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SITE EMERGING TECHNOLOGIES PROJECT: BABCOCK & WILCOX CYCLONE VITRIFICATION

by

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FOREWORD

The U.S. Environmental Protection Agency (EPA) is charged by congress with protecting the Nation's land, air, and water resources. As the enforcer of national environmental laws, the EPA strives to balance human activities and the ability of natural systems to support and nurture life. A key part of the EPA's effort is its research into our environmental problems to find new and innovative solutions.

The Risk Reduction Engineering Laboratory (RREL) is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes,and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Now in its eighth year, the Superfund Innovative Technology Evaluation (SITE) Program is part of EPA's research into cleanup methods for hazardous waste sites around the nation. Through cooperative agreements with developers, alternative or innovative technologies are refined at the bench- and pilot-scale level and then demonstrated at actual sites. EPA collects and evaluates extensive performance data on each technology to use in remediation decision-making for hazardous waste sites.

This report documents the results of laboratory and pilot-scale field testing of the vitrification of soil contaminated with methods.

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ABSTRACT

The Babcock & Wilcox cyclone vitrification furnace appears well suited to treating high inorganic content hazardous wastes and contaminated soils, which exist at many Superfund sites. In a study performed under the U.S. EPA Superfund Innovative Technology Evaluation (SITE) Emerging Technologies Program, the Babcock & Wilcox six million Btu/hr pilot cyclone furnace was used to vitrify an EPA Synthetic Soil Matrix (SSM) spiked with 7,000 ppm lead, 1,000 ppm cadmium, and 1,500 ppm chromium.

During 1990 to 1992, pilot-scale testing of the Babcock & Wilcox six million Btu/hr pilot cyclone furnace for the vitrification (immobilization) of heavy metals from contaminated soil was conducted. The tests were conducted on wet and dry contaminated soil (synthetic soil matrix) fed at several feed rates ranging from 50 to 300 lb/hr. The soil is captured and melted In the molten slag layer that forms at the cyclone furnace wall, exits the cyclone furnace, and is dropped into a water-filled slag tank where it solidifies.

The cyclone vitrification process successfully treated several tons of SSH. The vitrified soil was non-leachable by the Toxicity Characteristic Leaching Procedure (TCLP). The volume of the vitrified soil was reduced by approximately 25-35% when compared to dry SSM.

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Subsequent to the SITE Emerging Technologies project described here, the U.S. Environmental Protection Agency conducted a SITE Demonstration of the B&W cyclone vitrification process in November, 1991. The results of this Demonstration are expected to be published by the U.S. EPA in 1992.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ASTM -- American Society for Testing of Materials
Btu -- British thermal units
B&W -- Babcock & Wilcox
Cd -- cadmium
Cr -- chromium
cu ft -- cubic foot
DRE -- destruction and removal efficiency
EPA -- United States Environmental Protection Agency
kg -- kilogram
L -- liter
lb/hr -- pounds per hour
MBtu -- Million British thermal units
mg -- milligram
MSW -- municipal solid waste
MW -- megawatt
Pb -- lead
PSIG -- pounds per square inch gage
QA -- quality assurance
QAPP -- quality assurance project plan
RPD -- relative percent difference
RREL -- Risk Reduction Engfneering Laboratory (EPA)
SBS -- small boiler simulator pilot facility
SITE -- Superfund Innovative Technology Evaluation
SSH -- synthetic soil matrix
TCLP -- toxicity characteristic leaching procedure
ug -- microgram

ACKNOWLEDGMENTS

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R. Bailey, S. Boyce, L. Breyley, V. Burgess, J. Curtis, R. Huskins, J. Lyden, K. Nevitt, R. Schreckengost, E. Stoffer, and T. Wilson.

1. EXECUTIVE SUMMARY

The SITE Emerging Technologies Project

During 1990 to 1992, pilot-scale testing of the Babcock & Wilcox six million Btu/hr pilot cyclone furnace for the vitrification of soil and immobilization of heavy metals was conducted. The tests were conducted on wet and dry contaminated soil (synthetic soil matrix) fed at several different feed rates.

Summary Results

The pilot cyclone furnace was successfully used to vitrify an EPA Synthetic Soil Matrix (SSM) spiked with 7,000 ppm lead, 1,000 ppm cadmium, and 1,500 ppm chromium. Tests showed 95 to 97% of the non- combustible portion of the input SSM was incorporated within the slag. When operated at 50 to 150 lb/hr of dry SSM feed, and from 100-300 lb/hr of wet SSM feed, the cyclone technology was able to produce a non-leachable product. Average lead, cadmium, and chromium TCLP leachabilities in the untreated SSM were 104, 54, and 2.3 mg/L, respectively. Average lead, cadmium, and chromium TCLP leachabilities in the treated SSM from the 50 to 150 lb/hr dry SSM tests were 0.20, 0.13, and 0.11 mg/L, respectively, and for the treated SSM from the 100 to 300 lb/hr wet SSM tests were 0.20, 0.07, and 0.04 mg/L, respectively. All of these TCLP results are close to the analytical detection limit and, hence, the results for wet vs. dry soil are not likely significantly different. All of these treated SSM TCLP results are well below the TCLP limits.

Using natural gas as the fuel, the CO and NO, stack emissions gases from the process averaged 19 and 352 ppm at 3% O_2, respectively. Stack CO_2 averaged 11.5%. These stack levels are within acceptable ranges. The capture of heavy metals in the vitrified slag from all tests ranged from 8-17% for cadmium, 24-35% for lead, and 80-95% for chromium. Addition of 10% of a Borax flux did not significantly improve the heavy metals capture in the vitrified slag despite lower cyclone temperatures (≈100°F).

The capture of heavy metals in the slag increased with increasing feed rate, likely due to shorter cyclone furnace residence times. The capture of metals in the slag increased with decreasing metal volatility. This suggests the cyclone vitrification process would be well suited to treatment of low volatility contaminants, such as many radionuclides.

The treatment of the synthetic soil matrix resulted in a volume reduction of 25-35% (dry basis). The vitrification treatment results in an easily-crushed, glassy product.

2. INTRODUCTION AND BACKGROUND INFORMATION

The Superfund Amendments and Reauthorization Act of 1986 directed the U.S. Environmental Protection Agency to establish an "Alternative or Innovative Treatment Technology Research and Demonstration Program". In response, the EPA Office of Solid Waste and Emergency Response and the Office of Research and Development established a formal program called the Superfund Innovative Technology Evaluation (SITE) Program to accelerate the development and use of innovative cleanup technologies at hazardous waste sites across the country.

This project was sponsored under the SITE Emerging Technologies Program. Before a technology can be accepted into the Emerging Technologies Program, sufficient data must be available to validate its basic concepts. The technology is then subjected to a combination of bench- and pilot-scale testing in an attempt to apply the concept under controlled conditions.

The Babcock & Wilcox cyclone furnace is a well-established design (over 26,000 MW installed electrical capacity) for the combustion of high inorganic (ash) coal. The combination of high heat release rates (450,000 Btu/cu ft for coal) and high turbulence in cyclones assures the high temperatures required for melting the high ash fuels. The inert ash exits the cyclone furnace as a vitrified slag.

Taking advantage of the ability of the cyclone furnace to form a vitrified slag from waste inorganics, the cyclone furnace was used in a research and development project to vitrify municipal solid waste (MSW) ash containing heavy metals. The cyclone furnace produced a vitrified MSW ash which was below EPA leachability limits for all eight RCRA metals. The successful treatment of MSW ash suggested that the cyclone vitrification technology would be applicable to high inorganic content hazardous wastes and contaminated soils that also contain organic constituents. These types of materials exist at many Superfund sites, as well as sites where petrochemical and chemical sludges have been disposed. Our approach for establishing the suitability of the cyclone vitrification technology relies on the premise that for acceptable performance in treating hazardous waste mixtures containing organic and heavy metals constituents, the cyclone furnace must melt EPA's synthetic soil matrix (SSM) while producing a non-leachable slag and must achieve the destruction and removal efficiencies (DRE's, currently 99.99%) for organic contaminants normally required for RCRA hazardous waste incinerators. The high temperature (>2,500 to 3,000°F), turbulence, and residence time in the cyclone and main furnace are expected to result in high organics destruction and removal efficiencies (DRE's).

A SITE demonstration was performed on the pilot cyclone furnace in November of 1991. An EPA-supplied synthetic soil matrix spiked with heavy metals (cadmium, chromium,and lead), organics (anthracene and dimethyl phthalate), and simulated radionuclides (cold strontium, bismuth, and zirconium) was used. Depending on the results of the SITE demonstration, the next step for product development would be conceptualization, design, construction, field testing, and economic analysis of a full-scale unit (e.g., 80 tons per day).

This report will present the results of both the Phase I (1990-1991) and Phase II (1991-1992) Emerging Technologies efforts. The two Phases had specific goals as given in Table 1. Roth Phases used an EPA synthetic soil matrix spiked with lead, cadmium, and chromium. The most important goal for both Phases was to produce a vitrified soil that passes the Toxicity Characteristic Leaching Procedure (TCLP) limits for lead, cadmium, and chromium. Because the most significant difference between Phases I and II is the use of a dry or wet soil feed system, Phases I and II nay also be referred to in this report as "Dry Soil Feed System" and "Wet Soil Feed System," respectively. The wet soil feed system was used for the EPA Demonstration of the technology and, thus, this report will emphasize the results for this final system configuration.

TABLE 1

Phases and Specific Goals of the SITE Emerging Technologies Project

Phase	Specific 6oals
Phase I (1990-91) - Dry Soil Feed System	• Determine synthetic soil matrix (SSM) properties. . Establish cyclone operability (e.g., feeding, melting behavior, operational data). . Determine slag leachability and volume reduction. . Determine preliminary heavy metals mass balance for cyclone treatment process.
Phase II (1991-92) - Wet Soil Feed System	. Design of wet soil feed system and atomizer. . Establish cyclone operability (e.g., feeding, melting behavior, operational data). . Determine slag leachability and volume reduction. . Optimize heavy metals capture and determine metals mass balance for cyclone treatment process.

Measurement of organics destruction efficiencies, thought to be less of a technical challenge compared with metals capture, was reserved for a SITE Demonstration performed in November 1991. The remainder of this report describes the cyclone furnace used in this study, the tests that were conducted, the results achieved and, finally, conclusions that can be drawn about the usefulness of the cyclone furnace for the treatment of hazardous waste.

3. PROCESS DESCRIPTION

The Babcock & Wilcox six million Btu/hr cyclone furnace located in Alliance, Ohio, was used to perform all pilot-scale vitrification tests discussed in this report. The furnace is water-cooled and simulates the geometry of B&W's front- wall fired cyclone coal-fired boilers. This cyclone facility has been proven to simulate typical full-scale cyclone units in regard to furnace/convection gas temperature profiles and residence times, NOx levels, cyclone slagging potential, ash retention in the slag, unburned carbon, and flyash particle size.

The pilot cyclone furnace, shown in Figure 1, is fired by a single, scaled-down version of a commercial coal combustion cyclone furnace. The furnace geometry is a horizontal cylinder (barrel). A summary of the process is illustrated in Figure 2. Both the primary air and secondary air were heated to approximately 820°F. Primary air, secondary air, and soil conveying air (150°F) used to transport the soil into the furnace accounted for 25%, 72%, and 3% of the total air input, respectively. For these tests, natural gas and preheated primary combustion air enter tangentially into the cyclone burner. In dry soil processing, preheated secondary air, the soil matrix, and a portion of the natural gas enter underneath the secondary air and parallel to the cyclone barrel axis. For wet soil processing, an atomizer is used to spray the soil paste directly into the furnace.

Upon entering the cyclone furnace, soil is captured and melted, and organics are destroyed in the molten slag layer that is formed and retained on the furnace barrel wall by centrifugal action created by the tangentially fired combustion air. The soil melts, exits the cyclone furnace from the tap at the

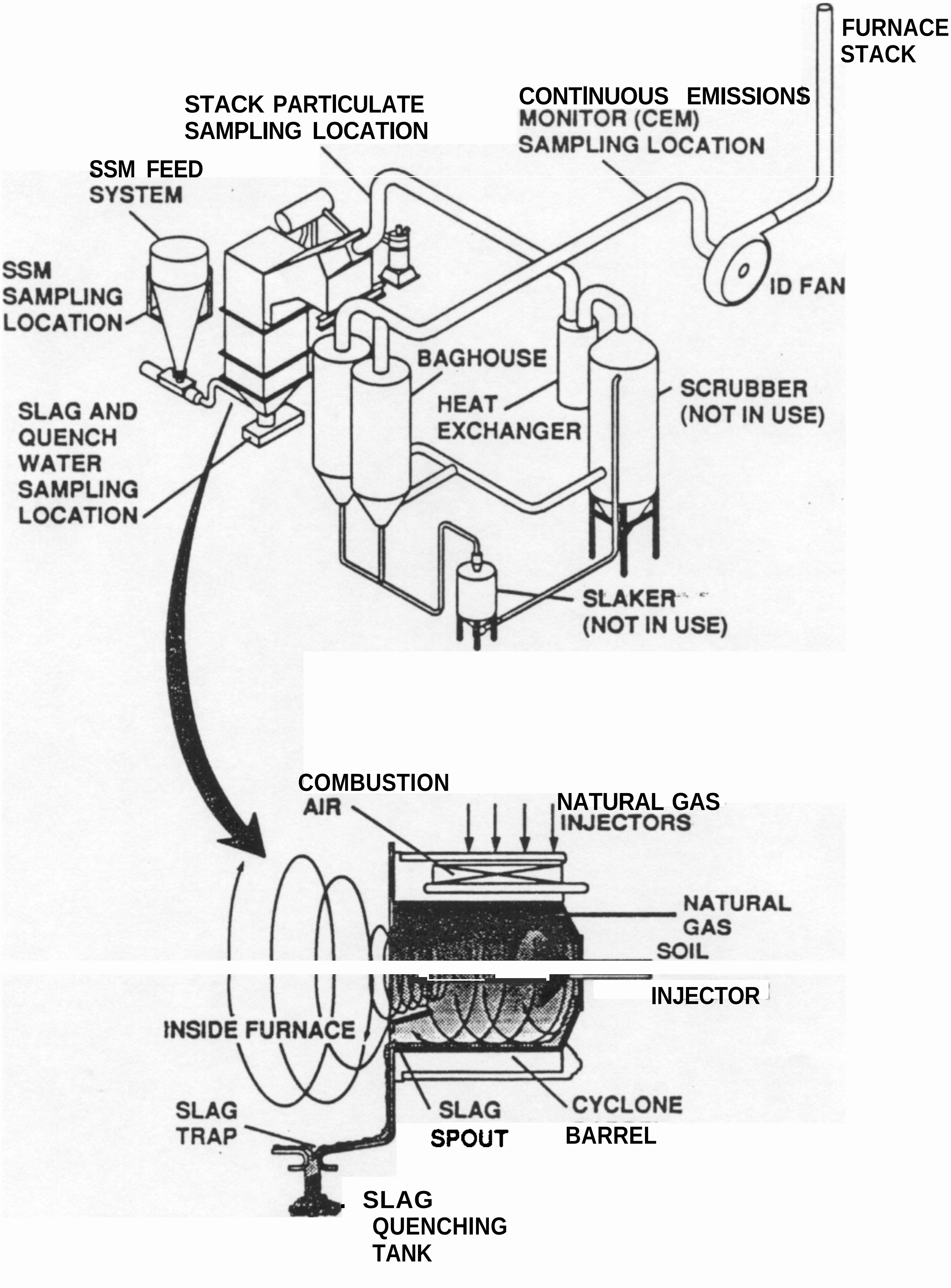


FIGURE 1 Pilot Cyclone Test Facility

cyclone throat, and is dropped into a water-filled slag tank where it solidifies. Operation of the cyclone at a load of 5 million Btu/hr produced the best slag tapping conditions. Operation at both 6 and 4 million Btu/hr load conditions decreased slag tapping due to changes in cyclone flow patterns.

A small quantity of soil also exits as flyash with the flue gas from the furnace and is collected in a baghouse. This flyash can be recycled to the furnace as indicated in Figure 2 to increase the capture of metals and to minimize the volume of the potentially hazardous fly ash waste stream.

Flue gas passes through a baghouse for purposes of particulate control. To maximize the capture of metals, a heat exchanger is used to cool the stack gases to approximately 200°F before entering the baghouse. Although the cyclone facility is equipped with an acid gas scrubber, it was not used for these tests because acid gas generation (e.g., HCl) from the vitrification of the SSH was expected to be low.

Phase I (Dry Soil Processing) Configuration

The furnace configuration used in Phase I is-shown in Figure 3. Natural gas and preheated primary combustion air enter tangentially into the cyclone burner. Preheated secondary air, the soil matrix (fed into the furnace pneumatically by a screw feeder), and natural gas enter parallel to the cyclone axis into the cyclone furnace. The soil is captured and melted and organics destroyed in the molten slag layer that is formed and retained on the furnace wall by centrifugal action. Most of the soil melts, exits the cyclone furnace from the tap at the cyclone throat, and is dropped into a water-filled slag tank where it solidifies. A small quantity of soil exits as flyash with the flue gas from the furnace and is collected in a baghouse.

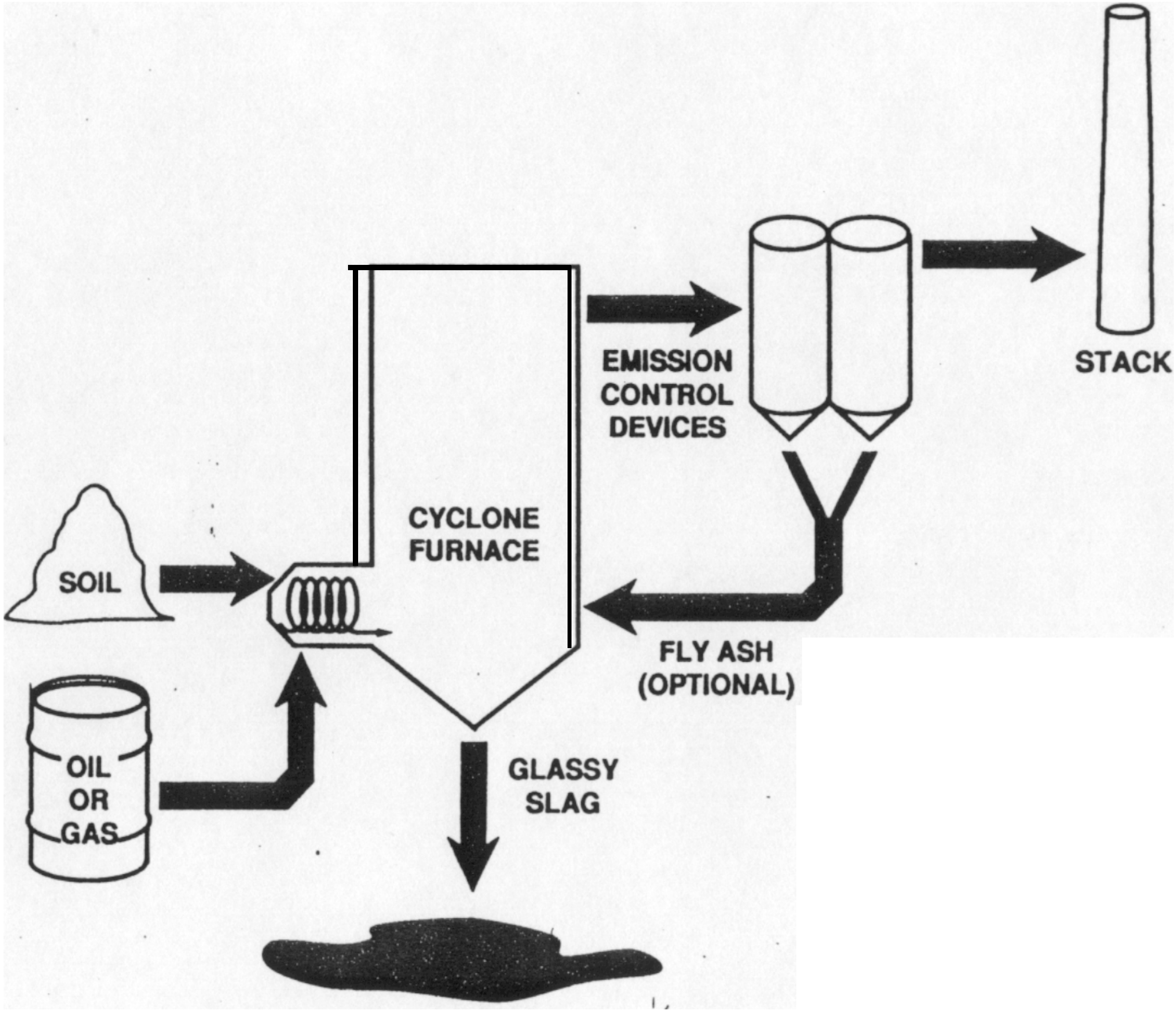


FIGURE 2 Schematic of the Cyclone Vitrification Process

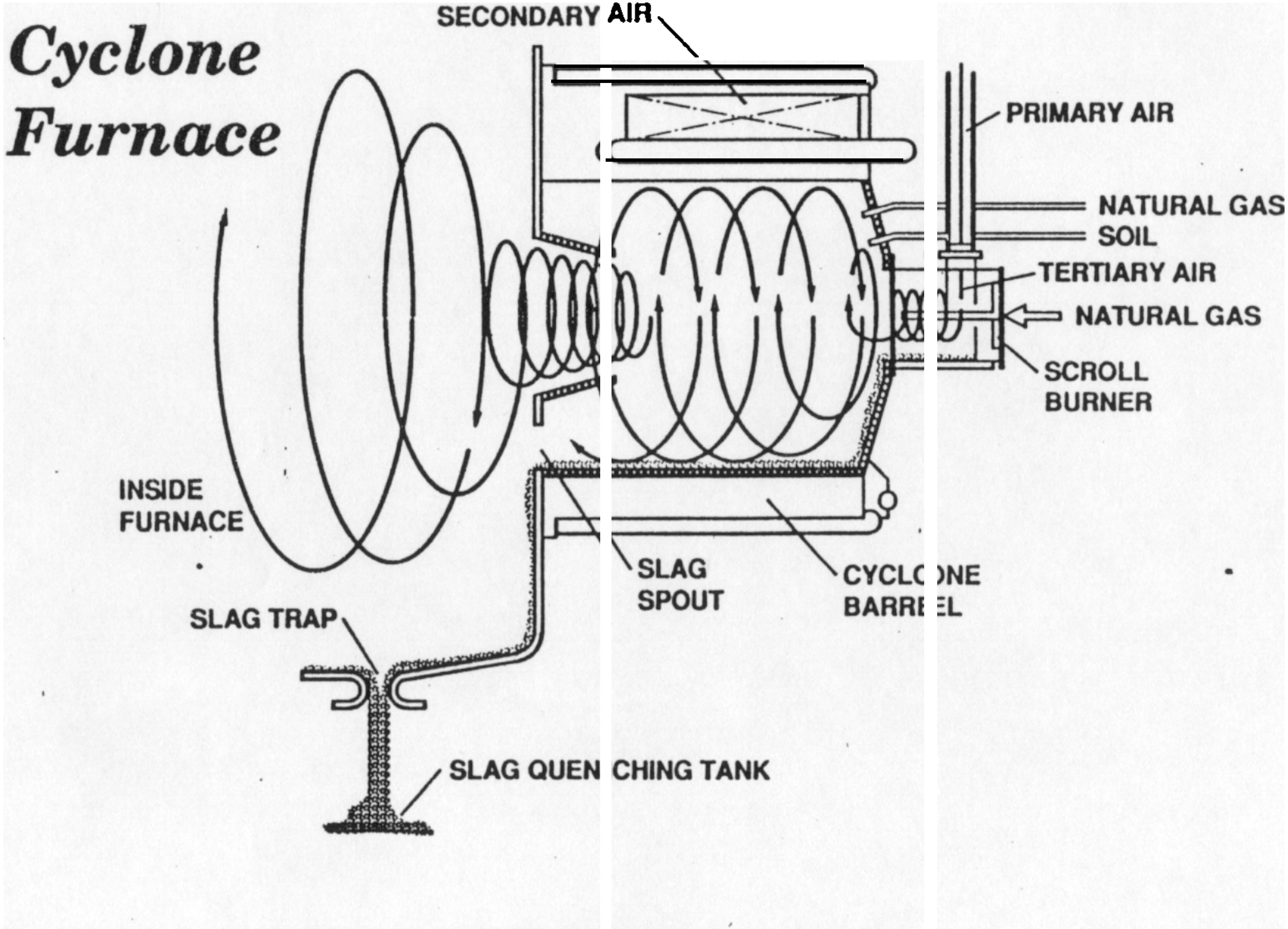


FIGURE 3 Cyclone Furnace Configuration for Phase I

Particulate control was achieved by way of a MikroPul, Inc.baghouse containing twenty-three 10-ft. Nomex bags and operated at an air-to-cloth ratio of 2.8 at 150°F. A single-pass, water-cooled heat exchanger with seventy 1.5" x 8 ft U-tubes is used to cool the stackgases to approximately 200°F before entering the baghouse. Although the cyclone facility is equipped with an acid gas scrubber, it was not used because acid gas generation (e.g., HCl) from the vitrification of SSM was expected to be low.

Configuration for Phase II (Wet Soil Feed Processing)

The primary difference between the cyclone furnace configurations for Phase I and Phase II is in the feed system. While Phase I tests used dry soil, Phase II used soil with a high moisture content and a muddy consistency. It is generally thought that Superfund soils will range from very dry to wet or muddy. Because feed system problems are often encountered at Superfund sites, it was important to demonstrate that the cyclone furnace could operate with a wet soil feed. In addition, it was not known how well the vitrification process would tolerate a high moisture feed (e.g., possible heat losses due to evaporation or entrainment of particulate by the generated steam). Thus, wet soil feed system design and testing were a major goal of the Phase II effort.

The wet feed system furnace modifications are shown in Figure 4. The modifications were performed not only to add wet soil feeding capability, but also to improve the distribution of soil to the soil- melting surfaces of the furnace barrel. Modifications made on the furnace to accomplish these two goals included: (1) removal of the scroll so that no primary air or natural gas are added at the furnace front location; (2) installation of natural gas jets at

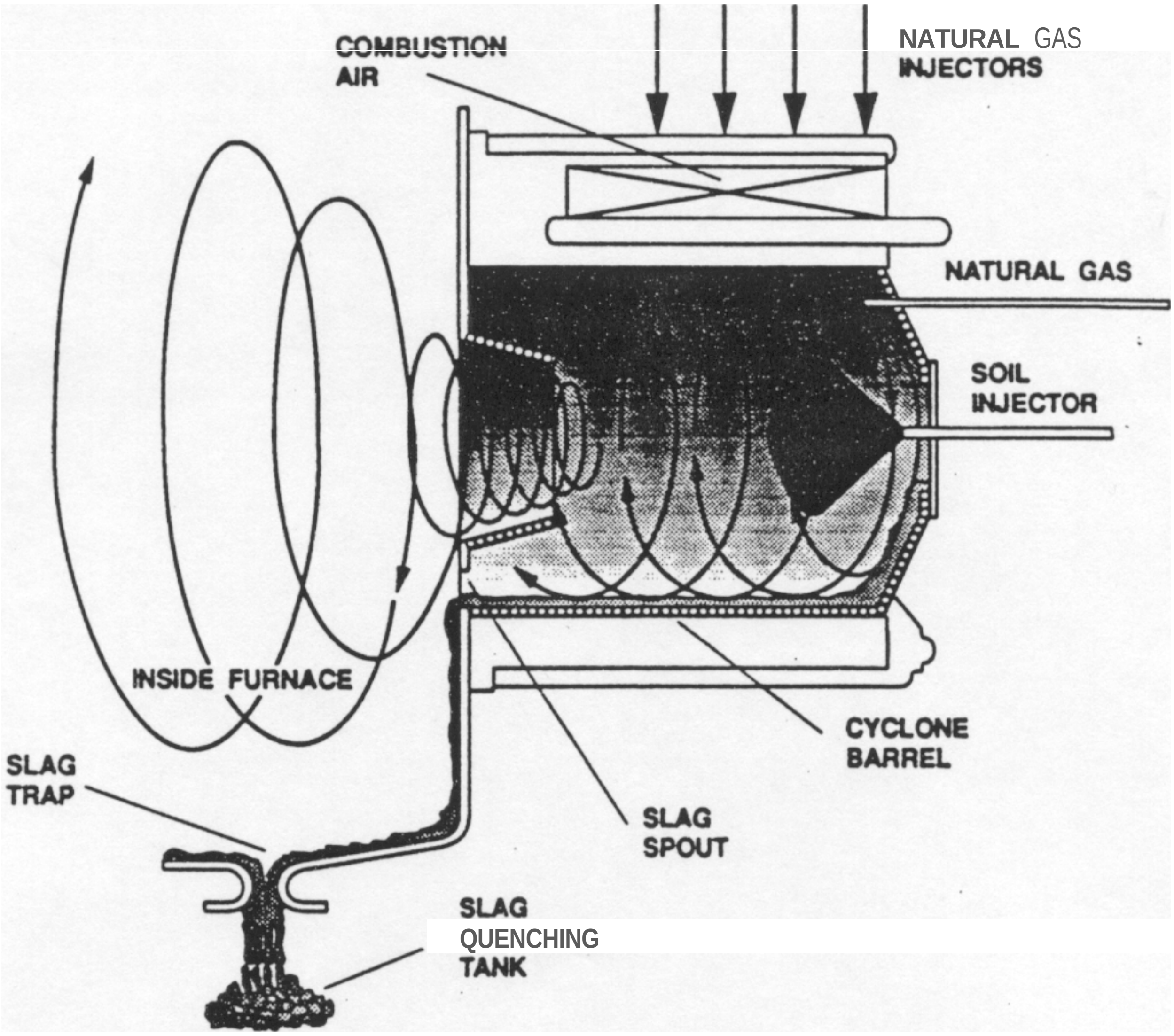


FIGURE 4 CYCLONE FURNACE FOR WET SOIL INPUT

the secondary air entrance. These were used together with the gas lighter; and (3) installation of a soil atomizer using variable compressed air at the former scroll burner location (see Section C, below).

To improve the feeding of wet soil to the cyclone furnace a Moyno progressing cavity pump with speed controller (Frame 2J3, Type CDR AAA) was used to feed the high viscosity soil. A maximum feed rate of 620 lb/hr is possible with this pump model. The pump stator material is natural rubber and the rotor is chromium steel. The speed controller is designed to maintain a constant motor speed and, thus, a constant soil feed rate to the cyclone furnace (200 lb/hr feed at a pump speed of 631 rpm).

The Phase II feed system was installed and tested using clean, wet SSM to which water was added to produce a moisture content of 24% (the as-received $SM was approximately 20% moisture). A schematic of the system is shown in Figure 5.

The soil was added to the feed hopper as follows: Yater was added to each drum of SSM. After replacing the drum lid, the soil was mixed using a drum tumbler operated for 1 hour. The drum lid was replaced by a discharge cone, and the drum was emptied into the feed hopper by way of two valves. Particles larger than 1/2" were screened from the soil during transfer to the feed hopper. After loading the hopper, a two-blade mixer was turned on. The feed system was calibrated and SSM was fed to the cyclone furnace for initial combustion optimization. Several SSM moisture contents were tested, and the most effective operation was found at 26% moisture. Therefore, the pump was recalibrated at 26% molsture and the remaining Phase II experiments were conducted at this moisture level.

SSM Feed System

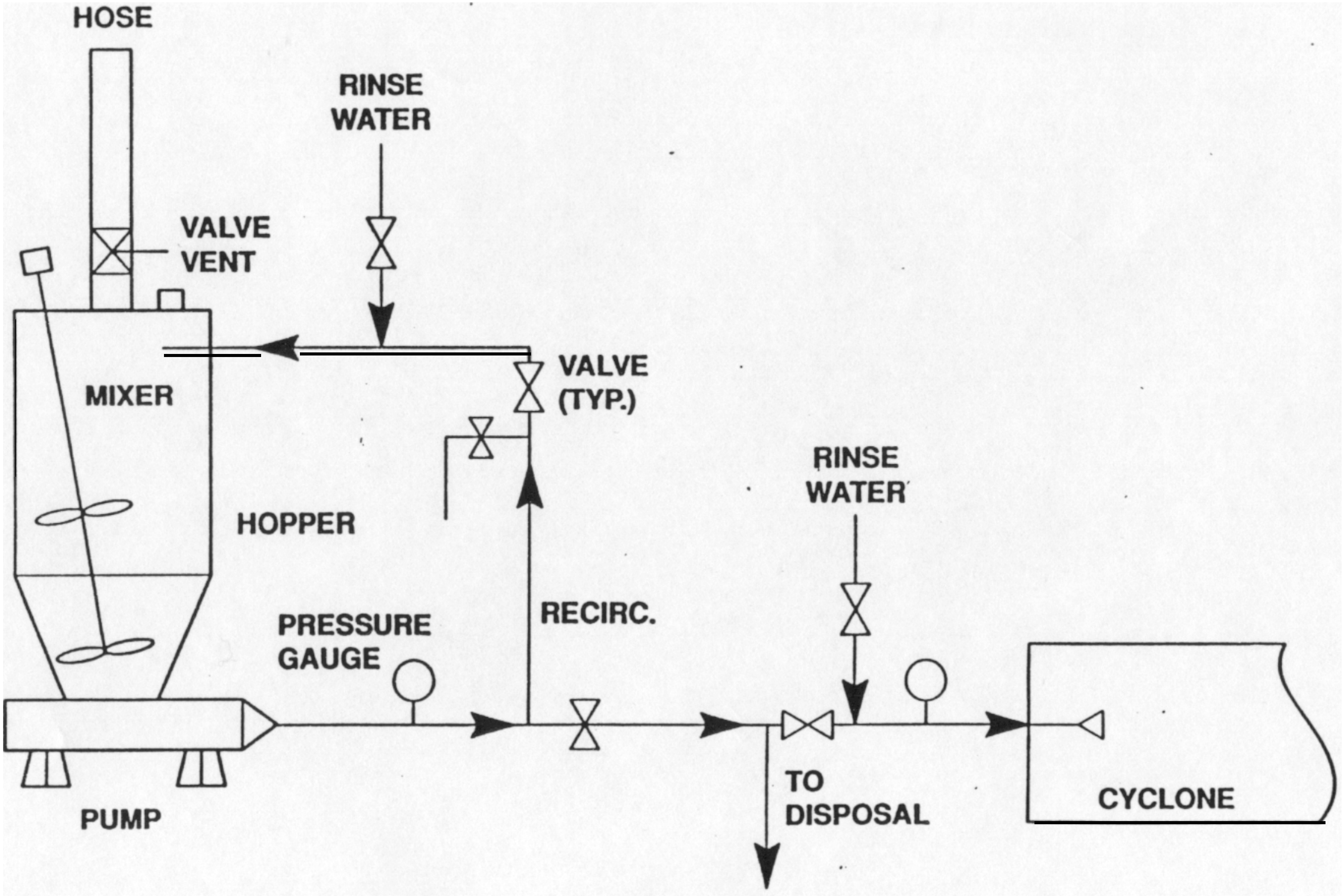


FIGURE 5 Wet Soil Feed System

Atomizer Design for Phase II Tests

To optimize the distribution of wet feed inside the cyclone furnace, preliminary testing with simple nozzles was performed to determine the atomization design for SSM. An externally-mixed atomizer appears to work well for the SSM. High-velocity air was used to achieve atomization. The objective for this project was to evenly spray SSM to the cyclone furnace barrel walls where combustion and melting will take place. The droplet size must also be large enough to avoid merely entraining the SSM in the combustion gases exiting the furnace, but not so large as to form deposits in the furnace.

An atomizer was designed, modified, and tested during Phase II. For successful vitrification of the soil paste, the atomizer has to meet the special requirements associated with the soil material and furnace geometry. Commercial atomizers or nozzles of the required flow capacities have flow passages that are too small to pass the soil paste or the expected small pebbles in the soil. The specific parameters deemed important to the operation of the atomizer are as follows: (1) atomize a high solid4 soil slurry consisting of approximately 75% to 80% solids; (2) accommodate flow rates up to about 400 lb/hr of slurry; (3) permit passage of pebbles or agglomerates up to about 3/8 inch in diameter; (4) have a compressed air consumption of about 200 lb/hr or less (pilot-scale only); (5) minimize flow constrictions that would tend to plug; (6) provide a directional spray that could be pointed toward the hottest surfaces in the interior of the cyclone combustor; and (7) have an overall diameter of 1 to 1-1/2 inches to accommodate installation through existing ports in the cyclone combustor.

The atomizer, shown in Figure 6, was-developed to inject and disperse the soil paste into the cyclone combustor. Photographs of the atomizer are enclosed in the Appendix. The atomizer consists of two concentric tubes. The inner tube provides the flow passage for the soil paste, while compressed air is supplied in the annular space between the two tubes. At the outlet end of the atomizer, flow passages between the soil tube and the annulus provide the high velocity air streams for atomization of the soil. The outlet end of the soil paste tube is shaped in a rectangle and attached to a tungsten carbide insert. This insert

Schematic Diagram of the Soil Paste Atomizer

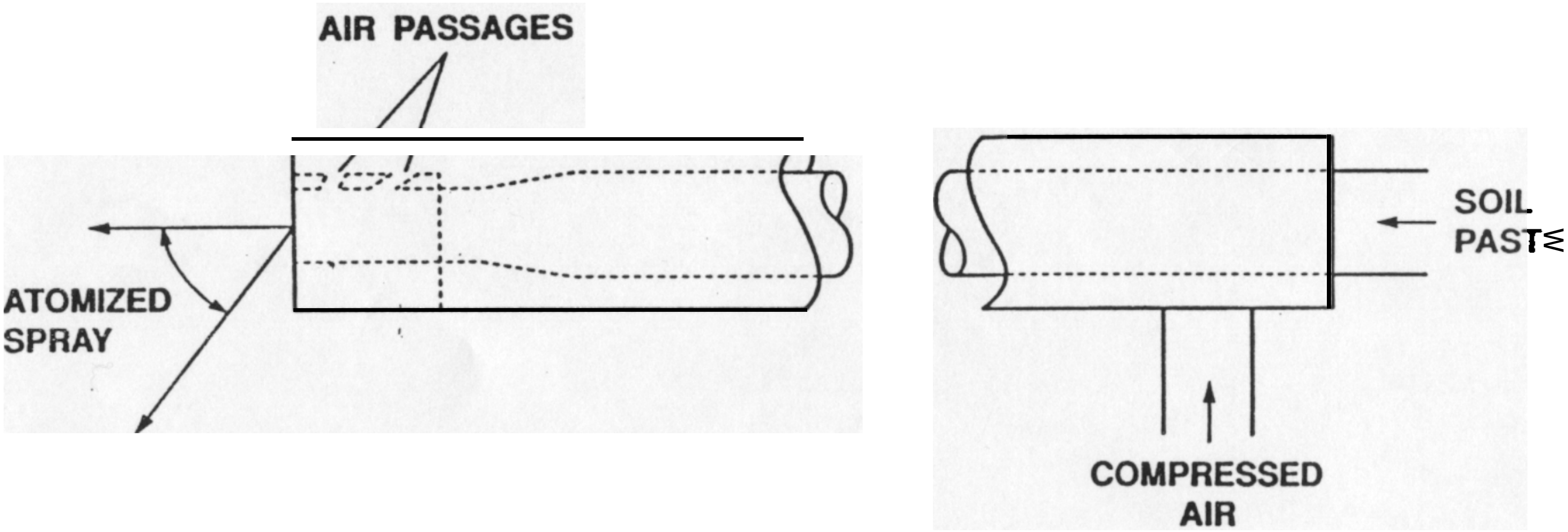


FIGURE 6 Schematic Diagram of the Wet Soil Atomizer

is in the form of a billet with a machined slot. The tungsten carbide insert forms three of the four walls of the rectangular opening, while a flow distributor plate forms the fourth wall. Rectangular flow passages machined into the flow distributor plate provide the high velocity air streams that atomize the soil paste.

The flow passages are inclined at different angles relative to the axis of the atomizer in order to distribute the soil particulate over a large area. The tungsten carbide insert is used to minimize erosion due to the high velocity air and soil particles impacting the wall of the tube opposite the air passages.

This style of atomizer provides a "straight through" passage of the soil paste into the combustor to minimize pluggage problems due to agglomerates or pebbles. Also, the flow of compressed air in the annulus surrounding the soil paste tube provides cooling which minimizes the chance of the soil drying out in the tube and plugging the atomizer. The atomizer designs were initially cold-tested outside the cyclone furnace by spraying clean SSM into a 55-gallon barrel to observe the SSM spray pattern and flow.

In final operation, atomizer air flow rates of 90 to 130 lb/hr, and static pressure of 15 to 100 PSI6 were used. The soil atomizer was inserted at two locations; next to the gas lighter or at the middle of the cyclone using the scroll burner initially and eventually replacing the scroll burner with a plate (see picture in the Appendix). The latter configuration was the most optimal. The direction of the dispersed soil can be controlled by adjusting the atomizer direction. Soil atomizer direction was upward for the best results; when pointed downward slag accumulation was observed.

Furnace Conditions Monitors

To monitor the operation of the cyclone furnace during Phase I and Phase II tests, the following operating parameters were monitored. Carbon monoxide and carbon dioxide were measured during both phases of cyclone testfng using Beckman Model 864 Infrared Analyzers. Oxygen was measured using Beckman Model 755 and Bailey Model OC1530 Oxygen Analyzers. Nitrous Oxides were measured using a Beckman Model 951A NO/NOx Analyzer.

Calibration was performed before and after each day's test with SSM spiked with heavy metals using calibration gases supplied by Linde (Somerset, NJ). Fluke digital readout and Type K thermocouples were used for temperature readings. Air flow rates were measured using ASTM orifices. Rosemont pressure transducers were used. Data acquisition was by an IBM PC using a Keithley 570 system and LabTech software.

Applicable Wastes and Soils and Possible Technology Configurations

An advantage of vitrification over other thermal destruction processes is that in addition to the destruction of organic constituents, the resulting vitrified product captures and does not leach heavy metals or radionuclides.

The cyclone vitrification technology would be applicable to high inorganic content hazardous wastes, sludges, and contaminated soils that contain heavy metals and organic constituents. These types of materials exist at many Superfund and Department of Energy sites, as well as sites where petrochemical and chemical sludges have been disposed. These wastes may be in the form of solids, a soil slurry (wet soil), or liquids. To be treated in the cyclone furnace, the ash or solid matrix must melt and flow at cyclone furnace temperatures (2800 to 3000^0F).

Because of the technology's ability to capture heavy metals in the slag and render these non-leachable, an important application of the technology is contaminated soils which contain non-volatile radionuclides (e.g., strontium, transuranics).

The cyclone furnace can be operated with gas, oil, or coal as the supplemental fuel (the likely application for coal-fired use is waste treatment at an existing electrical generating utility). The waste itself may also supply a significant portion of the required heat input. Heat recovery is available, but is unlikely to be a priority for the final design. Recycling of the small volume of baghouse ash may be advantageous in field operation.

Additional air pollution control devices, such as NOx reduction technologies, can be applied as needed. An acid gas scrubber would be required, for example, when chlorinated wastes are treated. The final process configuration will determine the size of the full-scale system.

4. EXPERIMENTAL DESIGN

The studies discussed in this document occurred in two phases. Both phases will be described in more detail later in the report. For purposes of describing the process, Phase I concerned feeding dry soil to the cyclone and Phase II concerned feeding wet soil to the cyclone. The process configuration used for each phase will be described below.

Description of Phase I and Phase II Tests

The most important goal for both Phases was to produce a vitrified soil that passes the Toxicity Characteristic Leaching Procedure (TCLP) limits for lead, cadmium, and chromium. Because the most significant difference between Phases I and II is the use of a dry or wet soil feed system, Phases I and II may also be referred to in this report as "Dry Soil Feed System" and "Wet Soil Feed System," respectively. The wet soil feed system was used for the EPA Demonstration of the technology. Thus, this report will emphasize the results for this final system configuration. Both Phases used an EPA synthetic soil matrix spiked with lead, cadmium, and chromium.

Typical run conditions for the Phase I and Phase II tests are given in Table 2, below.

TABLE 2

Typical Cyclone Furnace Tests Conditions

Condition	Typical Range of Values
Heat Input (natural gas fuel)	5 million Btu/hr
SSM Feed Rate	50 to 300 lb/hr
Excess Oxygen	1.0%
Primary and Secondary Air Temperature	820°F
Total Air Split - Phase I	
Primary Air	25%
Secondary Air	72%
Feed Air	3%
Total Air Split - Phase II	
Primary Air	not used
Secondary Air	96.5%
Soil Atomizer Air	3.5%
Slag Temperature (in cyclone barrel)	2370-2460°F
Gas Temperature (cyclone exit)	2800-3000°F
Furnace Exit Temperature	2100-2200°F
Baghouse Temperature	200°F
Flyash/Flyash + Slag Ratio - Phase I	5%
Flyash/Flyash + Slag Ratio - Phase II	3%

Measurement of organics destruction efficiencies, thought to be less of a technical challenge compared with metals capture, was reserved for a SITE Demonstration performed in November 1991

A description of both Phase I and Phase II will be provided, below followed by a description of the SSM used in each-test.

Description of Phase I (Dry SSM Feed) Tests

Phase I tests ranged from 3-1/4 to 14 hours. The cyclone furnace was first fired on natural gas (with gradual addition of primary and secondary air) for approximately 2-3 hours before adding the SSM. After the furnace barrel was heated, SSM feed was started and soil melting and tapping was observed through observation ports. Minor adjustments were made, as needed, to maintain soil melting and tapping. Sensors, emissions monitors, and sampling were initiated after conditions stabilized. The test conditions for the preliminary vitrification tests are given in Table 3

TABLE 3

Phase I Test Matrices

Test	Cyclone Load MBtu/hr	SSM Feed Rate, lb/hr	Stack % Excess Oxygen	Slag Temp. °F	Flyash/ Slag	Primary & Secondary Air Temp. °F
Preliminary Vitrification Tests (Dry, Clean Soil)						
10/25/90	4.8	50	1.1	2340		813
10/26/90	4.6	100	0.8	2430	<5%*	821
10/26/90	4.9	150	0.5	2370		824
10/26/90	4.7	200	0.7	2380		823
Heavy *Metals Tests (Dry, Spiked Soil)*						
11/01/90	4.6	100	0.7	2350		
11/15/90**	4.7	46	0.5	2400	7.5%***	830
11/16/90**	4.8	141	0.7	2375	5.9%***	817
11/19/90	4.6	94	0.9	2390	5.8%***	826

*Amount of the SSM leaving the furnace as ash, preliminary estimate.

**Tests used for TCLP and heavy metals mass balance.

***Includes estimate of amount of particulate deposited in the convection pass.

The purpose of the preliminary tests was to optimize cyclone conditions for the vitrification of the SSM. Because the purpose was to establish run conditions, clean (unspfked) SSM was used. Furnace optimization included minor adjustments in the thermal load, SSM inlet location, primary air temperature, and damper settings to optimize soil melting and throughput. The SSM inlet location was changed from the scroll burner at the furnace front to along the secondary air inlet location on the furnace barrel side.

During the four days of tests, the cyclone operation remained very stable. Soil input was increased from 46 to 141 lb/hr with test durations of 3 to 6 hours. The slag tapped well, and no buildup of deposits was observed in the furnace. The surface slag temperature was measured using a two-color optical pyrometer and ranged from 2340 to 2430°F. Measurements of the gas temperature were not made during the tests. However, previous work with MSW flyash vitrification showed gas temperatures in the range of 2840 to 2940°F at the cyclone outlet. The cyclone temperature was adequate to melt the soil, but not excessive, which could lead to increased metals volatilization.

Description of the Phase II (Wet SSM Feed) Tests

The Phase II test conditions for the preliminary vitrification tests and heavy metals tests are given in Table 4.

TABLE 4

Phase II Test Matrices

Test	Cyclone Load MBtu/hr	SSM Feed Rate, lb/hr	Stack % Excess Oxygen	Slag Temp. °F	Flyash/ Slag (X)	Primary & Secondary Air Temp. °F
*Preliminary Vitrfficatfon Tests (Met, Clean Soil)**						
8/20/91	5.1	100	0.77	2455	1.77	814
8/21/91	5.3	100	0.76	2420	2.01	794
8/27/91	5.0	100	0.62	2370	1.73	814
8/27/91	4.9	150	0.56	2410	0.4	814
8/28/91	4.9	200	0.58	2410	0.4	810
8/28/91	4.9	300	0.53	2390	1.49	813
8/29/91	4.9	300	0.56	2405	1.89	810
9/03/91	5.1	300	0.47		1.94	807
*Heavy Metals Tests (wet, Spiked Soil)**						
9/09/91	4.8	200	1.2	2430	2.32	823
9/09/91	4.9	200	1.0	2420	2.63	825
9/10/91	4.9	100	0.6	2470		813
9/10/91	4.9	300	0.7	2400		822
9/11/91	4.1***	200	4.7	2320	3.53	810

*Atomizer air 90 to 130 lb/hr, 15 to 100 PSIG static pressure.
**Atomizer air flow rates of 128 to 134 lb/hr were used.
● **10% Borax was added to the SSM.

For Phase II tests the cyclone was operated at a nominal load of 5 MBtu/hr and 1% excess oxygen. The SSM input was varied between 100 to 300 lb/hr. The cyclone operating conditions were relatively smooth, and the longest continuous operation was six hours at 200 lb/hr of SSM feed rate.

The preliminary tests were mainly performed to observe the operational condition of the cyclone. Cyclone temperature, SSM feed rate, and slag tapping conditions of the SBS are the operational variables that were monitored. If too much SSM is fed to the cyclone, assuming the soil melts, the cyclone throat will be flooded by the molten slag and slag will stay inside the cyclone and adversely impact the cyclone operation. Larger particles in the SSM (3/8") will stay in the cyclone until they melt, but if they do not melt, then they should leave the cyclone encapsulated by the slag. The slag/large particle removal from the cyclone essentially determines the maximum load. The cyclone was operated at a nominal load of 5 MBtu/hr and about 3 to 10% excess air. The SSM feed was gradually Increased from 100 lb/hr to the maximum of 300 lb/hr. The critical factors were to observe whether the SSM indeed melts down to slag and if the cyclone taps freely.

When the soil was evenly dispersed around the cyclone barrel, the slag melted readily. Slag accumulated inside the cyclone (approximately 1.5 to 2 inches) until the slag started tapping. This behavior may be specific to a small water-cooled cyclone. Cyclone tapping was good until the feed rate increased to 400 lb/hr. The cyclone was cold and slag tapping stopped or was blocked.

Use of a Fluxing Agent to Increase metal Retention in the Slag.

Fluxing agents that cause the soil to melt and tap at lower temperatures may decrease metals volatilization and, thus, increase the capture of the metals in the slag. Borax was reported as a fluxing agent for MSW ash vitrification [5]. For one of the tests during Phase II 10% by weight Borax (20 lb/hr) $(B_4Na_2O_7/10H_2O)$, was mixed with SSM. After Borax was added, the cyclone load could easily be reduced to 4.1 MBtu/hr without any problem with slagging. With the added Borax, the slag temperature was reduced from 2430°F (200 lb/hr SSM feed rate) to 2320°F and NOx levels decreased from 318-337 ppm (200 lb/hr feed rate) to 260 ppm, as shown in the Appendix figures. The Borax appeared to facilitate the movement of slag out of the cyclone furnace barrel. When Borax was added, the flyash produced increased to 3.53% of the input SSM, presumably due to vaporization of sodium from the Borax.

Synthetic Soil Matrix (SSM)

The synthetic soil matrix formulated by EPA was used for cyclone testing. Both clean and spiked synthetic soil matrix (SSM) were obtained from the EPA Risk Reduction Engineering Laboratory (RREL) Releases Control Branch in Edison, NJ. SSM, used by EPA for treatment technology evaluations, has been well characterized in previous studies [1]. The spiked SSM used in this study contained 7,000 ppm (0.7%) lead, 1,000 ppm cadmium, and 1,500 ppm chromium. For each project Phase, clean, unspiked SSM (up to 3 tons) was used for preliminary cyclone optimization, and then heavy metal spiked SSM (up to 2.5 tons) was used for the heavy metals tests.

The SSM moisture content as-received was approximately 20%. For Phase I, the small amount of spiked SSM used was passively dried in plastic-lined trays, lumps crushed, and screened to minus 1/4". For Phase II, the moisture content of the SSM was increased to 24-263 and a wet feed system was installed (see below) to feed the SSM in this configuration.

Before Phases I and II, analyses were made to characterize SSM to determine combustion conditions, ash melting behavior and need, if any, for a slag fluxing agent. The results are given in Table 5. The Phase II results are for the spiked rather than clean SSM. The soil contained mainly inert components, low organic carbon (most carbon was present as carbonate), and a low heat content (41 Btu/lb for clean SSM). The soil was largely composed of silicates (50.3%). A significant portion of the SSM consisted of small particles; 21.4% of the particles were less than 149 microns and 7.4% of the particles were less than 44 microns. Gravel of up to 1/4" was also present in the SSM.

TABLE 5

Typical SSM Characterization Results (Dry Basis)

Parameter	Phase I (Dry, Unspiked SSM)		Phase II (Wet, Spiked SSM)	
Moisture	1.2%		20.4%	
Volatile Matter	18.9%		--	
Fixed Carbon	--		--	
Ash	80.3%		81.7%	
Heating Value, Btu/lb	41		878	
Total Sulfur	0.004%		--	
Total C (corr. for CO_2)	0.64%		--	
Total Carbonate, % CO_2	15.3%		15.4%	
Silicon as SiO_2*	50.3%		47.0%	
Aluminum as Al_2O_3*	9.2%		8.9%	
Iron as Fe_2O_3*	3.0%		2.2%	
Titanium as TiO_2*	0:35x		0.35%	
Calcium as CaO*	16.8%		15.1%	
Magnesium as MgO*	3.8%		4.4%	
Sodium as Na_2O*	1.1%		0.6%	
Potassium as K_2O*	1.3%		1.1%	
Sulfur as SO_3*	0.41%		0.70%	
Phosphorous as P_2O_5*	1.3%		0.35%	
Slag Viscosity (in °F at 250 poise, red. atm.)	2319°F		2350°F	
Ash Fusion Temp., °F				
Atmosphere	red.	oxid.	red.	oxid.
A (I.D.)	2220	2240	2250	2240
B (S.T., SP)	2250	2250	2280	2270
C (S.T., HSp)	2260	2280	2290	2300
D (F.T., 1/16")	2420	2520	2600	--
E (F.T., Flat)	2540	>2750	--	--

* Ash analysis.

-- Showed no further physical change up to a maximum of 2750°F.

The chemistry of the SSM resulted in a low ash fusion temperature under oxidizing and reducing conditions and low slag (melted soil) viscosity. This is essential for the soil to melt and flow during furnace operation and ensure encapsulation of hazardous constituents and continuous, controlled removal of the molten slag from the cyclone furnace. The analysis results were similar for the SSM used for both project Phases. For example, the slag viscosity (T,, temperature at which the material has a viscosity of 250 poise) of the Phase I SSM was 2319°F and for the Phase II SSM was 2350°F. The slag viscosity of the clean, dry SSM enabled it to be treated in the cyclone furnace without the addition of fluxing agents (coals with similar slag viscosities are known to readily melt in a cyclone furnace). The spiked soil gave slightly higher ash fusion temperatures than the clean SSM.

Before the Phase I tests, spiked SSH samples were submitted wet (as-received) and dry (oven-dried at ~95°C) for TCLP testing (EPA 1311) for Pb, Cd, and Cr by Aquatec, Inc. (So. Burlington, VT) to verify that the starting soil failed the TCLP. The leachability of the lead averaged 81 mg/L; cadmium, 40 mg/L; and chromium, 2.8 mg/L. With the exception of chromium, the spiked soil exceeded EPA limits for lead (5 mg/L) and cadmium (1 mg/L). This below-EPA-limit (5 mg/L limit) result for chromium agrees with previous reports for SSM [1]. The low chromium leachability may be caused by the clay component of SSM, which may adsorb chromium.

Sampling Methods

Sampling and analysis followed guidelines in the U.S. EPA SW-846 Manual, and the Quality Assurance Project Plan (QAPP) [2] met RREL Category III requirements. Performance criteria were set for critical measurements (TCLP) and non-critical measurements (heavy metals mass balance. volume reduction). Several systems conditions were monitored.

Sampling locations for the various measurements and analyzers are shown in Figure 7. Duplicate soil and slag grab samples were obtained at approximately one hour intervals during the heavy metals tests. The soil was collected by way of a sampling valve in the soil feeder line (Phase I) and by sampling the feed hopper using a plastic ladle (Phase II). The slag was collected with a steel shovel.

Particulate loading was measured at a location after the convection pass and before the baghouse using an EPA Method 5 Train [4]. Stack metals were measured using the EPA Multiple Metals Train (BIF Method, see Reference 3) with

CYCLONE TREATMENT OF CONTAMINATED SOIL SAMPLING LOCATIONS AND ANALYSERS

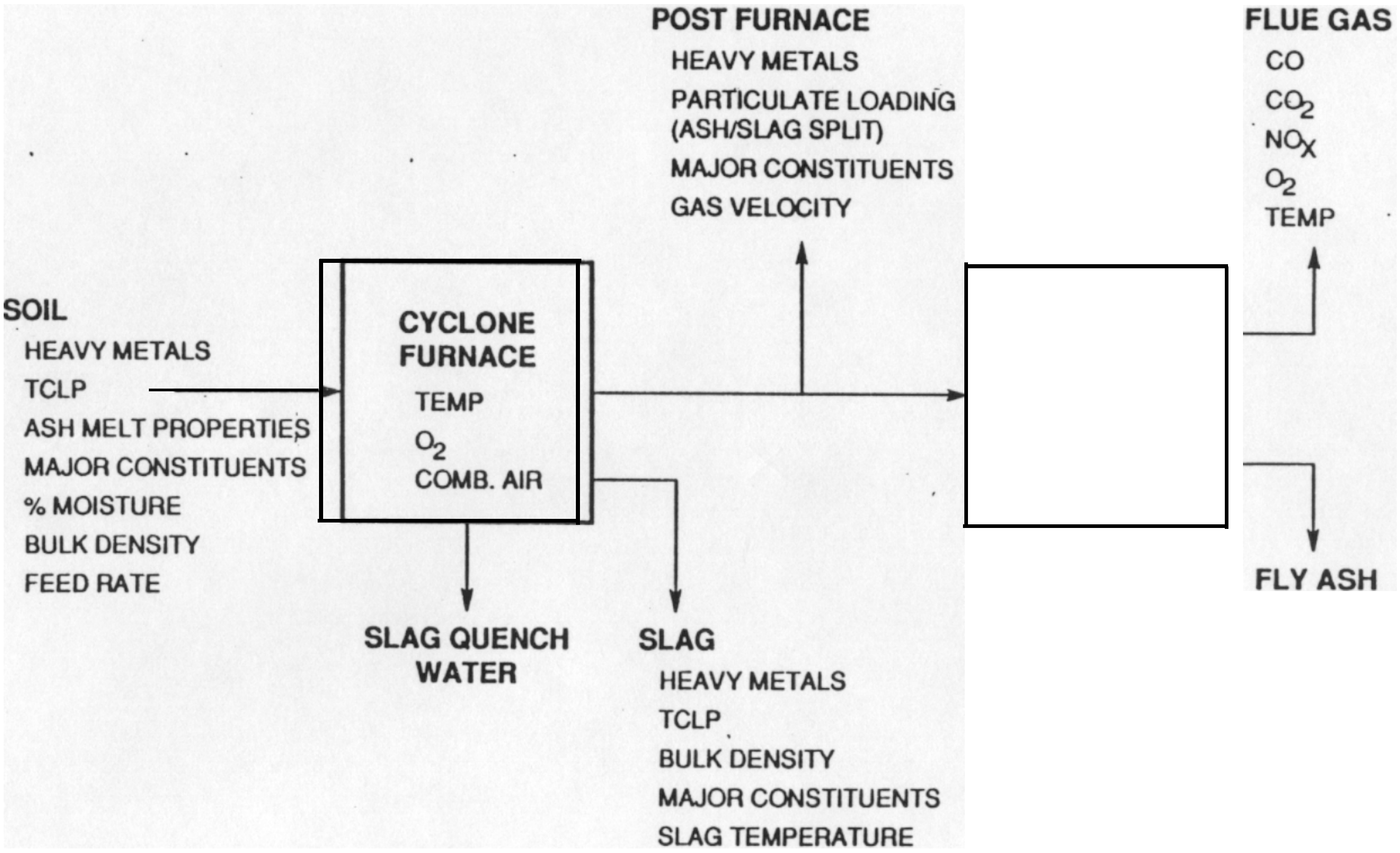


FIGURE 7 Sampling and Analysis Locations

the exception that the HNO_3 and $KMnO_4$ impingers were not used. This exception was made because previous sampling with the filter temperature held at 120 ± 14°C, as specified in the Multiple Metals Train Method [3], showed no more than 0.2% of the total lead, cadmium, and chromium were present in the impingers. Metals levels determined using this method should be considered lower estimates. Post-furnace CO, CO_2, and NOx levels were measured using continuous emissions monitors.

Analytical Methods

TCLP analyses were performed by Aquatec, Inc. (So. Burlington, VT) using EPA Method 1311. The metals in the TCLP extracts were determined by EPA Method 6010. Total metals in the SSM, slag, and particulates were determined using EPA 6000 and 7000 methods, with the exception that the total digestion of the samples was performed using a modified ASTH E926-88 (the EPA digestion methods do not completely dissolve the solid matrix). Preparation of stack samples for metals determination followed the Multiple Metals Train method. The accuracy of all metals analyses was verified using check standards from EPA or other sources. Analyses of the soil for fuel properties, major constituents, and bulk density were performed using standard ASTH methods. Particle size determinations were made by way of standard U.S. sieve numbers. Quality assurance results for the analytical measurements are given in Section 7.0.

5. RESULTS

Four major results were obtained from the Phase I and Phase II studies. They are as follows.

1. The Cyclone Furnace successfully vitrified the SSM feed and produced a leachate that passed the TCLP test.

2. The Cyclone Furnace achieved a volume reduction of 25-35% when treating SSM during Phase I and Phase II.

3. A majority of the heavy metals in the SSM were retained in the slag during treatment in Phase II.

4. The Cyclone Furnace operated well during treatment of SSM and produced no unusually high levels of gaseous emissions.

Each of these results is discussed in more detail below.

Vitrification as Measured by TCLP Test Results.

The pilot cyclone furnace was successfully used to vitrify an EPA Synthetic Soil Matrix (SSM) spiked with 7,000 ppa lead, 1,000 ppm cadmium, and 1,500 ppm chromium. A photograph of the vitrified SSM is shown in Figure 8. TCLP results for the Phase I and Phase II heavy metals tests are shown in Figure 9, and original analytical reports are presented in the Appendix. Table 6 Summarizes the results achieved.

FIGURE 8 Vitrified Synthetic Soil Matrix

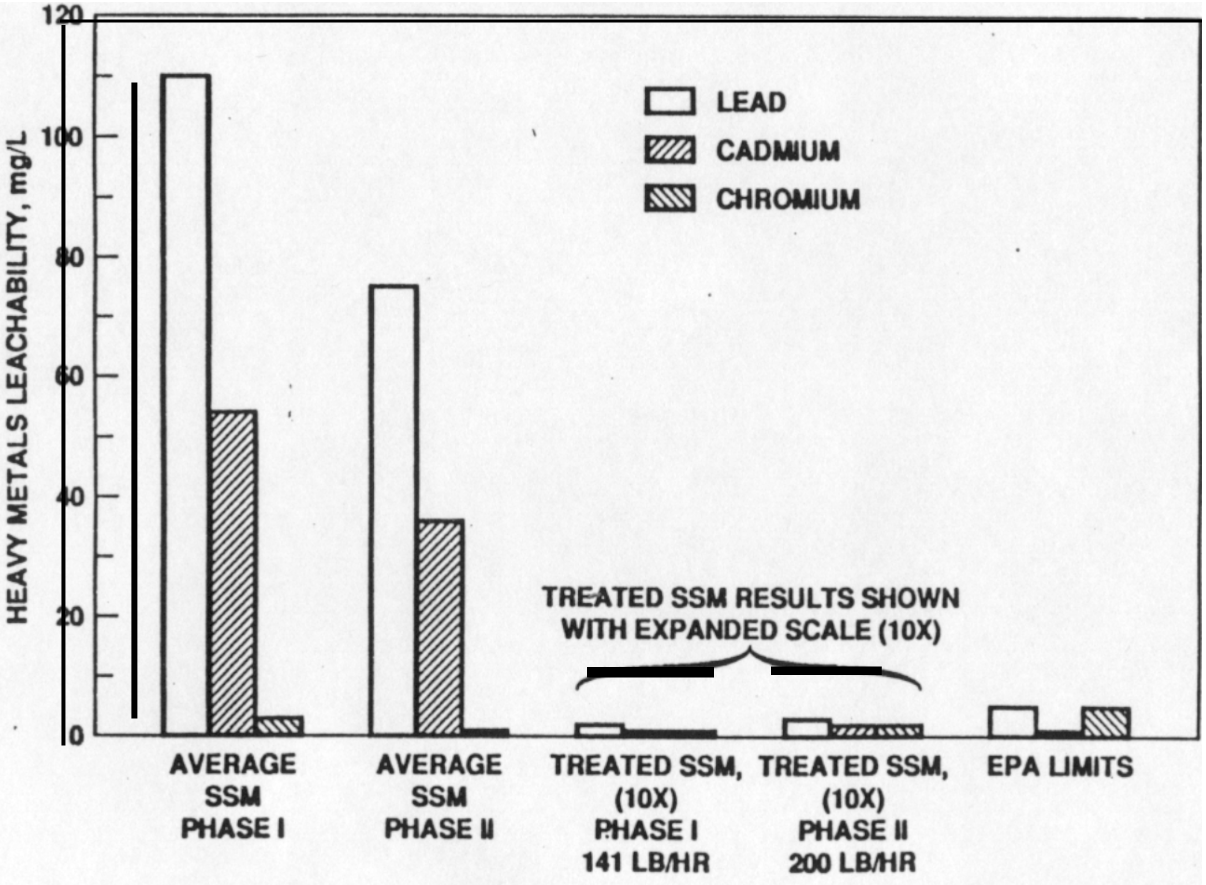


FIGURE 9 Toxicity Characteristic Leaching Procedure (TCLP) Results

Table 6
Results of TCLP Tests for Untreated and Treated SSM

	Phase I mg/L	Phase II	With Borax Flux	Regulatory Levels µg/L
UNTREATED SSM				
Cadmium	54.2 ∓ 3.6	34.2 ∓ 2.9	30.3 ∓ 0.57	1.0
Chromium	2.3 ∓ 1.3	0.48 ∓ 0.08	0.20 ∓ 0.11	5.0
Lead	104 ∓ 34	74 ∓ 0.0	50.6 ∓ 3.5	5.0
TREATED SSM				
Cadmium	0.13 ∓ 0.05	0.07 ∓ 0.03	0.27	1.0
Chromium	0.11 ∓ 0.09	0.04 ∓ 0.08	0.02	5.0
Lead	**0.20 ∓ 0.06**	**0.20** ∓ 0.11	0.39	5.0

All of these treated SSM TCLP results are well below the TCLP regulatory limits set by EPA. The results show that the cyclone vitrification process succeeded in producing a non-leachable slag. All of these TCLP results are close to the analytical detection limit and, hence, the results for both Phase I and Phase II tests are not significantly different.

The laboratory blank submitted with these samples gave lead, cadmium, and chromium levels below the detected levels. For two Phase I slag samples, the measured chromium leachabilities were not significantly different from that of the laboratory blank.

The reduced TCLP results shown in Table 6 for the SSM from the Borax test suggest a small amount of stabilization of lead in the SSM occurs by the addition of Borax. These differences still remain when the dilution of the sample by Borax is taken into account. This slight trend would have to be verified by additional sampling; nevertheless, it did not render the SSM non-hazardous.

The vitrification treatment results in an easily-crushed, glassy product which minimizes the volume required for landfilling. The slag from the tests appeared to be a black, glassy, obsidian-like mass as shown in Figure 8. Some large, white, glass particulates are readily visible in the slag fragments. When viewed under a low-magnification microscope, both the slag (soil) matrix and the embedded white particles appeared to have completely melted. Yhen examined by a Scanning Electron Microscope-Energy Dispersive Spectroscopy, the white particles are enriched in oxygen and silicon and, thus, may be composed of silicon dioxide (quartz). The darker regions are enriched in aluminum, iron, calcium, and magnesium, but also contain oxygen and silicon.

Did the Cyclone Furnace immobilize metal contamination in the vitreous slag it produced, or did the high process temperatures volatilize all of the metal contamination? This can be evaluated by calculating the percent of each heavy metal that was leachable for the untreated and treated soil as given in Table 7.

TABLE 7

Percent of Leachable Metals Before and After Treatment (Phase I and Phase II)

	Phase I		Phase 2	
Heavy Metal	% of Total Metal Present That Leached Before Treatment (SSM)	% of Total Metal Present That Leached After Treatment (Vitr. SSM)	% of Total Metal Present That Leached Before Treatment (SSM)	% of Total Metal Present That Leached After Treatment (Vitr. SSM)
Lead	29	0.18	20	0.09
Cadmium	84	2	57	0.70
Chromium	3.8	0.07	0.55	0.02

The percentage of metals that leached from the slag was less than that for the SSM feed for each metal tested and for both phases of testing. These results indicate that the vitrification process has changed the physical/chemical form of the soil in such a manner as to render the heavy metals much less leachable.

Volume Reduction

The treatment of the synthetic soil matrix resulted in a volume reduction of 25-35% as calculated on a dry basis. Figure 10 shows the volume per ton of SSM or slag which must be sent for disposal. The volume for SSM (dry basis) and

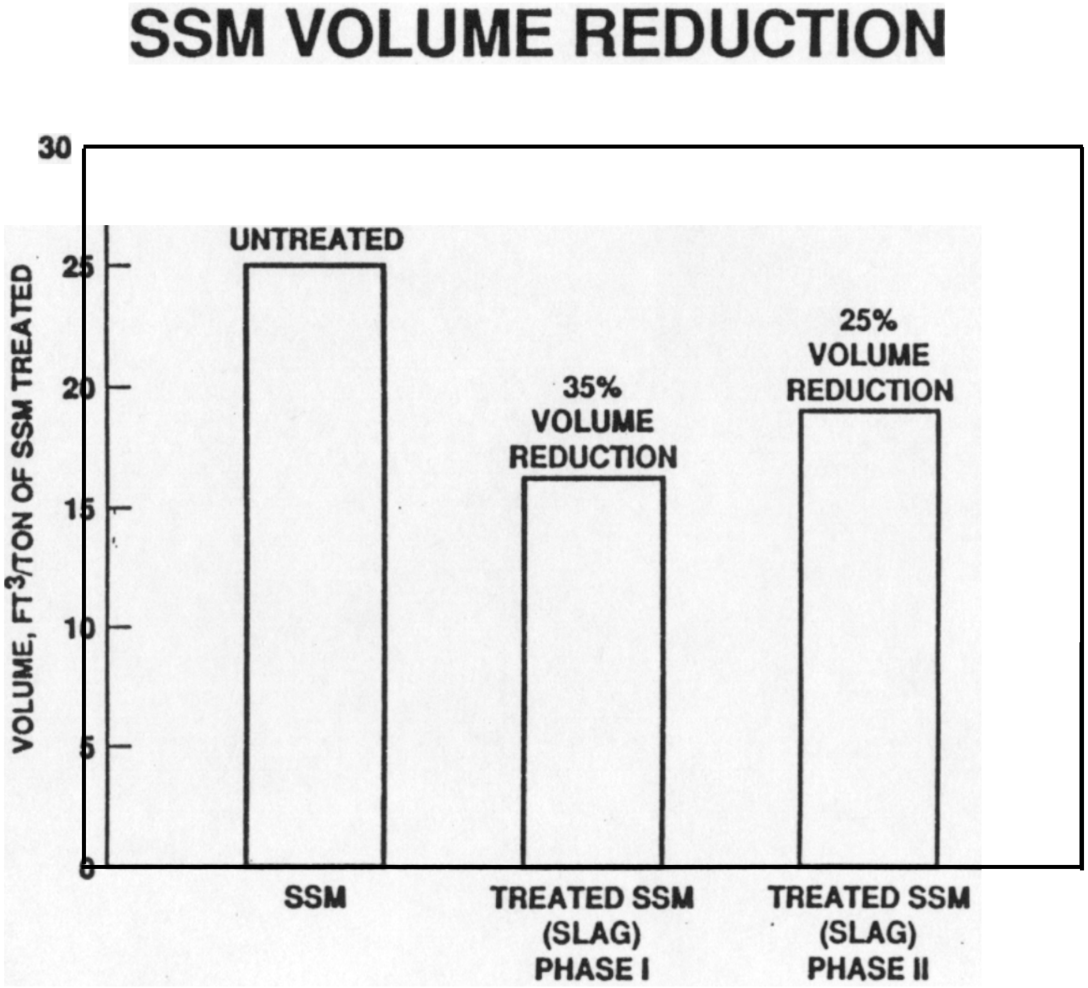


FIGURE 10 Volume Reduction

Phases I and II vitrified slag are shown. Approximately 35% and 25% volume reduction was obtained by vitrification of dry SSM and wet SSM, respectively. The volume reduction is a combination of 22% mass reduction by calcination of limestone component of SSM and the increased bulk density from 80 lb/cu ft for SSM to 86-92 lb/cu ft for slag. The resulting volume reduction estimate calculated on a dry basis is conservative since the as-received SSM contained approximately 25% water, which will be vaporized and contribute further to volume reduction.

Differences in volume reduction calculated for Phase I and Phase II may simply reflect the difficulty in obtaining representative samples of the wide particle size ranges in the slag. Still, the Phase II (25%) volume reduction is probably a more accurate measurement because special care was taken to assure that water was removed from the collected slag after the test.

A specific volume reduction for the Borax test could not be calculated. However, the total volume reduction is expected to decrease because of: (1) the addition of Borax, and resulting ash, to the feed SSM; and (2) the lower bulk density of the resulting slag (81 lb/cu ft) compared with the non-Borax slag (86-92 lb/cu ft).

Metals Retention

A mass balance for total ash, cadmium, chromium, and lead was performed for the cyclone furnace treatment process. A description of the way in which metal mass balances are calculated as well as examples of the calculation tables used for the Phase II mass balances are attached in the Appendix. The purpose of the mass balance was to determine the fate of the heavy metals during soil treatment. During the thermal vitrification process, heavy metals partition between the vitrified slag and the stack flyash. It is desirable to maximize the capture of the heavy metals in the non-hazardous vitrified slag.

For the Phase I tests, the overall mass balance achieved was 79 to 103% output divided by input, and the heavy metals mass balance accounted for 65 to 77% of the input lead, 56 to 61% of the cadmium, and 141 to 145% of the chromium.

The lead and cadmium were below 100% consistently. Heavy metal deposits on the wall and convection pass of the furnace were likely the most important factor in lead and cadmium mass balances below 100%.

In the case of chromium, mass balances in excess of 100% were calculated. The most likely source of excess chromium was a newly installed refractory which contains 9.6% chromium oxide (Cr_2O_3), and "bake-out" or abrasion of tbe material elevated the stack chromium levels.

Analytical accuracy is also a source of errors. As a part of analytical quality assurance, spike samples, containing a known amount of heavymetals, were measured. Cadmium and lead in the slag were detected within 15%.

An additional source of error may have been in the assumption that no vapor phase metals exist after the Multiple Metals Train filter, operated at 120°C.

For the Phase II tests, the overall and heavy metals mass balance were closer to 100%. An overall balance achieved 102 to 107% input, and the heavy metals mass balance accounted for 74 to 87.5% of the lead Input, 50.5 to 71.5% of the cadmium, and 78.9 to 96.8% of the chromium. The use of chromium refractory was minimized to prevent any chromium contamination.

Determining the fate of heavy metals in the cyclone furnace depends upon determining the relative amounts of SSM that leave the cyclone furnace in the slag and fly ash and a determination of the concentration of metals in each of those streams. Since the exhaust gas from the cyclone is cooled to 120°F prior to release to the atmosphere, all of the metals that escape the cyclone furnace should be captured in one of these two solid streams. None of the metals should be present In the exhaust gas in the gas phase. A discussion of the relative mass flowrates of the fly ash and slag streams and of the relative metals concentrations in each is presented below.

Mass Flowrates of the Fly Ash and Slag Streams

Tests showed 95 to 97% of the non- combustible portion of the input SSM was incorporated within the slag. The amount of SSM leaving the furnace as flyash was approximately 5-7%. Because the generation of flyash will be partly a function of fuel particle size, and because drying the SSM produced a finer particulate, this 5%-7% estimate is higher than that found for a wet feed system. A portion of the heavy metals from the SSM will condense on the flyash. This flyash residue may be treated by another technology or simply be recycled to the cyclone for further treatment.

The Borax flux added during one of the Phase II tests, appeared to facilitate the movement of slag out of the cyclone furnace barrel. When Borax was added, the flyash produced increased to 3.53% of the input SSM, presumably due to vaporization of sodium from the Borax.

Relative Concentrations of Metals in the Slag and Fly Ash

During the Phase I and Phase II heavy metals tests, soil and slag samples were collected, composited, and analyzed. The total metals results, averaged and reported on a dry basis, are given in Table 8.

TABLE 8

Total Metals in Soil, Slag, and Multiple Metals Train Particulates

Sample	Total Metals, ppm (mg/kg) Cadmium	Chromium	Lead
Phase 1			
<u>Composite Soil (Dry SSM)</u>			
46 lb/hr	1316 ∓ 40*	1391 ∓ 86	8007 ∓ 248
141 lb/hr	1223 ∓ 34	1339 ∓ 93	7390 ∓ 214
reagent blank	<0.05	<0.05	<0.05
<u>Composite Slag</u>			
46 lb/hr	101	1907	1624
141 lb/hr	134 ∓ 3.2	2169 ∓ 147	2432 ∓ 221
reagent blank	<0.05	<0.05	<0.05
<u>Multiple Metals Train Particulates</u>			
46 lb/hr	15146	12493	80414
141 lb/hr	14816	9893	99880
filter blank	15	108	149
Phase II			
<u>Composite Soil (SSM, Dry Basis)</u>			
100 lb/hr	1227	1527	7198
200 lb/hr	1261 ∓ 17	1550 ∓ 14	7708 ∓ 110
300 lb/hr	1329	1594	7701
200 lb/hr + Borax	1259	1565	7838
reagent blank	<0.5	<0.5	<0.5
<u>Composite Slag</u>			
100 lb/hr	113	1455	2077
200 lb/hr	190 ∓ 6.1	1488 ∓ 10	3592 ∓ 56
300 lb/hr	179	1421	2552
200 lb/hr + Borax	284	1208	3834
reagent blank	<0.2	<0.2	<0.2
Multiple Metals Train Particulates			
200 lb/hr	17720	7874	98736
200 lb/hr	23603	9027	120970
200 lb/hr + Borax	13103	5258	70939
filter blank	<37	43	<37

*Standard deviations shorn for triplicate or greater analyses.

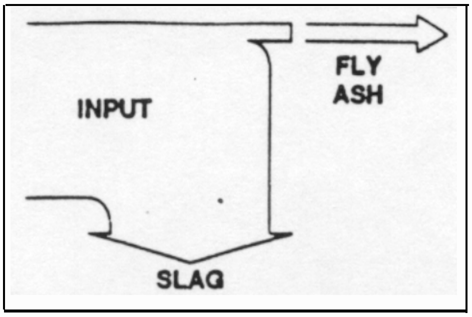
When compared with the soils metals levels, the slag was relatively enriched in chromium and depleted in lead and cadmium. The capture of heavy metals in the vitrified slag from all tests ranged from 8-17% for cadmium, 24-35% for lead, and 80-95% for chromium.

Addition of 10% of a Borax flux did not significantly improve the heavy metals capture in the vitrified slag despite a decrease in cyclone operating temperature of approximately 100°F.

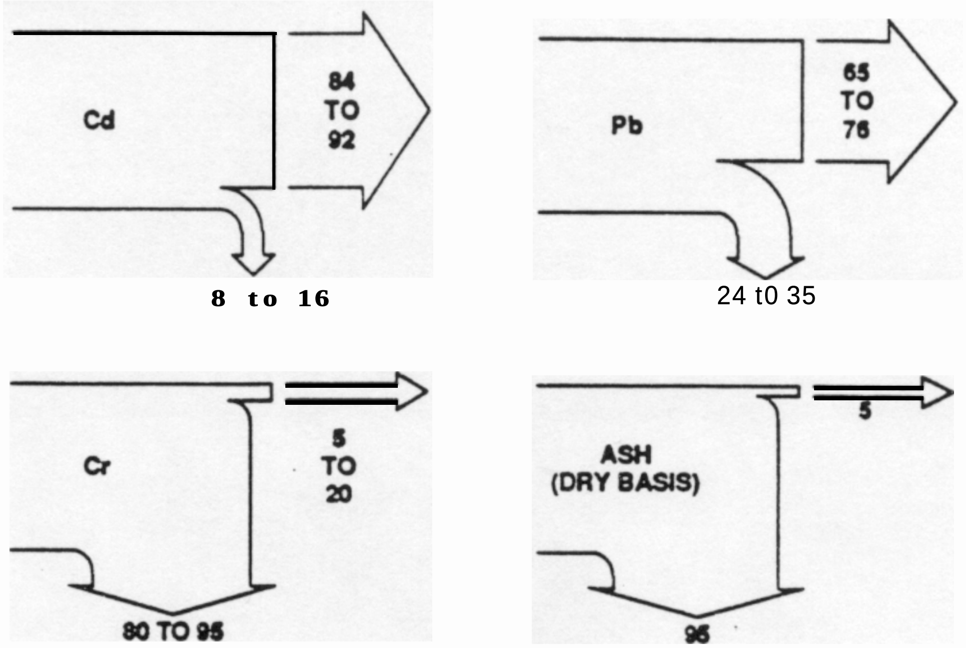
Several other trends can be seen from this data. The capture of heavy metals in the slag increased with increasing feed rate, likely due to shorter cyclone furnace residence times. As expected, less volatile metals were more readily captured in the slag. The capture of metals in the slag increased with decreasing metal volatility. This suggests the cyclone vitrification process would be well suited to treatment of low volatility contaminants, such as many radionuclides.

Lower cadmium, chromium, and lead levels were observed in fly ash from the Borax tests. More fly ash was generated for the Borax tests, however. Thus, metals Missions rates were only slightly lower for the Borax test.

Figure 11 shows the estimated overall split of heavy metals between fly ash and vitrified slag. For the Phase I dry soil feed, from 8 to 17% cadmium, 24 to 35% lead, and 80 to 95% of chromium were retained in the slag. For the Phase II wet soil feed system, from 12 to 23% cadmium, 38 to 54% lead, and 78 to 95% of chromium were retained in the slag. The ranges were determined using non-normalized and normalized concentrations of heavy metals as determined by mass balance (see Section 5.0, D).



A. PHASE 1 (DRY SOIL, 141 LB/HR)



B. PHASE 2 (WET SOIL, 200 LB/HR)

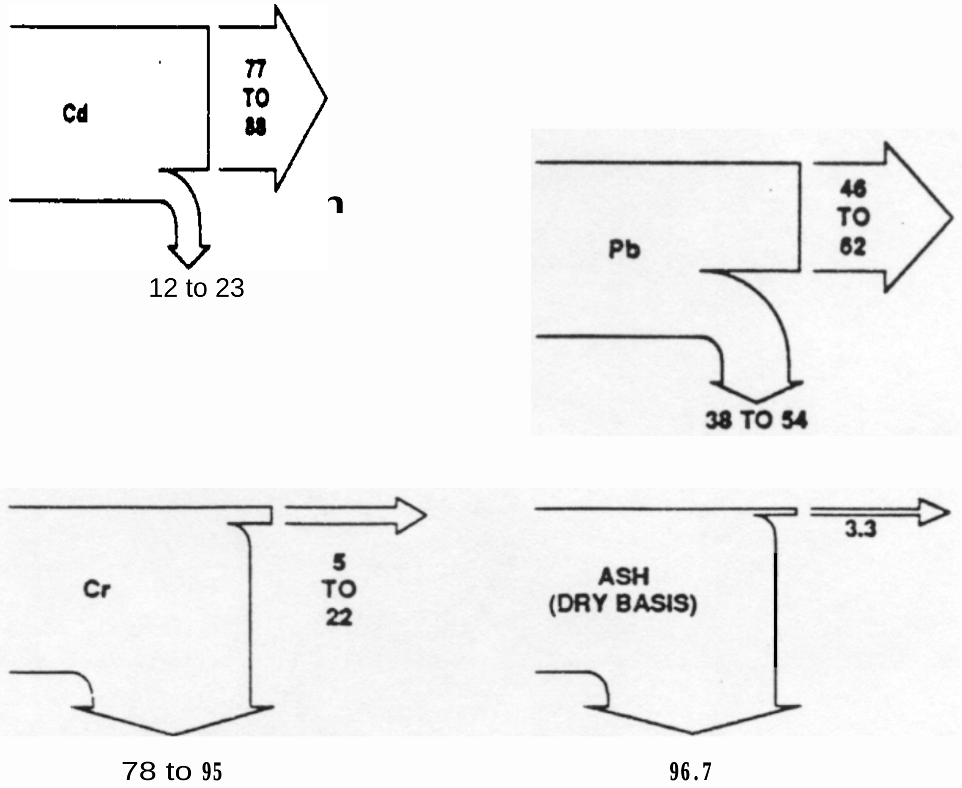


FIGURE 11 Heavy Metals and Ash Mass Salance

Figure 12 shows that heavy metals content in the slag increases with increasing SSM feed rate between 50 to 300 lb/hr. Since fuel (natural gas) feed was relatively constant, this suggests that increasing SSM feed rate reduces the solid residence time (and/or slag temperature, see Appendix figures) in the cyclone furnace and, consequently, reduces vaporization of heavy metals into the flue gas. This increasing capture with feed rate shows some promise for further metals capture optimization, and is an encouraging trend for process scale-up.

An attempt was also made to correlate the different behavior of the metals during cyclone treatment with their volatility. The temperature at which the metal vapor pressure was 100 mm Mercury was chosen as the volatility parameter. Figure 13 shows the heavy metals retained in the slag as a function of volatility of the metal. A marked trend was obtained, and we concluded that increasing volatility is the dominant factor over the fate of heavy metals. Figure 13 shows the volatility of the metal is inversely proportional to the slag metal concentration. These results suggest that the cyclone vitrification process may show very high capture for very low volatility contaminants, such as many radionuclides. Conversely, high volatility metals are likely to be concentrated in the flyash which may then be suitable for metals recovery. Intermediate volatility species, such as lead, are captured to some degree in the flyash and may be recycled to the furnace to increase the overall capture of the metal in the slag.

Figures 11 and 13 suggest better capture of the metals in the slag for the Phase II wet feed system compared with the Phase I dry soil feed system. The reason for the improved capture may be a combination of any of the following: (1) increased feed rates, resulting in lower slag temperatures and, thus, less metals volatilization; (2) reduced soil residence time in the furnace and, thus, less metals volatilization; or (3) larger particle size distribution in the wet

FEED RATE AND HEAVY METALS CAPTURE

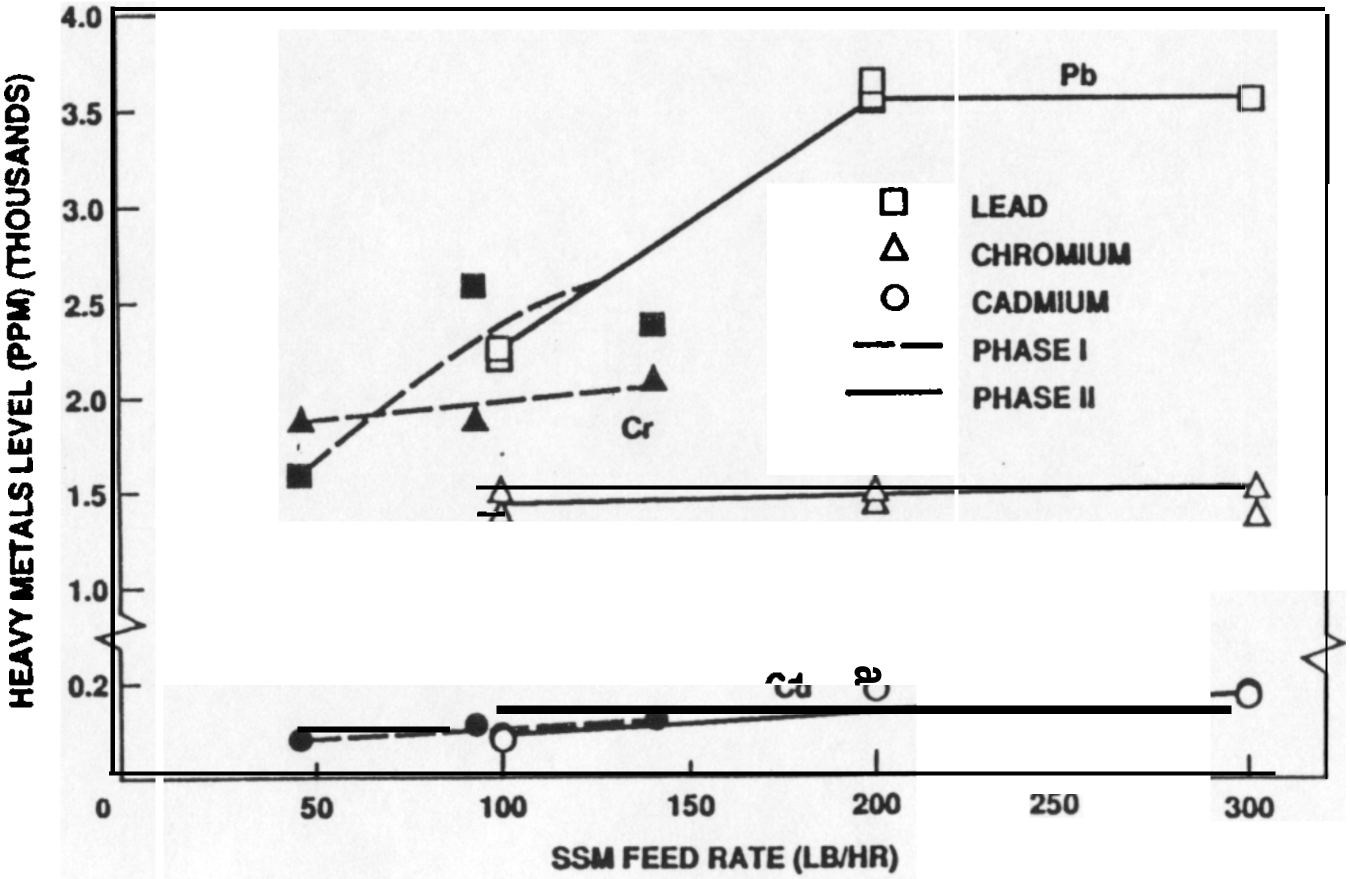


FIGURE 12 Heavy Metals Capture vs. Feedrate

VOLATILITY & HEAVY METALS CAPTURE

(NORMALIZED DATA FROM PHASE I AND PHASE II TESTS)

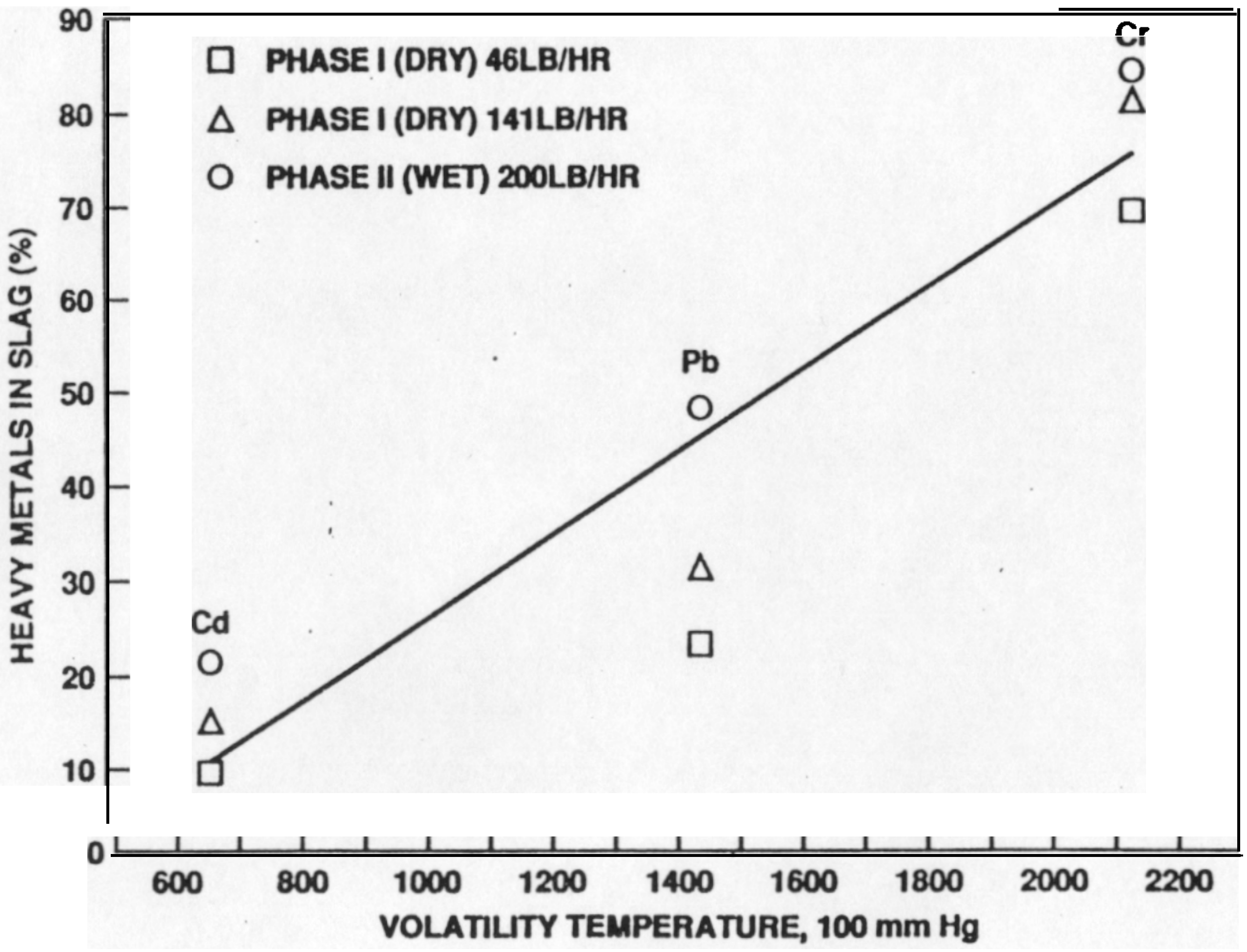


FIGURE 13 Heavy Metals Capture vs. Volatility Temperature

SSM, thus reducing the surface exposed for metals volatilization.

With the possible exception of cadmium, the addition of a 10% Borax fluxing agent did not significantly improve the capture of the heavy metals. For the Borax test; from 17.9 to 30.5% cadmium, 37.8 to 54.7% lead, and 62.8 to 91.7% of chromium were retained in the slag. The Borax flux reduced the slag temperature from 2430°F to 2320°F by reducing the natural gas load from 5 to 4.1 MBtu/hr. Only for the most volatile metal, cadmium, does this temperature difference appear to affect volatilization. This small improvement in cadmium capture Is offset by an increase in volume to be processed (and, thus, decrease in volume reduction for a glven weight of SSM treated) and an Increase in the weight of potentially hazardous flyash stream. Still, the Borax improved soil melting and tapping from the furnace. If a small amount of Borax can improve soil melting, the feed rate may be increased for a given heat input rate.

Operability/Emissions

Stable cyclone operation was achieved during the pilot tests. Post-furnace CO, CO_2, and NO_x levels were measured using continuous emissions monitors, Average levels measured during the heavy metals tests are given in Table 9.

TABLE 9

Average Phase I CO, CO_2, and NOx Levels (Spiked SSM)

		Measurements			
Test	Cyclone Load MBtu/hr	Feed Rate, lb/ hr	Stack CO, ppm at 3% O_2	Stack CO_2, %	Stack Nox ppm at 3% O_2
11/15/90	4.7	46	18	11.4	365
11/16/90	4.8	141	19	11.5	319

Although the NOx levels are relatively low, the measured NOx levels can be further reduced, if desired, by application of NOx reduction technologies. This may be necessary for wastes intrinsically high in nitrogen compounds which produce higher levels of NOx emissions. Carbon monoxide (CO) levels were very low, indicating stable combustion. The CO_2 levels measured are typical for combustion of natural gas.

The slag did not appear homogeneously melted; larger particles appeared unmelted, but after viewing under a microscope, the particles appeared completely melted.

Average post-furnace NOx, CO_2, and CO levels for the five heavy metals tests in Phase II were 322 ppm, 10.5%. and 27 ppm, respectively (see Appendix for specific measured values). These levels are similar to those measured in Phase I. The Appendix contains graphs of NOx levels and slag temperatures plotted against feed rates for the preliminary and heavy metals tests. As expected, the NOx levels decrease with increasing SSM feed rates (and, thus, cyclone temperatures). The slag temperature was sensitive to the SSM feed rate; it decreased from 2470 to 2400°F.when SSM feed rate increased from 100 to 300 lb/hr, respectively (see Appendix figures). The flyash (measured at convection pass exit) remained low, at approximately 2% of SSM input (See Appendix Dust Loading data).

Some operability problems and feed rate will be improved by full-scale design and operation. For example, the surface-area-to- volume ratio of the pilot unit is much larger than that expected for a full-scale unit. This will decrease the heat input required to melt a given amount of soil.

With the added Borax, the slag temperature was reduced from 2430°F (200 lb/hr SSM feed rate) to 2320°F and NOx levels decreased from 318-337 ppm (200 lb/hr feed rate) to 260 ppm, as shown in the Appendix figures.

6. QUALITY ASSURANCE

Quality assurance systems audits and a performance evaluation audit were conducted by the B&W Quality Assurance Unit. The activities included an audit of the instruments and calibrations, heavy metals tests soling procedures, and an audit of the Aquatec laboratory (Phase I). Audit and performance results are summarized below.

Systems Audits

During Phase I, the systems audit of the instrument calibration found that the transducer used for the indication of secondary combustion air flow rate was calibrated to an accuracy specification of 0.4% of span (0-5 volts). The manufacturer's specification for accuracy deviation is 0.2% of span and, thus; the instrument was out of calibration. Because secondary air flow rate is not a critical measurement, this deviation had no impact on the project. During Phase I, the sampling objective of 30-minute intervals for sequential soil (SSM) and slag samples was not met because the sampling times required to obtain a given weight of soil from the soil sampling valve were longer than anticipated (up to 35 minutes per sample). Thr impact of this deviation from the Quality Assurance Project Plan (QAPP) was minimal because the soil sampling was nearly continuous. A second sampling deviation was the use of a metal shovel to collect the slag from the slag tank. Ideally, metals collection devices should be avoided for trace metals sampling; however, plastic and glass devices could not be used. The effect of metals introduced from the shovel, if any, would result in a more conservative estimate of the metals leachability.

During Phase II, the systems audit found, for two multiple metals trains (16:10 and 17:44 on 9/9/91), the pump was turned off before removing the probe from the stack, while Method 5 specifies that the probe is removed before the pump is shut off. The impact of this deviation is thought to be negligible. The train performed at 16:10 (200 lb/hr test) omitted the 0.1N HNO_3 probe rinse specified in the Multiple Metals Train procedure [3]. For the train run at 17:44 (also 200 lb/hr test), the percentages of the total cadmium, chromium, and lead found in the 0.1N HNO_3 rinse were 2.6, 4.9, and 2.4%, respectively. This can be compared with the relative percent difference for the total cadmium, chromium, and lead collected by the two trains which was 25, 4 and 2.5%. respectively. Thus, for chromium and lead, the differences in the total particulate metals found can be completely explained. by losses due to omitting the 0.1N HNO_3 rinse (with an overall impact of a few percent difference). The omission of the 0.1N HNO_3 rinse explains only a small portion of the differences for cadmium. Thus, the effect of omitting the 0.1N HNO_3 rinse is insignificant for cadmium. Bacause the particulate stream is a small portion of the overall materials balance for the cyclone process, the differences introduced by omitting the 0.1N HNO_3 rinse are not thought to significantly affect the mass balance results for the project.

The QAPP specified that ASTN Method E886 be used for the digestion of soil and slag samples for total metals. However, to achieve complete digestion of these matrices, modifications to the ASTN method were required. The Modified ASTM E886 Method is attached in the Appendix.

Performance Audits for Critical Measurements

The quality assurance results for the critical measurements, TCLP of the SSM feed material, and the vitrified soil product are given in Table 10. The TCLP analyses met Performance Evaluation objectives based on results for EPA check standards of 97.2-99.5%, compared with an acceptance criteria of 90-110%. Detection limits surpassed those specified in the QAPP. matrix spikes ranged from 79-152% recovery for Phase I and 25-118% for Phase II, which exceeded the cadmium and lead QA objectives, but was within expected performance for environmental matrices. Because the measured values were orders of magnitude above or below the TCLP limit, exceeding this criterion should not affect conclusions made regarding whether a sample met or exceeded TCLP limits.

For the TCLP leaching analyses, precision was determined by duplicate determinations of one slag and one soil durlng each heavy metals test. The precision for several of the measurements'exceeded the QA objective of 20% relative percent difference (% RPD). Precision objectives may have been higher than can reasonably be expected of these samples (indeed, 50% is generally considered excellent precision for environmental samples). The lack of precision for certain soil TCLP analyses may have been due to the heterogeneous nature of the soil matrix. The soil contains a wide range of particle sizes,

TABLE 10

QA Data for TCLP Analyses

Quality assurance Parameter	Cadmium		Chromium		Lead	
	Objective	Found	Objective	Found	Objective	Found
Phase I						
Accuracy, %	50-150	100-138	50-150	79-107	50-150	108-152
Precision, %						
soil*	20	2,2	20	4,98	20	11,64
slag*	20	6,43	20	41,91	20	9,25
TCLP Detection Limit, µg/L	10	9.1	20	10.6	5	1.3
Phase II						
Accuracy, %	50-150	39.7	50-150	100-118	50-150	25-50
Precision, %						
soil*	20	5,3	20	3,1	20	6,10
slag*	20	29,6	20	62,26	20	22,3
TCLP Detection Limit, µg/L**	10	10	20	10	5	5

• Data for two determinations (one for each heavy metals test).
**Data from blank determinations used.

which stratify in layers, making representative sampling more difficult. A relative enrichment in smaller particles relative to the bulk sample would increase the detected metals (small particles contain higher amunts of the contaminants because of their relatively high surface-to-volume ratio). Because the soil samples already exceeded the TCLP limits for lead and cadmium by 20-50 times, the higher-than-expected relative percent difference has no impact on the project. For example, for lead in one soil sample, a relative percent difference of 64% would still result in a soil which fails the TCLP by one order of magnitude.

The precision for a number of slag TCLP leaching analyses also did not meet the QA objectives. This was likely due to the very low levels of leachable metals in these samples that gave results near the analytical detection limits. As measurements approach the detection limit for an analytical method, the relative percent differences between duplicates is expected to increase. This was especially evident for the chromium measurements (up to 91% RPD). For example, for the three slag samples analyzed from the Phase I 11/15 test, one sample was measured to be at the detection limit, one at 1.5 times the detection limit, and one was at 4 times the detection limit. Because the slag samples were below the TCLP limits for lead, cadmium, and chromium by one to two orders of magnitude, the higher-than-expected relative percent difference has no impact on the project.

Performance Audits for Non-Critical Measurments

The quality assurance objectives and results for the non-critical measurements (total metals analysis) are given in Table 11. The metals analysis met QA data quality objectives for accuracy based on recovery of check standards added to matrix spike samples. Precision, determined from duplicate (or more) analyses of samples, exceeded the QA objective of 20% relative percent difference, with the exception of cadmium in the multiple natals train in Phase II (the precision appears to be related to the volatility of a given metal and may reflect differences in combustion conditions rather than analytical differences). Laboratory blank levels were well below the detected levels for the metals determinations. For the multiple metals trains, the acceptance criterion for percent isokinetic sampling was 90-110%. For Phase I and Phase II tests, percent isokinetic sampling was 99-101%, which exceeded the acceptance criterion.

The non-critical measurements included analyses of check standards during continuing calibration. Recalibration was performed when continuing calibration standards failed to meet the 90-110% acceptance criterion stated in the QA Project Plan

TABLE 11

QA Data for Non-Critical Metals Determinations

Quality Assurance Parameter	Cadmium		Chromium		Lead	
	Objective	Found	Objective	Found	Objective	Found
Phase I						
Accuracy, %						
soil	50-150	81	50-150	106	50-150	77
slag	50-150	114	50-150	88	50-150	110
Precision, %						
soil	20	2.6-4.3	20	1.6-12	20	3.8-5
slag	20	1.9-6.4	20	4-13	20	1.7-17
MMT*	20	5.9	20	5.2	20	10
Phase *II*						
Accuracy, %						
soil	50-150	107	50-150	103	50-150	96.8
slag	50-150	92.0	50-150	96.9	50-150	95.6
Precision, %						
soil	20	0.7-5.5	20	0.3-3.4	20	0.3-5.0
slag	20	0.5-4.4	20	1.1-4.7	20	0.08-2.1
MMT*	20	25	20	4	20	2.5

*Multiple Metals Train

7. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions can be drawn about the ability of the cyclone furnace to process organic and heavy metal contaminated soil based upon the results of the Phase I and Phase II tests. These conclusions are as follows.

1. The Babcock & Wilcox six million Btu/hr pilot cyclone furnace was successfully used to vitrify an EPA-Synthetic Soil Matrix (SSM) spiked with 7,000 ppm lead, 1,000 ppm cadmium, and 1,500 ppm chromium. When operated at 50 to 150 lb/hr of dry SSM feed, and from 100-300 lb/hr of wet SSM feed, the cyclone technology was able to produce a non-leachable product (well below TCLP limits).
2. The cyclone vitrification process would be well suited to treatment of low volatility contaminants, such as many radionuclides. At least 95 to 97% of the input SSM was incorporated within the slag. During the thermal vitrification process, the heavy metals partition between the vitrified slag and the stack flyash. The capture of heavy metals in the slag was found to increase with increasing feed rate and with decreasing metal volatility.
3. Stable cyclone operation was achieved during the pilot tests. Using natural gas as the fuel, the CO and NOx, stack emissions gases from the process were within acceptable ranges.
4. The treatment of the synthetic soil matrix resulted in a volume reduction of 25-35% (dry basis). Vitrification results in an easily- crushed, glassy product.

Recommendations for Future Work

The cyclone furnace may be best suited to the treatment of soils contaminated by organics and either very high- or low-volatility metals/radionuclides. This statement can be explained as follows:

(1) the high heat release rates and turbulence make the cyclone vitrification process well suited for organics destruction;

(2) vitrification of very high-volatility metals or radionuclides would tend to concentrate those elements in the relatively small flyash stream, which may then be suitable for recovery;

(3) vitrification of very low-volatility metals or radionuclides would tend to concentrate those elements in a non-leachable product (the slag)

and produce only low flyash levels. Such elements are present at Department of Energy and Department of Defense contaminated soil sites. Feasibility for these elements will be verified in the SITE Demonstration.

For intermediate volatility metals/radionuclides, the best process option may be to recycle the flyash to the furnace in order to maximize the capture of heavy metals in the non-leachable slag and minimize the size of the flyash waste stream.

The flyash recycling concept should be demonstrated on a pilot- scale process to verify feasibility and potential advantages. The effect on the percent capture of metals in the slag and TCLP performance should be evaluated. Even if recycling proves undesirable, the heavy metals are contained in a relatively small flyash stream that may then be stabilized for disposal. This represents a much smaller stream requiring hazardous waste treatment and disposal (3-5% of the original contaminated soil).

The heat input for a given rate of soil feed for the pilot-scale unit should be improved in the field-scale design. This improvement will come from lower cooling surface-to-furnace-volume ratios which will result in lower heat losses from the unit. The feed rates achieved during this project are likely minimum values because of the limits imposed by working with a cyclone furnace designed for coal combustion rather than waste vitrification. Feed rates will be increased by improved gas burner design and placement for a vitrification application.

In addition to the Emerging Technologies effort, a U.S. EPA SITE Demonstration of the cyclone furnace was performed in November of 1991. Heavy metals, volatile and non-volatile radionuclides, and organic hazardous constituents were spiked into the synthetic soil matrix. Measurements will be made to verify previous TCLP leachabilities, volume reduction, and heavy metals capture in the slag. DRE's for organic contaminants will be measured. The immobilization of radionuclides will be measured using American Nuclear Society leaching procedures. Conventional air pollutants will be measured to test regulatory compliance. Potential technology applications and estimated process economics will be addressed.

Based on the results of the SITE Demonstration, B&W will assess the further development/commercialization of the cyclone vitrification process. Conceptualization and design of a full-scale system have not been performed. An important next step is the design, fabrication, and demonstration of a full-scale vitrification furnace. The operation of a full-scale unit can be used to obtain accurate process economics.

8. REFERENCES

1. P. Esposito, J. Hessling, B. Locke, M. Taylor, M. Szabo, R. Trumau. C. Rogers, R. Traver and E. Barth, "Results of Treatment Evaluations of a Contaminated Synthetic Soil," JAPCA, 39: 294 (1989).

2. RREL Quality Assurance Project Plan No. P-309-B. submitted by B&W to RREL July 2, 1990, and Phase II modifications submitted by letter to RREL August 28, 1991.

3. "Methodology for the Determination of Trace Metal Emissions in Exhaust Gases From Stationary Source Combustion Processes," Subsection 3.1 of the Methods Manual for Compliance with BIF Regulations (EPA/530-SW-91-010, December 1990).

4. 40 CFR 60, Appendix A, July 1990, Method 5.

5. J. Nowok and S. A. Benson, University of North Dakota, Gas Research Institute Report No. GRI-89/0078.

9. APPENDIX

Calculation of Heavy Metals Mass Balance

A mass balance for total ash, cadmium, chromium, and lead was performed for the cyclone furnace treatment process. The purpose of the mass balance was to determine the fate of the heavy metals during Phase I (at 46 and 141 lb/hr) and Phase II (200 lb/hr and Borax test). Proximate and ultimate analysis was performed to determine the volatile compounds (e.g., CO, from $CaCO_3$) In the SSM. Each day the soil feeder was calibrated before and after the tests, and an average feed rate was used. Each day's slag was collected and weighed. The. weight was corrected for water. The particulate loading of flyash to the stack was isokinetically measured and averaged. Some flyash also deposits in the convection pass or on the furnace walls. The convection pass flyash deposit could not be measured, but was estimated at 50% of the stack flyash. This was based on the amount of convection pass deposit that has been measured previously with Ohio #6 coal flyash (50% of stack flyash).

To determine the mass balance, total heavy metals analysis was performed on the feed SSM, vitrified slag, and captured flyash. For each test, duplicate Multiple Metals Trains were collected and heavy metals were determined (with the exception of the Borax test, where only one train was performed). Slag and feed soil (SSM) samples were collected at approximately one hour intervals. The samples collected were composited and analyzed for total heavy metals in duplicate or triplicate. The volatile matter, slag, and flyash loading were normalized to 100% of dry, CO_2-free SSM. The results consistently showed that flyash loading was very small (5% or less of the SSM input).

A normalized and non-normalized mass balance was calculated as follows:

(1) The amount of SSM, flyash, and slag was measured for each test,

(2) A material balance was performed on the SSM and combination of flyash, slag, SSM water, SSM CO, in the flue gas (achieved 79 to 103% input for Phase I and 102 to 107% input for Phase II).

(3) The flyash and slag streams were normalized to 100%, assuming the average of the SSM feed rate measured before and after the test.

(4) Using the normalized ash and slag percentages, performed a mass balance on lead, cadmium, and chromium (mass times concentrations). This mass balance in Phase I accounted for 65 to 77% of the input lead, 56 to 61% of the cadmium, and 141 to 145% of the chromium (chromium result discussed in Section 6.0, H), and in Phase II accounted for 74 to 87.5% of the lead input, 50.5 to 71.5% of the cadmium, and 78.9 to 96.8% of the chromium.

(5) The mass balance was normalized to 100% (100% = amount of heavy metals measured in input SSM using the SSM rate and the SSM metal concentrations -- this assumes the SSM input rate and concentrations were the most accurately measured parameters).

(6) The mass balance range reported was the percent mass balance for the slag with the lower end of the range being the non-normalized data and the upper limit being the normalized data to which 15% was added to account for analytical error. The mass balance range for the flyash was calculated from (100 - the slag range).

Dust Loading Data

Identification Number	001-A03	002-A04	003-A06	004-A07	005-A08	006-A09
Date	8-20-91	8-21-91	8-27-91	8-27-91	8-28-91	8-28-91
Soil Moisture Content (%)	25	25	25	25	25	25
Stack Ash,(%) of Input	1.77	2.01	1.73	0.4	1.91	1.49
Stack Pressure," Water	0.55	0.55	0.55	0.55	0.55	0.55
Dust Sample, (g)	0.46	0.51	0.31	0.07	0.50	0.51
Flue Gas Sampled, (CuFt)	30.47	30.42	25.94	25.27	25.07	24.63
Temperature, (F)	101	103	114	118	114	120
Sample Flue Gas Mass, (lb)	2.14	2.14	1.79	1.73	1.73	1.69
Total Flue Gas, (lb/hr)	2793	2874	3416	3380	3386	3361
Barometric, "Hg	28.76	28.92	29.01	29.00	29.03	29.02
Stack Abs. Pressure, (psi)	14.14	14.21	14.26	14.26	14.27	14.27
Gas Mol. Weight	29.84	29.84	29.84	29.84	29.85	29.85

Identification Number	007-A10	009-A12				
Date	8-29-91	9-3-91				
Soil Moisture Content (%)	25	25				
Stack Ash,(%) of Input	1.89	1.94				
Stack Pressure," Water	0.55	0.55				
Dust Sample, (g)	1.02	1.02				
Flue Gas Sampled, (CuFt)	25.71	25.71				
Temperature, (F)	112	112				
Sample Flue Gas Mass, (lb)	1.79	1.79				
Total Flue Gas, (lb/hr)	3383	3474				
Barometric, "Hg	29.04	29.04				
Stack Abs. Pressure, (psi)	14.28	14.28				
Gas Mol. Weight	29.85	29.86				

Identification Number						
Date						
Soil Moisture Content (%)						
Stack Ash,(%) of Input						
Stack Pressure," Water						
Dust Sample, (g)						
Flue Gas Sampled, (CuFt)						
Temperature, (F)						
Sample Flue Gas Mass, (lb)						
Total Flue Gas, (lb/hr)						
Barometric, "Hg						
Stack Abs. Pressure, (psi)						
Gas Mol. Weight						

SBS DATA AVERAGES

Test ID	Cyclone (Temp)	Overall Stoichiometries	Total Load (MBTU/HR)	Soil Feed Rate (LB/HR)	Soil Disperser Air (LB/HR)	Stack Oxygen (%)	Stack CO (PPM)	Stack NOx (PPM)	Pri. Air to Cyclone (LB/HR)	Total Sec. Air Flow (LB/HR)	Sec. Air Cyclone (Temp)
001 - A03	2455	1.03	6.12	100	100	0.77	19	299	754	2978	814
002 - A04	2420	1.03	6.28	100	130	0.78	23	309	771	3023	794
003 - [illegible]	2370	1.03	4.97	100	99	0.62	29	394	N/A	3693	814
004 - A07	2410	1.02	4.98	150	90	0.65	61	436	N/A	3686	814
005 - A08	2370	1.02	4.94	200	99	0.68	29	250	N/A	3570	810
006 - A09	2390	1.02	4.91	300	105	0.63	29	224	N/A	3543	813
007 - A10	2405	1.02	4.94	300	111	0.66	26	209	N/A	3680	810
008 - A12		1.02	6.09		111	0.47	24	256	N/A	3852	807

SBS DATA AVERAGES

Spiked Synthetic Soil Matrix

Test ID *	Cyclone (Temp)	Overall Stoichiometries	Total Load (MBTU/HR)	Soil Feed Rate (LB/HR)	Soil Disperser Air (LB/HR)	Stack Oxygen (%)	Stack CO (PPM)	Stack NOx (PPM)	Pri. Air to Cyclone (LB/HR)	Total Sec. Air Flow (LB/HR)	Sec. Air Cyclone (Temp)
001-A01	2430	1.05	4.84	200	128	1.19	30	318	N/A	3553	823
002-A02	2420	1.04	4.86	200	128	0.96	30	337	N/A	3525	825
003-A03	2470	1.02	4.83	100	128	0.58	21	326	N/A	3542	813
004-A04	2400	1.03	4.83	300	128	0.73	28	306	N/A	3553	822
*005-A05	2320	1.25	4.14	200	134	4.71	28	260	N/A	3609	816

* Borax Added

Phase II Heavy Metals Tests Material Balance

Test	Feed Rate, Lb/hr	Material balance, % of wet soil input				Material balance, % of wet soil input, normalized to 100%	
		% H2O	%Flyash	% Slag	Total*	%Flyash	% Slag
AO1	201.50	25.29	2.32	68.11	107.34	2.08	61.02
AO2	201.50	25.29	2.63	68.11	107.65	2.35	60.75
AO5	196.15	28.88	3.53	59.82	102.12	3.42	57.82

* Included 15.44% CO2 dry basis, and 10% Borax in last test

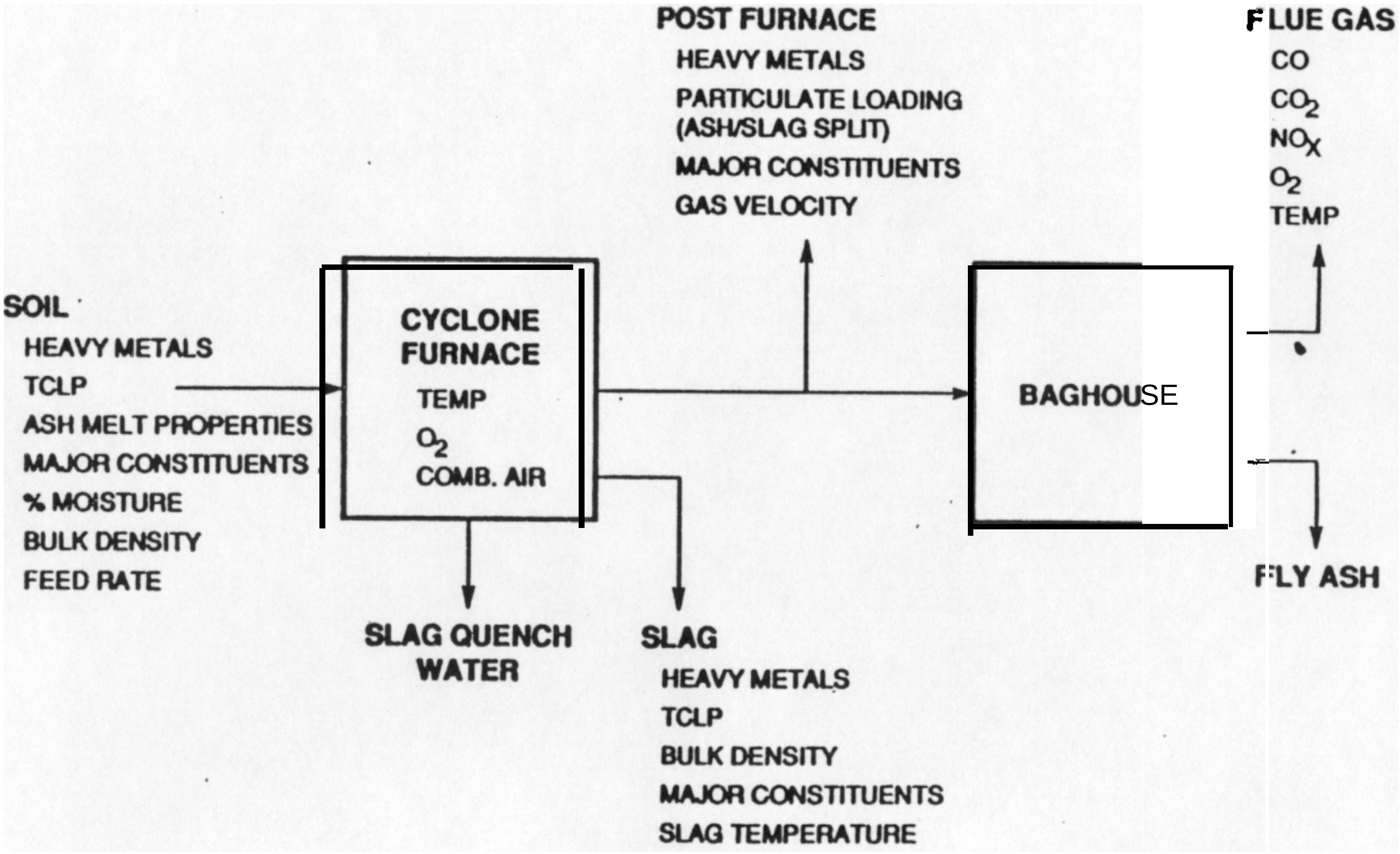


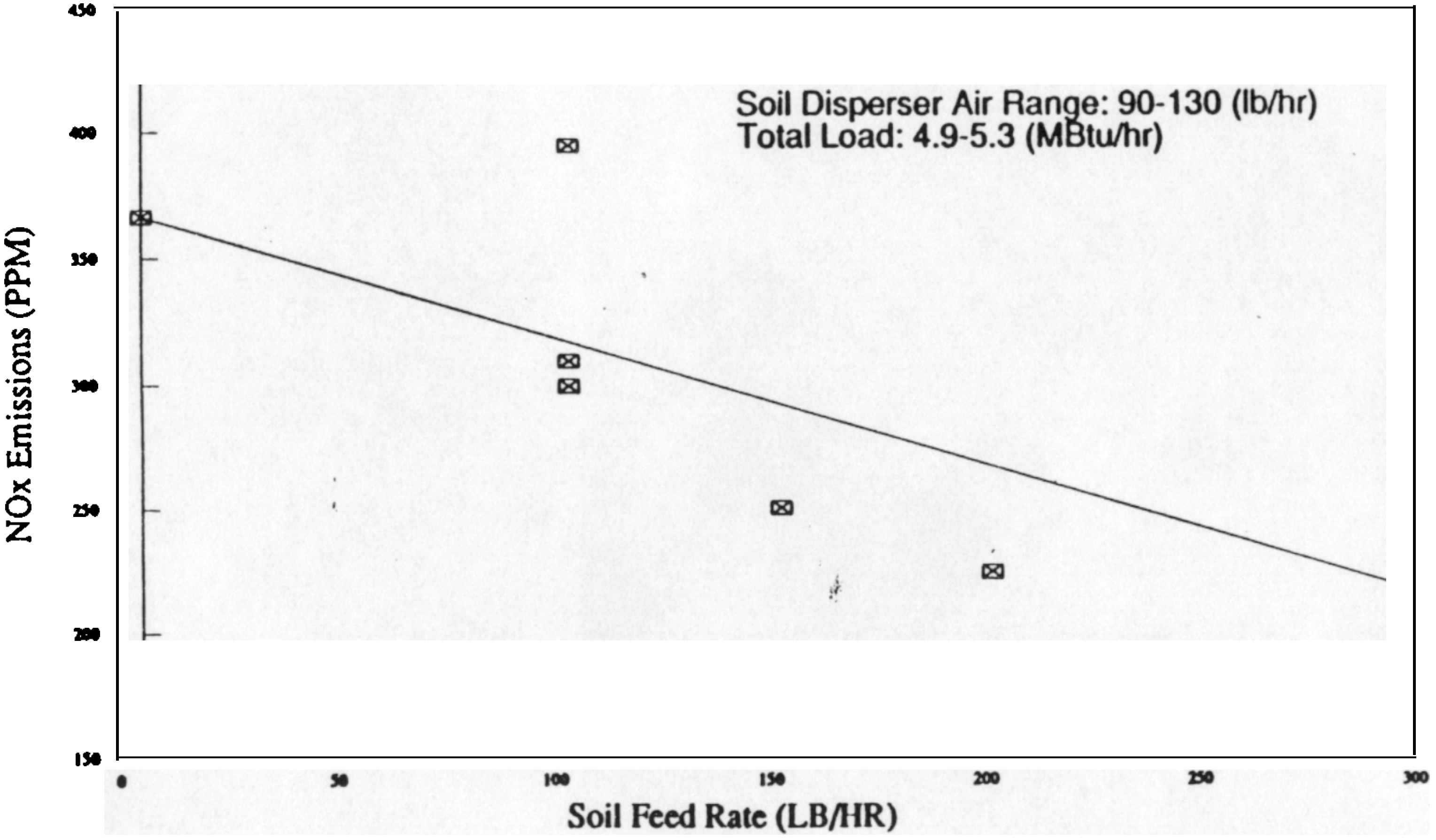
FIGURE 7. Sampling locations and analyses for the Phase I and Phase II heavy metals tests used for the heavy metals mass balance, TCLP leachability, and volume reduction.

Phase II Total Metals and Percent Weight for Soil, Slag, and Fly Ash (Heavy Metals Mass Balance)

		Metal Concentration (ppm)			Weight, % of Input			Weight, % of input, normalized	
Test	Element	Soil	Slag	Flyash	Slag	Flyash	Total	Slag	Flyash
9/9/91	Lead	7635	3550	98736	38.0	36.0	74.0	51.3	48.7
	Cadmium	1281	187	17720	11.9	38.5	50.5	23.7	76.3
	Chromium	1544	1500	7874	79.3	14.2	93.5	84.8	15.2
9/9/91	Lead	7655	3570	120970	37.9	49.6	87.5	43.3	56.7
	Cadmium	1248	186	23603	12.1	59.4	71.5	17.0	83.0
	Chromium	1540	1484	9027	78.4	18.4	96.8	81.0	19.0
9/9/91	Lead	7836	3551						
	Cadmium	1255	197						
	Chromium	1566	1481						
9/9/91 Average of 3 samples	Lead	7709	3557	109853	37.6	42.2	79.8	47.1	52.9
	Cadmium	1261	190	20662	12.3	48.5	60.8	20.2	79.8
	Chromium	1550	1488	8451	78.3	16.1	94.4	82.9	17.1
9/11/91 Test with 10% Borax	Lead	8208	3813	70939	37.8	41.5	79.3	47.6	52.4
	Cadmium	1268	279	13103	17.9	49.6	67.5	26.5	73.5
	Chromium	1577	1219	5258	62.8	16.0	78.9	79.7	20.3

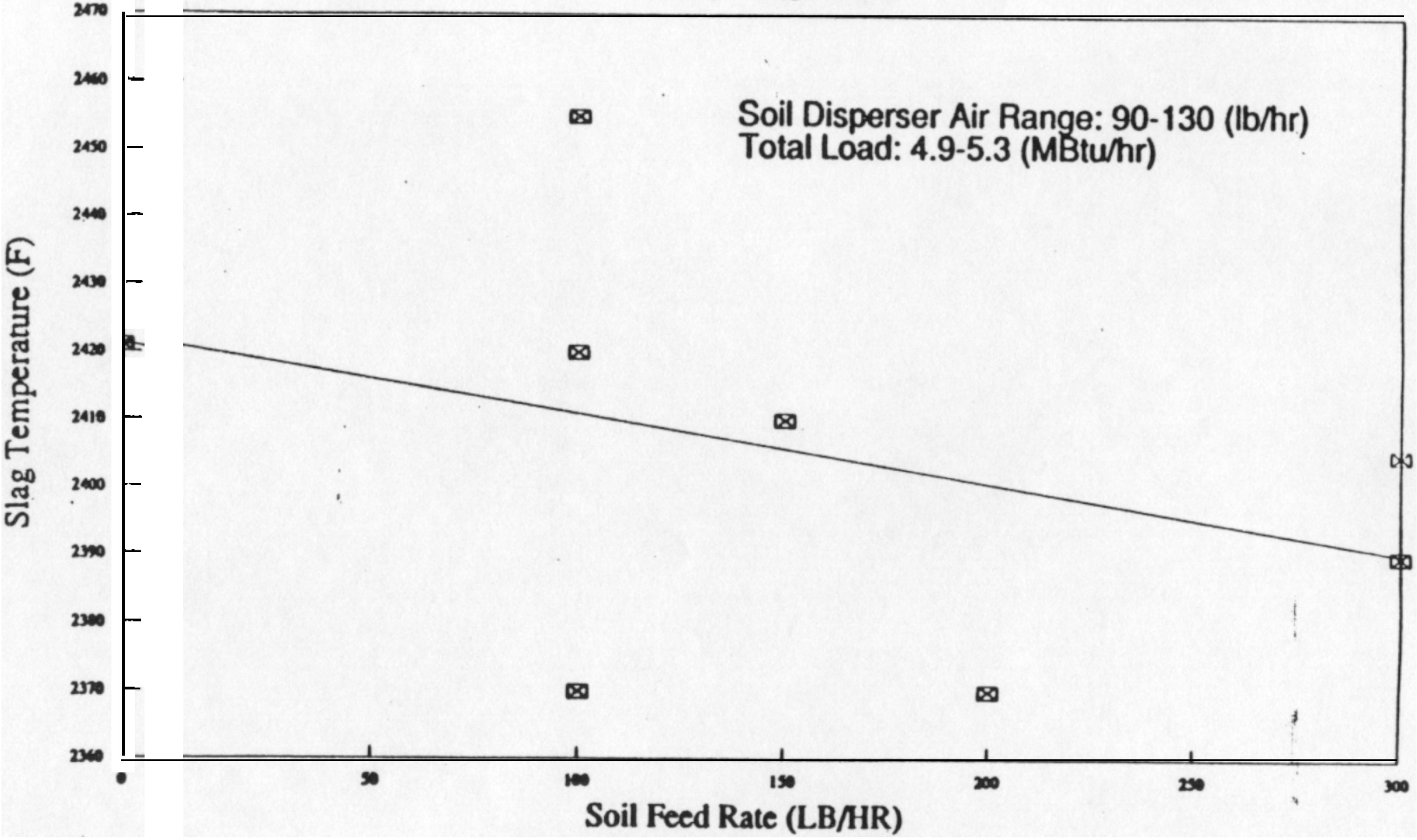
Clean Soil Testing

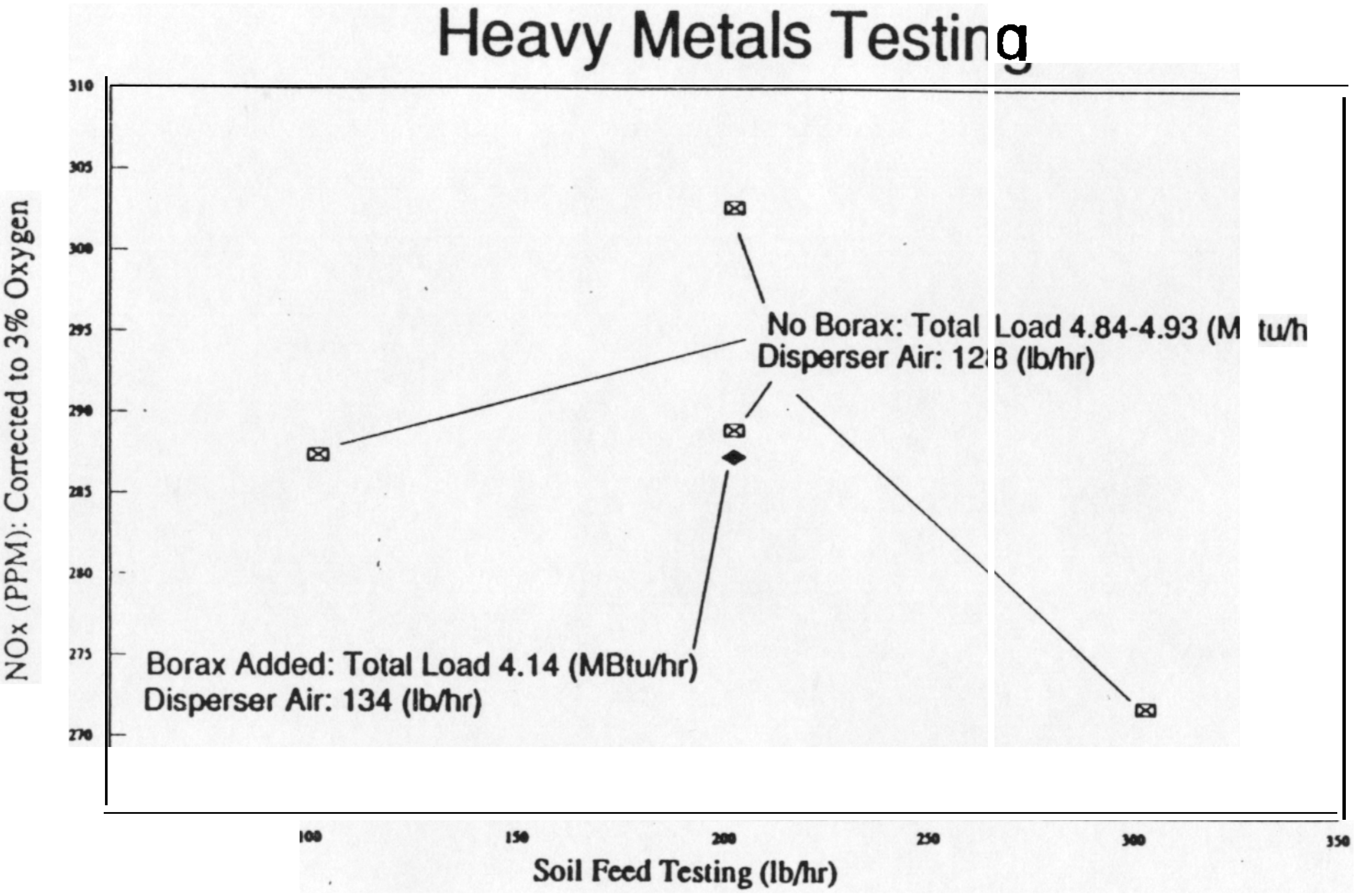
NOx Emissions



Clean Soil Testing

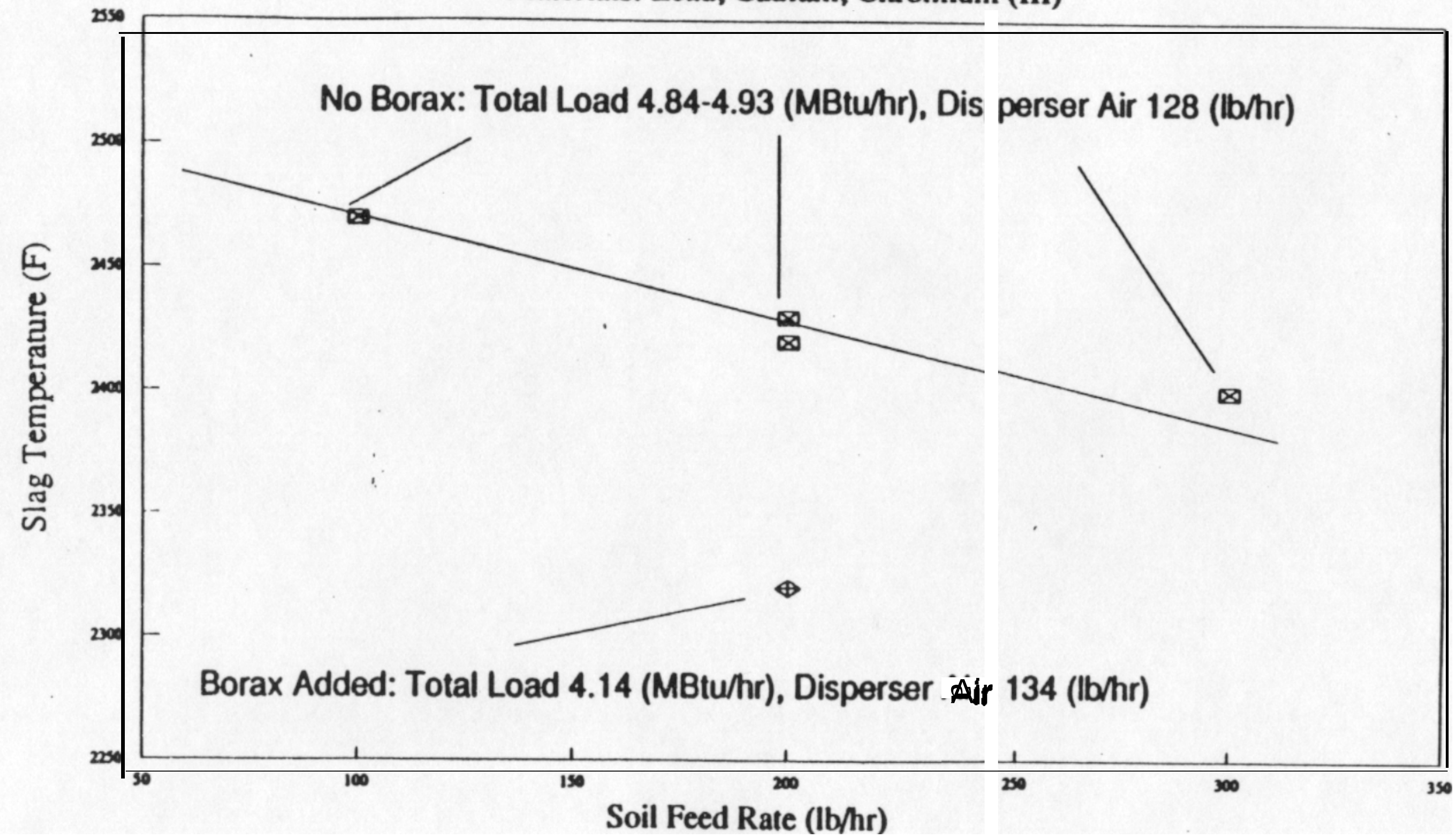
Slag Temperatures

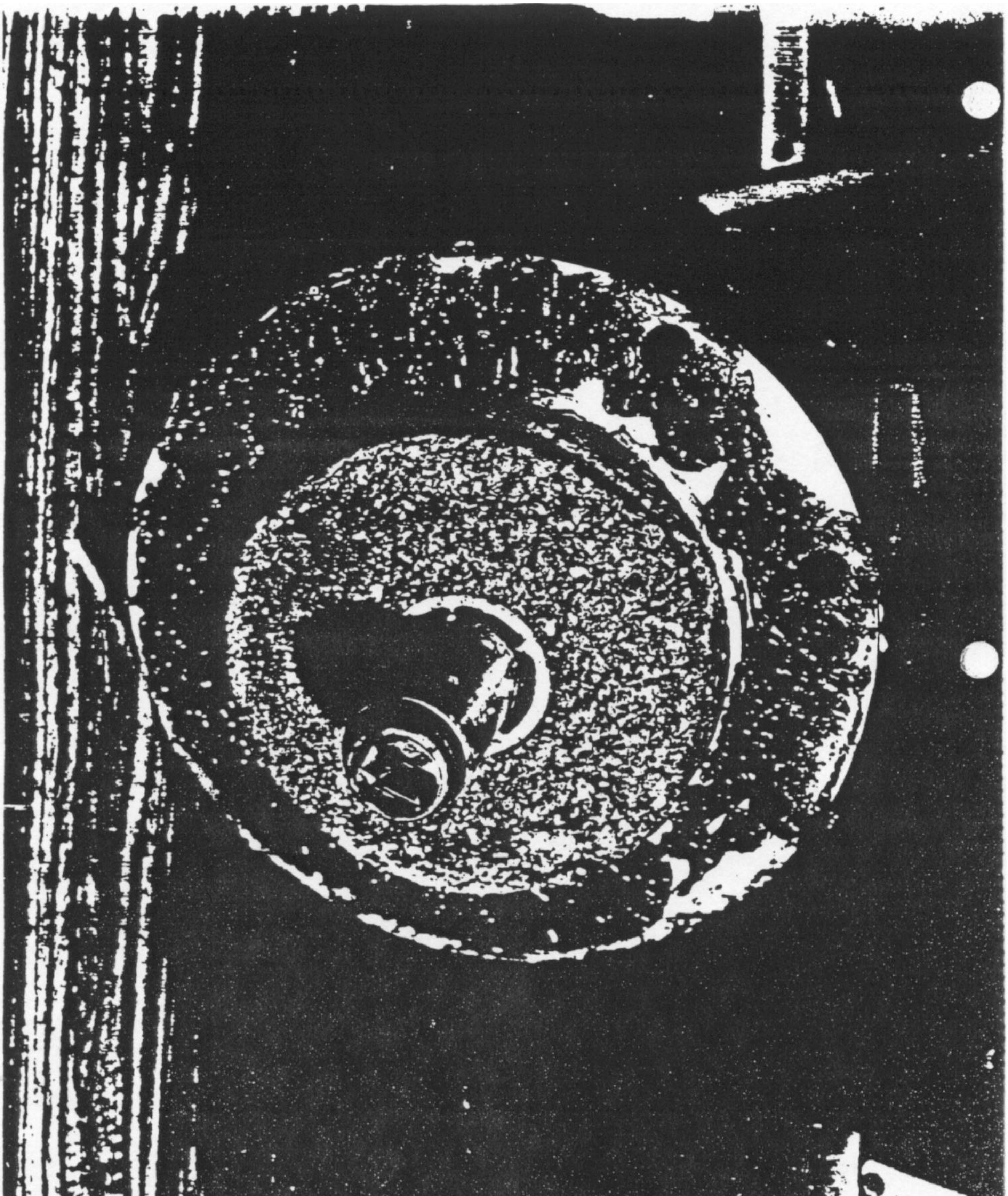


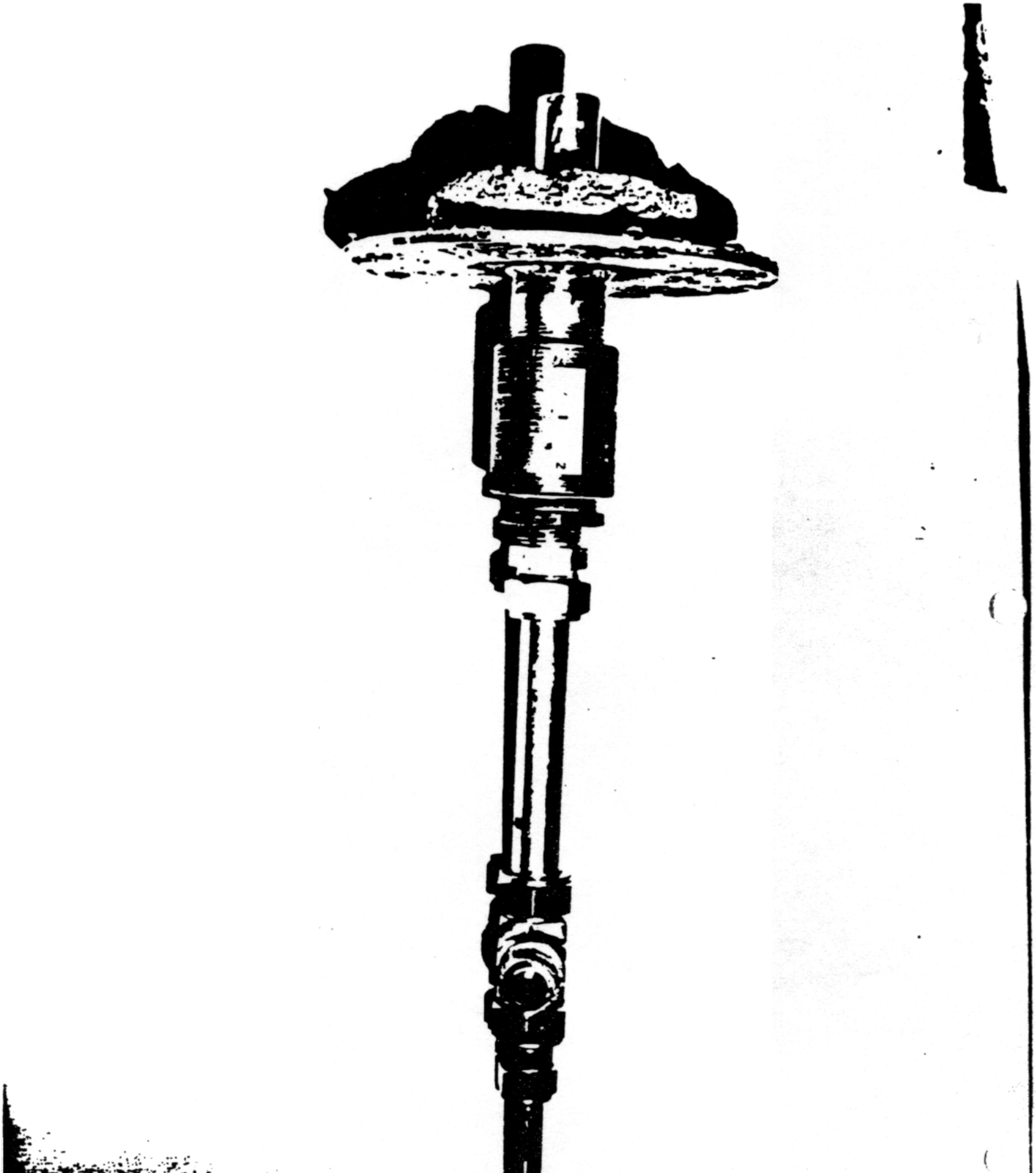

Heavy Metals Testing

Spiked Synthetic Soil Matrix

Materials: Lead, Cadium, Chromium (III)







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TEL. 802/658-1074

ANALYTICAL REPORT

Babcock & Wilcox Company
R&D Division, Att: A/P
1562 Beeson Street
Alliance, OH 44601

Attention : Jean Czuczwa

Date : 12/07/90
ETR Number: 24003
Project No.: 90000
No. Samples: 24
Arrived : 11/16/90
P.O. Number: 537-OA247838

Page 1

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result'
124376	Soil-Spike 2, 1400-1412:(TCLP Ext)	
6010	Cadmium, Total	55000 a
6010	Chromium, Total	3200 a
6010	Lead, Total	146000 a
125161	Soil-Spike 2, 1400-1412:[MS](TCLP Ext)	
6010	Cadmium, Total	54000 a
6010	Chromium, Total	4100 a
6010	Lead, Total	145000 a
124376DP	Soil-Spike 2, 1400-1412:[REP](TCLP Ext)	
6010	Cadmium, Total	54000 a
6010	Chromium, Total	1090 a
6010	Lead, Total	75000 a
124378	Soil-Spike 2, 1545-1555:(TCLP Ext)	
6010	Cadmium, Total	60000 a
6010	Chromium, Total	3300 a
6010	Lead, Total	112000 a
124380	Soil-Spike 2, 1735-1745:(TCLP Ext)	
6010	Cadmium, Total	58000 a
6010	Chromium, Total	2800 a
6010	Lead, Total	139000 a

Comments/Notes

= ug/l

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ENVIRONMENTAL SERVICES
75 Green Mountain Drive, So. Burlington, VT 05403
TEL. 802/658-1074

ANALYTICAL REPORT

Babcock & Wilcox Company
R&D Division, Att:A/P
1562 Beeson Street
Alliance, OH 44601

Attention : Jean Czuczwa

Date : 12/07/90
ETR Number: 24003
Project No.: 90000
No. Samples: 24
Arrived : 11/16/90
P.O. Number: 537-OA247838

Page 2

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
124383	Slag-Spike 2, 1419:(TCLP Ext)	
6010	Cadmium, Total	170 a
6010	Chromium, Total	74 a
7471	Lead, Total	155 a
125162	Slag-Spike 2, 1419:[MS](TCLP Ext)	
6010	Cadmium, Total	220 a
6010	Chromium, Total	166 a
7421	Lead, Total	210 a
124382DP	Slag-Spike 2, 1419:[REP](TCLP Ext)	
6010	Cadmium, Total	110 a
6010	Chromium, Total	49 a
7411	Lead, Total	121 a
124384	Slag-Spike 2, 1534-1543:(TCLP Ext)	
6010	Cadmium, Total	53 a
6010	Chromium, Total	<20 a
7421	Lead, Total	125 a
124386	Slag-Spike 2, 1730-1750:(TCLP Ext)	
6010	Cadmium, Total	166 a
6010	Chromium, Total	36 a
7421	Lead, Total	132 a

Comments/Notes

a = ug/l

< Last Page >

Submitted By : Neal E. Van Wyck

Aquatec Inc

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ENVIRONMENTAL SERVICES
75 Green Mountain Drive, So. Burlington, VT 05403
TEL. 802/658-1074

ANALYTICAL REPORT

Babcock & Wilcox Company
R&D Division, Att: A/P
1562 Beeson Street
Alliance, OH 44601

Attention : Jean Czuczwa

Date : 12/07/90
ETR Number : 24022
Project No.: 90000
No. Samples: 22
Arrived : 11/16/90
P.O. Number: 537-OA247838

Page 1

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
124517	Soil-Spike 3, 1245-1310:(TCLP Ext)	
6010	Cadmium, Total	54000 a
6010	Chromium, Total	880 a
6010	Lead, Total	73000 a
124517MS	Soil-Spike 3, 1245-1310:[MS] (TCLP Ext)	
6010	Cadmium, Total	54000 a
6010	Chromium, Total	1670 a
6010	Lead, Total	81000 a
124517DP	Soil-Spike 3, 1245-1310:[REP] TCLP Ext)	
6010	Cadmium, Total	55000 a
6010	Chromium, Total	910 a
6010	Lead, Total	82000 a
124519	Soil-Spike 3, 1420-1433:(TCLP Fxt)	
6010	Cadmium, Total	46000 a
6010	Chromium, Total	890 a
6010	Lead, Total	55000 a
124521	Soil-Spike 3, 1642-1648:(TCLP Ext)	
6010	Cadmium, Total	52000 a
6010	Chromium, Total	4400 a
6010	Lead, Total	132000 a

Comments/Notes

[a] = ug/l

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ENVIRONMENTAL SERVICES
75 Green Mountain Drive, So. Burlington, VT 05403
TEL. 802/658-1074

ANALYTICAL REPORT

Babcock & Wilcox Company
R&D Division, Att: A/P
1562 eeson Street
Alliance, OH 44601

Attention : Jean Czuctva

Date : 12/07/90
ETR Number : 24022
Project No.: 90000
No. Samples: 22
Arrived : 11/16/90
P.O. Number: 537-0A247838

Page 2

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
124523	Slag-Spike 3, 1230-1237:(TCLP Ext)	
6010	Cadmium, Total	137 a
6010	Chromium, Total	220 a
7421	Lead, Total	250 a
124523MS	Slag-Spike 3, 1230-1237:[HS] (TCLP Ext)	
6010	Cadmium. Total	210 a
6010	Chromium, Total	320 a
7421	Lead, Total	330 a
124523DP	Slag-Spike 3, 1230-1237:[REP] (TCLP Ext)	
6010	Cadmium, Total	145 a
6010	chromium, Total	81 a
7421	Lead, Total	230 a
124525	Slag-Spike 3, 1418-1435:(TCLP Ext)	
6010	Cadmium, Total	60 a
6010	Chromium, Total	28 a
7421	Lead, Total	210 a
124527	Slag-spike 3, 1640-1649:(TCLP Ext)	
6010	Cadmium, Total	107 a
6010	Chromium, Total	112 a
7421	Lead, Total	250 a

Comments/Notes

a = ug/l

< Last Page > submitted By : Ned E. VanWyk Aquatec Inc.

aquatec
ENVIRONMENTAL SERVICES
75 Green Mountain Drive, So. Burlington, VT 05403
TEL. 802/658-1074

ANALYTICAL REPORT

Babcock and Wilcox

Date: 7 December 1990
Project No: 90000
ETR No: 24003 and 24022
Sample(s) Received On: 16 November 1990
Page 1 of 1

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the [redacted] of Water and Wastewater. All results are in mg/l unless otherwise noted.

Parameter	112690A							
Cadmium	<10							
Chromium	<20							
Lead	< 5							

Lab No.	Sample Description
112690A:	Method Blank for TCLP Extract samples 124376, 124376DP, 125161, 124378, 124380, 124382, 124382DP, 125162, 124384, 124386, 124517, 124517DP, 124517MS, 124519, 124521, 124523, 124523DP and 124523MS. Results are reported in ug/L.

Submitted By: Neil E. VanWyck

Aquatec Inc

Spike Sample Recovery
Inorganic Data

ETR No. 24003

Sample ID: Soil-Spike 2, 1400-1412 (TM Ext)

Parameter	Spiked Sample Result (ug/L)	Sample Results (ug/L)	Spike Added (ug/L)	% Recovery
Cd	53763.00	55112.00	NA	NA
Cr	4147.90	3161.84	1000.0	98.6
Pb	145453.06	146062.18	NA	NA

Sample ID: Slag-Spike 2, 1419 (TCLP Ext)

Parameter	Spiked Sample Result (ug/L)	Sample Results (ug/L)	Spike Added (ug/L)	% Recovery
Cd	219.91	169.64	50.0	100.5
Cr	166.19	73.88	100.0	92.3
Pb	209.41	155.24	50.0	108.3

Spike Sample Recovery
Inorganic Data

ETR No. 24022

Sample ID: Soil-Spike 3. 1245-1310 (TCLP Ext)

Parameter	Spiked Sample Result (ug/L)	Sample Results (ug/L)	spike Added (ug/L)	% Recovery
Cd	53518.00	53857.00	NA	NA
Cr	1665.66	875.01	1000.0	79.1
Pb	80592.76	72956.19	NA	NA

Sample ID: Slag-Spike 3, 1230-1237 (TCLP Ext)

Parameter	Spiked Sample Result (ug/L)	Sample Results (ug/L)	Spike Added (ug/L)	% Recovery
Cd	205.76	136.90	50.0	137.7
Cr	323.88	216.69	100.0	107.2
Pb	325.10	249.26	50.0	151.7

Duplicate Sample Recovery
Inorganic Data

ETR No. 24003

Sample ID: Soil-Spike 2, 1400-1412 (TCLP Ext)

Parameter	Sample Result (ug/L)	Duplicate Results (ug/L)	% RPD
Cd	55112.00	53971.00	2.1
Cr	3161.84	1086.63	97.7
Pb	146062.18	74810.21	64.5

Sample ID: Slag-Spike 2, 1419 (TCLP Ext)

Parameter	Sample Result (ug/L)	Duplicate Results (ug/L)	% RPD
Cd	169.64	110.03	42.6
Cr	73.88	48.94	40.6
Pb	155.24	121.21	24.6

Duplicate Sample Recovery
Inorganic Data

ETR No. 26022

Sample ID: Soil-Spike 3, 1245-1310 (TCLP Ext)

Parameter	Sample Result (ug/L)	Duplicate Results (ug/L)	% RPD
Cd	53857.00	54863.39	1.9
Cr	875.01	909.18	3.8
Pb	72956.19	81766.37	11.4

Sample ID: Slag-Spike 3, 1230-1237 (TCLP Ext)

Parameter	Sample Result (ug/L)	Duplicate Results (ug/L)	% RPD
Cd	136.90	145.38	6.0
Cr	216.69	81.13	91.0
Pb	249.26	229.02	8.5

QC summary
ETR No. 24003 and 24022

Page 1 of 2

Parameter	EPA Standard	Found (ug/l)	True (ug/l)	% Recovery
Cadmium	IVQCS	483.63	500.0	96.7
		485.34	500.0	97.1
		491.92	500.0	98.4
	IVQCS	474.83	500.0	95.0
		495.72	500.0	99.1
		495.60	500.0	99.1
		497.21	500.0	99.4
	IVQCS	493.07	500.0	98.6
		499.36	500.0	99.9
		503.59	500.0	100.7
		513.71	500.0	102.7
	IVQCS	484.18	500.0	96.8
		491.18	500.0	98.2
	IVQCS	477.14	500.0	95.4
		482.30	500.0	96.5
		495.00	500.0	99.2
		488.83	500.0	97.8
Chromium	IVQCS	488.96	500.0	97.8
		480.54	500.0	96.1
		478.31	500.0	93.7
	IVQCS	500.78	500.0	100.2
		511.80	500.0	102.4
		525.72	500.0	105.1
		515.87	500.0	103.2
	IVQCS	480.46	500.0	96.1
		508.08	500.0	101.6
		494.23	500.0	98.8
		497.37	500.0	99.5
	IVQCS	509.24	500.0	101.6
		514.91	500.0	103.0
		499.33	500.0	99.9
	IVQCS	478.58	500.0	95.7
		475.31	500.0	95.1
		489.01	500.0	97.8
		477.24	500.0	95.4

QC Summary
ETR No. 24003 and 24022

Page 2 of 2

Parameter	EPA Standard	Found (ug/l)	True (ug/l)	% Recovery
Lead	IVQCS	976.61	1000.0	97.7
		929.70	1000.0	93.0
		1020.58	1000.0	102.1
		1019.33	1000.0	101.9
	IVQCS	904.55	1000.0	90.5
		981.35	1000.0	98.1
		1005.24	1000.0	100.5
	IVQCS	975.77	1000.0	97.6
		983.23	1000.0	98.3
		907.34	1000.0	90.7
		1005.46	1000.0	100.5
	378-5	35.00	34.0	102.9
		35.83	34.0	105.4
		36.65	34.0	107.8
	378-5	34.49	34.0	101.4
		35.00	34.0	102.9
		35.51	34.0	104.4
	378-5	34.08	34.0	100.2
		34.08	34.0	100.2
		32.34	34.0	95.1
		32.58	34.0	95.8

Method Detection Limit Study

ETR 24003 and 24022

Method	**Parameter**	**Date**	S_b	m	**MDL (ug/L)**
6010	Cadmium	12-05-90	2.55	0.839	9.1
6010	Chromium	12-05-90	2.89	0.816	10.6
7421	Lead	11-29-90	0.40	0.912	1.3
6010	Lead	12-05-90	22.13	0.854	77.8

$$MDL = 3 \times S_b/m$$

MDL = **Method detection** limit.

S_b = Standard deviation of the average noise level.

m = **Slope** of the calibration line.

90000E07DEC90

aquatec
A Member of the Inchcape Environmental Group
55 South Park Drive, Colchester, Vermont 05446
TEL. 802/655-1203 FAX 802/655-1248

ANALYTICAL REPORT

Date : 11/05/91
ETR Number: 26202
Project No.: 91000
No. Samples: 29
Arrived : 09/13/91
P.O. Number: *

Babcock & Wilcox Company
R&D Division, Aft: A/P
1562 Beeson Street
Alliance, OH 44601

Attention : Jean Czuczwa

Page 1

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
143696	Feed Hopper 200lb/hr:(TCLPExt)	
6010	Cadmium, Total	33
6010	Chromium, Total	0.46
6010	Lead, Total	78
143696MS	Feed Hopper 200lb/hr:[MS](TCLPExt)	
6010	Cadmium, Total	31
6010	Chromium, Total	0.67
6010	had, Total	66
143696DP	Feed Hopper 200lb/hr:[REP](TCLPExt)	
	Cadmium, Total	34
6010	Chromium, Total	0.46
6010	Lead, Total	70
143698	Feed Hopper 200lb/hr:(TCLPExt)	
6010	Cadmium, Total	34
6010	Chromium, Total	0.50
6010	Lead, Total	88
143700	Feed Hopper 200lb/hr:(TCLPExt)	
6010	Cadmium, Total	32
6010	Chromium, Total	0.46
6010	Lead, Total	65
143702	Slag Tank 200lb/hr:(TCLPExt)	
6010	Cadmium, Total	0.11
6010	Chromium, Total	0.02
7421	Lead, Total	0.19

< Cont. Next Page >

Babcock & Wilcox Company
R&D Division, Att: A/P
1562 Beeson Street
Alliance, OH 44601

Attention : Jean **Czuczwa**

Date : 11/05/91
ETR Number: 26202
Project No.: 91000
No. **Samples:** 29
Arrived : 09/13/91
P.O. **Number:** •

Page 2

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
143704	Slag Tank 200lb/hr:(TCLPExt)	
6010	Cadmium, Total	0.04
6010	Chromium, Total	0.02
7421	Lead, Total	0.14
143706	Slag Tank 200lb/hr:(TCLPExt)	
6010	Cadmium, Total	0.07
6010	Chromium, Total	0.02
7421	Lead, Total	0.20
143708	Feed Hopper 100lb/hr:(TCLPExt)	
6010	Cadmium, Total	36
6010	Chromium, Total	0.42
6010	Lead, Total	72
143710	Slag Tank 100lb/hr:(TCLPExt)	
6010	Cadmium, Total	0.03
6010	Chromium, Total	<0.01
7421	Lead, Total	0.06
143712	Feed Hopper 300lb/hr:(TCLPExt)	
6010	Cadmium, Total	40
6010	Chromium, Total	0.42
6010	Lead, Total	78
143714	Slag Tank 300lb/hr:(TCLPExt)	
6010	Cadmium, Total	0.07
6010	Chromium, Total	<0.01
7421	Lead, Total	0.19

< Cont. Naxt Page >

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TEL. 802/655-1203 FAX 802/655-1248

ANALYTICAL REPORT

Babcock & Wilcox Company
R&D Division, Att: A/P
1562 Beeson Street
Alliance, OH 44601

Attention : Jean Czuczwa

Date : 11/05/91
ETR Number : 26202
Project No.: 91000
No. **Samples**: 29
Arrived : 09/13/91
P.O. **Number**: •

Page 3

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
143716	Food Hopper Borax:(TCLPExt)	
6010	Cadmium, Total	30
6010	Chromium, Total	0.13
6010	Lead, Total	54
143718	Slag Tank Borax:(TCLPExt)	
6010	Cadmium, Total	0.27
6010	Chromium, Total	0.02
7421	Lead, Total	0.43
143720	Slag Tank Borax:(TCLPExt)	
6010	Cadmium, Total	0.27
6010	Chromium, Total	0.01
7421	Lead, Total	0.35

< ,Last Page >   Submitted By :   Aquatec Inc.

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A Member of the Inchcape Environmental Group
55 South Park Drive, Colchester, Vermont 05446
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ANALYTICAL REPORT

Babcock & Wilcox Co.

Date: 02 October 1991
Project No: 91000
ETR No: 28202
Sample(s) Received on 13 September 1991
Page 1 of 1

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Parameter	Blank
Cadmium	<0.01
Chromium	<0.01
Lead	<0.005

Lab No.	**Sample Description**
Blank.	TCLP extraction blank for samples labalad 143696, 143696DP, 143696MS, 143698, 143700, 143702, 143704, 143706, 143708, 143710, 143712. 143714, 143716, 143718 , and 143720.

Submitted By: R. Mason McNeer Aquatec Inc.

aquatec

A Member of the Inchcape Environmental Group
55 South Park Drive, Colchester, Vermont 05446
TEL. 802/655-1203 FAX 802/655-1248

ANALYTICAL REPORT

Babcock and Wilcox Company

Date: 05 November 1991
Project No: 91000
ETR No: 28477
Sample(s) Received On: 13 September 1991
Page 1 of 1

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Parameter	PBLK							
Cadmium	<0.01							
Chromium	<0.01							
Lead	<0.005							

Lab No.	Sample Description
PBLK	Prep blank for samples 143702MS, 143702DP, 143716MS, 143716DP, 143718MS and 143718DP.

Submitted By: Aquatec Inc.

aquatec
A Member of the Inchcape Environmental Group
55 South Park Drive, Colchester, Vermont 05446
TEL. 802/655-1203 FAX 802/655-1248

ANALYTICAL REPORT

Babcock & Wilcox Company
R&D Division, Att: A/p
1562 Beeson Street
Alliance, OH 44601

Attention : Jean Czuczwa

Date : 11/05/91
ETR Number: 28477
Project No.: 91000
No. Samples: 6
Arrived : 09/13/91
P.O. Number: *

Page 1

Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
143702MS	Slag Tank 200lb/hr:[MS](TCLPExt)	
6010	Cadmium, Total	0.13
6010	Chromium, Total	0.23
7421	Lead, Total	0.44
143702DP	Slag Tank 200lb/hr:[REP](TCLPExt)	
6010	Cadmium, Total	0.08
6010	Chromium, Total	0.03
7421	Lead, Total	0.24
143716MS	Feed Hopper Borax:[MS](TCLPExt)	
6010	Cadmium, Total	30
6010	Chromium, Total	0.33
6010	Lead, Total	47
143716DP	Feed Hopper Borax:[REP](TCLPExt)	
6010	Cadmium, Total	31
6010	Chromium, Total	0.14
6010	Lead, Total	51
143718MS	Slag Tank Borax:[MS](TCLPExt)	
6010	Cadmium, Total	0.36
6010	Chromium, Total	0.25
7421	Lead, Total	0.55
143718DP	Slag Tank Borax:[REP](TCLPExt)	
6010	Cadmium, Total	0.25
6010	Chromium, Total	0.02
7421	Lead, Total	0.41

< Last Page > Submitted By : Aquatec Ins.

QC Summary
ETR 28477

Parameter	EPA Standard	Found (ug/L)	True (ug/L)	% Recovery
Cadmium	IVQCS	490.68	500.0	98.1
		491.74	500.0	96.3
		490.89	500.0	98.7
		487.69	500.0	97.5
	IVQCS	494.15	500.0	90.0
		500.04	500.0	100.0
		505.49	500.0	101.1
		504.66	500.0	100.9
Chromium	IVQCS	483.05	500.0	96.6
		493.38	500.0	96.5
		482.88	500.0	96.6
		489.70	500.0	97.9
	IVQCS	475.05	500.0	95.0
		408.73	500.0	97.7
		478.30	500.0	9s.7
Lead	IVQCS	15.74	15.0	104.9
		15.56	15.0	103.7
		16.18	15.0	107.9
	IVQCS	967.96	1000.0	96.8
		1030.30	1000.0	103.0
		1009.99	1000.0	100.6
		984.88	1000.0	98.5

QC Summary
ETR 26202

Parameter	EPA Standard	Found (UG/L)	True (UG/L)	% Recovery
Cadmium	IVQCS	495.65	500.0	99.1
		478.73	500.0	95.7
		476.02	500.0	95.2
		478.48	500.0	95.7
	IVQCS	498.48	500.0	99.7
		494.79	500.0	99.0
		484.18	500.0	96.8
	IVQCS	525.62	500.0	105.2
		501.06	500.0	100.2
		539.70	500.0	107.9
	IVQCS	504.61	500.0	100.9
		499.31	500.0	99.9
	IVQCS	494.42	500.0	98.9
		497.78	500.0	99.6
Chromium	IVQCS	489.02	500.0	97.8
		476.42	500.0	95.3
		486.05	500.0	97.2
		470.07	500.0	94.0
	IVQCS	485.61	500.0	97.1
		512.47	500.0	102.5
		478.26	500.0	95.7
		504.55	500.0	100.9
Lead	IVQCS	15.53	15.0	103.5
		14.08.	15.0	93.9
		13.54	15.0	90.3
	IVQCS	14.60	15.0	97.3
		14.84	15.0	98.9
	IVQCS	1032.56	1000.0	103.3
		936.27	1000.0	93.6
		911.79	1000.0	91.2
	IVQCS	1010.32	1000.0	101.0
		991.36	1000.0	99.1

QC **Summary**
ETR No. 28477/28202
Results in ug/L

Sample#	Parameter	Sample Result	Duplicate Result	RPD	Matrix Spike Result	Spike Added	% Recovery
143702	Cadmium	109.4740	81.8600	28.9	128.9970	49.19	39.7
143702	Chromium	15.0750	28.7660	62.5	234.2180	196.77	111.4
143702	Lead	189.3980	237.1300	22.4	435.4300	492.42	50.0
143716	Cadmium	29929.4000	31408.4390	4.8	30366.8320	49.73	NC
143716	Chromium	132.3950	136.4310	3.0	331.8620	198.93	100.3
143716	Lead	54027.0160	51023.5780	5.7	47450.1640	497.31	NC
143718	Cadmium	267.9530	253.1760	5.7	358.9100	49.47	NC
143718	Chromium	18.6640	24.1630	25.7	253.6400	197.86	118.8
143718	Lead	428.5714	413.7400	3.5	551.3000	494.27	24.8
143696	Cadmium	32656.9372	33795.2173	3.4	31437.8611	49.98	NC
143696	Chromium	459.5020	464.3000	1.0	665.8240	199.90	103.2
143696	Lead	77898.9380	70342.8830	10.2	65792.0230	499.75	NC

NC = Sample result is greater than 4 times the spike added therefore % recovery is non-calculable.

ANALYSIS BY ICP-AES
DRY BASIS

Sample No. and Description..	Cadmium, ppm Cd	Chromium, ppm Cr	Lead, ppm Pb
M-48652 Soil, 100 lb/hr Test, Composite of 1025, 1115, 1245 hrs, 9/10/91	1,232 1,223	1,541 1,513	7,247 7,150
M-48653 Soil, 200 lb/hr Test, Composite of 1225, 1615, 1700, 1750 hrs, 9/9/91	1,281 1,248 1,255	1,544 1,540 1,566	7,635 7,655 7,836
M-48654 Soil, 300 lb/hr Test, Composite of 1435, 1700, 1745 hrs, 9/10/91	1,292 1,366	1,567 1,622	7,509 7,894
M-48655 Soil with Borax, 200 lb/hr Test, Composite of 1030, 1250, 1350 hrs, 9/11/91	1,268 1,251	1,577 1,553	8,208* 7,838
Acid Reagent Blank (Aqua Regia -HF- Boric Acid)	<0.5	<0.5	<0.5

Note: Replicate values were determined from separate acid digestions.

* This value is probably too high - Pb calibration was difficult to maintain. ICP was recalibrated 3 times during this run because 5ppm Pb standards were too low or too high. See calibration data shown for 9/23/91. The lead level measured in the Cr Spiked Sample was also lower than 8208ppm. See Spiked Sample Recovery data sheet in this report.

ANALYSIS BY ICP-AES
DRY BASIS

Sample No. and Description	Cadmium, ppm Cd	Chromium, ppm Cr	Lead, ppm Pb
M-48656 Slag, 100 lb/hr Test, Composite of 1045, 1240, 1325 hrs, 9/10/91	116 111	1,489 1,421	2,097 2,053
M-48657 Slag, 200 lb/hr Test, Composite of 1245, 1615, 1730, 1820 hrs, 9/9/91	187 186 197	1,500 1,484 1,481	3,550 3,570 3,656
M-48658 Slag. 300 Ib/hr Test, Composite of 1445, 1700, 1800 hrs, 9/10/91	178 180	1,440 1,403	3,551 3,554
M-48659 Slag with Borax, 200 lb/hr Test, Composite of 1215, 1300, 1408 hrs, 9/11/91	279 289	1,219 1,197	3,813 3,856
Acid Reagent Blank (Aqua Regia -HF- Boric Acid)	<0.2	<0.2	<0.2

Note: Replicate values were determined from separate acid digestions.

ANALYSIS BY ICP-AES
DRY BASIS

Sample No. and Description	Cadmium, ppm Cd	Chromium, ppm Cr	Lead, ppm Pb
M-48694 Filter & Combined Particulates, 200 lb/hr Test, 1610-1646 hrs, 9/9/91, 0.92 g Total particulates	17,720	7,874	98,736
M-48695 Filter & Combined Particulates, 200 lb/hr Test, 1744-1820 hrs, 9/9/91, 0.69 g Total Particulates	25,625	9,580	131.669
0.1N HNO_3 Rinse for M-48695, 0.08g solids	6,159	4,259	28,694
M-48696 Filter & Combined Particulates with Borax, 200 lb/hr Test, 1238-1314 hrs, 9/11/91, 1.23g Total Particulates	13,103	5,258	70,939
0.1N HNO_3 Rinse for M-48696, 0.11g solids		Sample Lost	
Acid Reagent Blank (Aqua Regia-HF-Boric Acid)	<0.5	<0.5	< 0.5
M-48697 Filter Blank	< 37	43	< 37
0.1N HNO_3 Rinse Blank	<0.2	<0.2	<0.2
Acetone Blank	<0.1	<0.3	<0.1

MAJOR CONSTITUENTS BY ICP-AES*

DRY BASIS

Sample No.	**M-48653**	**M-48655**	**M-48657**	**M-48659**
Description:	Soil Composite, 200 lb/hr Test, 1225, 1615, 1700, 1750 hrs, 9/10/91	Soil Composite with Borax, 200 lb/hr Test, 1030, 1250, 1350 hrs, 9/11/91	Slag Composite, 200 lb/hr Test, 1245, 1615, 1730 1820 hrs, 9/9/91	Slag Composite, with Borax, 200 lb/hr Test, 1215, 1300, 1408 hrs, 9/11/91
SiO_2, %	47.35 46.80	47.27 44.93	60.87 59.26	59.54
Al_2O_3, %	9.07 8.83	9.15 8.96	13.25 12.88	10.29
Fe_2O_3, %	2.28 2.22	2.23 2.18	2.83 2.84	2.77
TiO_2, %	0.35 0.34	0.41 0.32	0.67 0.65	0.54
CaO, %	15.26 14.99	13.20 13.20	16.87 16.81	17.51
MgO, %	4.45 4.33	3.99 3.96	4.74 4.64	4.77
SO_3, %	0.67 0.72	0.69 0.61	0.30 0.36	0.27
P_2O_5, %	0.39 0.31	0.34 0.33	0.42 0.40	0.41
Na_2O, %	0.59	1.93 1.93	0.74	1.95 1.89
K_2O, %	1.12	1.13 1.13	1.30	1.20 1.18
B_2O_3, %	-------	2.69	-------	1.81

Note: Replicate values were determined from separate acid digestions.

· Elements are reported as oxides for convenience and arc not necessarily present in that form. Na_2O and K_2O were determined by flame photometry.

Sample No.	**M-48653**
Description:	Soil Composite, 200 lb/hr **Test,** 1225, 1615, 1700, 1750 hrs, 9/10/91
Carbonate, % CO_2	15.44

Sample No. & Description	Moisture, % H_2O (Before Compositing)
M-48652 Soil, 100 lb/hr Test, 9/10/91	
1025 Hrs	25.02
1115 Hrs	26.32
1245 Hrs	24.32
M-48653 Soil, 200 lb/hr Test, 9/9/91	
1225 Hrs	24.94
1615 Hrs	25.42
1700 Hrs	25.73
1750 Hrs	25.12
M-48654 Soil, 300 lb/hr Test, 9/10/91	
1435 Hrs	26.35
1700 Hrs	26.19
1745 Hrs	27.43
M-48655 Soil, with Borax, 200 lb/hr Test, 9/11/91	
1030 Hrs	28.89
1250 Hrs	28.44
1350 Hrs	29.30

SLAG BULK DENSITY*, POUNDS/FT^3
AS RECEIVED

M-48656 Slag Composite, 100 lb/hr Test, 1045, 1240, 1325hrs, 9/10/91	**90.52**
M-48657 Slag Composite, 200 lb/hr Test, 1245, 1615, 1730, 1820, 9/9/91	85.47
M-48658 Slag Composite, 300 lb/hr Test, 1445, 1700, 1800 hrs, 9/10/91	82.40
M-48659 Slag Composite with Borax, 200 lb/hr Test, 1215, 1300, 1408 hrs, 9/11/91	81.45

- Values reported are average of 2 determinations within 10% of each other.

SOIL BULK DENSITY*, POUNDS/FT^3
DRY BASIS

M-48652 Soil, 100 lb/hr Test, Partial Composite	76.57
M-48653 Soil, 200 lb/hr Test, Partial Composite	81.90
M-48654 Soil, 300 lb/hr Test, Partial Composite	81.53
M-48655 Soil with Borax, 200 lb/hr Test, Partial Composite	75.76

• Values reported are average of 2 determinations within 10% of each other. Samples were dried at 150°F, and crushed with a jaw crusher (approximately 1/4"). Portions from 2 different hour tests were used to fill the box for each sample.

SPIKED SAMPLES, % RECOVERY BY ICP

Sample No. & Description	Cadmium, Cd	Chromium, Cr	Lead, Pb
M-48652 Soil Composite, 100 lb/hr Test, 1025, 1115, 1245 hrs, 9/10/91	107.34 %R	(1.565)	(7.417)
M-48654 Soil Composite, 300 lb/hr Test, 1435, 1700, 1745 hrs, 9/9/91	(1.315)	(1,613)	96.86 %R
M-48655 Soil Composite with Borax, 200 lb/hr Test, 1030, 1250, 1350 hrs, 9/11/91	(1,233)	103.43 %R	(7,733)
M-48656 Slag Composite, 100 lb/hr Test, 1045,1240,1325 hrs, 9/10/91	92.03 %R	(1,465)	(2,085)
M-48658 Slag Composite, 300 lb/hr Test, 1445,1700,1800 hrs, 9/10/91	(167)	96.91 %R'	(3,425)
M-48659 Slag Composite with Borax, 200 lb/hr Test, 1215, 1300, 1408 hrs, 9/11/91	(293)	(1,242)	95.60 %R

Note: Values shown in parentheses are ppm of the 2 elements not spiked in each sample.

CALIBRATION VERIFICATION

9/23/91

Cadmium, 5ppm		**Chromium, 5ppm**		**Lead, 5ppm**	
Initial	**%R**	**Initial**	**%R**	**Initial**	**%R**
4.86	97.2	4.97	99.4	5.07	101.4
Continuing	**%R**	**Continuing**	**%R**	**Continuing**	**%R**
5.09	101.8	5.13	102.6	5.11	102.2
4.90	98.0	5.00	100.0	5.16	103.2
5.28	105.6	5.19	103.8	5.41	108.2
		(Recalibrated)			
4.93	98.6	4.90	98.0	5.03	100.6
4.98	99.6	4.81	96.2	4.73	94.6
4.85	97.0	4.84	96.8	4.56	91.2
		(Recalibrated)			
5.09	101.8	5.13	102.6	5.28	105.6
5.06	101.2	5.04	100.8	5.54	110.8

CHECK STANDARD

Cadmium, 0.5ppm		**Chromium, 0.5ppm**		**Lead, 0.5ppm**	
Measured	**%R**	**Measured**	**%R**	**Measured**	**%R**
0.57	114.0	0.56	112.0	0.42	84.0
0.52	104.0	0.51	102.0	0.48	96.0

CALIBRATION VERIFICATION
9/26/91

Cadmium, 5ppm		Chromium, 5ppm		Lead, 5ppm	
Initial	%R	Initial	%R	Initial	%R
4.98	99.6	4.95	99.0	4.95	99.0
Continuing	%R	Continuing	%R	Continuing	%R
4.83	96.6	4.85	97.0	5.25	105.0
4.87	97.4	4.97	99.4	5.21	104.2

CHECK STANDARDS
9/26/91

Cadmium, 50ppm		Chromium, 50ppm		Lead, 50ppm	
Measured	%R	Measured	%R	Measured	%R
49.96	99.9	49.44	98.9	50.69	101.4

Cadmium, 0.5ppm		Chromium, 0.5ppm**		Lead, 0.2ppm	
Measured	%R	Measured	%R	Measured	%R
0.53	106.0	0.63	126.0	0.53	106.0
0.46	92.0	0.32	64.0	0.52	104.0

Cadmium, 0.2ppm		Chromium, 0.2ppm		Lead, 0.2ppm	
Measured	%R	Measured	%R		
0.21	105.0	0.20	100.0	*	

Cadmium, 20ppm		Chromium, 20ppm		Lead, 20ppm	
Measured	%R	Measured	%R	Measured	%R
19.59	98.0	19.99	100.0	19.60	98.0
19.50	97.5	20.16	100.8	19.65	98.3

* **No peak** found.

** These values were not used in reporting results.

CALIBRATION VERIFICATION

10/3/91

Cadmium, 5ppm		Chromium, 5ppm		Lead, 5ppm	
Initial	**%R**	**Initial**	**%R**	**Initial**	**%R**
4.99	99.8	5.04	100.8	5.06	101.2

Continuing	%R	Continuing	%R	Continuing	%R
4.96	99.2	4.99	99.8	4.98	99.6
4.96	99.2	4.82	96.4	5.00	100.0
4.96	99.2	4.92	98.4	5.09	101.8

CHECK STANDARDS

10/3/91

Cadmium, 10ppm		Chromium, 10ppm		Lead, 10ppm	
Measured	%R	**Measured**	**%R**	Measured	%R
10.25	102.5	**10.00**	**100.0**	10.19	101.9
9.85	98.5	9.92	99.2	9.43	94.3
9.46	94.6	9.64	96.4	9.67	96.7

Cadmium, 1ppm		**Chromium, 1ppm**		Lead, 1ppm	
Measured	**%R**	**Measured**	**%R**	Measured	%R
0.98	98.0	0.94	94.0	0.95	95.0
1.02	102.0	0.95	95.0	0.96	96.0

CALIBRATION VERIFICATION
10/4/91

Cadmium, 5ppm

Initial	%R
4.96	99.2

Continuing	%R
4.77	95.4

Chromium, 5ppm

Initial	%R
5.09	101.8

Continuing	%R
5.02	100.4

Lead, 5ppm

Initial	%R
5.21	104.2

Continuing	%R
4.84	96.8

CHECK STANDARDS
10/4/91

Cadmium, 20ppm

Measured	%R
19.81	99.1

Chromium, 20ppm

Measured	%R
19.71	98.6

Lead, 20ppm

Measured	%R
19.23	96.2

Cadmium, 0.5ppm

Measured	%R
0.50	100.0

Chromium, 0.5ppm

Measured	%R
0.52	104.0

Lead, 0.5ppm*

Measured	%R
0.70	140.0

- Lead value was outside ± 10% range but samples contained much higher lead levels. Calibration was within ±10% at the higher levels.

CALIBRATION VERIFICATION

10/8/91		10/13/91	
Boron, 5ppm		**Chromium 5.ppm**	
Initial	**%R**	**Initial**	**%R**
5.09	101.8	5.04	100.8
Continuing	**%R**	**Continuing**	**%R**
5.13	102.6	5.15	103.0
5.07	**101.4**		
5.12	102.4		
5.17	103.4		

CHECK STANDARDS

10/8/91		10/13/91	
Boron, 1ppm		**Chromium 0.5ppm•**	
Measured	**%R**	**Measured**	**%R**
1.00	100.0	0.42	84.0
0.97	97.0		
0.98	98.0		
		Chromium 50ppm•	
		Measured	**%R**
		50.16	100.3
		50.39	100.8

- Approaching detection limit in this matrix. These values are for indication of acid reagent blank levels.

CALIBRATION VERIFICATION
10/21/91

Cadmium, 5ppm

Initial	%R
4.61	92.2

Continuing	%R
4.63	92.6

Chromium, 5ppm

Initial	%R
4.93	98.6

Continuing	%R
5.03	100.6

Lead, 5ppm

Initial	%R
4.79	95.8

Continuing	%R
4.71	94.2

CHECK STANDARDS

Cadmium, 0.5ppm

Measured	%R
0.46	92.0

Chromium, 0.5ppm

Measured	%R
0.50	100.0

Lead, 0.5ppm

Measured	%R
0.64	128.0

Cadmium, 0.2ppm

Measured	%R
0.20	100.0
0.18	90.0
0.16	80.0

Chromium, 0.2ppm

Measured	%R
0.22	110.0
0.20	100.0
0.20	100.0

Lead, 0.2ppm

Measured	%R
•	

• No peak found. The above low level values (0.2ppm) were used only to report < values for Cadmium and Chromium in the filter blank and acid reagent blanks.

CALIBRATION VERIFICATION

10/22/91

Cadmium, 5ppm		Chromium, 5ppm		Lead, 5ppm	
Initial	**%R**	**Initial**	**%R**	**Initial**	**%R**
4.86	97.2	5.20	104.0	4.77	95.4
		(Recalibrated)			
5.08	101.6	5.26	105.2	4.94	98.8
Continuing	**%R**	**Continuing**	**%R**	**Continuing**	**%R**
4.78	95.6	4.85	97.0	4.81	96.2
5.17	103.4	5.13	102.6	4.80	96.0

CHECK STANDARDS

10/22/91

Cadmium, 0.5ppm		Chromium, 0.5ppm		Lead, 0.5ppm*	
Measured	**%R**	**Measured**	**%R**	**Measured**	**%R**
0.48	96.0	0.54	108.0	0.49	98.0
		(Recalibrated)			
0.49	98.0	0.53	106.0	0.80	160.0
0.48	96.0	0.51	102.0	0.65	130.0
0.47	94.0	0.52	104.0	0.50	100.0

- At low lead levels (0.5ppm) the lead intensities measured are close to background levels in the matrix.

CALIBRATION PROCEDURE FOR ICP

This instrument is calibrated using acid/matrix reagent blank (same matrix used in standards preparation) as standard 1 and a matrix-matched standard (in this case 50ppm of each element) as standard 2. An analytical curve is drawn by the instrument using the data obtained from standards 1 and 2.

Instrument calibration is verified using a separate matrix-matched standard (or standards) in the working range of the samples. The calibntion standard(s) are checked throughout the analysis and recalibration (using standards 1 and 2) is performed when the calibration verification standard falls outside (or sometimes near) the 90 to 110% range.

An independent check standard can also be used for calibration verification if it is in the working range of the samples. An acid/matrix reagent blank which has been digested along with the samples is also run as an unknown.

Form VI
QC Report No. ACG-92-4191-07
DUPLICATES

Lab. Name ARC - Analytical Chemistry

Date: September 23. 1991 / October 3. 1991

Project No. 4191-07
Sample No. M-48652
Units: ppm

Compound	Control Limit	Sample(S)	Duplicate (D)	RDP
1. Cadmium		1,232	1,223	0.733
2. Chromium		1,541	1,513	1.834
3. Lead		7,247	7,150	1.347

N - Out of Control
RDP = [{S-D}]/[(S+D)/2)] x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form VI
QC Report No. ACG-92-4191-07
DUPLICATES

Lab. Name ARC - Analytical Chemistry
Project No. 4191-07
Sample No. M-48653
Date: September 23, 1991/October 3, 1991
Units: ppm

Compound	Control Limit	Sample(S)	Duplicate (D)	RDP *
1. Cadmium		1,281	1,248	2.609
2. Chromium		1,544	1,540	0.259
3. Lead		7,635	7,655	0.262

- First 2 replicate samples were used to calculate RDP values.

N - out of Control
RDP= [{S-D}]/[(S+D)/2)] x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form VI
QC Report No. ACG-92-4191-07
DUPLICATES

Lab. Name ARC - Analytical Chemistry

Date: October 3, 1991

Project No. 4191-07
Sample No. M-48655
Units: ppm

Compound	Control Limit	Sample(S)	Duplicate (D)	RDP
1. Cadmium		1,268	1,251	1.349
2. Chromium		1,577	1,553	1.534
3. Lead				

N - Out of Control
RDP= [{S-D}]/[(S+D)/2)] x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form VI
QC Report No. ACG-92-4191-07
DUPLICATES

Lab. Name ARC - Analytical Chemistry
Project No. 4191-07
Sample No. M-48657
Date: September 26, 1991 / October 3, 1991
Units: ppm

Compound	Control Limit	Sample(S)	Duplicate (D)	RDP*
1. Cadmium		187	186	0.535
2. Chromium		1,500	1,484	1.074
3. Lead		3,550	3,570	0.562

- First 2 replicates were used to calculate RDP values.

N - out of Control
RDP= $[\{S-D\}]/[(S+D)/2)]$ x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form VI
QC Report No. ACG-92-4191-07
DUPLICATES

Lab. Name **ARC - Anlytical** Chemistry	Project No. 4191-07
	Sample No. M-48654
Date: September 23, 1991 / October 3, 1991	Units: ppm

Compound	Control Limit	Sample(S)	Duplicate (D)	RDP
1. Cadmium		1,292	1,366	5.568
2. Chromium		1,567	1,622	3.448
3. Lead		7,509	7,894	4.999

N - Out of Control
RDP= **[{S-D}]/[(S+D)/2)]** x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form VI
QC Report No. ACG-92-4191-07
DUPLICATES

Lab **Name** **ARC - Analytical** Chemistrv

Project No. 4191-07
Sample No. M-48656

Date: September 26. 1991 / October 3. 1991

Units: ppm

Compound	Control Limit	Sample(S)	Duplicate (D)	RDP
1. Cadmium		116	111	4.386
2. Chromium		1,489	1,421	4.674
3. Lead		2,097	2,053	2.120

N - Out of Contro1
RDP = **[{S-D}]/[(S+D)/2)]** x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form V
QC Report No. ACG-92-4191-07
DUPLICATES

Lab. Name ARC - Analytical Chemistry

Project No. 4191-07
Sample No. M-48658

Date: September 26. 1991 / October 3. 1991

Units: ppm

Compound	Control Limit	Sample(s)	Duplicate (D)	RDP
1. Cadmium		178	180	1.117
2. Chromium		1,440	1,403	2.607
3. Lead		3,551	3,554	0.084

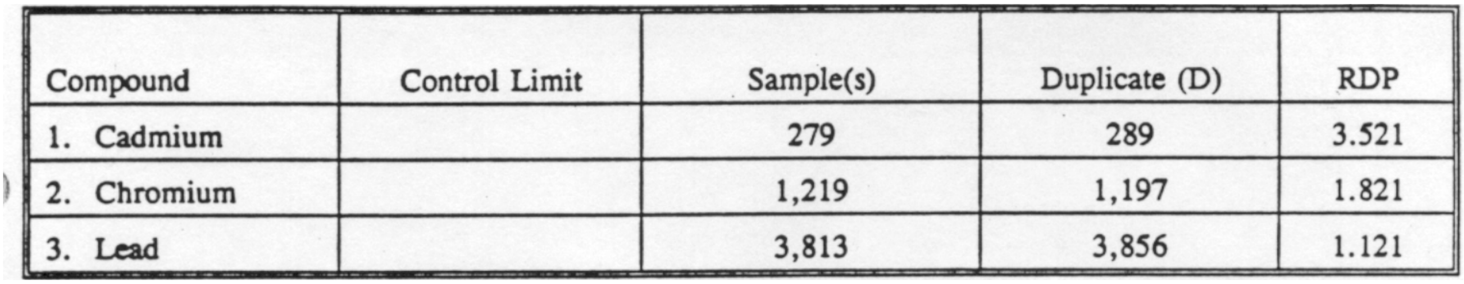
N - Out of Control
RDP= $[\{S-D\}]/[(S+D)/2)]$ x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form V
QC Report No. ACG-92-4191-07
DUPLICATES

Lab. Name **ARC - Analytical Chemistry**

Date: September 26, 1991 / October 3, 1991

Project No. 4191-07
Sample No. M-48659
U&S: ppm



Compound	Control Limit	Sample(s)	Duplicate (D)	RDP
1. Cadmium		279	289	3.521
2. Chromium		1,219	1,197	1.821
3. Lead		3,813	3,856	1.121

N - Out of Control
RDP- **[{S-D}]/[(S+D)/2)]** x 100
NC - Non calculable RDP due to value(s) less than CRDL

Form IV
QC Report No. ACG-92-4191-07
SPIKE SAMPLE RECOVERY

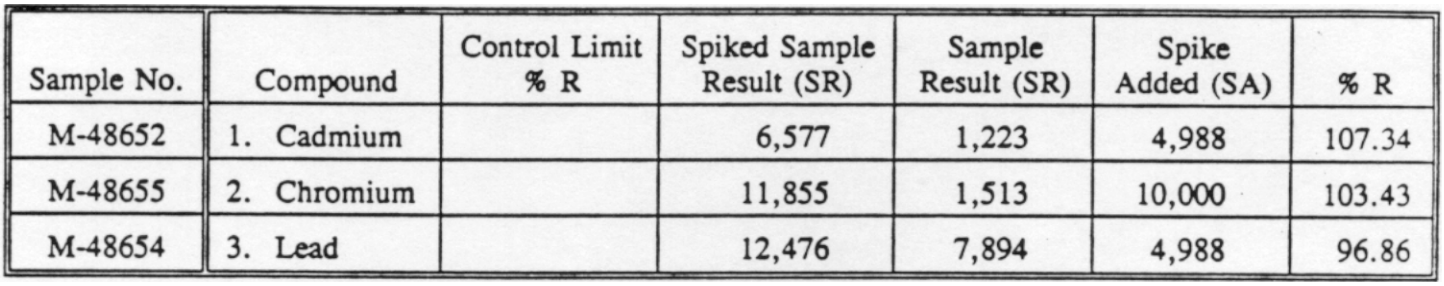
SOILS

Lab. Name ARC - Analytical Chemistry

Project No. 4191-07

Date: October 3. 1991

Units: ppm



Sample No.	Compound	Control Limit % R	Spiked Sample Result (SR)	Sample Result (SR)	Spike Added (SA)	% R
M-48652	1. Cadmium		6,577	1,223	4,988	107.34
M-48655	2. Chromium		11,855	1,513	10,000	103.43
M-48654	3. Lead		12,476	7,894	4,988	96.86

%R = [(SSR-SR/SA)] x 100
N - out of control
NR - Not Required

Form IV
QC Report No. ACG-92-4191-07
SPIKE SAMPLE RECOVERY

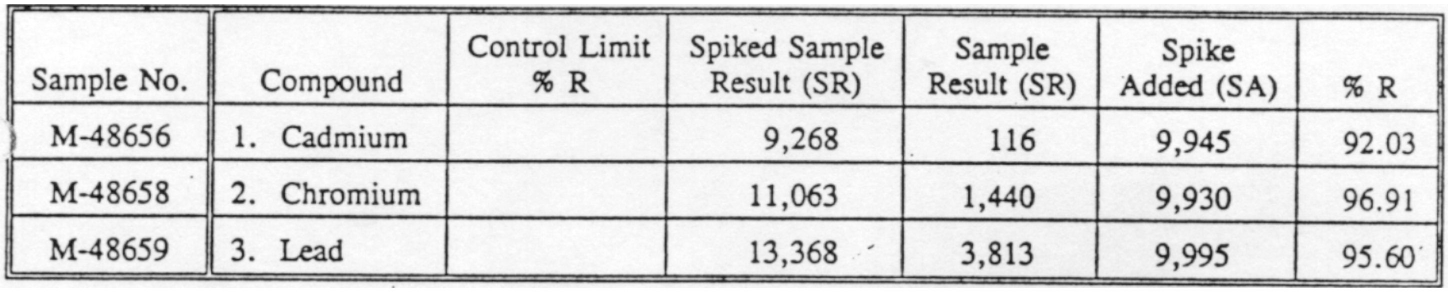
SLAGS

Lab. Name ARC - Analytical Chemistry

Project No. 4191-07

Date: September 26. 1991

Units: ppm



Sample No.	Compound	Control Limit % R	Spiked Sample Result (SR)	Sample Result (SR)	Spike Added (SA)	% R
M-48656	1. Cadmium		9,268	116	9,945	92.03
M-48658	2. Chromium		11,063	1,440	9,930	96.91
M-48659	3. Lead		13,368	3,813	9,995	95.60

%R = [(SSR-SR/SA)] x 100
N - out of control
NR- **Not** Required

Form III

QC Report No. ACG-92-4191-07

BLANKS

Lab. Name ARC-Analytical Chemistry

Project No. 4191-07

Date: September 23. 1991

Units: ppm

Aqua-Regia-HF-Boric Acid

	initial Calibration	Continuing Calibration	Preparation Blank
Compound	Blank Value	Blank Value	Blank Value
1. Cadmium	<0.5	< 0.5	
2. Chromium	<0.5	<0.5	
3. Lead	<0.5	<0.5	

Form III
QC Report No. ACG-92-4191-07
BLANKS

Lab. Name ARC - Analytical Chemistry

Project No. 4191-07

Date: September 26, 1991

Units: ppm

Aqua-Regia-HF-Boric Acid

	Initial Calibration	Continuing Calibration	Preparation Blank
Compound	Blank Value	Blank Value	Blank Value
1. Cadmium	<0.2	<0.2	
2. Chromium	<0.2	<0.2	
3. Lead	<0.2	< 0.2	

Form III
QC Report No. ACG-92-4191-07
BLANKS

Lab. Name ARC - Analytical Chemistry

Project No. 4191-07

Date: October 4, 1991

Units: ppm

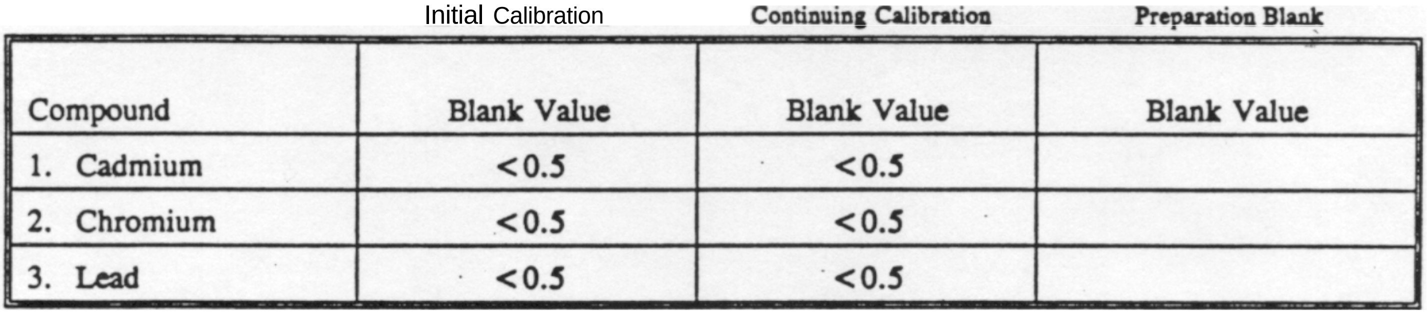
Aqua-Regia-HF-Boric Acid

	Initial Calibration	Continuing Calibration	Preparation Blank
Compound	Blank Value	Blank Value	Blank Value
1. Cadmium	<0.5	<0.5	
2. Chromium	<0.5	<0.5	
3. Lead	<0.5	<0.5	

Form III
QC Report No. ACG-92-4191-07
BLANKS

Lab. **Name** ARC - **Analytical Chemistry** Project No. 4191-07
Date: October 4.1991 units: ppm

Aqua-Regia-HF-Boric Acid



	Initial Calibration	Continuing Calibration	Preparation Blank
Compound	Blank Value	Blank Value	Blank Value
1. Cadmium	<0.5	<0.5	
2. Chromium	<0.5	<0.5	
3. Lead	<0.5	<0.5	

Form III
QC Report No. ACG-92-4191-07
BLANKS

Lab. Name ARC - Analytical Chemistry

Project No. 4191-07

Date: October 21, 1991

Units: ppm

0.1N HNO, Rinse Blank

	Initial Calibration	Continuing Calibration	Preparation Blank
Compound	Blank Value	Blank Value	Blank Value
1. Cadmium	<0.2	<0.2	
2. Chromium	<0.2	<0.2	
3. Lead	<0.2	<0.2	

Form III
QC Report No. ACG-92-4191-07
BLANKS

Lab. Name ARC - Analytical Chemistry

Project No. 4191-07

Date: October 21, 1991

units: ppm

Acetone Rinse Blank

	Initial Calibration	Continuing Calibration	Preparation Blank
Comoound	Blank Value	Blank Value	Blank Value
1. Cadmium	<0.1	<0.1	
2. Chromium	< 0.3	<0.3	
3. Lead	<0.1	<0.1	

aquatec

A Member of the Inchcape Environmental Group
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TEL. 802/655-1203 FAX 802/655-1248

ANALYTICAL REPORT

Babcock & Wilcox Company
R&D Division, Att: A/P
1562 Beeson Street
Alliance, OH 44601

Attention : Jean Czuczwa

Date : 11/05/91
ETR Number : 28477
Project No.: 91000
No. Samples: 6
Arrived : 09/13/91
P.O. Number: ●

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Standard analyses were performed in accordance with Methods for Analysis of Water and Wastes, EPA-600/4/79-020, Test Methods for Evaluating Solid Waste, SW-846, or Standard Methods for the Examination of Water and Wastewater. All results are in mg/l unless otherwise noted.

Lab No./ Method No.	Sample Description/ Parameter	Result
143702MS	Slag Tank 200lb/hr:[MS](TCLPExt)	
6010	Cadmium, Total	0.13
6010	Chromium, Total	0.23
7421	Lead, Total	0.44
143702DP	Slag Tank 200lb/hr:[REP](TCLPExt)	
6010	Cadmium, Total	0.08
6010	Chromium, Total	0.03
7421	Lead, Total	0.24
143716MS	Feed Hopper Borax:[MS](TCLPExt)	
6010	Cadmium, Total	30
6010	Chromium, Total	0.33
6010	Lead, Total	47
143716DP	Feed Hopper Borax:[REP](TCLPExt)	
6010	Cadmium, Total	31
6010	Chromium, Total	0.14
6010	Lead, Total	51
143718MS	Slag Tank Borax:[MS](TCLPExt)	
6010	Cadmium, Total	0.36
6010	Chromium, Total	0.25
7421	Lead, Total	0.55
143718DP	Slag Tank Borax:[REP](TCLPExt)	
6010	Cadmium, Total	0.25
6010	Chromium, Total	0.02
7421	Lead, Total	0.41

< Last Page > Submitted By : Aquatec Inc.