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Evaluation of an Air Drilling Cuttings Containment System

Jim Westmoreland

Prepared by
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EVALUATION OF AN AIR DRILLING CUTTINGS CONTAINMENT SYSTEM

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ABSTRACT

Drilling at hazardous waste sites for environmental remediation or monitoring requires containment of all drilling fluids and cuttings to protect personnel and the environment. At many sites, air drilling techniques have advantages over other drilling methods, requiring effective filtering and containment of the return air/cuttings stream. A study of current containment methods indicated improvements could be made in the filtering of radionuclides and volatile organic compounds, and in equipment like alarms, instrumentation or pressure safety features. Sandia National Laboratories, Dept. 6111 Environmental Drilling Projects Group, initiated this work to address these concerns. A look at the industry showed that asbestos abatement equipment could be adapted for containment and filtration of air drilling returns. An industry manufacturer was selected to build a prototype machine. The machine was leased and put through a six-month testing and evaluation period at Sandia National Laboratories. Various materials were vacuumed and filtered with the machine during this time. In addition, it was used in an actual air drive drilling operation. Results of these tests indicate that the vacuum/filter unit will meet or exceed our drilling requirements. This vacuum/filter unit could be employed at a hazardous waste site or any site where drilling operations require cuttings and air containment.

ACKNOWLEDGEMENTS

The author extends his gratitude to the many people who were closely involved with this project for their support, encouragement, guidance, and assistance. Among the most important are Jim Dunn, John Gabaldon, Bob Meyer, George Staller, and Bob Wemple, all of Dept. 6111 Environmental Drilling Projects Group at Sandia National Laboratories; Jeff Rinehart, Quality Technical Services; Rodney Brown, Guzzler Manufacturing; Mark Gott, Air Draulics; and Cort Alexander, Co-Op Student, University of New Mexico.

A special thanks once again to Bob Wemple whose leadership, management, and wisdom were invaluable to the success of the project.

EXECUTIVE SUMMARY

The enclosed report describes the equipment and testing of the Drill Cuttings Containment System (DCCS) used for containment of contaminated drill cuttings while air drilling. In order to make the DCCS an operational system, several additional unique components or pieces of equipment had to be designed and developed. The vacuuming and filtering of a wide range of materials demonstrated that the DCCS is adequate for drilling at hazardous waste sites.

Most air filtering systems on operating drill rigs utilize compressed air to move the cuttings through the filtration process. Sandia Dept. 6111 Environmental Drilling Projects personnel believe that maintaining a vacuum atmosphere in the cuttings return line is a better method of containment. In this case, if any leaks occur at pipe joints, hoses, etc., contaminated air does not enter the external environment.

An industry search indicated that the asbestos abatement manufacturers had equipment that was close to our requirements. One manufacturer (Guzzler Manufacturing Inc., Birmingham, AL.) had a line of trailer-mounted vacuum/filter asbestos abatement equipment with distinct, separate stages of filtration. A six-month lease with an option to buy contract was placed with Guzzler to manufacture a prototype unit that would meet our specifications.

The Guzzler vacuum/filter is unique. Currently, there are no similar, competing units available. Upon receiving the Guzzler vacuum/filter unit, a six-month period of testing and evaluation took place.

Westinghouse Hanford is currently leasing the vacuum/filter unit and other pieces of the DCCS for testing and evaluation for an additional six months for possible use at their environmental restoration sites.

CONTENTS

FIGURES

TABLES

1. DRILL CUTTINGS CONTAINMENT SYSTEM- INTRODUCTION/DESCRIPTION

Testing and evaluation of the Guzzler vacuum/filter unit required that a total Drill Cuttings Containment System (DCCS) be designed, developed, and assembled (Figure 1). Funding for acquisition, testing, and evaluation of the DCCS came from Sandia National Laboratories's Mixed Waste Landfill Integrated Demonstration project (MWLID) through the Department of Energy's Office of Technology Development. Funding for this report is shared by Sandia's MWLID and Westinghouse Hanford Company's Volatile Organic Compound (VOC) Arid Integrated Demonstration project.

1.1 Main Components of the DCCS

The main components of the DCCS are shown as follows:

1. AIR COMPRESSOR - (Figure 2)

2. DRILL RIG - (Figure 3)

3. DIVERTER BOX - (Figure 4)

4. VACUUM/FILTER UNIT - (Figure 5)

The main components and their descriptions will generally follow the sequence where air enters the DCCS at the air compressor and exits to the atmosphere at the vacuum/filter unit.

The DCCS was designed to evaluate the Guzzler vacuum/filter unit while using compressed air to drive the air drilling motor and move drill cuttings to the top of the borehole. The diverter box is the area where the drill cuttings are diverted from a compressed air atmosphere to a vacuum atmosphere. In the vacuum atmosphere, drill cuttings and air move through the vacuum/filter unit and its multiple stages of filtration and are finally released to the atmosphere.

1.2 DCCS Component Descriptions

1.2.1 Air Compressor (Figure 2)

A GrimmerSchmidt model #800 was used as the compressed air source. The rating for this compressor is 800 cfm at 125 psi. The air compressor was rented from a local rental company. The air compressor has its own pressure relief valve, but rental companies are not required to have a pressure integrity program for certification of their pressure relief valves. By following SNL's pressure integrity program, a certified Kunkle pressure relief valve (calibrated at 125 psi) was installed on the outlet of the air compressor.

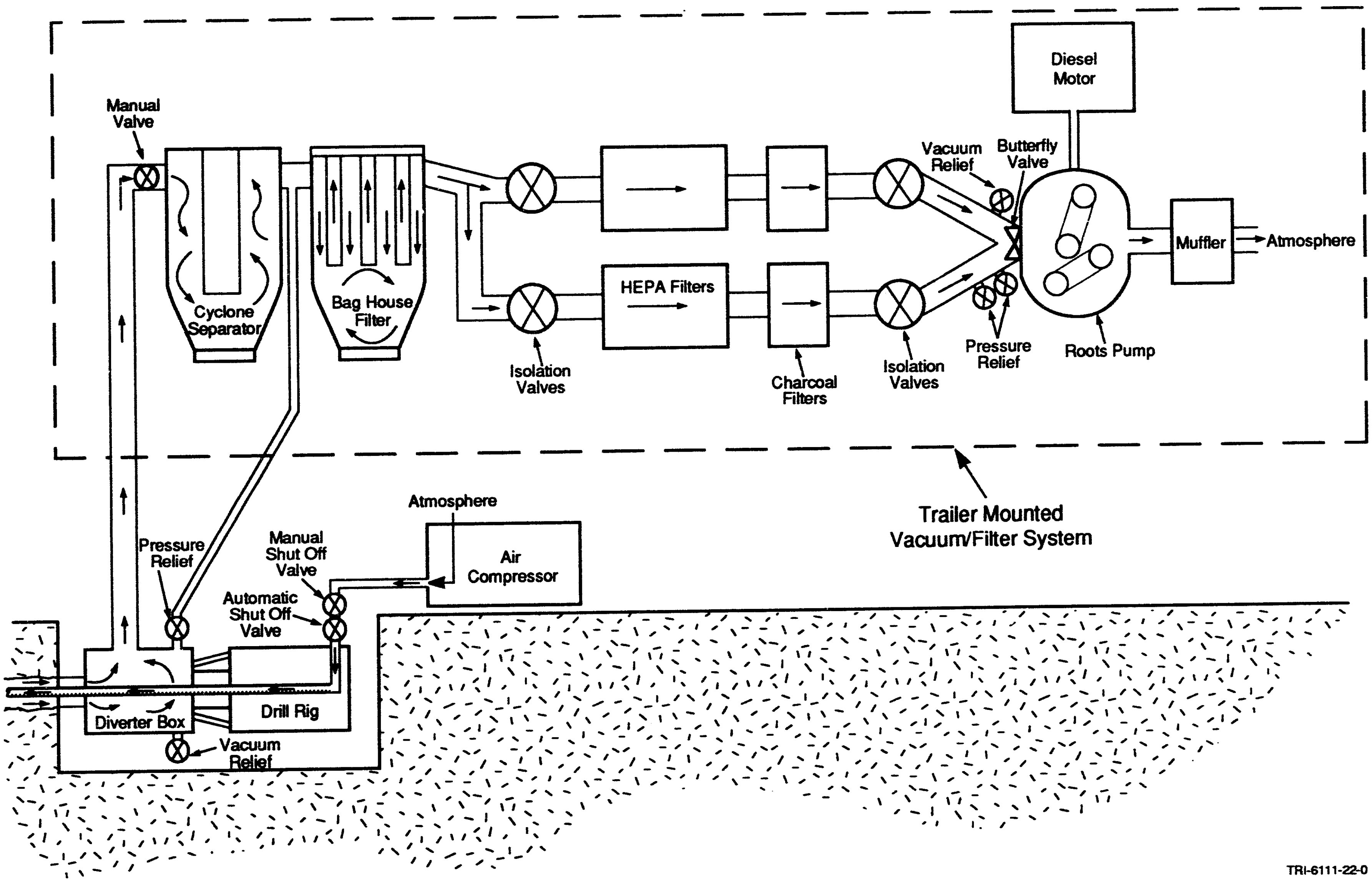

Figure 1. Drill cuttings containment system diagram.

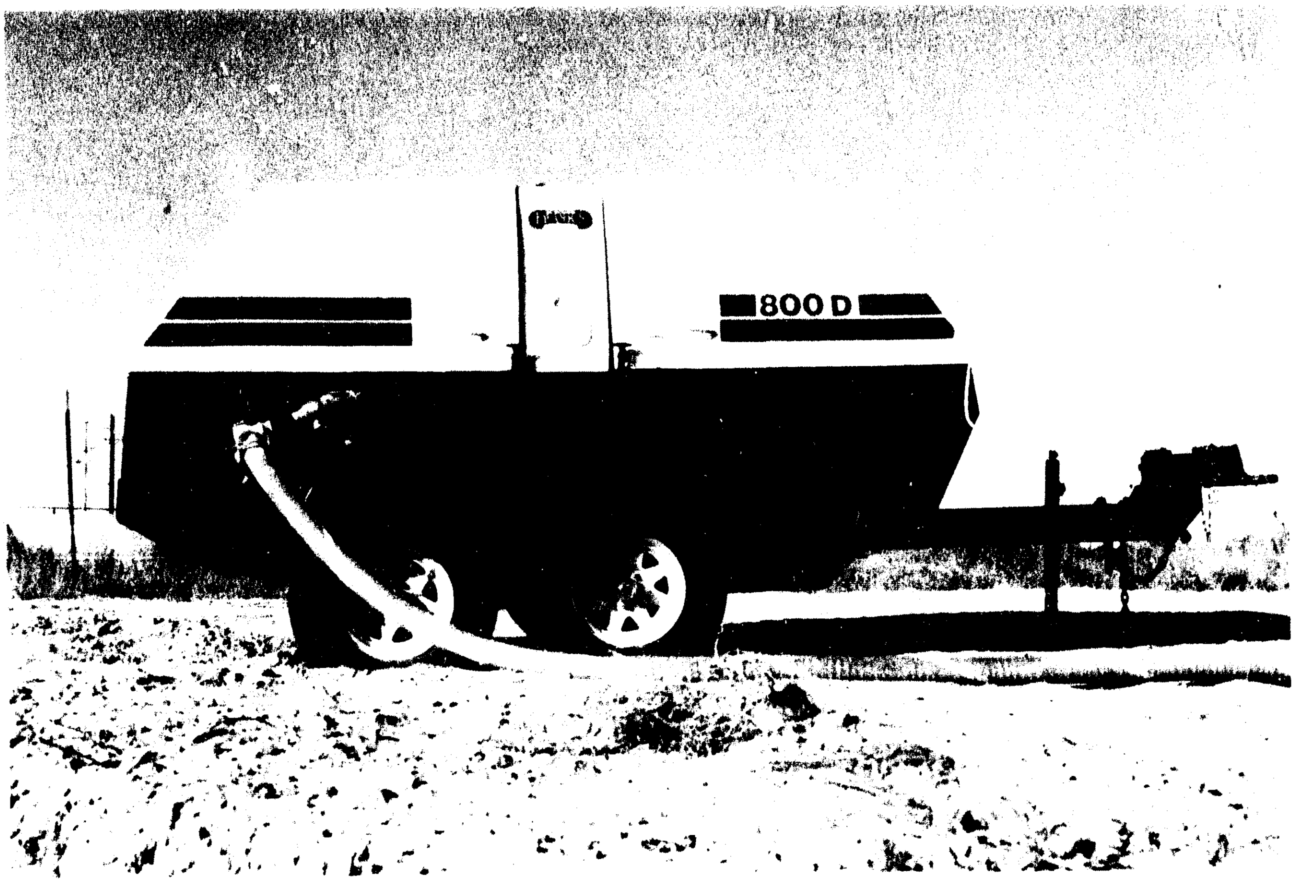

Figure 2. GrimmerSchmidt air compressor.

Figure 3. Ditch Witch True Trac drill rig.

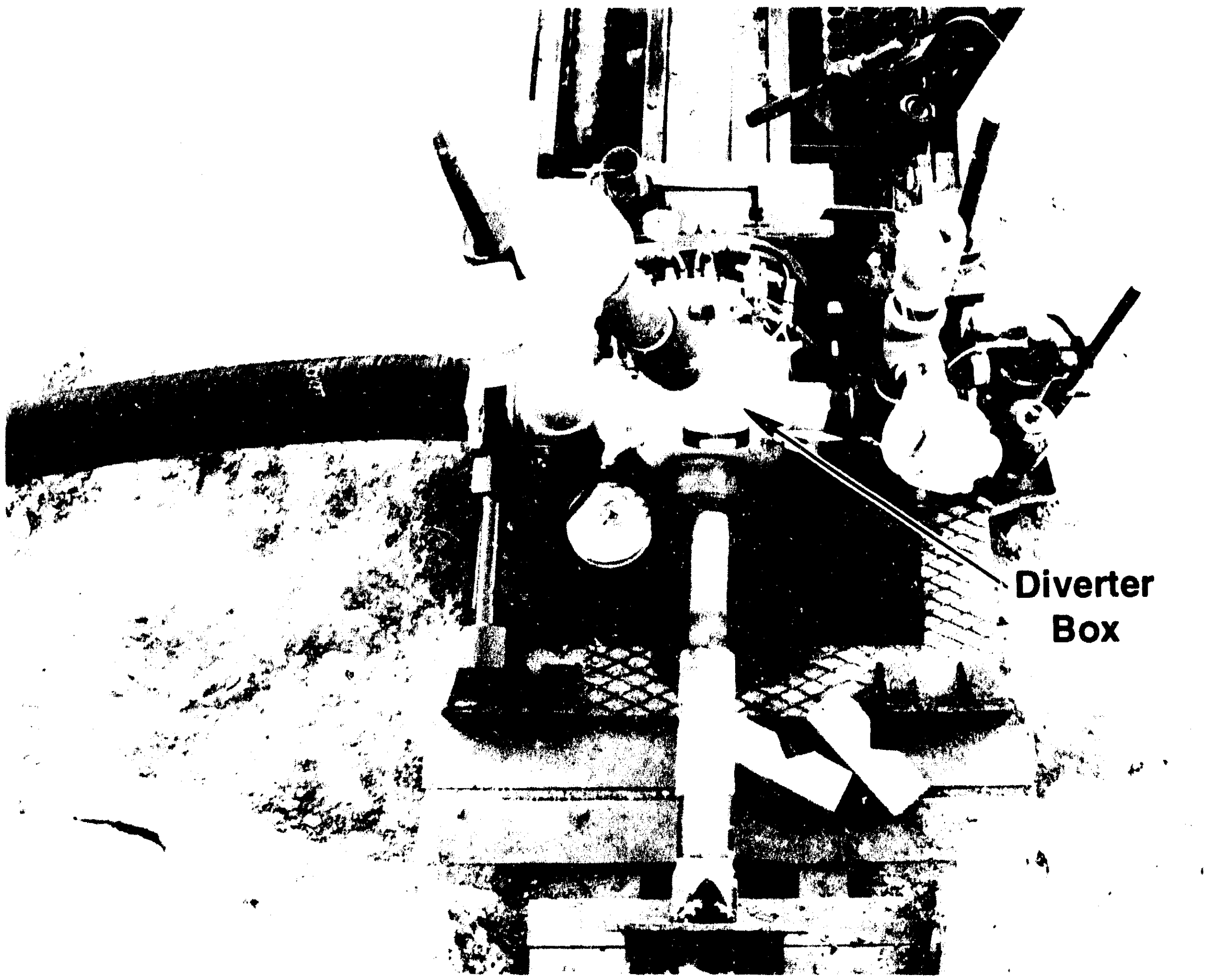

Figure 4. Diverter box.

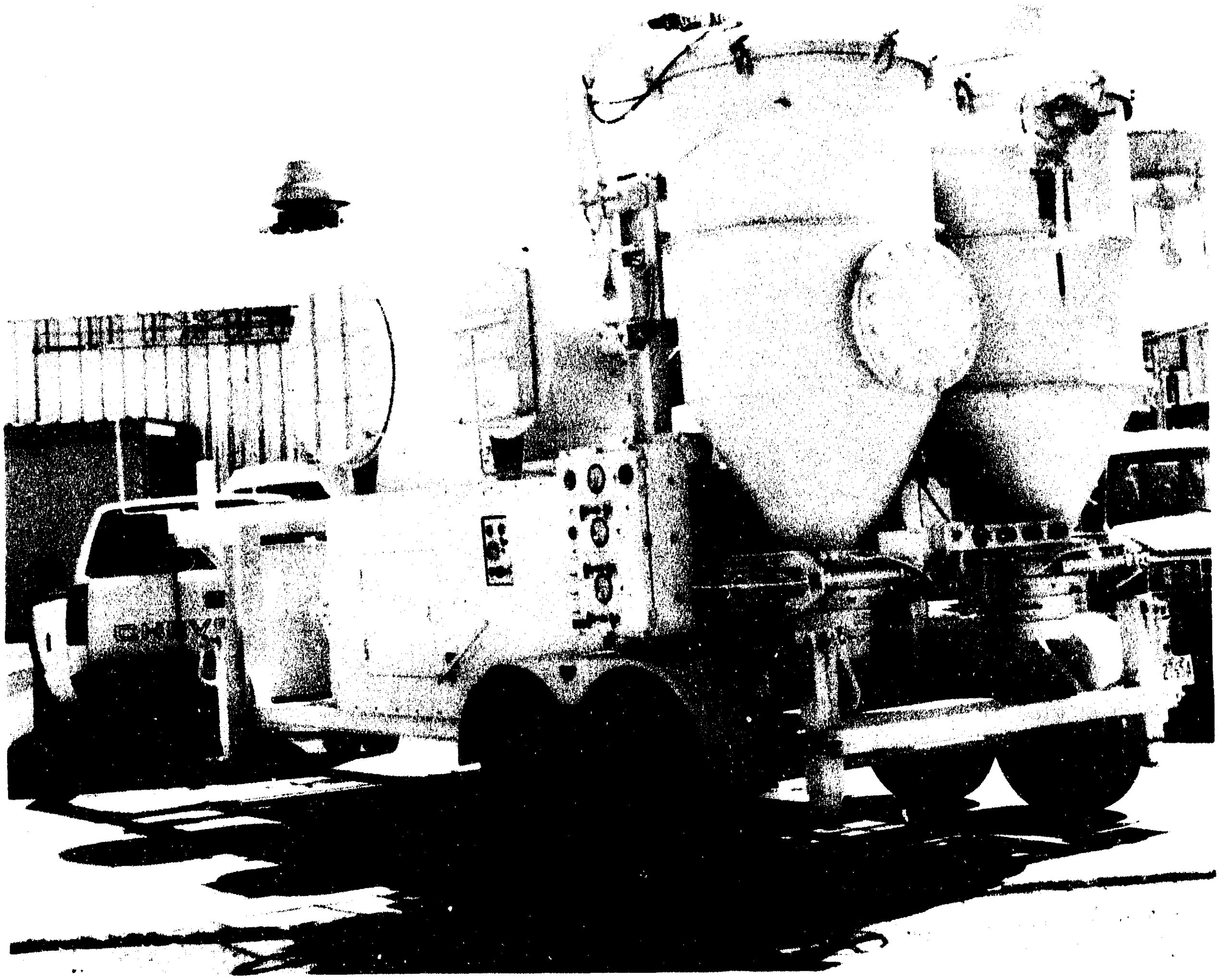

Figure 5a. Guzzler vacuum/filter unit.

Figure 5b. Guzzler vacuum/filter unit.

1.2.2 Drill Rig (Figure 3)

Through Dept. 6111's current industry partnership with Charles Machine Works Inc. (makers of Ditch Witch™), a drill rig used in trenchless technology was loaned to Dept. 6111. This air-driven drill rig is referred to as the True Trac™ model. The True Trac can drill to distances of 600 feet through a variety of soils, including solid rock. It has the steering technology for directional control to keep the drill head on path and maintain depth.

The True Trac has the capability to launch drilling from the ground surface or a pit. It is also designed to change the angle of the drill chassis from horizontal, or 0 degrees, to a 20 degree down angle.

The True Trac has its own trailer for transportation between sites. This trailer also incorporates a diesel driven hydraulic power pack for the hydraulic rotation and thrust of the True Trac.

The hollow steel drill rods used are 5' in length, 2 7/8" outside diameter, and 1 3/8" inside diameter.

1.2.3 Operator's Console

A pneumatic flow control system (Figure 7) was added to the True Trac Operators Console. A pneumatic type flow control system was selected because of its simplicity, reliability and low cost. The pneumatic flow control system is a redundant safety feature, to protect personnel and equipment from high pressure air when the drill cuttings and compressed air exit the borehole into the diverter box. An inline automatic valve downstream of the operator's manual shutoff valve, will close to shut off high pressure air from the air compressor. This automatic valve is controlled by pneumatic circuitry which senses the compressed air pressure when it exits the borehole into the diverter box. If the pressure reaches 5 psi in the diverter box, the automatic valve will close, shutting off incoming air from the air compressor.

There are additional adjustments in the pneumatic flow control system to allow for activation by different pressures and response time delays in case of rapid cyclic pressure pulses.

1.2.4 Bottom Hole Assembly (BHA) (Figure 6)

The BHA attaches to the leading end of the drill pipe and is the component that drills the borehole and allows directional steering.

The BHA consists of an air-motor rock bit, and sonde/bent sub.

The rock bit, used to make the test borehole, has a dome-shaped polycrystalline diamond compact design.

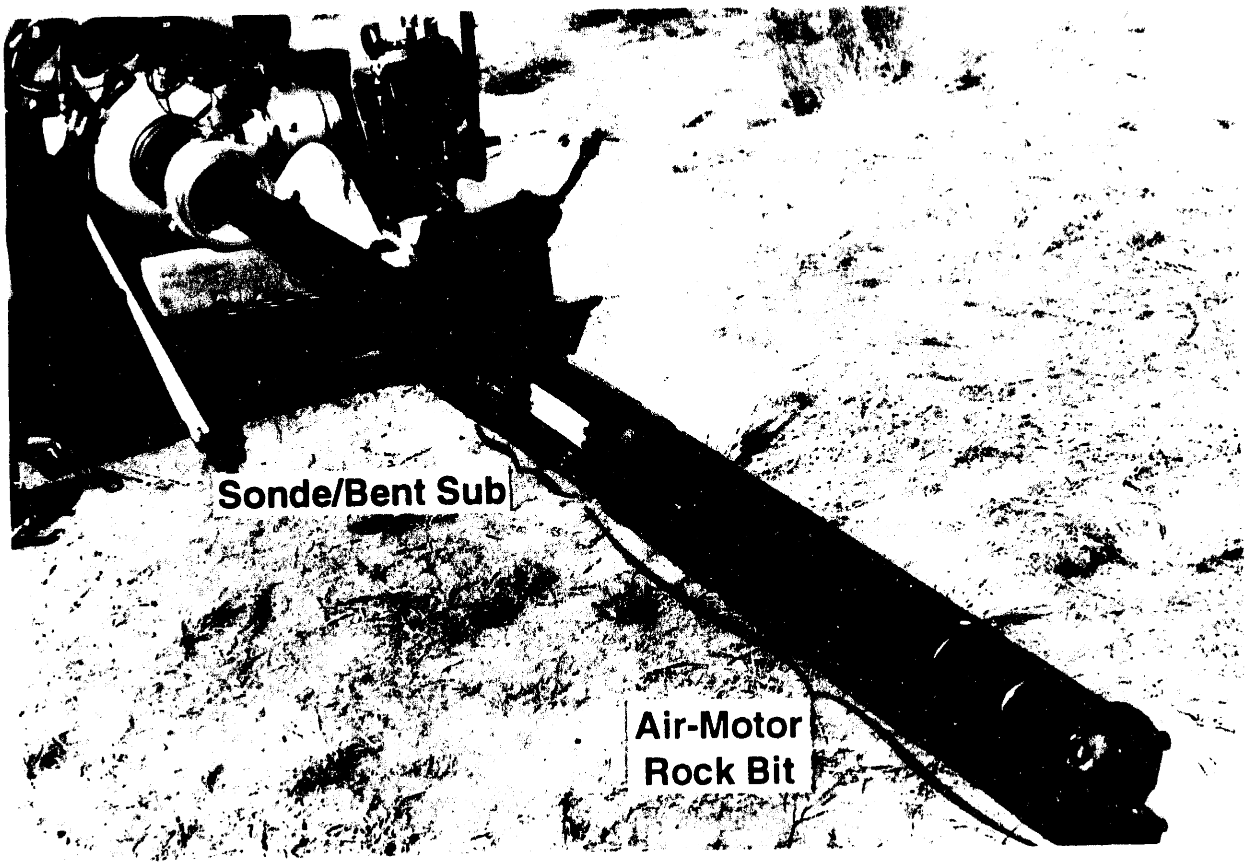

Figure 6. Bottom hole assembly.

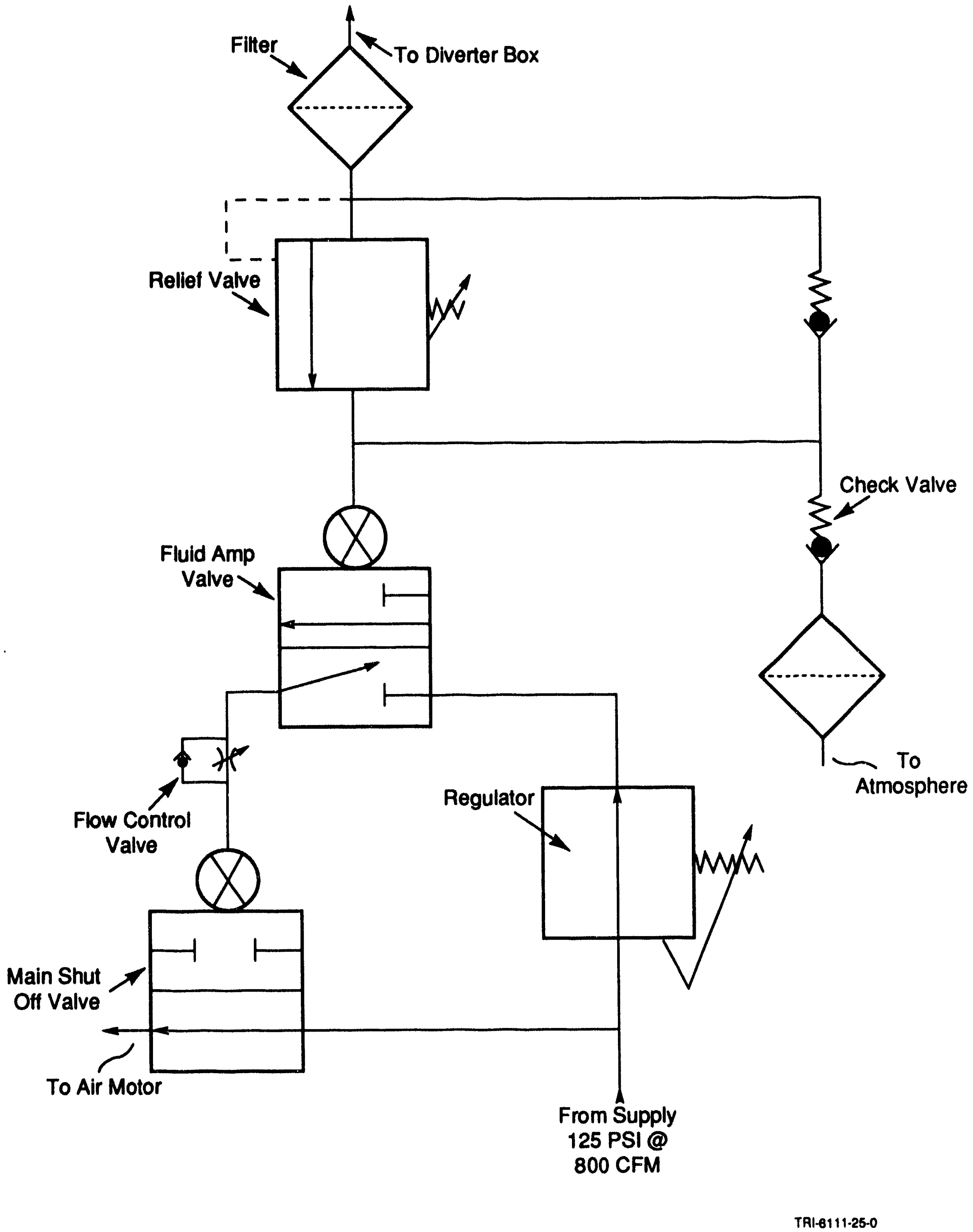

Figure 7. Pneumatic flow control diagram.

The sonde is the electronics transmitter that sends a RF signal through the soil to a walk-over detection antenna. The walk-over detection system is used for determining any needed borehole course corrections. The sonde is located within the housing of the bent sub.

The bent sub allows the BHA to be steered, depending upon its current degree of rotation while drilling the borehole. The sub used in the test had a 1.3 degree bend in it. The sonde was aligned to the bent sub, to transmit a 0 degree rotation signal when the bent sub was pointed upward.

1.2.5 Diverter Box (Figure 4)

Under normal operating conditions, the diverter box accepts returned air and cuttings and maintains a vacuum. Also, the diverter box surrounds the drill rod between the drill rig and the surface casing. The diverter box is a modified propane gas bottle. A propane gas bottle was selected for: availability, similarity in shape to design needs, low cost, and pressure rating. Although the original shape was not changed, the bottle length was shortened, ports were added for sampling, drill cuttings discharge, surface casing connection, instrumentation, seal housing, pressure relief valves, and vacuum relief valves.

On the end of the diverter box closest to the drill rig is the seal housing (Figure 8). The seal housing keeps the diverter box aligned to the drill rig and also contains three 1" thick natural rubber seals with metal spacers between them. The rubber seal design prevents any leakage into or out of the diverter box formed by the seal surfaces between the rotating drill rod and the diverter box. Remember, even though this region is normally maintained at a vacuum, under certain conditions it could see a compressed air atmosphere. For example, if the vacuum source is lost, or the vacuum portion of the system becomes plugged up. The reason for using three seals is to cover as much length of the drill rod as reasonable for surface irregularities that could be a path for compressed air or drill cuttings to escape out to the atmosphere.

The original propane gas bottle was designed for use on the order of 200 psig. With the modifications it was assigned a Maximum Allowable Working Pressure (MAWP) of 6 psig. This 6 psig comes from the ASME rating of MAWP 6 psig stamped on the vacuum/filter unit. To verify this rating the diverter box was hydrostatic tested to 32 psig. The hydrostatic testing pressure was selected to more than satisfy the normal pressure safety factor requirements of 4 to 1. All added ports, piping, and hardware pieces have at least a schedule 40 rating and a minimum pressure rating of 125 psig.

1.2.6 Diverter Box-Hydraulic System (Figure 9)

A hydraulic four-cylinder system is used to clamp the diverter box to the drill rig, and also to compress the rubber seals to compensate for normal wear of the seals on the drill pipe. This hydraulic system consists of the following:

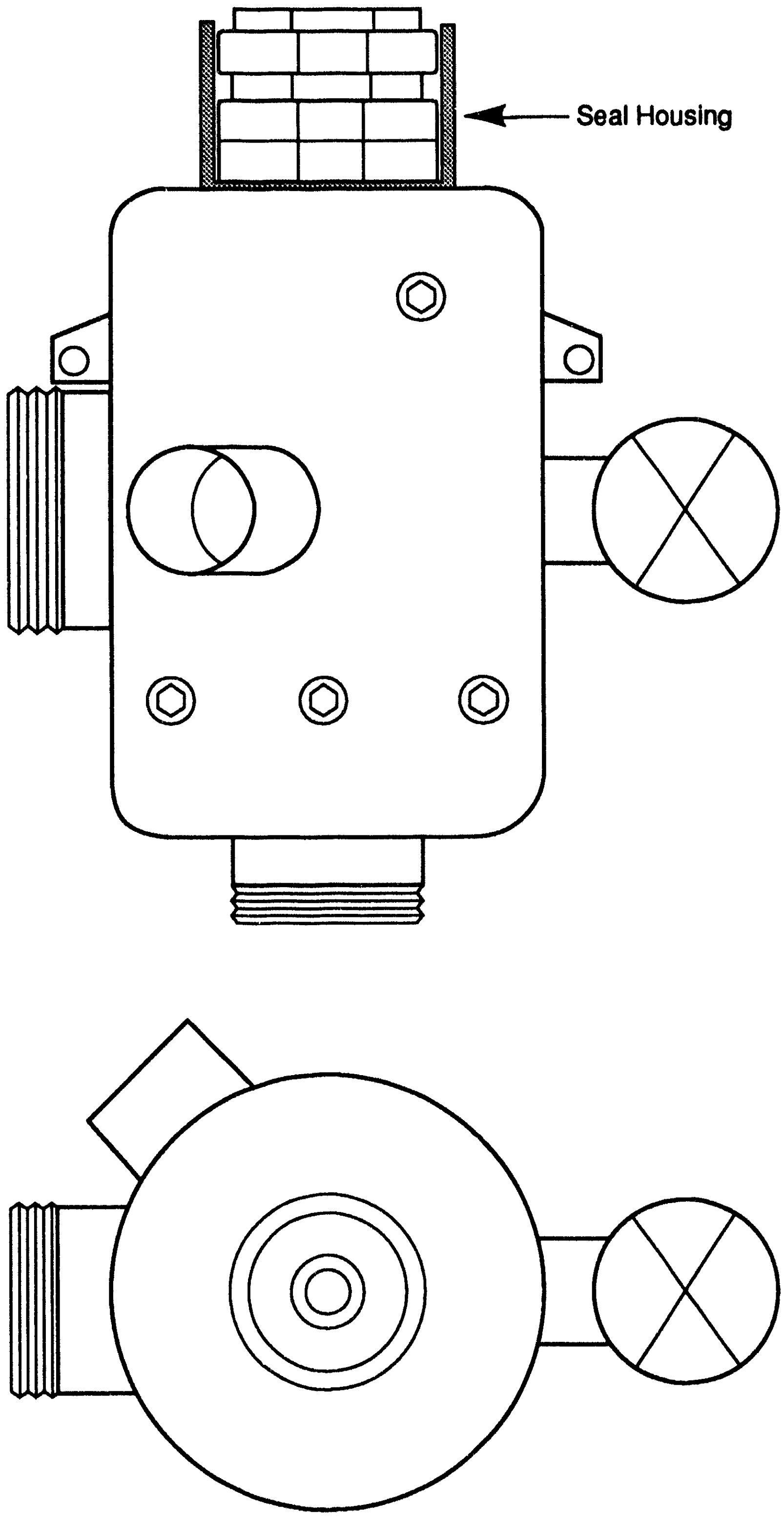

Figure 8. Diverter box seal diagram.

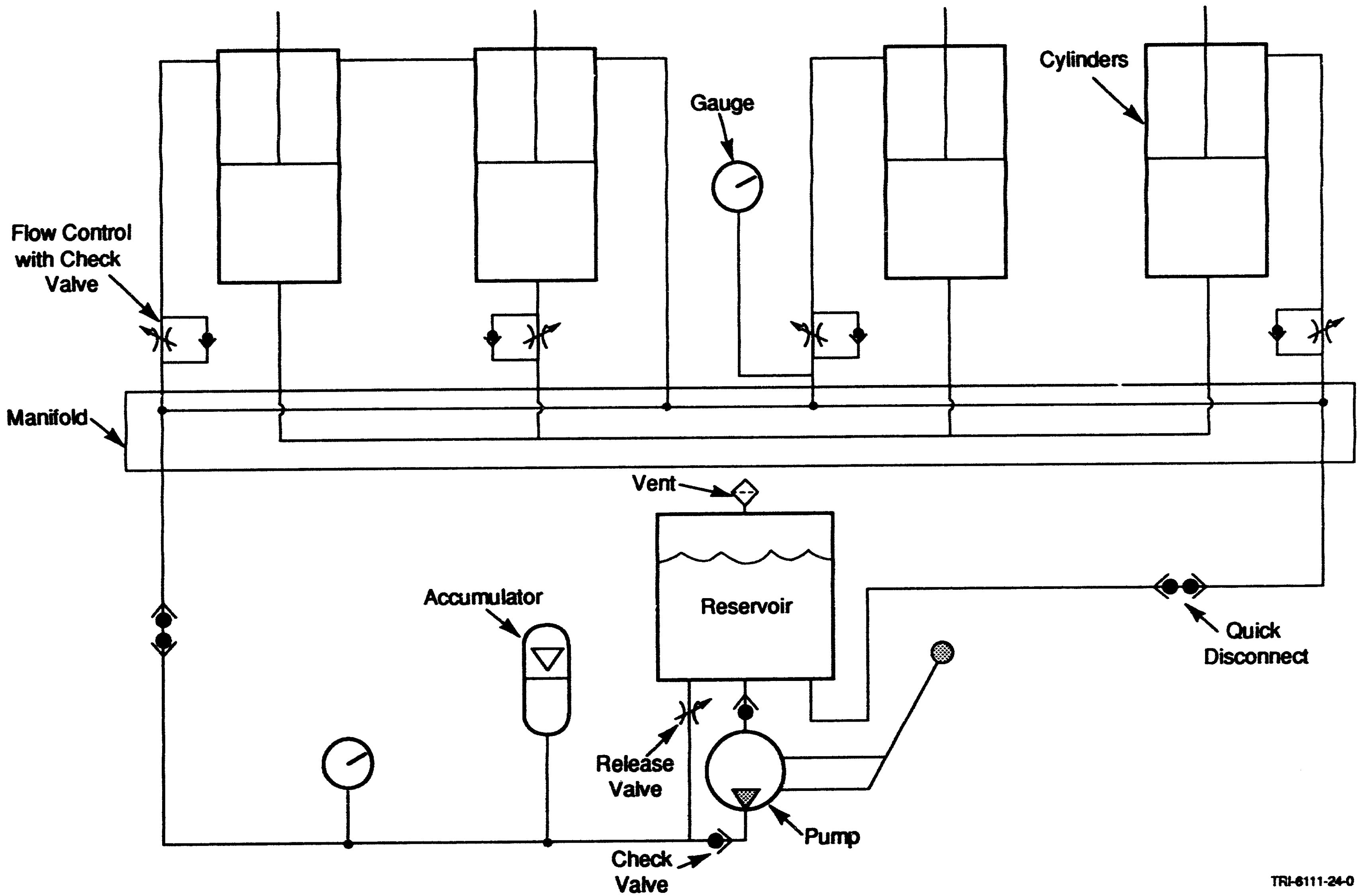

Figure 9. Diverter box hydraulic clamping diagram.

1. Handpump/Reservoir

2. Accumulator

3. Hydraulic Cylinders

4. Flow control/Check valves

5. Pressure Gauge

Testing of the hydraulic assembly indicated that 200 psig was the minimum hydraulic pressure needed to hold the diverter box securely clamped to the end of the drill rig. The seals probably did not need this much hydraulic pressure to maintain their sealing to the drill pipe when they were new. The system has the capability of being pressurized up to 800 psig to maintain an adequate seal as the seals wear.

The accumulator is a metal bottle containing nitrogen and hydraulic oil with a bladder separating them. The compressed nitrogen, via the bladder, is used to maintain a constant hydraulic pressure in case of minor leakages of hydraulic system fluid to the atmosphere.

The hydraulic cylinders are standard commercial cylinders sized to fit this application.

To allow the diverter box to be rigidly clamped to the drill rig, flow control/check valves are used for isolating each hydraulic cylinder from the other cylinders. Since the cylinders are connected in parallel, the flow control/check valves keep the fluid in one cylinder from being displaced to another cylinder.

To relieve hydraulic pressure on the cylinders, the release knob on the hand pump and each cylinder flow control/check valve was opened.

1.2.7 Vacuum and Pressure Relief Valves

The diverter box has two Kunkle 3" vacuum relief valves. The valves are for assisting the flow of cuttings material through the diverter box and limiting the vacuum applied to the borehole. Limiting the amount of vacuum applied prevents excess vacuum from adversely affecting the borehole by causing sloughing. The vacuum relief valves do not have a calibrated setting for opening, but are adjusted in the field.

The diverter box also has one Kunkle 3" pressure relief valve. It is a redundant safety feature to prevent overpressuring the diverter box. For test purposes, it was vented to the atmosphere. During drilling operations at a hazardous waste site, the pressure relief valve normally would be connected to a hose going to the inlet of the vacuum/filter unit's baghouse. In case the cyclone separator becomes clogged from a liquid or slurry mix, this configuration would open the relief valve and send liquid or slurry mix to the baghouse which has a differential pressure alarm to alert the drill rig operator. The pressure relief valve was calibrated to open at 6 psig.

1.2.8 Instrumentation

A 4 1/2" diameter pressure gauge with a range of 1-15" psig and a 4 1/2" diameter vacuum gauge with a range of 0-30" Hg were mounted on the diverter box. They both faced the operator on the drill rig for observation.

1.2.9 Vacuum/Filter Unit (Figures 5a and 5b)

The prototype unit is a modified version of Guzzler Manufacturing's line of MiniReach asbestos abatement vacuum/filter equipment.

The vacuum/filter unit has a length of 25', a width of 102", a height of 12', and a wet weight (ready for use) of 15,980 lb.

The rated flow and vacuum rating is 1,700 cfm at 12.8" Hg.

The sequence for the flow of drill cuttings and air flow through the vacuum/filter unit is as follows: cyclone, baghouse, either or both legs of High Efficient Particulate Absolute (HEPA) and charcoal filters, Roots pump, a muffler and lastly to the atmosphere.

1.2.9.1 MAIN COMPONENTS OF THE VACUUM/FILTER UNIT

The main components of the vacuum/filter unit are as follows:

1. Cyclone Separator
2. Baghouse Filter
3. HEPA Filters
4. Charcoal Filters
5. Roots Blower
6. Diesel Engine
7. Air Cannon
8. Instrumentation Panel
9. Pressure and Vacuum Relief Valves
10. Paint
11. Miscellaneous

There are many minor components, that will be described with their associated main components.

All the major and minor components on the vacuum/filter unit have been designed for ease of removal for repair, replacement, modification, or contamination reasons.

Cyclone Separator

This is the first stage of separation (filtration) for the drill cuttings and its induced air. The cyclone sets the drill cuttings and induced air into a spinning motion, which causes heavier materials to fall out of suspension and be captured in the bottom of the unit. This removes an estimated 95% plus of the materials being vacuumed. It is made of stainless steel and has a material capacity of 1 cubic yard.

The cyclone separator is stamped with an ASME code rating of 6 psig.

The cyclone separator has a removable lid for access to its interior. A cast-in rubber seal in the lid is the sealing barrier between the lid and the cylinder of the cyclone. The lid can be removed with a hand operated hoist that pivots in a stanchion to lower the lid to ground level.

Six inch Camlock™ fittings are used on the inlet and outlet ports of the cyclone separator to attach hoses, caps, etc.

A hydraulically driven auger can be installed inside, if needed, to assist materials in dropping to the bottom of the cyclone. The efficiency of the cyclone drops from approximately 95% to approximately 70% if the auger is used. The auger was removed prior to the beginning of the test period.

A 12" hydraulic activated knife gate valve is connected on the bottom of the cyclone separator to control dumping of cuttings out of the cyclone separator into debris bags or barrels. The hydraulic activated gate valve can also be moved manually with a wheel screw. The wheel screw is used primarily during decontamination of the equipment when hydraulic pressure is not available because the diesel engine is not running. This also serves as a backup safety method to empty the cyclone separator in case of diesel engine or hydraulic failure.

Below the hydraulic gate is a 12" agriculture-irrigation type clamp fitting used to retain the cuttings bag when emptying the cyclone separator. This fitting has a vacuum port attached to completely evacuate the cuttings bag prior to emptying the cyclone separator. Evacuating the cuttings bag prior to emptying the cyclone separator ensures that no air in the bag is displaced into the cyclone separator when it is emptied of drill cuttings. A manual ball valve controls the vacuum applied to this port.

When emptying the cyclone separator and baghouse filter, a electrical/pneumatic wafer valve upstream of the Roots pump must be opened. This relieves vacuum applied to the entire vacuum/filter unit and allows cuttings to drop down and out of the cyclone separator or baghouse filter into their drill cuttings bags.

The operator's control panel for the hydraulic gates is located between the cyclone separator and baghouse filter.

Baghouse Filter

This is the second stage of filtration for the drill cuttings and its induced air. The baghouse filter profile is similar to the outside shape of the cyclone separator, and is also made of stainless steel. This includes a removable lid, hydraulic/manual knife gate valve, and an agriculture irrigation type fitting with a vacuum port attached.

The baghouse filter has a stamped ASME code rating of 6 psig.

The internal structure of the baghouse filter is completely different from the cyclone separator. Internally, the baghouse contains 36 Dacron (polyester) filter bags. These bags filter material down to 1 micron in size. The bags are 42" long, 5 1/4" diameter, and are closed at one end. A removable metal frame cage is inserted into each bag. This cage supports the bags in their normal expanded shape for maximum filtration and air flow through the bags.

The lid contains the plumbing for the air cannon outlets. The air cannon is addressed below. Each of the 36 bags has an air cannon nozzle directly above it. The nozzle directs timed pulses of compressed air into each bag for timed cleaning of any material that was built up on the outside surfaces of the bag.

A Magnehelic™ differential pressure gauge is installed on the baghouse to give continuous differential pressure readings between the input and output ports of the baghouse filter to monitor the accumulation of drill cuttings fines on the outside surfaces of the bags.

HEPA Filters

The third stage of filtration removes any particle size greater than .3 micron from the air stream. The air flow at this area of filtration is split upstream of the HEPA filters into two paths. Each path is composed of a nuclear grade HEPA filter and a nuclear grade charcoal filter. The charcoal filters are addressed in component section #4. The paths join back together again downstream of the charcoal filters. Either path can be isolated by closing a Grinnell 6" butterfly valve on either side of the HEPA and charcoal filter housing. This allows replacing filters in one path while the other path is still in use.

The HEPA filter frame is 24" height, 24" width, and 11 1/2" thick. The actual filter medium depth is 8". The nominal rated flow capacity through the filter is 1,000 cfm. The filter element material is a non-woven glass paper (boron silicate micro fibers) rated to filter out particles to .3 micron.

One face of the filter frame has a circumferentially continuous channel that contains a highly-viscous, silicone compound fluid seal. This is where the HEPA filter is sealed to it's housing.

The sealing occurs because a continuous knife edge on the housing frame mates into th circumferentially continuous channel.

Each HEPA housing has a Magnehelic, differential pressure gauge attached to it for comparing the input and output condition of the HEPA filter assembly.

The housing has the capability of using a bag-in/bag-out method of changing the filters. The bag-in/bag-out method is a simple and safe way of filter change-out, without exposing the filter or interior of the housing to personnel or the environment. When it is necessary to change a filter, the path is isolated. The housing cover is removed, exposing a double plastic bag. The outer bag has gloves molded into it. This allows the HEPA filter to be placed into the inner bag and secured for removal.

If industrial hygiene or health physics personnel need to monitor the air quality across the HEPA filters, multiple monitoring ports are located upstream and downstream of each filter housing for withdrawing samples.

Charcoal Filters

The fourth stage of filtration removes any volatile organic compounds (VOC). The filter medium is made from nuclear grade granular activated coconut shell charcoal impregnated with potassium iodine.

The charcoal filters are 24" height, 24" width, and 16" thick. They have an airflow rating of 1,000 cfm. The size and rated flow capacity combine to give a residence time of at least 1/8 second. Residence time measures how long the gas stream is in contact with the carbon. The residence time of 1/8 second is the minimum needed for VOCs to be absorbed into the charcoal.

The method of sealing charcoal filters to their housing is the same design as used by the HEPA filters. Each charcoal filter housing incorporates the same design as the HEPA housing for using the bag-in/bag-out method of filter removal and filter flow path isolation. Multiple sample ports both upstream and downstream are also provided.

Roots Blower

The Roots blower type vacuum pump is the source of vacuum for the Guzzler vacuum/filter unit and is manufactured by Dresser Industries. The Roots blower is designated as a positive displacement rotary lobe vacuum pump.

It consists of two double-lobe impellers mounted on parallel shafts and rotating in opposite directions within a housing closed at both ends by headplates. As the impellers rotate, air is drawn into one side of the cylinder and forced out the opposite side against the existing pressures. The differential pressure developed, therefore, depends on the resistance of the connected systems.

The vacuum rating is 12.8" mercury (Hg) at 1,700 revolutions per minute (rpm). The rotational speed of the blower is always higher than the rotational speed of the diesel drive engine (see below). This is because of the gearing ratio of the power take off (pto) unit between the Roots blower and the diesel engine. For example, when the diesel engine is running at 1,200 rpm the Roots blower is turning at 1,700 rpm.

The output of the Roots blower is connected to a residential quiet muffler which exhausts to the atmosphere.

Diesel Engine

The power source for the Guzzler vacuum/filter unit is the diesel engine. The motor is turbocharged and has four cylinders. The engine produces 100 horsepower (hp.) at 1,200 rpm.

The diesel engine drives the Roots blower and the air cannon's (see below) air compressor via the pto. The hydraulic pump for the cyclone separator and baghouse filter hydraulics is v-belt driven from the diesel engine.

Engine Operator's Panel (Figure 14)

This panel contains a tachometer and manual throttle to control the vacuum levels needed for testing. The oil pressure and temperature analog gauges have built-in switches to shut down the engine in event of low oil pressure or high temperature.

Air Cannon

The air cannon is a system used to clear the baghouse filter bags of drill cutting fines that accumulate on the outside walls of the bag. A timed pulse of air is injected into the inside of each bag during operation.

Compressed air for the air cannon comes from a small air compressor driven by the diesel engine. An air dryer/heater receives this compressed air and acts as the air accumulator for the baghouse filter bag cleaning nozzles.

The air cannon system only clears half the bags during each timed pulse. Thus, an interval of two timed pulses are required to clean all the bags.

The timed pulse is controlled by an electronic circuit board. The electronic circuit board has potentiometers to adjust pulse duration and time delay between pulses. The electronics circuit board is located above the instrumentation panel inside a weather-proof enclosure.

Instrumentation Panel (Figure 10)

Three Magnehelic differential gauges are mounted on the instrumentation panel. These gauges have analog readouts and adjustable differential pressure switches. The differential pressure switches are activated when their set points are exceeded, thus turning on a red light and the 120 db. two-tone audible alarm horn mounted on the instrumentation panel.

One gauge is used to monitor the baghouse filter differential pressure and has an analog scale of 0-100" of water. The gauge set point switch is set to activate at 80" of water. The other two gauges monitor the HEPA filters differential pressure. They have an analog scale of 0-10" of water. Their differential pressure switches are set at 3" of water.

All three gauges have individual mini valves in their monitoring tubing to isolate them for zero setting or replacement of the gauge without stopping the Guzzler vacuum/filter unit.

A 0-30" Hg liquid filled analog vacuum gauge is provided to read the Guzzler vacuum/filter unit's vacuum. The sensor for this gauge is upstream of the Roots blower.

An analog temperature gauge with an adjustable switch is used to monitor the temperature of the Roots blower. Continuous maximum vacuum being pulled or loss of lubrication are the main reasons for high temperatures. The switch, when activated, will turn on a red light and sound the 120 db audible alarm horn.

There are three manual toggle switches. The first switch is to activate the air dryer/heater associated with air cannon. The second switch is to control the electronics circuit board of the air cannon. The third switch is used to control the electro/pneumatic vacuum relief valve.

All plumbing for the panel to the various locations on the vacuum/filter unit is connected by 1/4" nylon tubing. Tubing connections are of the quick disconnect type. This permits easy troubleshooting and/or replacement. Replacement may be required for chemical resistance compatibility with the drill cuttings being vacuumed.

Pressure and Vacuum Relief Valves

Two Kunkle 3" pressure relief valves upstream of the Roots blower limit the maximum pressure to the vacuum/filter unit. They are calibrated to open at 6 psig and have a air flow rating of 1,200 SCFM. Each valve is capable of more than handling any incoming compressed air by itself. Guzzler Manufacturing installed redundant pressure relief valves because of their concern that the vacuum/filter unit never exceed 6 psig.

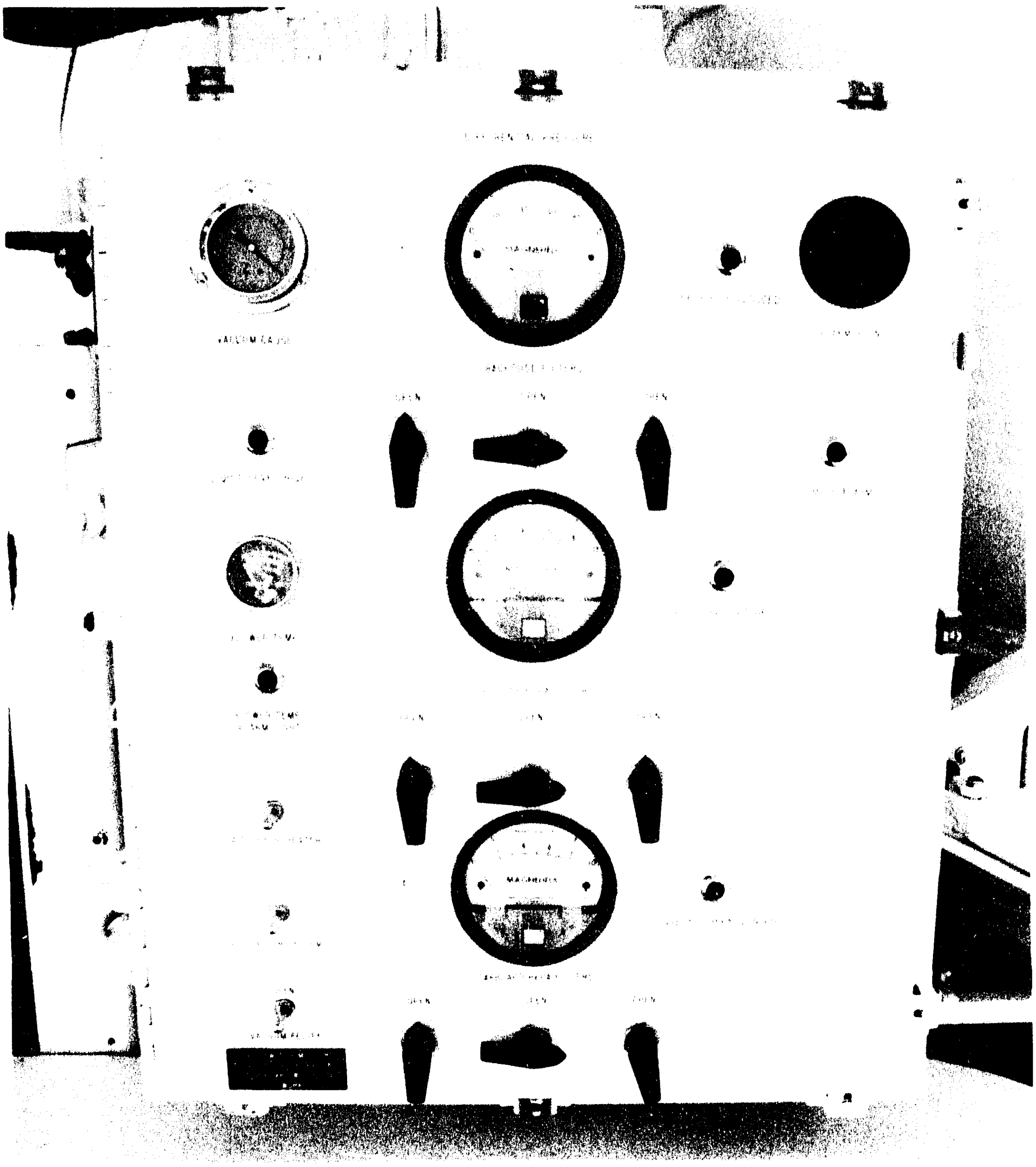

Figure 10. Instrumentation panel.

One Kunkle 3" vacuum relief valve upstream of the Roots blower limits the maximum vacuum on the vacuum/filter unit. It is calibrated to open at 14.5" Hg. To prevent any dust or sand from being pulled into the Roots blower when this relief valve opens, a Donaldson air filter was adapted to the inlet of the relief valve.

A Grinnell 8" electro/pneumatic butterfly valve with Jamesbury air actuator relieves the vacuum/filter unit's vacuum prior to emptying drill cuttings from the cyclone separator or baghouse filter. The valve is located upstream of the Roots blower. This allows the Roots blower to pull its needed air supply directly from the atmosphere, and vacuum is reduced to none or minimal on the Guzzler vacuum/filter unit. The valve is manually controlled by a switch located on the hydraulic gate control panel for the cyclone separator and baghouse filter. The other method of reducing vacuum is to lower engine speed or disconnect the PTO, both of which are more involved and cumbersome to do during normal operations. To prevent any dust or sand from being pulled into the Roots blower when the Grinnell valve is open, a Donaldson air filter was adapted to the inlet of the Grinnell valve.

Laminar Flow Array

A Laminar Flow Array (LFA) is located upstream of the pressure and vacuum relief valves. The LFA is 1' in length and has fifty-two 3/4" inside diameter pieces of tubing installed inside of it. The purpose of the LFA is to minimize any turbulence of the air flow in this area for the installation of a velocity meter probe. The area around the velocity meter probe needs all air flow to be parallel through the piping for accuracy in measuring velocity. The velocity meter was used to measure velocity of air flow through the Guzzler vacuum/filter during testing.

Paint

The finish paint and primer is manufactured by Ameron. The finish paint is the same specification used by Westinghouse Hanford for their drill cuttings containment box. This paint is Amercoat #66. It is a polyamide-cured epoxy paint. The manufacturer recommends this paint for use in extremely high nuclear radiation areas.

The paint primer was a substitute for the primer used by Westinghouse Hanford. The original primer Amercoat #71 has been discontinued and Amercoat #182 is the recommended replacement for the finish paint, Amercoat #66. Amercoat #182 is a polyamide epoxy primer.

Miscellaneous

Camlock fittings were used on all pneumatic hoses that had to be removed occasionally.

The concern for personnel safety due to static buildup was addressed. To minimize static buildup in the vacuum hoses, the Camlock fittings were connected at each end of the hoses to the wire helix in the hose wall. This connected the drill rig, vacuum hoses, and vacuum/filter unit to each other. The vacuum/filter unit's chassis was connected to a 5/8" diameter copper rod, driven 8' into the ground. This made a common connected ground for the drill rig, hoses and vacuum/filter unit. Sandia Laboratories Electromagnetic Test and Analysis Department stated that a common connection to a ground is an accepted practice for minimizing static problems. The National Electric Code requires that a ground electrode (rod) be driven at least 8' into the ground.

All common connections and connections to ground were checked with an ohm meter daily, for continuity, prior to DCCS operation.

2. DRILL CUTTINGS CONTAINMENT SYSTEM- TESTING

Sandia Laboratories Dept. 6111 leased the Guzzler vacuum/filter unit for a six-month period of test and evaluation. Testing and evaluation of this unit required a complete and operational field system. Thus the Drill Cuttings Containment System (DCCS) was designed to test and evaluate the Guzzler vacuum/filter unit.

The first two months of the lease period were spent acquiring materials and accessories, making equipment modifications, and resolving unforeseen engineering problems. Hands-on training time was spent on the operation of the Guzzler vacuum/filter unit and, as required, on each piece of the DCCS equipment.

The last four months of the lease period were spent field testing the vacuum/filter unit. Final testing of the entire DCCS began in July and was completed by the end of August. Field testing of the DCCS took place at the Dept. 6111 Directional Boring Test Range (DBTR) (Figure 11). The DBTR is located on the southern end of Sandia Laboratories Technical Area III within Kirtland Air Force Base and is six acres in size.

The ground at the DBTR is composed of layers of sand, sandstone, caliche clay, and alluvial gravel with occasional large quartz stones. This variable geology can occur as close as five feet below the surface.

A pit located on the DBTR, known as the West Pit (Figure 12) was the location selected at the DBTR for testing of the DCCS. The pit size is 15' width, 40' length, and 5' depth. Previously this pit had been used for testing horizontal directional boring equipment.

Testing and evaluation of the DCCS involved four phases:

Phase I. Shakedown of the Guzzler vacuum/filter unit using commercial crushed stone and sand as test samples.

Phase II. Operating the Guzzler vacuum/filter unit attached to a wellhead diverter box, and using commercial crushed stone, sand, and bentonite powder as test samples.

Phase III. Operating the Guzzler vacuum/filter unit with wellhead diverter box and air compressor to test system flow parameters.

Phase IV. Operating the Guzzler vacuum/filter unit with wellhead diverter box, air compressor, and drilling rig during actual drilling operations.

The four phases of testing and evaluation were needed to evaluate the Guzzler vacuum/filter unit for possible use at hazardous sites.

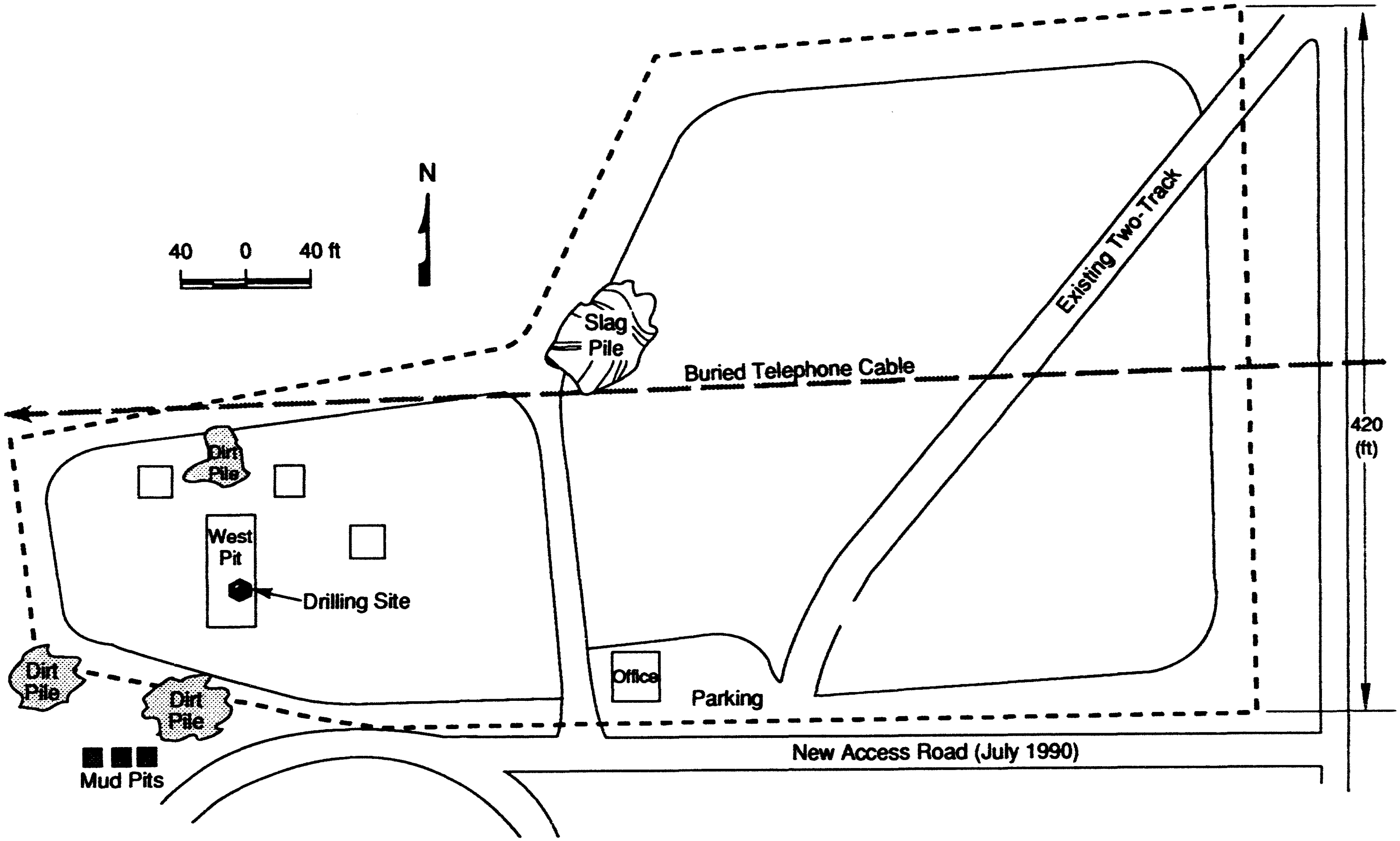

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Figure 11. Directional boring test range.

Figure 12. West pit.

In the first two phases, simple direct vacuuming of various materials was done. Direct vacuuming uses the hose connected to the inlet of the cyclone separator as the nozzle for actual contact with the different materials during vacuuming. Measuring the volume before and after vacuuming would give the efficiency of the cyclone and baghouse. The volume vacuumed was 2 cubic feet. Only the material emptied from the baghouse filter was measured after each test. The volume of 2 cubic feet vacuumed, minus the baghouse filter material, gave the volume dropped out by the cyclone separator. The diverter box was checked for any material dropout after each test in Phase II. Three different engine speeds were used with each material. The reason for using different engine speeds was to determine the lowest engine speed required to move material through the vacuum hoses and the vacuum/filter unit. Using three different engine speeds for each material in Phases I and II gave three points of data for each material vacuumed. Air velocity was recorded during all phases. A calculation was done to convert air velocity to CFM. The vacuum/filter unit's vacuum was recorded during each test in inches of mercury. The differential pressure readings were recorded before, during, and after each test.

After three sequential tests of vacuuming each material, the HEPA filters were removed and visually inspected for any material buildup.

Phase III did not involve active vacuuming of any material. This phase, particularly with the addition of the pneumatic flow control system and the air compressor, was needed to prove the compatibility of the DCCS components. This phase was covered from laboratory development of components to a simulated integration of all DCCS components in the field as an actual operation. In the field test a 25' section of hose simulated the borehole. Data was recorded at different engine speeds, but not to the extent of Phases I and II. The Phase III test was done in four steps.

The fourth phase tested the DCCS as a complete system during actual horizontal directional drilling operations. Data similar to the first two phases plus the additional data from other DCCS components was recorded.

Initial data recording (Table 1) of the vacuum/filter unit components was taken prior to any of the test phases, including HEPA visual examination. This established a baseline level for the vacuum/filter unit.

Periodically during the various test phases, material was sieved to identify particle size. This gives an idea of the efficiency of the cyclone separator and baghouse filter.

In the Test Results Section, only the tests that had additional, significant, or different information from the test data sheets are expanded upon.

Table 1. Initial Vacuum and Differential Pressure Readings of Guzzler Vacuum/Filter Unit 4-26-93

ENGINE RPM	VACUUM ("HG.)	BAGHOUSE ("H2O)	PORT HEPA ("H2O)	STARBOARD HEPA ("H2O)
600	2.0	2.0	.4	.4
800	2.5	3.0	.65	.65
1,000	3.3	5.0	1.0	1.0
1,200	4.5	6.5	1.2	1.3
600	2.0	2.0	1.4	Isolated
800	3.0	3.0	2.3	Isolated
1,000	4.0	4.2	3.2*	Isolated
1,200	5.0	6.0	4.3	Isolated
600	2.0	2.0	Isolated	1.3
800	3.0	3.0	Isolated	2.3
1,000	4.0	4.0	Isolated	3.2*
1,200	5.0	6.0	Isolated	3.9

* Port and starboard HEPA alarms sounded when differential pressure across them reached 3.2" Hg.

2.1 Test Instrumentation

1. A portable air velocity kit (Figure 13) was used to measure air flow. The meter has a direct air velocity analog readout of 0-12,000 fpm. The sensor is a platinum Resistance Temperature Detector (RTD) device. No temperature or pressure compensation is required. The sensor was located in a sample port, approximately 4' upstream of the roots blower and 1.5' downstream of the laminar flow array. To correctly locate the sensor, velocity readings were taken at six equal depths inside the 6" pipe and three engine speeds at the sample port to find the best velocity average. The center of the 6" pipe was the best average location for the tip of the air velocity sensor.

2. A calibrated 0-30" Hg vacuum gauge was connected to a vacuum port located a few inches downstream of the air velocity sample port. This gauge was used for recording vacuum data of the Guzzler vacuum/filter unit.

3. The magnehelic differential pressure gauges for the baghouse filter and HEPA filters were checked for an initial zero reading prior to daily operations.

4. The engine tachometer gauge (Figure 14) was used as the indicator for setting different engine speeds.

Figure 13. Omega velocity meter.

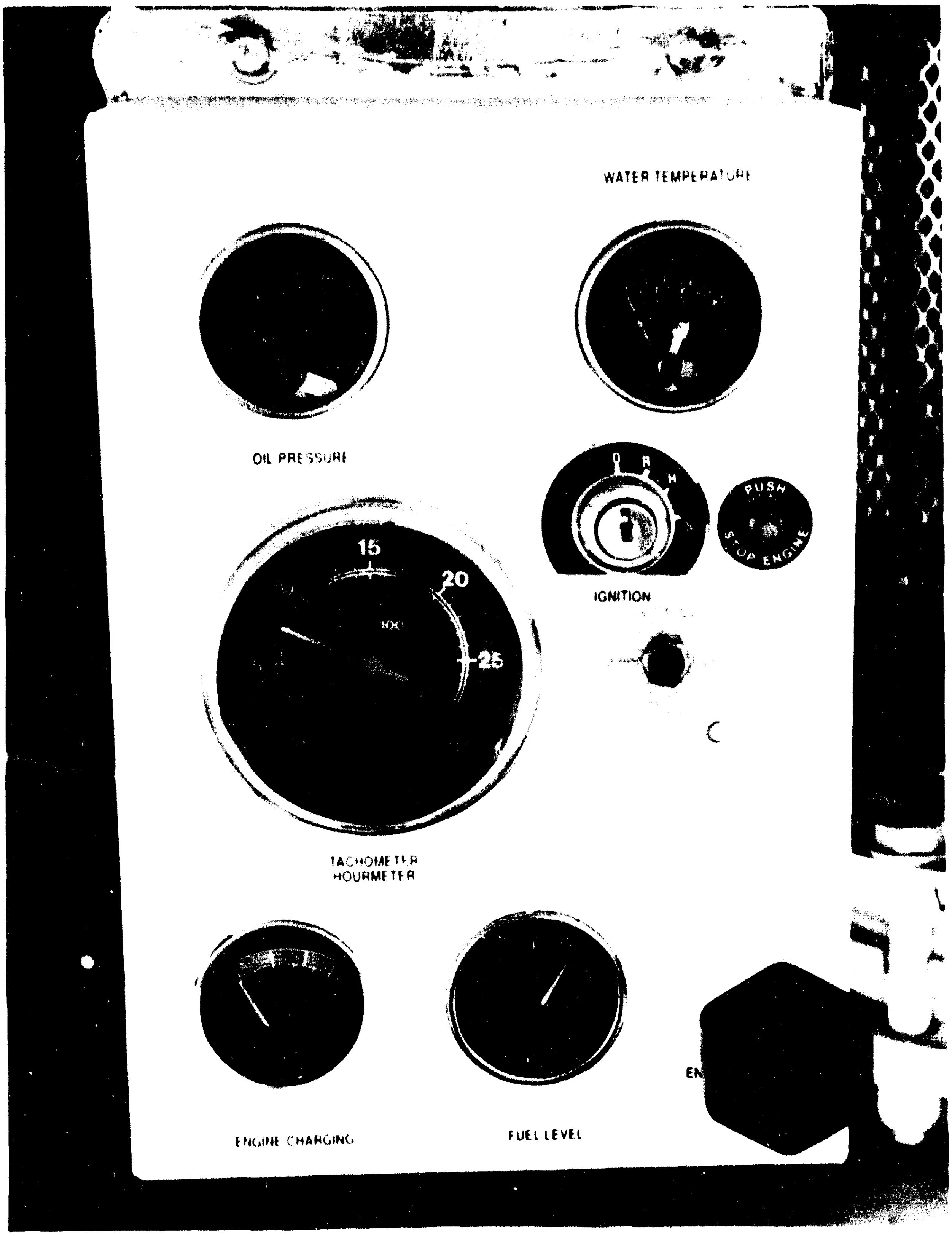

Figure 14. Engine operators panel.

2.2 Test Materials

Phase I: Known amounts of eight geologic simulation materials (Figure 15) were vacuumed and filtered. The eight materials were acquired locally from a sand and gravel company. The materials are as follows:

1. 3/4" Crushed Quartz Riverbed Stone

2. 1/2" Crushed Quartz Riverbed Stone

3. 1/4" Crushed Quartz Riverbed Stone

4. 1/8" Crushed Quartz Riverbed Stone

5. Concrete/Natural Sand

6. Brick Sand

7. Plaster Sand

8. Play Sand

Phase II: The materials were the same as Phase I, with the addition of bentonite powder.

Phase IV: The borehole entrance for the horizontal drilling was located 5' below the ground surface in a soft sandstone layer. Cuttings consisted of very fine dust, sand, and occasional broken stone of 1/8" to 3/4" in size.

2.3 Test Results

2.3.1 Phase I

A total of eight tests were completed. The test data recorded show normal increases for the system vacuum and differential pressure as the engine speeds were increased. The comment section of the test data contains remarks for each test. One thing identified in direct vacuuming was that 800 rpm engine speed is barely acceptable. An engine speed of 1,000 rpm should be the minimum speed used during direct vacuuming.

In test #4, the material used was 1/8" unwashed crushed stone, and all of its crushed fines were still mixed with the 1/8" stone. When emptying the baghouse filter, a smaller amount of fines were removed than what was removed in test #1, #2, & #3. This was a surprise. After test #6, an answer was found. Visibly, the 1/8" unwashed crushed stone had the most fines compared to the other materials.

After test #6, there was a concern as to why there had been a smaller amount of fines in test #4, when logically there should have been more. The Roots blower was disconnected when the

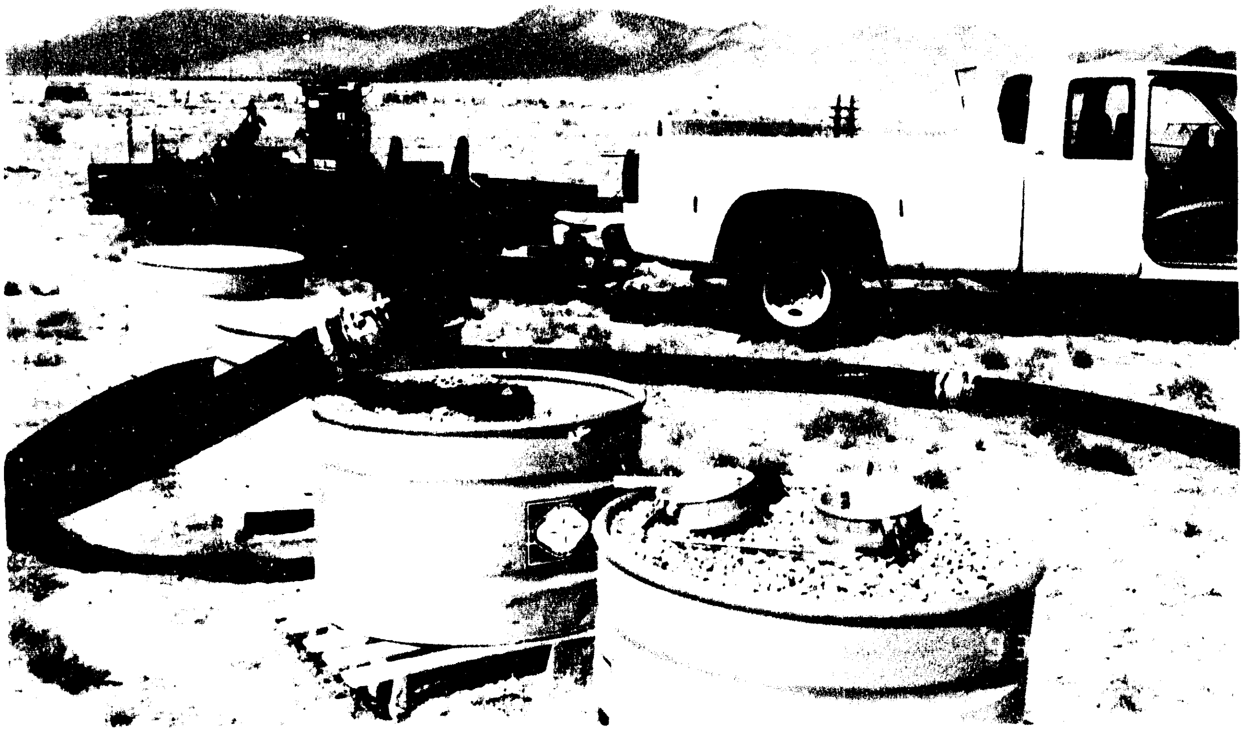

Figure 15. Various vacuumed materials.

test material was being removed from the cyclone separator and baghouse filter. This was not normal procedure. There was no change in the amount of material from the cyclone separator. A substantial amount of fines dropped out of the baghouse filter. The disconnection was done to see if extra fines were staying attached to the baghouse filter bags. In a normal procedure for emptying the cyclone separator and baghouse filter, the 8" electro/pneumatic butterfly valve is opened to relieve system vacuum. The Roots blower is still engaged and pulls its air from the atmosphere through the 8" valve. However, there is still a slight amount of vacuum that is felt on the baghouse filter bags. This is enough to keep some of the very light fines from dropping to the bottom of the baghouse filter for removal.

The baghouse had a gradual increase of differential pressure to about 11-15" of water as each test continued. After completion of the Phase I test, the baghouse filter bags were removed for inspection and cleaning. Visual inspection indicated that no vacuumed material passed through the bags. Every bag had a fairly heavy coating (about 1/8" thick) of fines on its exterior. Buildup of fines on the bag material actually increases the efficiency of filtration, although the differential pressure across the bag also increases. The differential pressure alarm for the baghouse filter is set at 80" of water. Thus the 11-15" of differential pressure observed during testing was of no concern. For test purposes only, each bag was removed and cleaned with a commercial vacuum cleaner. Differential Pressure readings (Table 2) of the baghouse filter, after cleaning the bags, returned to approximately the same level as at the start of Phase I.

Table 2. Baghouse Filter Differential Pressure Readings: Initially, After Phase I, After Cleaning Bags

Engine RPM	Initially (4-26-93) ("H2O)	After Phase I (5-25-93) ("H2O)	After Cleaning* (6-8-93) ("H2O)
800	3.	6.	3.
1,000	5.	10.	4.5
1,200	6.5	12.	6.2

* Bags were removed individually and cleaned by hand vacuum.
* Approximately .268 ft^3 of fines were removed from baghouse.

After three tests of each material were completed, the HEPA filters were inspected. No material fines were seen on the filtering medium. A wipe of the internal surfaces of the HEPA housing, upstream of the filter, did not show any fines.

A sample of the baghouse fines from 1/8" crushed stones was sieved (Table 3).

PHASE I - Drill Cuttings Containment System Tests

Test Date: 5/21/93 Test # 1

Test Sample - 3/4" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed, RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	810	Idle=2, Pk=4.5	Bfr=6, After=7	Bfr=.7, After=.7	Bfr=.7, After=.7	0	2
1000	1025	Idle=3, Pk=5	Bfr=10, After=10	Bfr=1, After=1	Bfr=1, After=1	0	2
1200	1115	Idle=3.8, Pk=7	Bfr=12, After=12	Bfr=1.2, After=1.2	Bfr=1.2, After=1.2	0	2

Comments: Had to go to 1200 RPM to clear crushed stone from hose after 800 RPM vacuum, Air flow was measured on 5/24/93 thru 50 Ft. of open 6" hose

Test Date: 5/21/93 Test # 2

Test Sample - 1/2" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	810	Idle=2, Pk=4.5	Bfr=6, After=6	Bfr=.7, After=.7	Bfr=.7, After=.7	0	2
1000	1040	Idle=3, Pk=5.5	Bfr=9, After=9	Bfr=1, After=1	Bfr=1, After=1	0	2
1200	1115	Idle=3.8, Pk=7	Bfr=12, After=12	Bfr=1.2, After=1.2	Bfr=1.2, After=1.2	0	2

Comments: Had to go to 1200 RPM to clear crushed stone from hose after 800 RPM vacuum, Air flow was measured on 5/24/93 thru 50 Ft. of open 6" hose

Test Date: 5/25/93 Test # 3

Test Sample - 1/4" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	883	Idle=2, Pk=5	Bfr=5, After=5	Bfr=.7, After=.7	Bfr=.7, After=.7	?	2
1000	981	Idle=2.8, Pk=6	Bfr=8, After=8	Bfr=.9, After=.9	Bfr=.95, After=.95	Dust only	2
1200	?	Idle=3.5, Pk=6.5	Bfr=11, After=12	Bfr=1.2, After=1.2	Bfr=1.3, After=1.3	0	2

Comments: Had to go to 1000 RPM to clear hose after the 800 RPM vacuum, We installed the air velocity meter at position 3 in the Guzzler manifold for tests 3 thru 8
We dumped alot of dust from the baghouse after the 800 RPM vacuum. The ? was a result of the air velocity meter overheating in the sun and oscillating wildly, it's OK in the shade

PHASE I - Drill Cuttings Containment System Tests

Test Date: 5/25/93 Test # 4

Test Sample - 1/8" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed, RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	825	Idle=2, Pk=5	Bfr=5, After=6	Bfr=.7, After=.7	Bfr=.7, After=.7	.008	2
1000	923	Idle=3, Pk=6.7	Bfr=10, After=10	Bfr=.95, After=.9	Bfr=1, After=1	.008	2
1200	1080	Idle=3.5, Pk=7.5	Bfr=11, After=11	Bfr=1.2, After=1.1	Bfr=1.3, After=1.2	.008	2
Comments:	Not necessary to increase RPM's after 800 RPM vacuum to clear hose, Some moisture in sample, Removed about 21 oz. of dust from baghouse						

Test Date: 5/25/93 Test # 5 (TUB 6)

Test Sample - concrete/natural sand Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	746	Idle=2, Pk=6.5	Bfr=7.5, After=8	Bfr=.7, After=.7	Bfr=.7, After=.7	.014	2
1000	981	Idle=2.8, Pk=5.5	Bfr=10, After=10	Bfr=.9, After=.8	Bfr=.9, After=.9	.014	2
1200	1021	Idle=3.7, Pk=8.3	Bfr=15, After=15	Bfr=1.2, After=1.1	Bfr=1.3, After=1.3	.014	2
Comments:	Sand sample slightly moist, We removed dust from baghouse after test #6						

Test Date: 5/25/93 Test # 6 (TUB 7)

Test Sample - Brick sand Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	746	Idle=2, Pk=6.5	Bfr=5, After=5	Bfr=.6, After=.6	Bfr=.7, After=.7	.014	2
1000	1040	Idle=2.8, Pk=5.5	Bfr=9, After=9	Bfr=.95, After=.9	Bfr=1, After=1	.014	2
1200	1080	Idle=3.7, Pk=7.5	Bfr=11, After=13	Bfr=.9, After=1.2	Bfr=1.2, After=1.3	.014	2
Comments:	We found that if we disconnected the vacuum from the baghouse prior to dumping contents more dust was dumped We dumped approximately 5 pt. of dust from the baghouse after vacuuming the three samples in tests 5 & 6						

PHASE I - Drill Cuttings Containment System Tests

Test Date: 5/25/93 Test # 7 (TUB 8)

Test Sample - Plaster sand Test Sample Volume - 2 CU. FT.

Engine Speed, RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	825	Idel=2, Pk=5	Bfr=5, After=6	Bfr=.7, After=.6	Bfr=.8, After=.7	.021	2
1000	1001	Idle=2.8, Pk=6	Bfr=9, After=9.5	Bfr=1, After=.9	Bfr=1, After=1	.021	2
1200	1080	Idle=3.7, Pk=7.5	Bfr=13, After=13	Bfr=1.2, After=1.2	Bfr=1.3, After=1.3	.021	2

Comments: After we finished the three vacuuming tests we disconnected the blower and dumped the baghouse and removed about 60 oz. of dust

Test Date: 5/25/93 Test # 8 (TUB 9)

Test Sample - Play sand Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	746	Idle=2, Pk=4.75	Bfr=5, After=6	Bfr=.7, After=.6	Bfr=.7, After=.7	.009	2
1000	982	Idle=2.8, Pk=6.5	Bfr=9.5, After=10	Bfr=1, After=1	Bfr=1, After=1	.009	2
1200	1080	Idle=3.7, Pk=7.5	Bfr=13, After=14	Bfr=1.2, After=1.2	Bfr=1.3, After=1.3	.009	2

Comments: Again after we finished the three vacuuming tests we disconnected the blower and dumped the baghouse and removed about 24 oz. of dust

Table 3. Sieve Chart of Baghouse Filter Fines from 1/8" Crushed Stones After Phase I, 5-1-93

Mesh	Aperture (in)	Weight (g)	% of Total Weight
>100	.0059	4.71	1.61
>115	.0049	6.07	2.07
>200	.0029	128.05	43.74
>230	.0025	125.37	42.83
>270	.0021	21.15	7.23
>400	.0015	4.21	1.44
<400		3.17	1.08
		292.73	100.

2.3.2 Phase II

Seven tests were done during Phase II. Brick sand and plaster sand were not vacuumed, as they were similar in size and consistency to concrete/natural sand, which was vacuumed. Bentonite powder was not vacuumed in Phase I and was the last material vacuumed in Phase II, because of concern that the extra fine powder of bentonite could pass through the baghouse filters and clog the HEPA filters. The vacuuming sequence of the six materials in Phase I, starting with the largest material and going to smallest, was reversed. The addition of the diverter box and concern for any damage to it from the larger stones was the reason for reversing the sequence. After vacuuming the larger stones (larger than 1/8"), the diverter box was visually inspected for damage. None was found, and further concern for integrity of the diverter box was unnecessary.

Initially, the diverter box was inspected after each test for any material dropout. Some dropout did occur in the diverter box at 800 engine rpm. However, the material moved to the vacuum/filter unit once the rpm was increased to at least 1,000 rpm.

The baghouse pressure differential had a slight increasing trend similar to Phase I, until the bentonite powder was vacuumed. After the last test of vacuuming bentonite powder, the baghouse pressure differential was 22" of water. Still, this is significantly below the alarm maximum of 80" of water.

The day after the bentonite test approximately .134 ft^3 of fines were removed from the baghouse filter upon powering the Guzzler vacuum/filter unit up. The maximum differential pressure was now one half the 22" water reading on the previous day. This material apparently fell off the bags after the Guzzler vacuum/filter unit was idle overnight. An attempt to remove more fines from the bags was done by isolating each HEPA path and operating the air cannon for one hour. The HEPA's paths were isolated to prevent any vacuum from being applied to the baghouse filter. About .2 ft^3 of fines were removed from the baghouse filter after one hour.

The differential pressure readings (Table 4) were now close to the initial readings prior to Phase II.

Table 4. Baghouse Filter Differential Pressure Readings 6-17-93: After Phase II, After Cleaning Bags First Time, After Cleaning Base Second Time

Engine RPM	After Phase II ("H2O)	After 1st Cleaning* ("H2O)	After 2nd Cleaning* ("H2O)
800	6.	4.	4.
1,000	8.	6.	5.5
1,200	10.	8.	7.5

* First cleaning lasted 30 minutes and .134 ft^3 of fines were removed from baghouse.
* Second cleaning lasted 30 minutes and .05 ft^3 of fines were removed from baghouse.

After each series of materials tests the HEPA filters were inspected. No material fines were seen until the bentonite powder was vacuumed. A very slight color change occurred on the leading edge of the filter pleats. This indicated that some minute amount of bentonite had passed through the baghouse filter. A wipe of the internal surfaces of the filter housing, upstream of the filter, did not reveal the presence of bentonite.

The efficiency of the cyclone separator was readily observed in the bentonite powder test. The cyclone was able to drop out 95% plus of the material vacuumed. A sample of baghouse bentonite fines were sieved (Table 5).

Table 5. Sieve Chart of Bentonite Powder, 6-18-93

Mesh	Aperture (in)	Weight (g)	% of Total Weight
>100	.0059	34.14	8.27
>115	.0049	13.09	3.17
>200	.0029	75.19	18.22
>230	.0025	57.65	13.97
>270	.0021	32.63	7.91
>400	.0015	80.13	19.41
<400		199.90	29.05
		412.73	100.

PHASE II - Drill Cuttings Containment System Tests

Test Date 6/10/93 Test # 1 (TUB #9)

Test Sample - Play sand Test Sample Volume - 2 CU. FT.

Engine Speed, RPM	System Air Flow at Peak Vacuum, CFM	Peak System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	942	4	Bfr= 3 After= 3	Bfr= .6 After= .55	Bfr= .65 After= .65	0	2
1000	1139	6.3	Bfr= 4.5 After= 4	Bfr= .8 After= .75	Bfr= .95 After= .85	0	2
1200	1335	7.5	Bfr= 6.1 After= 6.2	Bfr= 1.0 After= 1.0	Bfr= 1.2 After= 1.2	0	2

Comments: Diverter box approximately 1/3 full of sand after 800 RPM vacuum, and had 2 cups of sand after 1000 RPM vacuum, had to go to 1200 RPM to clear the diverter box. No cleanout of the diverter box was required after the 1200 RPM vacuum. There was 30 Ft. of 6" dia. hose from the guzzler to the diverter box and 50 Ft. from the diverter box to tubs

Test Date: 6/10/93 Test # 2 (TUB #5)

Test Sample - concrete/natural sand Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	Peak System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	942	5.2	Bfr= 3.8 After= 3.6	Bfr= .6 After= .6	Bfr= .7 After= .68	0	2
1000	1139	6.9	Bfr= 4.8 After= 4.6	Bfr= .8 After= .78	Bfr= .97 After= .95	0	2
1200	1374	9.8	Bfr= 6.8 After= 6.8	Bfr= 1.2 After= 1.0	Bfr= 1.2 After= 1.2	.011	<2

Comments: Sample was slightly damp.

Test Date: 6/10/93 Test # 3 (TUB #4)

Test Sample - 1/8" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	Peak System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	942	5.8	Bfr= 2.9 After= 2.8	Bfr= .6 After= .6	Bfr= .63 After= .61	.037	<2
1000	1139	6.8	Bfr= 4.5 After= 4.5	Bfr= .8 After= .6	Bfr= 1.0 After= .98	.022	<2
1200	1335	9.3	Bfr= 8 After= 8	Bfr= 1.1 After= 1.0	Bfr= 1.2 After= 1.2	.017	<2

Comments: Sample was slightly damp.

PHASE II - Drill Cuttings Containment System Tests

Test Date: 6/10/93 Test # 4 (TUB #3)

Test Sample - 1/4" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed, RPM	System Air Flow at Peak Vacuum, CFM	Peak System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	942	6.0	Bfr= 4 After= 4	Bfr= .6 After= .5	Bfr= .65 After= .64	.005	<2
1000	1139	8.3	Bfr= 6.5 After= 6.4	Bfr= .8 After= .8	Bfr= .95 After= .9	.005	<2
1200	1335	9.1	Bfr= 9.8 After= 9.8	Bfr= 1.0 After= 1.1	Bfr= 1.2 After= 1.2	.005	<2

Comments:

Test Date: 6/11/93 Test # 5 (TUB #2)

Test Sample - 1/2" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	Peak System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	785	5.0	Bfr= 5 After= 5	Bfr= .6 After= .6	Bfr= .7 After= .7	Dust	2
1000	844	7.5	Bfr= 8 After= 7	Bfr= .8 After= .8	Bfr= 1.0 After= .95	.008?	2
1200	923	9.1	Bfr= 9 After= 10	Bfr= 1.0 After= 1.0	Bfr= 1.2 After= 1.2	Dust	2

Comments: Baghouse purge pressure was 90 to 100 psi. After 800 RPM vacuum we dumped cyclone and opened diverter box, had about 2 cups sample in diverter box, had to go to 1200 RPM to clear diverter box and hose. Diverter box empty after the 1000 and 1200 RPM vacuums

Test Date: 6/11/93 Test # 6 (TUB #1)

Test Sample - 3/4" Crushed Test Sample Volume - 2 CU. FT.

Engine Speed RPM	System Air Flow at Peak Vacuum, CFM	Peak System Vacuum Inches Hg	Diff. Pressure Baghouse Filters Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters Inches Water	Sample Removed from Baghouse CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	746	5.5	Bfr= 5 After= 5	Bfr= .6 After= .6	Bfr= .7 After= .7	Dust	2
1000	864	7	Bfr= 8 After= 8	Bfr= .8 After= .8	Bfr= 1.0 After= 1.0	Dust	2
1200	923	8.9	Bfr= 10 After= 10	Bfr= 1.0 After= 1.0	Bfr= 1.3 After= 1.3	Dust	2

Comments: After the 800 RPM vacuum we dumped the cyclone and ran a 1200 RPM vacuum to clear diverter box and hose, we removed an additional .23 Cu. Ft. of sample from cyclone. After the 1000 RPM vacuum there was a handfull of sample in the diverter box, we again ran a 1200 RPM vacuum to clear diverter box and hose.

PHASE II - Drill Cuttings Containment System Tests

Test Date: 6/11/93 Test # 7

Test Sample - Bentonite Powder Test Sample Volume - 2 CU. FT.

Engine Speed, RPM	System Air Flow at Peak Vacuum, CFM	Peak System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.
800	825	4.8	Bfr= 6 After= 8	Bfr= .6 After= .5	Bfr= .7 After= .7	.1337	<2
1000	942	5.5	Bfr= 8 After= 15	Bfr= .8 After= .7	Bfr= .95 After= .9	.2006	<2
1200	1042	7.5	Bfr= 12 After= 22	Bfr= 1.0 After= .9	Bfr= 1.2 After=1.1	.2674	<2
Comments:	Majority of sample was in cyclone separator after vacuuming at each speed.						

2.3.3 Phase III

The Phase III testing was divided into four steps:

Step 1. Laboratory Pneumatic Flow Control - Setup and testing of the pneumatic flow control safety system in the laboratory. The setup and testing was done with lab supplied compressed air set at 30 psig maximum.

Step 2. Field Pneumatic Flow Control - A field pneumatic flow control system test was done with the diverter box and the air compressor running. The flow control system was mounted on the operator's console of the drill rig. Two lengths of drill rod (10') were added to the drill rig through the diverter box. A 25' length of 6" hose was connected to the inlet of the diverter box. The other end of the hose was capped off. The outlet of the diverter box was uncapped. The compressed air flow direction was through the center of the drill pipe, returning by the annulus of the 6" hose to the diverter box and out the outlet of the diverter box to the atmosphere.

Step 3. Choked Pneumatic Flow Control - A field choked pneumatic flow control system test was done on the diverter box with the air compressor running to test the automatic shutoff valve for the incoming compressed air at 5 psig. The hardware arrangement of step #2 was used, except a 3" ball valve on the diverter box was utilized and the outlet of the diverter box was capped. The diverter box outlet had to be capped because the pressure drop through a 6" opening was so large. When it was uncapped, the 3" ball valve had no effect in increasing diverter box pressure. The 3" ball valve was slowly closed to increase the air pressure in the diverter box, activating the flow control system, and shutting off incoming compressed air at the operators control panel on the drill rig.

The incoming compressed air, arriving at the drill rig, fluctuated between 50-60 psig due to low restrictions in the air flow path. It was determined that going to a higher pressure would allow for better adjustment of components in the flow control system. The drill air motor was installed on the end of the 10' of drill rod to act as a restriction. The air pressure at the drill rig was now 115 psig.

Step 4. Complete System - The hardware arrangement of step 3 was used, except the vacuum/filter unit was connected to the outlet of the diverter box and a 3" vacuum relief valve was installed on the diverter box.

The vacuum relief valve on the diverter box was field calibrated to open at 4" Hg. With the DCCS running in a normal operational mode at 800 rpm, the vacuum reading at the vacuum/filter unit was 9" Hg. The vacuum reading at the diverter box was 6" Hg. Another vacuum relief valve was needed on the diverter box to lower the vacuum levels of the vacuum/filter unit and diverter box. A lower vacuum at the diverter box was used because of the concern that in Phase IV the borehole could collapse at high vacuum. The second 3" vacuum relief valve was installed after step #4. Both valves were field calibrated to open at 5" Hg and utilized in Phase IV.

Test data was only taken for step #4.

Test procedures are as follows:

1. Setup and test pneumatic flow control safety system in the laboratory.
   Date Tests Completed: 7-6-93

2. Conduct system flow and pressure field tests on the wellhead diverter box, without the Guzzler unit attached.
   Date Tests Completed: 7-9-93

3. Conduct choked flow field tests from the wellhead diverter box to verify pneumatic flow control safety system operation.
   Date Tests Completed: 7-16-93

4. Attach the Guzzler to the wellhead diverter box and conduct system flow field tests.
   Date Tests Completed: 7-26-93

Guzzler Engine Speed RPM	Air Compressor Output Flow CFM	Guzzler System Air Flow CFM	Wellhead Diverter Box Pressure psi	Wellhead Diverter Box Vacuum Inches Hg
800	OFF	883	0	3
1000	OFF	982	0	3.8
1200	OFF	1040	0	4
Comments: (1) Ball Valve open during entire test. (2) VRV opened at 1050 RPM. Vacuum was steady.				

Guzzler Engine Speed RPM	Air Compressor Output Flow CFM	Guzzler System Air Flow CFM	Wellhead Diverter Box Pressure psi	Wellhead Diverter Box Vacuum Inches Hg
800	800	T1=785 / T2=883	0	T1 = 2.75 / T2 = 2.
1000	800	T1=1080 / T2=1080	0	T1 = 3.50 / T2 = 3.
1200	800	T1=1178 / T2=1178	0	T1 = 4.50 / T2 = 4.
Comments: (1) Air compressor running at max flow and ball valve open. (2) At 1200 RPM VRV opened at 4" Hg., Vacuum then climbed slightly.				

Guzzler Engine Speed RPM	Air Compressor Output Flow CFM	Guzzler System Air Flow CFM	Wellhead Diverter Box Pressure psi	Wellhead Diverter Box Vacuum Inches Hg
800	800	T1=903 / T2=412	0	T1 = 2.0 / T2 = 6.0
800	800	T1=883 / T2=432	0	T1 = 2.2 / T2 = 6.2
Comments: (1) Air compressor running and ball valve being closed. (2) VRV opened at 4" Hg., but vacuum continued to climb to 6" Hg.				

2.3.4 Phase IV

Phase IV testing utilized all four main components of the DCCS.

Only one run of drilling was planned, but weather-related problems required two runs.

Surface casing had to be installed horizontally into the ground prior to Phase IV. The surface casing acted as a pilot/alignment hole for the borehole and as the seal between the drill rig, borehole, and atmosphere to prevent any air used during drilling operations from escaping into the atmosphere. The surface casing was 9 1/2' length, 10" inside diameter, and 1/4" thick wall steel pipe and was encased in a slab of reinforced concrete 2' by 2' for its full length and covered with base course to ground level. Base course is a concrete mixture with very little cement powder and is applied dry. The concrete held the surface casing pipe rigidly in place in the ground and acted as a seal along with the base course to prevent any air from escaping between the surface casing and the ground surface.

The drill rig was placed in a horizontal position and aligned with the surface casing. The center of the air motor, attached to the drill rig, was aligned as close as possible to the center of the casing. This center was approximately 5' below the ground level. A flex hose was connected between the diverter box and the surface casing. This provided a flexible connection between the drill rig and surface casing and permitted easy installation and removal of the BHA.

The drilling sequence for each rod was to drill the first half of the rod at 180 degrees, with the sonde down, rotate the rod to 0 degrees, with the sonde up, and drill the second half of the rod. The rod was pulled back every time before rotating to allow the air motor ports to open and blow the cuttings through the borehole annulus to the diverter box.

Run #1

Seven rods (35') were used with five (25') drilled into the ground. The first 3 rods (15') drilled produced very little fines in the cyclone separator or baghouse filter, although rods 4 and 5 produced the expected amount of fines. Sudden weather deterioration forced the drilling operation to stop. All rods had to be removed back to the point of having access to the sonde within the BHA. When the surface casing flange was removed for access to the BHA, the surface casing was approximately half filled with cuttings. Apparently, the surface casing acts like a horizontal cyclone separator. The hole being drilled has a diameter of 5.25" diameter and the surface casing has a inside diameter of 10". As the cuttings were flowing to the diverter box a difference in velocities occurred in the surface casing causing the cuttings to drop out. The casing filled with cuttings until air velocity in the casing was sufficient to remove cuttings. Any more cuttings from drilling would move to the diverter box and on to the cyclone separator and baghouse filter.

The borehole consisted of typical soft and hard alluvial materials, and the hard materials were in a layer no more than six inches thick.

After drilling was terminated the diverter box was opened and about .07 ft^3 of pebbles were lying in the bottom of the box. They were 1/4" to 5/8" in size. No fines were seen.

Table 6 shows the before and after baghouse differential pressure after the baghouse was isolated and pulsed for one hour.

Table 6. Baghouse Filter Differential Pressure Readings 8-13-93: Before Phase IV, After Phase IV-Run 1, After Pulsing for 1 Hour

Engine RPM	Before Phase IV ("H2O)	After Phase IV ("H2O)	After Pulsing* ("H2O)
800	4.	11.	4.
1,000	6.	16.	5.
1,200	8.	19.	7.

* Bags were removed individually and cleaned by hand vacuum.
* Approximately .268 ft^3 of fines were removed from baghouse.

The baghouse was isolated and pulsed for a total of one hour to reduce differential pressure readings and to find out how much material could be removed. About .6 ft^3 of fines dropped out of the baghouse. This was much more than expected, more than when vacuuming straight bentonite powder. The answer that seems most logical is that the oil vapor in the air supplied to the air motor was going to the baghouse filter and eventually plugging the voids in the material that was already collected on the bags. A large amount of fines dropped out of the baghouse because the oil vapor tended to solidify the fines. Pulsing the bags forced the material to break off and fall to the bottom of the baghouse.

Run #2

Upon re-entering the hole and drilling further, twelve rods (60') were used, with ten (50') drilled in the ground. The first five rods (25') just pushed through to the end of the borehole that had previously been made. All rods were rotated in the method previously mentioned, except rod 10, which was drilled entirely in the 0 degree orientation. This was to correct the BHA from diving downward as rod 9 started to do. The last two rods in the ground, rods 9 and 10, were very hard to drill. The BHA was apparently going through a layer of large stones. During this time the BHA was pulled back frequently to blow cuttings out of the hole and the force required to pull back the BHA during this time was substantially higher than normal. Movement of the stones along the borehole walls was apparent cause for the extra force needed in pulling back the BHA.

The Phase IV testing was discontinued after drilling rod 10 (50'). Substantial data had been recorded and the potential of being unable to retrieve the BHA, necessitated terminating Phase IV tests.

A sample of cyclone and baghouse fines was sieved (Tables 7 and 8).

A chart showing the before and after baghouse filter differential pressure (Table 9) after it was isolated and pulsed for one hour is included with the test data. The volume of fines removed from the baghouse were .6 ft^3. An explanation of the large amount of fines is presented in the writeup of Run #1.

Table 7. Sieve Chart of Cyclone Fines After Phase IV Run #2, 6-18-93

Mesh	Aperture (in)	Weight (g)	% of Total Weight
>100	.0059	523.40	46.26
>115	.0049	166.28	14.70
>200	.0029	291.85	25.80
>230	.0025	76.24	6.74
>270	.0021	20.51	1.81
>400	.0015	25.07	2.22
<400		28.04	2.48
		1,131.29	100.

Table 8. Sieve Chart of Baghouse Filter Fines After Phase IV Run #2, 6-18-93

Mesh	Aperture (in)	Weight (g)	% of Total Weight
>100	.0059	294.88	95.34
>115	.0049	12.63	4.08
>200	.0029	.69	.22
>230	.0025	.39	.13
>270	.0021	.33	.11
>400	.0015	.13	.04
<400		.23	.07
		1,131.29	100.

Table 9. Baghouse Filter Differential Pressure Readings 8-20-93: Before Phase IV, After Phase IV-Run 2, After Pulsing for 1 Hour

Engine RPM	Before Phase IV ("H2O)	After Phase IV ("H2O)	After Pulsing* ("H2O)
800	4.	11.	3.
1,000	5.	14.5	4.25
1,200	7.	18.	8.5

* See explanation in DCCS-Testing regarding large amount of fines removed from baghouse.

PHASE IV - Drill Cuttings Containment System Tests

Data Taken at Guzzler Unit

Rod #	Guzzler Engine Speed, RPM	Guzzler System Air Flow, CFM	Guzzler System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.	Date Data Taken
BHA	N / A	The bottom hole assembly (BHA) was 4.5 feet long and consisted of the drill motor and bent sub.							8/12/93
1	N / A	The new borehole distance will be measured relative to the flange installed on the well casing.							8/12/93
2	N / A	The distance from the well casing flange to the beginning of the new borehole is 9.75 feet.							8/12/93
3	800	Bfr=883, Dur=785	Bfr=4.5, Dur=6.0	Bfr= 10, Aft= 10	Bfr= .5, Aft= .5	Bfr= .7, Aft= .7	.004	.034	8/12/93
4	800	Bfr=844, Dur=785	Bfr=5.0, Dur=6.0	Bfr= 10, Aft= 12	Bfr= .4, Aft= .4	Bfr= .7, Aft= .6	.004	.66	8/12/93

Comments: We ran the Guzzler at 1200 RPM after drilling rod #4 to attempt to remove additional debris, but we removed only a small amount of additional sand.

Data Taken at Drill Rig

Rod #	Tru-Trac Drill Rig Thrust Pressure, psig	Air Compressor Pressure at Tru-Trac Drill Rig, psig drilling / cleaning	Tru-Trac Drill Rig Borehole Distance Rod Number / Total Ft.	Wellhead Diverter Box Pressure / Vacuum psig / inches Hg	Date Data Taken
BHA	N/A	N/A	BHA / 0	N/A	8/12/93
1	N/A	N/A	#1 / 0	N/A	8/12/93
2	N/A	N/A	#2 / 0	N/A	8/12/93
3			#3 / 4.5		8/12/93
4			#4 / 9.5		8/12/93

Comments: Rods are drilled with the locater tool oriented at 180 degrees during the first half and at zero degrees during the second half.

PHASE IV - Drill Cuttings Containment System Tests

Data Taken at Guzzler Unit

Rod #	Guzzler Engine Speed, RPM	Guzzler System Air Flow, CFM	Guzzler System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.	Date Data Taken
5	1000	Bfr=982, Dur=883	Bfr=4.5, Dur=6.0	Bfr= 14, Aft= 17	Bfr= .6, Aft= .6	Bfr= .8, Aft= .8	No dump	No dump	8/12/93
6	1000	Bfr=982, Dur=923	Bfr=5.0, Dur=6.0	Bfr= 17, Aft= 20	Bfr= .6, Aft= .5	Bfr= .8, Aft= .8	None	1	8/12/93
7	1000	Bfr=982, Dur=923	Bfr=6.0, Dur=7.0	Bfr= 19, Aft= 23	Bfr= .5, Aft= .5	Bfr= .9, Aft= .8	No dump	No dump	8/12/93
8	1000	Bfr=1020, Dur=923	Bfr=7.5, Dur=8.5	Bfr= 23, Aft= 30	Bfr= .6, Aft= .6	Bfr= .9, Aft= .9	None	1.33	8/12/93
7 Rept	1000	Bfr=1080, Dur=785	Bfr=7.0, Dur=8.5	Bfr= 7, Aft= 7	Bfr= .7, Aft= .5	Bfr= .9, Aft= .8	No dump	No dump	8/17/93
Comments:	We air purged the baghouse filters prior to beginning the repeat push/drilling of rods #7 & #8 on 8/17/93.								

Data Taken at Drill Rig

Rod #	Tru-Trac Drill Rig Thrust Pressure, psig	Air Compressor Pressure at Tru-Trac Drill Rig, psig drilling / cleaning	Tru-Trac Drill Rig Borehole Distance Rod Number / Total Ft.	Wellhead Diverter Box Pressure / Vacuum psig / inches Hg	Date Data Taken
5			5 / 14.5		8/12/93
6			6 / 19.5		8/12/93
7			7 / 24.5		8/12/93
8			8 / 29.5		8/12/93
7 Rept			7 Rept / 24.5		8/17/93
Comments:	We opened the flex lines between the diverter box and the well casing and between the diverter box and the Guzzler. The diverter box had about 1 to 2 Qts. of pea sized stone in the bottom, the well casing was about half full of dirt and stones.				

PHASE IV - Drill Cuttings Containment System Tests

Data Taken at Guzzler Unit

Rod #	Guzzler Engine Speed, RPM	Guzzler System Air Flow, CFM	Guzzler System Vacuum, Inches Hg	Diff. Pressure Baghouse Filters, Inches Water	Diff. Pressure Port HEPA Filters, Inches Water	Diff. Pressure Starboard HEPA Filters, Inches Water	Sample Removed from Baghouse, CU. FT.	Sample Removed from Cyclone Separator, CU. FT.	Date Data Taken
8 Rept	1000	Bfr=785, Dur=923	Bfr=8.5, Dur=7.0	Bfr= 7, Aft= 8	Bfr= .5, Aft= .5	Bfr= .8, Aft= .8	None	.034	8/17/93
9	1200	Bfr=903, Dur=1021	Bfr=9.5, Dur=8.5	Bfr= 8, Aft= 16	Bfr= .4, Aft= .4	Bfr= .8, Aft= .8	No dump	No dump	8/17/93
10	1200	Bfr=883, Dur=1001	Bfr=9.8, Dur=8.5	Bfr= 16, Aft= 25	Bfr= .4, Aft= .5	Bfr= .9, Aft= 1.0	.13	3+	8/17/93
11	1200	Bfr=942, Dur=1001	Bfr=8.5, Dur=8.0	Bfr= 13, Aft= 21	Bfr= .6, Aft= .5	Bfr= 1.0, Aft= .9	.2	2	8/17/93
12	1200	Bfr=903, Dur=1001	Bfr=9.5, Dur=8.5	Bfr= 14, Aft= 23	Bfr= .6, Aft= .5	Bfr= 1.0, Aft= .9	.13	2+	8/17/93

Comments: We pushed and drilled rod #10 the full length at zero degrees to correct the downward drift observed drilling rod #9.

Data Taken at Drill Rig

Rod #	Tru-Trac Drill Rig Thrust Pressure, psig	Air Compressor Pressure at Tru-Trac Drill Rig, psig drilling / cleaning	Tru-Trac Drill Rig Borehole Distance Rod Number / Total Ft.	Wellhead Diverter Box Pressure / Vacuum psig / inches Hg	Date Data Taken
8 Rept			8 Rept / 29.5		8/17/93
9			9 / 34.5		8/17/93
10	700	115 / 90	10 / 39.5	0 / 4.5	8/17/93
11			11 / 44.5		8/17/93
12	1200+	115 / 90	12 / 49.5	0 / 4.5	8/17/93

Comments:

3. SUMMARY

The goals of testing and evaluating the Guzzler vacuum/filter unit and in conjunction with the Drill Cuttings Containment System were met. These goals were (1) to contain all drilling returns during air drilling operations; (2) to design safety measures with redundancy for compressed and vacuum air; (3) to contain drill cuttings in a total vacuum atmosphere upon exiting the borehole; and (4) that all DCCS components could function together as an operational drill system.

Although it was not tested using liquid-bearing materials, the versatility and features of the Guzzler vacuum/filter unit make it ideal for use at environmental waste sites for drill cuttings containment and any general vacuuming of material while keeping them in a vacuum atmosphere.

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Hill AFB, UT 84056-5127

A1/EQW
Attn: Bruce Nielsen
139 Barnes Dr.
Tyndall AFB, FL 32403-5323

NASA

Martin-Marietta Manned Space Systems
Attn: Marty Rowland
P.O. Box 29304, MS 3141
NASA Michoud Facility
Facilities Environmental Engineering
New Orleans, LA 70189

USGS

U.S. Geological Survey (2)
Water Resources Division
Attn: R. Livingston
W. Dam
4501 Indian School NE, Suite 200
Albuquerque, NM 87110

USGS
Mail Stop 101 National Center
Attn: Robert M. Hirsch, Acting Director
12201 Sunrise Valley Dr.
Reston, VA 22092

USGS
Mail Stop 911 National Center
Attn: Benjamin Morgan, Chief Geologist
12201 Sunrise Valley Dr.
Reston, VA 22092

USGS
Director's Representative
Attn: Harry A. Tourtelot
Box 25046
Denver Federal Center
Denver, CO 80225-0046

USGS
Director's Representative
Attn: George Gryc
Bldg. 345 Middlefield Rd.
Menlo Park, CA 94025-3591

USGS
Director's Representative
Attn: Paul Brooks
Grace Hall APU
4230 University Dr.
Anchorage, AK 99508-4664

State

Colorado Center for Environmental Management
Attn: Dawn Kaback
999 18th St., Suite 2750
Denver, CO 80202

Environmental Evaluation Group (3)
Attn: Library
7007 Wyoming NE, Suite F-2
Albuquerque, NM 87109

NM Bureau of Mines and Mineral Resources
Socorro, NM 87801

NM Energy, Minerals, and Natural Resources Dept.
Attn: Library
2040 S. Pacheco
Santa Fe, NM 87505

NM Environment Department (3)
Attn: J. Espinosa
1190 St. Francis Drive
Santa Fe, NM 87503-0968

City

Albuquerque Public Works
Attn: Rick Roybal, City Engineer
P.O. Box 1293
Albuquerque, NM 87103

Private Sector

CDM Federal Programs
Attn: Dave Wilson
1626 Cole Blvd., Suite 100
Golden, CO 80401

ALCOA South Carolina, Inc.
Attn: P. H. LeRoy
P.O. Box 819
211 Charles St.
Beaufort, SC 29901

ALCOA Technical Center
100 Technical Dr.
Alcoa Center, PA 15069-0001

FERMCO Restoration Management Corp.
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Others

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American Fork, Utah 84003

Rodney Brown
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Birmingham, AL 35222

Western Governors' Association
Attn: James Souby, Executive Director
600 17th St., Suite 1705, South Tower
Denver, CO 80202

Universities/Libraries

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Las Cruces, NM 88001

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Albuquerque, NM 87131

New Mexico Junior College
Pannell Library
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New Mexico State Library
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New Mexico Tech
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Westinghouse-Savannah River
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Env. Technology
Westinghouse Hanford (H4-54)
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Richland, WA 99352

University of California-Berkeley
Attn: G. Cooper, Professor of
Petroleum Engineering
Department of Materials Science and Mineral
Engineering
Berkeley, CA 94720

University of Missouri-Rolla
Attn: D. Summers
Dept. of Materials Science & Mineral
Engineering
213 Rock Mechanics Facility
Rolla, MO 65401-0249

Trenchless Technology Center
Department of Civil Engineering
Louisiana Tech. University
P.O. Box 10348
Ruston, LA 71272

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