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Alternate Retrieval Technology Demonstrations Program—Test Report

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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Alternate Retrieval Technology Demonstrations Program— Test Report

Prepared by
ARD Environmental, Inc.

Prepared for
Lockheed Martin Hanford Corporation
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ENVIRONMENTAL

ARD Environmental, Inc.

Ms. Judy K. Gustafson
Senior Procurement Specialist
Lockheed Martin Hanford Corporation
P.O.Box 1500
Richland, WA 99352-1505

7/23/97

Re: Purchase Order MJG-SLD-A31520, Reporting for Public Disclosure

Dear Ms. Gustafson:

The final reports were delivered to Mr. James Yount on 7 July, 1997, and the computer copy forwarded to your attention on 7/18/97.

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Yours truly,

Sy Kotler
Chief Engineer and COO
ARD Environmental, Inc.

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

ALTERNATE RETRIEVAL TECHNOLOGY DEMONSTRATIONS PROGRAM — TEST REPORT

Date: July 3, 1997
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PREPARED FOR:

LOCKHEED-MARTIN HANFORD COMPANY
P.O. #MSJ-SLD-B1504

PREPARED BY:

ARD ENVIRONMENTAL, INC.
9115 WHISKEY BOTTOM ROAD
LAUREL, MD 20723
410-724-0004

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EXECUTIVE SUMMARY

A prototype vehicle, control system, and waste and water scavenging system were designed and fabricated with essentially the full capabilities of the vehicle system proposed by ARD Environmental. A test tank mockup, including riser and decontamination chamber were designed and fabricated, and approximately 830 cubic feet of six varieties of waste simulants poured. The tests were performed by ARD Environmental personnel at its site in Laurel, Maryland, from 4/22/97 through 5/2/97.

The capabilities tested were deployment and retrieval, extended mobility and productivity, the ability to operate the system using video viewing only, retrieval after simulated failure, and retrieval and decontamination. Testing commenced with deployment of the vehicle into the tank. Deployment was accomplished using a crane and auxiliary winch to position the vehicle and lower it through the decontamination chamber, into the 36" diameter x 6' high riser, and touch down on the waste field in the tank.

The initial mobility tests were conducted immediately after deployment, prior to sluicing, as the waste field exhibited the greatest amount of variation at this time. This test demonstrated the ability of the vehicle to maneuver over the simulated waste field, and the ability of the operator to work with only video viewing available. In addition, the ability of the vehicle to right itself after being turned on its side was demonstrated. The production rate was evaluated daily through the testing period by measuring the surface and estimating the amount of material removed. The test demonstrated the ability of the vehicle to reduce the waste surface using 400 psi (nominal) water jets, scavenge water and material from the work area, and move to any location, even in the relatively confined space of the 20' diameter test tank. In addition, the ability to sluice to a remote scavenging module was demonstrated.

The failure mode test demonstrated the ability to retrieve a stuck vehicle by pulling on the tether, even if the vehicle wheels were locked or the vehicle was on its side. Line pull required to retrieve the vehicle was measured, and side load on the riser calculated from the line pull and line angles. Finally, the decontamination test demonstrated the ability to effectively clean the umbilical and vehicle.

The issues addressed and resolved during the testing were: Feasibility of deploying a vehicle-based system, mobility, production rate and limitation of water in the tank during sluicing, mining strategy, operator efficiency, vehicle recovery, and decontamination. Water usage and waste removal rates were used to estimate the time and water usage requirements for cleaning a Hanford SST.

1 INTRODUCTION

The purpose of these tests was as follows: To evaluate the capabilities of a prototype vehicle-based waste removal system using a mockup tank and test apparatus that simulated in-tank conditions; to identify and resolve design, safety and operational issues; and to identify other issues that would have to be resolved in the future.

A prototype vehicle, control system, and waste and water scavenging system were designed and fabricated with essentially the full capabilities of the vehicle system proposed by ARD Environmental. A test tank mockup, including riser and decontamination chamber were designed and fabricated, and approximately 830 cubic feet of six varieties of waste simulants poured.

The tests were performed by ARD Environmental personnel at its site in Laurel, Maryland, from 4/22/97 through 5/2/97. The capabilities tested were deployment and retrieval, extended mobility and productivity, the ability to operate the system using video viewing only, retrieval after simulated failure, and retrieval and decontamination.

2 TESTS PERFORMED

2.1 DESCRIPTION OF TESTS

2.1.1 System Deployment (Pre-Insertion)

Calibration of pressure, flow and level sensors was accomplished from 4/14 through 4/18. The working water pumping system, consisting of the CD100 transfer pumps, HL80 feedwater pump, and the Paco pressure pumps were also tested and flushed during that week, as were the free water scavenging module, vehicle scavenging module, and sluicer. Pre-testing commenced on Monday, 4/19 with checkout of the vehicle and control system, the data logging system, and the camera systems. The test plan and procedures were reviewed, and duties assigned to test personnel.

2.1.2 Deployment

Testing commenced on 4/22 with deployment of the vehicle into the tank. Deployment was accomplished using a crane and auxiliary winch to position the vehicle and lower it through the decontamination chamber, into the 36" diameter x 6' high riser, and touch down on the waste field in the tank.

2.1.3 Extended Mobility/Production Rate

The extended mobility testing was accomplished throughout the test period, as the vehicle was maneuvered in the waste field. However, the initial mobility tests were conducted immediately after deployment, prior to sluicing, as the waste field exhibited the greatest amount of variation at this time. This test demonstrated the ability of the vehicle to maneuver over the simulated waste field, and the ability of the operator to work with only video viewing available. In addition, the ability of the vehicle to right itself after being turned on its side was demonstrated.

The production rate was evaluated daily through the testing period by measuring the surface and estimating the amount of material removed. The test demonstrated the ability of the vehicle to reduce the waste surface using 400 psi (nominal) water jets, scavenge water and material from the work area, and move to any location, even in the relatively confined space of the 20' diameter test tank. In addition, the ability to sluice to a remote scavenging module was demonstrated.

2.1.4 Failure Mode Test

The failure mode test demonstrated the ability to retrieve a stuck vehicle by pulling on the tether, even if the vehicle wheels were locked or the vehicle was on its side. Line pull required to retrieve the vehicle was measured, and side load on the riser calculated from the line pull and line angles.

2.1.5 System Retrieval and Decontamination

This test demonstrated the ability to retrieve and decontaminate the umbilical and the vehicle, using water jets only. The volume of water required for a decontamination was also determined.

2.2 TEST METHODS AND TEST EQUIPMENT

2.2.1 Test Methods

2.2.1.1 Deployment

To gain insight into the process of deploying, operating, and retrieving the system in a tank, and aid in the identification of any critical procedural or design issues, the prototype components of the system were deployed into, operated within, and retrieved from the test tank following a set of prescribed operating procedures. The components of the system tested included the vehicle, equipped with the sluicing system, manipulator, umbilical, tether cable, and its control and power units; the sluicer scavenger module with its umbilical; the free-water scavenger module with its umbilical; and a mockup of the umbilical handling reel. The sluicer and scavenger systems were inserted and removed through the decontamination chamber by the crane. The umbilicals were passed over a cable reel to simulate the umbilical handling winch.

The objective was a better understanding of the steps that should be taken during the operation of the various components of the system in a tank. The vehicle and its scavenger module were inserted, positioned, operated, and removed in accordance with the prescribed operating procedures. In addition, the entire procedure was video taped for subsequent analysis.

2.2.1.2 Extended Mobility/Production Rate

The objectives of this area of testing were to demonstrate that the candidate system can traverse and function in the physical environment characteristic of the waste in a tank, to obtain data needed to allow the estimation of the in-tank operational time to clean a tank, and to evaluate the ability of the operator to function effectively using only video viewing. In addition, the mobility test included a demonstration of the ability of the vehicle to restore itself to an upright condition after being rolled over on its side.

The vehicle, equipped with the sluicing system, manipulator and umbilical, and the control and power units were tested. The sluicer was operate using sluicing water supplied at 100 gpm and 400 psi, while the sluicer scavenger and free-water scavenger eductors were operated at 25 gpm at 400 psi. Sluicer supply water, eductor motive water, and waste discharge water flow rates and pressures were monitored and recorded. In addition, the level of free water in the tank was monitored and recorded so that the average and peak levels could be determined in correlation with specific steps in the procedure. The material removed from the tank was discharged into dumpsters, and the water decanted off and reused. The total volume of water used to remove the simulants was determined, as was the time to effect the removal. The operations were video taped for analysis.

2.2.1.3 Failure Mode Test

This test was conducted to determine whether the sluicer system can be extracted from the tank if an immobilizing failure of the vehicle or its controls occurs. Three separate tests were run, one with the vehicle in free-wheeling mode, one with the wheels locked, and one with the vehicle partially on its side. The failure mode tests were performed at a point in the cleaning process when the vehicle was at the opposite side of the tank from the riser, and deliberately mired as deeply as possible in the clay-based simulant.

The vehicle controls were shut off and the vehicle was removed using its tether cable, which was led up the riser and over pulleys to a hydraulically driven winch located outside of the tank. A pulley was located at the lower opening of the riser and was secured via a cable to a point outside of the tank. This pulley prevented side loading on the riser that might distort it, and the pulley's cable was attached to a load cell that provided a measurement of the sideload forces involved in the vehicle's extraction. The extraction demonstration was timed and video taped.

2.2.1.4 Retrieval and Decontamination

A decontamination demonstration was performed to prove the feasibility and effectiveness of the proposed decontamination approach, to identify any critical decontamination procedural issues, and to identify hardware design improvements that would improve decontamination.

A mockup of the decontamination chamber was built and incorporated a water jetting configuration similar to that described in our proposal. A fluorescent dye tracer was mixed with the waste simulants. The vehicle was driven into a deep puddle of the clay-based waste simulant until it was well covered, and then moved back on to the solid waste surface. Additional clay-based waste was plastered on to the vehicle by hand, and allowed to dry for a period of time before commencing the decontamination.

The vehicle was then lifted into the decontamination chamber mockup and decontaminated following the prescribed decontamination procedures. The time and amount of decontamination water required to decontaminate the vehicle were measured. When the vehicle was deemed to be clean, it was moved to a location where it was thoroughly examined to determine the effectiveness of the decontamination process. The decontamination process was videotaped.

2.2.2 Test Equipment

2.2.2.1 Test Materials

The test materials used were simulants mixed in accordance with the formulas and processes defined by Hanford in appendix A3 of the RFP (see section 5, References), as follows:

First pour, wet sludge: 433 gallons of water, 7000 pounds of kaolin, mixed in the bottom of the tank. Approximately 100 cubic feet.

Second pour, hard pan #1: 914 gallons of water, 4950 pounds of kaolin, 5375 pounds of plaster, prepared in a concrete mixing truck. Approximately 190 cubic feet. Note that the mixture started to set during the pour, and only 100 cubic feet were poured, the rest remaining in the truck. This was caused by the exothermic reaction of the plaster setting up, after the concrete mixer was stopped and the delivery chute positioned.

Third pour: hard pan #2: 859 gallons of water, 4300 pounds of kaolin, 7625 pounds of plaster. Approximately 190 cubic feet.

Fourth pour, salt cake #1: 513 gallons of water, 22,400 pounds of K-Mag fertilizer, approximately 190 cubic feet.

Fifth pour, salt cake #3: 803 gallons of water, 20,080 pounds of K-Mag fertilizer. Approximately 190 cubic feet.

Sixth pour, salt cake #4: 16 gallons of water, 262 pounds of plaster, 2400 pounds of rock salt.

Approximately 30 cubic feet.

The total poured volume was approximately 820 cubic feet. A fluorescing dye tracer was added to the mixing water to aid in evaluating the decontamination process, and all pours were allowed to cure for the prescribed period of time. The last two pours were arranged to provide a rugged surface for the mobility tests, and to test the ability of the system to flatten the surface. In addition, tramp material was dispersed through the simulants to provide more realistic test conditions. This material included chunks of cinder block, pea gravel, plastic sheets, and steel tapes. Photographs (1), (2) and (3) show the simulants being poured. Photograph (4) shows the simulant surface after the final pour.

In the course of performing the project, ARD Environmental forwarded simulant samples for analysis by Pacific Northwest National Laboratory (PNNL) personnel. PNNL raised a question concerning the particle size of the K-Mag simulant. ARD Environmental used a coarse grained material based on the vendor's information and the use of the descriptive word "fertilizer" in the PNNL specification (and used the same material for phase 1 testing). PNNL informed ARD Environmental that although the specification called for "fertilizer" grade, the fine grain material was intended. This raised the issue of the strength of the simulant as a function of particle size. At this writing, the sample analysis has not been conveyed to ARD Environmental, however the simulants in question proved to be extremely hard, as evidenced by the removal rates.

2.2.2.2 Test Equipment

Site Layout

The site layout is shown in figure 2.2-1. The tank mockup was assembled alongside the rear of the building, and the water and waste containers arranged along the same wall. The transfer pumps and feedwater pump were mounted on top of the containers, and the pressurizing pumps were located on the ground nearby. The remainder of the equipment was located in the immediate vicinity, and all hoses and piping located between the equipment and the building wall.

The crane and forklift were aligned with each other and the center of the decontamination chamber and riser assembly. The forklift served as the mount for the winch used to raise and lower the vehicle, via cable and blocks fixed to the crane boom. The crane hook was used to raise and lower the vehicle and the vehicle water scavenging module. The free water scavenging module was positioned in the tank at approximately the 2 o'clock position in the figure.

The site layout is shown functionally in figure 2.2-2, which indicates the locations of the pressure and flow sensors. All transfer and pressurizing pumps were electrically operated; the scavenging module pumps, which were submerged, were driven hydraulically.

Tank Mockup

The test tank, shown in figure 2.2-3, is a 20' diameter by 5' deep steel structure that was partially filled with mixed simulants to a depth of 3' to provide a test volume of approximately 830 cubic feet. The tank was enclosed in a scaffolding and truss structure, decked over to provide a simulated tank top 20' above the level of the tank bottom. The deck was plywood, sealed to exclude rain, and the scaffolding was equipped with OSHA rated guard rails and stairway. A grid of holes on a 2' spacing was drilled in the deck to allow soundings to be taken and the surface topology of the waste evaluated. The layout of the grid is shown in figure 2.2-4. Grid intersections were numbered serially in serpentine fashion for convenience in sounding the waste surface. Heavy duty tarpaulins were hung from the truss to enclose the tank in a curtain which to exclude rain, and contain spray and material from the tests, and further simulate operation in a tank. The tank is shown under construction in photograph (5), and the scaffolding during erection in photograph (6).

A mockup riser, 36" in inside diameter and 6' long was installed extending from the deck downward, as shown in photograph (7). A functional decontamination chamber was mated to the upper flange on the riser. Installation of the decontamination chamber is shown in photographs (8), (9) and (10). The tank also included four vertical pipes welded to its bottom to simulate risers and other obstructions that might be found in an actual tank; these pipes were extended to the scaffolding deck with plastic pipe. The operator used video monitors to guide the equipment, and did not have direct visual contact with the interior of the tank. Cameras were located at four positions, 90° apart and 18' above the level of the tank bottom. The camera diametrically opposite the riser was equipped with a pan and tilt, while the other cameras were hard mounted. All four cameras were equipped with zoom lenses. The ability of the operator to control the vehicle under these conditions was evaluated.

Sluicer and Eductor Water Supply System

The water supply system consisted of all of the components of the test setup involved in providing sluicing water to the sluicer and motive water to the two eductors used in the tank. A block diagram of the system is provided in figure 2.2-5. Four containers (sealed dumpsters) were used to recycle water during the tests. Two were designated waste tanks; one being used while the other was emptied. The other two tanks were on line permanently as water supply tanks.

Discharge from the test tank was decanted to successive containers using transfer pumps, and the last container was the source of feed water for the sluicer and eductors. Successively finer strainers were used between the containers to filter solids suspended in the water. The total area of each strainer was about 24 square feet, and the mesh was large enough to prevent clogging. The pumps used to supply sluicer and eductor water would pass any particles that could pass through the finest mesh strainer (1/16"), and no difficulties were experienced with suspended kaolin or plaster particles. The strainer boxes are shown in photograph (11).

The tanks were filled initially, and refilled as needed, from a municipal water hydrant. A water meter and backflow check valve was included in this line as required by the county. The main feed pump drew feed water from the supply tank at a rate of about 300 gpm, the actual value was measured by flow meter Q1. A flowmeter installation is shown in photograph (12), and the water supply tanks, transfer pump and feedwater pump in photograph (13). To increase the pressure of the flow to the desired level, two main pressure pumps were plumbed in parallel.

A pressure sensor, P1, was placed in the main feed line at the distribution manifold. This manifold divided the feed water into three separate lines, one to the sluicer input, one to the sluicer eductor motive water input, and one to the free-water eductor motive input. The pressures at these three points was monitored by pressure sensors P2, P3, and P4, respectively. The combined outlet size of the sluicer nozzles and the eductor nozzle orifice sizes were chosen to distribute the feed water among the sluicer and two eductors at the rate of about 100 gpm at 400 psi for the sluicer, and 25 gpm at 400 psi (nominal) for each of the eductors. The valve assembly is shown in photograph (14).

Waste/Water Scavenging System

The waste/water scavenging system consisted of the components of the test setup involved in removing waste and water from the test tank. Waste broken up by the sluicer vehicle, sluicing water from the vehicle itself, and free water in the tank were collected and conveyed topside using ARD proprietary pumping modules. For the purpose of this test, the vehicle and two waste scavenger modules were employed. One module pumped waste and water scavenged by the vehicle sluicer head, while the other scavenged waste and water that escaped from the sluicer.

Waste water was conveyed through 3" flexible hoses that passed through the decontamination module attached to the riser. The flows were measured by flow sensors Q2 and Q3 before passing through valves that were placed in the system to permit adjustment of back pressure to simulate the 55' head specified for the waste discharge lines by Hanford. The dynamic losses in the discharge hose amounted to another 18' of equivalent head. During initial system checkout , it was determined that the back pressure due to line losses was 35 psi (79') without throttling, therefore the valves were left fully open during the tests. The discharge pressures were continually monitored by pressure sensors P6 and P7. The waste water was emptied into the waste tank where waste settled out, and the water transferred to the water supply tanks and recycled.

Decontamination Water System

The water supply and instrumentation for the decontamination portions of the test are shown in figure 2.2-6. Water was obtained for decontamination from the municipal water hydrant. The amount of water used for decontaminating the system was computed from the measured flow rate and time, and was checked roughly by measuring the level of water in the tank mockup after completion of decontamination.

The water was filtered, and flow rate was measured using flow sensor Q4. A commercial high-pressure washer-type pump was used to drive the water. It provided water at the decontamination chamber at a rate of 40 gpm (nominal) at approximately 3000, 2000, and 1000 psi, depending on how many spray rings were on at any time. The pressure was monitored by pressure sensor P8 at the decontamination module. The flow could be directed to any of the three spray rings or the manual spray wand by a set of valves at the decontamination chamber.

Decontamination Chamber and Riser Assembly

The decontamination chamber consisted of a 71.5" inside diameter by 84" high aluminum cylinder with an integral flange welded to the bottom. It was bolted to the top of the riser, which had an inside diameter of 36" and was 6' long. The assembly is shown in figure 2.2-7.

The decontamination module contained three spray rings around its inner circumference, located near the bottom of the chamber. Each ring had eight spray nozzles, equally spaced around it, spraying in toward the center axis of the cylinder. The nozzles of the top ring point downward at 45°; those on the center ring straight inward; and those on the lower ring upward at 45°. The three-ring stack was mounted on a swivel that allowed 45° of rotation, enabling the spray to be directed at any portion of the unit being decontaminated. The spray ring assembly is shown in figure 2.2-8, and photograph (15).

In addition to these fixed spray rings, the chamber included two rings of eight holes, equally spaced around its circumference to allow the use of a manually operated spray wand. The holes were plugged when not in use. Components were moved vertically within the spray field by raising and lowering the component using the handling crane. Two sets of four observation windows equally spaced around the chamber were also provided. The holes for the wand, and the windows, were located one quarter and three quarters the way up the cylinder. The interior of the chamber is shown in photograph (16).

Vehicle and Sluicing Assembly

The vehicle and sluicing assembly are shown in figure 2.2-9. The vehicle is driven hydraulically, and has a maximum available torque of about 4800 foot-pounds. The vehicle weighs approximately 2000 pounds, and is equipped with hydraulic actuators to permit positioning of the sluicer over a wide range, as shown in the figure. This permits the use of the sluicer to excavate beneath the vehicle, as well as washing down walls and other structure up to the height of the sluicer in the fully raised position. The vehicle is shown in photograph (17) during construction, and the control station in photograph (18).

The sluicer is shown in figure 2.2-10, and in photograph (19), during test. It is equipped with 14 sluicing nozzles, with a nominal diameter of 0.140" and a measured diameter of 0.128", and a 0° spray angle. These nozzles deliver 114 to 122 gpm at 400 psi and 450 psi, respectively. Nozzle performance data are shown in figure 2.2-11. The sluicer is equipped with an eductor, located in the center of the sluicing nozzles. The eductor has a suction capacity of 100 gpm, therefore it is capable of scavenging all the water delivered by the sluicing nozzles, when conditions are favorable.

2.2.2.3 Instrumentation

The instrumentation that was used for this test effort is delineated in Table 2-I, below.

Table 2-I. Test Instrumentation.

Item	Description	Sensor Accuracy	Measurement Accuracy	Vendor	Part Number
P1	Pressure Transducer, 0-500 pig	±0.5% FS (±2.5 pig)	±1.7% @ P_{op} (±6.6 psi)	NOSHOK	100-500-1-1-2-2
P2	Pressure Transducer, 0-500 pig	±0.5% FS (±2.5 pig)	±1.7% @ P_{op} (±6.6 psi)	NOSHOK	100-500-1-1-2-2
P3	Pressure Transducer, 0-500 pig	±0.5% FS (±2.5 pig)	±1.7% @ P_{op} (±6.6 psi)	NOSHOK	100-500-1-1-2-2
P4	Pressure Transducer, 0-500 pig	±0.5% FS (±2.5 pig)	±1.7% @ P_{op} (±6.6 psi)	GNEISSIC	100-500-1-1-2-2
P5	Pressure Transducer, 0-500 pig	±0.5% FS (±2.5 pig)	±1.7% @ P_{op} (±6.6 psi)	GNEISSIC	100-500-1-1-2-2
P6	Pressure Transducer, 0-150 pig	±0.5% FS (±0.75 pig)	±3.3% @ P_{op} (±4.2 psi)	GNEISSIC	100-150-1-1-2-2
P7	Pressure Transducer, 0-150 pig	±0.5% FS (±0.75 pig)	±3.3% @ P_{op} (±4.2 psi)	GNEISSIC	100-150-1-1-2-2
P8	Pressure Transducer, 0-5000 pig	±0.5% FS (±25 pig)	±1.9% @ P_{op} (±56.5 psi)	GNEISSIC	100-5000-1-1-2-2
Q1	Flow Sensor, 0.7-30 fps	±0.2 fps	±11.4% @ Q_{op} (17 gpm) uncal, ±1 gpm cal'd	Omega	FP-6000

Table 2-I. Test Instrumentation.					
Item	Description	Sensor Accuracy	Measurement Accuracy	Vendor	Part Number
Q2	Flow Sensor, 0.7-30 fps	±0.2 fps	±11.4% @ Q_{op} (17 gpm) uncal, ±1 gpm cal'd	Omega	FP-6000
Q3	Flow Sensor, 0.7-30 fps	±0.2 fps	±11.4% @ Q_{op} (17 gpm) uncal, ±1 gpm cal'd	Omega	FP-6000
Q4	Flow Sensor, 0.7-30 fps	±0.2 fps	±11.4% @ Q_{op} (17 gpm) uncal, ±2 gpm cal'd	Omega	FP-6000
L1	Level Transmitter, Float Type	1/4" resolution	±1/8" max cal'd	Gems	XT-800 Type 3 SS w/ Buna N float
L2	Level Transmitter, Float Type	1/4" resolution	±1/8" max cal'd	Gems	XT-800 Type 3 SS w/ Buna N float
L3	Level Transmitter, Float Type	1/4" resolution	±1/8" max cal'd	Gems	XT-800 Type 3 SS w/ Buna N float
L4	Level Transmitter, Float Type	1/4" resolution	±1/8" max cal'd	Gems	XT-800 Type 3 SS w/ Buna N float
Vd	Water Meter	0.1 gal/gal	0.1 gal/gal	Rockwell	
R	Load Cell	0-2000 lbs		Tri-Coastal	Model 264-202
A&B	Plumb Level	1° resolution	±5°	Starrett	No. 12
Wr	Scale	0.1g resolution	±0.1g	Ohaus	Triple Beam

The pressure, flow rate, and tank water level sensors, shown in photograph (20), were automatically monitored and recorded by the data acquisition system. The sensors chosen provided 4 to 20 mA outputs, which allowed the sensors to be placed hundreds of feet away from the data acquisition system. The current outputs were converted to voltages on a signal conditioner board designed and built by ARD Environmental. The resulting sensor voltage outputs were connected to a National Instruments AT-MIO-64E-3 A/D PC board. The A/D board was configured in a differential input mode for all channels.

Labview software was used to control the A/D board and scale and record the sampled data. A single software Virtual Instrument (vi) was written to complete the data acquisition, scaling, display and recording tasks. All sensor channels were sampled at a one second rate. Each channel was scaled using a gain factor and offset parameter. These scale factors were embedded in the code so they couldn't be altered during data acquisition. Each sensor output was displayed to the operator on a numeric software display in the appropriate engineering units (pig, gpm or inches). All test data were recorded in a time stamped comma separated value (csv) ASCII file format. This csv file can be read by many spread sheet programs or by Labview software.

The flow sensors and standing water level sensors were calibrated prior to testing, the former to +/- 2 gpm, and the latter to +/- 1/8". Factory calibrations were utilized for the pressure sensors, electronic levels, and load cell.

2.3 TEST RESULTS

The test series as originally planned was modified because of repairs required during the test series, and the terms and conditions of the contract. However, nearly all of the major objectives of the test series were met. Table 2.3-1 summarizes the tests, test parameters, and data derived.

Table 2.3-1: Test Description and Data Derived

Test Phase	Test Focus	Test Parameters	Key Data Derived
1. System Deployment (Pre-Insertion)	- Procedures for preparing system for tank entry.	-Pre-insertion procedures.	-Operating procedure requirements -Video record of operations.
2. System Insertion and Positioning	- Procedures for insertion & positioning of equipment in tank.	- Deployment procedures. - Impact on riser.	-Operating procedure requirements - Insight into umbilical management. - Video record of operations.

Table 2.3-1: Test Description and Data Derived			
Test Phase	Test Focus	Test Parameters	Key Data Derived
3. Extended Mobility / Production Rate Note: The testing was limited to partial removal of material because of time and equipment constraints. Approximately 11.9% of the total waste volume was removed.	- Mobility around rugged surfaces. - Extended operation. - Determination of possible production rates. - Ability to operate in the presence of debris such as steel tapes, plastic sheets, cinder block fragments.	- Starting and ending volumes of simulant. - Time to remove specified amount of simulant. - Standing water levels in tank. - Sluicer & eductor water flow rates. - Sluicer & eductor operating water pressures. -Sluicer scavenger and free water scavenger discharge rates.	- Average cleaning rate of system based on data taken. -Effectiveness of sluicer-mounted scavenging system. - Average & peak standing water in tank. - Average sluicer and eductor water usage. - Average total water usage. -Operating procedure requirements - Insight into umbilical management. -Ability to deal with cinder block fragments and sheet plastic. - Video record of operations.
4. Failure Mode Demonstrations	- Extraction of failed vehicle.	- Cable side loads on riser. -Tether cable tensions. -Relative cable angles.	- Ability to recover disabled vehicle. - Effectiveness of failure mode extraction method. - Identification of vehicle design improvements. - Impact on riser. - Video record of operations.

Table 2.3-1: Test Description and Data Derived			
Test Phase	**Test Focus**	**Test Parameters**	**Key Data Derived**
5. System Retrieval and Decontamination	- Procedures for retrieving equipment from tank. - Ability and effectiveness of proposed decon approach.	- Presence of dye tracer. - Volume of decon water used. - Time to complete decon. - Weight of matter remaining after decon. - Decon water flow rate. - Decon water pressure.	-Operating procedure requirements - Insight into umbilical management. - Impact on riser. - Amount of simulated waste remaining on each component after decontamination. - Volume of water used to decontaminate each component. - Effectiveness of methodology. - Identification of dose traps on each component. - Video record of operations.
Items not addresses due to modification of the test plan to meet contractual requirements	-Demonstration of complete removal of bulk waste. -Ability to clean the tank bottom to a minimum level of residual waste. -Effectiveness in dealing with large sheets of plastic, steel tapes and other miscellaneous debris.		

2.3.1 System Deployment (Pre-Insertion)

The pre-insertion effort consisted of a review of the test procedures with all test personnel to confirm layout of the equipment, and the duties of the test personnel. When deployment commenced, the forklift, to which the vehicle winch was mounted, had to be repositioned to reduce side load on the crane boom. This was done, and no difficulties were experienced during the actual deployment.

2.3.2 Deployment

Deployment took place on Tuesday, 4/22. The vehicle, which weighed in at 1864 pounds, was lowered into the 36" riser using the winch mounted on the forklift. The sluicer tilt arm had to be adjusted once for clearance, and the vehicle was then lowered to the waste surface without incident. The vehicle operator performed all operations remotely using video only, which was a major parameter of the testing. The vehicle umbilical and hose were led over a large drum suspended for the end of the crane. The end of the sluicer eductor discharge hose was retained at the top of the decontamination chamber, for subsequent connection to the Vehicle Water Scavenging Module (VWSM).

The VWSM was lowered into the decontamination chamber, and then into the riser. The vehicle umbilical and hoses were also in the riser, but did not interfere with the insertion of the VWSM. The sluicer eductor discharge hose was connected to the VWSM, and it was then lowered the rest of the way to waste surface, using the hook on the crane. Note that the connection from the discharge hose to the VWSM would have to be made remotely in a deployed system.

Handling of the vehicle and the VSWM was observed by the crane operator via video camera mounted on the end of the crane boom. This image was also available to the system operator at the control console, and was videotaped. The system operator observed the deployment procedure from the control station via the video cameras installed in the tank mockup, and the main monitor video was also taped. One tank camera failed immediately prior to the deployment. This was traced to a loose wire, which was repaired immediately after deployment.

The system operator performed all manipulations of the vehicle during the deployment. This included positioning the sluicer to clear the riser, and to shift the center of gravity of the vehicle at touch down. The vehicle was driven forward after touch down to allow the VWSM to be inserted fully. After observing the arrangement in the tank, it was decided to suspend the VWSM several feet above the waste surface during operations. This was necessitated by the relatively confined space of the mockup, and may have to be done from time to time in a Hanford tank to permit removal of waste from beneath the module. However, this does not appear to pose an operational problem.

The deployment sequence is shown in photographs (21)-(25), commencing with preparation of the vehicle, the lift and insertion through the decontamination chamber, emerging from the riser, touchdown on the simulant surface, and finishing with insertion of the VWSM.

2.3.3 Extended Mobility/Production Rate

Narrative

Extended mobility and production rate testing was started on Wednesday, 4/23. The initial testing consisted of driving the vehicle around the tank to observe its characteristics. Maneuvering was not difficult, and the vehicle could easily skid steer, especially on the hard saltcake. The primary impediments to maneuverability were the small size of the tank and the umbilical, especially the high pressure water supply hoses and the discharge hose from the sluicer eductor to the VSWM.

Umbilical management will need to be improved for long term in-tank operations, primarily by the use of powered handling winches with constant-tension drives to control the amount of umbilical in the tank.

During the initial mobility tests the vehicle slid sideways off of a mound of saltcake # 4, and wound up with a mockup riser stuck between the front and rear wheels on one side of the vehicle. We believe the vehicle could have freed itself had the full range of rotary motion been available between the front and rear axles. Unfortunately, a minor design error resulted in mechanical interference that limited the range of motion to ±30°, instead of the design value of ±55°. In any event, shortening the distance between the wheels would eliminate this as potential failure mode. Recovery was accomplished using a "come-along" to pull the vehicle away from the mockup riser. Mobility in the tank is shown in photographs (26), (27), and (28).

After the initial mobility tests, material retrieval commenced. The vehicle was used to mechanically dislodge material, as well as sluicing, and removing material with the VSWM and FWSM. A pump failure was experienced in the Vehicle Water Scavenging Module (VWSM) late in the afternoon of 4/23. This was due to the sealing discs in the pump jamming on the pea gravel dispersed into the simulant. The sealing discs were replaced with a harder formulation material on Thursday, 4/24, and testing continued. At the end of testing on 4/24 a vehicle motor seal was observed to be leaking. This was traced to restricted flow in the case drain lines. Larger lines were installed and the motor seal replaced the following day. Case drain flow rates were also checked and discussed with the manufacturer, who indicated that the rates were within specification.

The rest of 4/24, and all of Friday, 4/25, were devoted to maintenance of the system. The flow meters in the waste discharge lines had exhibited erratic performance, and one failed completely. The flow sensors were removed and cleaned, and the failed unit was found to be jammed by a piece of foreign material between the paddle wheel and housing. The units were tested, and then reinstalled. The hydraulic fittings on the forward end of the sluicer lift cylinders were found have been damaged by the rotating couplings on the water supply hoses to the sluicer. The cylinders were repositioned and the fittings and hoses replaced. The umbilical was also redressed and the broken tie wraps replaced with steel hose clamps. In addition, ½" case drain lines were run to replace the existing 1/4" lines.

A protective bracket was installed over the front of the sluicer lift cylinders and testing resumed on Monday, 4/28. The Free Water Scavenging Module (FWSM) fill rate was observed to be reduced, indicating poor scavenging. In addition, the pressure sensors on the vehicle again became erratic, and the cables were serviced and redressed. The FWSM was first raised about 4" as it appeared that waste accumulation around the base was the cause of reduced scavenging performance, however, this had no effect.

The FWSM was disassembled on 4/29, and a triangular piece of stone, approximately 0.26" across, was found lodged in the eductor motive water nozzle. This stone must have been trapped in one of the rented pumps or associated hoses, despite the extensive flushing performed prior to the testing, as the water system intake screen is 1/16" mesh. The FWSM was reassembled, reinserted in the tank, and testing continued, with the FWSM operating properly. Note that the water level in the tank reached a maximum of 10" while the FWSM was not functioning properly, primarily due to the free use of sluicing water by the operator, and the limited vehicle scavenging performed by the operator during this period.

Maintenance was performed on 4/30 to repair a hydraulic leak on the vehicle hydraulic manifold. In addition, the temporary lift cylinder rod bracket fabricated at ARD Environmental prior to the start of testing was replaced with the permanent unit, which had finally arrived from a machine shop which shall remain nameless, and never used again.

Because of the need to complete testing by Friday, 5/2, it was decided that the hard saltcake would be removed manually in an area, and the vehicle operated in the hardpan and soft sludge to determine performance in those waste simulants. Accordingly, on Thursday, 5/1, a region of saltcake was loosened with a jackhammer and removed, and the vehicle driven onto the hardpan. The area cleared was only about the size of the vehicle. When the vehicle was maneuvered onto the hard pan, it sank in fairly easily, and could not move forward because of the tank wall, nor backward because the of the umbilical stinger.

Nonetheless, the vehicle was able to sluice and remove most of the waste in the immediate area, including waste beneath it. We believe that with design changes to permit the umbilical to lead upwards, instead of straight back, and prolonged operation, a vehicle in this circumstance could gradually remove enough waste to permit motion, and eventually free itself. Testing halted late in the day when the pump in the FWSM jammed. Upon examination it was found to have seriously distorted discs, again, these were the older style softer discs.

A final mobility test was conducted to determine if the vehicle could recover its footing if it was on its side. The vehicle was rolled over onto its right side on the saltcake. The sluicer was then move to its lowest position using the lift arms, thus shifting the Center of Gravity (CG) to the left. The rear axle was then rotated to the left, further shifting the CG to the left. At this point the vehicle tipped to the left. The sluicer was then shifted to the right (up), and the vehicle rolled back onto its wheels.

Test Results

When all systems were operational, the design goals were met. The system, including the transfer and pressure pumps, could be operated by a single person at the remote control station. The water and waste scavenging systems were effective in removing waste and water, and in limiting the amount of free water in the tank. A key factor in limiting the water is developing a mining strategy that results in flow of the waste and water to the scavenging module, which must be situated at a low point.

The vehicle eductor was effective in removing pooled water and waste wherever these were encountered, however, it was generally not possible to remove water as it was injected by the sluicer. Any ventilation of the shroud would result in air being taken up by the eductor, and not water or waste. When the shroud was buried in the waste, and angled properly, it could remove sluicing water almost as fast as it was injected.

The operation of the sluicer and sluicer eductor is shown in figures 2.3-1 and 2.3-2. These figures show sluicer and sluicer eductor pressure and flow, and the cycling by the operator. Operation of the VSWM and FSWM are shown in figures 2.3-3 and 2.3-4. The automatic cycling of the pumps in the two modules indicates that the modules are functioning properly. Cycle times vary somewhat for the FWSM, and greatly for the VSWM, because the FWSM was at a low point with waste and water flowing to it most of the time.

The cycling of the sluicer and eductor water supplies for the five material removal periods is shown in figures 2.3-5 through 2.3-9,. The X-axis is test time and the dark band indicates when the water supply is was on. The sluicer water supply shows the most activity, as it was turned on and off frequently by the operator during the testing. At times the vehicle was used primarily as an excavator, and at those times the sluicer and sluicer eductor were both turned off. The FWSM eductor was on almost all of the time.

The waste surface contours are shown in figures 2.3-10 through 2.3-14. The initial surface is shown in figure 2.3-10, and the reduced surfaces are shown in the remainder of the figures. The figures accurately reflect the topography. In the first figure, the central mound is the last pour, saltcake #4. There is a gully below and to the left of the riser, and there are two terraces above the riser proceeding counterclockwise. The FWSM was located in a pit at about 8 o'clock on the figures, against the tank wall.

The productivity data are summarized in the table below, however, the text that follows contains important additional information that bears on the interpretation of the data, and should be read carefully.

Table 2.3.3-1: Productivity Data

Run # /Material	Total Time	Sluicer Water Time	Sluicer Eductor Water Time	Free Water Eductor Water Time	Waste Volume Removed	Sluicer Water Used	Time/Cubic Foot Removed	Sluicer Water Volume / Sludge Volume Removed
	Minutes	Minutes/%	Minutes	Minutes	Cubic Feet	Gallons	Minutes	Volumetric Ratio
1/SC4	101.8	33.9/33.3	66.6	80.6	52.4	4746	1.94	12.11
2/SC3	111.5	22.2/19.9	98.1	100.1	10.85	3108	10.28	38.30

Table 2.3.3-1: Productivity Data								
Run # /Material	Total Time	Sluicer Water Time	Sluicer Eductor Water Time	Free Water Eductor Water Time	Waste Volume Removed	Sluicer Water Used	Time/Cubic Foot Removed	Sluicer Water Volume / Sludge Volume Removed
	Minutes	Minutes/%	Minutes	Minutes	Cubic Feet	Gallons	Minutes	Volumetric Ratio
3/SC3	200.1	58.0/29.0	159.9	164.3	11.9	8120	16.82	91.22
4/SC3	134.1	83.7/62.4	127.1	132.6	16.19	11,718	8.28	96.76
5/HP,SS	38.1	13.8/36.2	24.3	36.7	20.6	1932	1.85	12.54
Total	585.6	211.6/36.1	476	514.3	111.94	29,624	5.23	35.40

The data were extracted from the Labview files, and the last two columns calculated from the data. The "water" times were derived from the appropriate pressure sensor outputs, and total time from the pressurizing pump pressure sensor. The volumes of material removed were computed by the topographic software used to create the contour charts, except for run 5. This run was done in the hardpan and wet sludge deliberately exposed by manually removing the saltcake overburden. No waste surface readings were taken for run 5 since the removal was done in a localized area. The volume of material removed was estimated at 2.5' wide x 55' long x 1.5' deep based on the dimensions of the vehicle, the area exposed by removing the overburden, and the hole left after the removal. The water injected into the tank via the sluicer was derived from the average sluicer operating pressure, nozzle flow based on manufacturer's data, and sluicer operating time.

Run 1 shows a great deal of material removed for the amount of water and operating time, consistent with the nature of saltcake #4. Run 2 shows a significant increase in the time and water required per cubic foot of waste removed, due to the hardness of saltcake # 3. The vehicle was used as an excavator, and while it was able to tear up the surface of the waste, this took some time. Modifying the cleat design would improve the excavation capability.

Runs 3 and 4 exhibited a further increase in time and water used per cubic foot of material removed. This is primarily due to the greatly increased percentage of sluicer "on" time, compared to the previous run. This reflects the approach of the individual operator and the state of the equipment at the time. In this run, the operator chose to sluice extensively, and the FWSM was not fully functional due to the pebble trapped in the eductor nozzle.

It was noted that the saltcake softened during a run by excavation with the wheels would reharden overnight to its original consistency. Thus removal volume would have improved had the softened material been sluiced and removed at the end of each day. Whether or not the

Hanford tank wastes exhibit this characteristic is not known.

Run 5, which was in the relatively soft hardpan and sludge shows time and water use consistent with run 1, also in softer material.

Based on observation, the maximum amount of standing water in the tank was no more than 30-50 gallons, when the FWSM was fully operational. The amount of water in the tank could easily be limited by careful operation of the sluicer, and use of the sluicer eductor to remove trapped pockets of waste and water. The maximum amount of water in the tank was estimated at 400-500 gallons, during run 4. This occurred when the FWSM was not operating properly, and the system operator kept the sluicer on for extended periods.

The average performance against hard and soft materials are shown in Table 2.3.3-2. Run 4 was eliminated from the calculation, since the FWSM was not fully functional, and excess water was deliberately used. Note that the "soft" material includes low strength saltcake as well as hardpan and sludge.

Table 2.3.3-2: Average Performance Against Hard and Soft Simulants

Simulant	Total Time	Total Volume	Total Water	Time per Cubic Foot	Water / Sludge Ratio	Percent Solids by volume
Soft: SC4, HP, SS	139.9	73	6678	1.92	12.23	8.17
Hard: SC3	311.6	22.75	11228	13.7	65.98	1.52

These averages are realistic in that they reflect real operational time exclusive of breaks or downtime, but inclusive of production inefficiencies such as vehicle maneuvering, camera adjustment, reading of gauges, in-process discussions, and the like. Assuming that the simulants are representative of the characteristics of the material in the tanks, an estimate may be made of the time required to clean a Hanford tank.

Assume the following:

1. Heel thickness = 6", over entire tank bottom = 2209 cubic feet.
2. Soft sludge = 4' over entire bottom = 17671 cubic feet.
3. Medium saltcake = 1.5' in a single layer on top = 6627 cubic feet.
4. Two 8 hour shifts per day, 5 days per week, 75% productivity = 12 hours/day, or 60 hours per work week.

The time require to remove the hard heel is about 504 hours, or 8.4 calendar weeks. The time to remove the softer materials is about 778 hours, or 13 calendar weeks. The total removal time is thus 21.4 calendar weeks or about 5 months. The total sluicing water used is about 3.3 mgal, at an average rate of 43.1 gpm. Another 3.85 mgal of eductor motive water would also be required, at a rate of 50 gpm. Although the total volume of water is large, the total average rate is less than 100 gpm, which is entirely consistent with the use of recirculated working water.

Operation of the vehicle using the video system was relatively straightforward, although only one of the tank cameras was equipped with a pan and tilt. It would definitely be desirable to have multiple tank cameras, all equipped with zoom, pan and tilt, since this would permit the operator to view the work face no matter where the vehicle was in the tank. Fatigue did not appear to be a factor, probably because of the novelty of the situation and the fact that the longest run was only 3 hours and 20 minutes.

Standing water level sensors were installed at four locations in the tank in order to monitor residual water. These sensors proved to be unresponsive to anything but long term changes in level, and were most affected by the permeability of the waste. The standing water levels over the life of the test effort, about 9 days, is shown in figure 2.3-15. Note that at the end of the test, the drain valve for L1 was opened, and the water drained from the sensor column. No additional water drained from the tank, confirming that the sludge at the bottom of the tank was essentially clogging the flow and only allowing slow permeation. The sudden drop in level at L4, which occurred over a period of 18 minutes on 5/1, is unexplained, however the most likely reason is inadvertent cracking of the drain valve.

2.3.4 Failure Mode Test

The failure mode test was conducted on 5/1. Three tests were performed, the first with the wheels in free-wheel mode, which is the most realistic condition, the second with the wheels locked, and the third with the vehicle on its side with the wheels locked. In all cases, the vehicle was driven into the hole created in the hardpan opposite the riser during the last productivity test on 5/1. The test layout and geometry are shown in figure 2.3-16. Photograph (29) shows the vehicle during a retrieval test.

The measured loads and angles, and the resulting forces are tabulated in the table below. It appears that the principal component is the vertical lift of the vehicle, thus there is little difference in loads for the three tests. Although angles and loads were not measured for the third run, the winch pressure was monitored and was in the same range as the other two tests.

Table 2.3.4-1: Retrieval Loads									
Test Condition	Angle "A"	Angle "B"	Measu-red Load	Winch Pressure	Line Tension	Vehicle Horizo-ntal Load	Vehicle Vertical Load	Riser Horizo-ntal Load	Riser Vertical Load
Free Wheel	18.5	0.7	1260	1000-850	2061	1220	1015	1195	400
	19.2	0.4	1100	550	1707	1051	867	1039	362
	8	1.4	800	500	3480	877	774	792	111
Locked Wheel	17	0	1250	900	2138	1195	1036	1195	365
	21	0	1200	NM	1674	1120	892	1120	430
	20	0	530	NM	775	498	406	498	181
Tipped/Loc-ked	NM	NM	NM	900	NA	NA	NA	NA	NA
	NM	NM	NM	450-500	NA	NA	NA	NA	NA

In general, the loads appear to be reasonable and consistent. However, it is difficult to extrapolate to a worst case in a Hanford tank, as even in the worst stuck condition, the vehicle should be able to free itself by removing material, even if slowly.

2.3.5 Retrieval and Decontamination

Retrieval and decontamination was conducted on Friday, 5/2. A commercial pressure washer delivering 40 gpm (nominal) at 3000 psi (nominal) was rented for the day, with an operator. The supply to the washer was from the local fire main through a filter. The decontamination rings always had at least one valve open to avoid dead-heading the pump. The pressure and flow are shown in figure 2.3-17. The pressure varied with number of spray rings operating, however flow was fairly constant at 34 gpm under all conditions. Based on this average flow rate and the total decontamination time of 89 minutes, the process used a total of 3026 gallons of water, which drained back into the test tank.

The vehicle was manually loaded with sticky hardpan and sludge, and allowed to dry for 2 hours prior to starting decontamination. The output of the pressure washer was connected to the decontamination system, and decontamination commenced by bringing the umbilical up through the spray area. Decontamination continued by raising the vehicle into the chamber, and directing the spray rings around to cover all areas. In addition, the wheels were powered up and rotated to expose all areas to the spray. Once the sluicer cleared the riser, it was also operated to expose all areas to the cleaning process, particularly the inside of the shroud. The spray wand was used to clean areas that the spray rings could not reach effectively, such as the interior of the motor mount boxes.

Photograph (30) shows the vehicle after being loaded with waste prior to retrieval. Retrieval is shown in photograph (31), the spray deluge during umbilical decontamination in photograph (32), and the spray deluge during vehicle decontamination in photograph (33). The rest of the retrieval sequence is shown in photographs (34) and (35), and the vehicle after decontamination in photograph (36).

Upon completion of the decontamination, the vehicle and umbilical were carefully examined, with the following results:

A) The umbilical, consisting of hydraulic hoses, water supply hoses, discharge hose, and electrical cables, was very clean. No material was observed on the outside of any of the umbilical components, however, some material was trapped inside the bunched umbilical components.

B) The high pressure of the spray, combined with the use of 0° jets resulted in damage to the hydraulic hose and water hose outer jackets. The damage was most likely caused when a single ring was operated and the pressure reached 300 psi. Lower pressures would probably be as effective and would not cause any damage. Conversely, 15° nozzles would reduce the impact of the spray and eliminate damage.

C) Centering the umbilical was somewhat difficult, and would not have been an issue with 15° spray nozzles. However this would not be an issue in an operational system because of the integral handling system design.

D) Raising and lowering the vehicle, and powering the wheels and cylinders was an effective means of exposing all areas of the vehicle to spray.

E) Visibility during spraying was very limited, and would probably be even worse if a video camera were used to monitor the process. With the test setup, the only way to stop the spraying was to secure the pump, which was not very convenient. An operational system should incorporate a bypass to allow shutdown of the spray for examination of the vehicle.

F) The wand proved to be very useful, however an improved spray pattern probably could eliminate the need for the wand.

G) The vehicle was examined after completion of decontamination, and was found to be very clean. The spaces between the lift arms and motor mount box, and the lift arms and motor casing were completely clean. Some residual material was noted in the front motor mount box and in the sluicer shroud. In both cases the dose traps could be eliminated by design. Some material also flushed out of the left rear wheel, however this material was forced into the space by the water jets during decontamination due the failure of the R.V. sealant. Again, this could be eliminated by design. The vehicle was not disassembled because of lack of time.

H) The addition of tracer dye to the simulants proved to be unnecessary, as the volume of water used for decontamination would have diluted the dye to the point of invisibility.

I) The high pressure spray conveyed material to the walls of the decontamination chamber and to areas of the vehicle and umbilical that had already been cleaned. A separate washdown ring for the chamber, multiple passes of washdown of the vehicle and umbilical, and perhaps additional spray rings would alleviate this problem. In addition, the spray ring nozzles should be changed from 0° to 15°, which would eliminate dead spots and reduce damage to the umbilical hoses and other soft materials.

3 ISSUES RESOLVED

3.1 Water Usage and Potential Tank Leakage

Description: Water usage is of importance because of the limited storage volume available for process water and waste removed from the Hanford Single Shell Tanks (SSTs). Constant use of raw water for the cleaning process will result in unacceptably high storage requirements or high cost to remove radioactive particles and dispose of the water safely.

Method: The volume and rate of water usage was determined by measurement during the testing. Average usage rates were calculated, and the feasibility of recirculating working water was demonstrated by the test setup. Standing water at 4 locations in the tank were measured, however these only reflected permeation through the simulated waste, not reflect transient levels.

Result: Total water volume needed to clean a hypothetical tank with about 6' of material was also calculated, and about 7.1 mgal, or about 5.5 times the volume of a 40' tank. This clearly points to the need to use recirculated water to clean an SST. Usage rates are consistent with recirculation of working water. Tank leakage could not be determined, quantitatively or qualitatively, since this would be highly dependant on the specific waste field and location of leaks in a tank. The ability to recycle water using medium pressure centrifugal pumps was amply demonstrated during the testing. The medium pressure water, 400 to 450 psi, was very effective at dislodging all but the hardest materials, and was very effective at mobilizing and conveying all the wastes.

3.2 Waste Removal Rate

Description: The waste removal rates for hard and soft materials are important issues as they will determine the length and cost of a tank cleanout. The removal rates are also important as they will drive the rest of the remediation process - transport to a Double Shell Tank (DST), the number of DST's required, and the rate at which material can be fed to the vitrification or other process.

Method: The waste removal rates were determined by measuring the waste field surface and computing the volume removed. Times were determined from the logged pressure and flow data. Determinations were made for hard and soft simulants.

Result: Waste removal rates varied considerably between hard and soft materials, as expected. The solids content by volume for both hard and soft materials were consistent with our experience at industrial sites and nuclear power plants. A total of 11.9% of the waste was removed during the testing. The measured rates were used to estimate the time required to clean a Hanford SST, and the results appear reasonable. Improvements in excavation of hard materials could be realized by equipping the vehicle wheels with a more aggressive tread, and by adding high pressure capability to the sluicer.

3.3 Mining Strategy

Description: Mining strategy is an important issue as it is closely related to removal rate, water use and the amount of water resident in the tank at any given time. Resident water needs to be minimized to reduce any potential leakage.

Method: The mining strategy was determined prior to the testing by logical analysis of the test process. Since the Free Water Scavenging Module (FWSM) was placed at a low point in the tank, the strategy was to clear a path to the FWSM by sluicing and excavating, and attempt to move waste and water along that path. Isolated pockets of waste and water that were created were cleared using the Vehicle Water Scavenging Module (VWSM) which was fed by the eductor on the sluicing head.

Result: The mining strategy was generally effective. Most of the waste and water were removed by the FWSN, except when it lost efficiency due to a pebble being stuck in the motive water nozzle. When the sluicer could be buried in water and waste, it, too, was an effective means of removing material. Mining strategy in a Hanford SST would be dictated by the specific conditions in the tank.

3.4 Operator Efficiency

Description: Operator efficiency is an issue related to the overall effectiveness of the cleaning operation, duration of the operation, and cost.

Method: Operator efficiency was evaluated by observation, and videotaped for later review. In addition, sluicer "on" time as a percentage of total time was calculated.

Result: It was quite clear that the most experienced operator had a better ratio of maneuvering to mining time, and did a better job of utilizing the sluicer and excavation capabilities of the vehicle. The most experienced operator utilized the sluicer 19% of the time against hard saltcake, while the least experienced had the sluicer on 62.4% of the time. Training and experience in operating the equipment will therefore have a significant impact on all aspects of an SST cleaning effort.

3.5 Deployment

Description: The ability to deploy the system without incident is a condition precedent to the actual cleaning operation.

Method: Deployment was demonstrated by deploying the vehicle and the FWSM in the tank. All operations were videotaped.

Result: Deployment of the vehicle and the VWSM were without incident, however the need to connect the sluicer discharge hose to the VWSM by remote control will have to be addressed in the future. The connection was made by hand during the test, and the connection components were standard cam-lock fittings. A fitting suitable for remote make and break will either have to be found or designed.

3.6 Mobility

Description: Mobility is required to be able to retrieve waste from a tank.

Method: The vehicle was driven around the tank prior to starting removal of material, to observe handling and agility. The vehicle was maneuvered extensively during the removal testing, including driving it into a hole in soft material. In addition, the vehicle was turned on its side to demonstrate the ability to recover from a knockdown. All activities were videotaped.

Result: The vehicle could be maneuvered to any location in the tank, even though the space was cramped relative to the size of the vehicle. The principal impediment to maneuvering was the umbilical jutting out directly behind the vehicle. This would be less important in a larger tank, or if the umbilical could be controlled with a winch, instead of manually, as was done during the testing. In addition, improvements in umbilical design and layout, and the means of attaching it to the vehicle would remedy this deficiency. When the vehicle was driven into a patch of softer material, it worked its way to the bottom of the tank, and sluiced and removed most of the material around it. The space was so confined that, in the time available, the vehicle did not free itself, although it continued to remove material. Given sufficient time a large enough area could have been opened up to permit maneuvering. The rollover test was successful, the vehicle was able to right itself merely by shifting its center of gravity with the lift cylinders and rotary joint.

3.7 Vehicle Recovery

Issue: Although it may not be necessary to remove the vehicle for maintenance during a cleaning, it must be possible to do so even if the vehicle is immobilized.

Method: The vehicle was positioned in the hole opposite the riser, and three tests conducted. The first was with the vehicle in free-wheel mode, the second with the wheels locked, and the third with the vehicle on its side and the wheels locked. The vehicle was pulled from the hole and cable angles and line tension measured. Loads on the riser and at the vehicle were calculated.

Result: The vehicle was easily pulled from the hole. Loads were similar for all three tests, primarily because most of the force was used to lift the vehicle. Loads in a Hanford SST would probably be higher unless a method were developed to reduce friction of the umbilical across the bottom edge of the riser. Note, however, that the vehicle drive system utilizes four fully independent drive motors, and this high degree of redundancy greatly minimizes the potential for an immobilizing failure.

3.8 Decontamination

Description: The vehicle and umbilical must be decontaminated if repairs are required, or if the equipment is to be re-used after cleaning an SST.

Method: A working decontamination chamber was fabricated for the testing. It was equipped with three spray rings, one with nozzles pointing down 45°, a second with the nozzles horizontal, and the third with the nozzles pointed up at 45°. Each spray ring had eight nozzles, and the entire ring assembly could be rotated +/- 22.5° to permit aiming water at all portions of the vehicle. In addition, the chamber was equipped with a manually operated wand. The vehicle was loaded with sticky sludge prior to starting decontamination. It was then decontaminated by raising it up through the riser, and moving it up and down through the spray rings, rotating the vehicle wheels, positioning the sluicer head and lift arms for effective cleaning, and using the wand to reach difficult spots.

Result: The umbilical and vehicle were both decontaminated effectively. Some residual material remained in between the hoses in the umbilical, where they were bundled with tie-wraps. Some residual material remained in one of the vehicle motor mount boxes, and in the sluicer shroud. This material could have been removed if it had been seen. In any event, dose traps such these would be eliminated by design, and the umbilical would be sheathed to eliminate dose traps. Note that the dye tracer mixed in with the waste was not useful in determining the presence of residue on the equipment. The presence of residue was easily determined visually. In a real environment, radiation monitors would be used to detect hot spots.

4 DISPOSITION OF TEST ITEM

The test mockup and apparatus was broken down the week after the test. All rental equipment was returned to the vendors. The vehicle, control station and other apparatus purchased or fabricated for the tests are stored at ARD Environmental, Inc. All original data, photographs, videotapes and the like are archived at ARD Environmental, Inc.

5 REFERENCES

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Alternative Retrieval Technology Demonstrations Program - System Test Plan, ARD Environmental, Inc. 4/14/97.

Alternative Retrieval Technology Demonstrations Program - System Test Procedures, ARD Environmental, Inc. 4/21/97.

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Decontamination System Study for the Tank Waste Retrieval System, EGG-WTD-11311 5/94

Initial ACTR Retrieval Technology Evaluation Test Material Recommendation, PNNL-11021

6 APPENDICES

Appendix 6.1 Figures

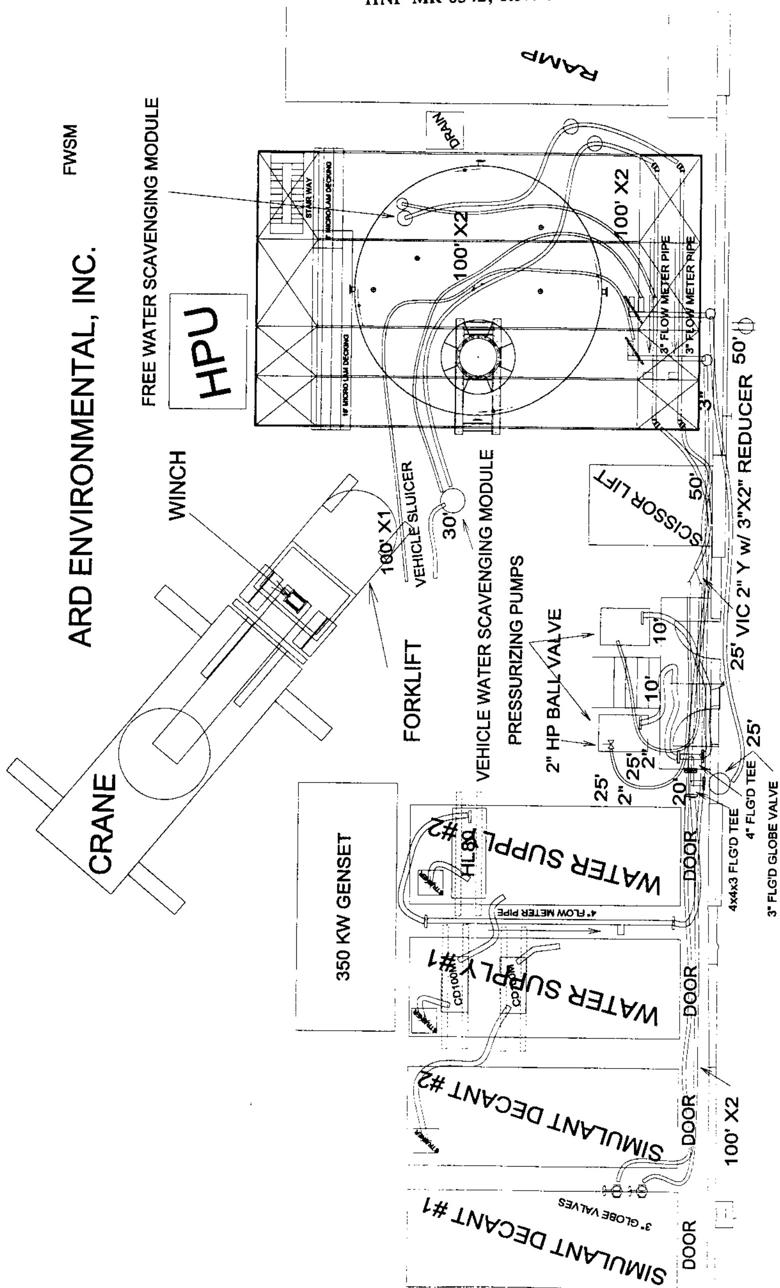


FIGURE 2.2-1: TEST SITE LAYOUT

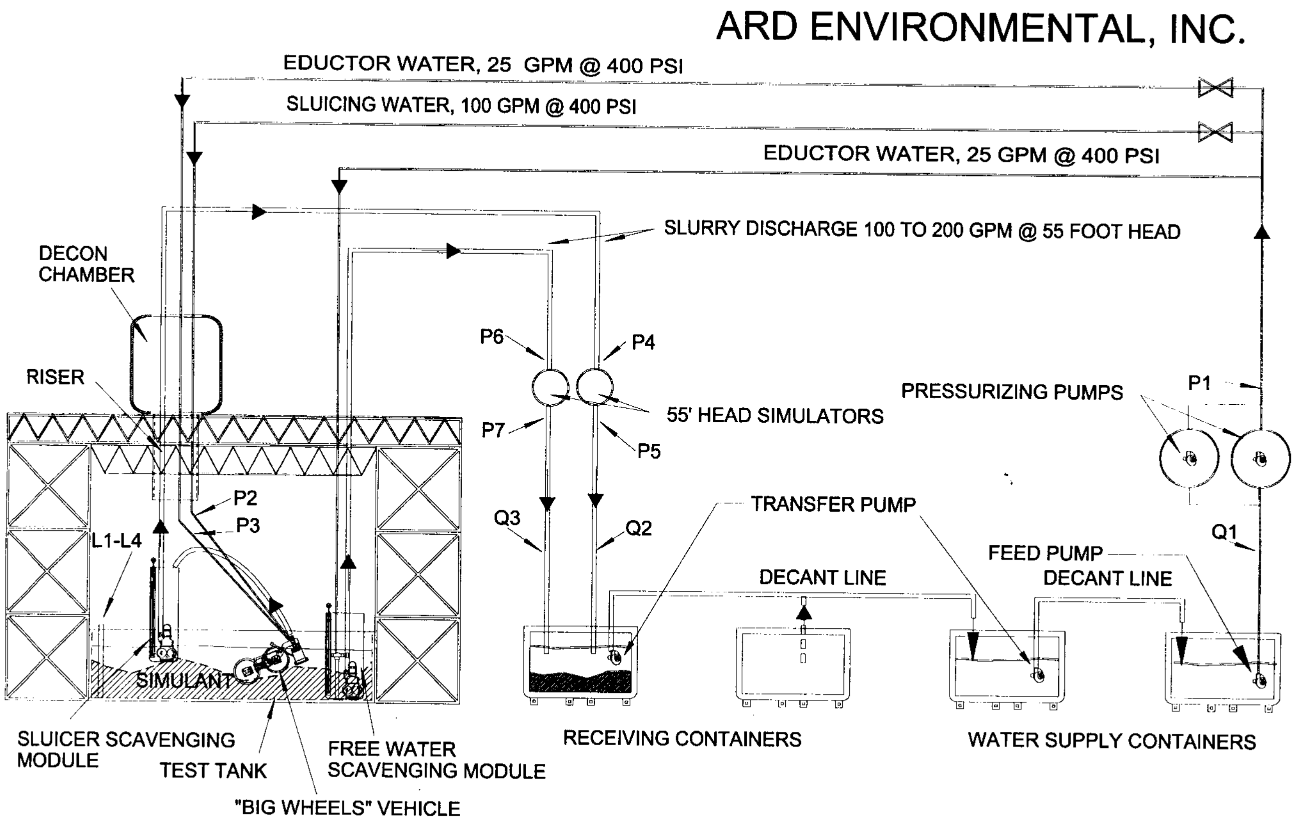


FIGURE 2.2-2: TEST SYSTEM BLOCK DIAGRAM

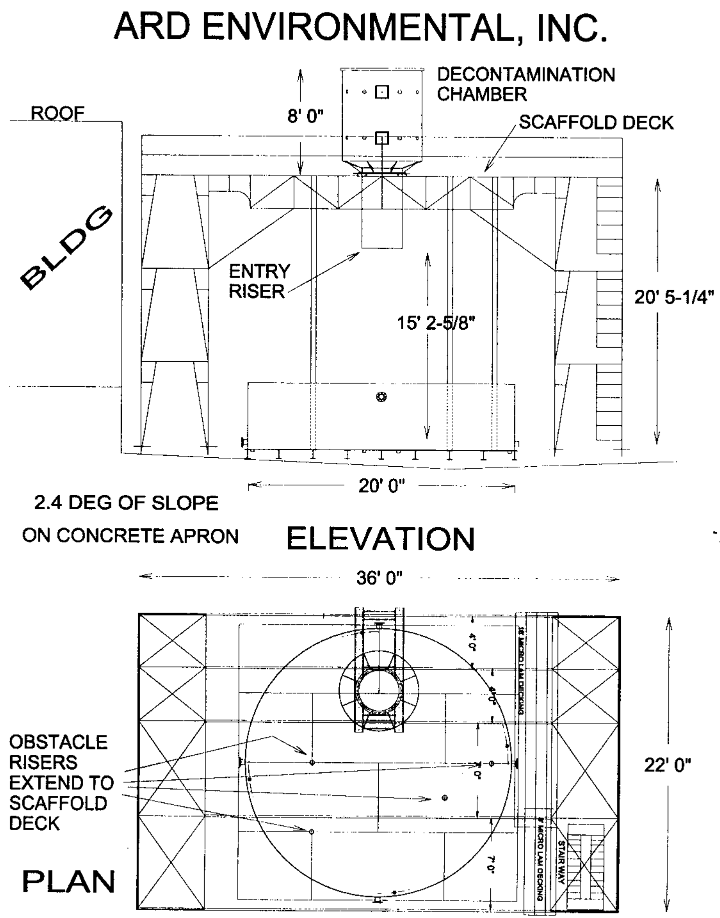


FIGURE 2.2-3: TANK MOCKUP LAYOUT

ARD ENVIRONMENTAL, INC.

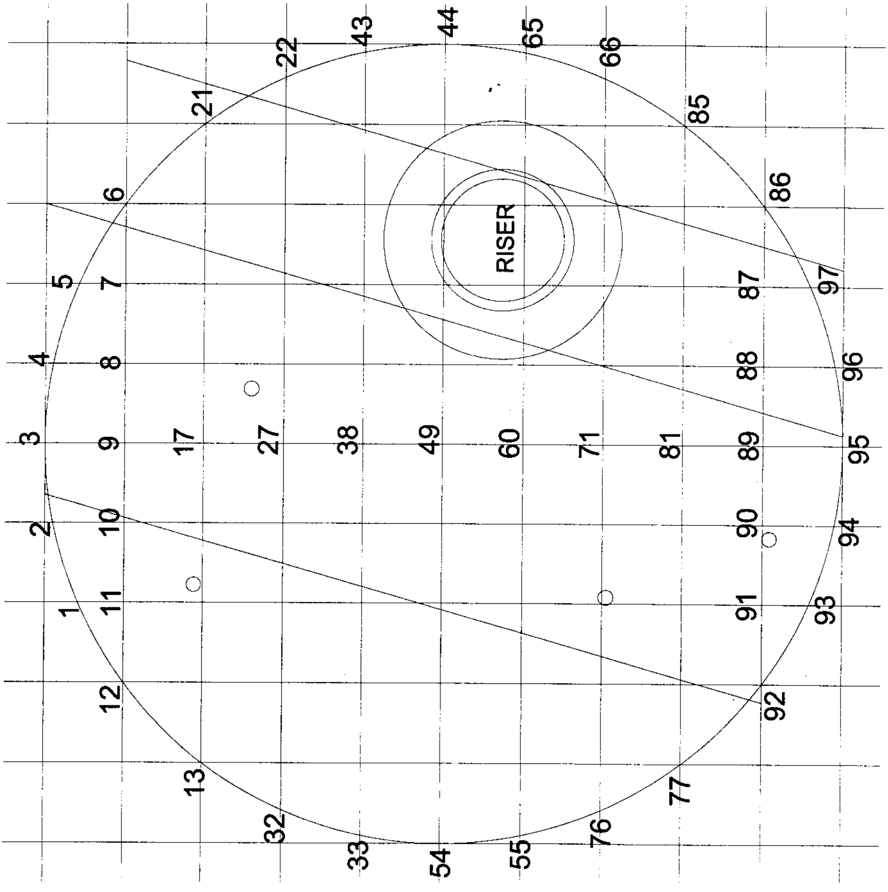


FIGURE 2.2-4: SURFACE MEASUREMENT DROPS

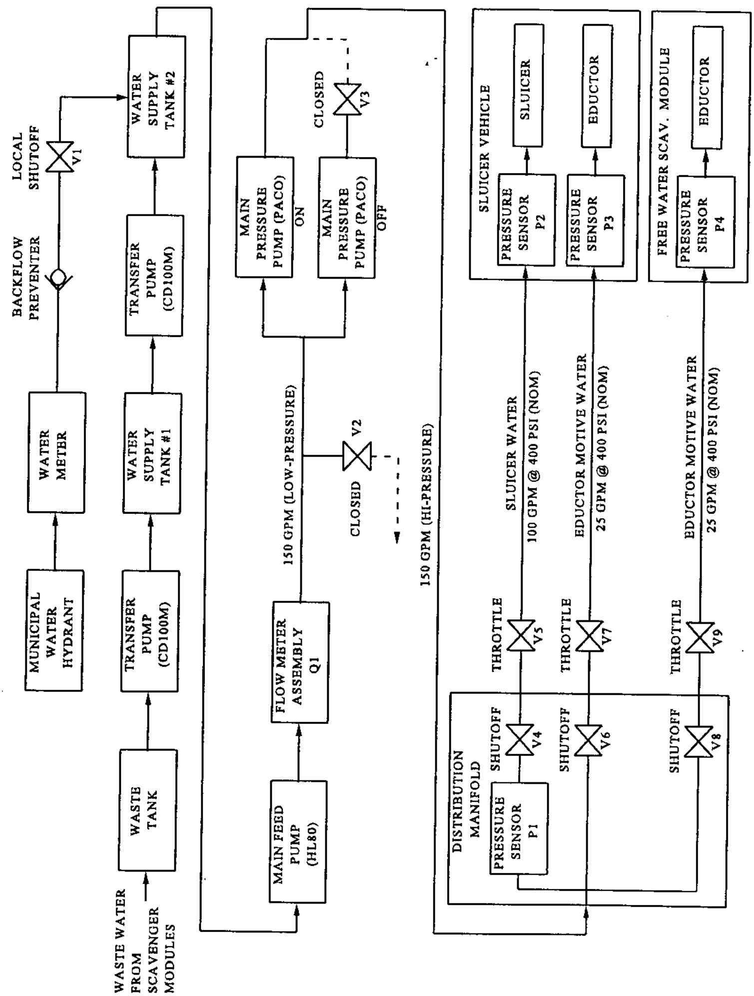


FIGURE 2.2-5: WATER SUPPLY BLOCK DIAGRAM

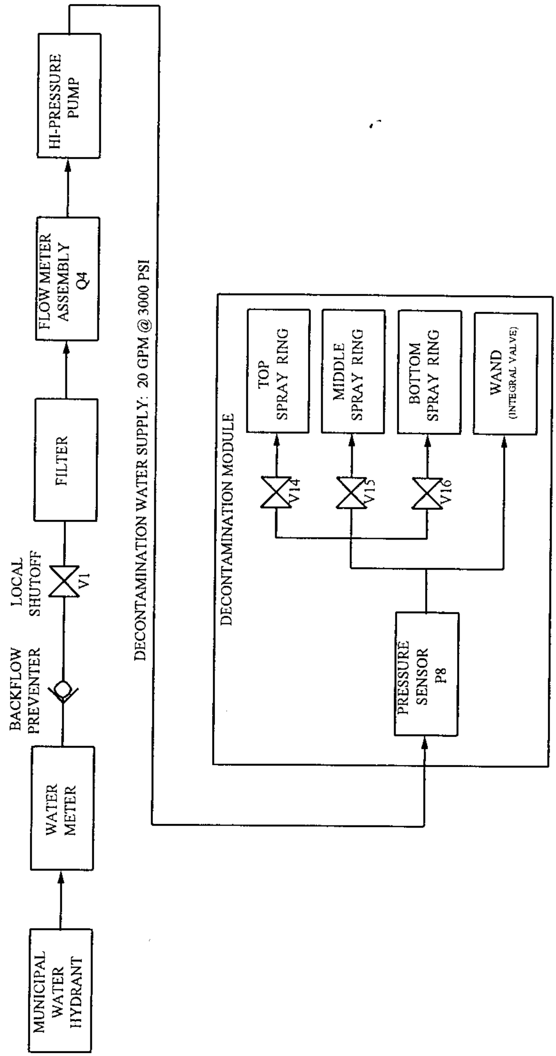


FIGURE 2.2-6: DECONTAMINATION WATER BLOCK DIAGRAM

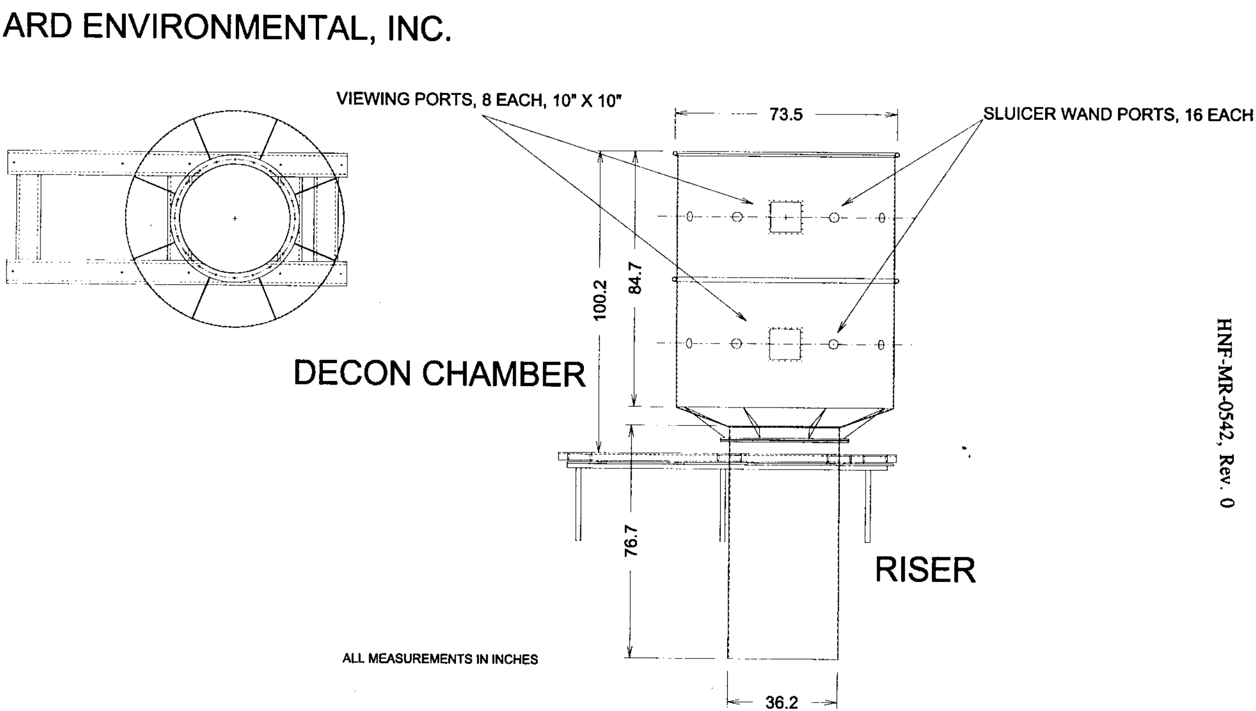


FIGURE 2.2-7: RISER MOCKUP AND DECONTAMINATION CHAMBER ASSEMBLY

ARD ENVIRONMENTAL, INC.

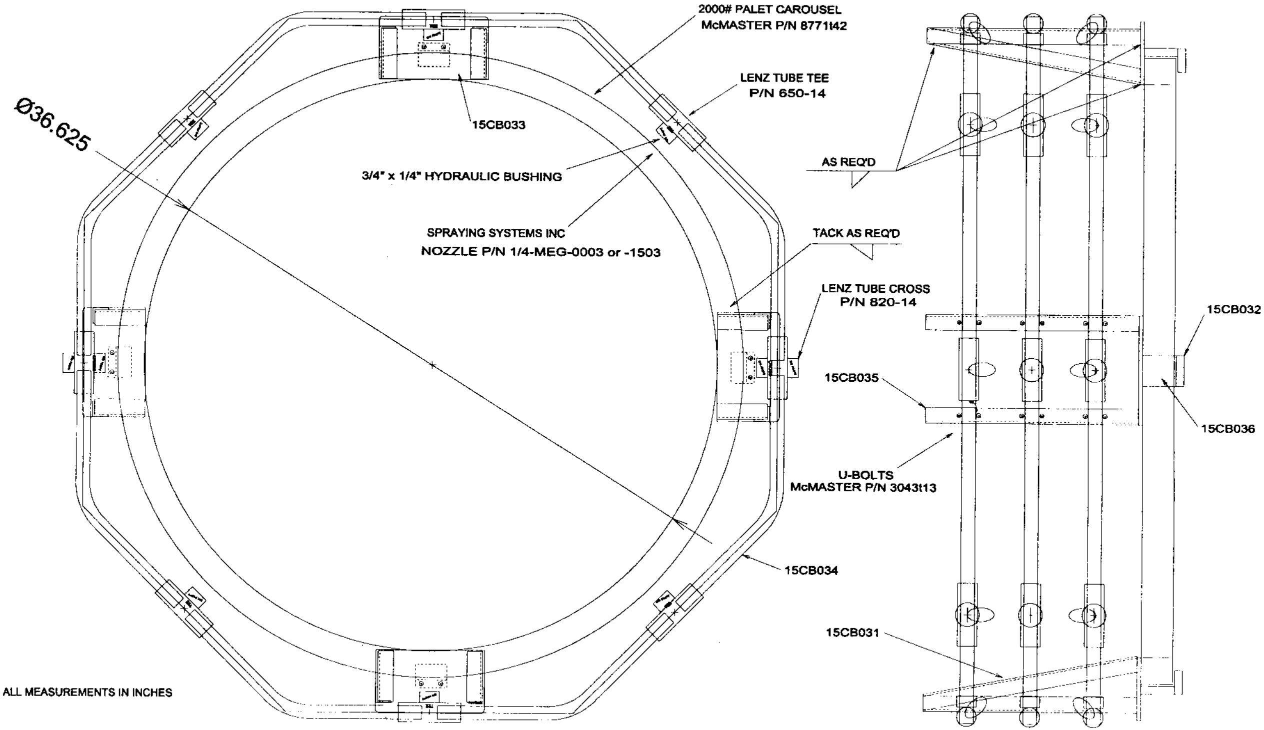


FIGURE 2.2-8: DECONTAMINATION SPRAY RING ASSEMBLY

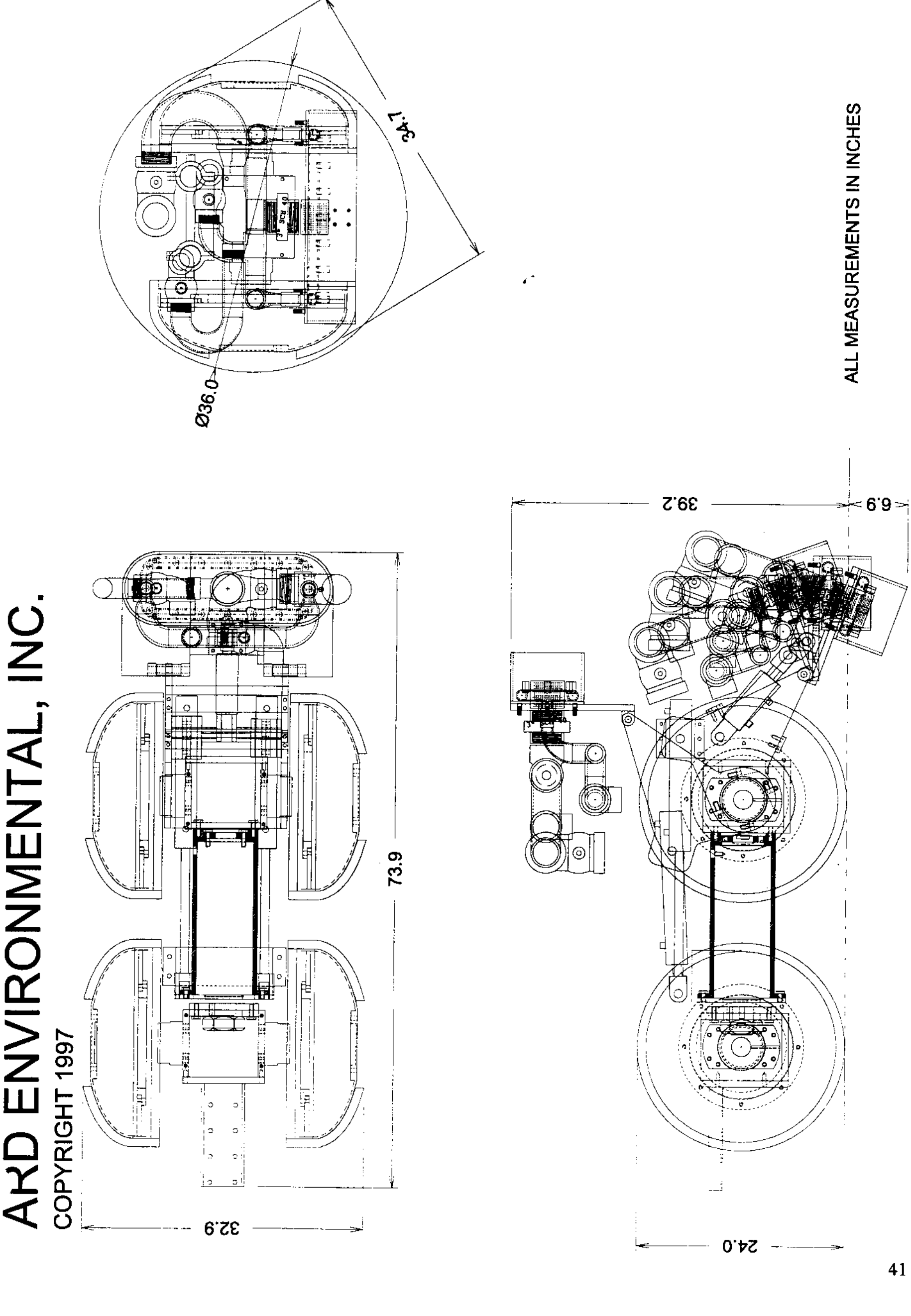


FIGURE 2.2-9: VEHICLE AND SLUICER ASSEMBLY

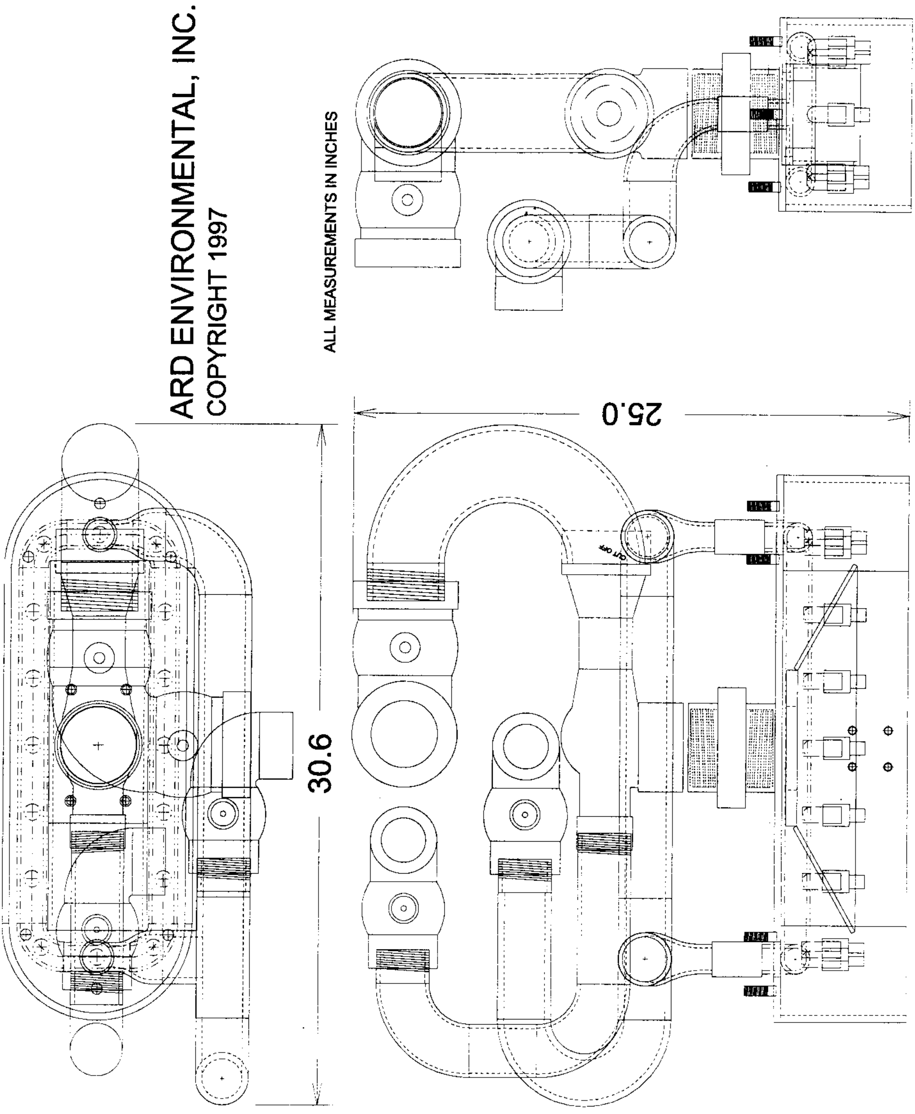


FIGURE 2.2-10: CONFINED SLUICER AND EDUCTOR ASSEMBLY

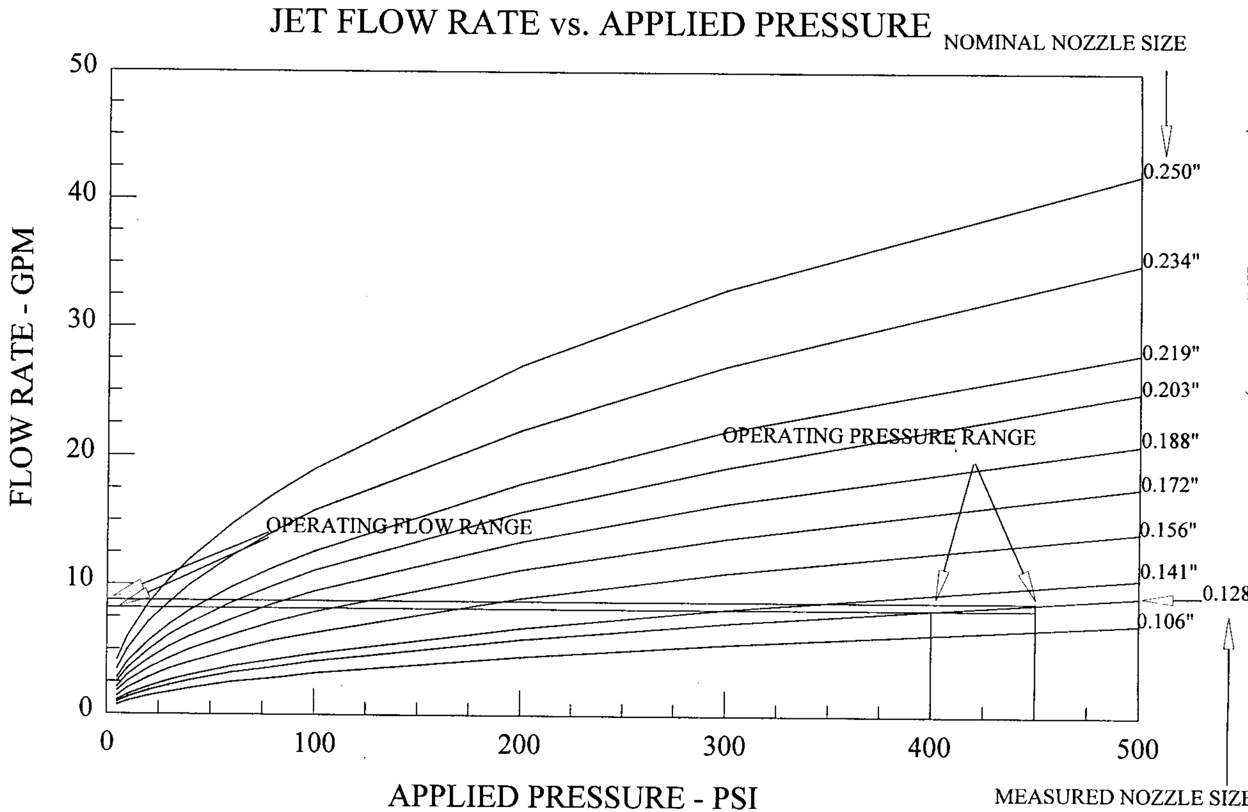


FIGURE 2.2-11: SLUICER JET CHARACTERISTICS

(BASED ON MANUFACTURER'S DATA)

ARD ENVIRONMENTAL, INC.
9115 WHISKEY BOTTOM ROAD
LAUREL, MD 20723

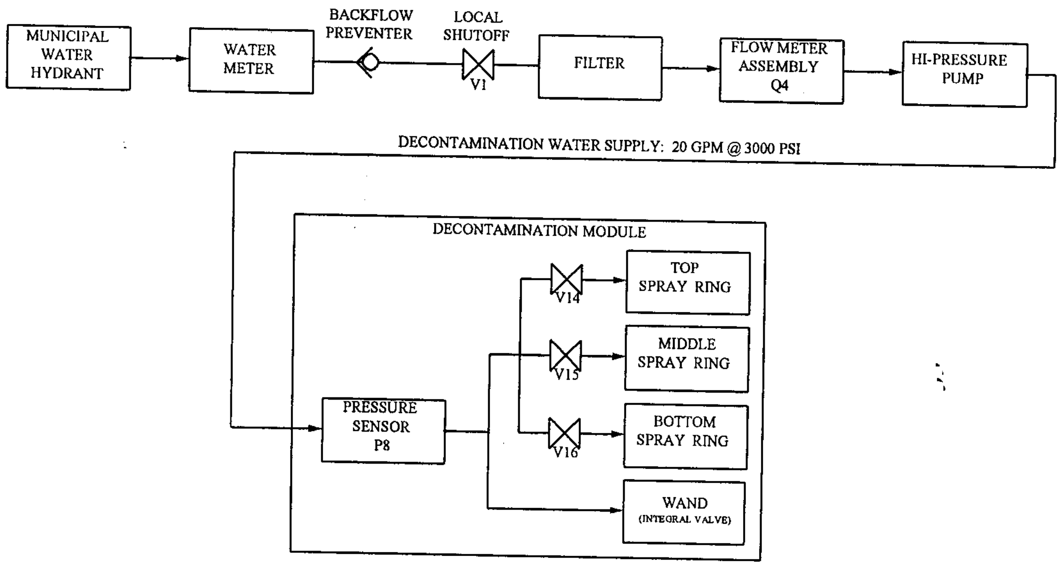


FIGURE 2.2-6:DECONTAMINATION WATER BLOCK DIAGRAM

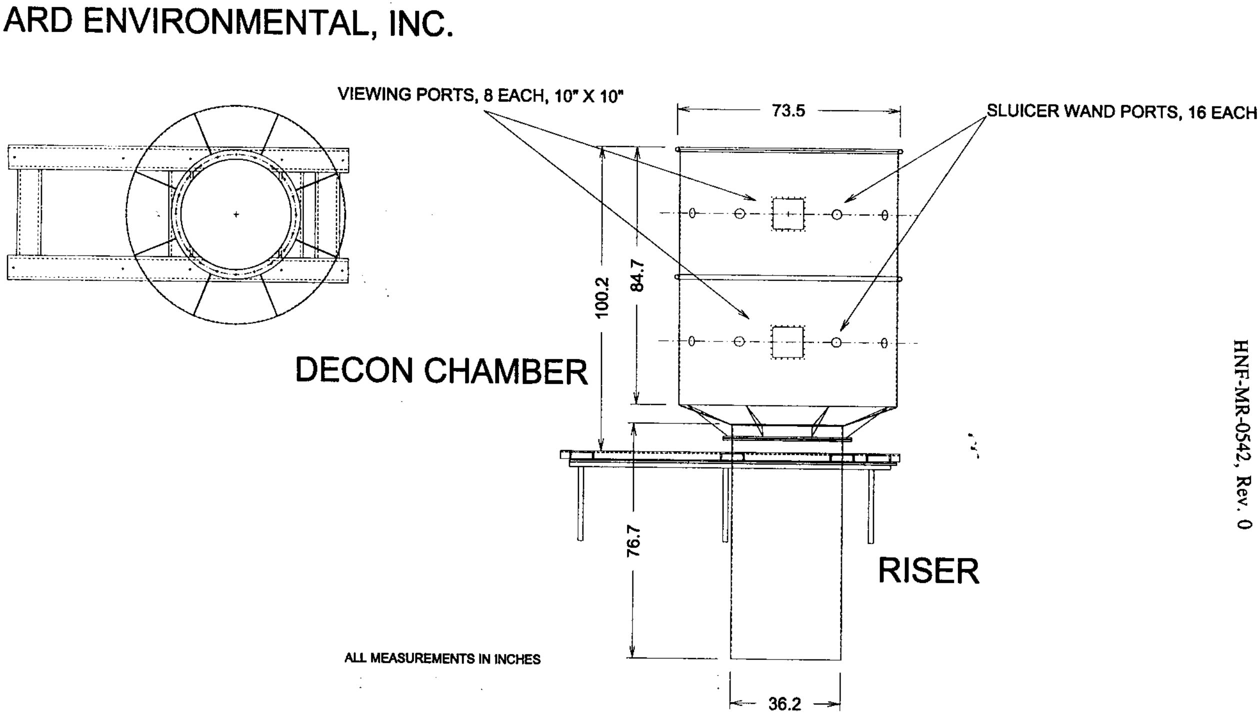


FIGURE 2.2-7: RISER MOCKUP AND DECONTAMINATION CHAMBER ASSEMBLY

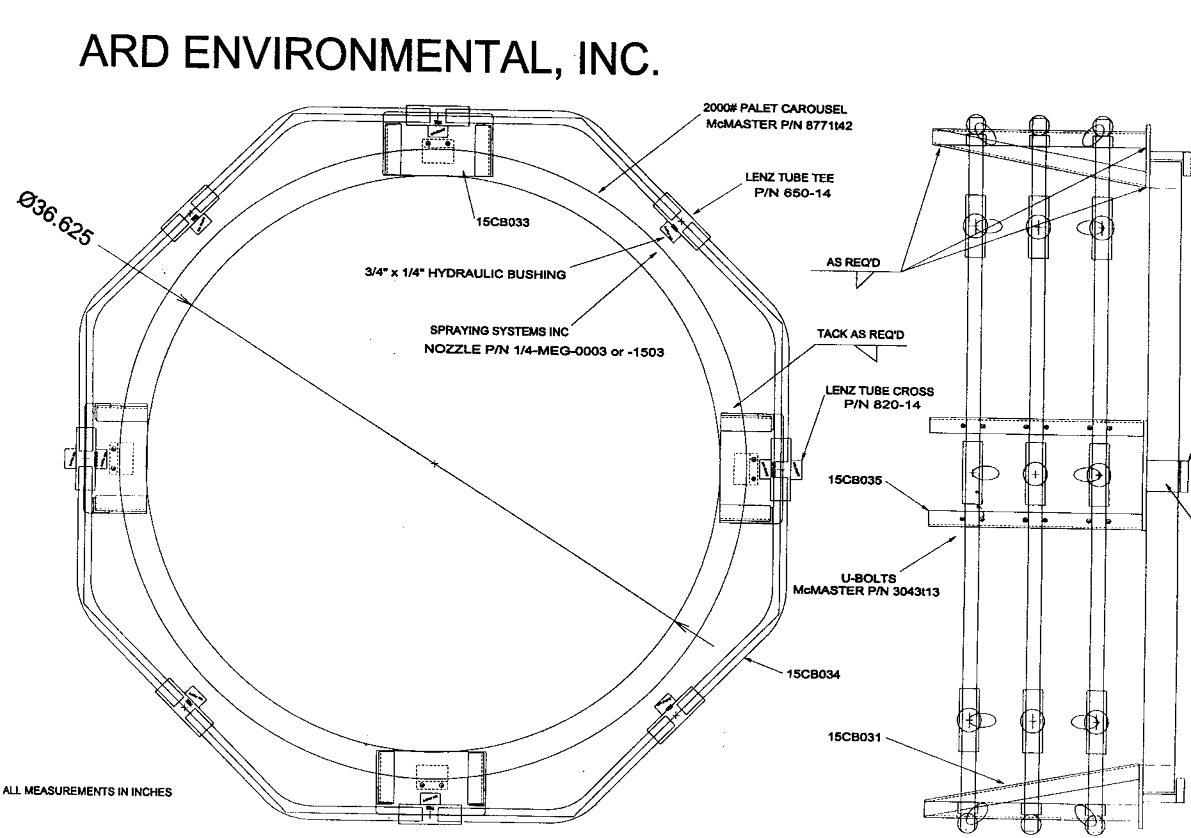


FIGURE 2.2-8: DECONTAMINATION SPRAY RING ASSEMBLY

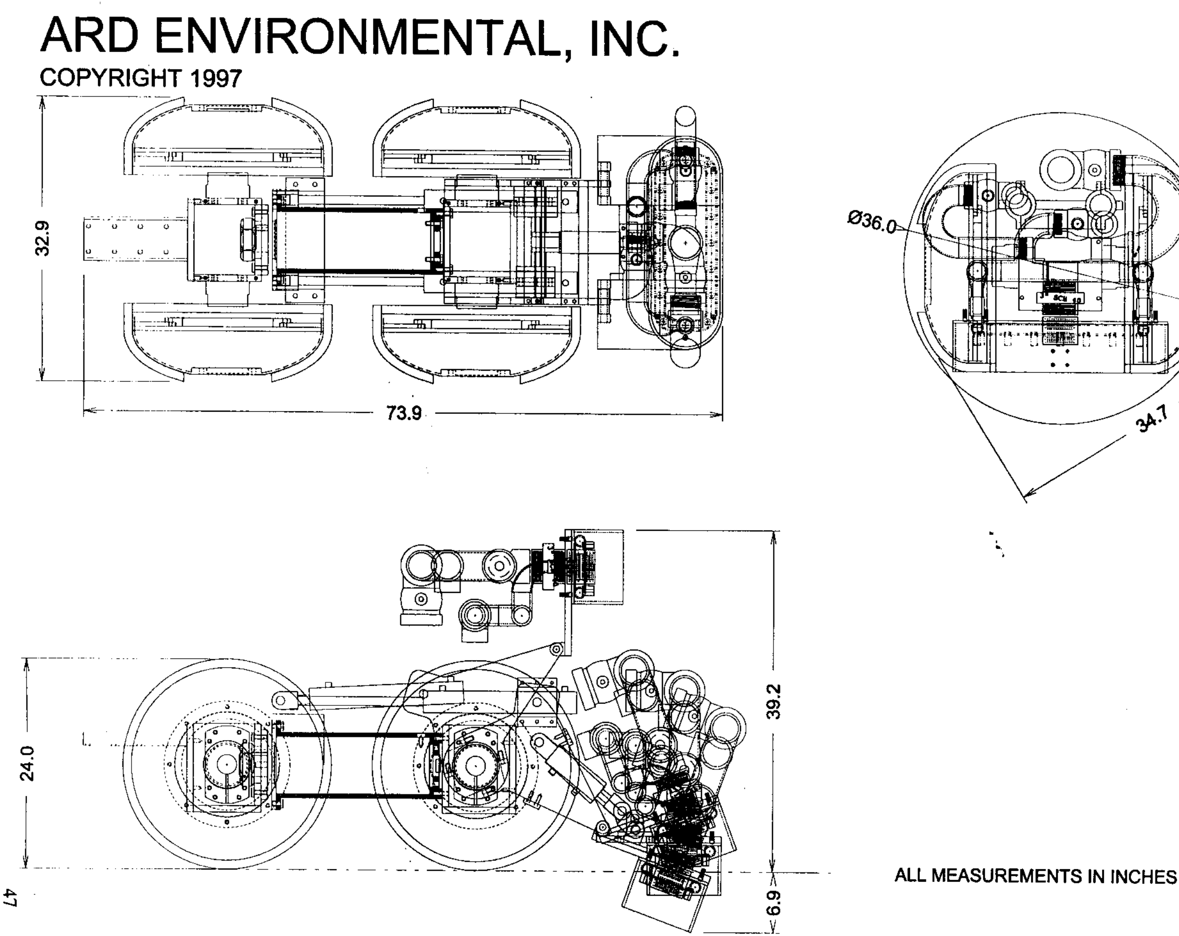


FIGURE 2.2-9: VEHICLE AND SLUICER ASSEMBLY

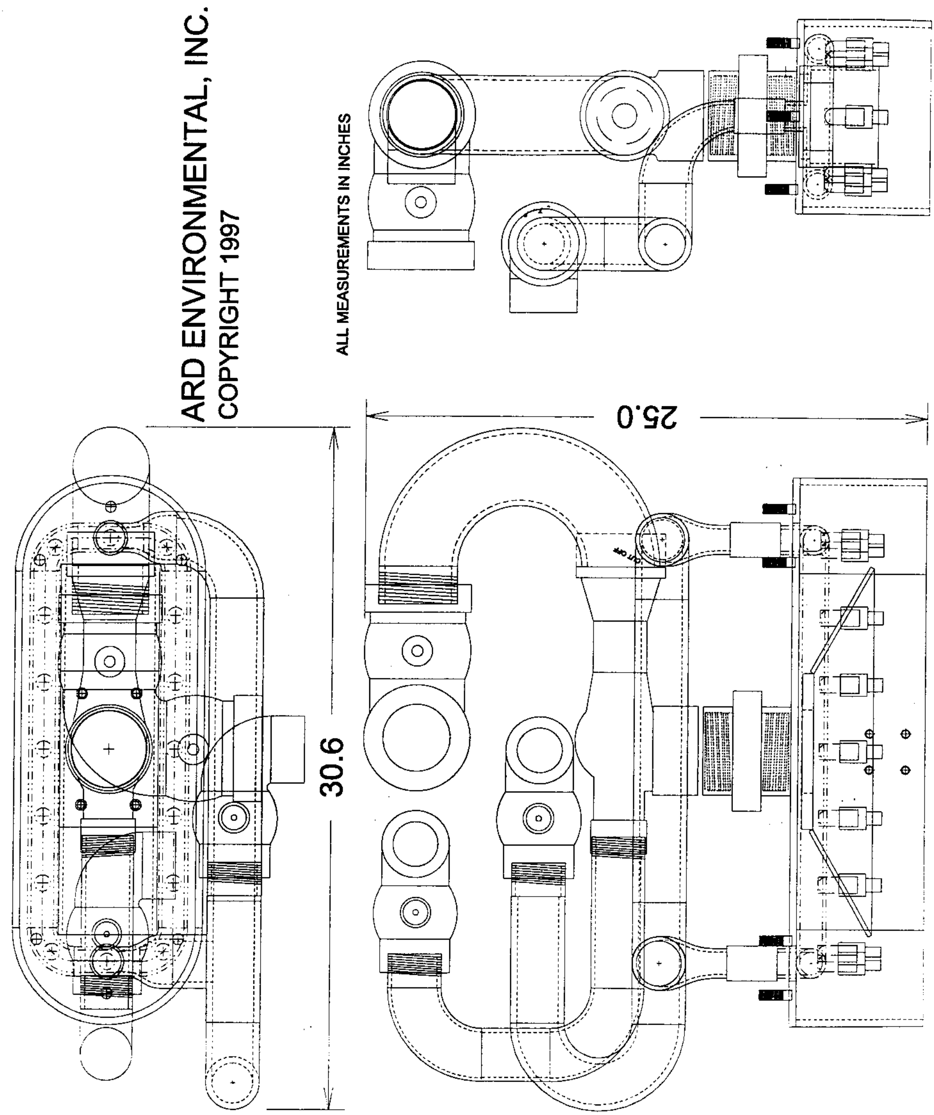


FIGURE 2.2-10: CONFINED SLUICER AND EDUCTOR ASSEMBLY

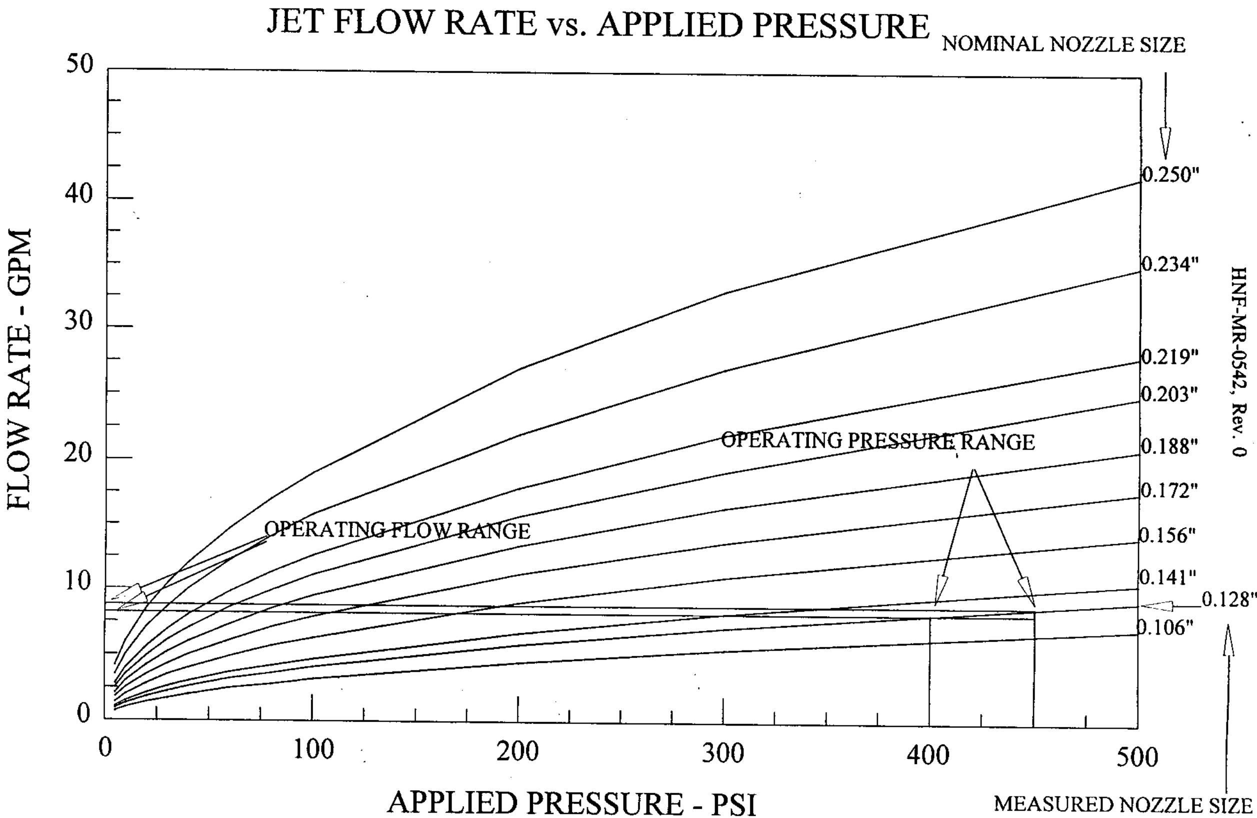


FIGURE 2.2-11: SLUICER JET CHARACTERISTICS
(BASED ON MANUFACTURER'S DATA)

ARD ENVIRONMENTAL, INC.
9115 WHISKEY BOTTOM ROAD
LAUREL, MD 20723

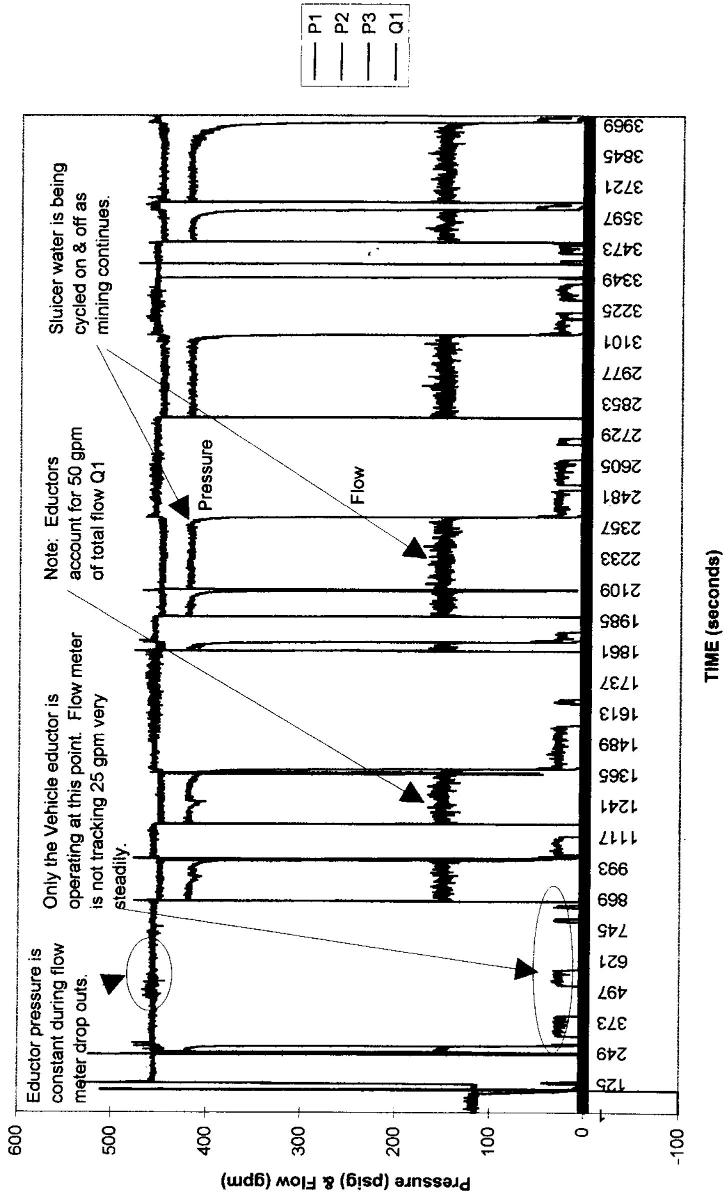


Figure 2.3-1 : Sluicer and Sluicer Eductor

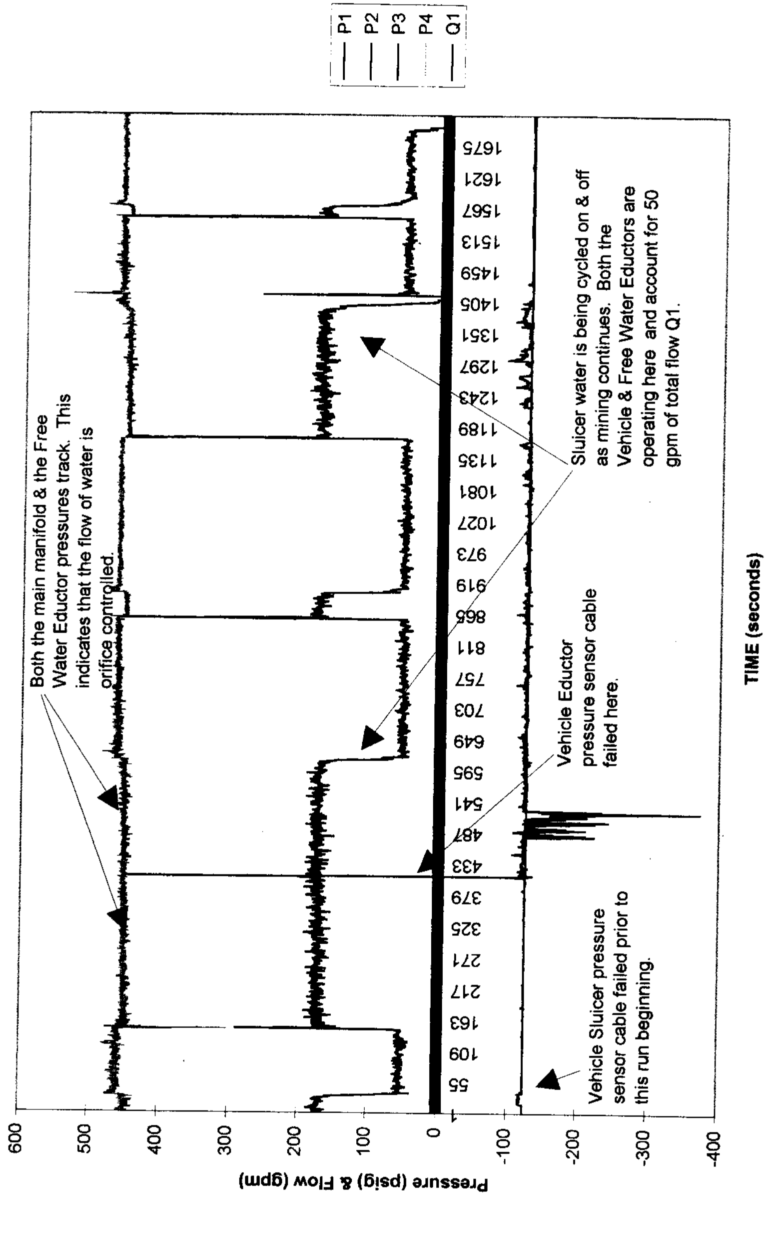


Figure 2.3-2 : Sluicer Eductor and Free Water Eductor

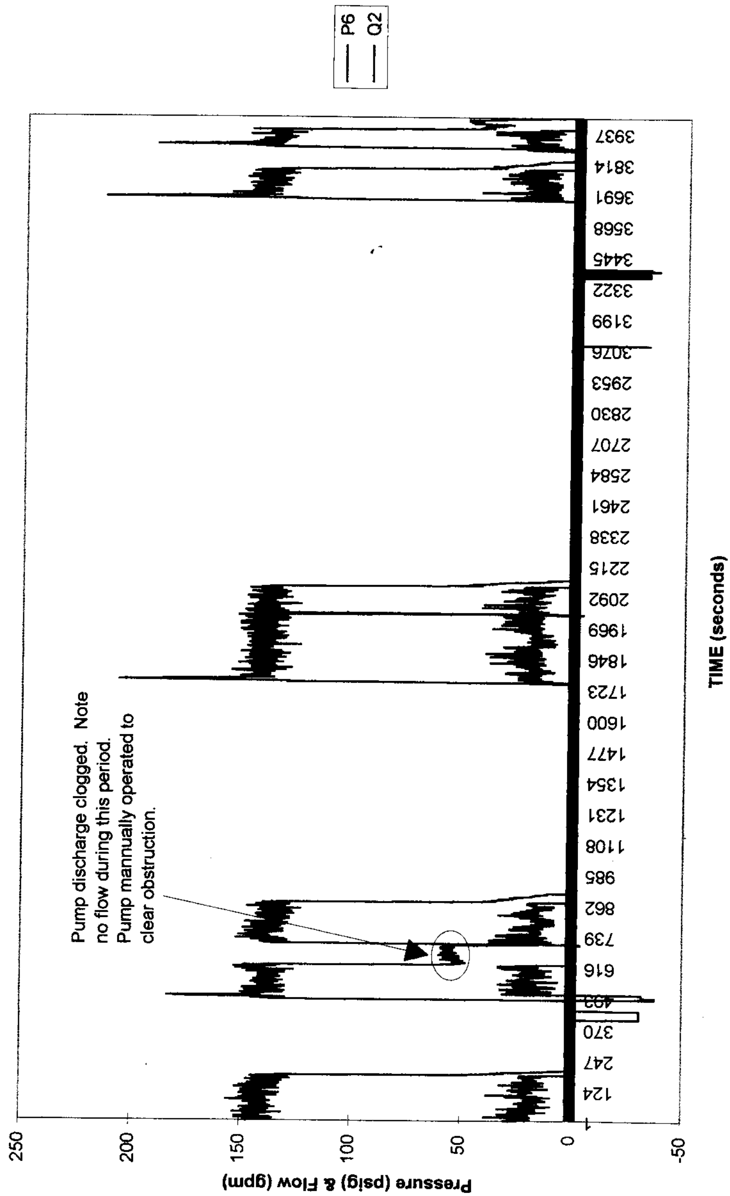


Figure 2.3-3 : Vehicle Water Scavaging Module Discharge

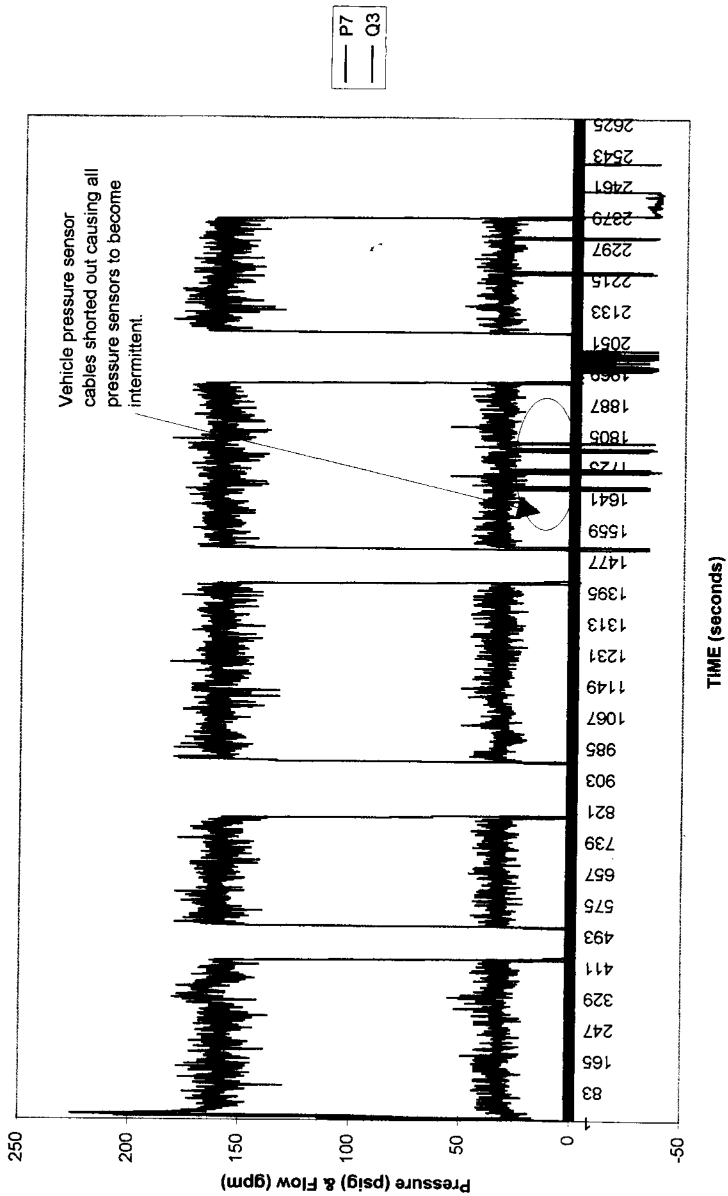


Figure 2.3-4 : Free Water Scavaging Module Discharge

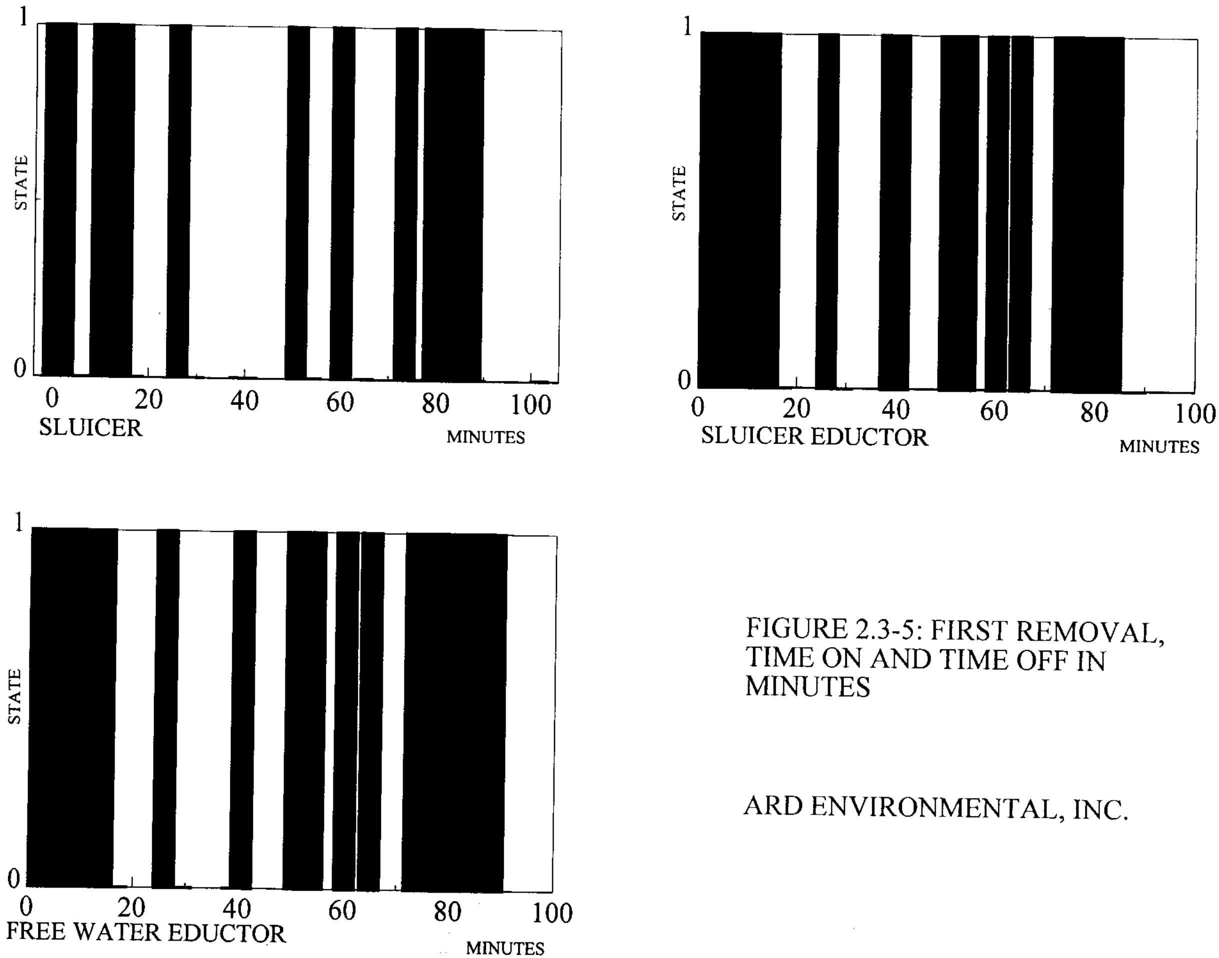
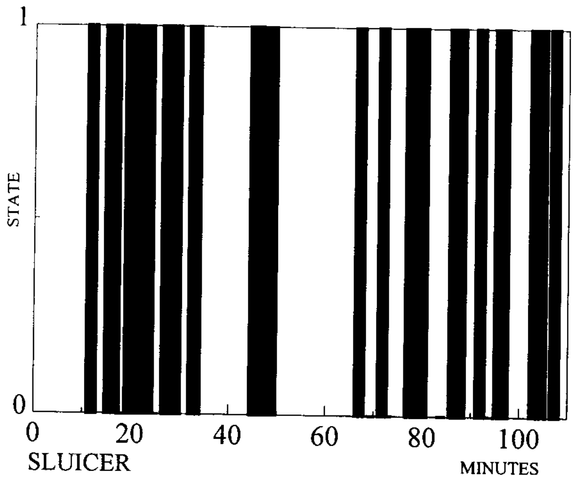
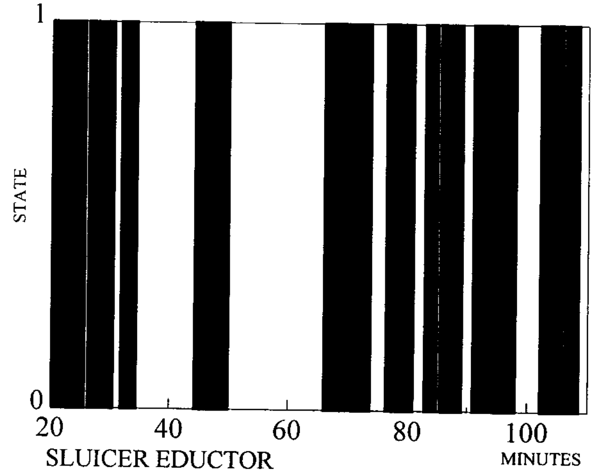


FIGURE 2.3-5: FIRST REMOVAL, TIME ON AND TIME OFF IN MINUTES

ARD ENVIRONMENTAL, INC.





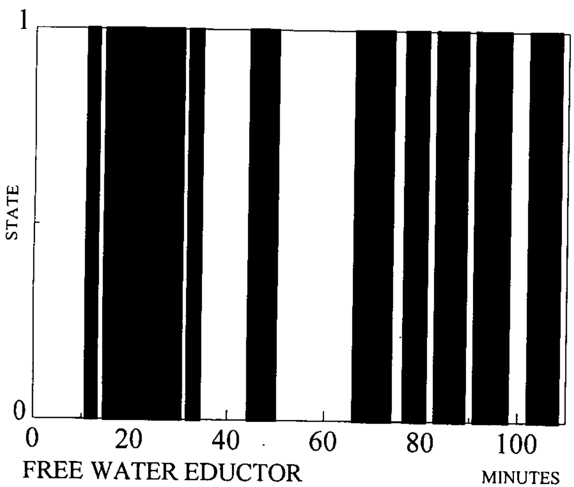


FIGURE 2.3-6: SECOND REMOVAL, TIME ON AND TIME OFF IN MINUTES

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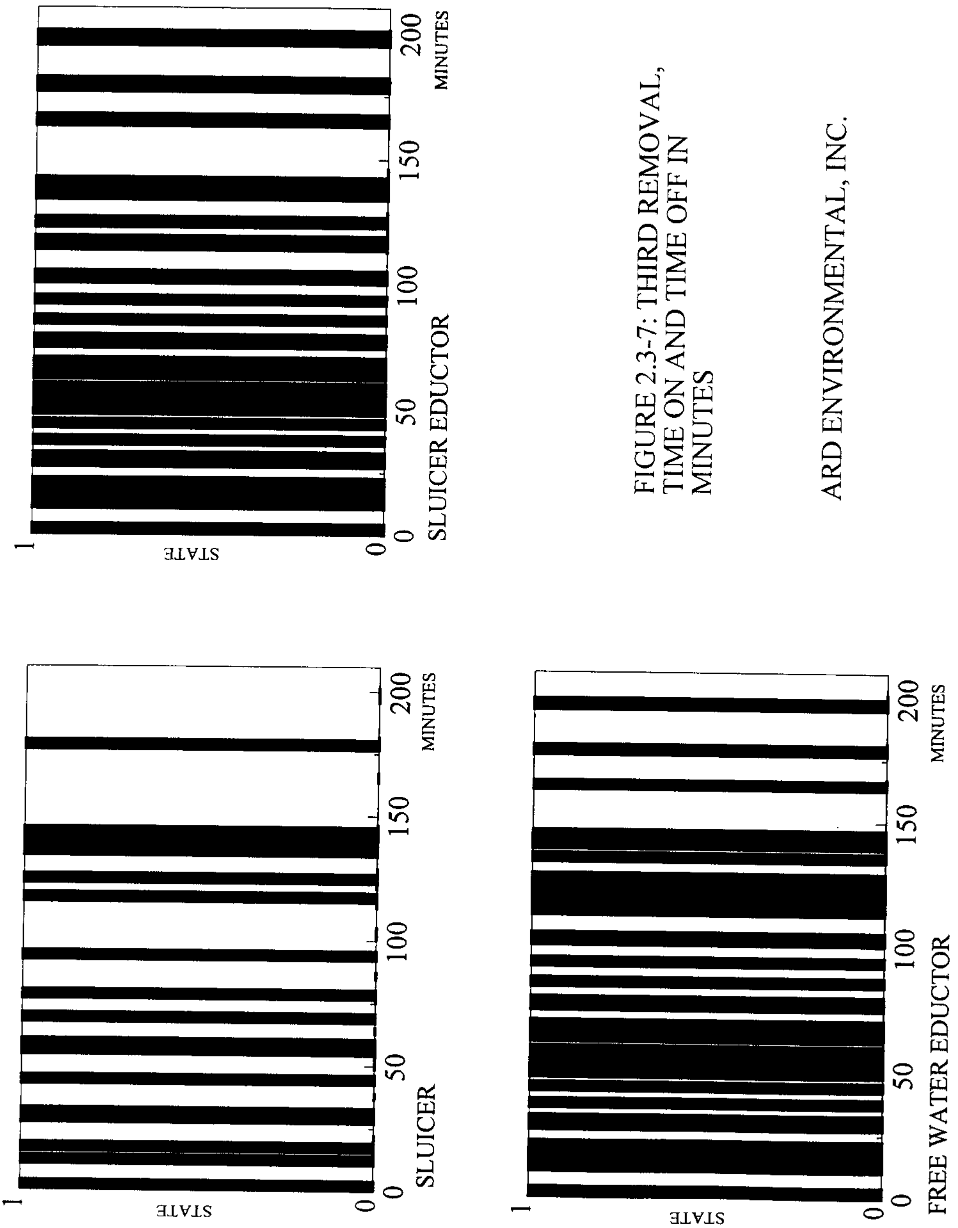

FIGURE 2.3-7: THIRD REMOVAL, TIME ON AND TIME OFF IN MINUTES

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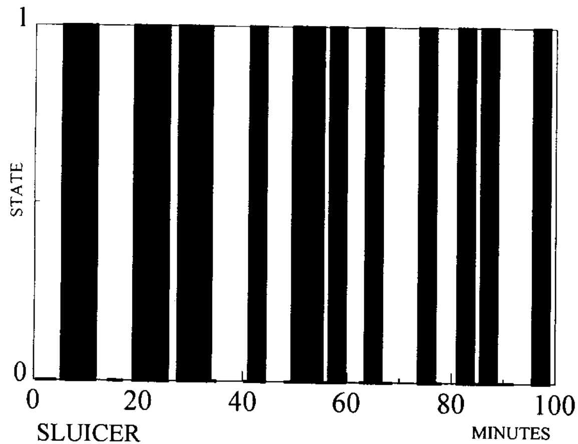

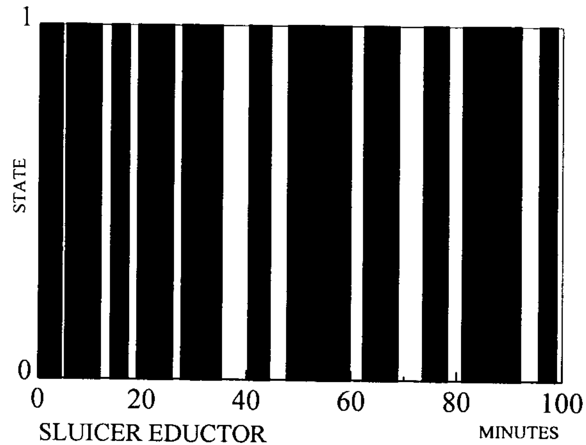

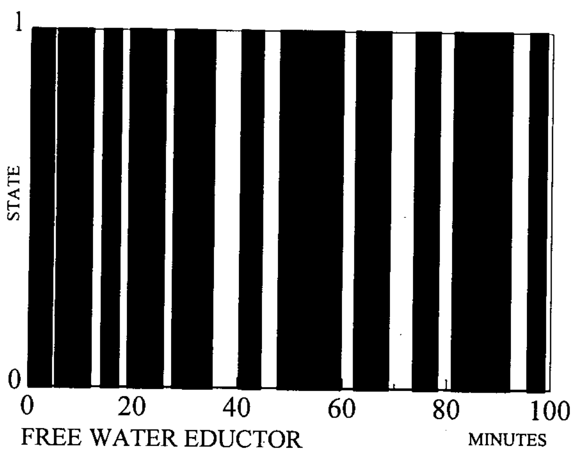

FIGURE 2.3-8: FOURTH REMOVAL, TIME ON AND TIME OFF IN MINUTES

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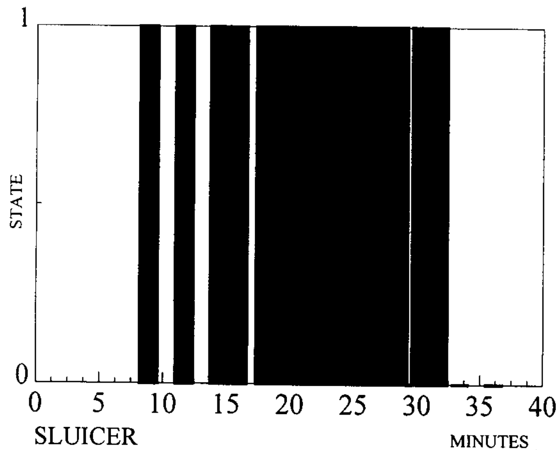

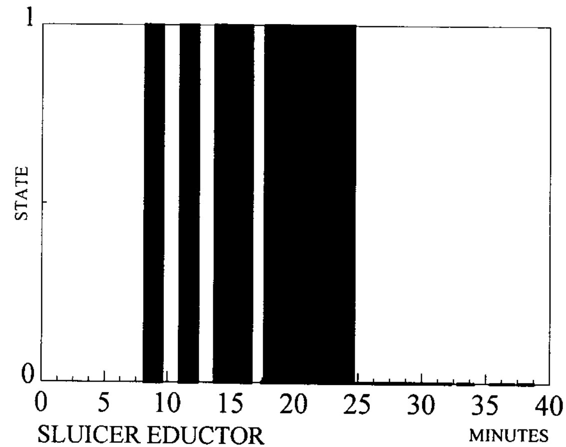

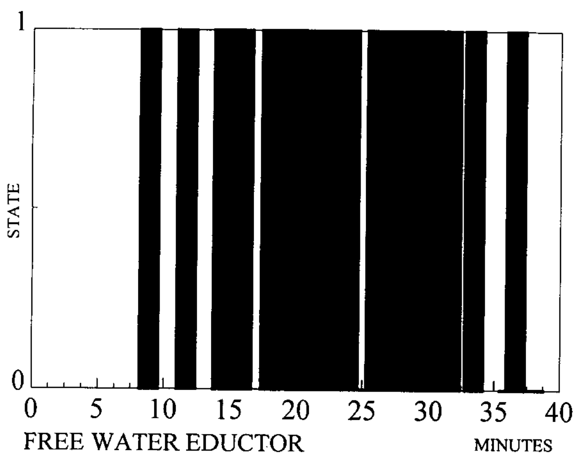

FIGURE 2.3-9: FIFTH REMOVAL, TIME ON AND TIME OFF IN MINUTES

ARD ENVIRONMENTAL, INC.

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CONTOURS AND DIMENSIONS IN INCHES

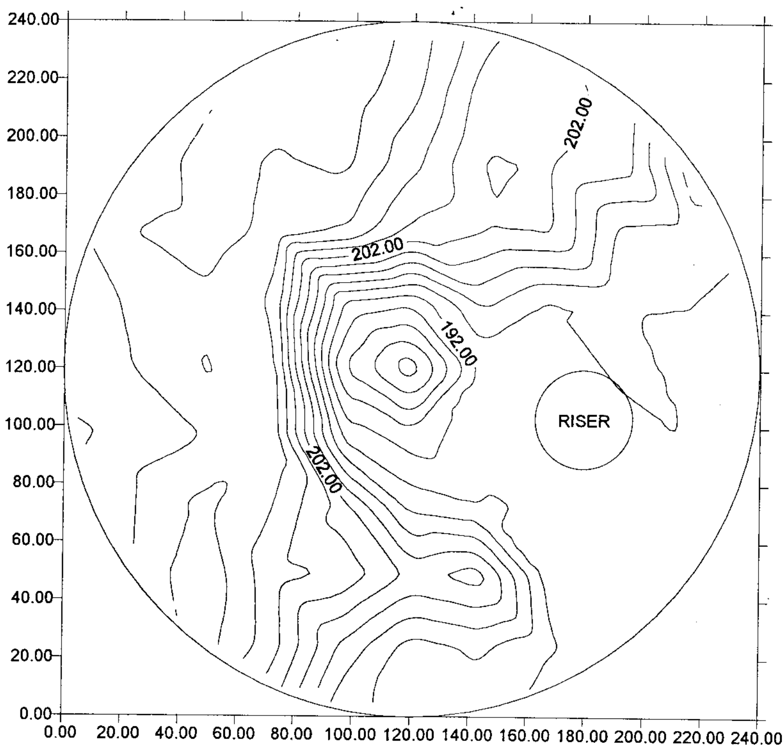


FIGURE 2.3-10: INITIAL WASTE SURFACE

ARD ENVIRONMENTAL, INC.

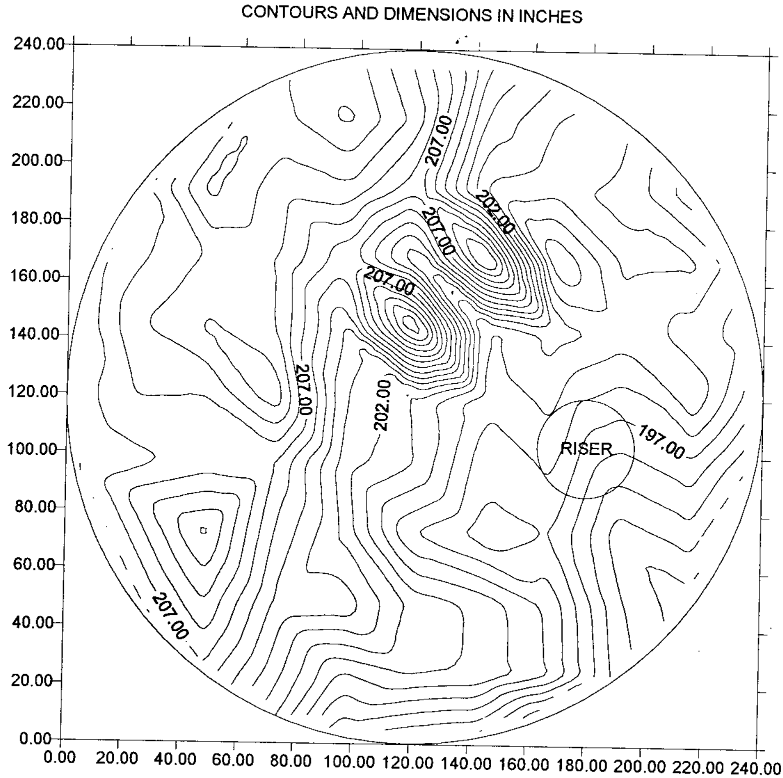


FIGURE 2.3-11 : WASTE SURFACE AFTER FIRST REMOVAL

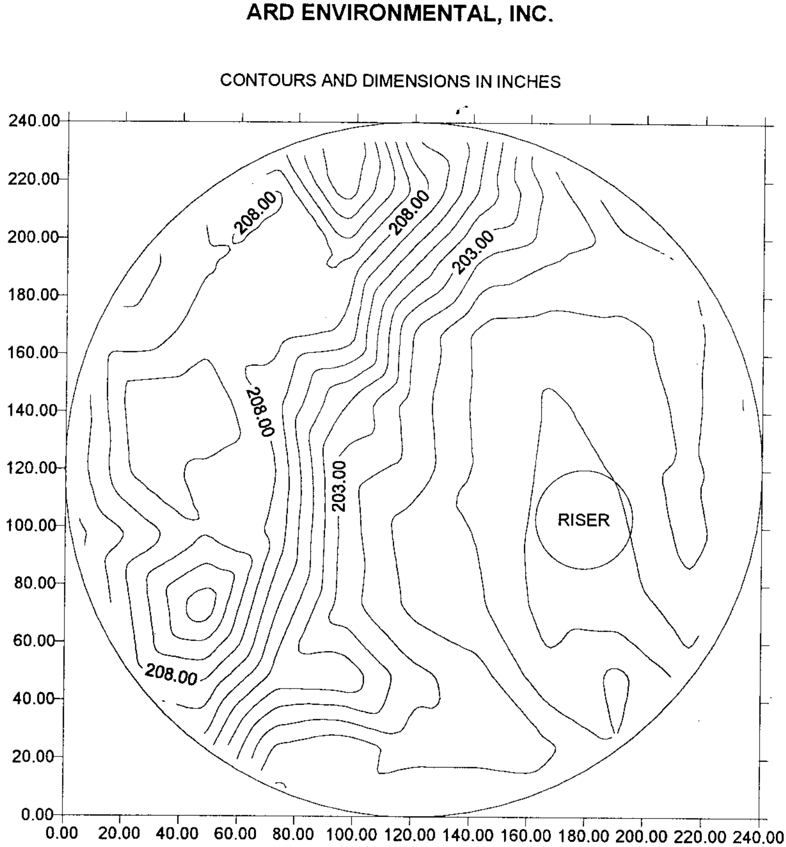


FIGURE 2.3-12: WASTE SURFACE AFTER SECOND REMOVAL

ARD ENVIRONMENTAL, INC.

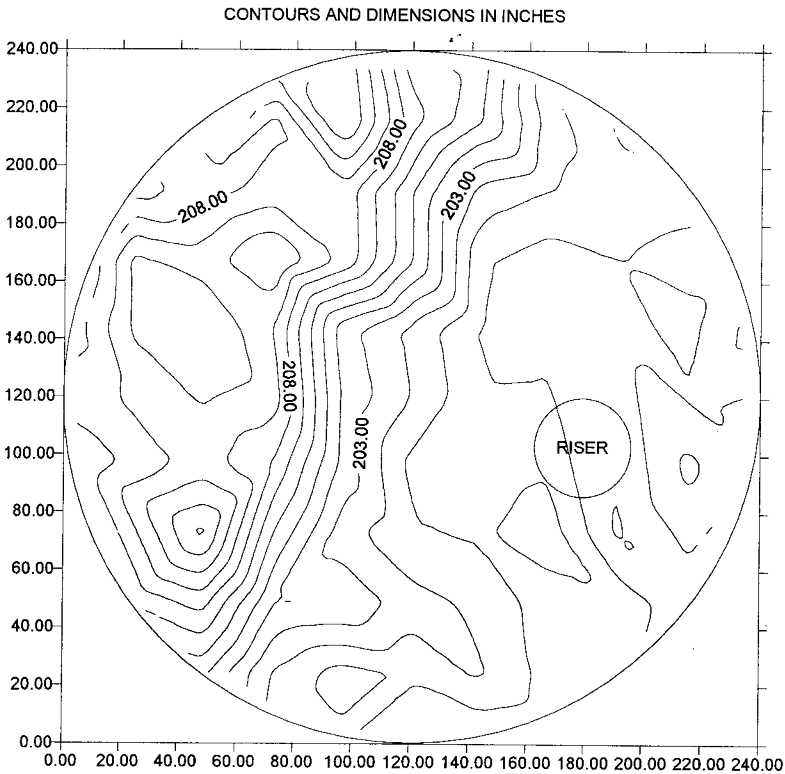


FIGURE 2.3-13: WASTE SURFACE AFTER THIRD REMOVAL

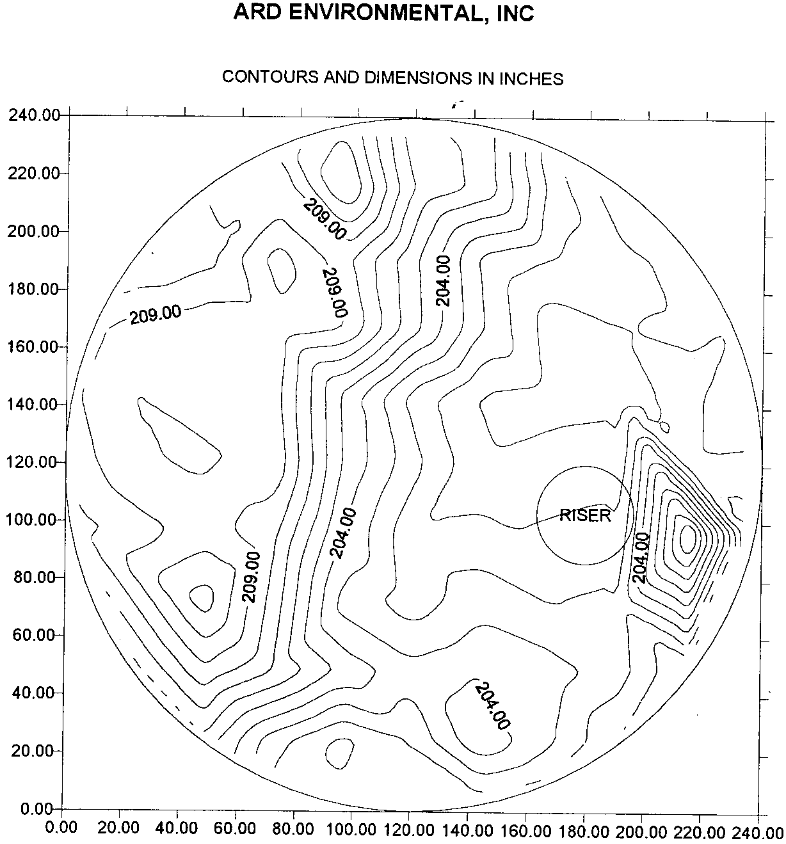


FIGURE 2.3-14: WASTE SURFACE AFTER FOURTH REMOVAL

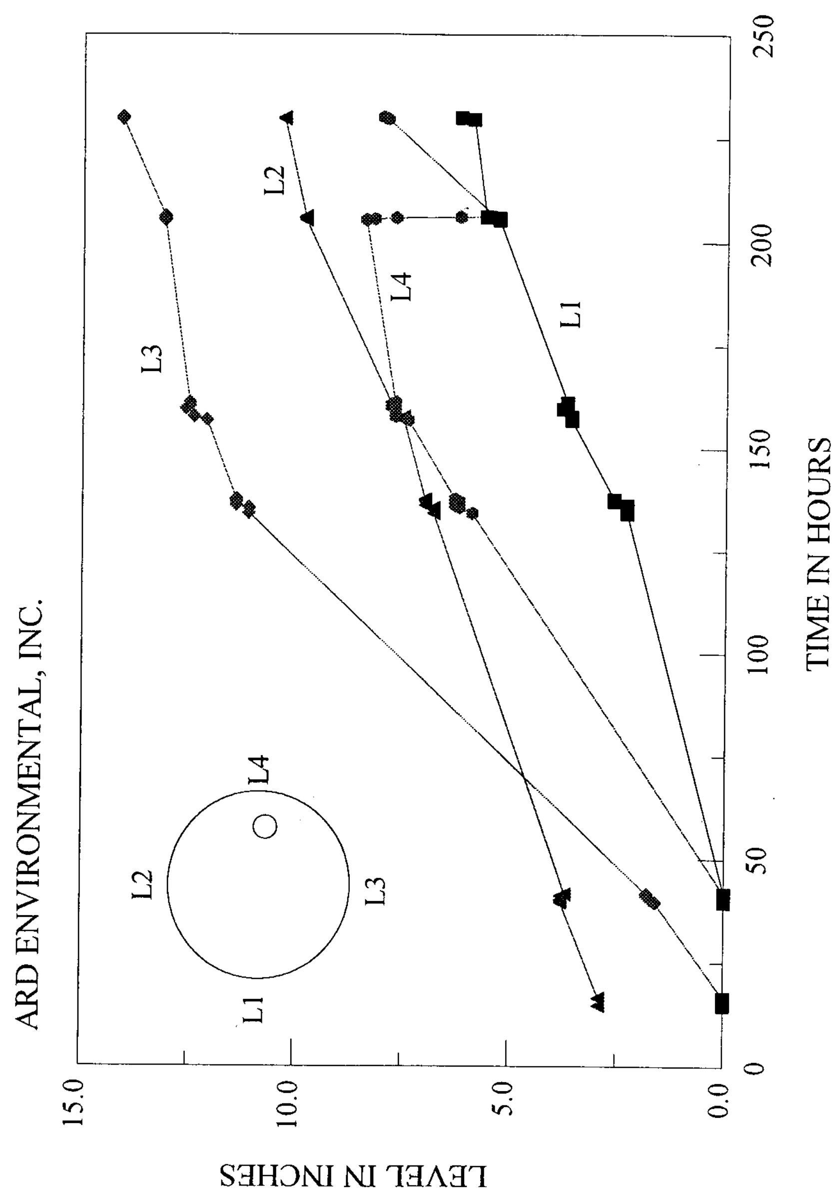


FIGURE 2.3-15: STANDING WATER LEVELS

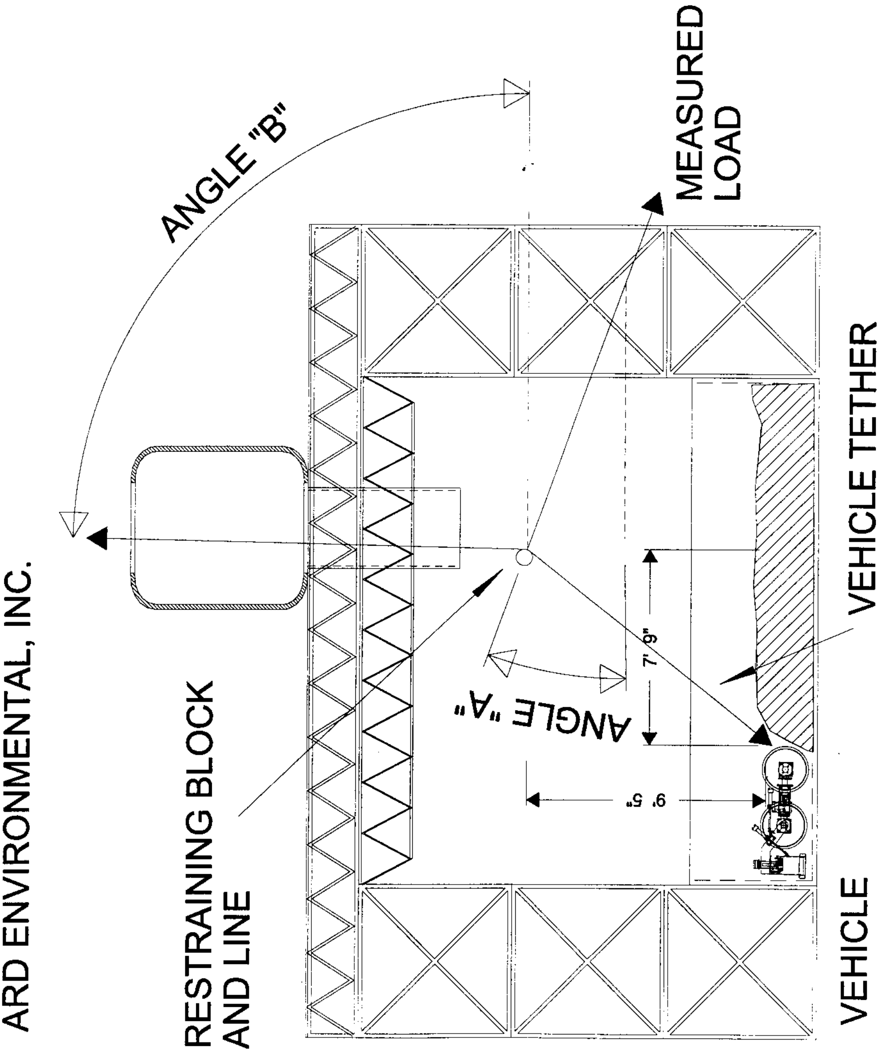


FIGURE 2.3-16: RETRIEVAL TEST GEOMETRY

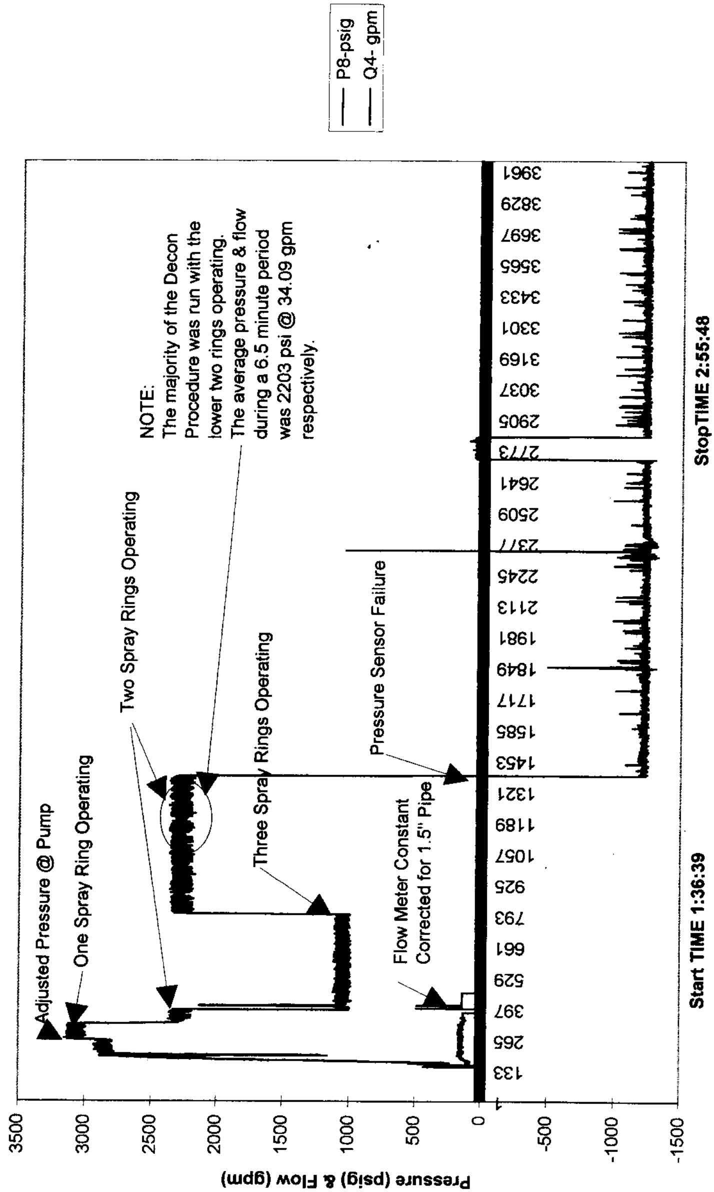


Figure 2.3-17 : Decon Pressure and Flow

Appendix 6.2 Photographs

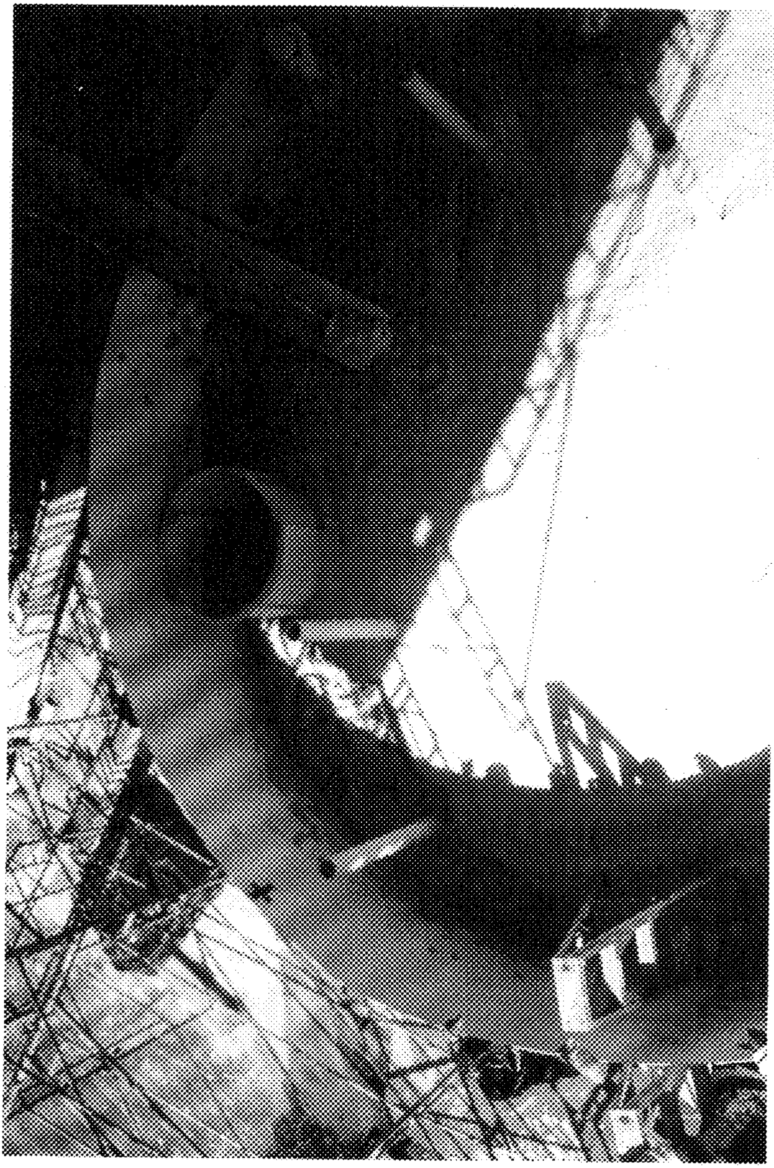


PHOTO 1: TANK MOCKUP DURING SIMULANT POURS

ARD ENVIRONMENTAL, INC.

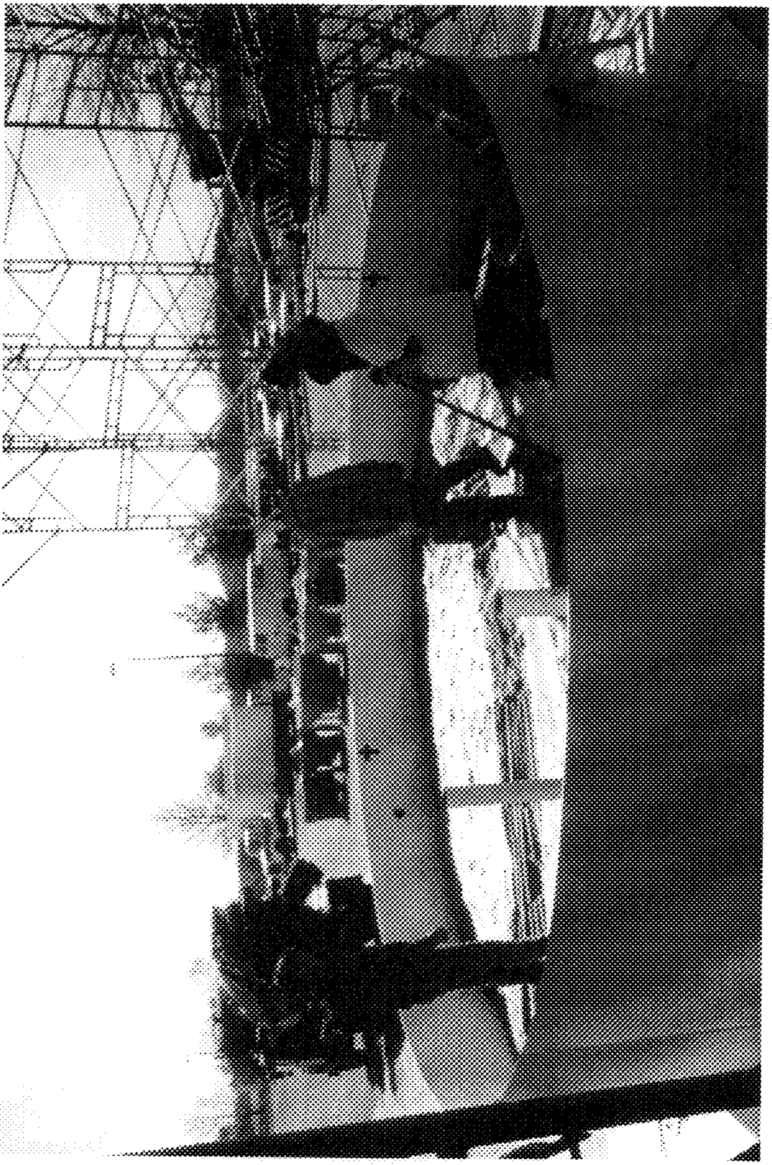


PHOTO 2: TANK MOCKUP DURING SIMULANT POURS

ARD ENVIRONMENTAL, INC.

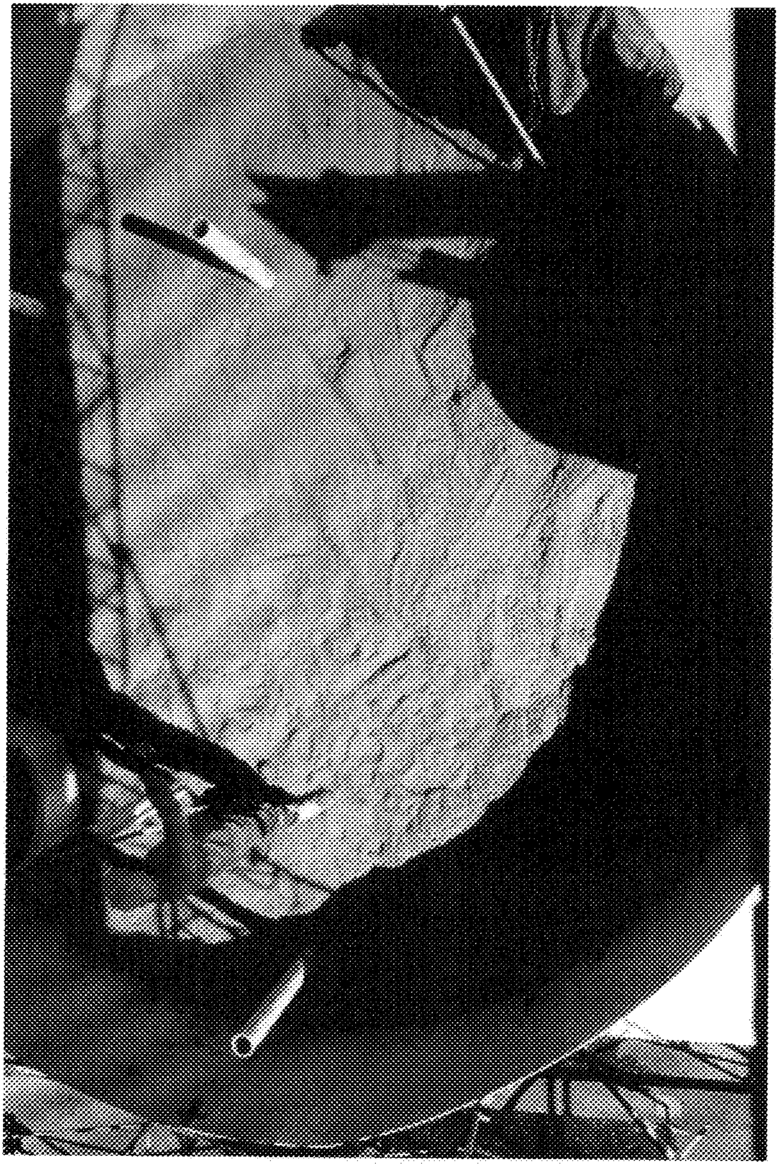


PHOTO 3: TANK MOCKUP DURING SIMULANT POURS

ARD ENVIROMENTAL, INC.

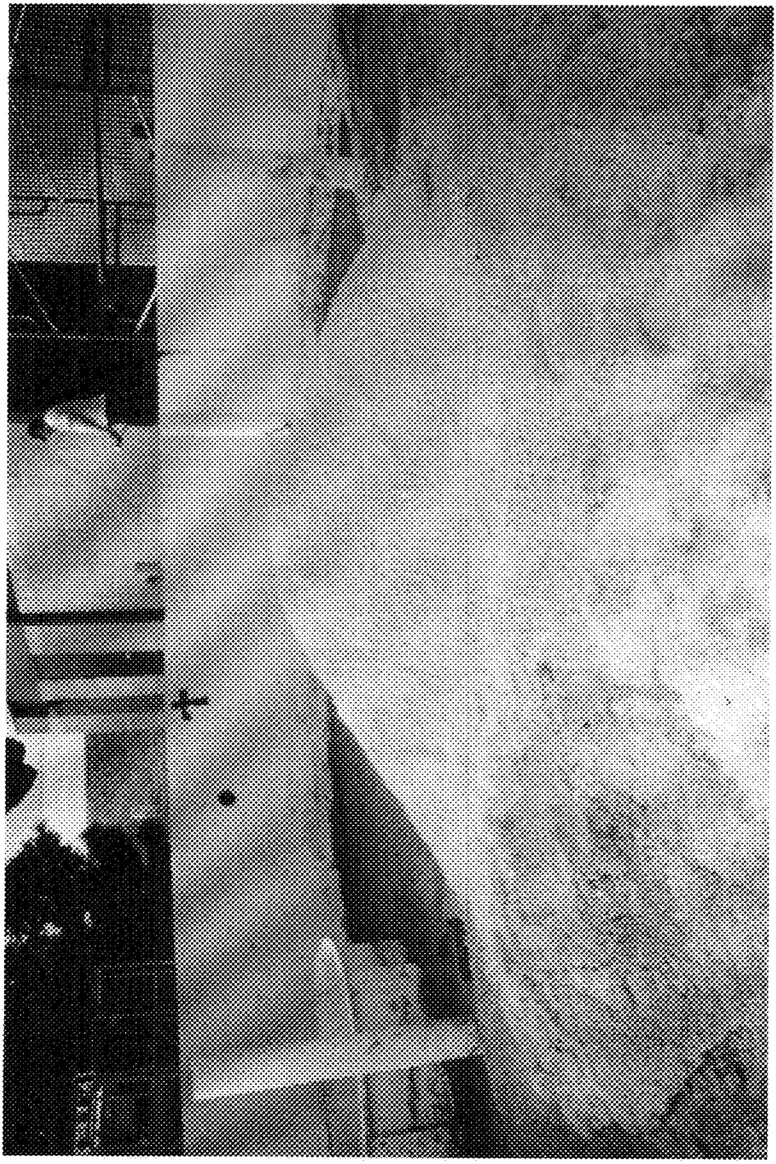


PHOTO 4: TANK MOCKUP DURING SIMULANT POURS, SHOWING FINAL POUR

ARD ENVIRONMENTAL, INC.

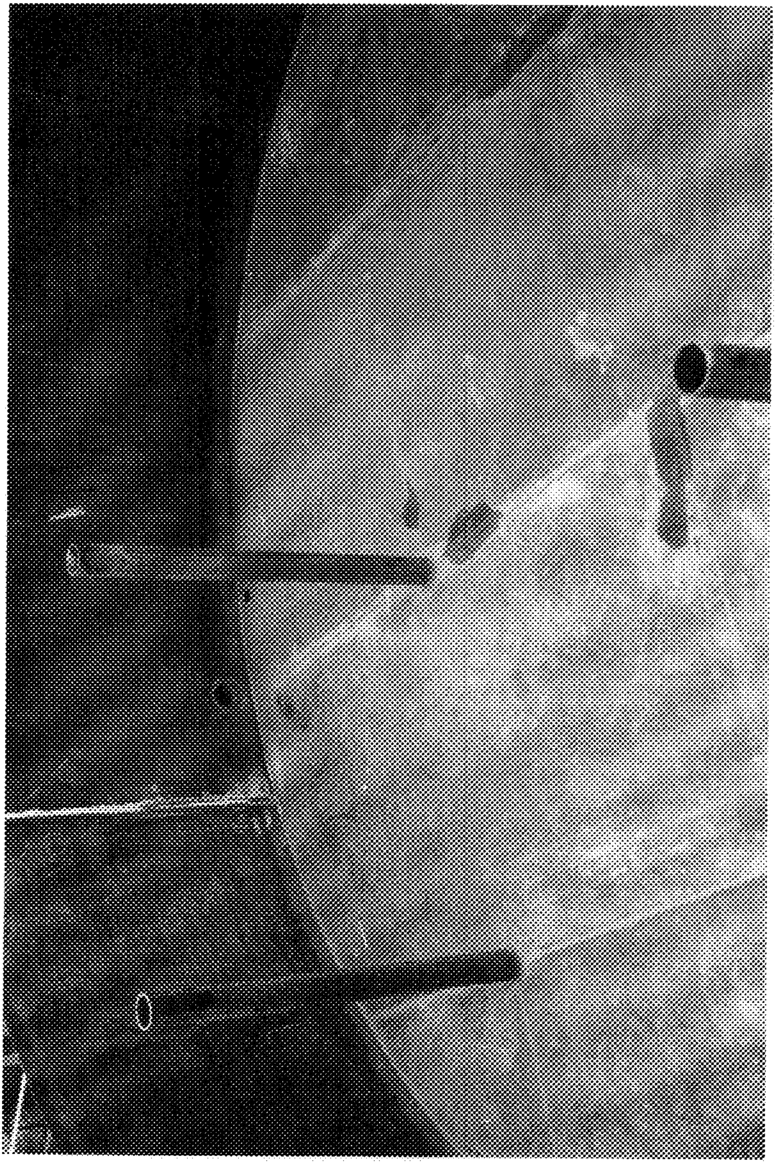


PHOTO 5: TANK MOCKUP DURING FABRICATION

ARD ENVIRONMENTAL, INC.

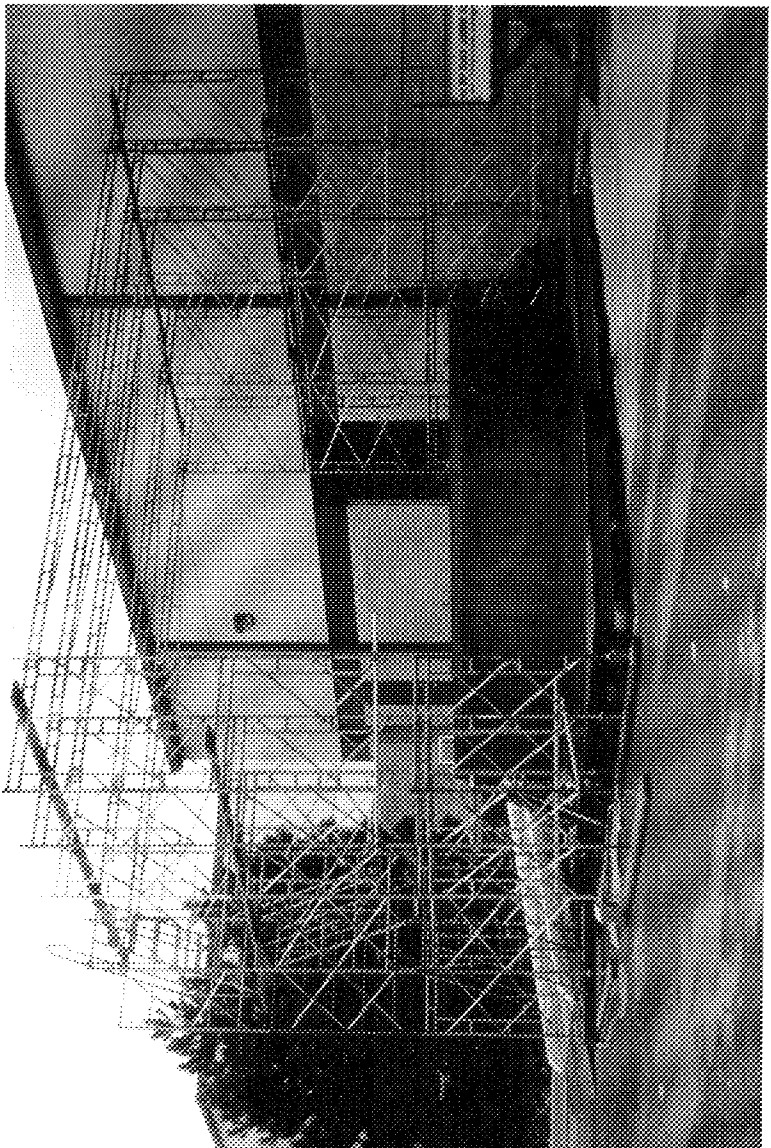


PHOTO 6. TANK MOCKUP DURING ERECTION OF THE SCAFFOLDING

ARD ENVIRONMENTAL, INC.

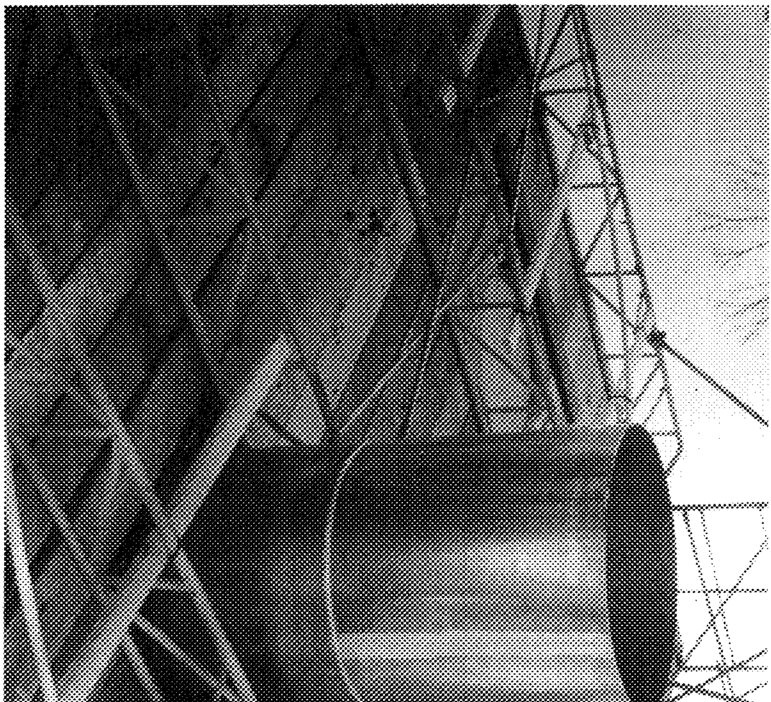


PHOTO 7: TANK MOCKUP SHOWING
36" x 6' RISER INSTALLED

ARD ENVIRONMENTAL, INC.

PHOTO 8: DECONTAMINATION CHAMBER DURING INSTALLATION ON TANK MOCKUP

ARD ENVIRONMENTAL, INC.

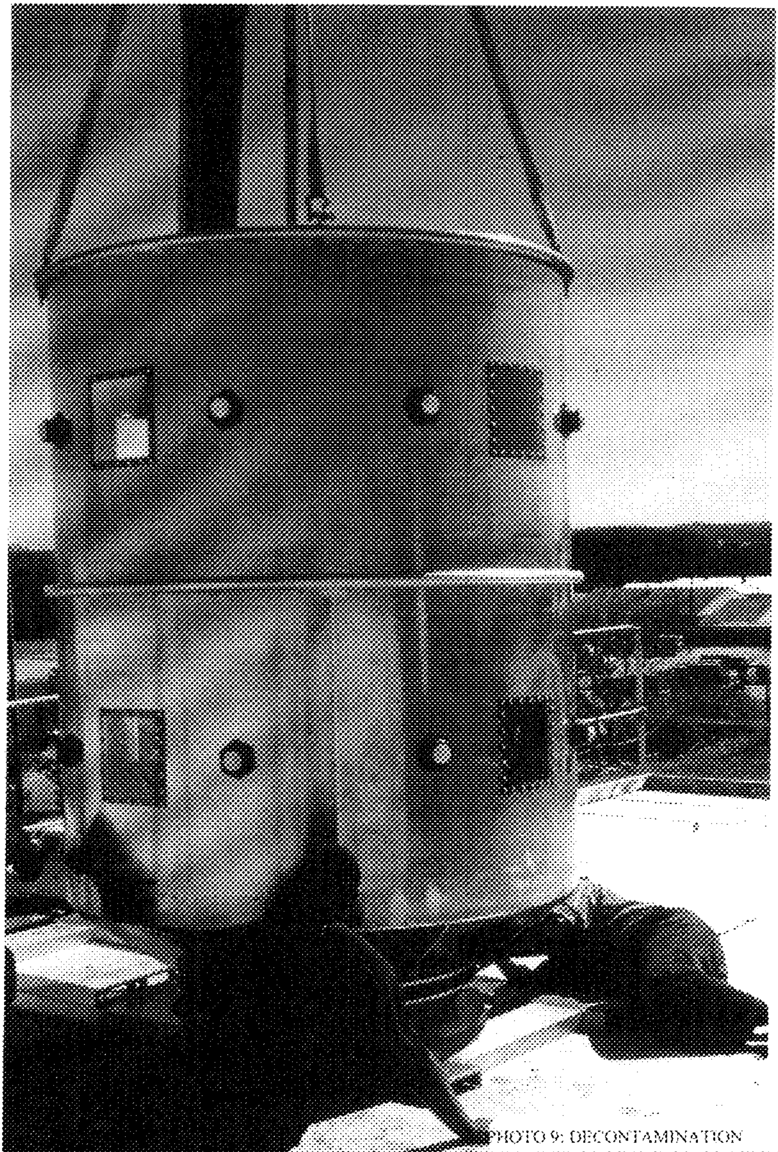


PHOTO 9: DECONTAMINATION CHAMBER DURING INSTALLATION ON TANK MOCKUP

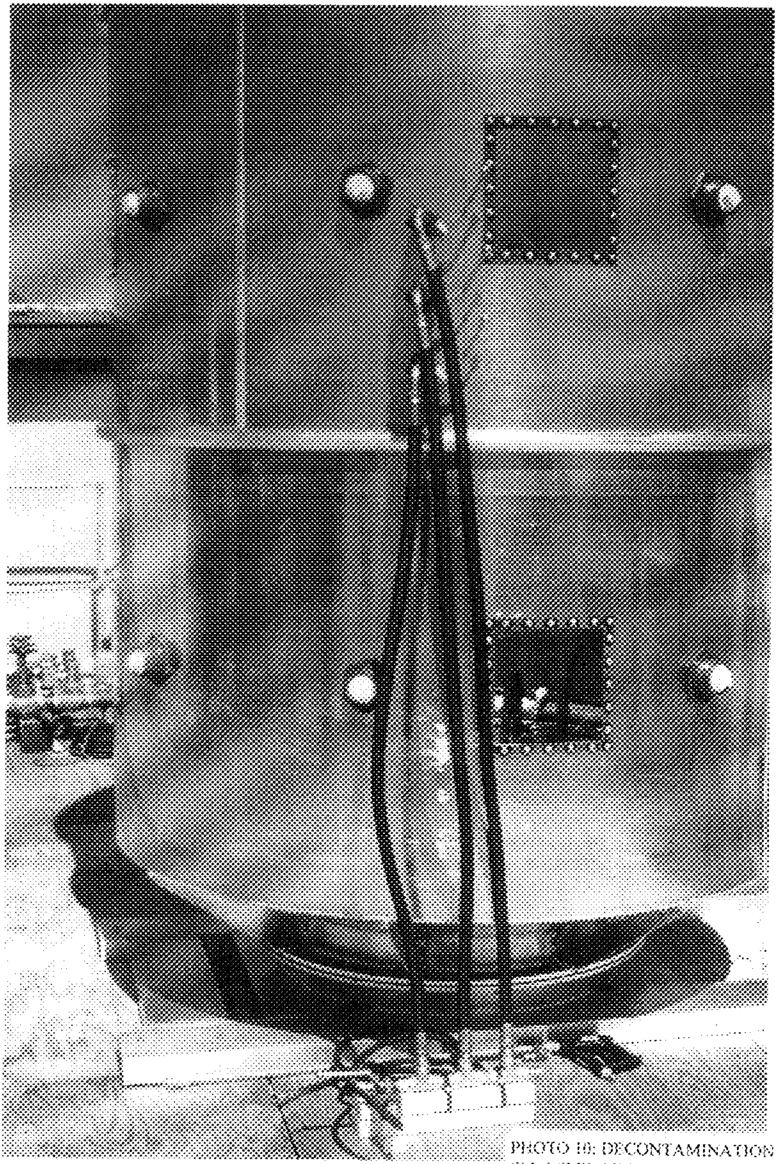


PHOTO 10: DECONTAMINATION CHAMBER SHOWING VIEWPORTS AND SPRAY CONTROL VALVES

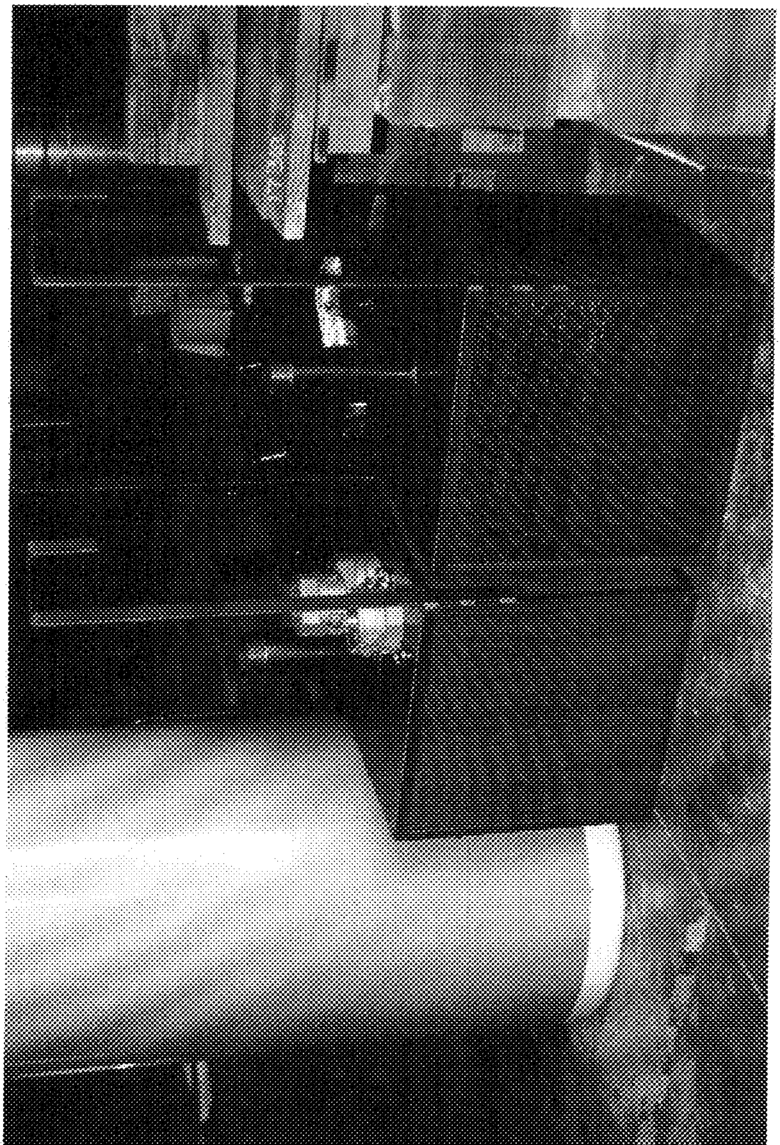


PHOTO 11: STRAINER BOXES FOR WATER RECYCLING

ARD ENVIRONMENTAL, INC.

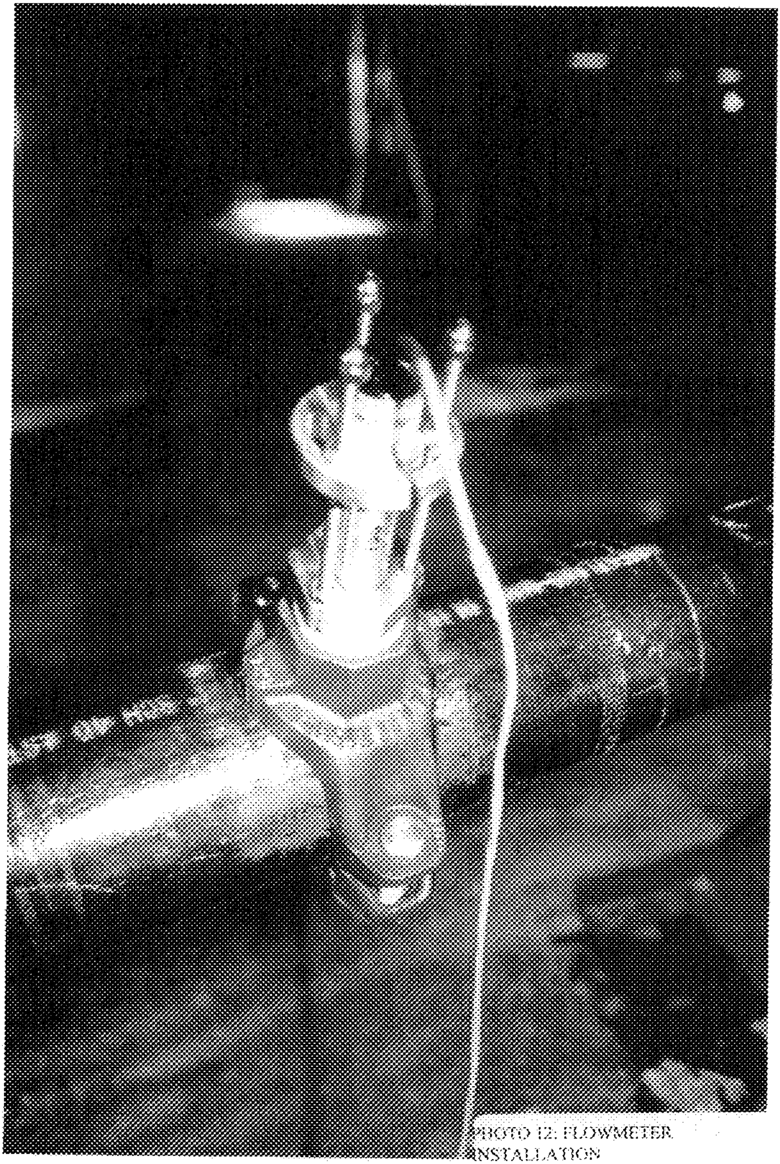


PHOTO 12: FLOWMETER INSTALLATION

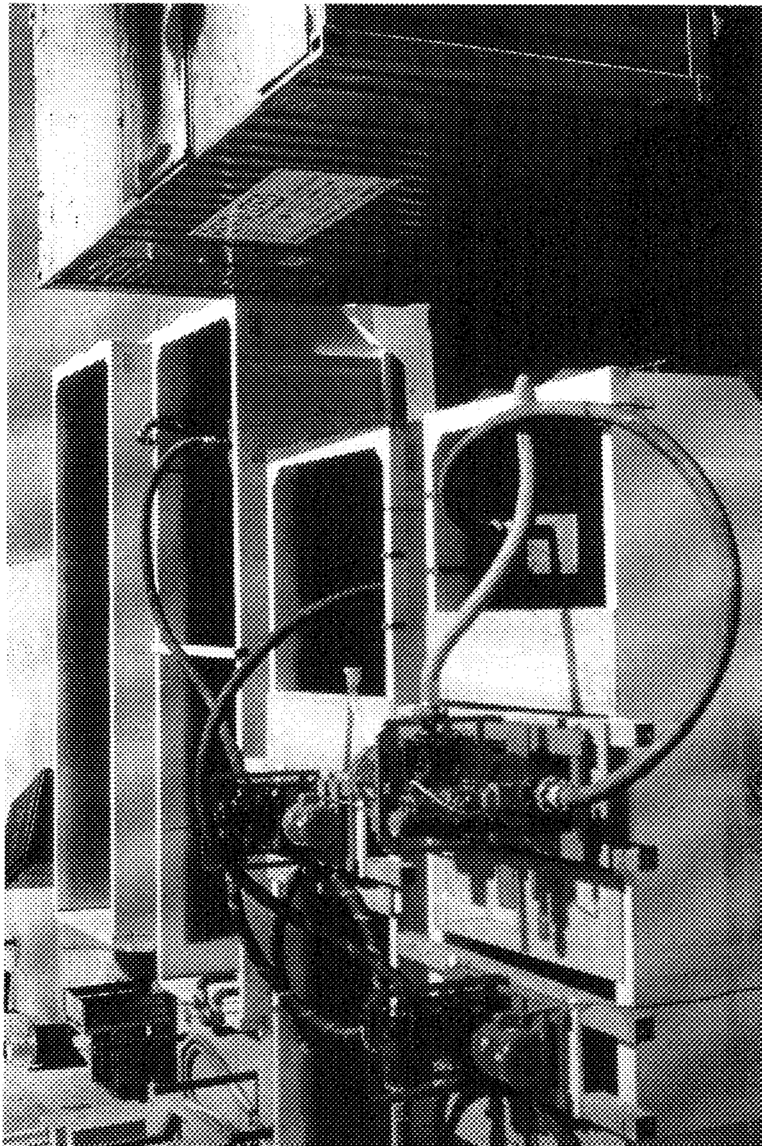


PHOTO 13: SLUICING WATER SYSTEM SHOWING TRANSFER PUMPS AND WATER CONTAINERS

ARD ENVIRONMENTAL, INC.

PHOTO 14: 400 PSI SLUICING WATER SOLENOID CONTROL VALVES

ARD ENVIRONMENTAL, INC.

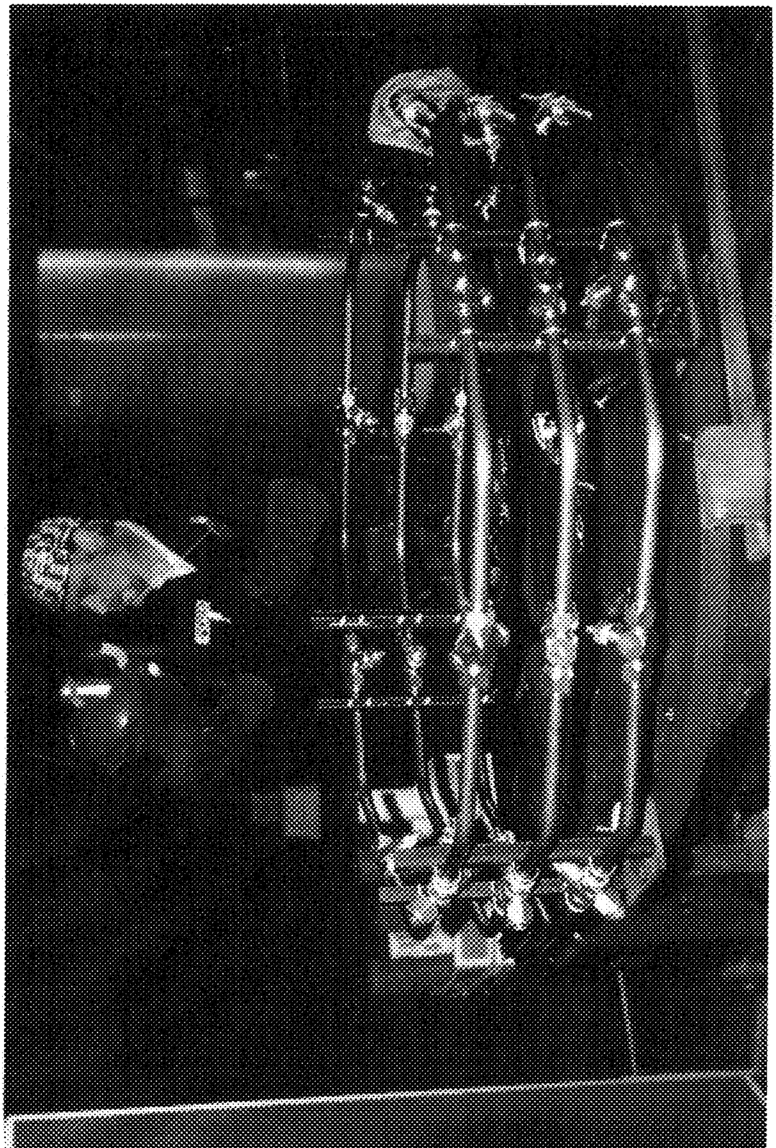


PHOTO 15: DECONTAMINATION SPRAY RING ASSEMBLY DURING FABRICATION

ARD ENVIRONMENTAL, INC.

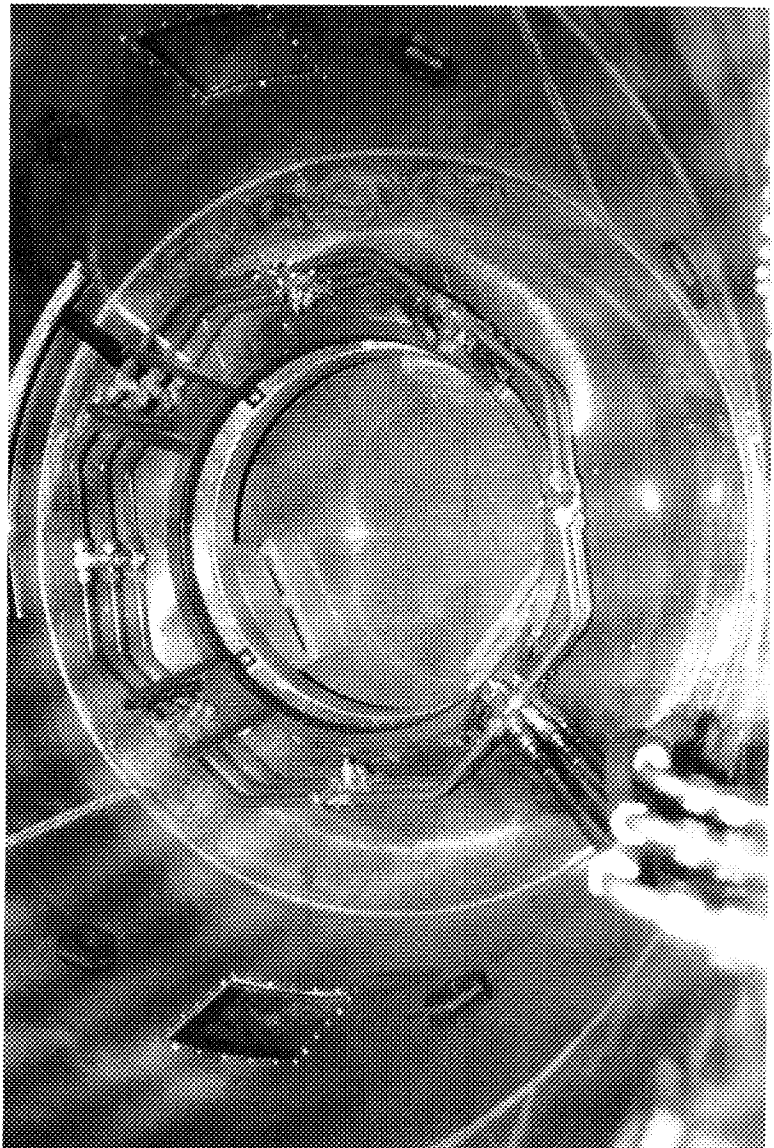


PHOTO 16 - DECONTAMINATION SPRAY RING INSTALLED IN DECONTAMINATION CHAMBER

ARD ENVIRONMENTAL, INC.

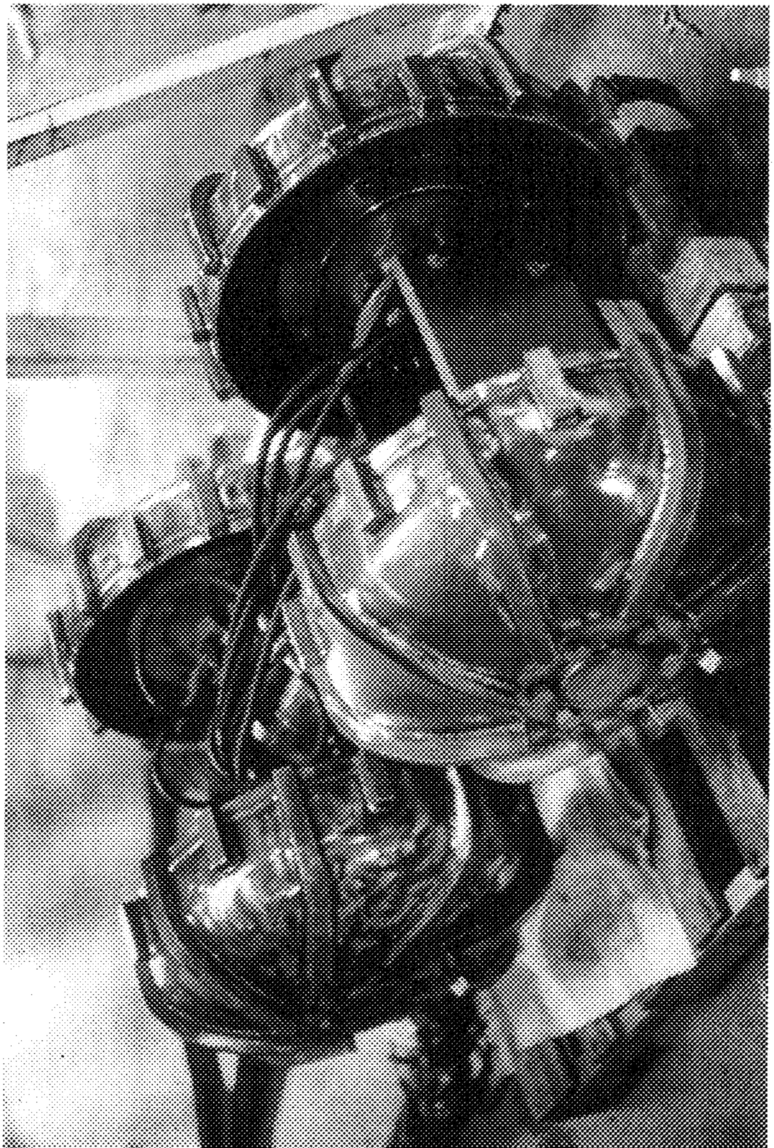


PHOTO 17: ARD VEHICLE DURING ASSEMBLY

ARD ENVIRONMENTAL, INC.

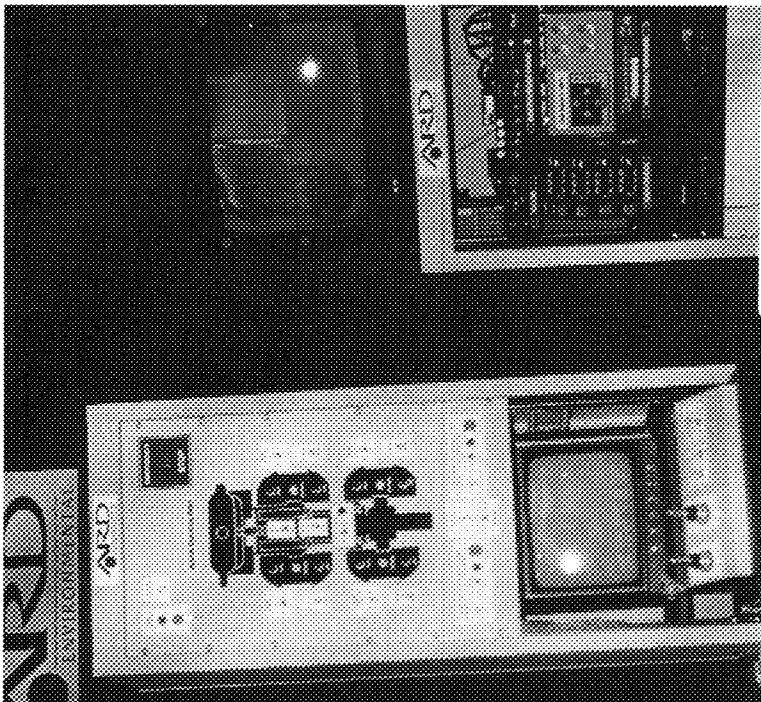


PHOTO 18: VEHICLE CONTROL STATION

ARD ENVIRONMENTAL, INC

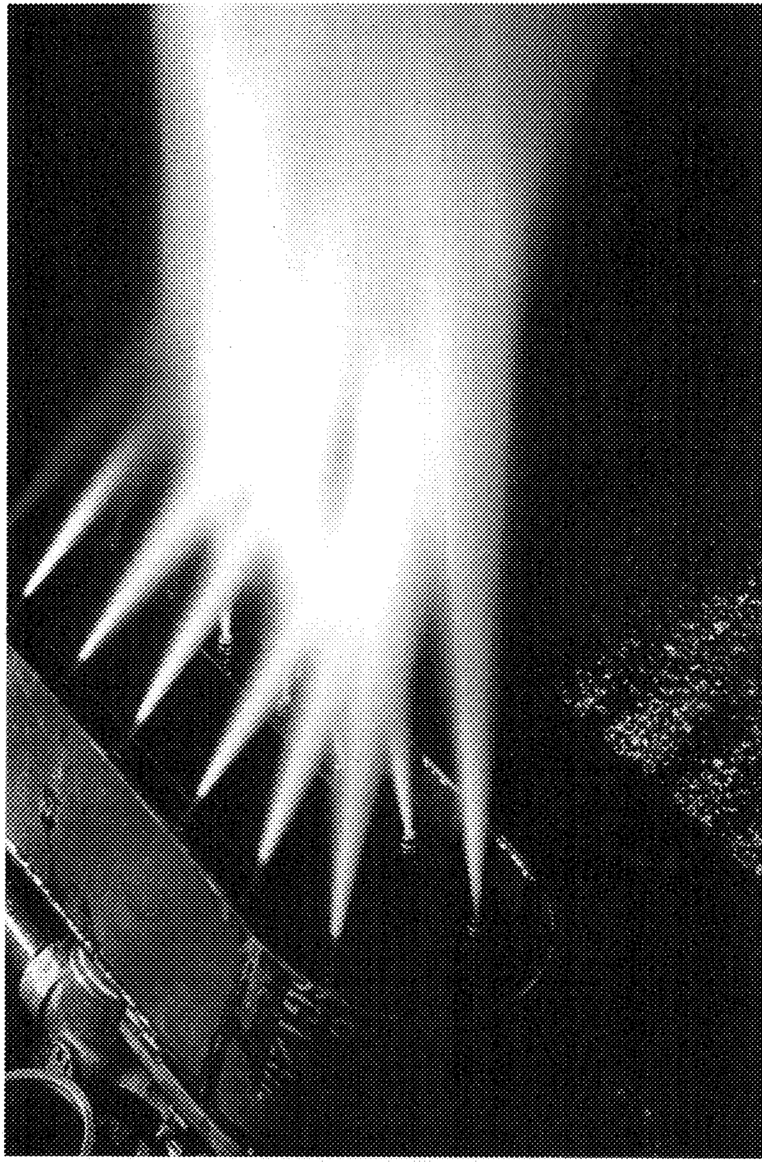


PHOTO 19: ARD SLUICING ASSEMBLY DURING TEST, SHOWING SPRAY PATTERN

ARD ENVIRONMENTAL, INC.

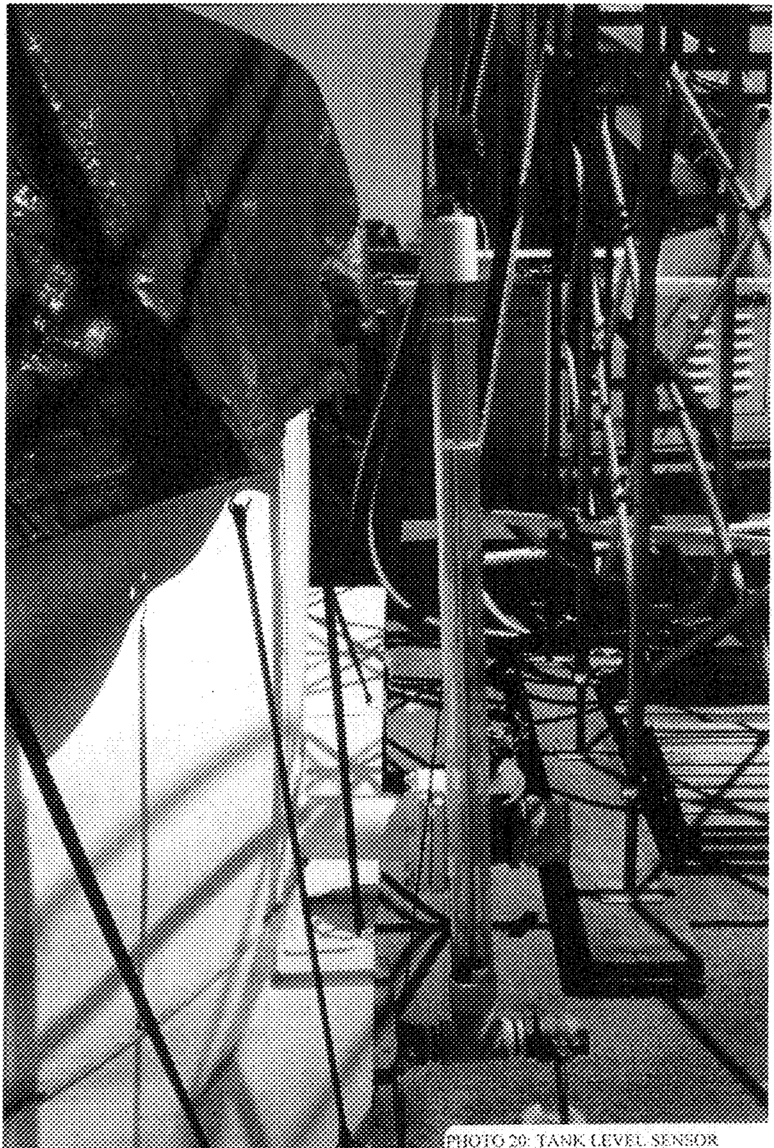


PHOTO 20: TANK LEVEL SENSOR MOUNTED ON TANK MOCKUP

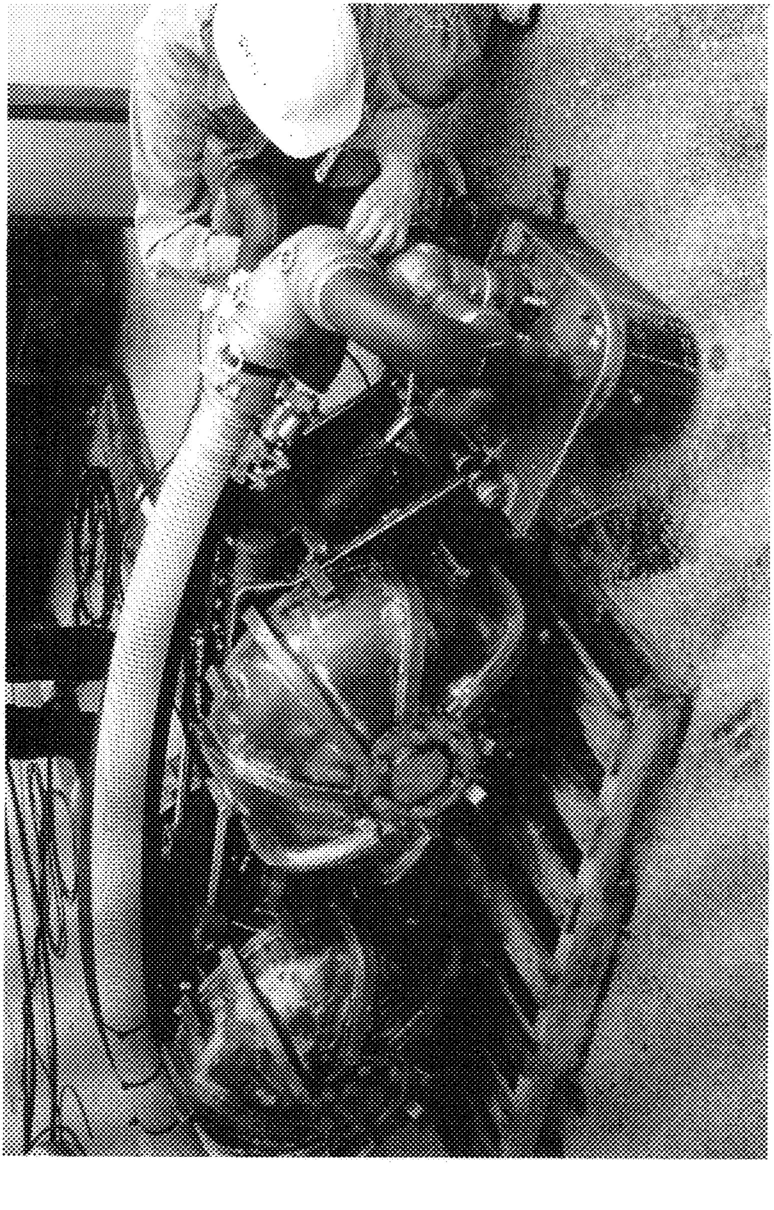


PHOTO 21: ARD VEHICLE BEING PREPARED FOR INSERTION IN THE TANK MOCKUP

ARD ENVIRONMENTAL, INC

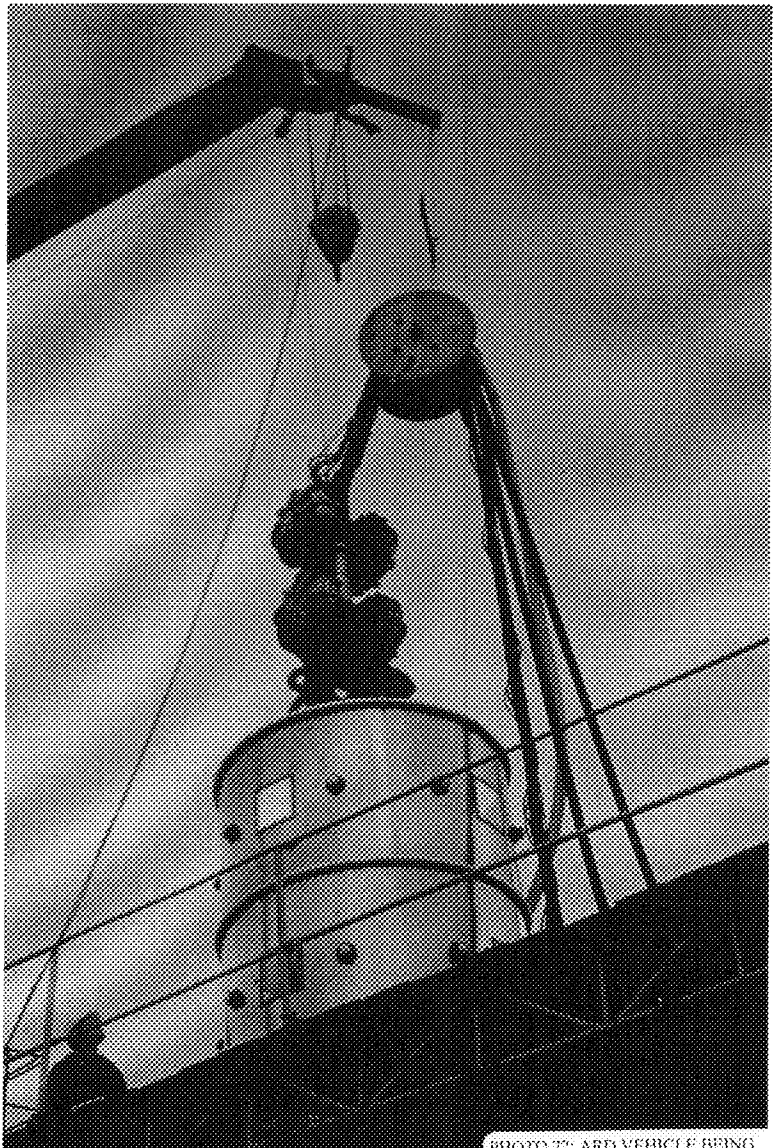


PHOTO 22: ARD VEHICLE BEING DEPLOYED INTO THE TANK MOCKUP

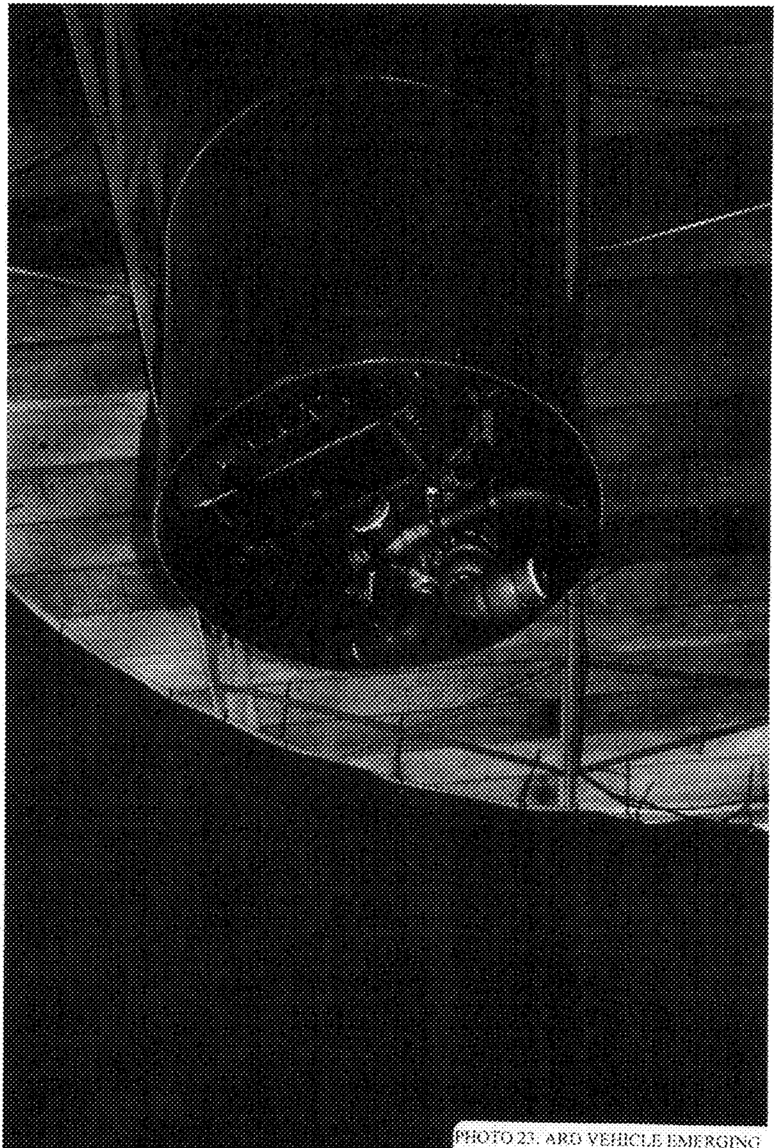


PHOTO 23. ARD VEHICLE EMERGING FROM RISER DURING DEPLOYMENT

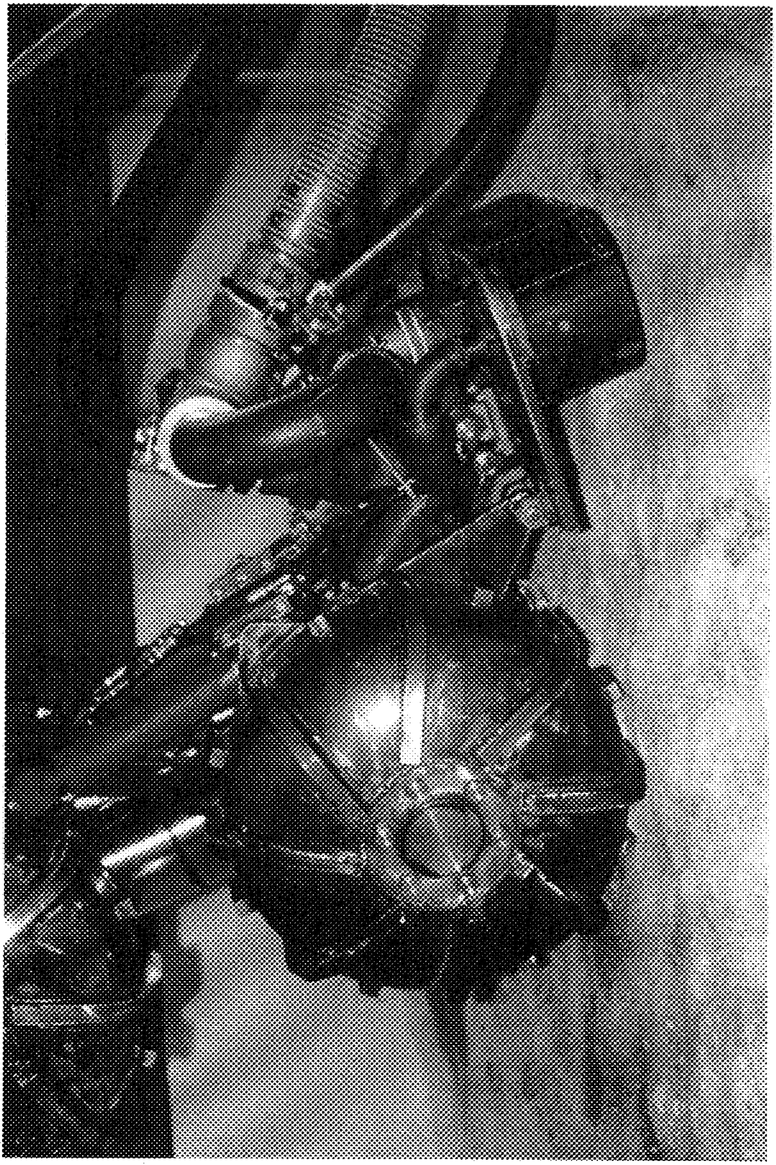


PHOTO 24: ARD VEHICLE LANDING ON THE WASTE SURFACE DURING DEPLOYMENT

ARD ENVIRONMENTAL, INC.

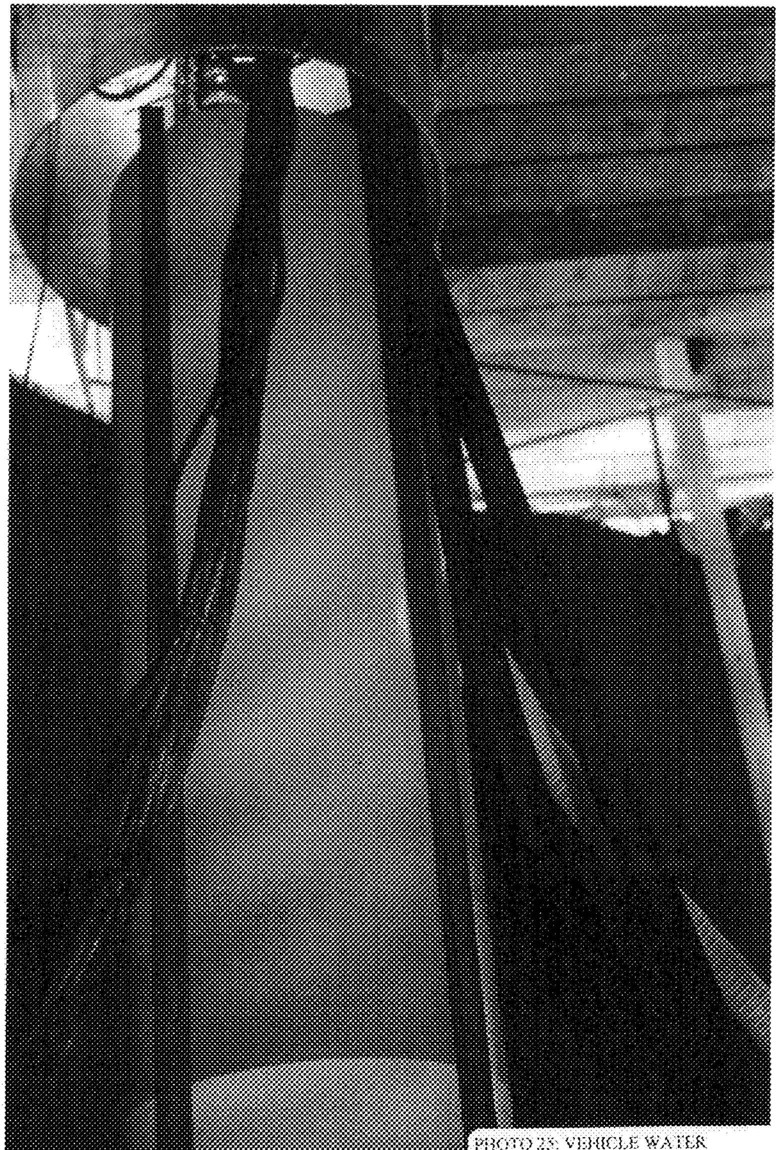


PHOTO 25: VEHICLE WATER SCAVENGING MODULE DURING DEPLOYMENT

ARD ENVIRONMENTAL, INC.

PHOTO 26: ARD VEHICLE DURING TESTING IN THE TANK MOCKUP

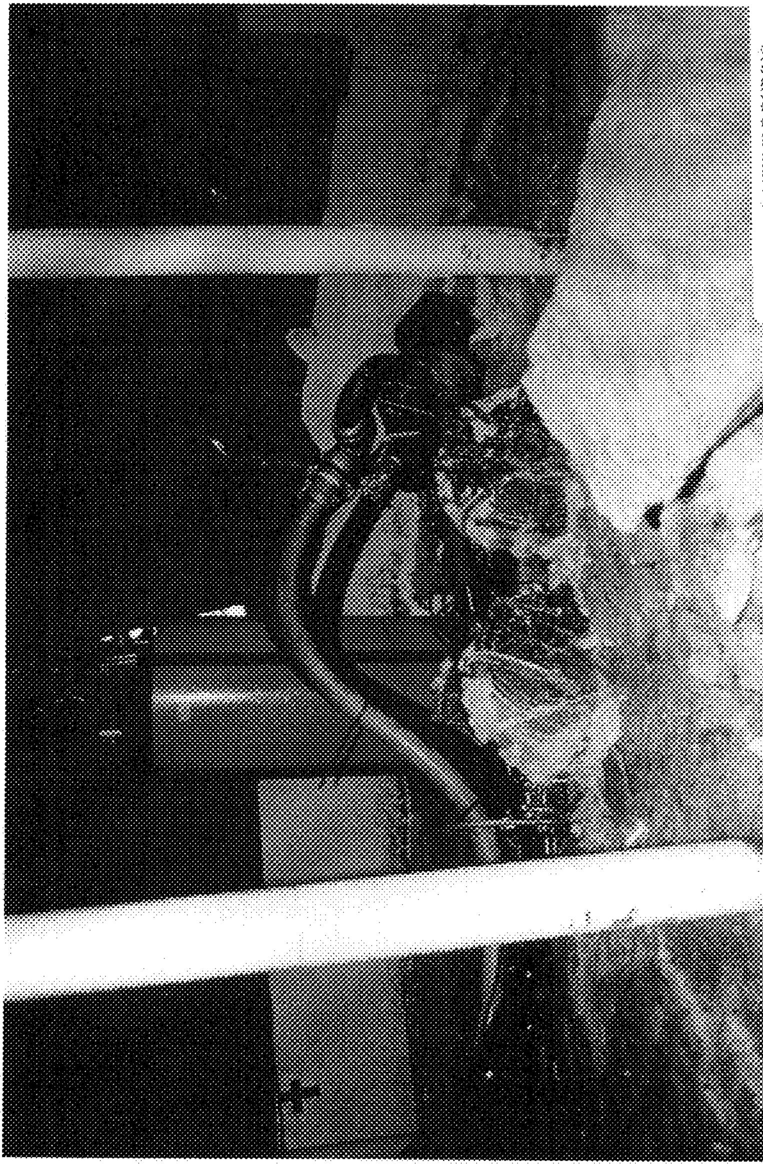


PHOTO 27: ARD VEHICLE DURING TESTING IN THE TANK MOCKUP

ARD ENVIRONMENTAL, INC.

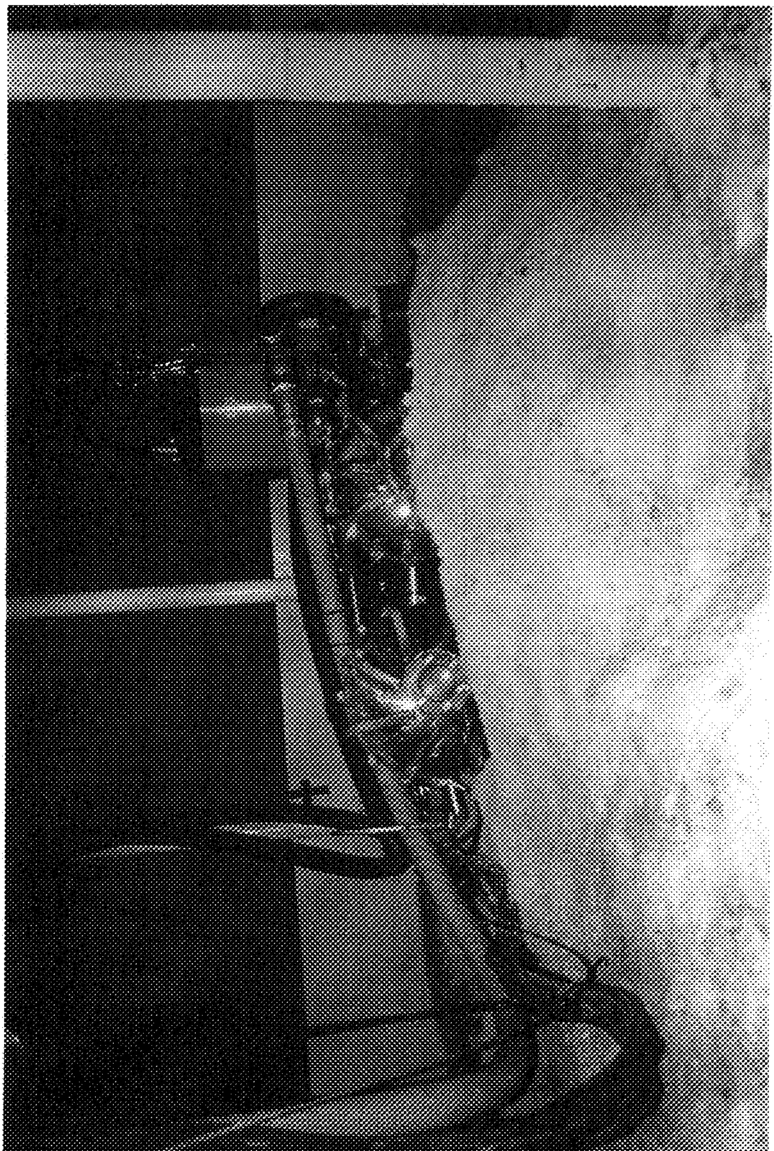


PHOTO 28: ARD VEHICLE DURING TESTING IN THE TANK MOCKUP

ARD ENVIRONMENTAL, INC.

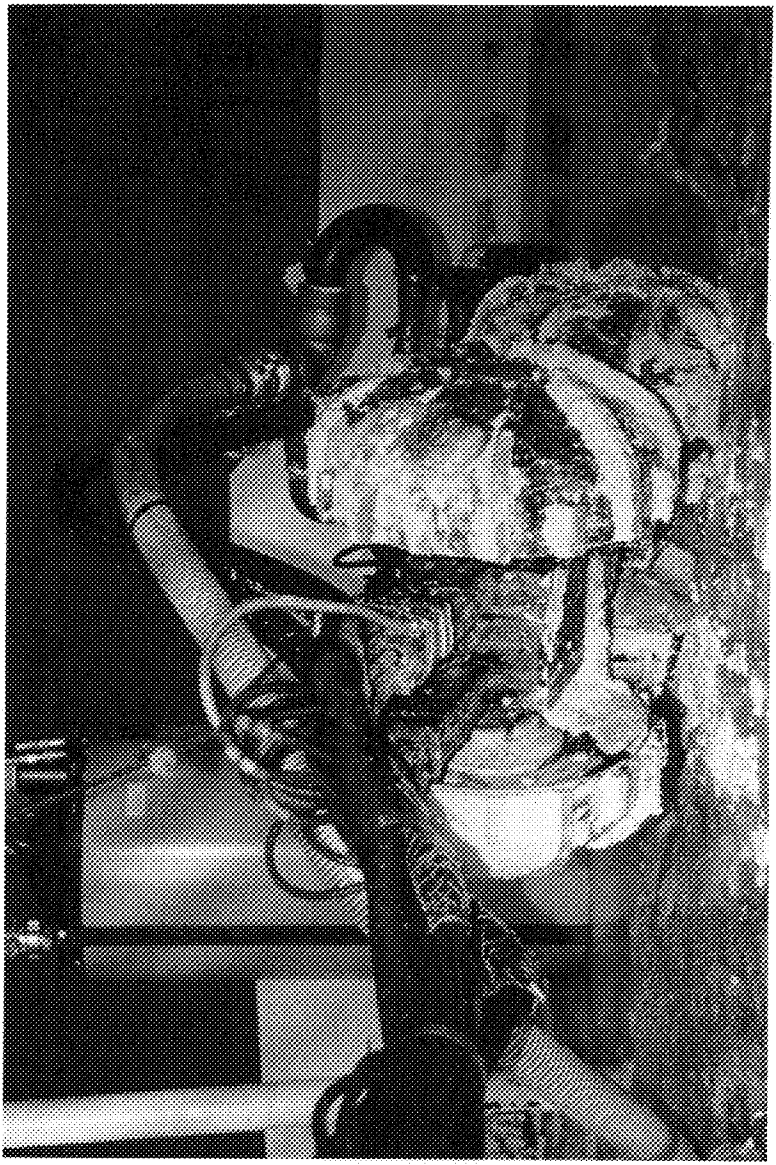


PHOTO 29: ARD VEHICLE DURING STUCK VEHICLE RETRIEVAL TESTING

ARD ENVIRONMENTAL, INC.

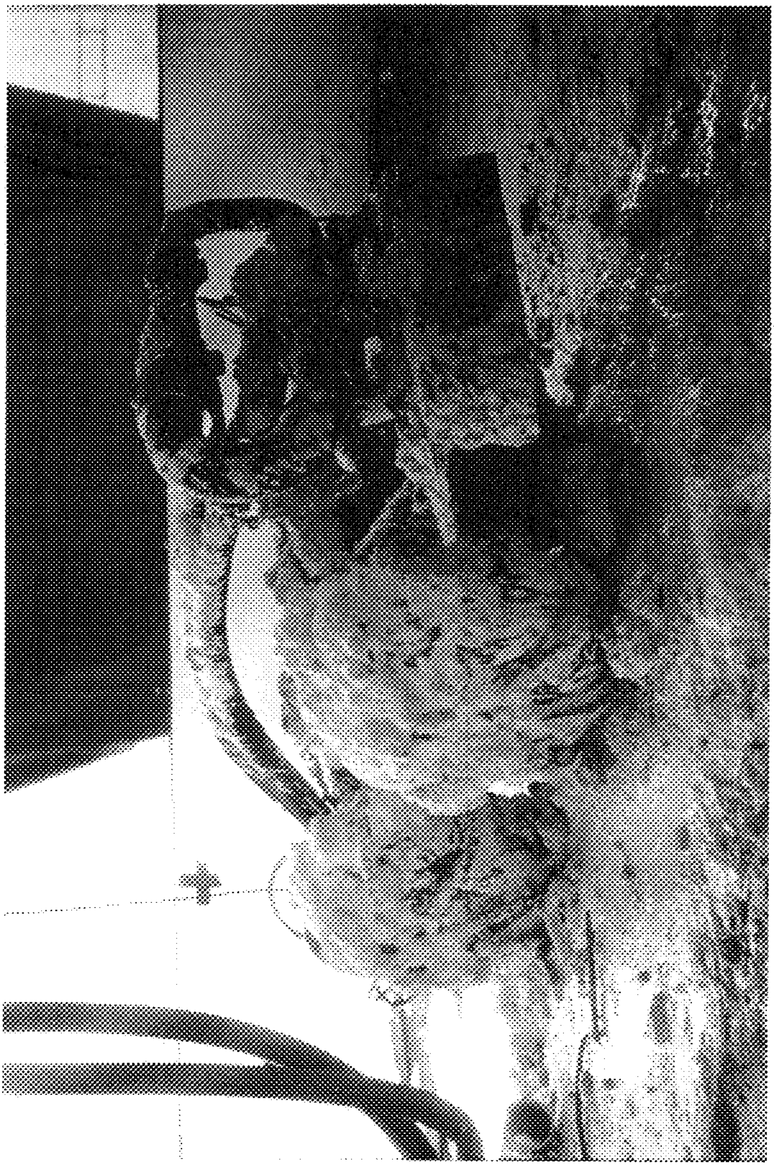


PHOTO 30: ARD VEHICLE CAKED WITH SIMULANT PRIOR TO DECONTAMINATION TESTING

ARD ENVIRONMENTAL, INC.

PHOTO 31. ARD VEHICLE DURING RETRIEVAL FOR DECONTAMINATION TESTING

PHOTO 32. ARD VEHICLE DURING DECONTAMINATION TESTING

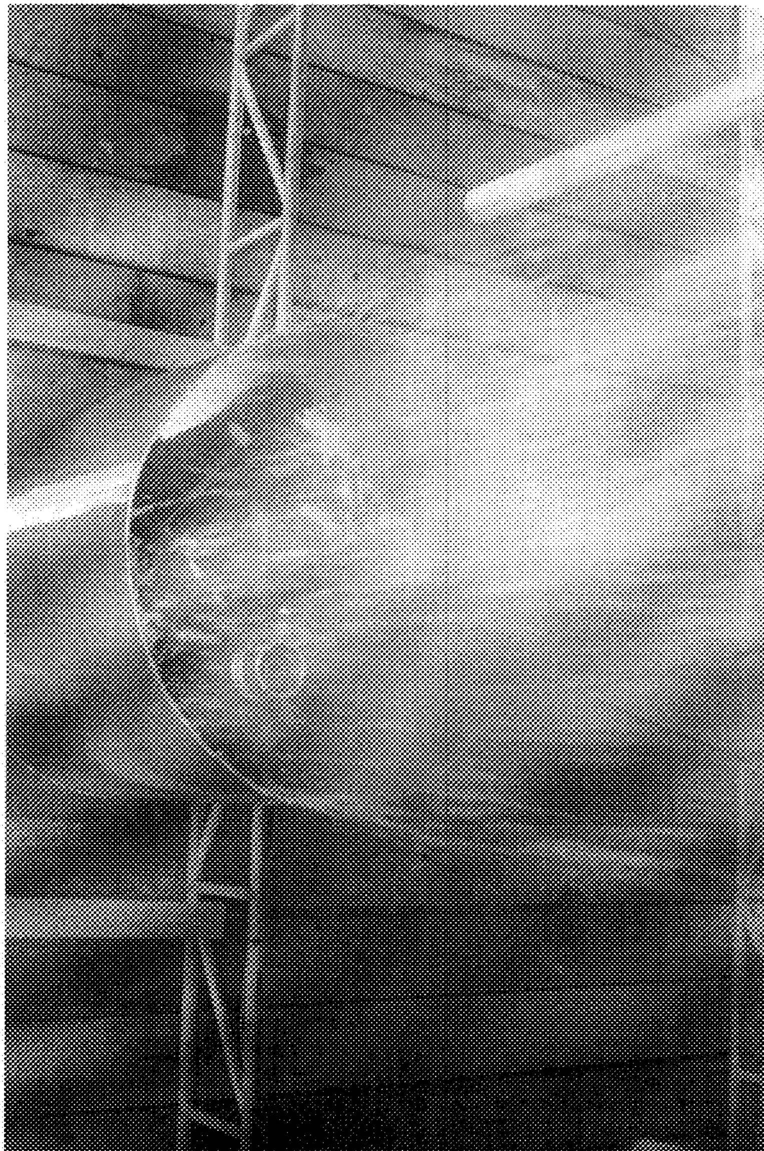


PHOTO 33: ARD VEHICLE DURING DECONTAMINATION TESTING

ARD ENVIRONMENTAL, INC.

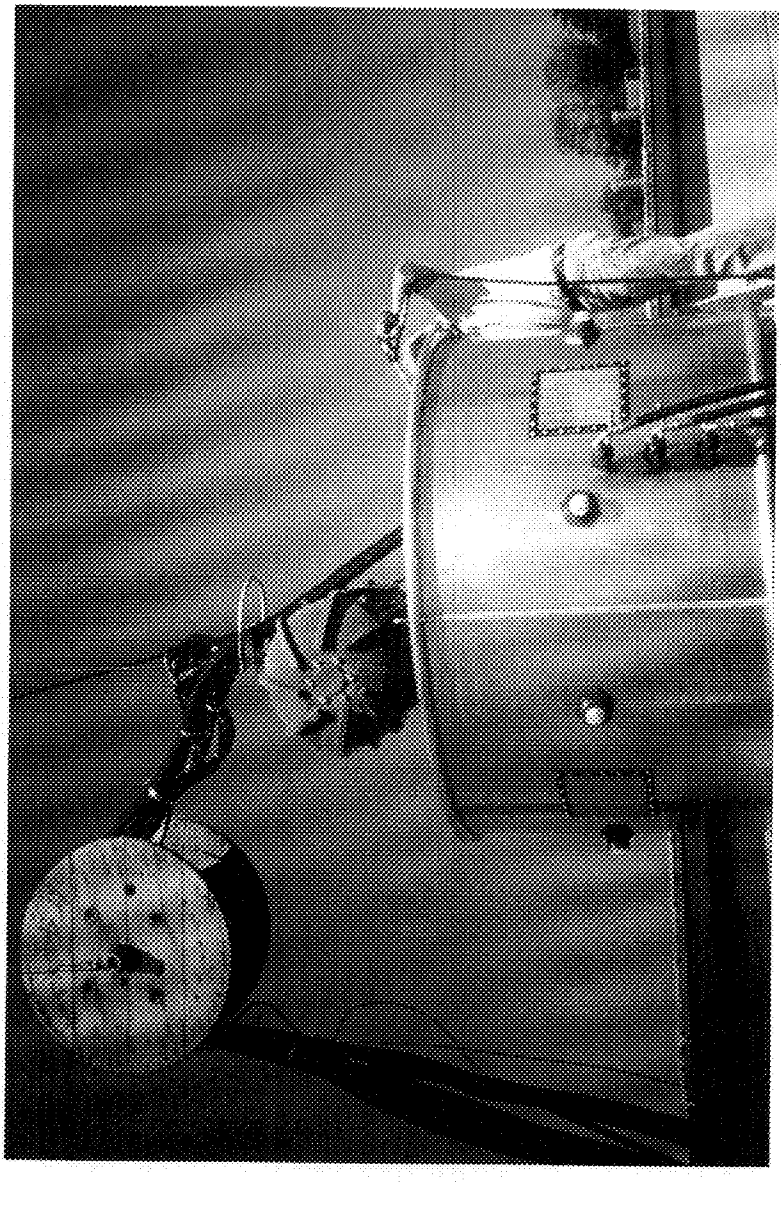


PHOTO 34: ARD VEHICLE BEING REMOVED AFTER DECONTAMINATION

ARD ENVIRONMENTAL, INC.

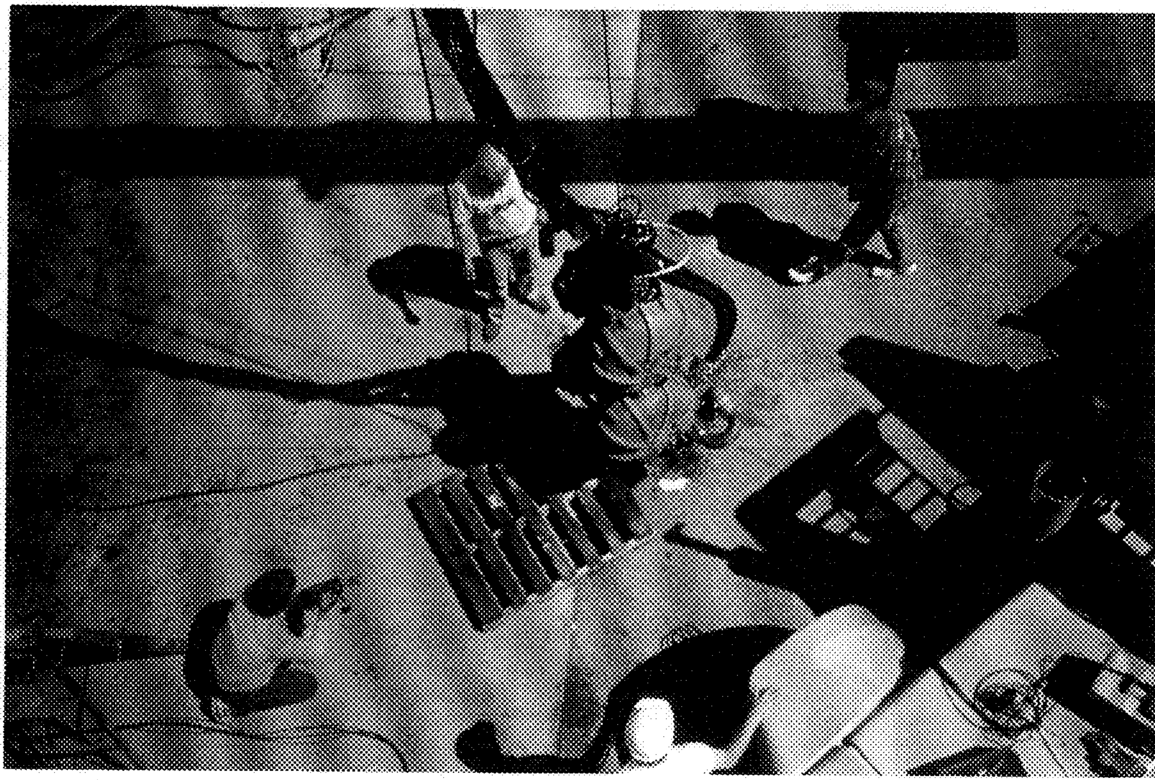


PHOTO 35: ARD VEHICLE AFTER DECONTAMINATION, BEING LOWERED TO THE GROUND

ARD ENVIRONMENTAL, INC.

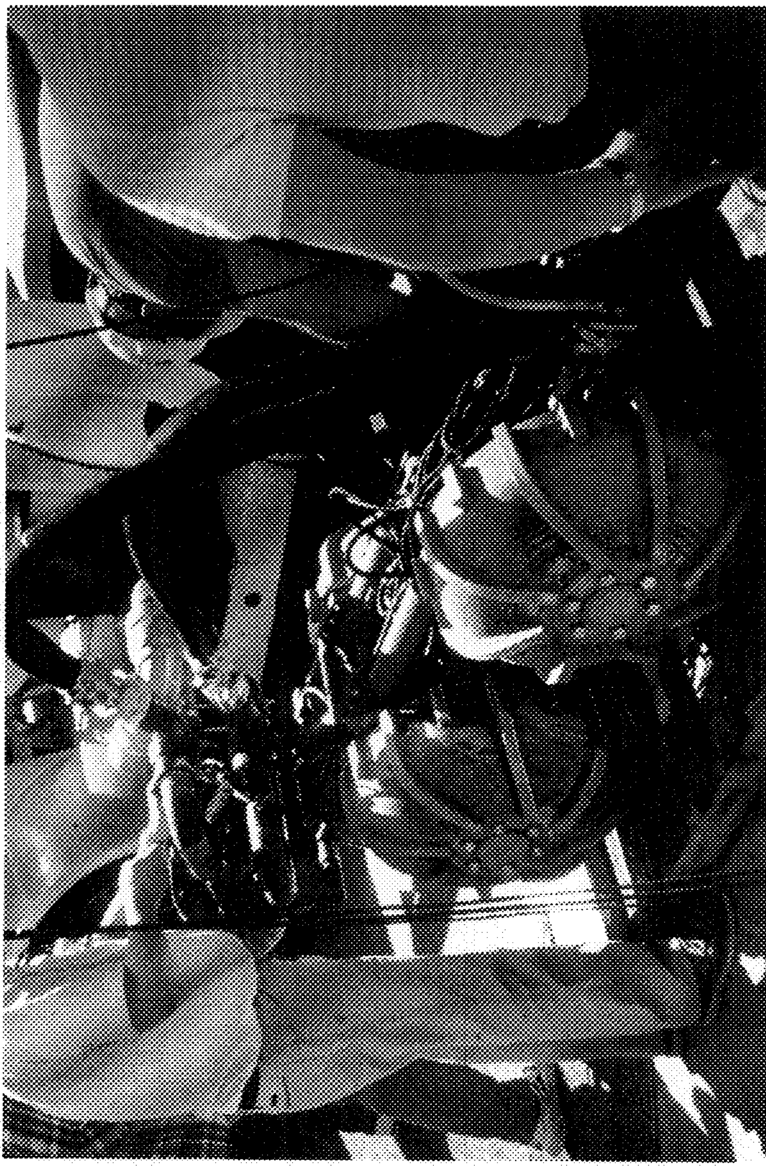


PHOTO 36: ARD VEHICLE AT THE CONCLUSION OF THE TESTING

ARD ENVIRONMENTAL, INC.

Appendix 6.3 Equipment Data Sheets

PERFORMANCE DATA

Spray Angle at 40 psi	Capacity Size	VEEJET NOZZLES NOZZLE TYPE/INLET CONNECTION												Equiv Orifice Diam Inches	CAPACITY (gallons per minute)											SPRAY ANGLE			
		H-VV		H-VVL		H-U					U				5 psi	10 psi	20 psi	30 psi	40 psi	60 psi	80 psi	100 psi	200 psi	300 psi	500 psi	20 psi	40 psi	80 psi	200 psi
		1/8	1/4	1/8	1/4	1/8	1/4	3/8	1/2	3/4	1	1-1/4	2																
	1560						●	●						3/16		3.0	4.2	5.2	6.0	7.3	8.5	9.5	13.4	16.4	21	11°	15°	18°	21°
	1570						●		●					13/64		3.5	4.9	6.1	7.0	8.6	9.9	11.1	15.7	19.2	25	11°	15°	18°	21°
	15100							●	●					1/4	3.5	5.0	7.1	8.6	10.0	12.2	14.1	15.8	22	27	35	13°	15°	17°	18°
15°	15120							●						17/64	4.2	6.0	8.5	10.4	12.0	14.7	17.0	19.0	27	33	42	13°	15°	17°	18°
	15150								●					19/64	5.3	7.5	10.6	13.0	15.0	18.4	21	24	34	41	53	14°	15°	17°	18°
	15200								●					11/32	7.1	10.0	14.1	17.3	20.0	25	28	32	44	55	71	14°	15°	17°	18°
	15250									●				3/8	8.8	12.5	17.7	22	25	31	35	40	56	68	88	14°	15°	16°	17°
	15500											●		33/64	17.7	25	35	43	50	61	71	79	112	137	177	14°	15°	16°	17°
	151000											●		47/64	35	50	71	87	100	123	142	158	223	273	353	14°	15°	16°	17°
	0003					●	●							.041	.10	.15	.21	.26	.30	.37	.42	.47	.67	.82	1.1				
	0004					●	●							.047	.14	.20	.28	.35	.40	.49	.57	.63	.89	1.1	1.4				
	0005					●	●							.053	.18	.25	.35	.43	.50	.61	.71	.79	1.1	1.4	1.8				
	0006					●	●							.058	.21	.30	.42	.52	.60	.73	.85	.95	1.3	1.6	2.1				
	0008					●	●							.067	.28	.40	.56	.69	.80	.98	1.1	1.3	1.8	2.2	2.8				
	0010					●	●							.073	.35	.50	.71	.86	1.0	1.2	1.4	1.6	2.2	2.7	3.5				
	0015					●	●							.092	.53	.75	1.1	1.3	1.5	1.8	2.1	2.4	3.4	4.1	5.3				
	0020					●	●	●						.106	.71	1.0	1.4	1.7	2.0	2.5	2.8	3.2	4.5	5.5	7.1				
	0030					●	●							[illegible]	1.1	1.5	2.1	2.6	3.0	3.7	4.2	4.7	6.7	8.2	10.6				
	0040					●	●							5/32	1.4	2.0	2.8	3.5	4.0	4.9	5.7	6.3	9.0	11.0	14.2	0°			
	0050						●							11/64	1.8	2.5	3.5	4.3	5.0	6.1	7.1	7.9	11.2	13.7	17.7	SOLID STREAM			
	0060						●							3/16	2.1	3.0	4.2	5.2	6.0	7.3	8.5	9.5	13.4	16.4	21				
	0070						●	●						13/64	2.5	3.5	4.9	6.1	7.0	8.6	9.9	11.1	15.7	19.2	25				
0°	0080						●	●						13/64	2.8	4.0	5.6	6.9	8.0	9.8	11.3	12.6	17.9	22	28				
	00100							●						15/64	3.5	5.0	7.1	8.6	10.0	12.2	14.1	15.8	22	27	35				
	00120							●						1/4	4.2	6.0	8.5	10.4	12.0	14.7	17.0	19.0	27	33	42				
	00150								●					19/64	5.3	7.5	10.6	13.0	15.0	18.4	21	24	34	41	53				
	00200								●					21/64	7.1	10.0	14.1	17.3	20.0	25	28	32	44	55	71				
	00250							●						3/8	8.8	12.5	17.7	22	25	31	35	40	56	68	88				
	00350									●				7/16	12.4	17.5	25	30	35	43	50	55	78	96	124				
	00700									●				39/64	25	35	50	61	70	86	98	111	157	192	247				
	001000										●			3/4	35	50	71	87	100	123	142	158	223	273	353				
	001100										●			25/32	39	55	78	95	110	135	156	174	246	301	389				
	001400											●		[illegible]	50	70	99	121	140	171	198	221	313	383	495				
	001800											●		[illegible]	64	90	127	156	180	220	254	285	402	493	636				
	002000												●	1 3/64	71	100	142	173	200	245	283	316	447	547	706				
	003500												●	1 3/8	125	175	247	303	350	428	494	553	783	958	1240				

MATERIALS

MATERIAL	MATERIAL CODE	VEEJET®				JET STABILIZERS
BRASS	NONE	●	●	●	●	●
MILD STEEL	I			●	●	●
303 STAINLESS STEEL	SS	●	●	●	●	●
316 STAINLESS STEEL	316 SS		●	●		
Polyvinyl Chloride	PVC			●		

ORDERING INFORMATION

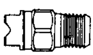
VEEJET SPRAY NOZZLE

H 1/4 VV - SS 11010

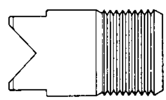
H	1/4	VV	SS	11010
Nozzle Type Prefix (H only)	Inlet Connection-Pipe Size	Nozzle Type	Material Code	Capacity Size

DIMENSIONS & WEIGHTS

Based on largest/heaviest version of each type.



Nozzle No.	Hex.	Nozzle Length	Net Weight
H1/8U	1/2"	7/8"	1/2 oz.
H1/4U	9/16"	1"	3/4 oz.
H3/8U	11/16"	1 1/4"	1 1/2 oz.
H1/2U	7/8"	1 1/2"	2 1/4 oz.
H3/4U	1 1/16"	2"	5 oz.



Nozzle No.	Diameter	Nozzle Length	Net Weight
1U	1 5/16"	2 1/2"	9 oz.
1-1/4U	1 11/16"	3 3/4"	1 1/4 lbs.
2U	2 3/8"	5"	4 1/4 lbs.

Nozzle No.	Hex.	Nozzle Length	Net Weight
H1/8VV	1/2"	7/8"	1/2 oz.
H1/8VVL		1 13/32"	3/4 oz.
H1/4VV	9/16"	29/32"	3/4 oz.
H1/4VVL		1 1/2"	1 oz.

DESIGN FEATURES

VeeJet nozzle strainers are available with either brass or 303 stainless steel bodies and come with 304 stainless steel screens. These strainers will fit in any H1/8 VV or H1/4 VV VeeJet nozzle. They provide an effective means of straining out particles that are too large to pass through the nozzle orifice.

VEEJET NOZZLE STRAINER

FOR NOZZLE SERIES	STRAINER ORDER NO.
H 1/8 VV–	12686-*-**
H 1/4 VV–	12687-*-**

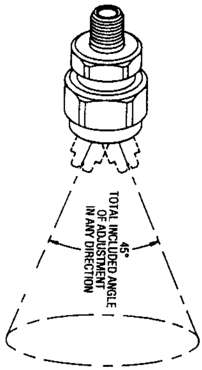
*Material Code
no material code = Brass
SS = 303 Stainless Steel
**Screen Mesh

MESH SELECTION GUIDE	
Equivalent Orifice Diameter	Recommended Screen Mesh
UP THROUGH .018" (.46 mm)	200
.019" (.47 mm) THROUGH .031" (.79 mm)	100
.032" (.80 mm) AND LARGER	50

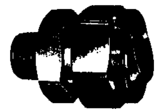
C 43

FLAT SPRAY

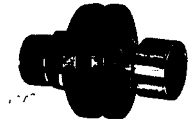
Adjustable
BALL FITTINGS



36275
male inlet, female outlet
1/8"- 3/4" NPT or BSPT



CAST
male inlet, female outlet
1"- 1 1/2" NPT or BSPT



CAST
male inlet, male outlet
1 1/4"- 2 1/2" NPT or BSPT

DESIGN FEATURES

Adjustable ball fittings provide adjustable positioning of spray nozzles for more exact control of spray direction. They permit accurate pipe alignment and convenient nozzle positioning without disturbing pipe connections. Adjustable ball fittings are available in a wide range of pipe connections. They feature large internal passages to minimize clogging and smooth finished sealing surfaces to assure leakproof connections.

The **machined-type** ball fitting features a lock ring that holds the nozzle in position when jarred or subjected to vibration. The fitting has a relatively small diameter for applications requiring a compact size. Its maximum pressure rating is 300 psi (21 bar). Nozzle removal for cleaning and readjustment is quick and simple.

Cast-type fittings feature locking screws that hold the nozzle in position when jarred or subjected to vibration. They are rated for pressures up to 125 psi (9 bar).

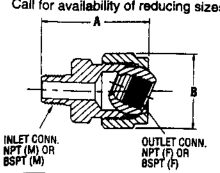
FLUIDLINE ACCESSORIES

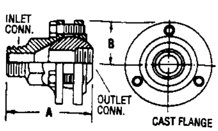
DIMENSIONS & WEIGHTS

Inlet Pipe Conn. NPT or BSPT	Outlet Pipe Conn. NPT or BSPT	Adjustable Ball Fitting Ordering No.	Type Flanges	DIMENSIONS		Total Included Angle of Adjustment	Net Weight lbs.
				A Overall Length inches	B inches		
1M	1F	1 x 1	CAST female outlet type	3 1/2	1 13/16	40°	4
1 1/4M	1 1/4F	1 1/4 x 1 1/4		5 1/8	1 13/16	40°	4 3/4
1 1/2M	1 1/4F	1 1/2 x 1 1/4		5 1/4	1 13/16	40°	5
1 1/4M	1 1/4M	1 1/4 x 1 1/4M	CAST male outlet type	5 1/8	1 13/16	40°	4 3/4
1 1/4M	1 1/2M	1 1/4 x 1 1/2M		5 1/8	1 13/16	40°	4 3/4
1 1/2M	1 1/2M	1 1/2 x 1 1/2M		5 1/8	1 13/16	40°	5
2M	2M	2 x 2M		8 1/4	3 1/8	40°	18
2 1/2M	2 1/2M	2 1/2 x 2 1/2M		9	3 1/8	40°	19 1/2

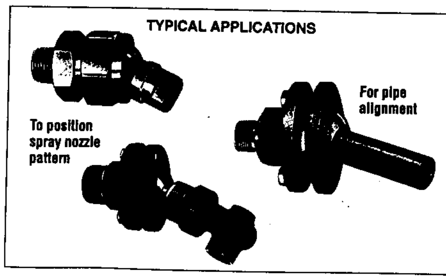
Inlet Pipe Conn. NPT or BSPT	Outlet Pipe Conn. NPT or BSPT	Adjustable Ball Fitting Ordering No.	Material	DIMENSIONS		Total Included Angle of Adjustment	Net Weight oz.
				A Overall Length inches	B inches		
1/8M	1/8F	36275-1/8 x 1/8	Brass	1 3/8	31/32	45°	2
1/8M	1/8F	36275-1/8 x 1/8-SS	St. Steel				
1/4M	1/4F	36275-1/4 x 1/4	Brass	1 9/16	1 3/32		3
1/4M	1/4F	36275-1/4 x 1/4-SS	St. Steel				
3/8M	3/8F	36275-3/8 x 3/8	Brass	1 25/32	1 3/8		5.5
3/8M	3/8F	36275-3/8 x 3/8-SS	St. Steel				
1/2M	1/2F	36275-1/2 x 1/2	Brass	2 7/32	1 21/32		10
1/2M	1/2F	36275-1/2 x 1/2-SS	St. Steel				
3/4M	3/4F	36275-3/4 x 3/4	Brass	2 13/32	1 29/32		17
3/4M	3/4F	36275-3/4 x 3/4-SS	St. Steel				

Call for availability of reducing sizes.





COMMON APPLICATIONS



MATERIAL CODE

36275 Type
no material code = Brass
SS = 303 Stainless Steel

Cast Type
no material code = Brass
I = Cast Iron
SS = 303 Stainless Steel and Cast 316 Stainless Steel

ORDERING INFORMATION

1 x 1 -SS

- 1 — Inlet Connection Size
- 1 — Outlet Connection Size
- SS — Material Code

PERFORMANCE DATA ON

WATER JET EDUCTORS

KETEMA
SCHUTTE AND KOERTING DIVISION

SCHUTTE & KOERTING WATER JET EDUCTORS

This supplement should be used in conjunction with S & K Bulletin 2M which describes the construction, operation, and application of Schutte and Koerting Water Jet Eductors (Ejectors).

Bulletin 2M also contains information on available types, sizes and dimensions. This supplement contains capacity data. If you do not have a copy of Bulletin 2M, request one.

For capacity data on the types of eductors offered, refer to the following index.

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Type Eductor	Source	Page
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222 (Portable)	Nomograph	8
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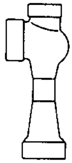
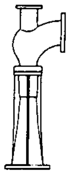
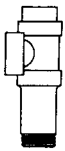
235	Nomograph	8
241	Table 6	5
242	Nomograph	8
254	Tables 9, 10 & 11	6 & 7
258	Table 7	6
264	Tables 1, 2 & 3	4
266	Tables 1 & 2	4
2645	Tables 4 & 5	5
267	Contact S & K	—
268	Chart 8	6



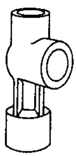
Typical Type 264 Eductor
Threaded Connections
(½″ thru 3″ sizes)



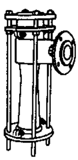
Typical Type 266 Eductor
Flanged Connections
(4″ or 6″ size)



Typical Type 264 Eductor
Made of PVC



Typical Type 264 Eductor
(Molded KYNAR or Polypropylene)



Typical Type 212 Eductor
(Haveg)

TABLE 1. Suction Capacities of Water Jet Eductors, Types 264, 266, and 212—1 Inch Size Only. To determine capacities for sizes other than 1 inch, multiply these capacities by the proper capacity ratio factor noted in Tables 2 or 3 (for PVC, KYNAR or Polypropylene Eductors).

Suction Lift in Ft. of Water	Disch. Press psi Gauge	Water Consumption gpm	Suction Cap. of Standard 1″ Water Jet Eductor—gpm—Water Temp. 80° F. Operating Water Pressure psi Gauge 10	20	30	40	50	60	80	100
0	0	Suction	5.85	8.1	9.5	10.0	12.0	12.0	12.0	12.0
		Operating	3.55	5.0	6.1	7.1	7.9	8.7	10.0	11.0
	5	Suction		1.4	4.1	6.0	8.0	10.0	11.0	12.0
		Operating		4.9	6.1	7.0	7.9	8.6	10.0	11.0
	10	Suction			0.28	2.3	4.8	6.4	8.8	11.0
		Operating			5.9	6.8	7.8	8.5	9.8	11.0
	15	Suction					1.2	3.4	5.9	8.6
		Operating					7.7	8.4	9.8	11.0
	20	Suction						0.3	3.5	5.9
		Operating						8.2	9.7	11.0
	25	Suction							0.83	3.9
		Operating							9.6	11.0
	30	Suction								1.7
		Operating								11.0
5	0	Suction	4.4	6.8	8.6	9.6	11.0	11.0	12.0	12.0
		Operating	3.9	5.3	6.4	7.3	8.1	8.8	10.0	11.0
	5	Suction		1.5	3.2	5.0	7.0	9.0	11.0	11.0
		Operating		5.2	6.3	7.2	8.0	8.7	10.0	11.0
	10	Suction				1.9	3.6	5.6	8.6	10.0
		Operating				7.1	7.9	8.6	10.0	11.0
	15	Suction					1.1	2.6	5.8	8.3
		Operating					7.8	8.6	9.9	11.0
	20	Suction							3.3	5.6
		Operating							9.8	11.0
	25	Suction							0.47	3.6
		Operating							9.8	11.0
	30	Suction								1.5
		Operating								11.0
10	0	Suction	2.0	4.6	6.7	8.3	9.0	10.0	10.0	10.0
		Operating	4.2	5.5	6.6	7.4	8.2	9.0	10.0	11.0
	5	Suction			2.0	4.3	5.9	7.7	9.9	10.0
		Operating			6.5	7.4	8.2	8.9	10.0	11.0
	10	Suction				1.1	3.0	4.5	8.1	9.6
		Operating				7.3	8.1	8.8	10.0	11.0
	15	Suction					1.1	2.1	5.6	7.3
		Operating					8.0	8.7	10.0	11.0
	20	Suction							2.8	5.3
		Operating							9.9	11.0
	25	Suction								2.8
		Operating								11.0
	30	Suction								1.1
		Operating								11.0
15	0	Suction		3.3	5.3	7.9	8.4	8.9	8.9	9.1
		Operating		5.7	6.8	7.6	8.4	9.1	10.0	12.0
	5	Suction				4.0	4.9	7.3	8.6	9.1
		Operating				7.6	8.3	9.0	10.0	11.0
	10	Suction					2.4	4.0	6.4	8.6
		Operating					8.2	9.0	10.0	11.0
	15	Suction							4.2	6.8
		Operating							10.0	11.0
	20	Suction							2.1	4.5
		Operating							10.0	11.0
	25	Suction								1.9
		Operating								11.0
20	0	Suction		2.0	4.0	6.4	7.8	7.8	7.8	7.8
		Operating		6.0	7.0	7.8	8.6	9.3	11.0	12.0
	5	Suction				2.8	3.9	6.3	7.8	7.8
		Operating				7.7	8.5	9.2	10.0	12.0
	10	Suction					1.2	3.1	5.7	7.1
		Operating					8.3	9.1	10.0	12.0
	15	Suction							3.6	5.4
		Operating							10.0	11.0
	20	Suction							1.4	3.8
		Operating							10.0	11.0
	25	Suction								1.5
		Operating								11.0

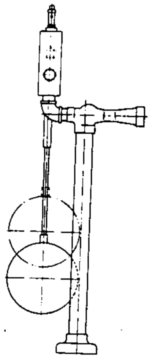
Performance is for standard stock units. If not satisfactory for your conditions, refer to Nomograph on page 8 for units to meet conditions.

TABLE 2. Relative Capacities of Water Jet Eductors, Types 264, 266, and 212. ▶

Size Eductor in Inches	½	¾	1	1½	2	2½	3	4	6
Capacity Ratio	0.36	0.64	1.00	2.89	4.00	6.25	9.00	16.00	36.00

TABLE 3. Relative Capacities of Water Jet Eductors Made from KYNAR, Polypropylene or PVC, Type 264. ▶

Size Eductor in Inches	¼	½	¾	1	1½	2	3
Capacity Ratio	0.15	0.36	0.64	1.00	2.89	4.00	9.00



Typical Type 2645
Automatic Eductor

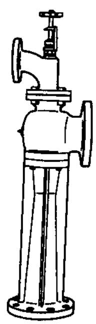
TABLE 4. Capacities of Automatic Water Jet Eductors, Type 2645—1 Inch Size Only. To determine capacities for sizes other than 1 inch, multiply these capacities by the proper capacity ratio factor noted in Table 5.

Suction Lift in Ft. of Water	Disch. Press. (psig)	Suction & Motive Capacities of 1" Eductor with water temp. of 80 F — gph	Motive Water Pressure — psig				
			40	50	60	80	100
5	0	Suction	576	652	681	708	720
		Motive	436	485	529	607	676
	5	Suction	300	420	540	650	675
		Motive	432	478	524	603	673
	10	Suction	114	216	336	515	600
		Motive	425	474	518	597	667
	15	Suction		66	153	348	498
		Motive		470	514	594	662
	20	Suction				200	337
		Motive				590	660
	25	Suction				28	216
		Motive				585	652
	30	Suction					80
		Motive					648

TABLE 5. Relative Capacities of Automatic Water Jet Eductors, Type 2645.

Size Eductor in Inches	¾	1	1½	2	2½	3
Capacity Ratio	0.64	1.00	2.89	4.00	6.25	9.00

NOTE: For total discharge capacity, add suction and motive capacities.

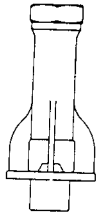


Typical Type 241 Eductor

TABLE 6. Suction Capacities, Pressure Data, and Motive Liquid Flows of SK Mixing Eductors, Type 241, in Typical Applications. Table Applies to Selected Standard Sizes.

Motive Liquid	Naphtha	Hydro-carbon	Gasoline	Gasoline	Sour Kerosene
Suction Fluid	Copper Chloride Slurry	Hydro-carbon	Slurry	Water	Kerosene Slurry
Pressure, psig					
Motive	165	295	170	75	145
Suction	40	5	75	50	60
Discharge	75	10	100	50	70
Flow, gpm					
Motive	30	10	90	170	482
Suction	20	58	74	42	700
Discharge	50	68	164	212	1182
Eductor Size	1½"	3"	4"	4"	6"

Note: Type 241 Mixing Eductors are built on special order for specific operating conditions. The table above is indicative of what is being accomplished in certain representative jobs. For capacity characteristics for your operation, please contact our engineers.

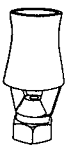


Typical Type 258 Eductor

TABLE 7. Capacities of Tank Mixing Eductors, Type 258.

Size in Inches	MOTIVE FLUID gpm WATER							
	Pressure Difference Inlet to Tank—psi Gauge							
	10	20	30	40	50	60	80	100
½	3.5	5.0	6.0	7.0	8.0	8.5	10.0	11.0
¾	8.0	11.5	13.5	16.0	18.0	19.0	22.5	25.0
1	14.2	20.0	25.0	28.0	30.0	34.5	40.0	44.5
1¼	22.0	31.0	37.5	44.0	50.0	53.0	62.5	69.0
1½	31.5	45.0	54.0	63.0	72.0	76.5	90.0	99.0
2	56.0	80.0	96.0	112.0	128.0	136.0	160.0	176.0
3	126.0	180.0	216.0	252.0	288.0	306.0	360.0	396.0
4	224.0	320.0	384.0	448.0	512.0	544.0	640.0	704.0
5	350.0	500.0	600.0	700.0	800.0	850.0	1000.0	1100.0
6	494.0	720.0	864.0	1008.0	1152.0	1224.0	1440.0	1584.0

CHART 8. Selection Chart for Determining the Number of Type 268 Eductors Required for Proper Mixing.



Typical Type 268 Eductor

Note: In order to select the number of eductors required, the volume of the tank in gallons should be divided by the number of minutes estimated for complete turnover. This rate, in gpm, divided by four will give the motive liquid flow requirement of a standard Type 268 Eductor. From the chart and the available operating pressure, the number of eductors required can be selected. For good practice, a minimum pressure drop of 20 psi should be maintained between the eductor inlet and the static pressure at the bottom of the tank.

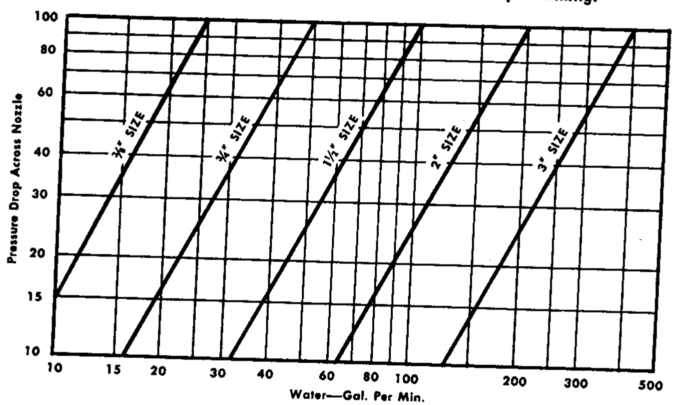
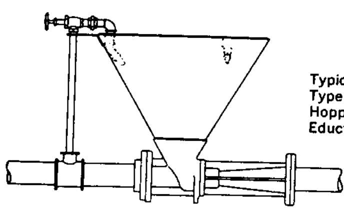


TABLE 9. Suction Capacities and Water Consumptions of Hopper-Equipped Eductors, Type 254—1½ Inch Size Only.
To determine capacities for sizes other than 1½ inch, multiply these capacities by the proper capacity ratio factor noted in Table 10.



Typical Type 254 Hopper Eductor

Operating Water Pressure psi Gauge	30	40	50	60
Suction Capacity Cu. Ft. per Hr.	13	36	72	90
Maximum Discharge Pressure psi Gauge	14	17	18	20
Motive Water Consumption, gpm*	35	40	45	50

**Based on using approximately 10% motive water through wash-down nozzles.*

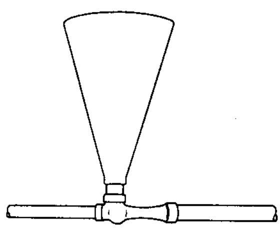
Note: Type 254 Eductors are built on special order for specific operating conditions. The table above is indicative only of what can be accomplished under certain conditions. For capacity characteristics for your operation, please contact our engineers.

TABLE 10. Relative Capacities of Hopper-Equipped Eductors, Type 254.

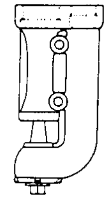
Size in Inches	1½	2	3	4	6
Capacity Ratio	1.00	1.60	3.50	6.00	18.00

TABLE 11. Typical Materials Handled by Hopper-Equipped Eductors, Type 254. Many More Can Be Handled Effectively.

Material	Approx. Bulk Density Lbs. per cu. ft.
Borax	50-55
Charcoal	18-28
Diatomaceous Earth	10-20
Lime, Pebble	56
Lime, Powdered	32-40
Mash	60-65
Fly Ash	35-40
Rosin	67
Salt, Granulated	45-51
Salt, Rock	70-80
Sand, Damp	75-85
Sand, Dry	90-100
Sawdust, Dry	13
Soda Ash, Light	20-35
Sodium Nitrate, Dry	80
Sulphur, Powdered	50-60
Wheat	48
Zinc Oxide, Powdered, Dry	10-35



Typical Type 267 Solids Handling Eductor. For performance characteristics, contact Schutte and Koerting.



Typical Type 224 Sand and Mud Eductor

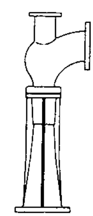
TABLE 12. Capacities of Water Jet Sand and Mud Eductors, Type 224 —3 Inch Size Only. To determine capacities for sizes other than 3 inch, multiply these capacities by the proper capacity ratio factor noted in Table 13.

SUCTION CAPACITY			
Operating Water Pressure, psi Gauge	40.0	50.0	60.0
Total Motive Fluid, gpm	69.5	77.5	85.0
Net Suction Fluid, gpm	30.0	34.5	38.5
Maximum Discharge Head in Ft.	22.0	26.0	32.0

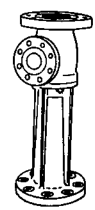
TABLE 13. Relative Capacities of Sand and Mud Eductors, Type 224.

Size Eductor in Inches	1½	2½	3	4	5	6
Capacity Ratio	0.29	0.62	1.00	1.85	2.80	3.80

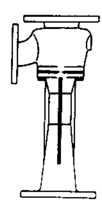
Performance Data for the Following Eductors can be Determined by Using the Procedure on Pages 8, 9 & 10.



Typical Type 222 Eductor

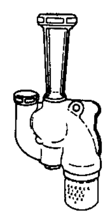


Typical Type 242 Eductor



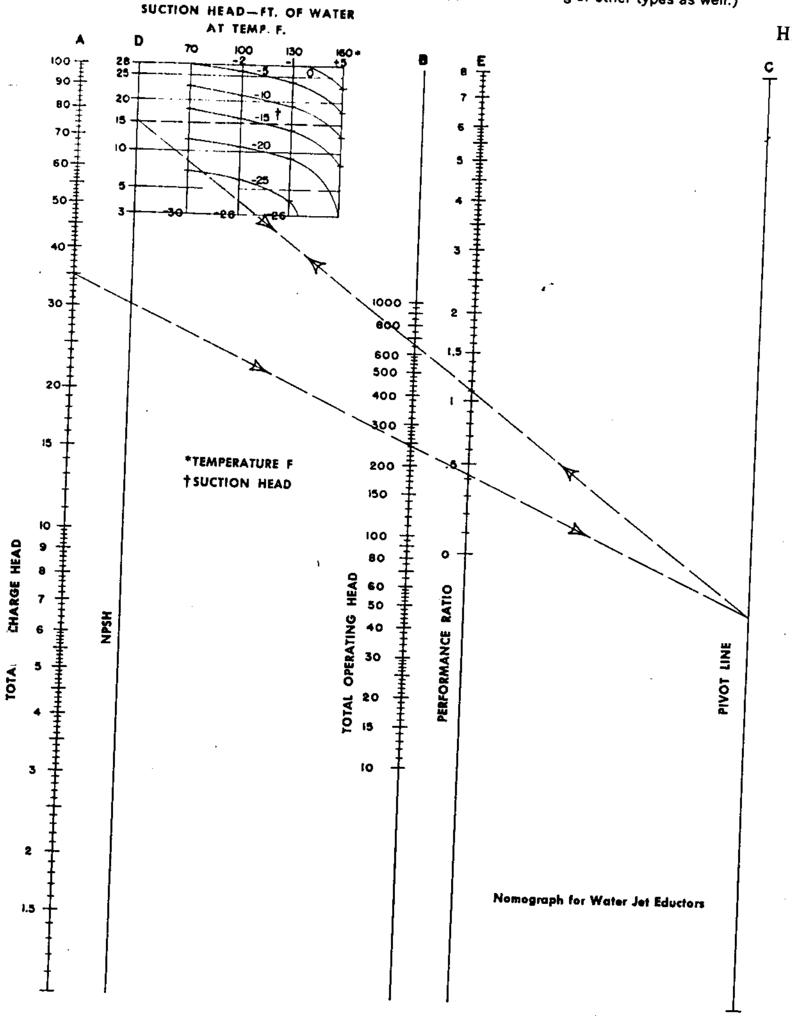
Typical Type 235 Eductor

(This unit's capacity 10% less than indicated by Nomograph)



Typical Type 222 Portable Eductor

Nomograph for Determining **Approximate** Performance Characteristics for Water Jet Eductors, Types 222, 242, 235, and 222 Portable. (This nomograph is also suitable for approximate sizing of other types as well.)



NOTE: In using the nomograph in connection with an application where the motive liquid is the greater in volume of two liquids, Type 242 Eductors are generally used. In applications where the suction fluid is greater, Type 264, Type 222 and Type 235 Eductors are generally used. Approximate sizes can be determined by selecting eductors with pipe connections appropriate to pipe sizes in Step 7.

Nomograph for Water Jet Eductors

Performance characteristics of standard and general purpose SK Water Jet Eductors can be determined from the tabular data included with the description of such eductors (Types 264, 224).

The following data and procedures can be used to determine approximate performance characteristics for those eductors which are individually designed to meet specific conditions. Using this procedure along with the nomograph above, the reader can determine whether or not an SK Eductor will perform a given job economically.

It should be noted, however, that the sizes of eductors noted in this bulletin are the sizes commonly manufactured by the company. Since it is possible to design, build, and supply other sizes, if conditions necessitate, it would be wise to submit your requirements to SK before deciding that an eductor cannot do your job.

The results obtained from the procedure which follows are approximations. Final calculations should be made by Schutte and Koerting Company engineers who will then recommend to you the proper type and size eductor required to perform a given operation.

1. **TOTAL HEAD (in ft. of fluid flowing):** Total difference between suction head and discharge head as measured from the level of the suction liquid to the level of discharge required, including pipe friction. (Line A in the nomograph, page 8.)
2. **TOTAL OPERATING HEAD (in ft. of fluid flowing):** Total difference between the motive and suction heads—or, the total difference between operating pressure and suction head. (Line B in the nomograph, page 8.)
3. **NET POSITIVE SUCTION HEAD (NPSH):** The head available at the centerline of the eductor to move and accelerate suction liquid entering the eductor mixing chamber. (NPSH is the difference between the suction pressure and atmospheric pressure corrected for the vapor pressure of the motive or suction fluid, whichever is higher.) (Line D in the nomograph, page 8.)
4. **PERFORMANCE RATIO:** Ratio of suction flow to motive flow in lb. of entrained liquid per lb. of motive liquid. (Line E in the nomograph, page 8.)

Sample Procedure

The following example, which is based upon data from the accompanying diagram of a typical installation, illustrates the basic procedure involved in approximating eductor performance requirements.

1. DETERMINE THE SUCTION HEAD

Suction Head = average suction lift during emptying of tank. (If suction fluid is not water, correct head to feet of water.)

$$\text{Suction Head} = \left(-4 + \frac{-13}{2}\right) \times \text{sp. gr. suction fluid}$$
$$= -10.5 \times 0.87 = -9.1 \text{ ft. of water}$$

(Quantities have a negative sign because of the location of the datum plane.)

2. DETERMINE THE DISCHARGE HEAD

Assume a specific gravity for the discharge mixture if suction fluid is not water.

Using a sp. gr. of 0.93 (an average between the sp. gr. of Toluene and water) for discharge mixture, then

$$\text{Discharge Head} = 25 \times \text{sp. gr. discharge mixture}$$
$$= 25 \times 0.93 = 23.3 \text{ ft. of water}$$

3. CALCULATE THE TOTAL HEAD AND THE TOTAL OPERATING HEAD

$$\text{Total Discharge Head (Line A)} = \frac{\text{Discharge Head} - \text{Suction Head}}{\text{sp. gr. discharge liquid}}$$
$$= \frac{23.3 - (-9.1)}{0.93} = 34.9 \text{ ft. of mixture}$$

$$\text{Total Operating Head (Line B)} = \frac{\text{Motive Head} - \text{Suction Head}}{\text{sp. gr. motive fluid}}$$
$$= \frac{(100 \text{ psig} \times 2.31 \text{ ft. water/psig}) - (-9.1)}{1.0}$$
$$= 240.1 \text{ ft. of fluid (in this case water)}$$

4. DETERMINE THE NET POSITIVE SUCTION HEAD (NPSH)

NPSH (Line D) = atmospheric pressure plus suction head minus vapor pressure (4.3 psia at operating temperature)

$$\text{NPSH} = 34 + (-9.1) - (+4.3) \times 2.31 \text{ ft. of water/psig}$$
$$= 34 - 9.1 - 9.9 = 15.00 \text{ ft. of water}$$

(In this example suction head is a negative quantity because of the location of the datum plane. The governing vapor pressure is motive or suction whichever is higher.)

NOTE: The NPSH figure can be determined without calculation using the small auxiliary chart to the right of Line D when the fluids are water.

5. REFER TO THE NOMOGRAPH TO DETERMINE THE PERFORMANCE RATIO

A. Lay a straight edge on the value, Total Head, on Line A and on the value, Total Operating Head, on Line B. Mark the point of intersection with pivot Line C.

B. Pivot the straight edge at the point of intersection on Line C to the value of NPSH on Line D.

C. The Performance Ratio is that point (value) on Line E which is intersected by the straight edge. In this example,

Performance Ratio = 1.1 lb. suction/lb. motive converted to a ratio in gallons, as

$$\text{Performance Ratio} = 1.1 \times \frac{\text{sp. gr. motive fluid}}{\text{sp. gr. suction fluid}}$$
$$= \frac{1.1 \times 1.0}{0.87} = 1.26 \text{ gal. suction/gal. motive}$$

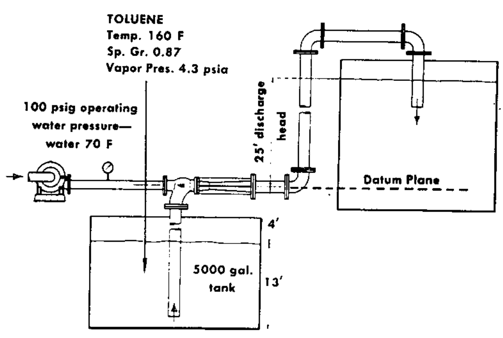
6. CALCULATE SUCTION FLOW TO EMPTY TANK

$$\text{Suction Flow} = \frac{5000 \text{ gal.}}{15 \text{ min.}} = 333.0 \text{ gpm}$$

$$\text{Motive Flow} = \frac{\text{Suction Flow}}{\text{Performance Ratio}}$$
$$= \frac{333}{1.26} = 264 \text{ gpm}$$

$$\text{Then, Discharge Flow} = 333 + 264 = 597 \text{ gpm}$$

continued on Page 10



Required: 15 min. to empty starting with 4' suction lift (negative head)

NOTE: After the weight ratio of "E" is obtained, the actual sp. gr. of the discharge mixture should be determined, for example

Sp. Gr. Mixture

$$= \frac{\text{suct. flow} \times \text{sp. gr. suct.} + \text{motive flow} \times \text{sp. gr. motive}}{\text{Discharge Flow}}$$

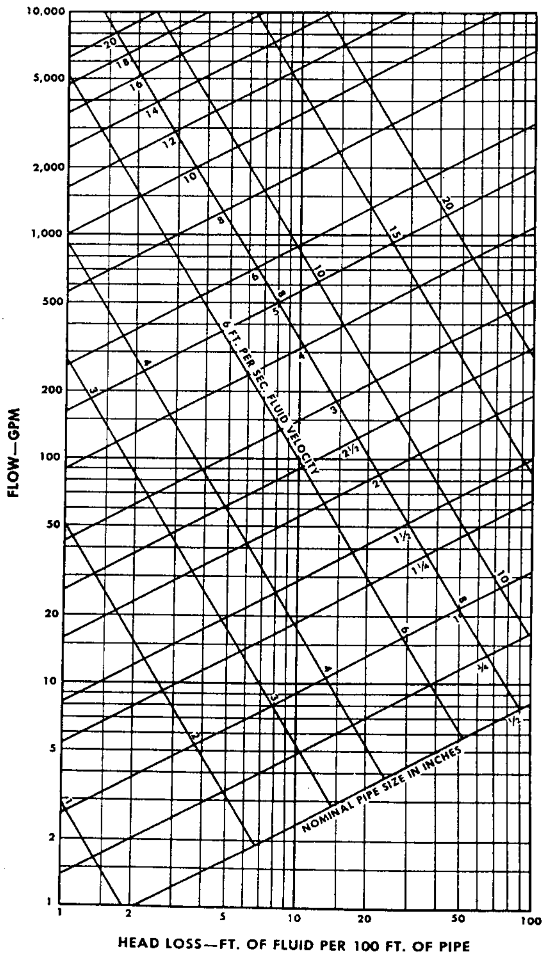
$$= \frac{333 \times 0.87 + 264 \times 1.0}{597}$$

$$= 0.93$$

If this calculated sp. gr. of the mixture does not closely agree with *assumed* sp. gr. of the mixture (Step No. 2), the approximation should be repeated using the final specific gravity.

7. DETERMINE HEAD LOSS DUE TO PIPE FRICTION
Using the final discharge flow approximation, refer to the chart below and calculate *head loss for the appropriate pipe sizes.* Expected head loss should be added to static heads and eductor recalculated.

8. USE PIPE CONNECTIONS AS GUIDE TO APPROXIMATE SIZES
Approximate sizes can be determined by selecting eductors with pipe connections appropriate to pipe sizes in Step 7.



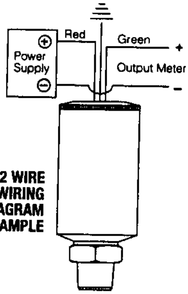
This chart is based on Williams and Hazen Formula using a constant of 1.00 for ordinary Wrought Iron Pipe. For friction loss in other types of pipe multiply the chart reading by the factors below:

1. Very smooth and straight Wrought Iron, Brass, Tin, Copper and Lead Pipe 0.54
2. Ordinary Straight Brass, Tin, Copper and Lead Pipe . . . 0.62
3. Smooth New Wrought Iron Pipe 0.71
4. Fairly Smooth New Wrought Iron Pipe and Rubber lined Hose 0.84
5. Ordinary Wrought Iron Pipe 1.00
6. Medium Old Wrought Iron Pipe and Linen Fire Hose . 1.22
7. Old Wrought Iron Pipe . . . 1.52
8. Very Rough Pipe 2.58
9. Badly Tuberculated Pipe . 5.46

NOSHOK TRANSMITTERS and TRANSDUCERS

Wiring Diagrams & Electrical Connections

SERIES 100



2 WIRE WIRING DIAGRAM EXAMPLE

100 Series	4-20mA 2 WIRE
+ Supply	Red/1/A
+ Output	Green/2/B
Case ground	Blue (or non-shielded)/4/D

Example: Red/1/A = Applicable color wire/bendix pin or din plug number.

Load Limitations 4-20mA Output Only

$V_{min} = 10V + (.022 \times R_L)$ 100 Series

$V_{min} = 12V + (.022 \times R_L)$ 300 Series

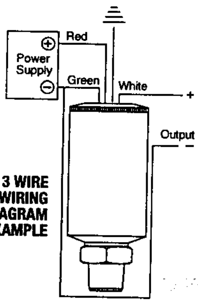
$R_L = R_S + R_W$

R_L = Loop Resistance (ohms)

R_S = Sense Resistance (ohms)

R_W = Wire Resistance (ohms)

SERIES 200

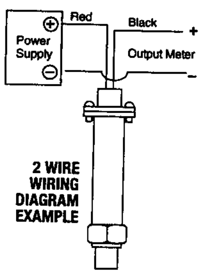


3 WIRE WIRING DIAGRAM EXAMPLE

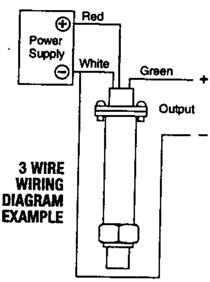
200 Series	0-5, 1-6, 0-10 1-11 VDC 3-WIRE
+ Supply	Red/1/A
Common	Green/2/B
+ Output	White/3/C
Case ground	Blue (or non-shielded)/4/D

Example: Red/1/A = Applicable color wire/bendix pin or din plug number.

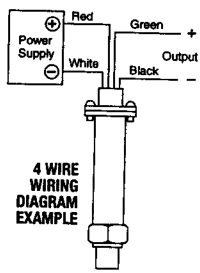
SERIES 300



2 WIRE WIRING DIAGRAM EXAMPLE



3 WIRE WIRING DIAGRAM EXAMPLE



4 WIRE WIRING DIAGRAM EXAMPLE

300 Series	MV 4 WIRE	4-20mA 2 WIRE	1-5, 1-6, 1-11VDC 3 WIRE	0-5, 0-10 VDC 4 WIRE
+ Supply	Red/A/1	Red/A/1	Red/A/4	Red/A/4
- Supply	White/D/4	-	White/D/2	White/D/2
- Output	Green/B/3	Black/B/2	Green/B/1	Green/B/1
- Output	Black/C/2	-	-	Black/C/3

Example: Red/1/A = Applicable color wire/bendix pin or din plug number.

Load Limitations 4-20mA Output Only

$V_{min} = 10V + (.022 \times R_L)$ 100 Series

$V_{min} = 12V + (.022 \times R_L)$ 300 Series

$R_L = R_S + R_W$

R_L = Loop Resistance (ohms)

R_S = Sense Resistance (ohms)

R_W = Wire Resistance (ohms)

The Instrumentation Company

NOSHOK INCORPORATED

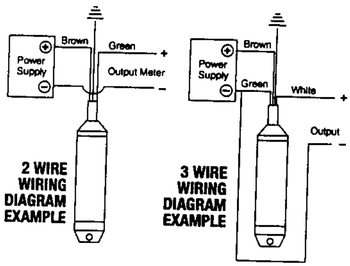
CORPORATE HEADQUARTERS
17820 Englewood Drive
Middleburg Hts., Ohio 44130
216/243-0888 • Fax: 216/243-3472

E-MAIL ADDRESS: noshok@cybergate.net
WEB SITE: http://www.oettco.com/noshok.html

NWD 96-1

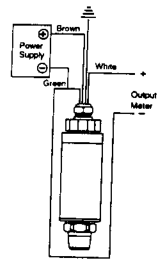
Wiring Diagrams and Electrical Connections for: 612, 615, 625, 640 and 700 Series

SERIES 612



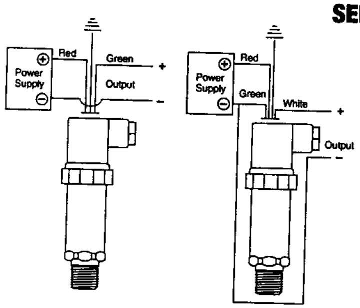
	4...20mA (2-wire)	0...10VDC (3-wire)
+ Supply	brown	brown
Common		green
+ Output	green	white
Case ground	blue	blue

SERIES 640



	0...20mA/0... 5VDC 4...20mA/0...10VDC (three wire)	
+ Supply	1, A	brown
- Supply	2, B	green
+ Output	3, C	white
- Output	2, B	green
Case ground	5, E	blue

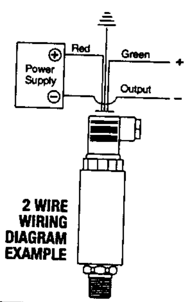
SERIES 615



615 Series	Voltage Output
+ Supply	Brown (or Red)/1/A
Common	Green/2/B
+ Output	White/3/C
Case ground	Blue (or non-shielded)/4/D

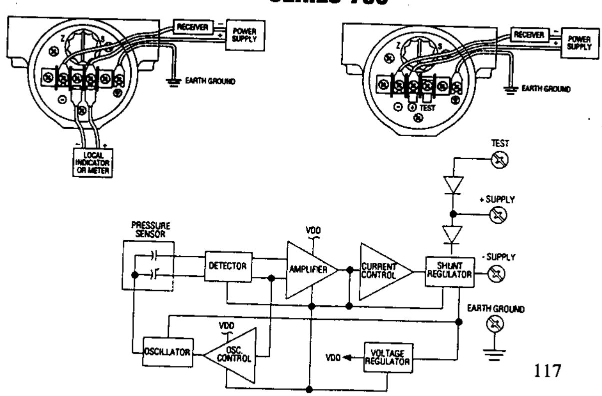
615 Series	4-20mA 2-Wire
+ Supply	Brown (or Red)/1/A
+ Output	Green/2/B
Case ground	Blue (or non-shielded)/4/D

SERIES 625



625 Series	4-20mA 2-Wire
+ Supply	Brown (or Red)/1/A
+ Output	Green/2/B
Case ground	Blue (or non-shielded)/4/D

SERIES 700



FAXIT! ...0-747-4244

...copy This Form
...form for each product ...you are selecting.

Page# ___

FaxIt! Order Sheet is Page 1 if placing an order.

Name MAX BECK
Company ARD ENVIRONMENTAL, INC
Street 9115 WHISKEY BOTTOM ROAD
City LAUREL State MD Zip 20723
Phone (410) 724-0004 Fax (301) 497-1645
This is a ☐ Request for a Quote ☑ Order P.O.# 9396
Quantity Needed 1 Date Required 3/19/97
Shipping Method: AR Partials Accepted: ☐ Yes ☑ No

...ustom Length Float Type Level Switches (Pages A-27 to A-40)

...pplication Environmental Conditions

This information is essential to the accurate and proper operation of your GEMS configurable sensors. Please complete fully and accurately.

1. Liquid Media: DIRTY WATER
2. Pressure: Minimum AMB psig Maximum AMB psig
3. Temperature: Minimum 0 °F Maximum 100 °F
4. Specific Gravity: Minimum 1.0 Maximum 1.0
5. Viscosity: 5 SSU
6. Tank Material: FIBERGLASS
   Tank Depth: 79" & 72"
7. Unit is Mounted In: ☒ Tank Top ☐ Tank Bottom

1. Series (Page No.):
☐ LS-300 (A-27) ☐ LS-700 (A-31) ☐ LS-700-EP (A-34)
☐ LS-800PVC (A-36) ☐ LSP-800 (A-38) ☐ LS-800 (A-40)
☑ LS-800-A (A-41)

2. Mounting Type:
☐ Type A ☐ Type B ☐ Type C ☐ Type D
Type E ☐ Type F ☐ Type 1 ☐ Type 2
Type 3 ☐ Type 4 ☐ Type 5 ☐ Type 6

3. Mounting and Stem Material (if choice available):
☐ Brass ☐ Polypropylene
☐ PVC ☐ Polysulfone
☐ PVDF ☐ Carbon Steel (Flanges Only, in association with stainless steel stems.)
☑ 316 Stainless Steel

4. Mounting Position:
☑ Tank Top ☐ Tank Bottom

5. Float Part Number: 110558
Matching floats will be used at each actuation level specified.

6. Switch Type and Rating:
A. ☐ Group I ☐ Group II
☐ Group III ☑ Group IV
B. ☐ SPST ☑ SPDT (20 VA only)
C. ☐ 20 VA ☐ 50 VA ☐ 100 VA

7. Switch Actuation Level

A.

Actuation Level	Distance to Actuation Level – Inches* #1	#2	SPST Switch Operation** (Check Type) N.O.	N.C.
L6	6.0"	5.0"		
L5				
L4				
L3				
L2				
L1***	72.0"	65.0"		

* Measured from inner surface of mounting plug or flange.
** Switch position is "normal" with unit dry (tank empty).
*** L1 is the distance to the lowest actuation level with mounting "up," and is the distance to the highest actuation level with mounting "down."

(✱) B. Length Overall 74" & 67" inches (Customer supplied support bracket assembly recommended for lengths over 72".)

8. Lead Wire Length:
☑ 12" ☐ 24" ☐ Other: ______ inches.

Options:
☐ Temperature Switch: ____ °F Temperature Setting; On rising temperature, switch...
☐ Opens ☐ Closes
☐ Slosh Shield ☐ Collars
☐ 1/2" NPT Conduit Connection (LS-700 Series Only)
J-Box Electrical Connection:
☐ Explosion Proof Type ☐ Explosion Proof/CSA Type
☒ NEMA 4 Type ☐ Plastic ABS Type

Please contact GEMS Sensors Division for any configuration or special requirements not covered on this form. **800-321-6070**

Quote $ ________ Date Quoted ___/___/___

(✱) PER CONVERSATION WITH MARK ZABAWA TUBE CONSTRUCTION RECOMMENDED

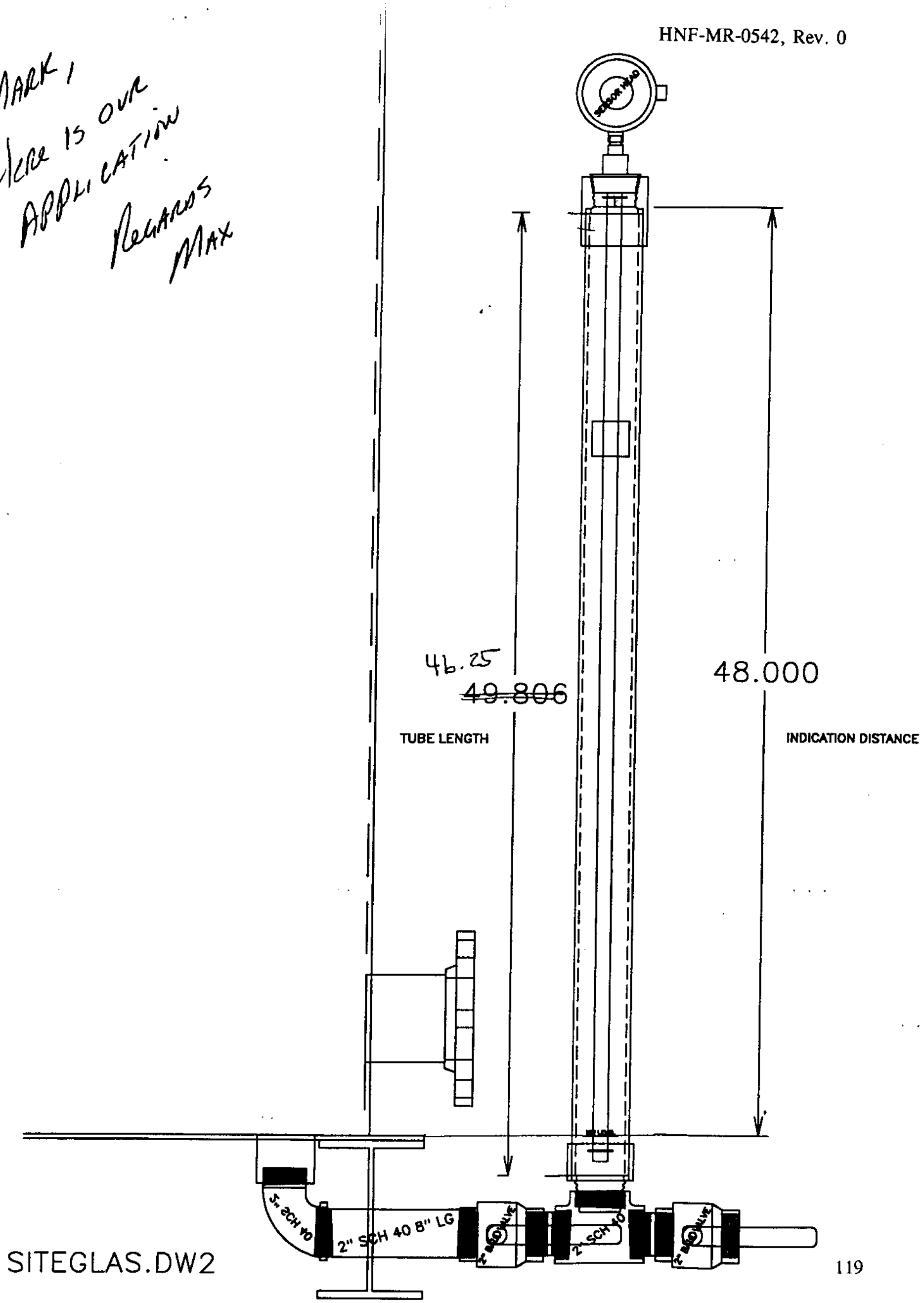
Gems Sensors
An Imo Industries Business

Gems Sensors
One Cowles Road
Plainville, CT
06062-1198
tel 860.747.3000
fax 860.747.4244

CUSTOM LENGTH FLOAT TYPE LEVEL SWITCHES

FAXIT!

Mark,
Here is our
application.
Regards
Max



☑ Product Check List

FAXIT! 860-747-4244

Photocopy This Form

Use one form for each product type you are selecting.

Page# ___

FaxIt! Order Sheet is Page 1 if placing an order.

Name MAX BECK
Company ARD ENVIRONMENTAL, INC.
Street 9115 WHISKEY BOTTOM Rd.
City LAUREL State MD Zip 20723
Phone (410) 724-0004 Fax (301) 497-1645
This is a ☑ Request for a Quote ☐ Order P.O.# ___
Quantity Needed 4 Date Required 3/7/97
Shipping Method: FASTEST Partials Accepted: ☐ Yes ☑ No

Float Type Level Transmitters – Small Size Alloys (Pages H-7 to H-8)

Application Environmental Conditions

This information is essential to the accurate and proper operation of your GEMS configurable sensors. Please complete fully and accurately.

1. Liquid Media: WATER
2. Pressure: Minimum AMB psig Maximum AMB psig
3. Temperature: Minimum 0 °F Maximum 100 °F
4. Specific Gravity: Minimum 1.0 Maximum 1.0
5. Viscosity: N/A SSU
6. Tank Material: STEEL / PVC
Tank Depth: 5 FEET
7. Unit is Mounted In: ☐ Tank Top ☐ Tank Bottom ☑ SITEGLASS

1. Series:
☐ XM-800 ☒ XT-800

2. Mounting Type:
☐ Type 1 ☒ Type 3 ☐ Type 4

3. Materials:
a. Stem:
☐ Brass* ☒ 316 Stainless Steel
b. Mounting:
☐ Brass* ☒ 316 Stainless Steel
☐ Carbon Steel (Type 4 flange only)
* (Type 1 and Type 3 only)

4. Float Type:
☒ Buna N (43359) ☐ Stainless Steel (43590)

5. Dimensions:

Float Type Selected	Indicating Length (Whole Inches)	+	C Dimension ±1/16" (1.6 mm)	+	Constant	=	Overall Length (70" (177.8 cm); Max.)
Buna N	48	+	0.25	+	2-1/2" (63.5 mm)	=	50 3/4"
Stainless Steel		+		+	3-7/16" (87.3 mm)	=	

Notes:
1. Indicating Length: 1/2" Increments
2. C Dimension: 1/4" (6.4 mm) min.; 1-1/4" (31.8 mm) on XT-800 Series Type 1 only)
c. Overall Length (complete one line only):

6. Input/Output:
a. Optional 24 VDC Power Supply:
☐ 115 VAC input ☐ 230 VAC input
b. Signal Conditioners (XT-800 Series Only):
☐ 51965 ☐ 51970 ☐ 52536
☐ 52537 ☒ 52555 ☐ 112300
☐ 52544-1

Optional Receivers – Section J
☐ The designated receiver is planned to be used with the transmitter specified above.
Receiver Part Number:
|_|_|_|_|_|_|_| – |_|_|_|_|_|
Note: Spaces are not completely filled out in all cases.

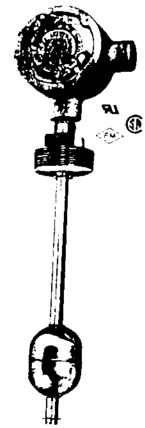
Please contact GEMS Sensors Division for any configuration or special requirements not covered on this form. **800-321-6070**

Quote $ ___ Date Quoted ___/___/___

IMO
Imo Industries Inc.
Gems Sensors Division
One Cowles Road
Plainville, CT 06062-1198
860-747-3000

Small Size – Alloys

XM/XT-800 Series Offer Both Analog and Digital Output



- Stainless or Brass Mountings and Stems
- 1/4" Resolution
- Lengths to 70 inches

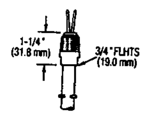
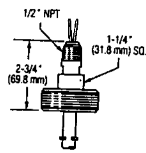
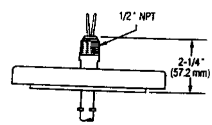
These compact transmitters feature the rugged durability of stainless steel or brass construction. The XM-800 series provides analog output, and combine with GEMS Analog Meter Receiver Stations and compact Level Cubes described in this catalog. Our versatile XT-800 Series adds a choice of signal conditioning for use with GEMS digital receivers or other digital instrumentation and control equipment.

Approvals

All XM-800 and XT-800 Series transmitters carry the following commercial approvals:
FM Approved, Explosion-Proof.
UL-Recognized.

XM-800 Series transmitters only:
CSA Listed.

1. Mounting Types

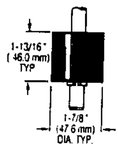
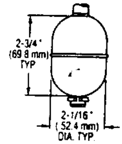
	Type 1 1/2"NPT	Type 3 2"NPT	Type 4 3"150# Flange
			
Stem Material	Brass or 316 Stainless Steel		316 Stainless Steel
Mounting Material	Brass or 316 Stainless Steel		Carbon or 316 Stainless Steel
Float Stop Material	Grip Rings (18-8 Stainless Steel)		
Operating Temperature* **With J. Box Mounted or XM Signal Conditioners**	Oil: -40°F to +230°F (-40°C to 110°C), Water to +180°F (82.2°C)—Buna N Float -40°F to +230°F (-40°C to 110°C)—Stainless Steel Float		
With Stem Mounted Signal Conditioners	+5°F to +160°F (-15°C to +70°C)		
Operating Pressure	Dependent on Float Type; See Next Page		
Overall Length, Max.	70"(177.8 cm); please consult factory for longer lengths		

* Consult factory for higher temperature ranges.

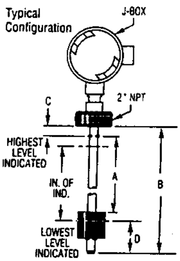
LEVEL TRANSMITTERS

2. Float Types

Either of these float configurations can be used with all compact transmitters shown below.

Float Material	Buna N	Stainless Steel
Float Dimensions		
Part Number	43359	43590
Min. Liquid Specific Gravity	.55	.75
Operating Pressure, Max.	150 PSI	300 PSI

3. Dimensions



A: Float Travel = Indicating Length + 3/8"(9.5 mm)
B: Overall Length (Not to Exceed 70 inches):
With Buna N Float = Indicating Length + 2-1/2"(63.5 mm) + C
With Stainless Steel Float = Indicating Length + 3-7/16"(87.3 mm) + C
C: Distance to Float Stop = 1/4"(6.4 mm) Min.;
1-1/4"(31.8 mm) Min. on Type 1 (XT only); specified by customer.
D: Distance lowest level indicated to end of stem
With Buna N Float = 1-5/16"(33.3 mm)
With Stainless Steel Float = 1-3/4"(44.5 mm)

Notes:
1. Distances for highest and lowest level indicated are based on use in liquid with specific gravity of 1.0, and are approximate values.
2. Indicating length must be specified in even increments of 1/2".

4. Input/Output

For XM-800 Series, no special output designation is necessary.
For XT-800 Series, specify the desired signal conditioning by Part Number.
Additional information about GEMS signal conditioning modules is found on Page H-15.

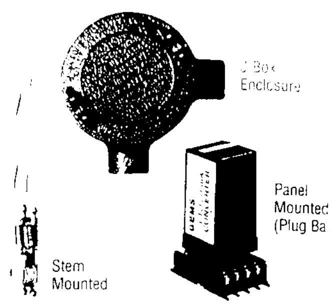
Series	Input Voltage	Output Signal	Part Number	Electrical Termination	Compatible Mountings		
					Type 1	Type 3	Type 4
XM-800	10 to 30 VDC	Proportional Voltage	–	Lead Wires (3), #22 AWG, 24"(60.9 cm), Teflon® Jacket	•	•	•
XT-800	8 to 24 VDC*	0-5 VDC	51965	Lead Wires, #22 AWG, 24"(60.9 cm), Teflon® Jacket	•	•	•
	14 to 30 VDC*	0-12 VDC	51970		•	•	•
	8 to 24 VDC	0-5 VDC	52536	Junction Box		•	•
	15 to 30 VDC	0-12 VDC	52537			•	•
	18 to 30 VDC**	0-12 VDC with Hi and Low Alarms	52544-1			•	•
	10 to 40 VDC	4-20 mA	52555			•	•
		4-20 mA	112300	Panel Mount with Plug-In Base	•	•	•

* Stem mounted.
** Consult factory for other alarm functions.

Signal Conditioning Modules, 0-5 VDC, 0-12 VDC and 4-20 mA Outputs

Provide signal conditioning as an integral part of the XT-Series and SureSite® Transmitters

- ▶ Stem Mounted
- ▶ Panel Mounted
- ▶ J-Box Enclosed
- ▶ Units with Preset High and Low Alarm



GEMS' signal conditioners provide outputs for direct connection to a wide range of instrumentation. They are ideal for large, multi-tank complexes. Units with 4-20 mA outputs are particularly well suited for instrumentation control loops. No intermediate receiver is required.

Specifications (Not included in table below)

System Accuracy	With XT-36000 Series Transmitters: ±0.4% of full scale or ±1", whichever is greater. With XT-800 Series Transmitters: ±0.4% of full scale or ±1/2", whichever is greater.
Operating Temperature	+5°F to +160°F (-15°C to +71.1°C)
Storage Temperature	-40°F to +212°F (-40°C to +100°C)
Output Temperature Coefficient (% of full scale, max.)	±0.00388%/°F (±0.007%/°C)
4-20 mA Types	To within ± 1% of 16 mA

Modules with High and Low Alarms

Featuring two SPDT switches, these units can trigger alarms, or start/stop pumps, open/close solenoid valves, etc. Ideal for use in process control applications. The high level alarm can be set between 50% and 98% of full indicating range and low level can be set between 2% and 50% of full range. If not specified, alarms are set 95% and 5% respectively.

Alarm Specifications

Configuration	1 high, 1 low, SPDT, each alarm
Contact Rating	2A @ 28 VDC; 1A @ 115 VAC
Repeatability	±0.1% of full scale with differential of .015% of full scale
Temperature Coefficient	±0.001388% of full scale/°F (±0.0025% of full scale/°C)

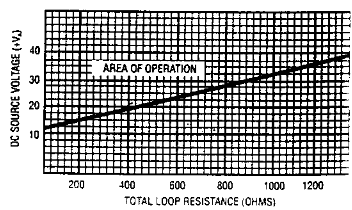
Power Supply Module

Input Power	Part Number
115 VAC, 60 Hz	52560
230 VAC, 60 Hz	52570

Operates on 115 VAC or 230 VAC inputs to supply a regulated 24 VDC the signal conditioned transmitter where external VDC power is not available. Maximum Load: 70 mA.

Excitation Required for Transmitters using 4-20 mA Signal Conditioners

The minimum excitation required for operation of transmitters with 4-mA, DC signal converters (See Chart) can be determined for a given t loop resistance from the graph shown. (Total loop resistance = the su of the DC termination resistance plus loop resistance.) For optimum operation, which is a function of source voltage (+V_s) and total loop resistance, the source voltage value used should be above the minim load line for the related loop resistance.



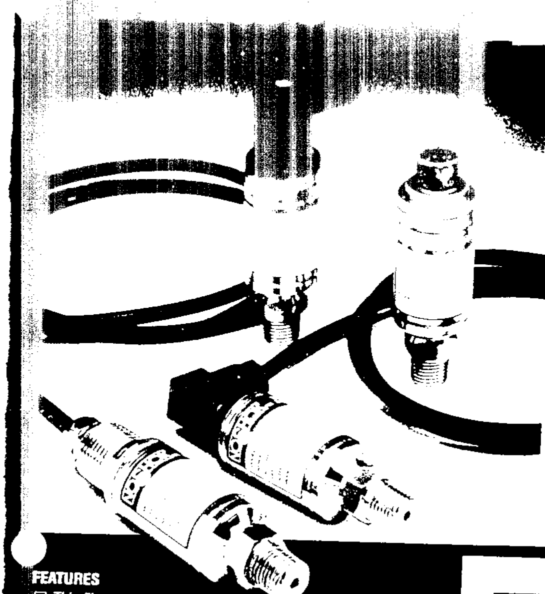
How To Order

Select Part Number based on Output Signal desired and Transmitter Series being used.

Output Signal	Input Voltage	Electrical Termination	Module Part Numbers For: XT-800 Series	XTP-800	XT-36488	XT-36490	SureSite Low Temperature	SureSite High Temperature
0-5 VDC*	8-24 VDC	Lead Wires, #22 AWG 24"(60.9 cm), Teflon® Jacket	51965	51965	–	–	–	–
0-12 VDC*	14-30 VDC		51970	51970	–	–	–	–
0-5 VDC	8-24 VDC	Junction Box	52536	154687	154687	52532	86156	52536
0-12 VDC	15-30 VDC		52537	154685	154685	52533	85997	52537
0-12 VDC Hi & Lo Alarms	18-30 VDC		52544-1	154091-1	154091-1	52541-1	86157	52541-1
4-20 mA	10-40 VDC		52555	116970	116970	[illegible]	86158	152800
		Panel Mount with Plug-In Base	112300					

*Stem mounted.

SIGNAL C[illegible]
— ±1% GAIN
ERROR. —
w/o CALIBRATION
Rick



SERIES 100

4-20mA CURRENT OUTPUT PRESSURE TRANSDUCERS

DESCRIPTION

Noshok 100 Series Current Output Pressure Transducers were designed to provide a previously unequalled level of performance, utilizing Piezo Resistive or Thin film sensor technology dependent on pressure range. 100 Series Transducers are highly accurate, shock resistant and extremely stable over a long period of time. EMC, electromagnetic compatibility, to IEC 801 has been engineered in as a standard feature along with reverse polarity, overvoltage, and short circuit protection.

Advanced manufacturing techniques combined with technologically advanced standard features allow Noshok to offer a level of performance previously found only on transducers costing hundreds of dollars more.

A final electrical output and calibration inspection is performed on all Noshok Transducers and Transmitters after final assembly and prior to shipment to insure 100% "out of the box" reliability.

FEATURES

- ☐ Thin film sensor, technology
- ☐ Current output signal
- ☐ High accuracy and long term stability
- ☐ Electromagnetic interference protection
- ☐ Available in gauge or absolute measuring ranges
- ☐ 0-5 and 0-10 PSI ranges available
- ☐ High alternating load resistance
- ☐ High overpressure protection
- ☐ Dynamic or static measurement capability
- ☐ Corrosion resistant stainless steel construction
- ☐ Compact size
- ☐ Mini-Hirschmann with mating connector electrical connection standard
- ☐ Compatible with Noshok 1900 series smart system indicators

APPLICATIONS

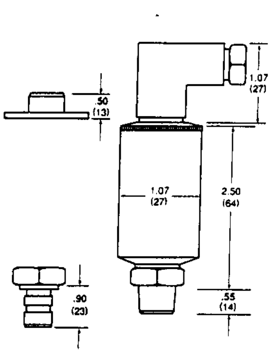
- ☐ Hydraulic and pneumatic systems
- ☐ Industrial machinery and machine tools
- ☐ Injection molding machines
- ☐ Stamping and forming presses
- ☐ Pumps and compressors
- ☐ Laboratory and test equipment
- ☐ Railroad equipment
- ☐ HVAC systems
- ☐ Medical
- ☐ Refrigeration equipment

SPECIFICATIONS

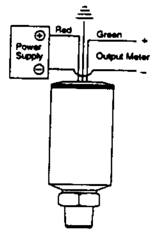
Output Signal	4-20 mA, 2 wire
Pressure Ranges	Vacuum and compound through 0-15000 PSI; gauge and absolute
Proof Pressure	0-5, 0-10, 0-7500 through 0-15000 PSI: 1.5 times range 0-15 PSI through 0-6000 PSI: 2 times range
Burst pressure	0-5, 0-10, 0-7500 through 0-15000 PSI: 2 times range 0-15 PSI through 0-6000 PSI: 5 times range
Accuracy (BFSL or RSS) (includes repeatability, hysterisis and linearity)	± 0.5% full scale standard ± 0.25% full scale optional
Repeatability	± 0.05% full scale
Hysterisis	± 0.1% full scale
Stability	± 0.2% full scale per year
Input Excitation	12-30 VDC unregulated
Temperature ranges	Compensated 32° to 175°F/0 to 80°C Effect ± 0.03%/50°F Storage -40° to 212°F/-40° to 100°C Medium -22° to 212°F/-30° to 100°C Ambient -40° to 185°F/-40 to 85° C
Response time	less than 1 ms (between 10-90% full scale)
Pressure cycle limit	150Hz
Operating life	100 million cycles
Adjustment	± 5% full scale of zero and span
Environmental protection	NEMA 4x, DIN IP65 (IEC 529)
Electromagnetic capability per IEC 801	Part 2 – ESD Level 2 Part 3 – Fields (RFI) Level 2 Part 4 – Burst Level 3 Part 5 – Surge Level 2
Electrical protection	Reverse polarity, overvoltage and short circuit protection
Shock	Less than ± 0.05% full scale effect or 100g's @ 20ms on any axis
Vibration	Less than ± 0.05% full scale effect for 35g's @ 5-2000 Hz on any axis.

PRESSURE TRANSDUCERS SERIES 10[illegible]

DIMENSIONS



WIRING DIAGRAMS AND ELECTRICAL CONNECTIONS



2 WIRE WIRING DIAGRAM EXAMPLE

100 Series	4-20mA 2 WIRE
+ Supply	Red/1/A
+ Output	Green/2/B
Case ground	Blue (or non-shielded)/4/D

Example: Red/1/A = Applicable color wire/bendix pin or din plug number.

Load Limitations 4-20mA Output Only

$V_{min} = 10V + (.022 \times R_L)$ 100 Series
$V_{min} = 12V + (.022 \times R_L)$ 300 Series
$R_L = R_S + R_W$
R_L = Loop Resistance (ohms)
R_S = Sense Resistance (ohms)
R_W = Wire Resistance (ohms)

ORDERING INFORMATION

SERIES 100

PRESSURE RANGES

0-30"VAC	**30V**	30"/200 PSIG	**30/200**	0-60 PSIG	**60**	0-600 PSIG	**600**	0-5000 PSIG	**5000**	0-15PSIA	**15A**
30"/15 PSIG	**30/15**	30"/300 PSIG	**30/300**	0-100 PSIG	**100**	0-750 PSIG	**750**	0-6000 PSIG	**6000**	0-30PSIA	**30A**
30"/30 PSIG	**30/30**	0-5 PSIG	**5**	0-150 PSIG	**150**	0-1000 PSIG	**1000**	0-7500 PSIG	**7500**	0-60PSIA	**60A**
30"/60 PSIG	**30/60**	0-10 PSIG	**10**	0-200 PSIG	**200**	0-1500 PSIG	**1500**	0-10000 PSIG	**10000**	0-100PSIA	**100A**
30"/100 PSIG	**30/100**	0-15 PSIG	**15**	0-300 PSIG	**300**	0-2000 PSIG	**2000**	0-15000 PSIG	**15000**	0-150PSIA	**150A**
30"/150 PSIG	**30/150**	0-30 PSIG	**30**	0-500 PSIG	**500**	0-3000 PSIG	**3000**			0-200PSIA	**200A**
										0-300PSIA	**300A**

PSIG = Gauge Pressure PSIA = Absolute Pressure Other ranges available on special request

ACCURACY (BFSL)	**1** ± 0.5% FULL SCALE	**2** ± 0.25% FULL SCALE
OUTPUT SIGNAL	**1** 4-20mA	
PROCESS CONNECTIONS	**2** 1/4" NPT MALE	**3** 7/16"-20 UNF (adjustable per SAE J-514) other connections available upon request
ELECTRICAL CONNECTIONS	**1** 36" CABLE (connected to option 7) **2** 4 PIN BENDIX **3** 6 PIN BENDIX	**6** 1/2" NPT CONDUIT (w/36" cable) **7** MINI-HIRSCHMANN (w/mating connector)
OPTION	SS THREADED ORIFICE **ORF**	

EXAMPLE

100 3000 2 1 2 7

Series	100
Pressure Range	3000 PSIG
Accuracy	±0.25%
Output Signal	4-20mA, 2 wire
Process Connection	1/4" NPT MALE
Electrical Connection	MINI HIRSCHMANN

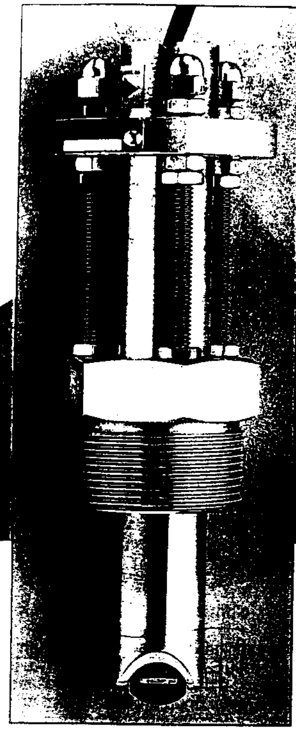
MODEL FP6000 ADJUSTABLE DEPTH BRASS FLOW SENSOR

USA 2 YEAR WARRANTY

Doesn't Need Special Installation Fittings!

- One Sensor for Lines 1½″ to 36″
- No Special Fitting Needed
- Low cost

$330



Shown Smaller Than Actual Size

When you want it all in one flow sensor...you want the FP-6000 sensor. Accuracy...Durability...Versatility...Easy installation...Low cost, the FP-6000 gives you all this.

The FP-6000 accurately measures a wide variety of fluids from flow rates as low as 0.7 feet per second up to 30 feet per second. It generates a sine-wave frequency output linearly proportional to flowrate with ±0.2 fps accuracy.

The FP-6000 is versatile because it adjusts to various pipe sizes. There is no need to buy a different sensor for every change in pipe size. You can position the FP-6000 to give you accurate readings in any size pipe, 1½″ to 36″, allowing tremendous cost savings.

And no special fittings are required. A standard 1½″ threadolet or saddle fitting is all you need.

Made of rugged brass, the FP-6000 can handle harsh environments. The output signal can be sent up to 100 feet without amplification. Each FP-6000 sensor comes with a 25′ cable and all necessary mounting hardware.

SPECIFICATIONS

Output Signal: Sine Wave
Output Frequency: Approximately 9-12 Hz/fps
Source Impedance: 10,000 Ohms
Flow Rate Range: .7 to 30 feet per second (fps)
Linearity: ±1% of full range
Repeatability: ±0.5% of full range
Maximum Operating Pressure: 225 PSI
Maximum Operating Temperature: 212°F
Maximum Amount of Suspended Particulate Matter: Up to 100% with particulate size not exeeding 5mm in cross section or length 10%
Max. Viscosity: 1 centipoise (water); up to 5 cp above 5 fps velocity

MATERIALS

Sensor

Rotor: CD4MCu Stainless Steel
Rotor Shaft: 316 Stainless Steel
Transducer Body: C 36000 Brass
Bearing: Carbon/graphite filled fluoroplastic (Fluoroloy B)

Fitting

Housing & Cover: Brass
Seal: Viton O-Ring
Shipping Weight: 6 lbs.
Dimensions: From flange to rotor pin, 5.94″

IN STOCK FOR FAST OFF-THE-SHELF DELIVERY!

To Order (Specify Model No.)

Part No.	Description	Price
FP-6000	Adjustable Brass Flow Sensor	$285

Complete replacement rotor/paddlewheel kit FP-52509-[illegible] $42.

[illegible]ATCHER
[illegible]r Frequency Input

Model DPF7[illegible]

$260

Basic Unit

- **Measures Rate from 0.5 Hz to 30 kHz**
- **Totalizes Up or Down From -99,999 to 999,999 or Acts as Accumulating Stopwatch**
- **Provides Fast, Low Frequency Measurements**
- **6-Digit, 7-Segment LED, 14.2 mm (0.56") High**

SIGNAL INPUT CHOICES (SELECTABLE BY DIP SWITCH)

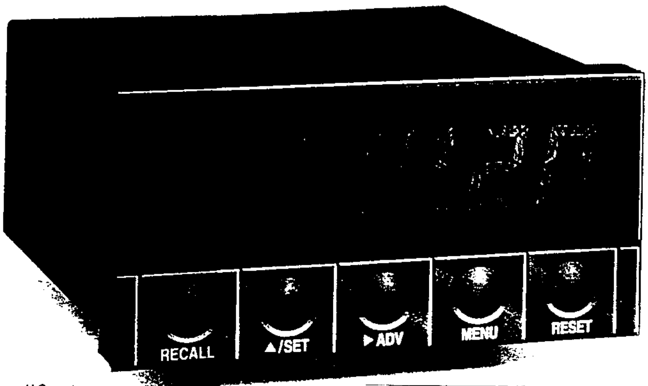
- **TTL Compatible with Protection to 15 V**
- **Low Level (25 mV rms)**
- **High Level Signals Protected to 115 V**
- **NAMUR**
- **Open Collector PNP or NPN**

REGULATED SENSOR EXCITATION OUTPUT

- **12.4 V @ 100 mA or**
- **8.2 V @ 70 mA or**
- **5.0 V @ 50 mA**

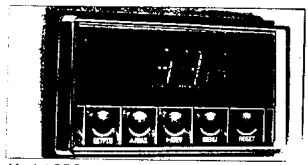
The DPF700 Series is front-panel programmable for rate or total display; it does not indicate both. (See OMEGA's DPF75 meter on page M-22 to indicate rate and total.) It offers user programming via the five front-panel keys. Scale factor may be programmed from -99,999 to 999,999 (any decimal point, multiply or divide), while offset may be programmed from -99,999 to 999,999 (any decimal point).

Above a display of 999,999, the DPF700 displays rate or total in exponential format, up to 9.99E9. It can totalize up to 500 billion input pulses, depending on your divide-by factor. Programs are stored in non-volatile memory, with three levels of program lockout for security. Fixed decimal point or autoranging is standard.



U.S. and Int'l Patents. Used Under License

Shown Actual Size



Model SPC18 ⅛ DIN Splashproof Cover, $1[illegible]

The DPF700 is compatible with a wide variety of frequency (pulse) output flowmeters and proximity switches. When purchased with the dual relay board, the DPF700 can be used as a two-stage batch controller.

SPECIFICATIONS

Functions: Rate or totalize selected by menu

INPUTS

Type: Single input. TTL, CMOS, NPN open collector, contact closure and magnetic pickup compatible; selected by dip switch. Non-isolated.

Level: max. 60 V; min. 25 mV rms

Accuracy: ±1/2" LSD of total; 0.01% of the rate ±1/2 LSD

Rate Measurement Technique: 1/TAU

Gate Time: 0.30 sec

Trigger Slope: Selectable by DIP switch

Leading Zeros: Blank

Power: 115 ±15% Vac @ 5 Watts max. or 7.5-13 Vdc @ 260 mA, field selectable. For DC power input, add 180 mA for analog board, add 120 mA for relay board, 20 mA for RS-232 board.

Dimensions: 48 H x 96 W x 152 mm D (1.89" x 3.78" x 6.0")

Panel Cutout: 45 H x 92 mm W (1.772" x 3.622")

Weight: 574 g (1.27 lb)

*Line voltage is limited to 115-230 ±10% for excitation >50 mA

IN STOCK FOR FAST DELIVERY!

To Order *(Specify Model Number)*

Model No.	Price	Description
DPF701	$260	115 Vac 7.5-13 Vdc Powered
DPF702	260	230 Vac 7.5-13 Vdc Powered
Field Installable Option Boards		
DPF700-A	$100	Analog Output Board
DPF700-R	75	Dual 5A Relay Board
DPF700-232	60	RS 232 Output Board

Comes with gray BUMPER BAND protective rubber guard and complete operator's manual.

Ordering Examples: *1) DPF701 meter ($260) plus DPF700-A analog output board ($100), $260 + 100 = **$360** OCW-3 three-year warranty extension [illegible] ($360) = **$36***
*2) DPF702 meter ($260) plus SPC18 splashproof cover [illegible] **$275***

TURBINE AND PADDLE WHEEL FLOWMETERS
Flow Reference Section

INTRODUCTION

Turbine flowmeters continue to be the most common way to measure flow electronically in a wide range of industries. A review of the advantages turbine flowmeters have to offer provides insight into the growing popularity of this versatile flow transducer.

Turbine flowmeters offer:

- Wide flow rangeability
- Outstanding accuracy at low cost
- Construction materials that permit applications in many process fluids
- Simple, durable, field repairable construction
- Flexibility in associated electronic readout devices for flow control and computer interface
- Wide variety of process connections
- Operation over a wide range of temperature and pressure

FLOWMETER SELECTION TO OPTIMIZE THE TURBINE ADVANTAGE

The turbine advantage may be defined as the unique blend of desirable attributes particular to the turbine type flowmeter, resulting in a transducer with the ability to measure wide flow ranges with outstanding accuracy, at low cost, with a convenient pulse output.

Flowmeter selection requires more than sizing of flow rates and selection of process fittings. The flowmeter must be compatible with the flow media to be measured, and must operate over the desired temperature and pressure range. In addition, maintenance requirements must be evaluated consistent with the installation, service and use. The following tutorial provides the background information required for the selection of a turbine flowmeter. Additional information may be found on the individual product pages within this section.

Operation

Within the turbine flowmeter, the flowing media engages a vaned rotor, causing it to rotate at an angular velocity proportional to the flow rate. As the turbine rotates, an AC voltage is induced in a magnetic pickup coil mounted externally to the fluid process. As each turbine blade passes the base of the pickup coil, the total magnetic flux density is changed, thus inducing a single voltage pulse. Each pulse represents a distinct finite volume of fluid that has been displaced through two adjacent rotor blades. The pulse rate generated becomes a very accurate measure of flow rate, and the total number of pulses in any time increment, an equally accurate measure of total volume displaced.

The turbine flowmeter is an intrusive flow measurement device, and therefore the pressure drop characteristic is an important consideration. Pressure drops at the maximum rated flow are shown with each individual product. These values are based on water at 60°F.

The most precise equation for calculating pressure drops in liquids with specific gravities and viscosities different from the fluid in which the flowmeter is calibrated (usually water at S.G. = 1.0, viscosity = 1.0 centipoise) is as follows:

$$(\Delta)P_2 = (\Delta)P_1\,(\rho_2/\rho_1)^{.81}\,(\mu_2/\mu_1)^{.27}\,(Q_2/Q_1)^{1.82}$$

Note: The pressure drop produced in a turbine can cause the flowing fluid to flash, or produce vapor bubbles which can damage the meter. To prevent this, a minimum downstream pressure is required. This is = (1.25 × vapor pressure) + (2 × ΔP_2)

Installation

Allow an inlet straight pipe run of at least 10 pipe diameters and outlet pipe runs of 5 diameters (minimum) of the same size as the flowmeter. For certain upstream piping obstructions, longer upstream straight pipe runs may be required.

Obstruction	Up[illegible] Straight [illegible]
Concentric Reducer	15 Pipe Diameters
Sweeping Elbow or Tee	20 Pipe Diameters
Two Sweeping Elbows	25 Pipe Diameters
Partially Opened Valve or Two Sweeping Elbows at 90°	50 Pipe Diameters
Ball, Gate or Butterfly Valve (wide open)	14 Pipe Diameters

Performance Characteristics

The K-factor is the number of output pulses the flowmeter produces per engineering unit of the volume thruput. The factor is represented by the following expression:

$K = 60f/Q$

where:

f = pulses per second

Q = flow rate, in gallons per minute

K = pulses per gallon

For ordering the proper readout devices, this equation can be rearranged to determine the minimum and maximum frequency output of the turbine meter.

$f = KQ/60$

where:

Q = minimum and maximum linear flow rates.

The linear range is that flow range over which the K-factor is constant, within the specified limits of linearity. Linearity is a measure of the accuracy of the device, and is the maximum percentage deviation from the average K-factor, $\overline{K}$. The linearity of turbine flowmeters is usually expressed as a percentage of the reading. Most other flow metering devices usually state linearity as a percentage of full scale, which infers a derated accuracy. Each OMEGA® FTB-100, 200 turbine meter is individually calibrated, and the resulting performance characteristics presented in a tabular format.

The repeatability of a turbine meter is a measure of the stability of the output under a given set of flowing conditions. The repeatability is defined as the allowable percentage deviation from the stated K-factor at that flow rate. The repeatability error is usually much smaller when compared to the linearity error, inferring a much greater accuracy if the known flow rate dependency of the K-factor is eliminated by the use of an external linearizing device.

MATERIAL SELECTION AND CONSTRUCTION

Turbine flowmeters are available in a range of standard materials. This range of construction options allows for the selection of the optimum combination of useful range, corrosion resistance and operating life for a particular application. A low mass rotor design allows for rapid dynamic response which permits the turbine meter to be used in puls ng flow applications. The defl or cones eliminate downstream thrust on the rotor and allow hydrodynamic positioning of the rotor between deflector cones. The hydrodynamic positioning of the ow mass rotor provides wider angeability and longer bearing life than that of conventional turbine owmeters. Integral flow straightening tubes or vanes minimize the effects of upstream ow turbulence.

The housing is made of non-magnetic materials. The rotor is ade of magnetic or magnetized aterials. Bearings are chosen ased on media service, cost and ccuracy considerations.

election of the materials of onstruction is usually dictated by e requirements of media mpatibility, availability and cost nsideration.

EARING SELECTION

any bearing types are available cluc ball bearings and sleeve-pe c structions in tungsten bide and ceramic.

hen selecting among several emically compatible bearings, the

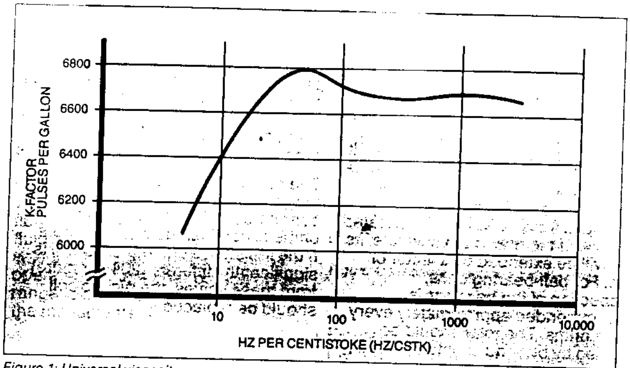


Figure 1: Universal viscosity curve

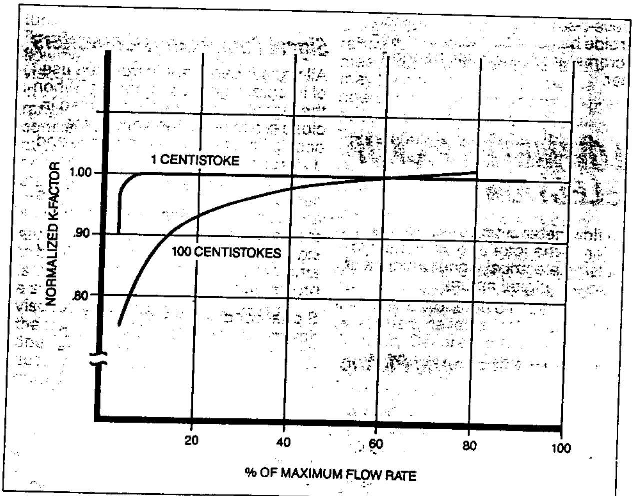


Figure 2: Viscosity effects on a 1" turbine meter

ball-bearing design offers the highest accuracy at lowest cost, and generally will have the widest usable range. It remains the bearing of choice in many fluids. Tungsten carbide and ceramic bearings offer the most durable bearing materials in service fluids in which they are compatible. These represent the standard bearing type for many industrial service environments.

In turbine flowmeters, the flowing fluid provides the bearing lubrication in most applications. It may be observed that fluids which offer a high natural lubricity tend to prolong the life of the flowmeter bearings. OMEGA® turbine meters are specifically designed for low bearing wear, even with low lubricity fluids, such as water. The ball-bearing units feature non-metallic bearing

TURBINE AND PADDLEWHEEL FLOWMETERS
Flow Reference Section

retainers to minimize wear, while sleeve-bearing units use very hard tungsten carbide and ceramic to minimize wear.

Bearing-life has been found to be approximately inversely proportional to the square of the bearing speed. To prolong the life of the flowmeter, it is therefore advantageous to operate the flowmeter at rates much less than the maximum flow rate. For example, if the flowmeter is operated at 33% of the maximum flow rate, its life will be extended by a factor of ten. For ball-bearing units, inspection of the bearings is recommended approximately every six months. The rotor should be rotated by blowing air into the unit. If the rotor comes to a sudden halt, the bearings should be replaced (this causes no loss of calibration). For sleeve-bearing units, the tungsten carbide ball can be measured with a micrometer to determine bearing wear.

FLOWMETER PICKUP SELECTION

The flowmeter pickup senses the motion of the rotor and converts it to a pulsing electrical signal which is of a discrete, digital nature.

High Output Magnetic Pickup

The standard high output magnetic pickup for OMEGA® turbine meters produces a high-level sinusoidal output. To produce this, the pickup generates a relatively strong magnetic field. The signal may be transmitted up to 200 feet without amplification. A flow range of 10:1 or better is common with this pickup type.

The output signal voltage of the magnetic coil is approximately sinusoidal. The frequency range of the pulsing signal varies from size to size. However, standard ranges allow for maximum output frequencies at the nominal maximum linear flow ranging from approximately 400 to 1100 Hz.

The amplitude of the output signal is a function of the flow rate. The voltage at the minimum linear flow is greater than 28 millivolts peak-to-peak when measured into a 10,000 ohm load. As the flow rate increases, particularly on the larger size flowmeters, the output level may exceed several volts peak-to-peak.

The dc output resistance of magnetic pickup coils for ball bearing units is nominally 1400 ohms at nominal room temperature. If the resistance of the pickup coil is significantly different (20% or more) from these values, the pickup coil should be replaced.

Signal Conditioners/Converters

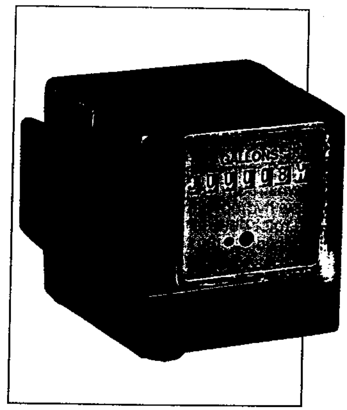
All transducers benefit from the use of integral signal conditioning. When the signal conditioner is mounted in close proximity to the sensor, the possibility of signal interference and distortion is significantly reduced. The conditioner takes the low-level sensor output, conditions, amplifies and transmits a high-level signal to the host system. This high-level signal is less likely to be affected by ambient conditions, thereby preserving system accuracy.

Signal conditioners for tubine flowmeters provide amplification, filtering and wave-shaping of the low-level flowmeter pickup output signal. They generate a high-level pulse output signal suitable for transmission to a remote host system through an electrically noisy environment.

Several output forms (i.e., amplified pulse, current and voltage) are available to suit various requirements. The amplified pulse, current and voltage signals may be transmitted several hundred feet through shielded cable, as long as the resistance in the cable is not large enough to degrade the signal. Enclosures are available which allow integral mounting of the signal conditioner to the flowmeter. Models suitable for explosion-proof environments are available.

Selection For Viscous Service

Turbine and positive displacement flowmeters are normally used where very high accuracy, high repeatability flow measurement is required (typically ±1% of rate or better). Paddlewheel flowsensors provide an economical alternative for applications with less demanding accuracy requirements (typically ±1% of full scale). For high accuracy applications, positive displacement flowmeters are employed when variations in viscosity are encountered. This is very typical for oil or other viscous fluid which is being measured over a



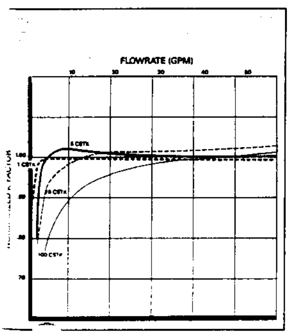
OMEGA FTB-30 Series Positive Displacement Flowmeters. See Page F-27 for Complete Details.

range of temperatures.The accuracy of positive displacement meters are unaffected by variations in viscosity when they are used over the allowable viscosity operating range. OMEGA currently offers two styles of PD meters: the FTB-1000 for viscosities from 30 to 1000 centistokes, and the FTB-1500 for 1 to 1000 centistokes. The FTB-1500 features a PVDF and Hastelloy construction for corrosive fluids.

The alternative flowmeter for high accuracy applications is the turbine flowmeter. Turbine meters operate ver much wider temperature and ressure range than do PD meters -450 to +450°F vs. -14 to 180°F ınd up to 7500 PSIG vs. 150 PSIG or PD meters). Although special nodifications can be made to extend the temperature and ressure range of PD meters, they still can't match a standard turbine neter. However, turbine meters are ery sensitive to viscosity and iscosity variations, and must be specially calibrated for such pplications. Where there's a will, here's a way!

urbine meters are calibrated tandard with water (1 centistoke iscosity). This calibration is suitable or fluids with viscosities less than or qual to that of water. For example, vhen a turbine meter is used to neasure liquid Freon (viscosity less han 1 centistoke), a standard urbine with water calibration data is sed. When a turbine meter is to be sed a single viscosity higher than hat of water, the user faces three pti

) **Narrow the operating range:** For given flowmeter size, it is observed hat as the viscosity increases, the w portion of the flowmeter's range more affected than the higher ortion of the flowmeter's range. For



ure 3: Viscosity effects on 2 inch turbine ading denotes error envelope of ±1% full ale

a required accuracy of measurement this results in a minimum linear flow rate increasing as the viscosity increases. There is also a slight change in the average calibration constant as the viscosity increases. Figure-4 shows the calibration trends typical of a ½", 1", and 3" turbine flowmeter. Note that the smaller the flowmeter, the more sensitive the unit will be to higher viscosity. Therefore, in selecting a flowmeter for operation in a viscous fluid, it is generally preferable to select a flowmeter size so it will be operated in the higher portion of its range to minimize viscosity effects in the measurement.

2) Accept a lesser accuracy: Due to the cost advantage of using a turbine flowmeter over other flowmetering types, turbine flowmeters are often used at viscosities that introduce some loss in accuracy and some loss in flow range. Often a flowmeter may be considered as a candidate for an application even if its accuracy is only ±1% of full scale instead of the standard ±0.5% of reading which may be achieved on low viscosity fluids. Figure-3 has plotted on it the allowable error band of ±1% of F.S. to be used as a frame of reference. It is therefore often possible to provide a standard turbine meter for a viscous fluid application so long as the user can accept a smaller operating range and/or a decreased accuracy. However, no general guidelines can be layed out, since accuracy, range, and viscosity vary with each application and each turbine meter size. So feel free to give us a call at 800-872-9436 to discuss your application.

3) Request a special calibration: A turbine flowmeter can be calibrated on a test fluid that approximates the viscosity it will see in service, rather than on water. However, this typically adds approximately $250 to the cost of the turbine meter, and extends the delivery time as well. Calibrations can be done on fluids up to 100 centistokes, depending on meter size. However, as we see from

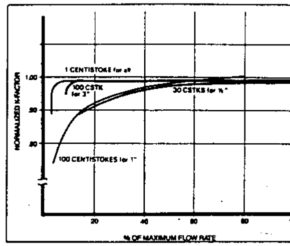


Figure 4: Viscosity effect on a turbine meter

Figure-4, depending on meter size, the turbine meter may be very non-linear (varying K factor, or pulses/gallon) at a particular viscosity and flowrange. This can be linearized in a computer for the entire operating range to maintain the highest measurement accuracy, or else it may be necessary to narrow the operating range and accept a lower accuracy to permit the use of a turbine meter. Again, feel free to contact the Flow Application Department to discuss the specifics of your situation.

What to do when the viscosity varies: Ideally, a positive displacement meter should be used. However, if the application requires the use of a turbine meter, a special viscosity calibration can be performed, called a Universal Viscosity Calibration (UVC). The turbine meter is calibrated over a range of viscosities (typically three) to generate a curve which characterizes the performance of the meter at different viscosities (see Figure-1).

A UVC can then be represented by a polynomial equation to program into

TURBINE AND PADDLEWHEEL FLOWMETERS
Flow Reference Section

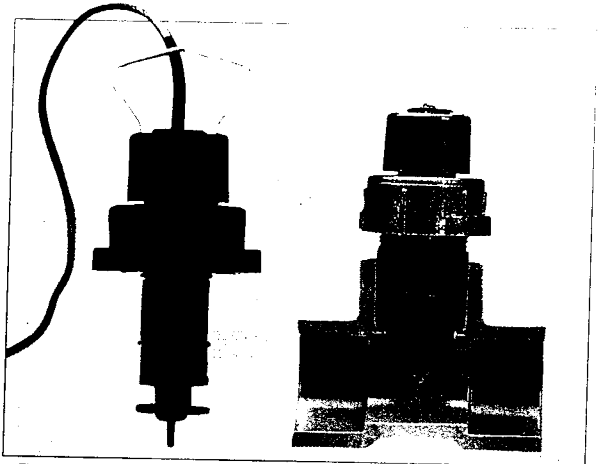


Figure 5: Paddlewheel flow sensor and installation fitting, which insures proper insertion depth into the pipe system

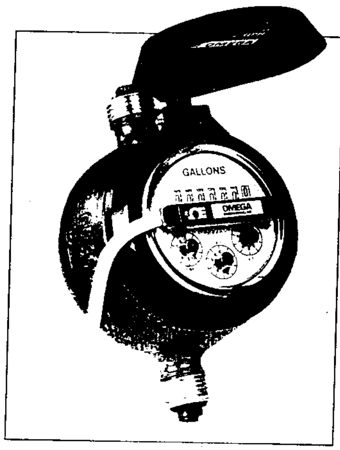
a computer. The computer receives a temperature sensor input (to calculate viscosity based upon a given equation) and the flowsensor input, and calculates out the UVC polynomial equation to give viscosity-corrected flowrate. This is easily done with a personal computer system combined with OMEGA's plug-in interface cards and software. However, a UVC will typically add between $600 and $900 to the cost of the meter, and will increase the delivery time as well.

Paddlewheel Flowmeters:
Because of their cost-effectiveness, paddlewheel flowsensors are often used in viscous applications without high accuracy requirements. So long as the Reynolds number is above 5000, the unit should not require field recalibration and will send out a frequency proportional to velocity (and thus, flowrate). The Reynolds number = (3160 × Q × SG)/(D × MU), where:

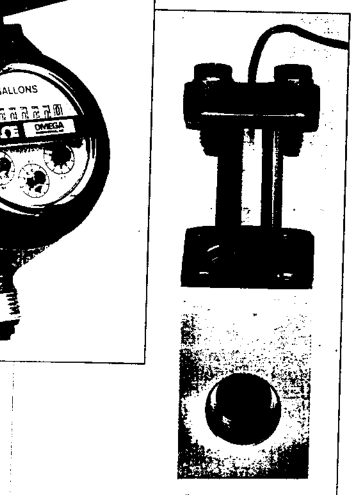
Q = liquid flowrate, in gpm
D = inside pipe diameter, in.
SG = liquid specific gravity
MU = liquid viscosity, centipoise

To convert centistokes to centipoise, multiply centistokes by specify gravity to get centipoise.

So, when it comes to measuring fluids from low viscosity to high viscosity to varying viscosity, OMEGA flow systems can handle it.



The OMEGA FTB-30P Series Positive Displacement Flowmeters are Ideally Suited for Viscous Fluids. See Page F-27 for Complete Details.



The Economical FP-5200 Series Paddlewheel Flow Sensors Shown. See Page F-47 and F-48 for Details.

FLOW STRAIGHTENERS, INSTALLATION KITS AND STRAINERS

Flow Straightening

Proper application of the turbine flowmeter requires a suitable piping section to achieve optimum accuracy. While an inlet straight pipe run of 10 pipe diameters and an outlet straight pipe run of 5 pipe diameters provide the necessary flow conditioning in general, some applications require an upstream flow straightener. Such applications include custody transfer. A flow straightener consists of a section of piping which contains a suitably dimensioned and position thin-w...d tube cluster to eliminate fluid s..., Fig. 6.

37° Flare Installation Kits

Installation kits for turbine meters with 37° flare end fittings consist of two lengths of stainless steel tubing cut to a length appropriate for the upstream and downstream straight pipe run and flared at one end. See page F-12. Mating sleeves and nuts are included. The kits may be conveniently butt-welded into the piping system. Flow straightening sections may be provided within the installation kit. These kits are available in tubing sizes from ½ to 2″.

Strainers/Filters

A strainer/filter may be required to reduce the potential hazard of fouling or damage that may be caused by foreign matter. Pipe rouge, which is the extremely fine rust which develops on the inside of some piping, is a serious pr...m for turbine meters, due to the di...ity in filtering out these particles. Consult the Flow Applications Department for applications involving pipe rouge.

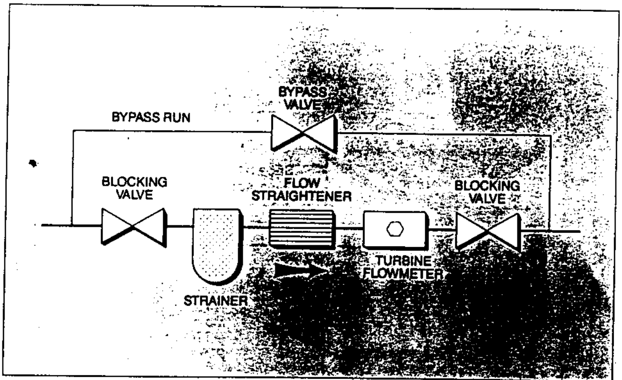


Figure 6: Typical turbine meter installation

Minimum Requirements for the FTB-100 and 200 Series Tubine Meters are the following:

Meter Size	Mesh Size	[illegible]
¼ to ½″	100	0.0055
⅝ to 1¼″	70	0.008
1½ to 3″	40	.015

PADDLEWHEEL FLOWMETERS

Paddlewheel flowmeters are very low cost substitutes for turbine flowmeters where the extremely high accuracy of the turbine is not required. In the case of the insertion-style paddlewheel sensors (FP-5000 Series), line sizes up to 36 inches can be accommodated at a much lower cost than competing in-line flowmeter systems. (See pages F-21 through F-32).

In paddlewheel flowmeters, the rotor and blades are perpendicular to the flow, not parallel as with the turbine flowmeters, Fig. 7. Owing to the solid rotor design of these paddlewheel sensors, which includes no ball bearings, this type of flowmetering system is very tolerant of particulates in the line, and no strainers are required, as compared to turbine flowmeters. Because the paddles contact only a limited cross section of the flow, the insertion depth of the rotor and proper flow profile are critical to accurate flowmeter performance. In the case of insertion-style paddlewheels (FP-5000 Series), installation fittings which have been specially modified to fix the insertion depth and direction of the rotor are sold separately (see Fig. 5).

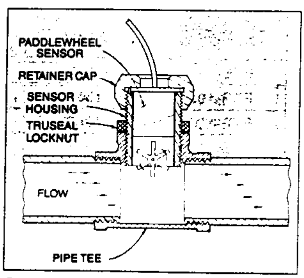
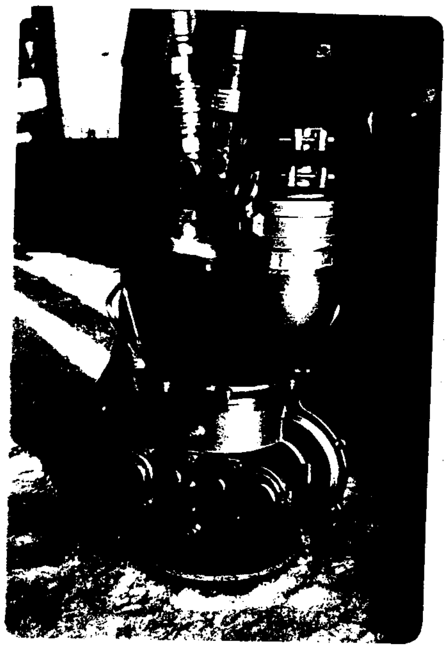


Figure 7. Paddlewheel flow sensor installation and operation

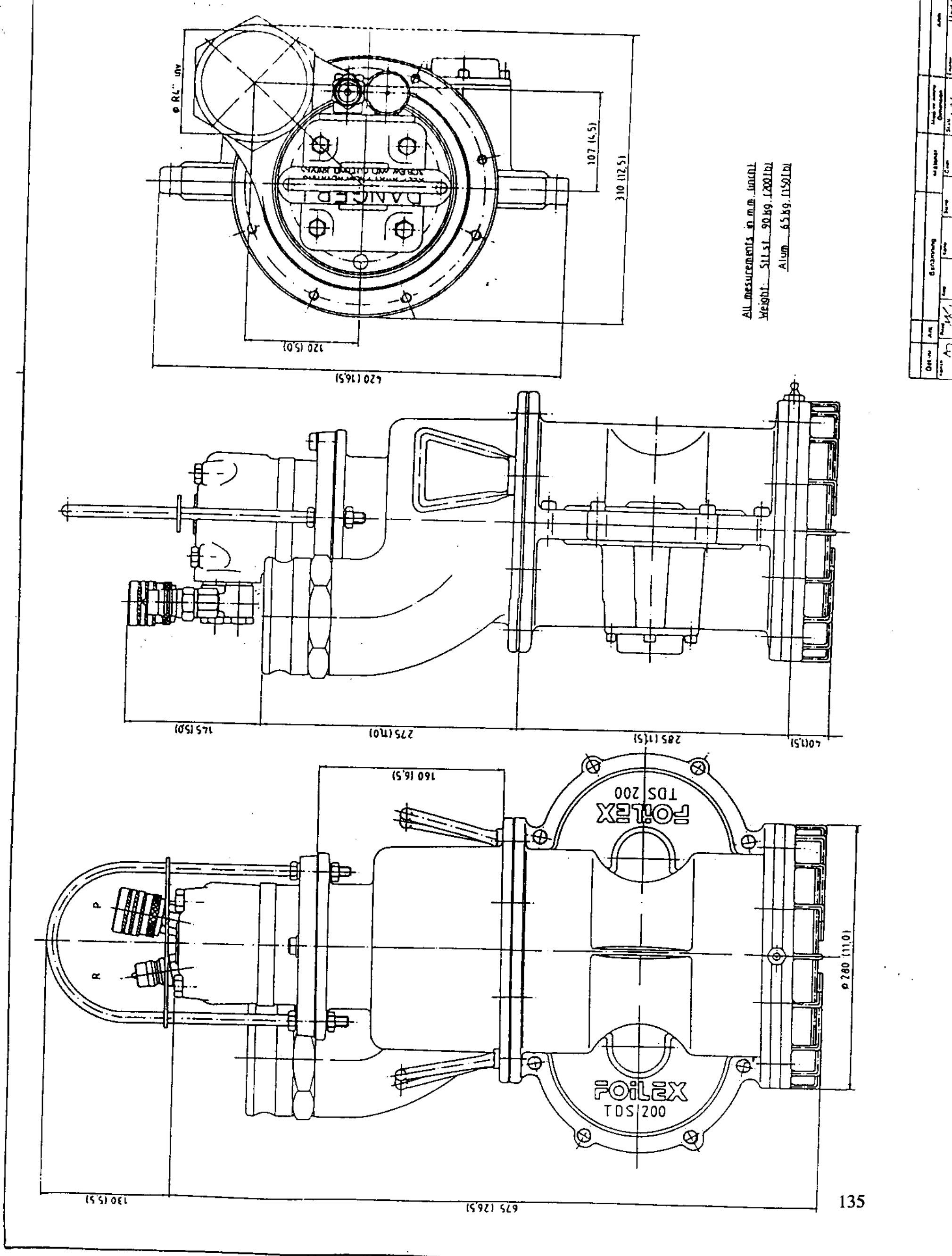
FOiLEX

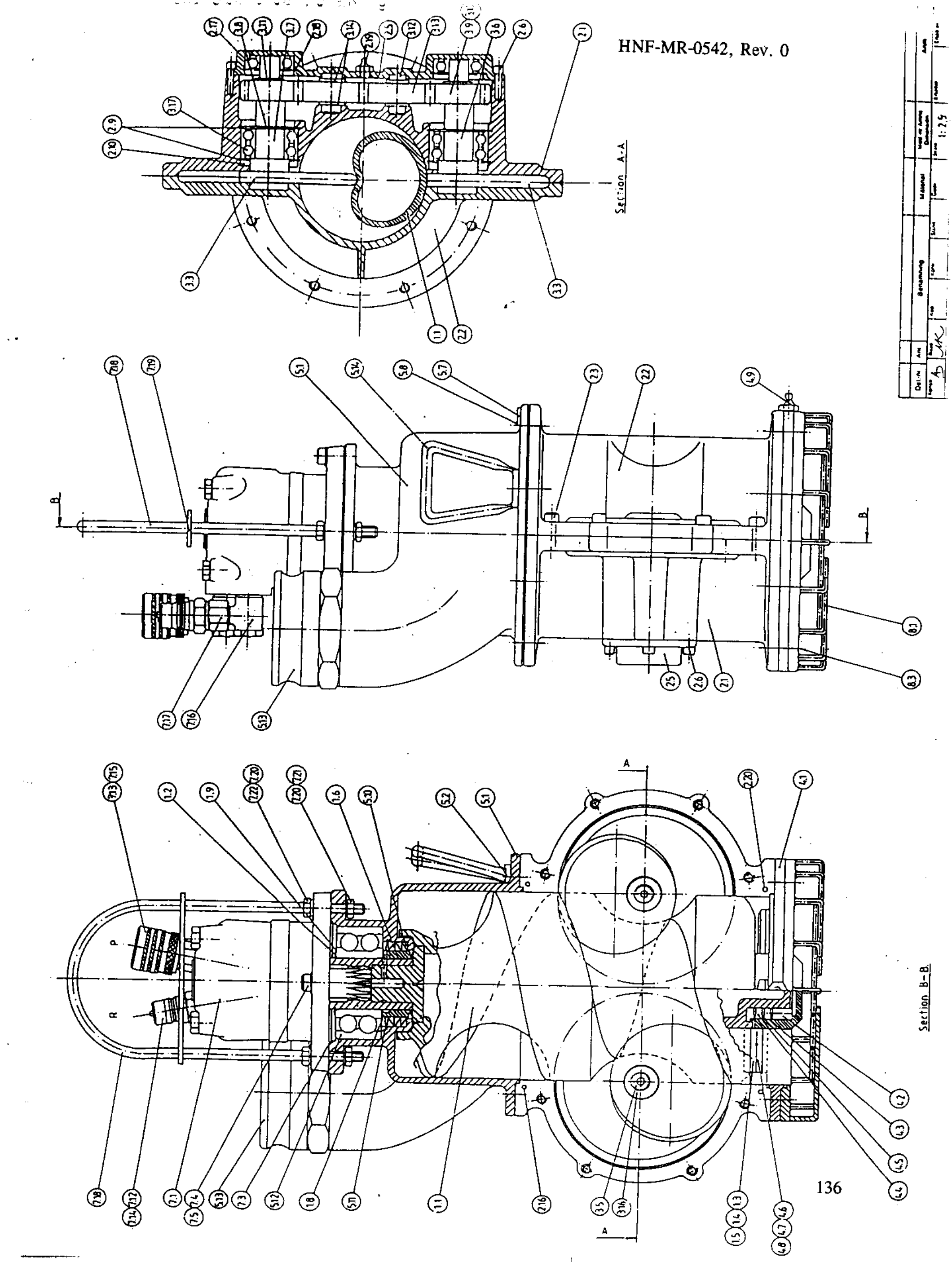
OFF LOADING PUMP
TDS 200 OLP



Instructions manual

FOILEX AB
[illegible]
[illegible] GOTHENBURG, SWEDEN
[illegible]


All mesurements in mm (inch)
Weight: Stl.st 90 kg (200 lb)
Alum 65 kg (150 lb)
DANGER
ø RL"
107 (4,5)
310 (12,5)
120 (5,0)
420 (16,5)
145 (5,0)
275 (11,0)
285 (11,5)
40 (1,5)
160 (6,5)
FOILEX
TDS 200
P
R
ø 280 (11,0)
130 (5,5)
675 (26,5)


Section A-A
Section B-B

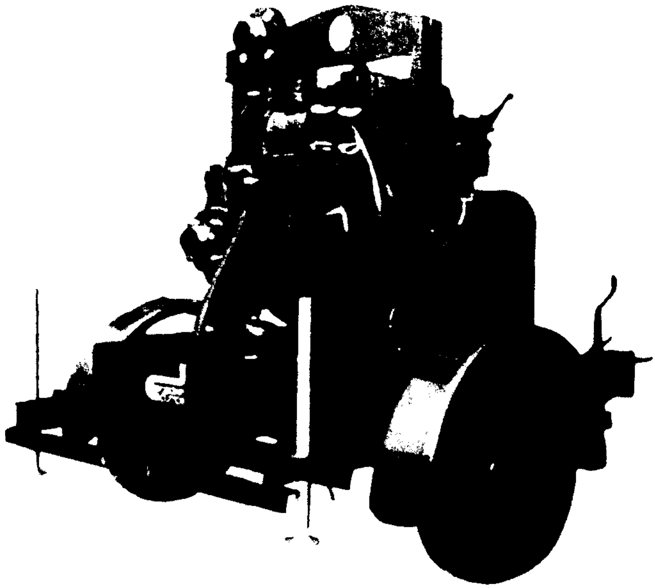
7. Technical data.

7.1 Technical specification

FOILEX TDS 200 Off-loading Pump.

Swedish patent no:	9001145
Max capacity, cont:	68 m^3/h (300 gal/min)
Max capacity, int:	85 m^3/h (375 gal/min)
Max pressure:	10 bar (140 psi)
Viscosity range:	0-10^6 cSt
Debris handling:	Cutting knives at inlet
Motor:	Hydraulic Danfoss OMTS 160
Max rpm cont:	625 rpm
Max rpm int:	780 rpm
Max oil flow cont:	100 l/min (26 gal/min)
Max oil flow int:	125 l/min (32 gal/min)
Max inlet pressure cont:	200 bar (2800 psi)
Max inlet pressure int:	240 bar (3360 psi)
Max return pressure cont: (without drain line)	0-100 rpm: 75 bar (1050 psi) 100-300 rpm: 40 bar (560 psi) >300 rpm: 20 bar (280 psi)
Max return pressure int:	0-max rpm: 75 bar (1050 psi)
Max power cont:	24.5 kW (32.8 hp)
Hydraulic couplings:	
Pressure:	Tema or Aeroquip 3/4" Female
Return:	Tema or Aeroquip 3/4" Male
Drain:	Tema or Aeroquip 1/4" Male
Discharge:	Inner BSP thread R4" with CAMLOCK male or custom choice.
Material:	
Pump screw:	Chem. nickel/Teflon coated steel
Pump casing:	Stainless steel / Aluminium
Outlet house:	Stainless steel / Aluminium
Sealing disc:	Polyurethan with steel core
Cutting knives:	Hardened stainless steel
Coating:	Oil and chemical resistant polyurethane.
Weight:	Stl.st.90kg (200 lb) / Al 65kg (145lb)
Dimensions LxWxH:	310x420x680 mm (12x16x26 in)

HL80 Dri-Prime™ Pumps



Features:

Close coupled arrangement carrying pump and automatic priming compressor mounted to a diesel engine.

All metal construction solids handling pump end.

Extensive application flexibility - will handle coarse abrasive slurries - gravel, coal, rock products and liquids with solids up to 1 in. in diameter.

Continuously operated 'Godwin' patented air ejector priming device requiring no form of periodic adjustment or control.

Dry running, oil bath lubricated, mechanical seal with high abrasion resistant silicon carbide interfaces.

Solids handling ball type non-return valve with renewable flexible rubber seat and quick release access feature.

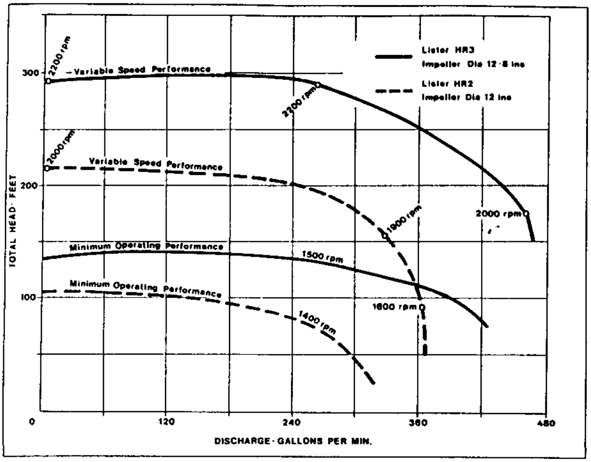
Compact unit mounted on two wheeled highway trailer incorporating integral overnight running fuel tank. Skid mounted versions are also available.

Very simple maintenance - normally confined to checking engine and seal cavity oil levels.

Available with a variety of engines and electric motors.

godwin® pumps

HL80 Performance Curve



Performance Tables

Diesel - John Deere 4039D - 71 h.p. at 2300 r.p.m.
Impeller Diameter 12.8 in.

	Total Delivery Head - Feet					
Total Suction	100	150	200	225	250	300
Head - Feet	Output	GPM				
10	465	460	455	450	420	325
15	465	460	450	410	390	320
20	465	450	420	400	380	320
25	465	420	400	385	360	300

Diesel Set - Lister HR3 - 43 h.p. at 2000 r.p.m.
Impeller Diameter 12.8 in.

	Total Delivery Head - Feet						
Total Suction	75	100	125	150	175	200	225
Head - Feet	Output	GPM					
10	465	460	455	445	440	400	336
15	465	460	455	445	440	380	235
20	450	445	440	430	400	345	
25	430	425	420	400	360	270	

MANOMETRIC or TOTAL Heads are given in the rating tables and curves based on water tests at sea level and 20°C.
For maximum flows larger diameter pipes may be required.

Dimensions in in. - Dry Weight - lbs. (Approximate)

	Highway Trailer			
	Length	Width	Height	Weight
John Deere 4039D	108	64	72	2750

Technical Notes:

Maximum operating speed:
2400 r.p.m.

Maximum operating temperature:
+212°F

Maximum working pressure:
155 p.s.i.

Maximum suction pressure:
14.5 p.s.i.

Maximum casing pressure:
232 p.s.i.

Fuel tank capacity:
40 gallons

Pipe connections:
3" suction A.S.A. 150
3" delivery A.S.A. 150

Material Specifications:

Pump casing, suction cover, separation tank and N.R.V. casing:
Close grained cast iron

Impeller:
Cast chromium steel
Minimum Brinell hardness, 341 HB

Shaft:
Nickel chromium steel

Wearplates:
Nickel chromium cast iron

N.R.V. Ball and Seat:
High nitrile rubber

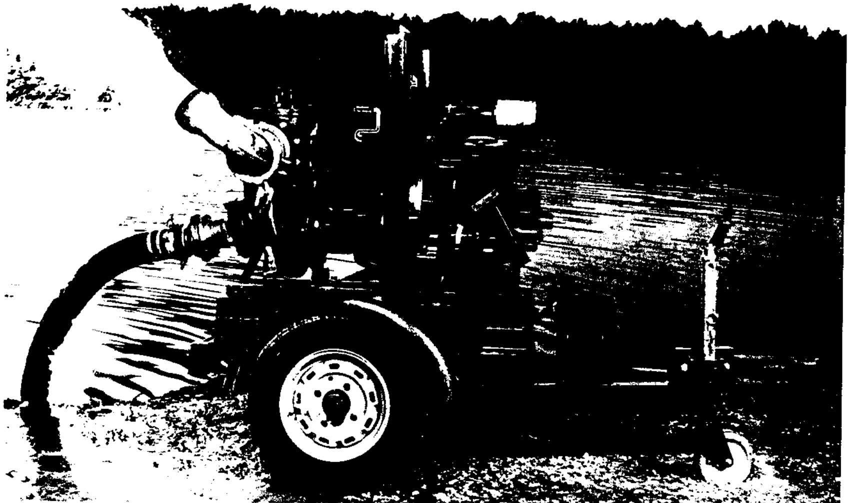
Mechanical Seal Faces:
Solid silicon carbide

godwin® pumps

Godwin Pumps of America, Inc.
Floodgate Road
Bridgeport, NJ 08014
Tel: (609) 467-3636
Fax: (609) 467-4841

GPA/HL80/91

CD 100M Dri-Prime™ Pumps



Features:

Close mounted arrangement carrying pump and vacuum priming compressor mounted to a diesel engine (Lister TS2 illustrated) or an electric motor.

All metal construction solids handling pump end.

Extensive application flexibility - will handle raw sewage, slurries and liquids with solids up to 1⅞ ins diameter.

Recessed impeller version available handling solids in excess of 2$\frac{3}{16}$ in. diameter.

Continuously operated 'Godwin' patented air ejector priming device requiring no form of periodic adjustment or control.

Dry running, oil bath, mechanical seal with high abrasion resistant silicon carbide interfaces.

Solids handling ball type non-return valve with renewable flexible rubber seat and quick release access feature.

Compact unit mounted on skid base or two wheeled highway trailer both incorporating integral overnight running fuel tank.

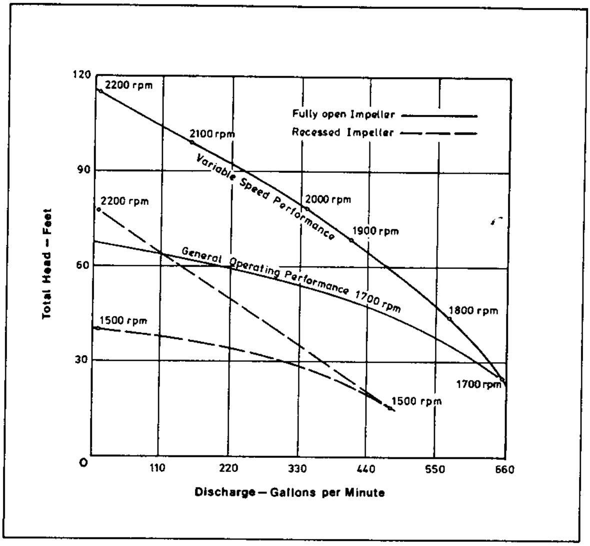
Very simple maintenance - normally confined to checking engine and seal cavity oil levels.

Available with a variety of engines including Lister, Hatz, Petter and Deutz.

Silenced and unsilenced versions can be supplied.

godwin® pumps

CD 100M Performance Curve



Technical Notes:

Maximum operating speed:
2200 r.p.m.

Maximum operating temperature:
+212°F

Maximum working pressure:
50.0 p.s.i.

Maximum suction pressure:
29.0 p.s.i.

Maximum casing pressure:
75 p.s.i.

Fuel tank capacity:
20 to 100 gal.

Pipe connections:
4" A.S.A. 150

Performance Tables

Diesel Set - Lister TS2 - 13.8 h.p. at 1700 r.p.m.
Impeller Diameter - 8⅝ in.

	Total Delivery Head - Feet				
Total Suction	10	20	30	40	50
Head - Feet	Output	GPM			
10	720	640	545	440	275
15	685	595	500	360	120
20	640	565	440	275	—
25	490	395	270	130	—

MANOMETRIC or TOTAL Heads are given in the rating tables and curves based on water tests at sea level and 20°C.
For maximum flows larger diameter pipes may be required.

Dimensions in in. - Dry Weight - lbs

	Highway Trailer			
	Length	Width	Height	Weight
100CD/Lister TS2	90	54	62	2,050
100CD/Hatz 2L30C	90	54	62	2,412

Material Specifications:

Pump casing, suction cover, separation tank and wearplates:
close grained cast iron

Impeller:
cast chromium steel hardened to minimum Brinell 341 HB

Shaft sleeve and shaft:
1½% nickel/chromium steel

N.R.V. Body:
silicon aluminium

N.R.V. Ball and Seat:
high nitrile rubber

Mechanical Seal Faces:
solid silicon carbide

godwin® pumps

Godwin Pumps of America, Inc.
Floodgate Road
Bridgeport, NJ 08014
Tel: (609) 467-3636
Fax: (609) 467-4841

Specifications and illustrations are subject to revision without notice.

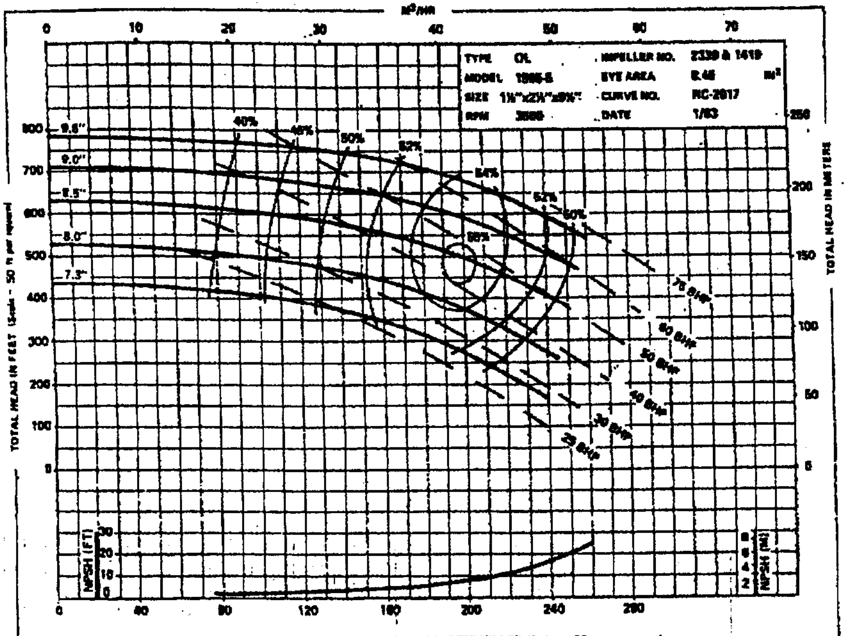
GPA/CD100/91

PACO PUMPS®

PACO Pumps, Inc.
P.O. Box 12924, 845 92nd Avenue
Oakland, California 94604-2924
(415) 639-3200 Telex: 33-5312

END SUCTION CENTRIFUGAL PUMPS
Type OL

PERFORMANCE CURVES — 3500 RPM



RPM 3500
3070
2400

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