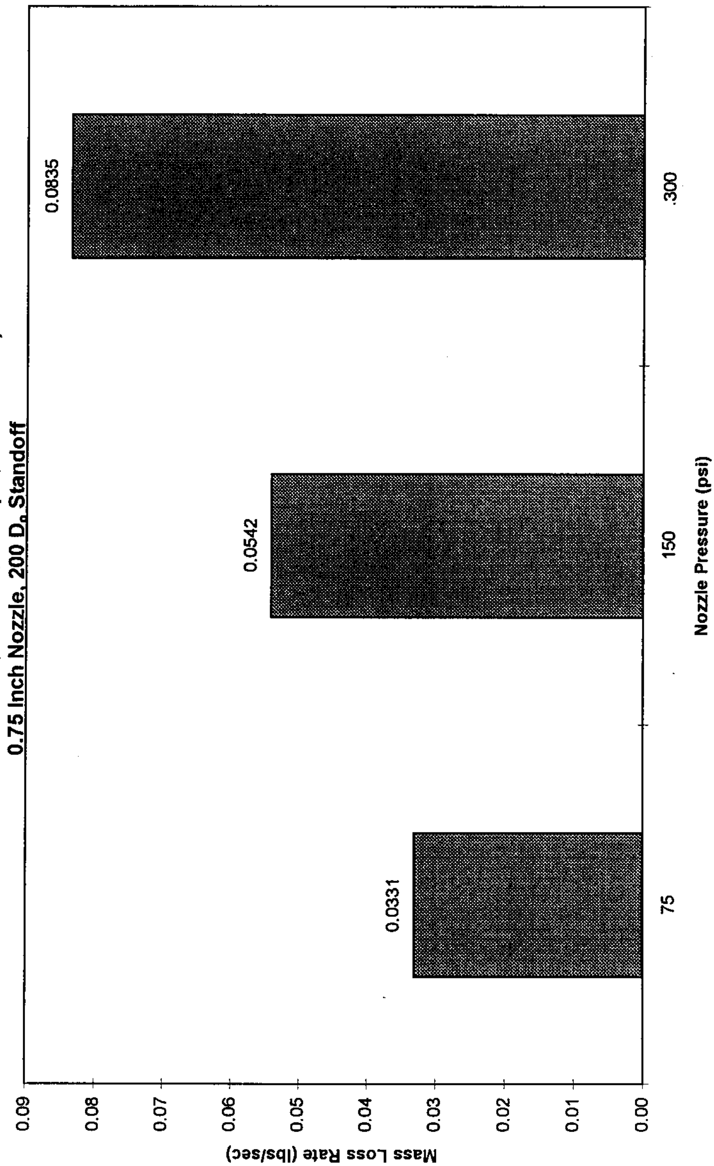


Figure 10. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 5 (Saltcake, 1500 psi, 0.0701 lb/in^3)
0.75 Inch Nozzle, 200 D_o Standoff

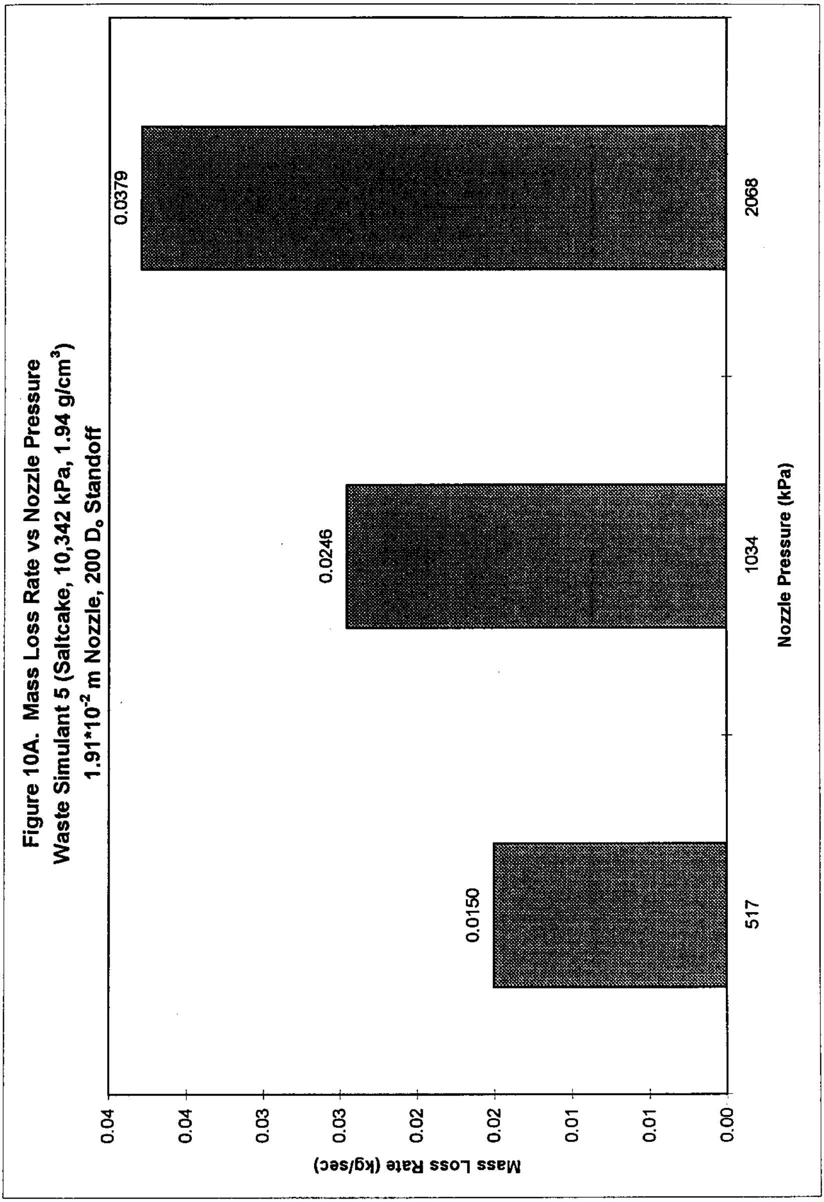


Figure 10A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 5 (Saltcake, 10,342 kPa, 1.94 g/cm^3)
1.91*10^{-2} m Nozzle, 200 D_o Standoff

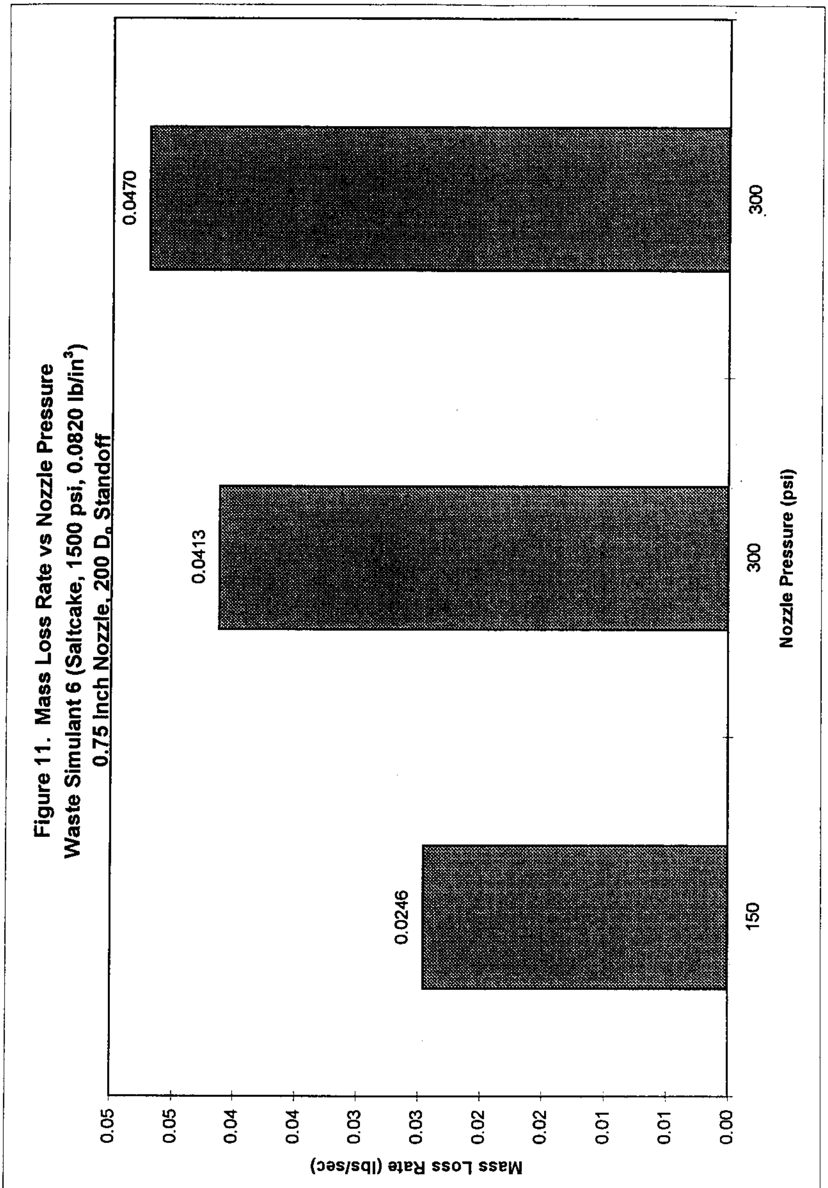


Figure 11. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 6 (Saltcake, 1500 psi, 0.0820 lb/in^3)
0.75 Inch Nozzle, 200 D_o Standoff

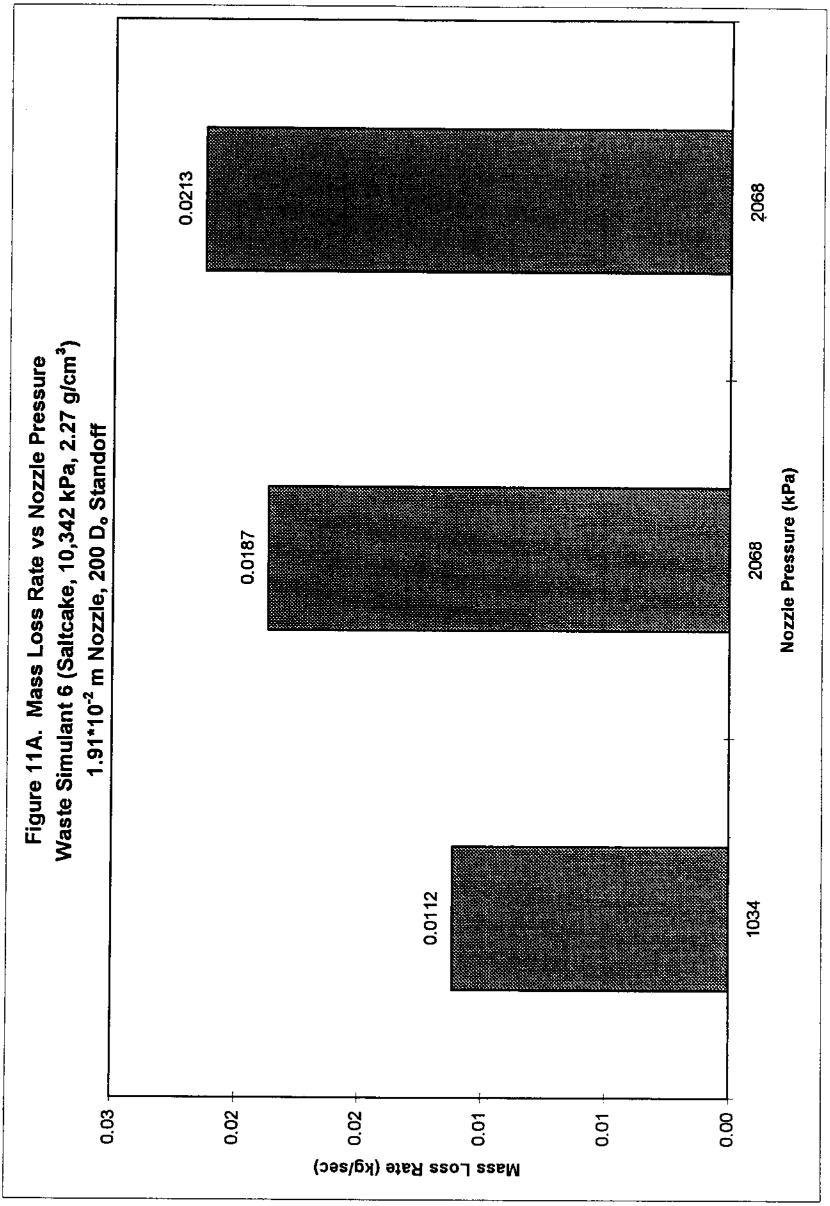
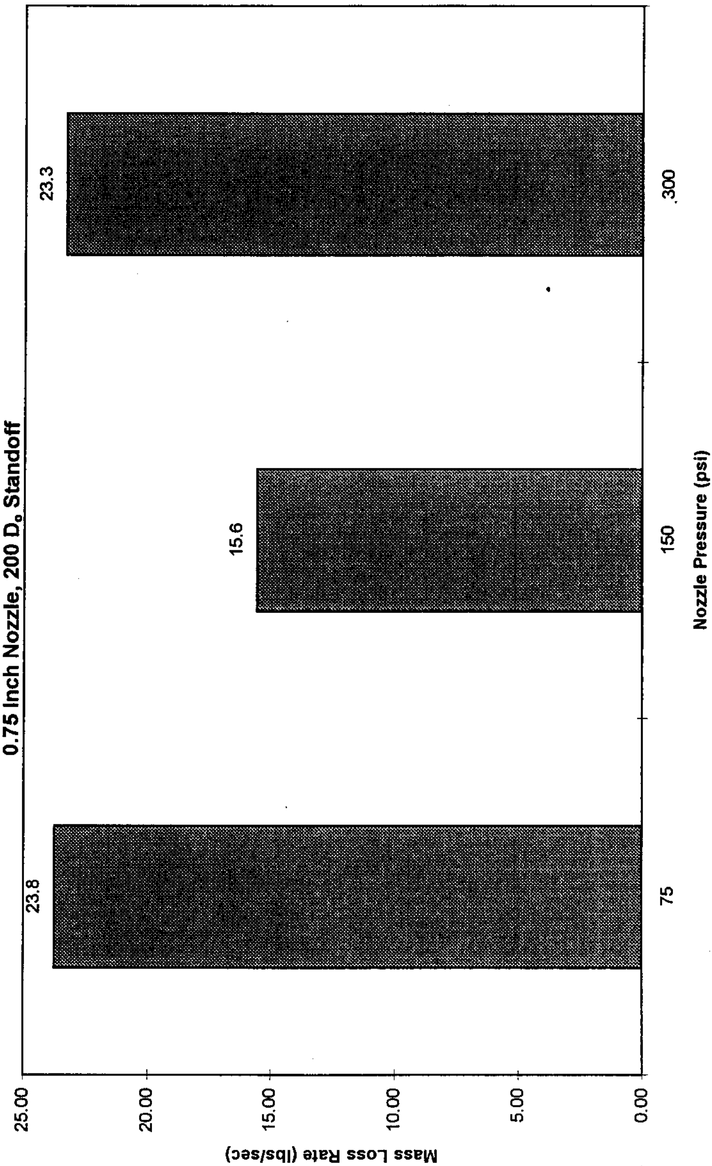


Figure 11A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 6 (Saltcake, 10,342 kPa, 2.27 g/cm^3)
1.91*10^{-2} m Nozzle, 200 D$_o$ Standoff

Figure 12. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 7 (Saltcake, 8.0 psi)
0.75 Inch Nozzle, 200 D_o Standoff



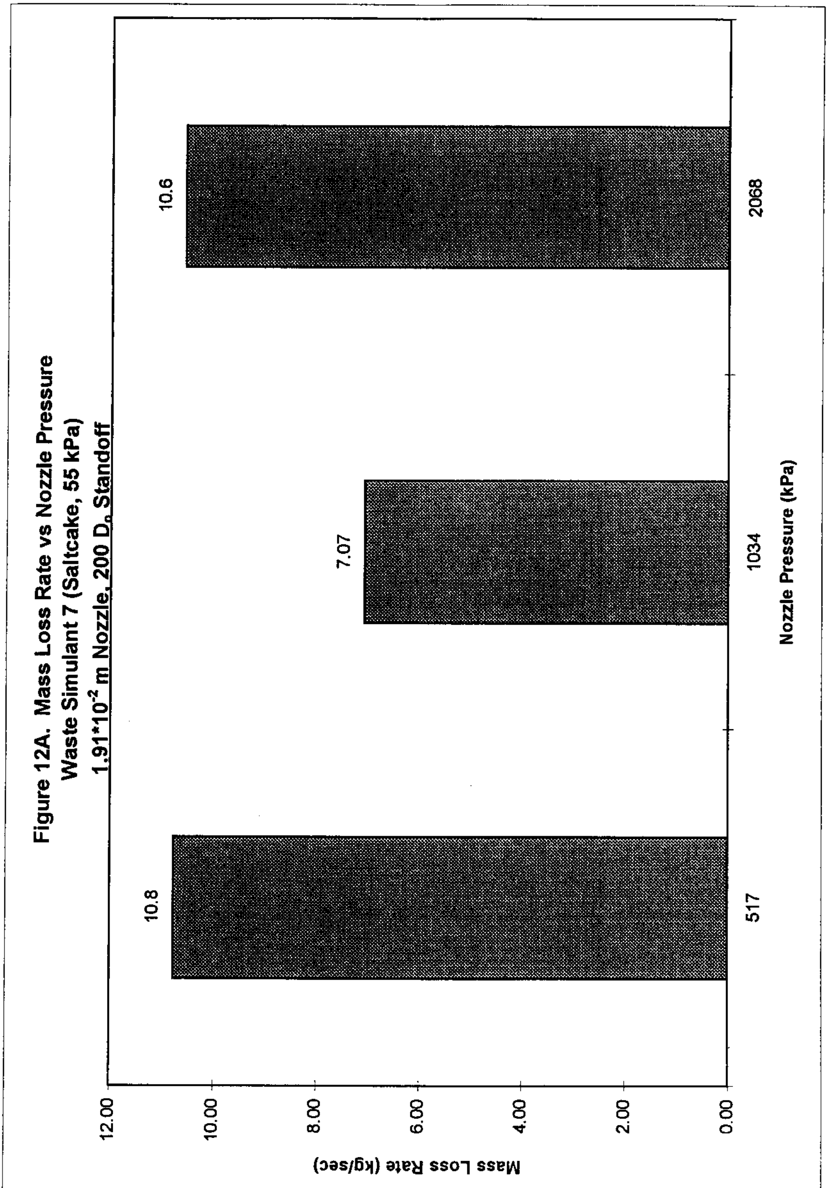
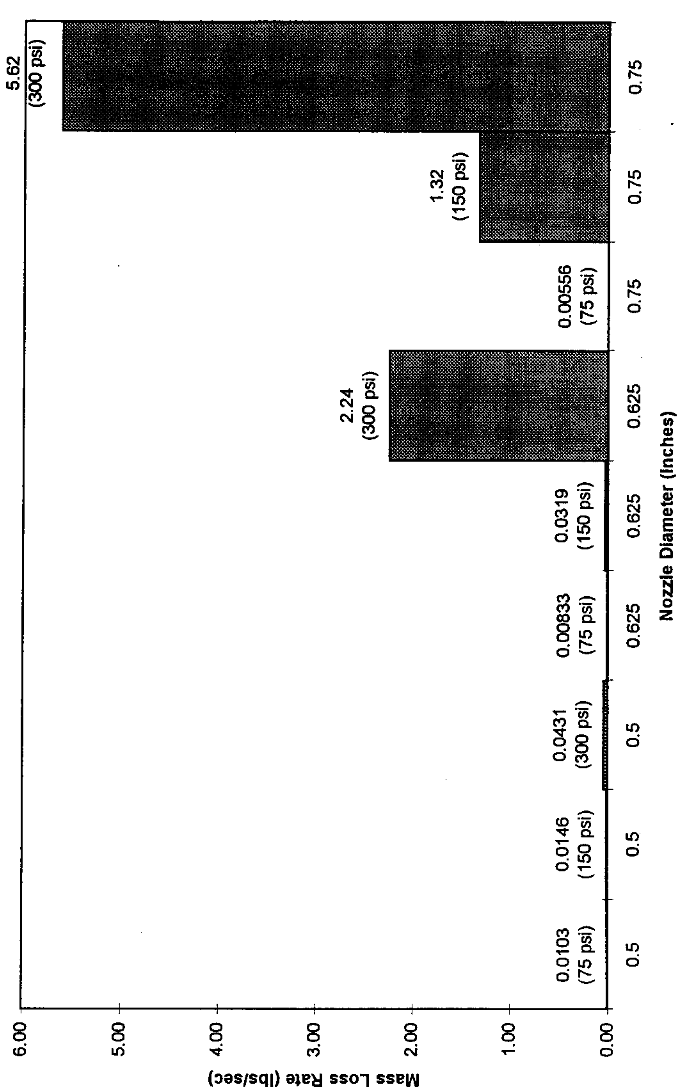


Figure 12A. Mass Loss Rate vs Nozzle Pressure
Waste Simulant 7 (Saltcake, 55 kPa)
$1.91*10^{-2}$ m Nozzle, 200 D_o Standoff

Figure 13. Mass Loss Rate vs Nozzle Diameter
Waste Simulant 3 (Hardpan/dried Sludge, 21.8 psi)



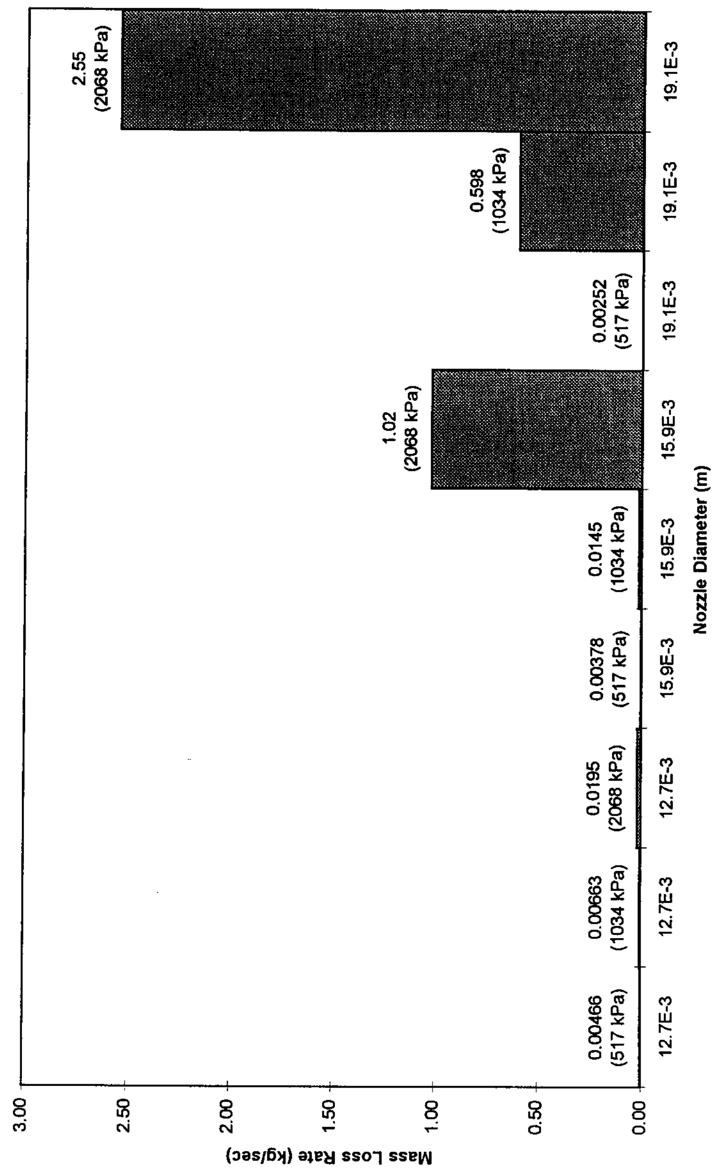


Figure 13A. Mass Loss Rate vs Nozzle Diameter Waste Simulant 3 (Hardpan/dried Sludge, 150 kPa)

APPENDIX A: WORK PLAN FOR SLUICING NOZZLE TESTS

PACKER ENGINEERING INC.

WORK PLAN FOR SLUICING NOZZLE TESTS

WESTINGHOUSE HANFORD COMPANY

INTRODUCTION

The Westinghouse Hanford Company (WHC) is exploring various options for retrieving waste materials from the underground storage tanks at the Hanford Site in Richland, Washington. One option under investigation is the use of a commercially available sluicing nozzle. The purpose of this test program is to determine the performance of a sluicing nozzle manufactured by Bristol Equipment Company (BEC) against several Hanford waste simulants. Sluicing nozzle performance will be determined as a function of nozzle diameter, nozzle pressure and standoff. This work plan describes the work that will be done by Packer Engineering. The work is divided into two test groups:

- Load Cell Tests
- Waste Simulant Reaction Tests

The next section discusses the rationale for the test program. Then, each test group is described below in terms of its objective, technical approach and data reduction. The outline for the test report is presented. The next section describes the test setup and equipment. Next, the quantities of materials are estimated. The schedule section concludes the work plan.

The specific procedures for each test group are not presented in this work plan. Once this test program is authorized by WHC, the design of the test setup will be finalized and both procedures and checklists will be developed for each test group. The written procedures will be included in the test report submitted to WHC as the final deliverable.

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RATIONALE FOR TEST PROGRAM

The purpose of this test program is to establish a performance baseline against which to compare other competing technologies. The test program is designed to provide sufficient data to determine:

- Jet quality as a function of standoff for different nozzle diameters and nozzle pressures.
- Material response of waste simulants as a function of nozzle pressure for different nozzle diameters.
- Threshold (minimum) impact pressure at which material is dislodged from the waste simulant surface.

The relevance of these test results is strictly limited to the BEC tank cleaning (sluicing) equipment. It is expected, however, that this test program will yield physical insights which will be relevant in the evaluation of competing technologies.

The experimental variables for this test program include the following:

- Nozzle diameter: internal diameter of nozzle at nozzle exit
- Nozzle pressure: static pressure at nozzle entrance
- Standoff: distance from nozzle exit to target
- Waste simulant material: each waste simulant has a different mechanical strength

The test matrix shown in Table 1 lists the choices for each experimental variable. Varying the nozzle diameter and pressure results in a wide range of fluid dynamic quantities (flow rate, velocity, Reynolds number, impact pressure and impact force). The nozzle diameters to be used in the test program are one-half, five-eighths and three-fourths inch; the three-fourths inch nozzle is the largest standard nozzle available from BEC. The nozzle pressures to be tested are 75, 150 and 300 psig. The nominal operating pressure of the one-inch diameter Hanford nozzle is 150 psig. The range of fluid dynamic quantities achievable is shown in Table 2. The dimensionless standoff distances (expressed as multiples of nozzle diameter) are converted to dimensional distances in Table 3.

The test program is divided into two test groups: load cell tests and waste simulant reaction tests. The load cell tests evaluate changes in jet quality as a function of standoff for different nozzle diameters and nozzle pressures. The data from the test group will enable WHC to determine the optimal standoff and the maximum effective standoff. The experimental design will also allow WHC to compare the effect on jet quality caused by changes in nozzle diameter (at fixed nozzle pressure) and nozzle pressure (at fixed nozzle diameter). The largest number of tests will be conducted with the three-fourths inch nozzle because it is closest in diameter to the Hanford nozzle.

The waste simulant reaction tests will evaluate the material response of the waste simulants to different impact pressures. All tests will be conducted at the optimal standoff. The experimental design will allow WHC to:

- Observe differences in sluicing behavior between different waste simulant materials
- Determine if there is a threshold dynamic pressure below which there is no dislodging of material
- Examine the influence of flow rate on material response at a fixed dynamic pressure
- Determine the fraction of oversize material defined as + 6.35 mm (+ 1/4 inch) generated

The waste simulant compositions and properties are summarized in Table 4.

LOAD CELL TESTS

Objective

The objective of the load cell tests is to determine jet quality as a function of standoff distance, nozzle pressure and nozzle diameter. Jet quality will be evaluated in terms of dynamic pressure and jet geometry. The results will be used to determine the optimal and maximum effective standoffs.

Technical Approach

All load cell tests will be conducted with a horizontal sluicing jet using clean water (i.e., no suspended solids). There will be a total of thirty tests. The test duration will depend on how long it takes to get a relatively stable signal from the load cell (probably one to two minutes). The load cell will consist of a metal target plate and an array of pressure transducers. It will be constructed and supplied by WHC. Photographs will be taken to record visual observations during each test. Both the nozzle flow rate and pressure will be measured during each test. To enhance visual quality, dye color may be added to the water reservoir and/or a photographic background may be used.

The test plan is summarized in Table 1. The one-half inch and five-eighths inch nozzles will be tested at a single nozzle pressure (150 psig or 1030 kPa). The three-quarter inch nozzle will be tested at three pressures: 75, 150 and 300 psig (520, 1030 and 2070 kPa). All three nozzles will be tested at six standoffs corresponding to 30, 100, 200, 300, 600 and 1000 nozzle diameters. No waste simulants will be used in these tests.

The definitions of optimal and maximum effective standoffs are not consistently applied in the published literature. For this test program, the optimal standoff will be defined as the standoff at which the jet is fully developed and has a mean impact pressure of at least 95% of the dynamic pressure which represents the theoretical upper bound. The maximum effective standoff is defined as the standoff where the mean impact pressure is 50% of the dynamic pressure. It is possible that each of these definitions will apply to a range of standoffs rather than a single standoff.

Data Reduction

The test data will be transmitted to WHC in both tabular and graphical form as an interim deliverable. All impact pressure data will be time-averaged to smooth the instantaneous data. A mean impact pressure will be calculated by averaging the time-averaged pressure data over the surface of the entire array. The test data to be reported in tabular format includes the following:

- Nozzle diameter
- Nozzle pressure
- Nozzle flow rate and velocity
- Standoff
- Test duration
- Jet impact pressure
  - Mean impact pressure (area-averaged and time averaged)
  - Impact pressure at each radial position (time-averaged)
  - Maximum impact pressure (time-averaged)
- Jet geometry
  - Continuous vs broken jet
  - Length of broken jet packets
  - Jet diameter at impact

There will be a total of 30 data tables.

The test data to be reported in graphical format includes the following (number of figures indicated in parentheses):

- Plots of impact pressure vs radial position for each test (30)
- Plot of mean impact pressure vs standoff for each nozzle diameter (1)
- Plot of mean impact pressure vs standoff for each nozzle pressure (1)

There will be a total of 32 graphs and two accompanying data summary tables.

A minimum of three photographs will be taken for each test (perspective photograph, impact zone photograph and a jet geometry detail photograph). One videotape will be taken of a representative test to document the basic test procedure. There will be a total of 90 photographs (minimum) and one videotape.

WASTE SIMULANT REACTION TESTS

Objective
The objective of the waste simulant reaction tests is to observe the reaction of a waste simulant block to a sluicing jet at optimal standoff. The results will be used as a screening tool to assess the effectiveness of the sluicing nozzle against waste materials as a function of material strength. An attempt will be made to determine the threshold (minimum) impact pressure at which material is dislodged from the waste simulant surface.

Technical Approach
All waste simulant reaction tests will be conducted with a horizontal sluicing jet with clear water (i.e., no suspended solids). Three nozzle diameters will be tested at their respective optimal standoffs. All eight waste simulants will be tested (one wet sludge, two hardpan/dried sludge and five saltcake) using the three-fourths inch nozzle. The one-half inch and five-eighths inch nozzles will be tested against only one waste simulant. Each nozzle will be tested at the same three nozzle pressures listed in Task 1. There will be a total of 30 tests.

The test duration is expected to take one to ten minutes, depending on the mass loss rate. The discrete mass loss will be determined by weighing the block before and after the test. The test duration will be determined by the time it takes to sluice the block. The test duration will not exceed ten minutes. If the waste block is consumed prior to ten minutes, the discrete mass loss will be calculated as the ratio of the mass of the block to the test duration time. Visual observations of the sluicing action will be recorded by photographs and videotape. Both the nozzle flow rate and pressure will be measured during the test.

The target for each test will be a block of waste simulant cured in a 19 liter (5 gallon) pail. The block will remain in the pail during the test. This will constrain the deformation and flow patterns of the block to better simulate the confinement provided by a large, lateral expanse of waste material.

The mass of oversize material, defined as +6.35 mm (+1/4 inch), will be determined at the end of each test. This will be accomplished by mounting a metal screen with 6.35 mm (1/4 inch) screen size holes between the waste simulant block and the collection vessel. The material retained on the screen will be removed and weighed.

An attempt will be made to determine the threshold (minimum) impact pressure at which material is dislodged from the waste simulant surface. A smaller version of the test setup will be constructed with the jet oriented vertically downwards. The nozzle pressure will be gradually increased until a visually noticeable amount of material is dislodged from the waste simulant.

Data Reduction

The test data will be transmitted to WHC in both tabular and graphical form as an interim deliverable. The test data to be reported in tabular format includes the following:

- Nozzle diameter
- Nozzle pressure
- Nozzle flow rate and velocity
- Standoff
- Test duration
- Initial mass of waste simulant
- Final mass of waste simulant
- Mass of oversize material, defined as +6.35mm (+1/4 inch)
- Mass of undersize material, defined as -6.35 mm (-1/4 inch)

- Sluicing behavior
  - Dislodging mechanism (dissolution; plastic flow; brittle fracture; no effect, i.e. elastic response)
  - Mobilization mechanism (slurry flow, tumbling, immobile)
  - Threshold pressure

There will be a total of 30 data tables and one summary table.

The test data to be reported in graphical format includes the following (number of figures indicated in parentheses):

- Histogram of global mass loss rate versus dynamic pressure for each waste simulant (fixed nozzle diameter) (10)
- Histogram of global mass loss rate versus nozzle diameter (fixed nozzle pressure) (1)

There will be a total of 11 graphs and two accompanying data summary tables.

A minimum of three photographs will be taken for each test (perspective photograph, impact zone photograph and a photograph of the waste simulant before and after the test is completed). One videotape will be taken of a representative test to document the basic test procedure. There will be a total of 120 photographs (minimum) and one videotape.

DOCUMENTATION

All test results will be incorporated into a single report. The outline of the report is shown below:

- Cover Page
- Executive Summary
- Table of Contents
- List of Tables
- List of Figures
- Introduction
- Test Setup and Equipment
- Deviations from the Work Plan
- Load Cell Test Results
- Waste Simulant Reaction Test Results
- Conclusions
- Appendices
  - Test Procedures
  - Test Results
  - Photographs
  - Videotape

The narrative sections ("Introduction" through "Conclusions") will be written in a concise style focused on presenting results. The report length will be limited to 15 pages or less. The appendices will be organized by test group.

A draft report will be submitted to WHC for review and discussion. Review comments will be incorporated as appropriate into a final report.

TEST SETUP AND EQUIPMENT

A conceptual drawing of the test setup is shown in Figure 1 and the sequence of material handling operations is shown in Figure 2. The raw materials for the waste simulant are mixed and cured. The waste simulant block (target) is mounted within the collection vessel. Water is pumped from a storage tank and ejected from the nozzle of the tank cleaner system. The jet impacts the target at some fixed standoff. The water and sluicing material are contained in the collection vessel. Upon completion of the test run, the water will be drained from the collection vessel. The solids will be removed manually. The solids will be disposed as special waste in accordance with applicable environmental regulations. The decanted water will be discharged to the sewer in accordance with the requirements of the local wastewater treatment plant.

The major pieces of equipment that Packer Engineering will require for the test program are listed below:

- Storage tank with 10,000 gallon capacity (1)
- BEC tank cleaner system
- Multistage centrifugal pump (125 horsepower, 300 gpm at 350 psi discharge pressure)

Various fittings, valves, a pressure gauge and a flow meter are also required. The collection vessel and the support stand for the BEC tank cleaner will be fabricated at Packer Engineering.

There are four measurement instruments that will be calibrated prior to use in the test program:

- Pressure gauge for measuring nozzle flow rate
- Flow meter for measuring nozzle flow rate
- Pressure transducer array for measuring jet impact pressure
- Scale for measuring waste simulant material weights

All instruments will be calibrated in accordance with the manufacturer's specifications.

SAFETY, HEALTH AND ENVIRONMENTAL PROTECTION

Packer Engineering is committed to protecting the safety and health of its employees and the community as well as protecting the environment. As with all jobs performed by Packer Engineering, this project will be conducted in accordance with all applicable regulations governing safety, health and the environment. Specific safety hazards to be managed in this test program include the following:

- High pressure water jet
- Movement of heavy objects
- Rotating machinery
- Overhead crane
- Forklift
- Electrical equipment and power

The materials used in the test program present minimal health hazards and will not require any personal protection equipment. The recovered solids materials can be disposed as a special waste at a permitted solid waste landfill. The collected water can be discharged (after filtration to remove suspended solids) to the sewer in accordance with the requirements of the local wastewater treatment plant.

SCHEDULE

A list of tasks with their respective start dates, finish dates and durations are shown in Table 6. The scheduling parameters are measured in business days from contract award. The contract award date will be counted as the first day (Day One) of the project. Upon contract award, a Gantt chart (bar chart) schedule will be prepared and submitted to WHC within ten business days of contract award.

Table 1 - Sluicing Nozzle Test Matrix						
Test Group	**Nozzle Diameter (in.)**	**Nozzle Pressure**	**Standoff**	**Waste Simulant**	**Sweep Rate**	**Number of Tests**
Load Cell Tests	0.5 0.625 0.75	1 1 3	6 6 6	0 0 0	0 0 0	30
Waste Simulant Reaction Tests	0.5 0.625 0.75	3 3 3	1 1 1	3 3 8	0 0 0	30

Table 2 - Fluid Dynamic Quantities for Different Nozzle Diameters

Nozzle Diameter in. (mm)	Nozzle Pressure* k Pa (psi)	Nozzle Flow Rate L/s (gpm)	Nozzle Velocity m/s (ft/s)	Reynolds Number **	Jet Dynamic Pressure* k Pa(psi)	Jet Impact Force N (lbf)
0.5 (12.7)	517 (75) 1034 (150) 2068 (300)	4.10 (65) 5.80 (92) 8.20 (130)	32.3 (106) 45.6 (150) 64.5 (212)	410,000 579,000 819,000	517 (75) 1034 (150) 2068 (300)	133 (29.9) 264 (59.4) 528 (119)
0.625 (15.9)	517 (75) 1034 (150) 2068 (300)	6.37 (101) 9.08 (144) 12.8 (203)	32.3 (106) 45.6 (150) 64.5 (212)	514,000 725,000 1,026,000	517 (75) 1034 (150) 2068 (300)	207 (46.5) 412 (92.6) 824 (185)
0.75 (19.1)	517 (75) 1034 (150) 2068 (300)	9.21 (146) 13.1 (207) 18.4 (292)	32.3 (106) 45.6 (150) 64.5 (212)	617,000 871,000 1,232,000	517 (75) 1034 (150) 2068 (300)	297 (66.8) 593 (133) 1190 (268)

* gauge pressure
** Reynolds number = $\rho vD/\mu$
where ρ = fluid density
v = fluid velocity
D = nozzle diameter
μ = fluid viscosity

Table 3 - Standoff Distance for Different Nozzle Diameters

Nozzle Diameter* (in.)	Standoff Distance, m (ft)					
	30 Do	100 Do	200 Do	300 Do	600 Do	1000 Do
0.5	0.381 (1.25)	1.27 (4.17)	2.54 (8.33)	3.81 (12.50)	7.62 (24.99)	12.7 (41.66)
0.625	0.477 (1.56)	1.59 (5.22)	3.18 (10.43)	4.77 (15.65)	9.54 (31.29)	15.9 (52.15)
0.75	0.573 (1.88)	1.91 (6.26)	3.82 (12.53)	5.73 (18.79)	11.46 (37.59)	19.1 (62.65)

metric dimensions: 0.5 in. = 12.7 mm area = 1.27 E-4m^2 (0.196 in^2)
0.625 in. = 15.9 mm area = 1.98 E-4m^2 (0.307 in^2)
0.75 in. = 19.1 mm area = 2.85 E-4m^2 (0.442 in^2)

Table 4 - Waste Simulant Compositions and Properties				
Recipe Number	Description	Composition*	Density g/cm^3 (lb./ft.^{3})	Strength kPa (psi)
1	Wet Sludge	66% clay/34% water	1.65 (103)	3.5 (0.51)
2	Hardpan/Dried Sludge	30% plaster/27.5% clay/42.5% water	1.48 (92.4)	32 (4.6)
3	Hardpan/Dried Sludge	40% plaster/22.5% clay/37.5% water	1.65 (103)	150 (21.8)
4	Saltcake	84% K-Mag/16% water	2.25 (140)	20,700 (3000)
5	Saltcake	88% K-Mag/12% water	1.94 (121)	10,300 (1500)
6	Saltcake	75% K-Mag/25% water	2.27 (142)	10,300 (1500)
7	Saltcake	86% salt/9.33% plaster/4.67% water	1.20 (74.9)	55 (8.0)
8	Saltcake	95% salt/3.33% plaster/1.67% water	1.20 (74.9)	10 (1.5)

All compositions in weight percent.

clay - kaolin clay
plaster - plaster of Paris
K-Mag - potassium magnesium sulfate
salt - sodium chloride rock salt

Table 5 - Estimate of Quantities of Water and Solids Handled During Test Program

Test Group	Number of Tests	Water Use/Test L (gal)	Solids Use/Test kg (lb)	Total Water L (gal)	Total Solids kg (lb)
Load Cell Tests					
75 psi tests	6	1,970 (520)	0	12,170 (3,120)	0
150 psi tests	18	2,800 (738)	0	50,330 (13,280)	0
300 psi tests	6	3,950 (1042)	0	23,690 (6,250)	0
Sub Total	30	N/A	N/A	86,190 (22,650)	0
Waste Simulant Reaction Tests					
75 psi tests	10	3,940 (1,040)	37.9 (83.6)	39,400 (10,400)	380 (836)
150 psi tests	10	5,600 (1,480)	37.9 (83.6)	56,000 (14,800)	380 (836)
300 psi tests	10	7,900 (2,080)	37.9 (83.6)	79,000 (20,800)	380 (836)
Sub Total	30	N/A	N/A	174,400 (46,000)	1,140 (2,510)
Total	68	N/A	N/A	260,590 (68,650)	1,140 (2,510)

Table 6 - Test Program Schedule (Business Days After Contract Award)			
Task or Milestone	Start Date	Finish Date	Duration
Contract Award	1	1	Milestone
Construction	1	15	15
Load Cell Tests			
Conduct Tests	16	20	5
Interim Deliverable	25	25	Milestone
Waste Simulant Reaction Tests			
Conduct Tests	21	25	5
Interim Deliverable	30	30	Milestone
Data Review by WHC	30	35	5
Documentation			
Draft Report	36	50	15
WHC Review	51	60	10
Final Report	61	70	10
Contract Closeout	75	75	Milestone

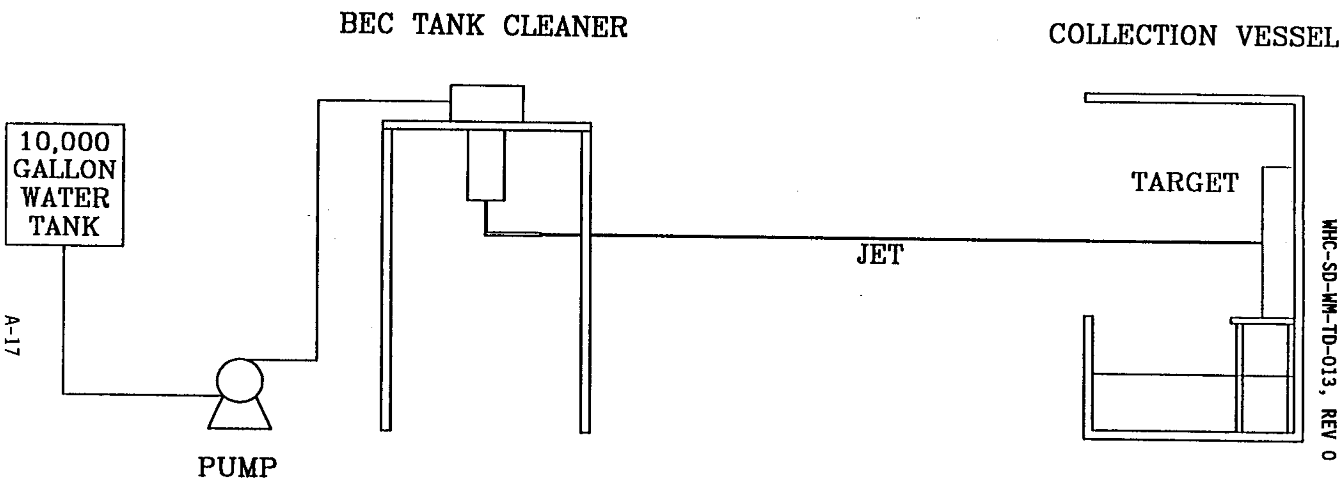

FIGURE 1: CONCEPTUAL DRAWING OF TEST SETUP

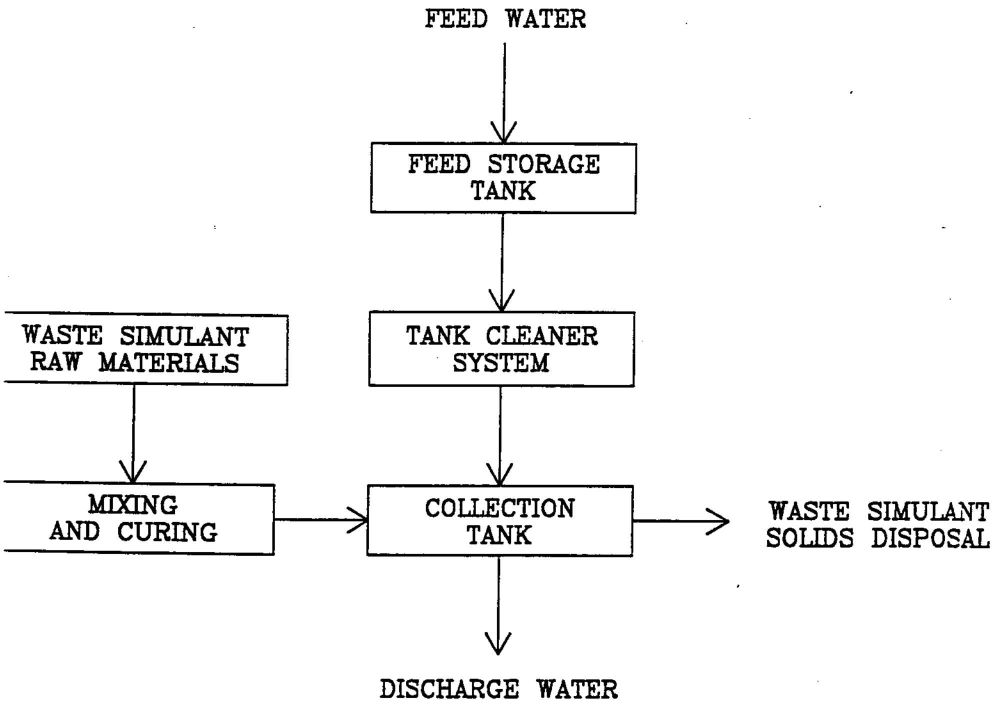

FIGURE 2: BLOCK FLOW DIAGRAM OF TEST SETUP

APPENDIX B: PROCUDURES FOR SLUICING NOZZLE TESTS

PACKER ENGINEERING INC.

PROCEDURES FOR SLUICING NOZZLE TESTS

WESTINGHOUSE HANFORD COMPANY

Introduction

Packer Engineering (PE) has been awarded a contract (P.O. # MKJ-SVW-400385) by the Westinghouse Hanford Company (WHC) to perform a test program with a commercially available sluicing nozzle system. The WHC-approved scope of work (SOW) discusses the test objectives and technical approach. This document presents the procedures for the test program.

Preparation of Waste Simulants

See Attachment A.

Assembly of Test Setup

1. Load Cell: The load cell is being fabricated and tested by Pacific Northwest Laboratory (PNL). A PNL technician will be onsite at the PE facility to assist in the setup of the load cell.

2. Electrical Generator: The electrical generator will be rented from a local supplier. The rental company will provide a technician to assist in the setup of the generator.

3. Large Pump: Upon receipt, verify that the large pump is undamaged and is in good working order. Upon acceptance, attach the large pump to the test platform (item fabricated at PE).

4. Storage Tank: The storage tank will be rented from a local supplier. Locate tank on level ground at test site.

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5. Small Pump: The small pump will be rented from a local supplier. Locate next to collection basin (item fabricated at PE).

6. Pipefitting: Piping, valves, and fittings will be a combination of purchased and rented items. Assemble piping in accordance with ASME Pressure Vessel Code. Use shortest lengths of pipe possible while keeping use of elbows and other fittings to a minimum. Use suitable method of attachment to prevent leaks or failures. Place valve on discharge side of pump.

7. Electrical Wiring: All electrical wiring is to be conducted under the supervision of a licensed electrician.

8. Nozzle Assembly: Nozzle assembly will be rented from a local supplier. Attach the nozzle assembly to the test platform. Attach pressure gauge to nozzle assembly.

Debug Test Setup

1. Electrical Generator: Verify operating characteristics of the generator. Confirm that the generator has the capacity to drive the large pump's electrical motor. Practice startup and shutdown procedures.

2. Large Pump: Test ability to attain steady values of nozzle pressure by adjusting valve on discharge side. Desired pressures are 75, 150, and 300 psi. Measure flow rates at these three pressures.

3. Small Pump: Confirm ability of small pump to transfer liquid from collection basin to storage tank.

Load Cell Tests

1. Test Matrix: The test matrix is shown in Table 1. Tests conducted at one nozzle pressure will be tested at 150 psi. Tests conducted at three pressures will be conducted at 75, 150, and 300 psi.

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2. Standoff Distances: The standoff distance is the horizontal distance from the tip of the nozzle to the front face of the load cell. The standoff distance is measured in terms of the number of nozzle diameters. A complete list of standoff distances is shown in Table 2.

3. Load Cell: The load cell is to be operated in accordance with the manufacturer's directions and the instructions of the PNL technician.

4. Strategy: Begin the test series at the closest standoff. Move to the next closest standoff for the second test. Continue the test series by moving the test platform in only one direction. This will minimize the number of adjustments required involving piping and cables. This will require, however, that the nozzle be changed from one test to the next.

5. Procedure:
   a. Verify the standoff distance, nozzle diameter, and nozzle pressure to be used in the test.
   b. Move test platform to standoff location.
   c. Attach appropriate nozzle tip.
   d. Turn on large pump and set nozzle pressure to desired value by adjusting the valve(s).
   e. Take required photographs and record data/observations.
   f. Turn off large pump after load cell data are acquired and saved.
   g. Check water accumulation in collection basin. If basin is filled halfway or more, pump it out using the small pump.
   h. Continue to the next test.

Waste Simulant Reaction Tests

1. Test Matrix: The test matrix is shown in Table 1. A screening test will be conducted first with recipes 1, 2, 3, 7, and 8 (pail numbers 1, 5, 9, 28, and 32). The waste simulant reaction tests will be conducted with the remaining pails. The tests will all be conducted at a standoff of 100 nozzle diameters. The tests will be conducted in a progression from the smallest to the largest nozzle diameter. Three nozzle pressures will be selected in the order 300, 150, and 75 psi.

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2. Screening Test Procedure:
   a. Select pail numbers 1, 5, 9, 28, and 32 for testing.
   b. Determine line pressure and flow rate for garden hose with nozzle attached and fully open.
   c. Open pail to be tested by removing lid.
   d. Test will be conducted with jet oriented vertically downwards.
   e. With the nozzle fully open, position the nozzle directly in the center of the pail at a standoff of 24 inches. Begin stopwatch at this instant and allow jet to strike the target for 60 seconds and then stop test.
   f. Record qualitative observations of material response to jet.
   g. If there is little material response to this test, repeat at a standoff of six inches.
   h. Continue to the next pail.

3. Waste Simulant Reaction Test Procedure
   a. Verify the standoff distance, nozzle diameter, recipe number, pail number, and nozzle pressure to be used in the test.
   b. Move test platform to standoff location.
   c. Attach appropriate nozzle tip.
   d. Turn on large pump and set nozzle pressure to desired value by adjusting the valve(s).
   e. Turn large pump off.
   f. Remove lid from pail.
   g. Insert open pail into test fixture and secure it in place.
   h. Turn on large pump and record time.
   I. Take required photographs and record data/observations.
   j. Turn off large pump and record time when ½ of the material in the pail is lost or after ten minutes of jet impact, whichever comes first.
   k. Remove pail from fixture.
   l. Weigh pail and record weight.
   m. Remove 1/4 inch screens and collect oversize material on screens.
   n. Weigh oversize material and record weight.
   o. Record visual observations of waste simulant material remaining in pail.
   p. Check water accumulation in collection basin. If basin is filled halfway or more, pump it out using the small pump.
   q. Continue to the next test.

Table 1 - Sluicing Nozzle Test Matrix						
Test Group	**Nozzle Diameter (in.)**	**Nozzle Pressure**	**Standoff**	**Waste Simulant**	**Sweep Rate**	**Number of Tests**
Load Cell Tests	0.5 0.625 0.75	1 1 3	6 6 6	0 0 0	0 0 0	30
Waste Simulant Reaction Tests	0.5 0.625 0.75	3 3 3	1 1 1	1 1 8	0 0 0	30

Table 2 - Standoff Distance for Different Nozzle Diameters						
Nozzle Diameter* (in.)	Standoff Distance, m (ft)					
	30 Do	100 Do	200 Do	300 Do	600 Do	1000 Do
0.5	1'-3"	4'-2"	8'-4"	12'-6"	25'	41'-8"
0.625	1-6 3/4"	5'-2 3/4"	10'-5 1/4"	15'-7 3/4"	31'-3 1/2"	52'-1 3/4"
0.75	1'-10 1/2"	6'-3"	12' - 6"	18'-9 1/2"	37'-7"	62'-7 3/4"

*metric dimensions: 0.5 in. = 12.7 mm area = 1.27 E-4m^2 (0.196 in^2)
0.625 in. = 15.9 mm area = 1.98 E-4m^2 (0.307 in^2)
0.75 in. = 19.1 mm area = 2.85 E-4m^2 (0.442 in^2)

APPENDIX C: PREPARATION OF WASTE SIMULANTS

PREPARATION OF WASTE SIMULANTS

WESTINGHOUSE HANFORD COMPANY

Recipe numbers 1 and 2 will be prepared directly in the 5 gallon pails and will be blended using a hand blender (similar to those used to blend paint). Recipe numbers 3 through 8 will be prepared batchwise in a 9 ft^3 concrete mixer and the material will be transferred from the mixer to the 5 gallon pails.

Recipes 1 through 8 are listed below along with the amount of each ingredient (in pounds) needed for the batches and the number of 5 gallon pails that need to be filled. One gallon extra has been figured into the amounts for recipes 3 through 8 to compensate for the expected hold up in the mixer. However, this additional one gallon may not be enough. The important thing, though, is that the number of pails required for each recipe need to be filled to the same level. Also, a space should be left at the top so a lid can be placed on the pails while the samples cure. The lids are used to **prevent evaporation and water loss**.

The following is a general description of the procedure that should be followed in preparing the pails for each recipe:

1. Label the pail (using a magic marker) with the following information: recipe #, pail # (1-35), and the date the recipe was mixed.
2. Weigh the pail empty, including the weight of any fixture bolts or fixture pieces (tare weight).
3. Record the tare weight in the data book and write the weight directly on the pail.
4. Prepare the simulant material either in the pail or mixer.
5. If prepared in the mixer, fill the pail with the simulant material.
6. Weigh the pail with simulant material.
7. Record the weight of the simulant material plus pail in the data book and write the weight directly on the pail.
8. Cover the pail with a lid while the sample cures.

Recipe # 1 - prepared in 5 gallon pails

34% wt water
66% wt Kaolin clay

mixture density = 103 lb/ft^3
4 pails needed (labeled as 1 through 4)

Mix 45.44 lbs of Kaolin clay and 23.41 lbs of water in each 5 gallon pail. No cure time is associated with this material. It may be used immediately after preparation. The mixed paste is **very sticky**.

Recipe # 2 - prepared in 5 gallon pails

30% wt Plaster of Paris
27.5% wt Kaolin clay
42.5% wt water

mixture density = 92.4 lb/ft^3
4 pails needed (labeled as 5 through 8)

Mix 17.03 lbs of Kaolin clay with 26.31 lbs of water in the 5 gallon pails until no more lumps are apparent. The consistency of this mixture will be similar to that of a thin milk shake. Then, add 18.57 lbs of Plaster of Paris while mixing and mix only until a smooth consistency is once again observed. The viscosity of this mixture will be similar to that of a thick milk shake. The simulant material should be allowed to cure for **16 hours**.

Recipe # 3 - prepared in 9 ft^3 mixer

40.0% wt Plaster of Paris
22.5% wt Kaolin clay
37.5% wt water

mixture density = 103 lb/ft^3
10 pails needed (labeled as 9 through 18)

Mix 158.00 lbs of Kaolin clay with 263.34 lbs of water in the mixer until no more lumps are apparent. The consistency of this mixture will be similar to that of a thin milk shake. Then, add 280.89 lbs of Plaster of Paris while mixing and mix only until a smooth consistency is once again observed. The viscosity of this mixture will be similar to that of a thick milk shake. At room temperature, the mixture must be cast into the pails within about 15 minutes of adding the Plaster of Paris. The simulant material should be allowed to cure for **16 hours**.

Recipe # 4 - prepared in 9 ft^3 mixer

84% wt Dynamate
16% wt water

mixture density = 140 lb/ft^3
3 pails needed (labeled as 19 through 21)

Mix 251.53 lbs of Dynamate and 47.92 lbs of water in the mixer. Transfer the slurry into the 5 gallon pails and allow the simulant material to cure for **14 days**.

Recipe # 5 - prepared in 9 ft^3 mixer

88% wt Dynamate
12% wt water

mixture density = 121 lb/ft^3
3 pails needed (labeled as 22 through 24)

Mix 227.87 lbs of Dynamate and 31.07 lbs of water in the mixer. Transfer the slurry into the 5 gallon pails and allow the simulant material to cure for **14 days**.

Recipe # 6 - prepared in 9 ft^3 mixer

75% wt Dynamate
25% wt water

mixture density = 142 lb/ft^3
3 pails needed (labeled as 25 through 27)

Mix 227.91 lbs Dynamate and 75.97 lbs of water in the mixer. Transfer the slurry into the 5 gallon pails and allow the simulant material to cure for **14 days**.

Recipe # 7 - prepared in 9 ft^3 mixer

86% wt Sodium Chloride Rock Salt
9.33% wt Plaster of Paris
4.67% wt water

mixture density = 74.9 lb/ft^3
4 pails needed (labeled as 28 through 31)

Mix 19.62 lbs Plaster of Paris and 9.82 lbs of water to a smooth consistency (in the mixer). Then, mix in 180.83 lbs of Sodium Chloride Rock Salt. Mixing should continue until the Plaster of Paris is uniformly distributed (approximately 2 to 4 minutes). The mixture must then be rapidly transferred to the test pails. This should be done 5-10 minutes after completion of mixing. The simulant material should be cured for **at least 16 hours**.

Recipe # 8 - prepared in 9 ft^3 mixer

95% wt Sodium Chloride Rock Salt
3.33% wt Plaster of Paris
1.67% wt water

mixture density = 74.9 lb/ft^3
4 pails needed (labeled as 32 through 35)

Mix 7.00 lbs Plaster of Paris and 3.51 lbs water to a smooth consistency (in the mixer). Then, mix in 199.76 lbs of Sodium Chloride Rock Salt. Mixing should continue until the Plaster of Paris is uniformly distributed (approximately 2 to 4 minutes). The mixture must then be rapidly transferred to the test pails. This should be done 5-10 minutes after completion of mixing. The simulant material should be cured for **at least 16 hours**.

Since **recipes 4-6** require 14 days to cure, they should be prepared first. Recipes 7, 8, 3, and 2 should be prepared next, **in that order** (16 hours to cure). Finally, recipe 1 should be prepared.

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