EPA/600/9-91/010
April 1991

OPERATIONS AND RESEARCH AT THE U.S. EPA INCINERATION RESEARCH FACILITY: ANNUAL REPORT FOR FY90

By
L. R. Waterland and J. W. Lee
Acurex Corporation
Environmental Systems Division
Incineration Research Facility
Jefferson, Arkansas 72079

EPA Contract 68-C9-0038

EPA Project Officer: R. C. Thurnau
Waste Minimization, Destruction, and Disposal Research Division
Risk Reduction Engineering Laboratory
Cincinnati, Ohio 45268

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

NOTICE

This material has been funded wholly or in part by the United States Environmental Protection Agency under Contract #68-C9-0038 to Acurex Corporation. It has been subject to the Agency's review and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

The U.S. Environmental Protection Agency's Incineration Research Facility in Jefferson, Arkansas, is an experimental facility that houses two pilot-scale incinerators and the associated waste handling, emission control, process control, and safety equipment; as well as onsite laboratory facilities.

During fiscal year 1990, two major test programs were completed at the facility: an evaluation of the thermal-stability-based principal organic hazardous constituent incinerability ranking for the Office of Solid Waste (OSW), and an incinerability evaluation of five contaminated materials from the Purity Oil Sales and the McColl Superfund sites for Region 9 and the Office of Emergency and Remedial Response (OERR). In addition, results of two test programs completed in FY89 were reported: an evaluation of the fate of trace metals fed to a rotary kiln incinerator equipped with a single-stage ionizing wet scrubber for air pollution control for OSW, and an incinerability evaluation of arsenic and pesticide contaminated soils from the Baird and McGuire Superfund site for Region 1 and OERR. Several facility and equipment construction and upgrade efforts were also completed.

TABLE OF CONTENTS

Section			Page
	ABSTRACT		iii
	FIGURES		vii
	TABLES		viii
1	**INTRODUCTION**		1
2	**ROTARY KILN INCINERATION SYSTEM RECONFIGURATION AND UPGRADE**		4
	2.1	ROTARY KILN SYSTEM UPGRADES	4
	2.1.1	Combustion System Repairs	4
	2.1.2	Venturi/Packed Column Scrubber Reconfiguration	6
	2.1.3	RKS Automation with the Foxboro Process Control System	7
	2.1.4	Ram Feeder	7
	2.2	BUILDING AND GROUNDS IMPROVEMENTS	8
	2.2.1	Office Space	8
	2.2.2	Flammable Chemical Storage Building	8
	2.2.3	Building Roof Repair	8
	2.2.4	Secured Tools/Parts Storage	8
	2.2.5	Worker Shower and Cool Down Facility	9
	2.2.6	Electrical systems	9
	2.2.7	IRF Scale Model	9
	2.3	MISCELLANEOUS PROJECTS FOR FUTURE IMPLEMENTATION	9
	2.3.1	RCRA Blowdown Tank Storage System	9
	2.3.2	Scrubber Suspended Solids Removal System	9
	2.3.3	Slagging Kiln Recommendation	10
3	**FATE OF TRACE METALS IN THE ROTARY KILN INCINERATION SYSTEM WITH AN IONIZING WET SCRUBBER**		11
	3.1	TEST PROGRAM	11

TABLE OF CONTENTS (concluded)

Section			Page
	3.1.1	Synthetic Waste Mixture	11
	3.1.2	Test Conditions	14
	3.2	TEST RESULTS	14
	3.2.1	Average Trace Metal Discharge Distributions	14
	3.2.2	Effects of Incinerator Operating Conditions on Metal Distributions	19
	3.2.3	Metal Distributions in Flue Gas Particulate by Particle Size	19
	3.2.4	Apparent Scrubber Collection Efficiencies	21
	3.3	CONCLUSIONS	23
4		**INCINERABILITY TESTING OF ARSENIC-CONTAMINATED SOIL FROM THE BAIRD AND MCGUIRE SUPERFUND SITE**	27
	4.1	MUFFLE FURNACE EXPERIMENTS	28
	4.2	PILOT-SCALE INCINERATION TESTS	29
	4.2.1	Test Program	29
	4.2.2	Test Results	29
4.3		CONCLUSIONS	34
5		**INCINERABILITY TESTING OF CONTAMINATED SOILS FROM THE PURITY OIL SALES AND THE McCOLL SUPERFUND SITES**	37
	5.1	TEST PROGRAM	38
	5.2	TEST RESULTS	40
	5.3	CONCLUSIONS	44
6		**PARAMETRIC TESTING TO EVALUATE THE PROPOSED POHC INCINERABILITY RANKING**	46
	6.1	TEST PROGRAM	46
	6.2	SAMPLING AND ANALYSIS	47
	6.3	TEST RESULTS	50
7		**EXTERNAL COMMUNICATIONS**	52
8		**PLANNED EFFORTS FOR FY91**	56

FIGURES

Number		Page
1	Schematic of the IRF rotary kiln incineration system	12
2	Sampling protocol.	17
3	Normalized distribution of metals in the discharge streams	18
4	Effects of kiln temperature on the discharge distributions of cadmium, bismuth, and lead	20
5	Average of metal distributions in the afterburner exit flue gas particle size fractions	21
6.	Effects of kiln temperature, afterburner temperature and waste feed chlorine content on the distribution of metals in the afterburner exit flue gas particle size fractions	22
7	Apparent scrubber collection efficiencies for metals	23
8	Apparent scrubber collection efficiencies for metals showing associated variations with changes in kiln exit temperature and waste feed chlorine content	24
9	Sampling matrix.	30
10	Sampling matrix.	39
11	Sampling matrix.	51

TABLES

Number		Page
1	Design characteristics of the IRF rotary kiln system	13
2	POHC concentrations in clay/organic liquid feed	15
3	Average integrated feed metal concentrations	15
4	Target and average achieved test conditions	16
5	Semivolatile organic hazardous constituents in test soils	31
6	Normalized metal discharge distributions for the Baird and McGuire incineration tests	32
7	Apparent particulate and metal scrubber collection efficiencies	33
8	Arsenic fractions — TCLP leachable	33
9	Nominal incinerator system operating conditions for Purity Soil Sales and McColl Site soil incineration tests	38
10	Ultimate analysis of the test soils and resulting kiln ashes	41
11	Semivolatile organic hazardous constituents in test soils	41
12	Lead distributions for the Purity Oil Sales site soil tests	42
13.	Lead discharge distributions for the Purity Oil Sales site soil tests	44
14	Incinerability ranking mixture composition	48
15	Test conditions	49
16	IRF program reports and presentations in FY90	53
17	Visitors to the IRF	54

SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency's (EPA) Incineration Research Facility (IRF) in Jefferson, Arkansas, is an experimental facility that currently houses two pilot-scale incinerators (a rotary kiln incineration system and a liquid injection incineration system) and their associated waste handling, emission control, process control, and safety equipment. The IRF also has onsite laboratory facilities for waste characterization and analysis of process performance samples.

The objectives of research projects conducted at the IRF have been and continue to be as follows:

- To develop technical information on the performance capability of the hazardous waste incineration process to assist EPA Regional Offices and state environmental agencies in the review, assessment, and issuance of reasonable and responsible permits for regulated hazardous waste incineration facilities, and to assist waste generators and incinerator operators in the preparation of permit applications

- To develop incinerator system performance data for regulated hazardous wastes to support current Resource Conservation and Recovery Act (RCRA) incinerator regulations and performance standards, and to provide a sound technical basis for any necessary future standards

- To promote an understanding of the hazardous waste incineration process and develop methods to predict the performance of incinerators of varying scale and design for the major classes of incinerable hazardous wastes as a function of key process operating variables. These methods would also help to simplify and perhaps reduce the cost of permit and compliance testing.

- To develop methods of improving reliability and control of the incineration process, including the use of destruction and removal efficiency (DRE) surrogates

- To provide a means of conducting specialized test burns (particularly for high hazard or special waste materials such as Superfund site wastes) in support of specific Regional Office permitting or enforcement actions and Regional Office or private party Superfund site remediation efforts

- To test the performance of new and advanced incinerator components and subsystems, and emission control devices

During fiscal year 1989 (FY89, October 1, 1988, through September 30, 1989) the IRF underwent a major expansion and reconfiguration construction effort, detailed in the annual report for FY89[1]. As part of this expansion and reconfiguration effort, a new building encompassing the former 3100 ft^2 facility building was erected to bring total enclosed space to 15,200 ft^2. During construction, the facility's rotary kiln incineration system (RKS) was relocated entirely inside the former building area; an ionizing wet scrubber was installed as a second primary air pollution control system (APCS) for use in place of the venturi/packed column scrubber originally installed; and a new carbon bed/high-efficiency particulate (HEPA) filter secondary APCS was installed.

The FY89 RKS reconfiguration effort, as originally planned was not completed in FY89. Instead, an interim configuration in which the ionizing wet scrubber could be operated was completed. This configuration was used to support two incineration test programs in FY89. Thus, completion of many aspects of the originally planned RKS reconfiguration and upgrade was suspended in FY89 so that the two test programs could be performed. As a consequence, a significant RKS reconfiguration and upgrade effort continued during FY90, resulting in the completion of the original reconfiguration plans. This effort included:

- Relocating the venturi/packed column scrubber system within the former building area
- Replacing the RKS kiln refractory
- Installing a refractory-lined afterburner extension so that afterburner flue gas residence times could be increased into the more typically encountered range, and so that isokinetic afterburner exit flue gas sampling was possible
- Installing a new afterburner flue gas quench system
- Installing new scrubber exit ductwork, sampling platforms, and stack
- Installing the automated process control system purchased in FY89, and bringing it into operation

Much of this reconfiguration and upgrade effort was completed in the October through December 1989 time period. A period of testing activity followed in January and February 1990. The reconfiguration and upgrade effort was then completed during the March through May 1990 period, followed by another period of testing activity in June and July 1990.

Two major EPA Program/Regional Office programs were supported through test activities in FY90.

- The hazardous waste incinerator regulation development program within the Office of Solid Waste (OSW), via testing to evaluate the principal organic

hazardous constituent (POHC) incinerability ranking developed under other OSW support efforts

- The Superfund site remediation program within the Office of Emergency and Remedial Response (OERR) as administered by EPA Region 9, via treatability testing of contaminated soil from the Purity Oil Sales and McColl Superfund sites in California

In addition, the results of a series of trace metal fate tests in the RKS with an ionizing wet scrubber for particulate and acid gas control, and the results of treatability testing of contaminated soil from the Baird and McGuire Superfund site in Massachusetts, both completed at the end of FY89, were assembled and reported in FY90.

Activities completed during FY90 are discussed in more detail in the following sections. Section 2 describes the RKS reconfiguration and upgrade efforts completed. Section 3 discusses the results of the trace metal ionizing wet scrubber tests reported in FY90. Section 4 discusses results of the Region 1 Superfund treatability tests reported in FY90. Section 5 discusses results of the Region 9 Superfund soil treatability tests completed in February 1990. Section 6 describes the POHC incinerability ranking tests completed in July 1990. Section 7 discusses external communication activities associated with the facility and its operation. Section 8, the final section, presents an outline of plans for activities to be completed in FY91.

SECTION 2

ROTARY KILN INCINERATION SYSTEM RECONFIGURATION AND UPGRADE

During FY90, significant efforts were devoted to improving the reliability and ease of operation of the RKS, and to implementing features required for good functioning of the expanded building completed in FY89.

RKS-related tasks in FY90 included repairing and replacing hardware components; completing the reconfiguration of the RKS; installing an automatic process control system; and formulating plans and designs for further improvements to be implemented in FY91. Facility and building related activities included installing a secured tools/parts storage area, installing a flammable chemical storage building; implementing a shower and cool-down facility for test support staff; and arranging for more adequate office space. These activities are discussed in the following sub-sections.

2.1 ROTARY KILN SYSTEM UPGRADES

The following discussion focuses on the activities related to the RKS. Needed repairs and upgrades that were either completed or initiated in FY90 are discussed in turn.

2.1.1 Combustion System Repairs

Several components of the RKS required maintenance or repair during FY90. Efforts completed are discussed in the following.

RKS Refractory

The IRF RKS has seen extensive use since 1985. As would be expected, by 1989 the refractory linings of the combustion chambers were nearing the end of their useful lives. In FY89, the refractory in the afterburner chamber was replaced. In FY90, the refractory in the kiln chamber had deteriorated to the point that hot spots were beginning to develop on the kiln outer steel shell.

Between October 9 and 12, 1989, the RKS kiln refractory was removed and replaced. The incinerator was operated for several days per manufacturer prescribed heat-up schedule to cure the refractory. However, on November 17, during routine operation of the RKS in a shakedown mode, the IRF staff discovered that the newly-installed RKS kiln chamber refractory had developed severe cracks. The refractory installation contractor was called in to inspect the

failed refractory. The contractor attributed the failure to the selection of incorrect materials for the application.

After consulting with the refractory manufacturer, the contractor recommended a different refractory, Plibrico HyResist 3000, to be used. This replacement refractory was installed on December 8, and cured from December 11 through 18. Experience during that period confirmed that the single layer cast replacement refractory had less insulating property, when compared to the former two-layer construction. Kiln steel shell temperatures between 400 and 500°F were established when the kiln was operated at 1800°F. This was in reasonable agreement with heat transfer calculations that predicted a metal shell temperature of about 400°F. These temperatures were judged to be acceptable. The refractory appeared to still be in good condition at the end of FY90.

Induced-Draft Fan #2

Over the past four years, the induced-draft (ID) fan just upstream of the stack has failed several times. On December 18, 1989, the same fan failed once again. Inspection of the ID fan's fiberglass-reinforced-plastic (FRP) impeller revealed that its hub had developed a crack and had opened sufficiently to lose the press-fit with its drive shaft. Several cracks had also developed at the vane-to-hub joint. The IRF staff members explored options in an attempt to correct the situation expeditiously but could not identify any reliable and minimal-effort approach to do so. Therefore, an identical replacement impeller was purchased and installed on January 17.

On initial start-up, the fan operated with little vibration and appeared to function properly. During the next several days, however, fan vibration and noise increased gradually but noticeably. On January 23, the vibration level became alarmingly high. Inspection of the newly-installed impeller revealed cracks that were similar to, but somewhat more severe than, those found on the previously-failed impeller. The modes of failure during these two episodes were consistent with earlier failures.

The repeated failure of the RKS induced-draft fan #2 prompted efforts to identify alternative equipment options to replace the apparently unreliable fan component. The IRF staff was able to locate a local fan manufacturer who could fabricate an impeller out of 316 stainless steel material. The fan, using the stainless steel impeller, was reassembled and the RKS resumed operation on January 30. An identical impeller was purchased and stored at the IRF as a ready replacement in case the impeller should also fail prematurely. To date, the stainless steel impeller has performed well, with only one malfunction that was related to a failed bearing. That malfunction did not result in any extended system downtime.

Rotary Kiln Drive System

It has been known for some time that performance of the rotary kiln drive mechanism is not optimal. For example, the rotating chamber tends to migrate axially. Often, the axial travel is sufficiently large to cause the chamber to jam against the fixed end plates. This resulting friction has caused excessive wear and can prevent the kiln drum from rotating at all. In addition, deterioration of mechanical parts has reduced the range of kiln rotation speed control. The increasingly limited rotation control limits flexibility in changing solid residence times in the kiln.

In August 1990, the IRF staff began investigation into possible solutions. By the end of September, design concepts were finalized, and an improved kiln drive system will be implemented in FY91.

Natural Gas Supply Pipe Repair

Small leaks from the natural gas supply system were discovered in the new building during August 1990. The possibility of catastrophic natural gas explosion mandated the situation be corrected before natural gas use resumed. The leaks were traced to pipe joints that developed seepage since the time of the original installation. The IRF staff took this opportunity to make a few improvements in the natural gas system. These included removing union joints and directing pressure regulator vents out of the building. These corrective measures were completed in September. It was further decided in September to replace all threaded pipe joints at the gas supply main entry to the building by weld joints.

2.1.2 Venturi/Packed Column Scrubber Reconfiguration

As discussed above, plans to reconfigure the RKS air pollution control systems were substantially completed in FY89. The reconfiguration resulted in the entire RKS residing in the old incinerator test bay. A significant portion of this reconfiguration effort was completed in FY89, including the installation of the new secondary air pollution control system (demister, activated carbon adsorber, and high efficiency particulate filters) and the installation of the ionizing wet scrubber. The RKS was returned to testing operations after this first phase of reconfiguration in FY89.

The remaining reconfiguration efforts were scheduled to take place in FY90. They involved relocating the venturi/packed column scrubber and the associated controls to a more appropriate location; installing a heat exchanger system to cool the scrubber liquor; installing a new refractory-lined afterburner exit duct; and installing a new flue gas quench unit.

Installation efforts were initiated in February 1990, immediately following completion of the Region 9 Superfund soil treatability tests discussed in Section 5. The installation was completed in April.

Some notable efforts completed included:

- Fabricating and installing the scrubber flow control and heat exchanger modules, and associated system surge tanks
- Fabricating and installing the overhead supports for the fiberglass reinforced plastic (FRP) duct work for the relocated scrubber and the refractory-lined afterburner exit duct
- Installing the new refractory-lined afterburner exit duct,
- Installing the new flue gas quench unit, the water seal, and the water-cooled adaptor

- Relocating the venturi and packed column scrubbers
- Fabricating and installing the induced-draft fan vibration-isolation mounts and installing the fan in its final position
- Completing the interconnecting plumbing and ducts within and between the scrubber and heat exchanger systems
- Installing process meters and sensing switches on the scrubber system
- Implementing revised electrical power distribution and system safety-interlock control logic

System checkout began in early April and was completed by the end of April. At this time the reconfigured RKS and the heat exchanger system were operational and the newly installed refractory and fiberglass reinforced plastic ducts were cured per manufacturer recommendations.

2.1.3 RKS Automation with the Foxboro Process Control System

In FY89, concurrent with the RKS reconfiguration, an automatic process control system (manufactured by Foxboro) was purchased. Efforts to install the system began in October 1989 in accordance with plans to develop control algorithms and systems in several phases.

The first phase included developing the controls for the burner management system and implementing extensive data acquisition functions. This phase was initiated in January 1990 and was completed and functional by June. It was used during the POHC incinerability ranking tests discussed in Section 6.

Planning of the next phase of automatic control was initiated in July. The scope of the second phase of implementation was defined in August and it included bringing the remaining planned process parameter sensors on-line; implementing the required automatic waste feed cut-off interlock functions mandated by the IRF's modified permit; enhancing the system's data gathering and recording features; and refining the burner-controls for automatic gradual start-up and shut-down. This effort will continue into FY91.

2.1.4 Ram Feeder

The RKS ram-feeder, as originally designed and supplied in FY85, was not fully functional. The original system suffered from many short-comings, the most serious being an inoperable control system for operating the moving belt, rams, and gates. In 1987, a programmable logic control system was installed. Since that time, the ram feeder has been functioning and has been used to feed wastes during numerous incineration tests, though not with ease. However, with repeated use, the incidence of mechanical failure of several system components has become increasingly frequent. In response, renewed and accelerated efforts to seek a more acceptable solution to meet the ram feeder requirement were initiated during FY90.

In September 1990, the performance requirements of a more appropriate ram feeder were formulated. The major functional aspects include the ability to support testing with operator attention required no more often than once every four hours, intrinsic reliability, ability to contain spills from the waste containers, and compatibility with the RKS's automatic control and data acquisition system. A tentative objective has been set to implement an appropriate ram feeder by spring 1991.

2.2 BUILDING AND GROUNDS IMPROVEMENTS

Efforts continued in FY90 to bring the IRF physical plant to a point where it can better support its testing activities. The following sections discuss these efforts.

2.2.1 Office Space

During the planning stages of the expanded building, consideration was given to arrange for a more appropriate office space for the IRF staff. In March 1990, efforts resumed in this regard. Competitive bids were solicited from building constructors to supply 5040 ft^2 of modular office space. By the end of FY90, a request to purchase the office complex was being considered by the RREL. If approved, the office complex will most likely be completed and ready for occupancy in March 1991.

2.2.2 Flammable Chemical Storage Building

Following the recommendations that resulted from an facility environmental audit in 1988, EPA sought to provide an adequate building for the IRF to store flammable chemicals. In March 1990, the EPA Engineering, Planning, and Architecture Branch (EPAB) accelerated efforts to procure the flammable chemicals storage building for the IRF. On May 17, the IRF received the 9 by 24 ft modular chemical storage building.

Actual installation of the foundation, utilities, and access way was completed in September, following the EPAB award of the installation contract. Completion of the building systems repairs and function checks will continue into FY91.

2.2.3 Building Roof Repair

After several years of use, the old incinerator building roof suffered severe and wide-spread leaks. In December 1989, efforts began to correct the problem. Bids were solicited from roof repair contractors. Repairs were expected to begin in June but were delayed until September 1990. They will continue into FY91.

2.2.4 Secured Tools/Parts Storage

Following completion of the expanded building, efforts began in December 1989 to procure the partitions and shelves to install a secured tool and parts storage area. The shelves were received in April. Assembly of these shelves and organization of the storage area followed and became operational in May 1990.

2.2.5 Worker Shower and Cool Down Facility

In June 1990, it became clear that the Level B personnel protection required during testing of some hazardous materials was going to strain the ability of the test crew to cope with potential heat exhaustion. The existing IRF, new building included, did not have the needed facilities to allow test teams to rest between duty rotations. A temporary trailer, with proper temperature controls and shower stalls was leased and put into service. The building proved to be indispensable during the POHC incinerability ranking test program discussed in Section 6.

2.2.6 Electrical systems

The new IRF building, as completed by the construction contractor, did not include electrical outlets. The IRF staff installed a system of electrical receptacles in the new building to mitigate the need to run excessive lengths of extension cords to power tools, pumps and other electrical equipment. The project was completed in September. Additional electrical outlets planned for the old incinerator test bay will be installed in FY91.

2.2.7 IRF Scale Model

Arrangements were made in FY90 to have a scale model of the IRF built for display at meetings and conferences to inform the technical community of the IRF's capabilities and features. The contractor selected for this project started work in late April and completed the model in June 1990. The scale model was subsequently delivered to RREL in July.

2.3 MISCELLANEOUS PROJECTS FOR FUTURE IMPLEMENTATION

Several facility and incinerator related projects were explored and considered in FY90. These are discussed in the following subsections.

2.3.1 RCRA Blowdown Tank Storage System

A scrubber liquor blowdown tank system was designed and incorporated into the application for the IRF modified hazardous waste management permit. Further design and specification efforts proceed in FY90. System procurement may occur in FY91.

2.3.2 Scrubber Suspended Solids Removal System

One aspect of the RKS operation related to the solids suspended in the scrubber liquor may require attention. The current scrubber arrangement prevents uncontrolled build up of suspended particulates by discharging a portion of the solids with the scrubber blowdown stream. While this is adequate for fine solids, it has proven ineffective for fibrous solids. Experience have shown that fibers tend to collect in the scrubber liquor control system's strainers eventually form a sufficiently thick layer to block off effective scrubber liquor flow. While this condition can be corrected by switching flow to a standby strainer, the frequent maintenance would render operation unacceptably labor-intensive.

As an alternative, installation of a solids removal system to improve scrubber operation flexibility is under consideration. Such a system had been studied during the early stages of the

recently completed reconfiguration effort. It was not implemented during that effort, however, so as not to delay system startup. With the RKS reconfiguration effort completed, the solid removal system will be reexamined in FY91.

2.3.3 Slagging Kiln Recommendation

The desirability of having slagging kiln capability at the IRF has been discussed from time to time over the past years. Interest in having this capability has remained high. In response, the IRF staff was asked to prepare a conceptual design and cost estimate for two approaches to adding slagging kiln capability to the IRF was completed in FY90. The two approaches were (1) replacing the existing RKS with a new slagging system, and (2) fabricating a separate, stand-alone system. A draft discussion document was completed in June. The conceptual designs and cost estimates were completed in early July.

SECTION 3

FATE OF TRACE METALS IN THE ROTARY KILN INCINERATION SYSTEM WITH AN IONIZING WET SCRUBBER

The RCRA hazardous waste incinerator performance standards, promulgated by EPA in January 1981, established particulate and HCl emission limits and mandated 99.99 percent DRE for POHCs. Subsequent risk assessments have suggested that, of the total risk to human health and the environment from otherwise properly operated incinerators, hazardous constituent trace metal emissions may pose the largest component. However, the data base on trace metal emissions from incinerators is sparse; data on the effects of waste composition and incinerator operation on these emissions are particularly lacking.

In response to these data needs, an extensive series of tests was conducted at the IRF for OSW (R. Holloway, S. Garg, coordinators) in the investigation of the fate of trace metals fed to a rotary kiln incinerator equipped with a single-stage ionizing wet scrubber. This program was a continuation of a previous IRF test program, conducted in FY88, that employed a venturi/ packed-column scrubber as the primary APCS.

The primary objective of these test programs was to investigate the fate of five hazardous and four nonhazardous trace metals fed to a rotary kiln incinerator in a synthetic solid waste matrix. Of interest was the distribution of the metals as a function of incinerator operating temperatures and feed chlorine content. The hazardous trace metals investigated were arsenic, barium, cadmium, chromium, and lead. The nonhazardous metals were bismuth, copper, magnesium, and strontium.

The actual tests were completed at the end of FY89[1]. However, data reduction, interpretation, and reporting occurred in FY90. An outline of the test program and test results is given in the following subsections.

3.1 TEST PROGRAM

The test program consisted of nine parametric tests in which test waste feed contained the nine metals identified above. All tests were performed in the IRF's RKS, which is illustrated in Figure 1. The design characteristics of the system are summarized in Table 1.

3.1.1 Synthetic Waste Mixture

The synthetic waste contained a mixture of organic liquids added to a clay absorbent material. Trace metals were incorporated by spiking an aqueous mixture of the metals of

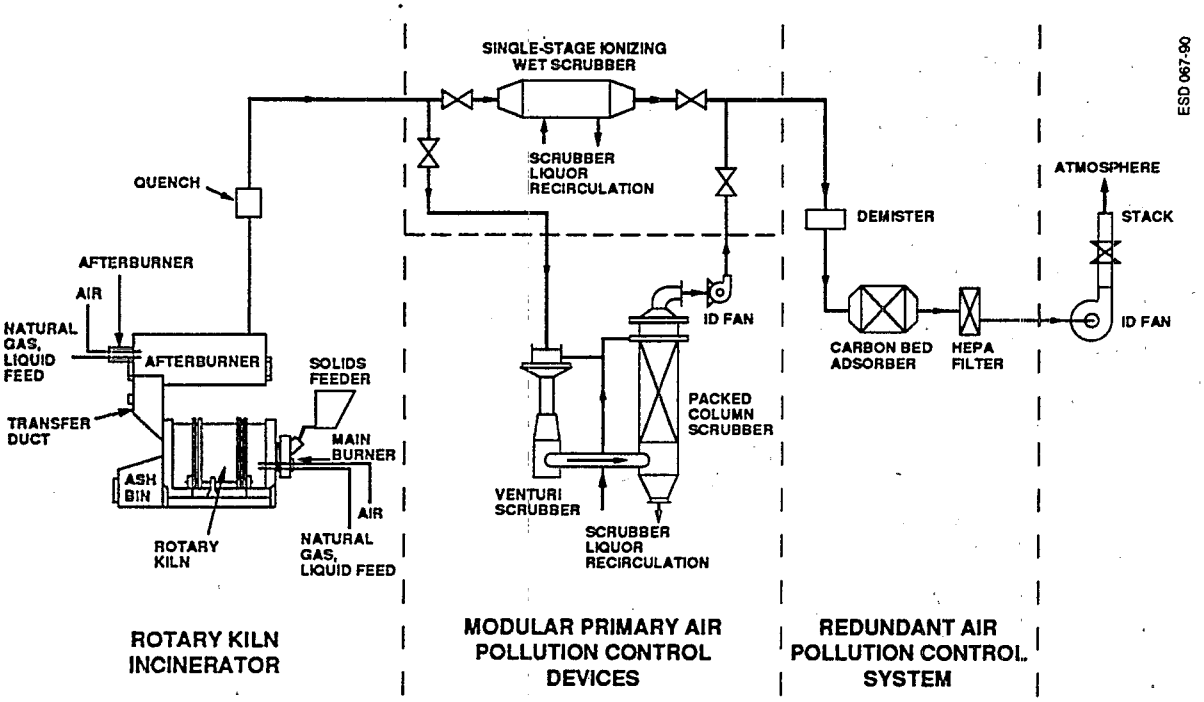


Figure 1. Schematic of the IRF rotary kiln incineration system.

TABLE 1. DESIGN CHARACTERISTICS OF THE IRF ROTARY KILN SYSTEM

Characteristics of the Kiln Main Chamber	
Length	2.49 m (8 ft-2 in)
Diameter, outside	1.37 m (4 ft-6 in)
Diameter, inside	Nominal 1.00 m (3 ft-3.5 in)
Chamber volume	1.90 m^3 (67.3 ft^3)
Construction	0.95 cm (0.375 in) thick cold-rolled steel
Refractory	18.7 cm (7.375 in) thick high alumina castable refractory, variable depth to produce a frustroconical effect for moving solids
Rotation	Clockwise or counterclockwise, 0.2 to 1.5 rpm
Solids retention time	1 hr (at 0.2 rpm)
Burner	North American burner rated at 800 kW (2.7 MMBtu/hr) with liquid feed capability
Primary fuel	Natural gas
Feed system:	
Liquids	Positive displacement pump via water-cooled lance
Sludges	Moyno pump via front face, water-cooled lance
Solids	Metered twin-auger screw feeder or fiberpack ram feeder
Temperature (max)	1010°C (1850°F)
Characteristics of the Afterburner Chamber	
Length	3.05 m (10 ft)
Diameter, outside	1.22 m (4 ft)
Diameter, inside	0.91 m (3 ft)
Chamber volume	1.80 m^3 (63.6 ft^3)
Construction	0.63 cm (0.25 in) thick cold-rolled steel
Refractory	15.2 cm (6 in) thick high alumina castable refractory
Gas residence time	0.8 to 2.5 s depending on temperature and excess air
Burner	North American Burner rated at 800 kW (2.7 MMBtu/hr) with liquid feed capability
Primary fuel	Natural gas
Temperature (max)	1200°C (2200°F)
Characteristics of the Ionizing Wet Scrubber APCS	
System capacity, inlet gas flow	85 m^3/min (3000 acfm) at 78°C (172°F) and 101 kPa (14.7 psia)
Pressure drop	1.5 kPa (6 in W.C.)
Liquid flow	230 L/min (60 gpm) at 345 kPa (50 psig)
pH control	Feedback control by NaOH solution addition
Characteristics of the Venturi/Packed Column Scrubber APCS	
System capacity, inlet gas flow	107 m^3/min (3773 acfm) at 1200°C (2200°F) and 101 kPa (14.7 psia)
Pressure Drop	
Venturi scrubber	7.5 kPa (30 in W.C.)
Packed column	1.0 kPa (4 in W.C.)
Liquid flow	
Venturi scrubber	77.2 L/min (20.4 gpm) at 60 kPa (10 psig)
Packed column	116 L/min (30.6 gpm) at 69 kPa (10 psig)
pH control	Feedback control by NaOH solution addition

interest onto the clay/organic liquid material. The waste was fed to the rotary kiln via a twin-auger screw feeder at a nominal rate of 63 kg/hr (140 lb/hr).

The organic liquid base consisted of toluene, with varying amounts of tetrachloroethylene and chlorobenzene added to provide a range of chlorine contents. Synthetic waste chlorine was varied from 0 to nominally 8 percent. The analyzed organic fractions for the three waste feed mixtures are given in Table 2. Table 3 summarizes the average metal concentrations in the combined waste feed over the nine tests.

3.1.2 Test Conditions

The test variables were kiln temperature, afterburner temperature, and the chlorine content of the synthetic waste feed. Seven specific combinations of these variables were selected as test points. Target and average achieved values for these three variables are summarized in Table 4. For all tests, excess air was nominally 11.5 and 8.0 percent oxygen in the kiln and the afterburner exit flue gas, respectively. Estimated solids residence time within the kiln was one hour. Figure 2 identifies the sampling locations for the tests. Flue gas samples were also collected at the stack for evaluating hazardous waste management permit compliance.

3.2 TEST RESULTS

3.2.1 Average Trace Metal Discharge Distributions

Figure 3 shows the amounts of metal found in each discharge stream, as a fraction of the total found in the three discharge streams—kiln ash, scrubber exit flue gas, and scrubber liquor. In Figure 3, the bar for each metal represents the range in the fraction accounted for by each discharge stream over all nine tests, with the average fraction from all tests noted by the midrange tick mark. Metal discharge distribution data in Figure 3 are plotted versus the volatility temperature of each metal, which is the temperature at which the effective vapor pressure of the metal is 10^{-6} atm^2. The effective vapor pressure is the sum of the equilibrium vapor pressures of all species containing the metal. It reflects the quantity of metal that would vaporize under a given set of conditions. A vapor pressure of 10^{-6} atm is selected because it represents a measurable amount of vaporization. The lower the volatility temperature, the more volatile the metal is expected to be.

Figure 3 indicates a correlation between observed volatility and volatility temperature for all the metals tested, except arsenic. With the exception of arsenic, average normalized kiln ash fractions generally increased with increasing volatility temperature. Cadmium and bismuth were relatively volatile and were less prevalent in the kiln ash than were the more refractory metals. Kiln ash fractions accounted for the majority of arsenic, lead, barium, copper, strontium, magnesium, and chromium.

Based on volatility temperature, arsenic is expected to be the most volatile element. However, the data show arsenic to be apparently refractory, remaining largely with the kiln ash. The volatility temperature for arsenic is based on the vapor pressure of As_2O_3. The fact that arsenic is significantly less volatile than expected (were As_2O_3 the predominant arsenic species) suggests that either some other, less volatile arsenic compound (perhaps an arsenate) was

TABLE 2. POHC CONCENTRATIONS IN CLAY/ORGANIC LIQUID FEED

Test	Weight % in mixture			
	Toluene	Tetrachloroethylene	Chlorobenzene	Chlorine content[a]
1	23.1	0	0	0
2 through 8 (average)	17.8	3.1	3.0	3.6
9	11.6	6.0	5.6	6.9

[a]Calculated based on measured tetrachloroethylene and chlorobenzene concentrations.

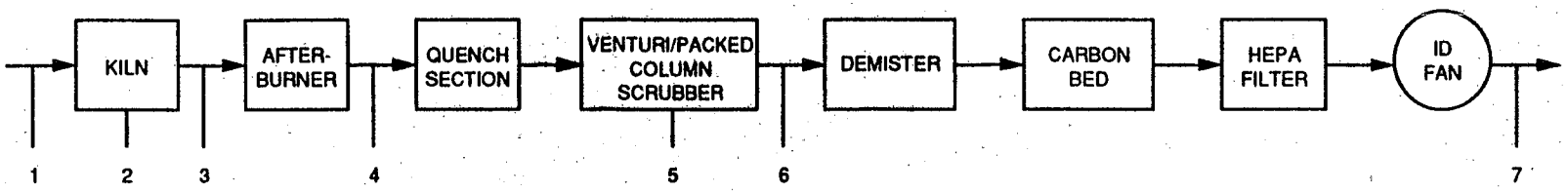
TABLE 3. AVERAGE INTEGRATED FEED METAL CONCENTRATIONS

Metal	Concentration (mg/kg)	Metal	Concentration (mg/kg)
Arsenic	48	Copper	380
Barium	390	Lead	45
Bismuth	330	Magnesium	18,800
Cadmium	10	Strontium	410
Chromium	40		

TABLE 4. TARGET AND AVERAGE ACHIEVED TEST CONDITIONS

		Feed mixture Cl content (%)		Kiln exit temperature °C (°F)		Afterburner exit temperature °C (°F)	
Test	Date	Target	Actual	Target	Average	Target	Average
1	8/17/89	0	0	871 (1600)	900 (1652)	1093 (2000)	1088 (1990)
2	8/2/89	4	3.5	816 (1500)	819 (1507)	1093 (2000)	1095 (2002)
3	8/4/89	4	3.5	927 (1700)	929 (1704)	1093 (2000)	1092 (1998)
4	8/1/89	4	3.5	871 (1600)	877 (1610)	1093 (2000)	1096 (2006)
5	8/16/89	4	3.7	871 (1600)	885 (1625)	1204 (2200)	1163 (2125)
6	8/15/89	4	3.6	871 (1600)	887 (1629)	982 (1800)	1017 (1863)
7[a]	8/9/89	4	3.5	871 (1600)	881 (1618)	1093 (2000)	1103 (2018)
8[a]	8/11/89	4	3.8	871 (1600)	879 (1615)	1093 (2000)	1098 (2008)
9	7/28/89	8	6.9	871 (1600)	881 (1617)	1093 (2000)	1087 (1988)

[a]Test points 7 and 8 are replicates of test point 4; together the three tests provided the components of an IRF trial burn.



SAMPLE LOCATIONS

	Feeds and residuals				Continuous monitor				Flue gas			
Sampling point	Clay/ organic liquid	Metal spike solution	Kiln ash	Scrubber blowdown	O_2	CO, CO_2	NO_x	Unheated TUHC	Method 17 with multiple metals impingers (particulate, metals, and HCl)	Method 5 with multiple metals impingers (particulate, metals and HCl)	VOST (volatile organics)	Method 5 (particulate and HCl)
1	X	X										
2			X									
3					X							
4					X	X		X	X		X	
5				X								
6					X		X	X		X	X	
7					X	X		X			X[a]	X

[a]Tests 4, 7, and 8 only.

Figure 2. Sampling protocol.

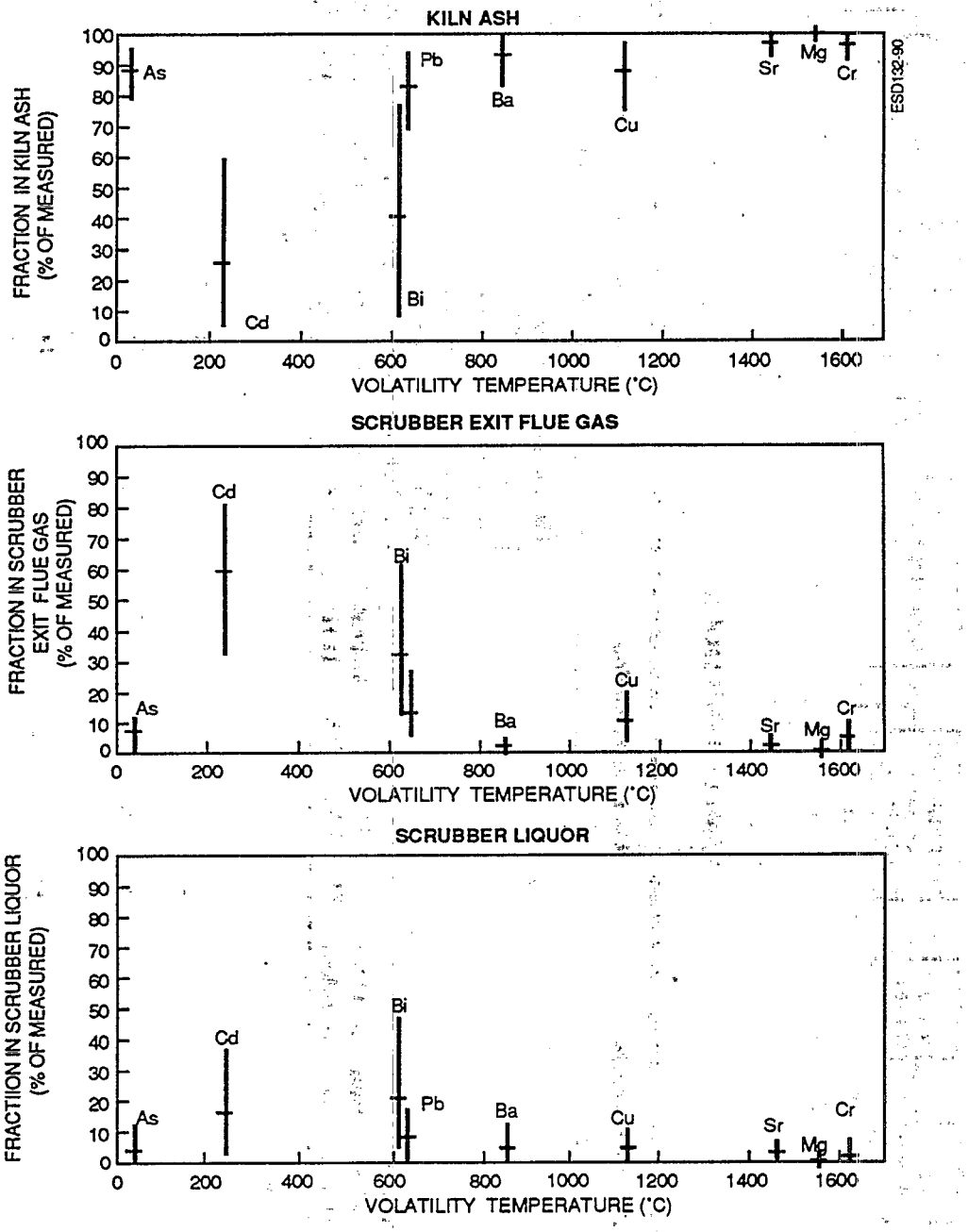


Figure 3. Normalized distribution of metals in the discharge streams.

preferred, or that some other chemical interaction, such as strong adsorption to the clay, occurred.

3.2.2 Effects of Incinerator Operating Conditions on Metal Distributions

Increased kiln temperature caused a noticeable increase in the volatility of cadmium, bismuth, and lead. Figure 4 shows that as the kiln temperature increased there was a significant decrease in the kiln ash fraction of these metals, with corresponding increases in the scrubber exit flue gas and scrubber liquor fractions. Although the volatility of lead increased with higher kiln temperature, lead still remained relatively refractory and was found primarily in the kiln ash. Kiln temperature within the tested range had no significant effect on the discharge distributions of any of the remaining metals.

Afterburner temperatures within the tested range did not clearly affect the distributions of any of the metals among the scrubber exit flue gas and scrubber liquor discharge streams. Data on the effect of feed chlorine content are inconclusive pending investigation of an apparent relationship between feed chlorine and the efficiency of the analytical procedure for metals in kiln ash.

3.2.3 Metal Distributions in Flue Gas Particulate by Particle Size

The particulate samples from the afterburner exit flue gas sampling train were size-fractionated, and trace metal distributions as a function of particle size were determined. Figure 5 shows the metal distributions in the particle size range of less than 10 μm, averaged over all nine tests. The average of the nine total particulate samples is also shown. The data show a relationship between the relative volatility of each metal (as indicated by its volatility temperature noted in the horizontal axis) and its propensity for redistribution to finer particulate. This is indicated by the higher fractions of the metals with lower volatility temperatures in the less than 10 μm particle size fractions.

This behavior is consistent with expectation. Most metal vaporized at some point in the incinerator will ultimately condense when the flue gas cools. Condensation occurs via fume formation or condensation onto available flue gas particulate. Fume formation results in very fine particulate. Condensation onto available particulate results in concentrating the metal in fine particulate, since condensation is a per-unit of surface area event, and the surface-area-to-mass ratio is increased in fine particulate. Both mechanisms tend to concentrate volatilized metal in fine particulate. Interestingly, arsenic behaves as a volatile metal with respect to enrichment in fine particulate.

The effects of kiln temperature, afterburner temperature, and waste feed chlorine content are shown in Figure 6. The size distributions of the metals most nearly reflect the overall entrained particle size distribution for Test 2 (lowest kiln temperature), Test 5 (highest afterburner temperature), and Test 1 (no chlorine in the waste feed); very little redistribution among the particulate was observed. For these three tests, about 20 to 25 percent of each metal and the total particulate sample were in the less than 10 μm particulate.

With increased kiln temperature, the size distributions of all metals except chromium shift to about 60 percent less than 10 μm. Increased afterburner temperature caused the overall

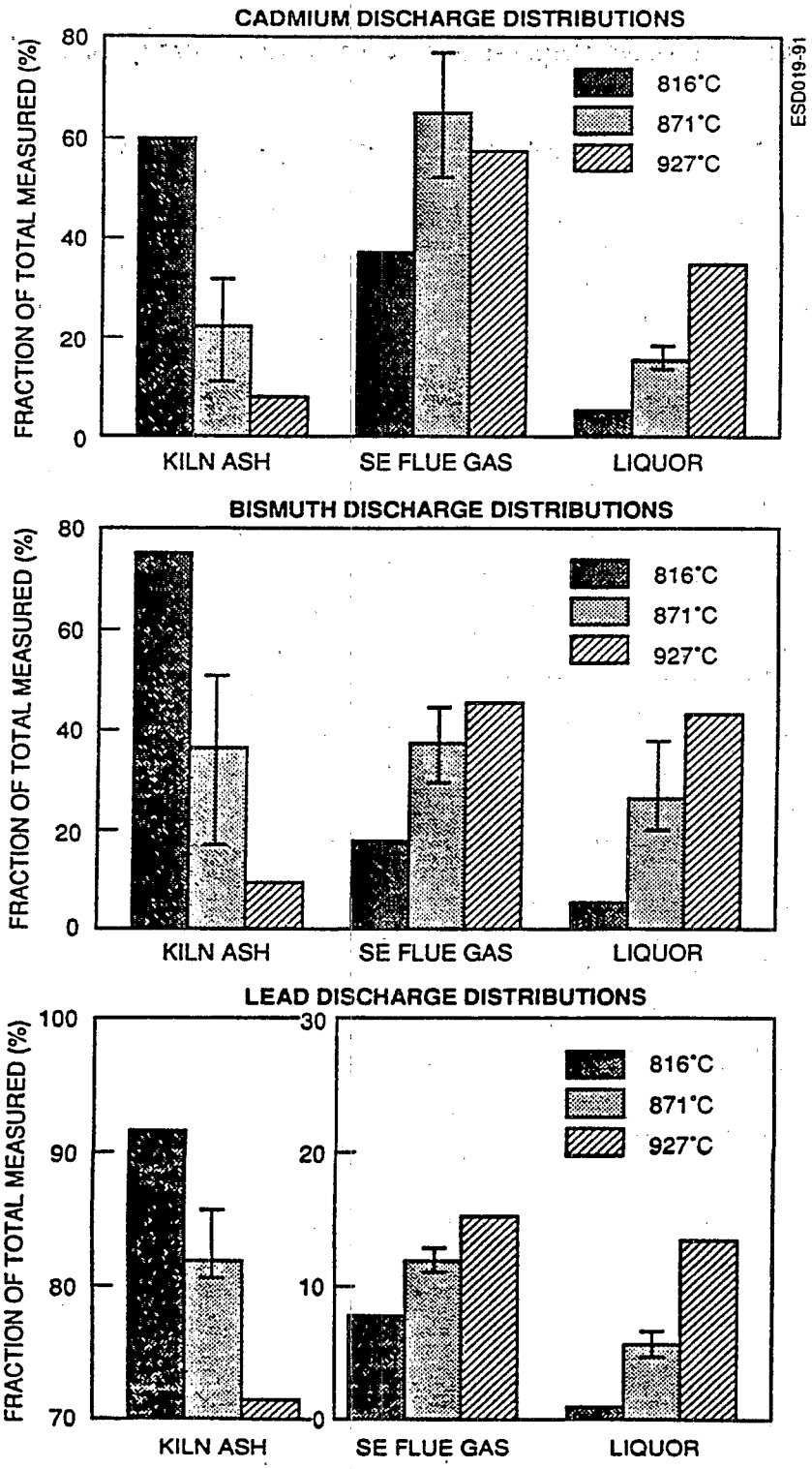


Figure 4. **Effects of kiln temperature on the discharge distributions of cadmium, bismuth, and lead.**

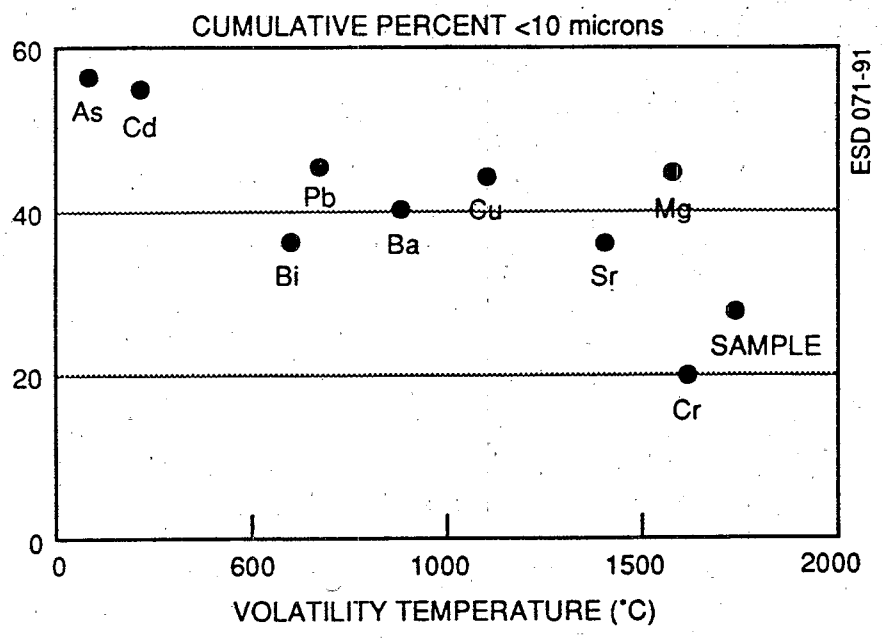


Figure 5. Average of metal distributions in the afterburner exit flue gas particle size fractions.

sample particle size distribution to shift to coarser particulate, most likely because of fine particles melting or softening and coalescing into larger particles. A corresponding shift in metal-specific distributions to coarse particulate was observed.

The addition of chlorinated compounds to the synthetic waste feed mainly affected cadmium, lead, copper and chromium distributions. With waste feed chlorine content increased from 0 to 4 percent, the fraction of cadmium, lead and copper in the less than 10 μm particulate increased from about 20 to roughly 55 percent. No further redistributions of these metals were observed with chlorine content increased from 4 to 8 percent. For chromium, increasing chlorine content from 0 to 4 to 8 percent caused a corresponding shift of 2 to 20 to 50 percent in particulate of less than 10 μm.

3.2.4 Apparent Scrubber Collection Efficiencies

The apparent scrubber collection efficiency for flue gas metals was determined for each test. The apparent scrubber efficiency represents the ratio of the normalized metal fraction measured in the scrubber liquor to the sum of the normalized metal fractions measured in the scrubber liquor and scrubber exit flue gas. Figure 7 summarizes the efficiency data. The bar for each metal represents the range of scrubber efficiencies over the nine tests, with the overall average for the nine tests noted by the midrange tick mark. Average metal collection efficiencies ranged from 22 to 71 percent; the overall average for all metals was 43 percent. Figure 7 shows that there were significant variations in the efficiencies for each metal. However, average efficiencies were generally higher for the less volatile metals. It should be noted that industrial applications of ionizing wet scrubbers are typically in multiple stages and, as such, would be expected to collect metals more efficiently than the single-stage scrubber at the IRF.

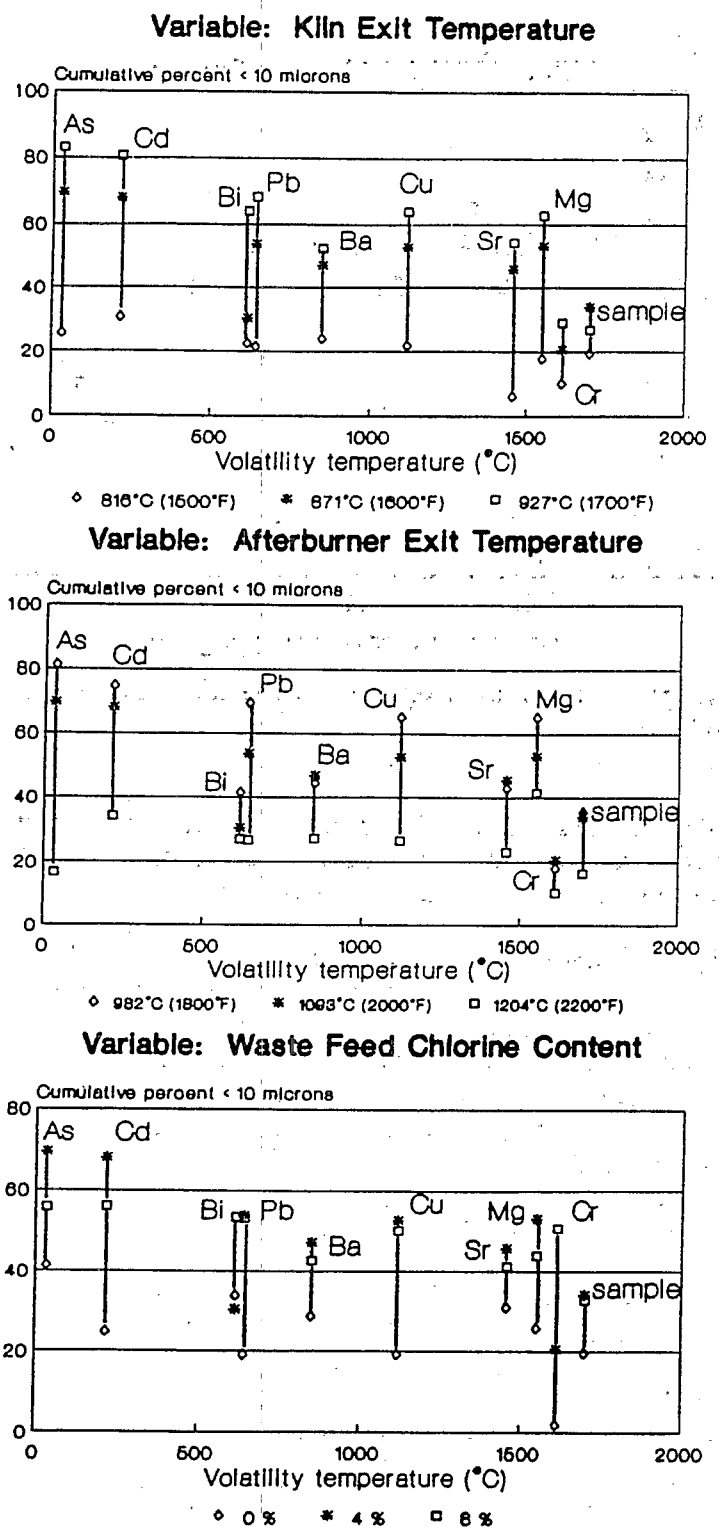


Figure 6. Effects of kiln temperature, afterburner temperature and waste feed chlorine content on the distribution of metals in the afterburner exit flue gas particle size fractions.

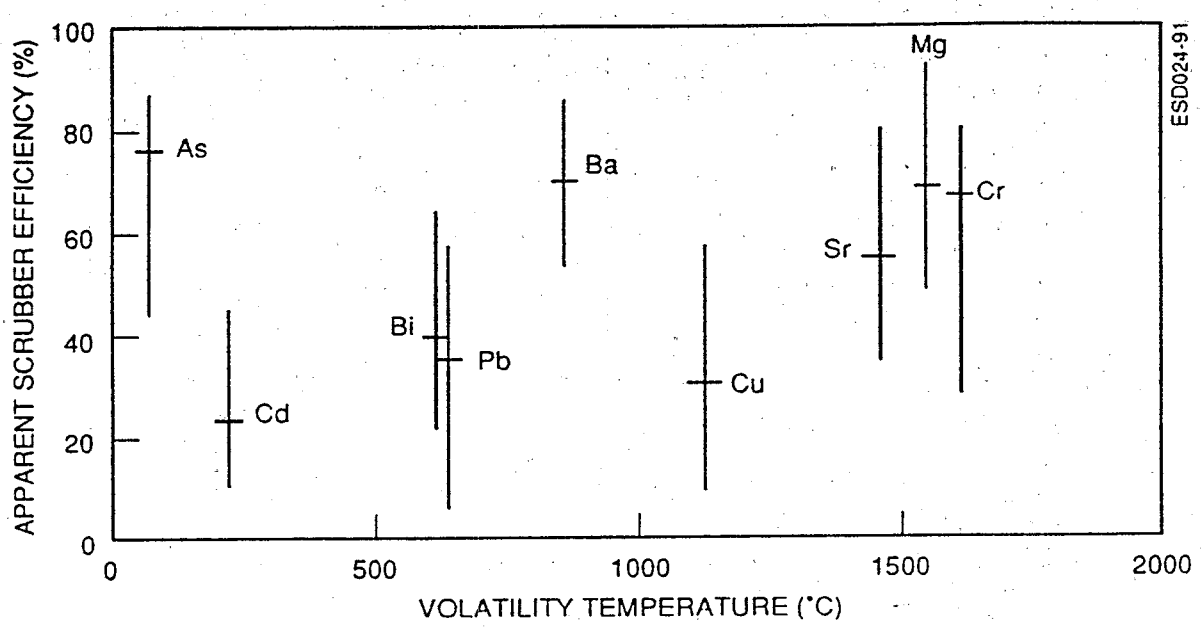


Figure 7. Apparent scrubber collection efficiencies for metals.

Figure 8 shows the effects of kiln temperature and waste feed chlorine content on the collection efficiencies for the metals. Within the limits of data variability, none of the test variables affected scrubber collection efficiencies for arsenic, barium, strontium, magnesium and chromium. Apparent scrubber collection efficiencies for cadmium, bismuth, lead, and copper increased with increased kiln temperature and waste feed chlorine content. Increased scrubber collection efficiency might be expected with increased feed chlorine content if the presence of chlorine leads to the formation of more soluble metal chlorides. However, it is unclear why increased kiln temperature would directly lead to increased collection efficiency. Apparent scrubber collection efficiencies for metals did not vary with afterburner exit temperature.

3.3 CONCLUSIONS

Test conclusions include the following:

- Cadmium and bismuth were relatively volatile, with an average of less than 40 percent of the discharged metal accounted for by the kiln ash. Arsenic, barium, chromium, copper, lead, magnesium, and strontium were relatively nonvolatile, with an average of greater than 80 percent of the discharged metal accounted for by the kiln ash.

- Observed metal volatilities generally agreed with the order predicted by metal volatility temperatures, with the notable exception of arsenic. Arsenic has the lowest volatility temperature of the metals tested, but was observed to be one of the least volatile of the metals. This suggests that As_2O_3 was not the predominant arsenic species in the incinerator, or that the arsenic was adsorbed by the clay/ash matrix.

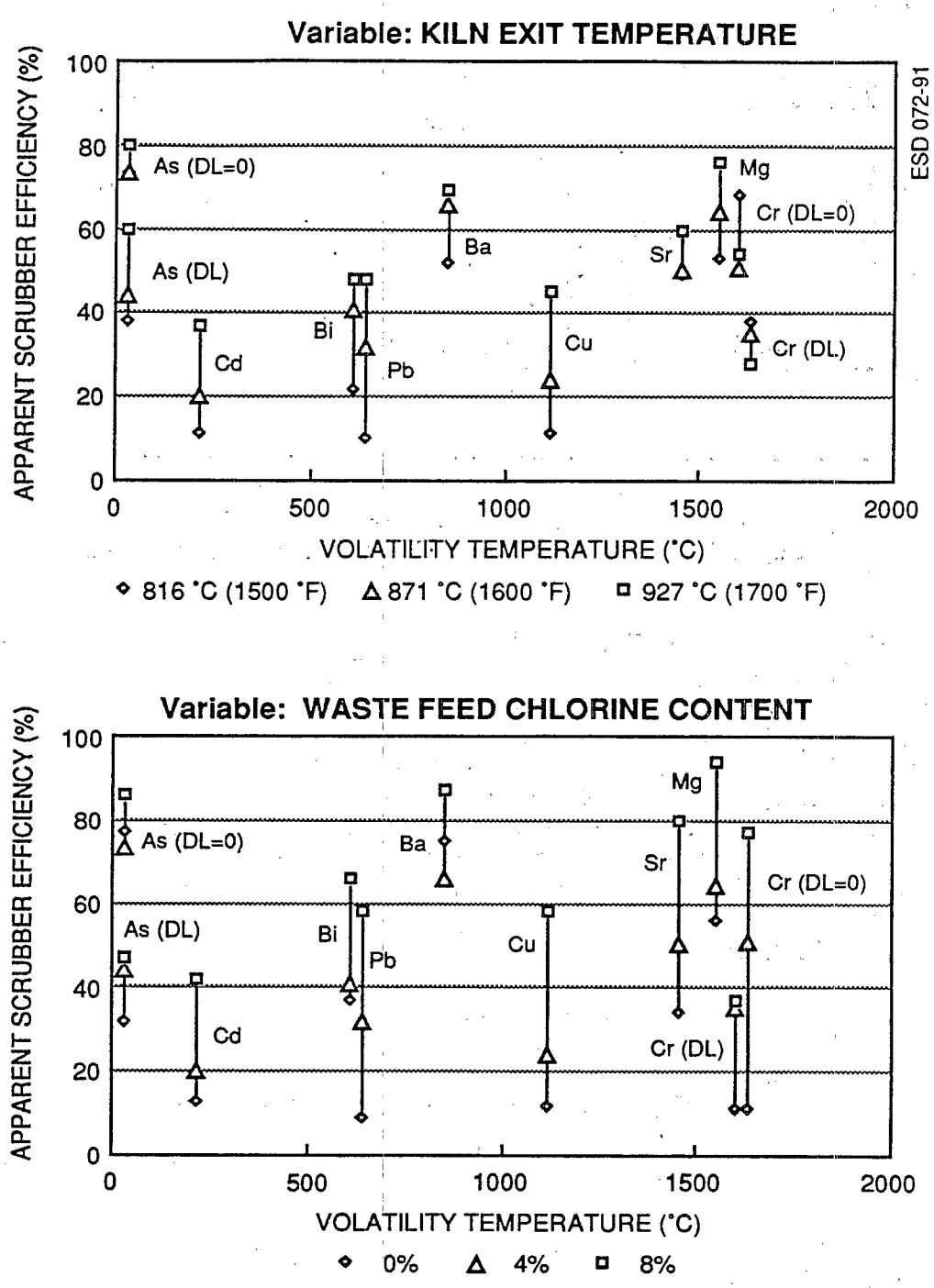


Figure 8. **Apparent scrubber collection efficiencies for metals showing associated variations with changes in kiln exit temperature and waste feed chlorine content.**

- Kiln temperature affected the relative volatility of cadmium, bismuth, and lead. The fractions of these metals retained in the kiln ash decreased with increasing kiln temperature.

- Afterburner exit temperature did not clearly affect metal partitioning among the scrubber exit flue gas and scrubber liquor discharge streams.

- Enrichment of metals in the fine-particulate fraction of the afterburner exit particulate was observed, with an average of roughly 50 percent of flue gas particulate metal in the less-than-10-μm size range, compared to an average of about 30 percent of the total particulate sample. The distributions of the more volatile metals were shifted to fine particulate more so than the less volatile metals. Arsenic behaved as a volatile metal with respect to its distributions among the afterburner exit flue gas particle size ranges. On average, roughly 40 percent of flue gas particulate metal was less than 10 μm.

- Each test variable affected the distributions of at least some of the metals among the flue gas particulate particle size ranges. Size distributions of the metals most nearly reflected the overall sample particle size distribution for Test 2 (lowest kiln temperature), Test 5 (highest afterburner temperature), and Test 1 (no chlorine in the waste feed); very little redistribution among the particulate was observed. For these three tests, about 20 to 25 percent of each metal and the total particulate sample were in the less than 10 μm particulate.

- Increasing kiln temperature to 816° to 927°C (1500° to 1700°F) caused the average distributions to shift from roughly 20 percent less than 10 μm to an average of 60 percent less than 10 μm for all test metals except chromium. For cadmium, copper, and lead, an increase in waste feed chlorine content from 0 to 4 percent caused their distributions to shift from roughly 20 percent less than 10 μm to 55 percent less than 10 μm. No further effects with feed chlorine increased to 8 percent were observed for these metals. For chromium, increasing chlorine content from 0 to 4 to 8 percent caused a corresponding shift of 2 to 20 to 50 percent in particulate less than 10 μm.

- The average apparent scrubber collection efficiencies for metals ranged from 22 to 71 percent, and generally increased with decreasing metal volatility. The overall average collection efficiency for all metals was 43 percent.

- Apparent scrubber collection efficiencies for cadmium, bismuth, lead, and copper increased with increased kiln temperature and waste feed chlorine content. Afterburner temperature had no discernible effect on apparent scrubber collection efficiencies for any of the metals.

Test results were documented in the test report:

- Fournier, Jr., D. J., and L. R. Waterland, "The Fate of Trace Metals in a Rotary Kiln Incinerator with an Ionizing Wet Scrubber," draft April 1990.

Test results were also presented in three technical papers:

- Waterland, L. R., D. J. Fournier, Jr., J. W. Lee, and G. J. Carroll, "Trace Metal Fate in a Rotary Kiln Incinerator with an Ionizing Wet Scrubber," presented at the Incineration Conference—1990, San Diego, California, May 1990.

- Fournier, Jr., D. J., L. R. Waterland, and G. J. Carroll, "Trace Metal Size Distributions in Flue Gas Particulate from a Rotary Kiln Incinerator," presented at the American Association for Aerosol Research 1990 Annual Meeting, Philadelphia, Pennsylvania, June 1990.

- Fournier, Jr., D. J., L. R. Waterland, and G. J. Carroll, "Size Distributions of Trace Metals in Flue Gas Particulate from a Pilot-Scale Rotary Kiln Incinerator," presented at the American Flame Research Committee 1990 Fall International Symposium on NO_x Control, Waste Incineration, and Oxygen-Enriched Combustion, San Francisco, California, October 1990.

Test results are planned for presentation in two additional technical papers:

- Waterland, L. R., D. J. Fourier, Jr., J. W. Lee, G. J. Carroll, and R. C. Thurnau, "The Fate of Trace Metals in a Rotary Kiln Incinerator: Tests with Two Different Scrubber Systems," for presentation at the Second International Conference of Toxic Combustion By-Products, Salt Lake City, Utah, March 1991.

- Fourier, Jr., D. J., L. R. Waterland, and G. J. Carroll, "The Behavior of Trace Metals in Rotary Kiln Incineration: An Overview of Incineration Research Facility Studies," for presentation at the 17th Annual Research Symposium on the Remedial Action, Treatment, and Disposal of Hazardous Waste, Cincinnati, Ohio, April 1991.

SECTION 4

INCINERABILITY TESTING OF ARSENIC-CONTAMINATED SOIL FROM THE BAIRD AND MCGUIRE SUPERFUND SITE

One of the primary missions of the Environmental Protection Agency's (EPA) Incineration Research Facility (IRF) is to support Regional Offices in evaluations of the potential of incineration as a treatment option for contaminated soils at Superfund sites. One priority site in Region 1 is the Baird and McGuire site in Holbrook, Massachusetts. EPA Region 1 (M. Sanderson, P. Fitzsimmons, Region 1; J. Ehresmann, USACE, Coordinators) requested that test burns be conducted at the IRF to support evaluations of the suitability of incineration as a treatment technology for the contaminated site soil.

The soil at the Baird and McGuire site is contaminated with low levels of several pesticide compounds and varying levels of arsenic and lead. Several areas of the site have arsenic contamination levels of the order of 100 ppm, although two "hot spots" have arsenic levels up to 3800 ppm. Thus, with respect to incinerability evaluation, the primary concern surrounds the fate of arsenic and lead in the soil when it is subjected to incineration. The effect of incineration on the fate of arsenic and lead in soil is currently unknown. A secondary concern relates to whether incineration can effectively destroy the organic pesticide contaminants in the soils. Therefore, the test conditions were designed to evaluate the effects of varying incinerator operating conditions on organic contaminant destruction and on the fate of the arsenic and lead in the soil. Specifically, the test program attempted to answer these questions:

- What is the distribution of arsenic and lead in the discharge streams during incineration of this metal-contaminated soil?
- To what extent can rotary kiln incineration effectively destroy the organic constituents in the soil?
- What are the effects of incineration excess air and temperature on organic constituent destruction and arsenic and lead distribution?

The test program consisted of two components. Initially, a series of bench scale experiments, using a muffle furnace, was performed to evaluate the leachability characteristics of the arsenic and the lead in the soil as a function of the arsenic/lead concentration in the soil. The second component of this test program consisted of a set of five incineration tests in the RKS. These tests were aimed at evaluating the fate of arsenic and lead in the soil as a function of kiln temperature and excess air level.

The muffle furnace testing and four of the five incineration tests were completed at the end of FY89[1]. The fifth incineration test and test program sample analyses, data evaluation and interpretation, and test reporting were completed during FY90. An outline of the test program and test results are given in the following subsections.

4.1 MUFFLE FURNACE EXPERIMENTS

A prerequisite to any onsite remediation treatment process is that the residue from the process (the treated soil) be able to be landfilled at the site. For incineration treatment, this would not be possible if the kiln ash residue had TCLP leachable arsenic and lead at levels greater than the toxicity characteristic (TC) limit. In an actual site remediation via incineration, soil with very high arsenic/lead levels can be blended with soils of low arsenic/lead contamination to give an incineration feed that results in a low concentration of leachable arsenic/lead in the kiln ash. But, the a priori unknown is how low the feed arsenic or lead concentration must be. To partially address this unknown, a series of muffle furnace tests was performed. The objective of these tests was to develop the data to guide the determination of appropriate maximum feed arsenic/lead concentrations.

For these tests, the primary variable was the arsenic/lead concentration in the test mixture. A contaminated soil containing 650 ppm arsenic and 45 ppm lead was mixed with various amounts of a background soil containing less than 5 ppm arsenic and 14 ppm lead to produce seven samples of varying arsenic/lead concentrations. Each sample was heated in a muffle furnace at 982° C (1800° F) for one hour. Analysis of the soil mixtures and the resultant ash residues show that:

- Arsenic volatility increased with soil arsenic concentration. Similarly, lead volatility increased with soil lead concentration.
- Soils containing less than 150 ppm arsenic would produce ash residues below the arsenic TC limit of 5 mg/L
- Lead content in all ash samples was constant at about 5 ppm
- All ash TCLP leachate lead concentrations were below detection, regardless of initial soil lead content
- Organics and moisture in the soil contributed to 25 percent weight loss

To achieve a secondary objective of determining whether the potential additives lime and alum can affect the distribution of metals to the resulting soil ash, two additional tests were conducted. In both tests, the test mixture consisted of the highly-contaminated soil, mixed with one of the additives to a level of 2 percent (wt). Analysis of the limited data suggests that:

- Lime appeared to reduce the volatility of the arsenic; a greater fraction of the soil arsenic remained with the resulting ash
- Alum appeared to increase arsenic volatility; less soil arsenic remained in the resulting ash

- Neither additive affected the volatility of lead

- Lime may be added to soils with arsenic concentrations greater than 150 ppm while yielding a thermal treatment ash that would not possess the toxicity characteristic

4.2 PILOT-SCALE INCINERATION TESTS

The pilot-scale incineration tests were conducted in the RKS to evaluate the fate of arsenic and lead in the soil as a function of kiln temperature and excess air level. A schematic of the RKS and its design characteristics are given in Figure 1 and Table 1 of Section 3.

4.2.1 Test Program

Four tests were performed at different combinations of kiln temperature of nominally 816° and 980°C (1500° and 1800°F) and kiln exit flue gas O_2 of nominally 6 and 10 percent. A fifth test was completed which was a repeat of the test that produced the kiln ash which contained the lowest levels of TCLP leachable arsenic and lead.

A bulk sample (nominally 1350 kg, 3000 lb) of arsenic-contaminated soil was excavated from the Baird and McGuire site to serve as the test waste. The bulk soil sample was packaged into four 55-gal drums and shipped to the IRF for testing. At the IRF the soil was re-packed into polyethylene-lined 1.5-gal fiber pack drums. Each fiber pack drum held about 4.5 kg (10 lb) of the test soil. In the tests one fiber pack drum was fed into the RKS with a ram feeder every 5 min. Thus, test soil feedrate was nominally 55 kg/hr (120 lb/hr). A kiln rotation speed of 0.65 rpm produced a solids residence time in the kiln of about 0.5 hr. Figure 9 identifies the sampling locations for the tests and summarizes the sampling protocols employed.

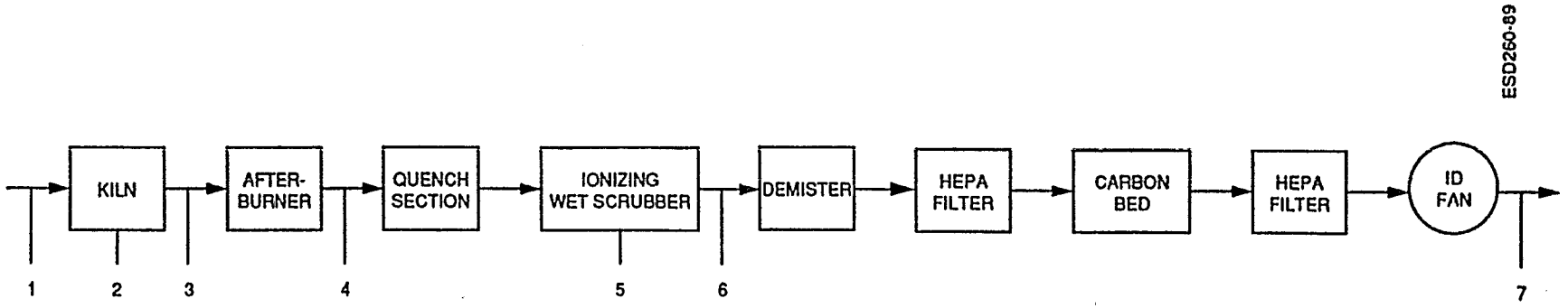
4.2.2 Test Results

Throughout the test program, CO levels at the scrubber exit and the stack were at most a few ppm. Total unburned hydrocarbons levels were similarly low at the afterburner exit, scrubber exit, and in the stack. Average NO_x concentrations at the scrubber exit ranged from 32 to 51 ppm, levels that are typical for the rotary kiln system.

Flue gas particulate concentrations ranged from 6 to 17 mg/dscm (at 7 percent O_2) at the scrubber exit. In the stack, concentrations ranged from 2 to 29 mg/dscm (at 7 percent O_2). These levels fell below the hazardous waste performance standard of 180 mg/dscm (at 7 percent O_2).

The only organic contaminants found in the test soils above method detection limits of 2 to 4 mg/kg were p,p'DDE, p,p'DDD, p,p'DDT, and methoxychlor. As shown in Table 5, DDE was present at 39 to 74 mg/kg, DDD at 181 to 310 mg/kg, DDT at 257 to 501 mg/kg, and methoxychlor at 54 to 81 mg/kg. None of these were present in the TCLP leachates of the test soils at a quantitation limit of 0.2 mg/L.

Organic analysis of kiln ash, kiln ash TCLP leachate, scrubber blowdown, and scrubber exit flue gas Method 0010 samples for each test showed that all semivolatile organic hazardous



Sampling point	Waste feed	Kiln ash	Ionizing wet scrubber blowdown	Continuous flue gas monitoring	Method 0010 (semivolatile organics)	Method 5 metals train (particulate, arsenic)	Method 5 (particulate and HCl)
1	X						
2		X					
3				X			
4				X			
5			X				
6				X	X	X	
7				X			X

Figure 9. Sampling matrix.

TABLE 5. SEMIVOLATILE ORGANIC HAZARDOUS CONSTITUENTS IN TEST SOILS

Test	Soil			
	Drum 15 (Test 1)	Drum 16 (Test 2)	Drum 18 (Test 3)	Drum 13 (Test 4)
p,p'-DDE	54	74	45	39
p,p'-DDD	228	310	197	181
p,p'-DDT	334	501	247	277
Methoxychlor	81	73	54	73
All other semivolatiles analyzed	<4	<4	<4	<4

constituents analyzed, including the pesticide contaminants in the test soil, were present at less than method detection limits in all cases. The quantitation limits of the Method 0010 sampling trains when combined with measured flue gas flow rates and soil feed concentrations and feed rates confirm that incineration destruction and removal efficiencies (DREs) for the pesticide contaminants in the soil feeds were at least greater than 99.5 percent to greater than 99.97 percent for the tests performed.

Table 6 summarizes the distributions of arsenic and lead among the incinerator discharge streams (kiln ash, scrubber blowdown and scrubber exit gas), expressed as fractions of the total metals measured in the three discharge streams. The data in Table 6 show that kiln temperature has a clear effect on both arsenic and lead distributions in that kiln ash concentrations of arsenic and lead were lower at the higher incineration temperatures. This is expected since both arsenic and lead are relatively volatile metals. Higher incineration temperatures would be conducive to greater volatilization of these metals in the kiln, resulting in decreased kiln ash concentrations. Scrubber blowdown and scrubber exit flue gas concentrations of both metals appear to be increased at the higher incineration temperature. Again, this is consistent with increased metal volatilization in the kiln at the higher temperature.

The data in Table 6 show no clear influence of kiln excess air level (as reflected in kiln exit flue gas O_2) on arsenic or lead distributions among the discharge streams at the low kiln temperature conditions. At high kiln temperature conditions, increasing excess air had the apparent effect of increasing the volatility of arsenic, as measured by the decreased kiln ash arsenic fraction. However, this apparent increase is most likely the result of increased ash entrainment and carryover by the increased kiln exit flowrate.

Scrubber inlet flue gas concentrations were not measured in these tests. However, if it is assumed that the total amount of metal measured in the sum of the scrubber liquor and the scrubber exit flue gas equals the amount present at the scrubber inlet, an apparent efficiency can be calculated. This apparent scrubber efficiency is ((scrubber liquor fraction)/(scrubber liquor fraction plus scrubber exit flue gas fraction)).

TABLE 6. NORMALIZED METAL DISCHARGE DISTRIBUTIONS FOR THE BAIRD AND MCGUIRE INCINERATION TESTS

Test	1 (9-26-89)	5 (10-5-90)	2 (9-29-89)	3 (9-27-89)	4 (9-28-89)
Kiln exit temperature, °C (°F)	832 (1529)	839 (1541)	844 (1552)	994 (1822)	994 (1822)
Kiln exit O_2, %	11.3	11.2	6.8	10.4	7.5
Kiln exit flue gas flowrate, acm/min[a]	22.8	22.6	11.1	34.8	21.6
	Distribution (% of metal measured)				
Arsenic					
Kiln ash	72	66	76	36	56
Scrubber liquor	23	29	22	55	38
Scrubber exit flue gas	5	5	2	9	6
Total	100	100	100	100	100
Lead					
Kiln ash	89	91	93	69	69
Scrubber liquor	4	3	3	12	13
Scrubber exit flue gas	7	6	4	19	18
Total	100	100	100	100	100

[a]Actual wet m^3/min.

As shown in Table 7, apparent scrubber collection efficiencies for arsenic ranged from 82 to 98 percent and were right in the range of overall particulate collection efficiencies. The apparent collection efficiencies for lead were significantly lower and ranged from 33 to 43 percent. Neither arsenic nor lead apparent collection efficiencies showed any significant variation with test variables (kiln temperature or excess air).

Table 8 shows that both increasing kiln temperature and decreasing kiln excess air increased the leachability of the kiln ash arsenic, with excess air level having the more significant effect. At 11 percent kiln exit O_2, between 8.3 and 13 percent of the kiln ash arsenic was leachable. At 7 percent kiln exit O_2, 28 and 67 percent of the arsenic was leachable, for kiln temperatures of 844° and 994°C (1552° and 1822°F), respectively. Clearly, to minimize arsenic leachability, the appropriate incineration conditions are low-temperature/high-excess air.

In contrast, the leachability of lead from the kiln ash was consistently low and lead was not detected in any of the soil and ash TCLP leachates.

TABLE 7. APPARENT PARTICULATE AND METAL SCRUBBER COLLECTION EFFICIENCIES

Test	1 (9-26-89)	5 (10-5-90)	2 (9-29-89)	3 (9-27-89)	4 (9-28-89)
Kiln exit temperature, °C (°F)	832 (1529)	839 (1541)	844 (1552)	994 (1822)	994 (1822)
Kiln exit O_2, %	11.3	11.2	6.8	10.4	7.5
	Apparent IWS collection efficiency (%)				
Arsenic	82	85	92	86	86
Lead	36	33	43	39	42
Overall particulate	92	84	95	90	82

TABLE 8. ARSENIC FRACTIONS — TCLP LEACHABLE

Test	1 (9-26-89)	5 (10-5-90)	2 (9-29-89)	3 (9-27-89)	4 (9-28-89)
Kiln exit temperature, °C (°F)	832 (1529)	839 (1541)	844 (1552)	994 (1822)	994 (1822)
Kiln exit O_2, %	11.3	11.2	6.8	10.4	7.5
	Fraction of As leachable (%)				
Soil feed	2.2	2.4	2.4	2.5	2.9
Kiln ash	9.3	8.3	28	13	67

4.3 CONCLUSIONS

Test conclusions include:

- Both arsenic and lead remain predominantly in the kiln ash when incinerated at a kiln temperature of nominally 840°C (1540°F). Between 66 and 76 percent of the arsenic discharged and 89 to 93 percent of the lead discharged was accounted for in this stream. Between 2 and 5 percent of the arsenic and 4 and 6 percent of the lead was present in the APCS exit flue gas; and 22 to 29 percent of the arsenic and 3 to 4 percent of the lead was collected by APCS.

- Lead remains predominantly in the kiln ash when incinerated at a kiln temperature of nominally 990°C (1820°F), with 69 percent of its amount discharged accounted for in the kiln ash. The APCS flue gas contained 18 to 19 percent of the discharged lead. The APCS collected 12 to 13 percent of the lead.

- A significant amount of arsenic escapes the kiln when incinerated at a kiln temperature of nominally 990°C (1820°F). At these higher temperatures, the kiln ash fraction is reduced to between 36 to 56 percent due to arsenic volatilization in the kiln. Most of this escaping arsenic is collected in the APCS (38 to 55 percent of the arsenic discharged is accounted for in the APCS). Between 6 and 9 percent of the arsenic discharged is found in the APCS exit flue gas.

- Incineration at both kiln temperatures noted above effectively destroys the organic contaminants in the soil. Pesticide constituent contaminants were reduced from soil levels ranging from 39 to 501 mg/kg to not detected at a level of 0.4 mg/kg in the kiln ash. The APCS blowdown discharge contained no detectable pesticide constituents at a level of 0.02 mg/L. No detectable pesticide constituents were found in the APCS exit flue gas at detection limits of nominally 6 µg/dscm.

- Increased incineration temperatures caused increased volatilization of both arsenic and lead in the kiln with the result that kiln ash fractions were decreased as noted above.

- Changes in kiln excess air level did not affect lead distributions among incinerator discharges and did not affect arsenic distributions at the low temperature (nominally 840°C (1540°F)) kiln condition. Increasing kiln excess air from a kiln exit flue gas of 7.5 to 10.4 percent apparently decreased the amount of arsenic discharged in the kiln ash from 56 to 36 percent of the discharged amount, with a corresponding increase in the APCS collected fraction from 38 to 55 percent.

- Changing incineration conditions had no affect on APCS apparent removal efficiency for either arsenic or lead. APCS apparent arsenic removal efficiency was in the 82 to 92 percent range, the same as for overall particulate. APCS apparent lead removal efficiency was lower, in the 33 to 43 percent range.

- Kiln ash lead was not leachable in the TCLP test (TCLP leachates contained no detectable lead at a level of 0.05 mg/L). Between 9 and 62 percent of the kiln ash arsenic was mobile, and found in the TCLP leachate. Increasing kiln temperature marginally increased kiln ash arsenic leachability. Decreasing kiln excess air significantly increased kiln ash arsenic leachability.

Other conclusions from the incineration tests include:

- The observed relative volatilities of arsenic and lead agree with expectations from physical vapor pressure data; arsenic is significantly more volatile than lead at both kiln temperatures tested

- No incinerator discharge stream (kiln ash nor APCS blowdown) had TCLP leachate concentrations exceeding TC limits for either arsenic or lead

- Particulate emissions after the APCS were significantly below the federal hazardous waste incinerator performance standard

Further conclusions from the muffle furnace tests include:

- Adding lime to the site soil significantly decreases both the volatility of arsenic in the soil, as well as the leachability of the arsenic remaining in the soil ash

- Adding alum to the soil significantly increases arsenic volatility but does not affect resulting ash arsenic leachability

- Neither lime nor alum affects lead volatility nor resulting ash lead leachability

The results from the test program suggest that incineration is a viable treatment technology for remediating the Baird and McGuire site. The muffle furnace results combined with the incineration results suggest that a soil with arsenic content below about 150 mg/kg can be incinerated under any combination of kiln temperature/kiln excess air level to given an organically decontaminated ash with TCLP leachable arsenic below the limit which would prevent its landfill disposal.

The incineration test results suggest that soil with arsenic levels as high as 1200 mg/kg could be incinerated to give a kiln ash with TCLP leachate concentration less than 5 mg/L, provided incineration was under low kiln temperature (nominally 840°C (1540°F))/high kiln excess air (kiln exit flue gas O_2 nominally 11 percent) conditions. The muffle furnace test results suggest that even higher soil arsenic levels could be incinerated to give a kiln ash with TCLP leachate arsenic concentration of less than 5 mg/L with lime addition to the soil.

Test results were documented in the test report:

- King C., and L. R. Waterland, "Pilot-Scale Incineration of Arsenic-Contaminated Soil from the Baird and McGuire Superfund Site," draft March 1990, revised May 1990.

Test results were also presented in two technical papers:

- Wall, H. O., and M. K. Richards, "The Incineration of Arsenic-Contaminated Soils Related to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)," presented at the Sixteenth Annual Research Symposium on the Remedial Action, Treatment, and Disposal of Hazardous Waste, Cincinnati, Ohio, April 1990.

- Waterland, L. R., C. King, R. C. Thurnau, and M. K. Richards, "Incinerability Testing of an Arsenic-Contaminated Superfund Site Soil," presented at the Pacific Northwest International Section of the Air and Waste Management Association 1990 Conference, Portland, Oregon, November 1990.

In addition, test results are planned for presentation in a third technical paper:

- Waterland, L. R., C. King, R. H. Vocque, M. K. Richards, and H. O. Wall, "Pilot-Scale Incinerability Evaluation of Arsenic- and Lead-Contaminated Soils from Three Superfund Sites," for presentation at the Incineration Conference — 1991, Knoxville, Tennessee, May 1991.

SECTION 5

INCINERABILITY TESTING OF CONTAMINATED SOILS FROM THE PURITY OIL SALES AND THE McCOLL SUPERFUND SITES

A second series of tests to evaluate the potential of incineration as a treatment option for contaminated soils at Superfund sites was completed during FY90. This series of tests, performed at the request of EPA Region 9 (J. Blevins, R. Blank, J. Rosati, P. Wieman, Coordinators), evaluated the incinerability of three contaminated materials from the Purity Oil Sales site in Fresno, California, and two contaminated soils from the McColl site in Fullerton, California.

The Purity Oil Sales site is an abandoned oil recycling facility. The results of a soil stratigraphy investigation of the site indicated that four contaminated subsurface layers are present in the waste pit area at the site. The top layer is comprised primarily of construction rubble, sand, and gravel. The second layer, or tar sludge, underlies the construction debris and is mixed, to some extent, with soil and rubble. The third layer is comprised of contaminated silty sand. The fourth layer is uncontaminated to slightly contaminated silty sand. The materials tested in this program were from the first (A layer), second (B layer), and third (C layer) subsurface layers. The materials are contaminated to varying degrees with organic contaminants and lead. Concentrations of both are highest in the B layer.

The McColl site is an abandoned refinery waste disposal area. The major contaminants in soil at the site are organic constituents and sulfur. The soil borings excavated from the site during the remedial investigation/feasibility study efforts were stored in drums at the site. The physical characteristics of the materials do not vary significantly from drum to drum. Two drums, one containing a high-sulfur-content material and a second containing a low-sulfur-content material, were selected for testing in this test program.

The overall objective of the test program was to determine whether treatment by incineration would result in a treated soil residue suitable for redeposit at each site during full-scale remediation. Specific technical objectives were as follows:

- To determine the distribution of lead present in the Purity Oil Sales site soils among the RKS discharges, and assist EPA in assessing the suitability of RKS incineration for treating the Purity Oil Sales site soils by identifying metal fate
- To determine the flue gas emission and incineration residuals concentrations of the semivolatile organic hazardous constituents to verify the suitability of RKS incineration for treating the materials

- To evaluate the effectiveness of the single stage ionizing wet scrubber APCS for removing lead (Purity Oil Sales site), SO_2, and SO_3, and thereby determine the suitability of this APCS for controlling flue gas lead, SO_2, and SO_3 emissions

- To demonstrate compliance with the hazardous waste incinerator performance standards for particulate emissions

The tests were completed during January and February 1990. The draft test report summarizing test results was completed in September 1990. An outline of the test program and test results are given in the following subsections.

5.1 TEST PROGRAM

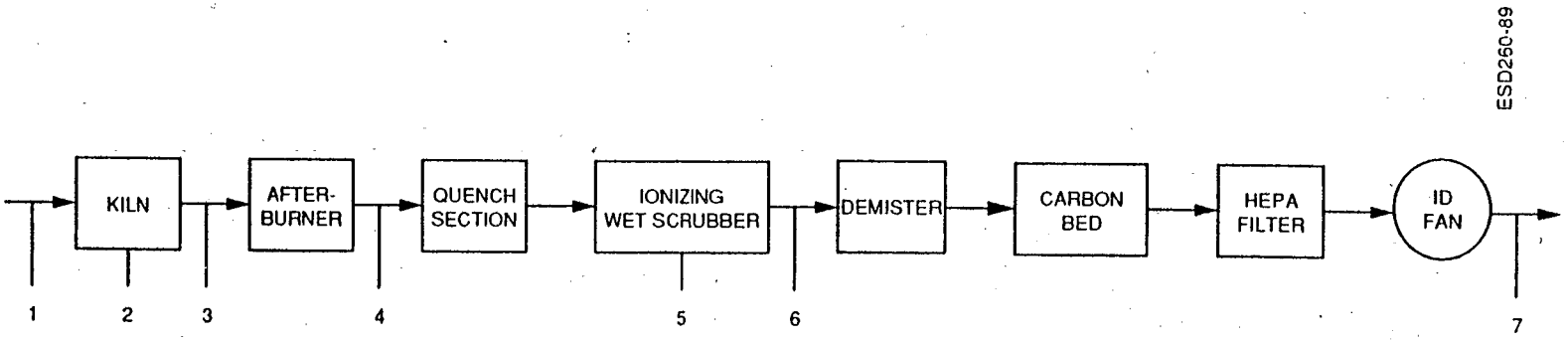
The test program consisted of five tests, one each with the three Purity Oil Sales soils and the two McColl soils. All tests were performed in the RKS at the IRF with the ionizing wet scrubber primary APCS in operation. A schematic of the RKS is given in Figure 1 and the design characteristics of the system are given in Table 1, in Section 3.

Each soil tested was shipped to the IRF in a 55-gal drum. Nominally 200 kg (440 lb) of each material was shipped. Prior to testing, each material was packaged into 1.5-gal fiberpack containers at the IRF for feeding to the RKS via the ram feeder system. Each fiberpack drum was filled with nominally 4.1 kg (9 lb) of test material. During the tests, each material was fed to the kiln at a rate of 12 fiberpack drums per hr (1 drum every 5 min). Thus, test material feedrate was approximately 49 kg/hr (108 lb/hr). Each test was nominally 4 hr in duration. All tests were conducted under nominally the same set of incinerator operating conditions. These conditions are listed in Table 9. The kiln rotation speed noted in Table 9 corresponds to a solids residence time in the kiln of about 1 hr.

Figure 10 identifies the sampling location for the tests and summarizes the sampling protocols employed.

TABLE 9. NOMINAL INCINERATOR SYSTEM OPERATING CONDITIONS FOR PURITY SOIL SALES AND McCOLL SITE SOIL INCINERATION TESTS

Total waste/soil feedrate	49 kg/hr (108 lb/hr)
Kiln temperature	871°C (1600°F)
Kiln exit flue gas O_2	11 to 13%
Afterburner	982°C (1800°F)
Afterburner exit flue gas O_2	9 to 11%
Kiln rotation speed	0.2 rpm
Scrubber blowdown flowrate	1.9 L/min (0.5 gpm)
Scrubber liquor flowrate	230 L/min (60 gpm)
Scrubber pressure drop	1.5 kPa (6 in W.C.)



Sampling point	Waste feed	Kiln ash	Ionizing wet scrubber blowdown	Continuous flue gas monitoring	Method 0010 (semivolatile organics)	Method 12 (lead)	Method 5/8 (particulate SO_2, SO_3)
1	X						
2		X					
3				X			
4				X			
5			X				
6				X	X	X	X
7				X	X	X	X

Figure 10. Sampling matrix.

5.2 TEST RESULTS

Throughout the test program, CO levels at the scrubber exit and the stack were at most a few ppm. Total unburned hydrocarbon levels were similarly low at the afterburner exit, scrubber exit, and in the stack. Average NO_x concentrations at the stack ranged from 20 to 38 ppm, levels typical for the RKS. Average SO_2 levels measured using a continuous SO_2 emission monitor at the stack were <1 ppm for the Purity Oil Sales site soil tests, and 4 to 7 ppm for the McColl site sulfur-contaminated soil tests.

Flue gas particulate levels at the scrubber exit ranged from 6 mg/dscm (at 7 percent O_2) for the Purity C layer material test to 126 mg/dscm (at 7 percent O_2) the McColl high-sulfur-material test. In the stack, particulate levels ranged from 7 mg/dscm (at 7 percent O_2) for the Purity C layer material test to about 70 mg/dscm (at 7 percent O_2) for both the Purity B layer and McColl high-sulfur-material tests. All levels fell well below the federal hazardous waste incinerator performance standard of 180 mg/dscm (at 7 percent O_2).

Table 10 summarizes the ultimate analysis data for the soil samples from each test drum. Table 10 also shows the carbon content of the kiln ash resulting from the incineration of each test soil. The data suggest that incineration was quite effective in destroying the overall organic content (as indicated by total carbon content) of the Purity site soils. However, the kiln ash resulting from the incineration of the McColl site materials still had significant carbon content.

Table 11 summarizes the semivolatile organic hazardous constituent analysis results for each soil. As shown, of the semivolatile organic hazardous constituents, naphthalene was found in four of the five soils, and bis-(2-ethylhexyl)-phthalate was found in three of the five. Organic analyses of kiln ash, kiln ash TCLP leachate, and scrubber blowdown TCLP leachate samples for each test showed that all semivolatile organic hazardous constituents analyzed were present at less than method detection limits in all cases. Thus, the kiln ash from all tests contained less than detectable concentrations of the semivolatile constituents analyzed at detection limits of 1 to 2 mg/kg. Semivolatile organic contaminants were specifically not detected in the McColl soil kiln ashes despite their significant residual carbon content noted above. Kiln ash and scrubber blowdown TCLP leachate samples contained less than detectable concentrations of semivolatile constituents at detection limits of 0.02 to 0.04 mg/L.

Scrubber exit and stack flue gas semivolatile organic concentrations were less than detectable at detection limits of 4 to 12 µg/dscm for all constituents except bis-(2-ethylhexyl)-phthalate. Apparent flue gas bis-(2-ethylhexyl)-phthalate concentrations of 8 to 80 µg/dscm are ascribed to commonly-encountered laboratory contamination for this compound.

Test results with respect to lead distributions for the Purity Oil Sales site soil tests are summarized in Table 12. The table shows lead concentrations measured in each soil feed, kiln ash, scrubber blowdown, flue gas, soil feed EP toxicity and TCLP leachate, kiln ash EP toxicity and TCLP leachate, and scrubber blowdown EP toxicity and TCLP leachate sample analyzed.

As shown in Table 12, the lead concentrations of the Purity Oil Sales site soils ranged from 780 to 10,200 mg/kg, with the highest concentrations found in the Purity B layer soil. Lead concentrations in resulting kiln ash from the incineration treatment of all soils were higher than the parent soil concentrations, consistent with the volume reduction of the material with

TABLE 10. ULTIMATE ANALYSIS OF THE TEST SOILS AND RESULTING KILN ASHES

Parameter (wt %)	Soil				
	Purity A layer (Test 1)	Purity C layer (Test 2)	Purity B layer (Test 3)	McColl low sulfur (Test 4)	McColl high sulfur (Test 5)
C	2.14	1.63	24.83	15.64	19.88
H	0.99	<0.5	4.64	3.36	3.65
O	5.27	2.75	17.50	17.13	20.83
N	<0.5	<0.5	<0.5	<0.5	<0.5
S	0.58	0.43	2.43	3.58	8.13
Cl	<0.18	<0.21	<0.27	<0.58	<0.28
Ash	86.09	86.15	58.39	57.29	41.40
Total organic carbon	1.74	1.61	24.83	15.60	19.88
	Kiln ash				
C	0.19	0.12	3.39	4.18	6.65

TABLE 11. SEMIVOLATILE ORGANIC HAZARDOUS CONSTITUENTS IN TEST SOILS

Constituent	Concentration (mg/kg)				
	Purity A layer (Test 1)	Purity C layer (Test 2)	Purity B layer (Test 3)	McColl low sulfur (Test 4)	McColl high sulfur (Test 5)
Naphthalene	ND[a]	35	90	96	340
Bis-(2-ethylhexyl)-phthalate	ND	77	41	ND	43
All other semivolatiles analyzed	<25	<25	<25	<25	<25

[a]ND — not detected.

TABLE 12. LEAD DISTRIBUTIONS FOR THE PURITY OIL SALES SITE SOIL TESTS

Parameter	Test 1 (1/19/90) Purity A layer	Test 2 (1/23/90) Purity C layer	Test 3 (1/31/90) Purity B layer
Lead concentration			
Soil feed, mg/kg	860	780	10,200
Kiln ash, mg/kg	1,620	1,830	23,800
Scrubber blowdown, mg/L	2.8	3.2	45
Scrubber exit flue gas, mg/dscm	1.6	1.0	24
Stack gas, mg/dscm	1.2	0.47	21
Lead flowrate, g/hr			
Soil feed	42	39	510
Kiln ash	61	63	588
Scrubber exit flue gas	3.3	1.9	46
Stack gas	2.8	1.0	45
Soil feed leachate			
EP toxicity concentration, mg/L	2.1	2.6	2.6
Fraction leachable, %	4.9	2.8	0.5
TCLP concentration, mg/L	5.7	18	21
Fraction leachable, %	13	46	4.1
Kiln ash leachate			
EP toxicity concentration, mg/L	<0.07	0.23	0.33
Fraction leachable, %	<0.1	0.25	0.03
TCLP concentration, mg/L	10	15	110
Fraction leachable, %	12	16	9.2
Scrubber blowdown leachate			
EP toxicity concentration, mg/L	1.4	1.2	19
TCLP concentration, mg/L	1.4	1.2	17

incineration. Kiln ash lead concentrations were roughly doubled over the parent soil concentrations. Scrubber blowdown lead concentrations were in the 3 mg/L range for the Purity A and C layer soils, and 45 mg/L for the Purity B layer soil. Similarly, scrubber exit flue gas concentrations were in the 1 to 2 mg/dscm range for the Purity A and C layer soil tests, and 24 mg/dscm for the high-lead-concentration Purity B layer soil test. Measured stack gas concentrations were generally slightly lower, and in the 0.5 to 1.2 mg/dscm range for the Purity A and C layer soil tests, and 21 mg/dscm for the high-lead-concentration Purity B layer soil test.

EP toxicity leachates of all three Purity Oil Sales site soils had comparable lead concentrations of about 2 mg/L. TCLP leachate concentrations were higher, ranging from 5.7 to 21 mg/L. The toxicity characteristic (TC) threshold concentration for lead is 5 mg/L. Thus, no Purity Oil Sales site soil would be considered a characteristic hazardous waste for lead, based on the EP toxicity test, but all three would be considered so based on the TCLP test.

Despite the fact that the kiln ash resulting from the incineration treatment of the Purity Oil Sales soils contained roughly twice the lead concentrations of the parent soil, their EP toxicity leachate concentrations were lower. TCLP leachate concentrations for the kiln ash of both soils were significantly greater than corresponding EP toxicity leachate concentrations, and generally greater than the parent soil TCLP leachate concentrations. As was the case with the Purity Oil Sales site soils, these tests suggest that the kiln ash resulting from incineration treatment of the soils would not be considered a characteristic hazardous waste for lead, based on the EP toxicity test, but would be considered so, and thus banned from landfill disposal without further treatment, based on the TCLP test (which is the current regulatory requirement).

Both the EP toxicity and TCLP leachate lead concentrations of the scrubber blowdown from all three Purity Oil Sales site soils were comparable, and were lower than the parent scrubber blowdown concentration. For the Purity materials, scrubber blowdown EP toxicity and TCLP leachate concentrations were half or less than half of the concentrations of the parent blowdown sample. This is understandable. Both the EP toxicity and TCLP methods for liquid samples specify filtering the blowdown sample, then weighing the solid residue. If the solid residue accounts for less than 0.5 percent of the original blowdown sample (as was the case for these tests), the solid residue is discarded, and the resulting filtrate is defined to be the corresponding leachate. The fact that scrubber blowdown EP toxicity and TCLP leachate concentrations were similar for all Purity Oil Sales site material tests is to be expected, therefore, since the procedures result in analyzing essentially the same sample (scrubber blowdown filtrate). The fact that leachate (i.e., filtrate) samples contained less lead than the unfiltered blowdown sample merely confirms that some of the blowdown lead was contained as insoluble lead in the blowdown suspended soils (i.e., collected particulate) fraction.

Table 13 summarizes the lead discharge distributions measured in each test on a percent of feed basis. Entries in Table 13 correspond to the fraction (in percent) of lead fed accounted for by each of the incineration system discharge streams: kiln ash, scrubber liquor, and scrubber exit flue gas. These fractions were calculated from the measured lead concentrations in samples analyzed from Table 12, and the appropriate stream flowrate (i.e., soil feedrate, flue gas flowrate, and kiln ash discharge rate). Also shown in Table 13 is the total ash fraction for each test. This represents the ratio of the total weight of kiln ash discharged in a test to the total weight of soil fed. The ash fractions measured from the RKS generally compare favorably to the ultimate analysis results for soil feed samples noted in Table 10.

TABLE 13. LEAD DISCHARGE DISTRIBUTIONS FOR THE PURITY OIL SALES SITE SOIL TESTS

Parameter	Test		
	Test 1 Purity A layer	Test 2 Purity C layer	Test 3 Purity B layer
Total kiln ash discharge (% of soil weight fed)	77	69	49
	Lead distribution (% of lead fed)		
Kiln ash	146	163	115
Scrubber liquor	1	1	2
Scrubber exit flue gas	8	5	9
Total	155	169	126

The data in Table 13 show that, for the Purity Oil Sales soil tests, between 5 and 9 percent of the soil lead was accounted for in the scrubber exit flue gas discharge, with 1 to 2 percent accounted for in the scrubber liquor. Most, between 115 and 163 percent, of the lead fed for the Purity soils was discharged in the kiln ash. Total balance closure for the Purity tests was 126 to 169 percent. This level of mass balance closure for lead in the system is considered acceptable when viewed in light of past experience in achieving trace metal mass balance closure from a variety of combustion sources, incinerators included. Typical mass balance closure results from this past experience have been in the 30 to 200 percent range.

5.3 CONCLUSIONS

Test conclusions include:

- The organic contaminants in all five test soils were completely destroyed based on the analytical methods used to measure contaminant concentrations. No detectable semivolatile organic constituents were present in the kiln ash, scrubber blowdown, or flue gas resulting from the incineration of any of the five tested contaminated soils, with the exception of bis-(2-ethylhexyl)-phthalate (a common laboratory contaminant) in flue gas samples.

- Particulate emissions at the exit of the single stage ionizing wet scrubber employed for particulate and acid gas control ranged from 6 to 126 mg/dscm at 7 percent O_2, depending on the test soil. All measured levels were below the federal hazardous waste incinerator performance standard of 180 mg/dscm at 7 percent O_2.

- For the Purity Oil Sales site soil tests, kiln ash lead concentrations were roughly double the parent soil concentrations. Scrubber blowdown lead concentrations

were about 3 mg/L for the two low-lead-concentration Purity soils (on the order of 800 mg/kg lead contamination). Scrubber exit flue gas concentrations were 1 to 1.6 mg/dscm for these soils. For the high-lead-concentration Purity soil (10,200 mg/kg lead), scrubber blowdown and exit flue gas concentrations were increased to 45 mg/L and 24 mg/dscm, respectively. Between 5 and 9 percent of the lead fed to the incinerator was accounted for in the scrubber exit flue gas for all three soils. Lead concentrations in the scrubber blowdown, EP toxicity leachates of the soil feed, kiln ash, and scrubber blowdown, and TCLP leachates of scrubber blowdown, were less than the TC threshold defining a characteristic hazardous waste for the two low-lead-concentration Purity soils. However, lead concentrations in TCLP leachates of the soil feed and kiln ash exceeded the TC threshold for these soils. Lead concentrations in the scrubber blowdown, EP toxicity leachates of the scrubber blowdown, and TCLP leachates of the soil feed, kiln ash, and scrubber blowdown, for the high-lead-concentration Purity soil, exceeded the TC threshold. EP toxicity leachates of the soil feed and kiln ash for this soil, however, did not exceed the TC threshold.

Test results suggest that incineration would be an acceptable treatment option for the McColl site materials. Based on these results, organic contaminant destruction is complete; particulate emissions comply with the federal hazardous waste incinerator performance standards; SO_2 emissions are low; and incineration residuals would not be considered characteristic hazardous wastes.

Incineration could be considered applicable to the treatment of the Purity Oil Sales site soils based on effective organic decontamination; in-compliance (with federal standards) particulate emissions; and low SO_2 emissions. However, these test results indicate that the resulting kiln ash would require further treatment to stabilize or remove leachable lead, and that the scrubber blowdown from the incineration of the high-lead-concentration soil would be considered a characteristic hazardous waste if a wet scrubber were used for air pollution control. Furthermore, the acceptability of lead emission levels from a wet scrubber control device would require further evaluation.

Test results were documented in the test report:

- Vocque R. H., and L. R. Waterland, "Pilot-Scale Incineration of Contaminated Soil from the Purity Oil Sales and McColl Superfund Sites," draft September 1990.

In addition, test results are planned for presentation in a technical paper:

- Waterland, L. R., C. King, R. H. Vocque, M. K. Richards, and H. O. Wall, "Pilot-Scale Incinerability Evaluation of Arsenic- and Lead-Contaminated Soils from Three Superfund Sites," for presentation at the Incineration Conference—1991, Knoxville, Tennessee, May 1991.

SECTION 6

PARAMETRIC TESTING TO EVALUATE THE PROPOSED POHC INCINERABILITY RANKING

One of the primary functions of the IRF is to conduct research activities for OSW in support of regulation development and implementation. One major regulatory issue of high priority during FY90 concerned the evaluation of the thermal stability-based POHC incinerability ranking developed over the past several years by the University of Dayton Research Institute (UDRI) under contract to RREL. Current hazardous waste incinerator permits have been issued based on the heat of combustion ranking of POHC incinerability. This ranking has several acknowledged deficiencies. UDRI has developed an alternative ranking based on the temperature required to achieve 99 percent destruction at 2 s residence time under oxygen-starved conditions as measured in laboratory experiments. The evaluation of this ranking under actual incineration conditions became a high-priority research need in FY90.

The test program discussed in this section was designed to develop the data to evaluate the POHC incinerability ranking. The specific objectives of the test program were to measure each POHC's DRE under each of several modes of incinerator operation, and compare relative POHC DREs as a function of incineration conditions and feed characteristics. In the tests, a mixture (soup) of 12 POHCs with predicted incinerability spanning the range of the most difficult to incinerate (refractory) class to the least difficult to incinerate (labile) class was tested. This mixture was combined with a clay-based sorbent solid matrix and packaged into fiberpack drums for batch feeding to the RKS at the IRF.

A series of five experiments were performed over which incinerator operating conditions and test mixture composition were varied. Specific test program variables were kiln temperature, feed batch charge mass, and feed composition, specifically H/Cl ratio. One test was performed under typical operating conditions with a baseline soup composition. The other tests varied the above in an attempt to simulate various modes of incineration failure: thermal failure, mixing failure, feed matrix effects, and a worst-case combination of these.

6.1 TEST PROGRAM

The test program was conducted in the IRF RKS with the venturi/packed column scrubber APCS in use. Figure 1 in Section 3 shows a simplified schematic of the RKS, and Table 1 gives the design characteristics of the key system components.

The 12 POHCs included in the test synthetic waste mixtures were selected in consultation with UDRI, RREL, OSW, and EPA incinerator permit writer personnel. The

incinerability ranking groups the 333 POHCs included in the ranking into 7 stability classes from most refractory (Class 1) to most labile (Class 7). UDRI recommended that two compounds from each class be included in the test mixture and provided a list of candidates for selection. The compounds tested were selected from this candidate list, their selection guided by ease of flue gas sampling and sample analysis, compound compatibility, compound availability, and safety considerations. The compounds in the test POHC mixture are listed in Table 14. The table also notes the target composition of two test mixtures containing the POHCs with different H/Cl ratios.

The POHC liquid mixtures prepared for the tests were combined with a clay-based oil sorbent solid and packaged into 1.5-gal fiberpack drums for feeding to the RKS. Each fiberpack contained nominally 3 lb of POHC test mixture and 5 lb of clay sorbent.

As noted above, the test program was designed to evaluate the relative incinerability of the POHCs in the test mixture under typical, or normal, incineration conditions, and then evaluate relative incinerability under several modes of potential incineration failure: thermal failure, mixing failure, more challenging feed mixture, and a worst-case combination of these three.

Table 15 summarizes the test conditions for each of the five tests performed. The normal incineration mode test was run at a kiln temperature of nominally 871°C (1600°F) with a baseline soup/clay feedrate of 1 fiberpack drum charge every 5 min. Thermal failure was achieved by decreasing kiln temperature to nominally 649°C (1200°F), by decreasing the auxiliary fuel (natural gas) feedrate to the kiln, and by introducing water in the POHC/clay mixture. Mixing failure was achieved by doubling the drum charge mass to two drums per charge, although overall drum feedrate was kept constant by decreasing the charge frequency to every 10 min. Doubling charge mass was expected to produce oxygen-starved pockets of combustion gas in the kiln. Matrix effects were investigated by testing the low-H/Cl-ratio POHC mixture at the baseline condition of nominally 871°C (1600°F) kiln temperature and 1 drum charge every 5 min. A worst-case condition of nominally 649°C (1200°F) kiln temperature and a 2-drum charge of the low-H/Cl-POHC mixture comprised the fifth test. Overall POHC feed mixture feedrate was held constant for all tests.

6.2 SAMPLING AND ANALYSIS

Satisfying the test objectives required that the DRE of each POHC be measured for each test, so that relative DREs among the test POHCs could be confirmed. For this purpose, the primary flue gas sampling location was at the kiln exit since incinerator failure modes were simulated in this test program by varying kiln conditions. However, it was also of interest to evaluate the relative magnitude of additional POHC destruction and removal achieved in the afterburner and APCS of the RKS, and to assess whether relative POHC DREs are preserved through these processes. Thus, a secondary flue gas sampling location was at the APCS exit. In addition, sampling was performed of the system's stack discharge, after further flue gas treatment in the system's secondary APCS, to meet the requirements of the IRFs hazardous waste management permit. Finally, POHC feed mixture, kiln ash, and APCS blowdown discharge samples were taken for POHC analysis. The specific sampling and analysis protocol employed for all five tests included:

TABLE 14. INCINERABILITY RANKING MIXTURE COMPOSITION

Component	Concentration (wt%) Mixture 1 high H/Cl	Mixture 2 low H/Cl	$T_{99}(2)$[a](°C)	Rank[b]	Stability class
Benzene	8	4	1150	3	1
Chlorobenzene	8	4	990	22	1
Tetrachloroethene	8	33	890	43	2
1,2,2-trichloro-1,1,2-trifluoroethane (Freon 113)	8	4	780	92	3
Benzenethiol	8	4	725	122	3
Nitrobenzene	8	4	655	150,151	4
Hexachlorocyclohexane (Lindane)	10	5	645	159	4
Hexachloroethane	10	25	585	213	5
1,1,1-trichloroethane	10	5	545	233	5
p-dimethylaminoazobenzene (Methyl yellow)	10	5	~400	268	6
Nicotine	10	5	<320	286 to 289	7
N-nitroso-di-n-butyl amine	2	2	<320	316 to 331	7
Ultimate composition					
C	46.0	29.8			
H	3.9	2.1			
O	2.3	1.2			
N	4.9	2.6			
S	2.3	1.2			
Cl	38.2	61.9			
F	2.4	1.2			
Higher heating value, MJ/kg (Btu/lb)	19.6 (8450)	12.0 (5170)			
H/Cl (molar)	3.6	1.2			

[a]Temperature required to achieve 99 percent destruction in 2 s.
[b]Incinerability rank in list range from most refractory (No. 1) to most labile (No. 333).

TABLE 15. TEST CONDITIONS

Parameter	Test 1 baseline (6/26/90)	Test 2, thermal failure (7/17/90)	Test 3, mixing failure (7/3/90)	Test 4, matrix effect (6/29/90)	Test 5, worst case (7/12/90)
Feed mixture (see Table 14)	1	1	1	2	2
Feedrate, kg/hr (lb/hr)					
Organic soup	17 (37)	17 (37)	17 (37)	17 (37)	17 (37)
Water	—	11(24)	—	—	—
Organic/clay/water mixture	46 (98)	56 (122)	46 (100)	46 (98)	46 (100)
Feed regimen					
Organic/clay/water per drum, kg (lb)	3.6(8)	4.6(10)	3.6(8)	3.6(8)	3.6(8)
Drums/charge	1	1	2	1	2
Charges/hr	12	12	6	12	6
Kiln					
Average temperature, °C (°F)	859 (1579)	663 (1226)	863 (1585)	876 (1609)	640 (1184)
Average exit O_2, %	—	14.9	—	12.2	15.2
Afterburner					
Average temperature, °C (°F)	988 (1810)	988 (1810)	988 (1810)	988 (1810)	988 (1810)
Average exit O_2, %	—	9.0	9.5	—	—

- Sampling the flue gas at the kiln exit, downstream of the APCS, and in the stack for
  - Volatile organic hazardous constituents using Method 0030 (VOST)
  - Semivolatile organic hazardous constituents using Method 0010 (MM5)
- Additional sampling of the stack gas for particulate and HCl emissions using Method 5 with impingers charged with dilute caustic for HCl capture
- Obtaining composite samples of the kiln ash and APCS blowdown, and analyzing them for both volatile and semivolatile organic hazardous constituents
- Analyzing aliquots of the prepared synthetic waste feed for POHCs

- Continuous monitor sampling of location-specific combinations of flue gas O_2, CO_2, CO, NO_x, and heated and unheated TUHC at the kiln, afterburner, and scrubber exits and in the stack

Figure 11 summarizes the test program sampling protocol.

6.3 TEST RESULTS

The test program was performed in late June and early July 1990. Most sample analysis efforts were completed by the end of FY90. However, test data reduction and interpretation were still underway.

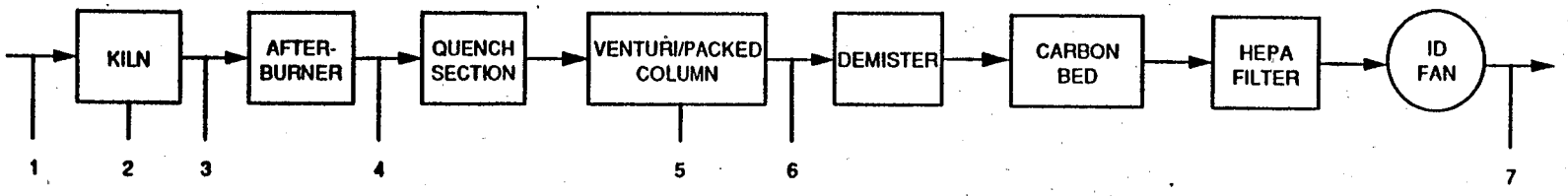
Preliminary results indicate the following:

- Benzenethiol, methyl yellow, nicotine, and N-nitroso-di-n-butyl amine destruction was essentially complete, even at the kiln exit, for all tests. These compounds were not detected in the kiln exit flue gas in any test.

- Kiln exit DREs for the other eight POHCs were, from test to test, comparable for Test 1 (baseline), Test 3 (mixing failure), and Test 4 (matrix effect). Benzene, chlorobenzene, tetrachloroethene, Freon 113, and 1,1,1-trichloroethane DREs were in the 99.99 to 99.999 percent range for all three tests. Nitrobenzene, Lindane, and hexachloroethane were not detected in the kiln exit flue gas in these three tests

- Kiln exit DREs for the other eight POHCs ranged from 99 to 99.9999 percent for Test 2 (thermal failure) and Test 5 (worst case), and were generally comparable for each POHC for both tests. From Freon 113 through hexachloroethane, measured DRE generally agreed with the incinerability ranking. Apparent 1,1,1-trichloroethane DRE was lower than would be predicted by the ranking; however, 1,1,1-trichloroethane is a common product of incomplete combustion (PIC) from chlorinated hydrocarbon combustion. Benzene, chlorobenzene, and tetrachloroethylene DREs were greater than the DRE for Freon 113, which is not expected from the incinerability ranking

Data interpretation and test reporting will proceed through completion in FY91.



ESD 044-89

SAMPLE LOCATIONS

	Feeds and residuals			Continuous monitors					Flue gas		
Sampling point	POHC/clay mixture	Kiln ash	Scrubber blowdown	O_2	CO, CO_2	NO_x	Unheated TUHC	Heated TUHC	Method 0010 (semivolatile organics)	Method 0030 (volatile organics)	Method 5 Particulate and HCl
1	X										
2		X									
3				X	X		X	X	X	X	
4				X							
5			X								
6				X		X	X	X	X	X	
7				X	X			X	X	X	X

Figure 11. Sampling matrix.

SECTION 7

EXTERNAL COMMUNICATIONS

During FY90, four reports were prepared and submitted, and eight technical papers were presented. These are listed in Table 16. This level of external communication and technology transfer is comparable to levels experienced over the preceding three years and testifies to the high level of important research being supported at the IRF.

Table 17 lists some of the visitors to the IRF during FY90. The length of the list attests to the visibility to the incineration research community of the work being performed at the IRF.

TABLE 16. IRF PROGRAM REPORTS AND PRESENTATIONS IN FY90

Reports

- Waterland, L. R., "Operations and Research at the U.S. EPA Incineration Research Facility, Annual Report for FY89," draft December 1989, revised January 1990, published as EPA/600/2-90/012, March 1990
- King C., and L. R. Waterland, "Pilot-Scale Incineration of Arsenic-Contaminated Soil from the Baird and McGuire Superfund Site," draft March 1990, revised May 1990
- Fournier, Jr., D. J., and L. R. Waterland, "The Fate of Trace Metals in a Rotary Kiln Incinerator with an Ionizing Wet Scrubber," draft April 1990
- Vocque, R. H., and L. R. Waterland, "Pilot-Scale Incineration of Contaminated Soil from the Purity Oil Sales and McColl Superfund Sites," draft September 1990

Papers and Presentations

- Carroll, G. J., L. R. Waterland, and D. J. Fournier, Jr., "Parametric Evaluation of Metal Partitioning at the U.S. EPA Incineration Research Facility," presented at the Sixteenth Annual Research Symposium on the Remedial Action, Treatment, and Disposal of Hazardous Waste, Cincinnati, Ohio, April 1990
- Wall, H. O., and M. K. Richards, "The Incineration of Arsenic-Contaminated Soils Related to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)," presented at the Sixteenth Annual Research Symposium on the Remedial Action, Treatment, and Disposal of Hazardous Waste, Cincinnati, Ohio, April 1990
- Thurnau, R. C., and J. W. Lee, "IRF Update," presented at the Sixteenth Annual Research Symposium on the Remedial Action, Treatment, and Disposal of Hazardous Waste, Cincinnati, Ohio, April 1990
- Waterland, L. R., D. J. Fournier, Jr., J. W. Lee, and G. J. Carroll, "Trace Metal Fate in a Rotary Kiln Incinerator with an Ionizing Wet Scrubber," presented at the Incineration Conference — 1990, San Diego, California, May 1990
- Waterland, L. R., "The EPA Incineration Research Facility: Capability, Availability," presented at HazWaste Expo Atlanta 90, Atlanta, Georgia, May 1990, and at HazWaste Expo San Diego 90, San Diego, California, June 1990
- Fournier, Jr., D. J., L. R. Waterland, and G. J. Carroll, "Trace Metal Size Distributions in Flue Gas Particulate from a Rotary Kiln Incinerator," presented at the American Association for Aerosol Research 1990 Annual Meeting, Philadelphia, Pennsylvania, June 1990
- Fourier, Jr., D. J., L. R. Waterland, and G. J. Carroll, "Size Distributions of Trace Metals in Flue Gas Particulate from a Pilot-Scale Rotary Kiln Incinerator," presented at the American Flame Research Committee 1990 Fall International Symposium on NO_x Control, Waste Incineration, and Oxygen-Enriched Combustion, San Francisco, California, October 1990
- Waterland, L. R., C. King, R. C. Thurnau, and M. K. Richards, "Incinerability Testing of an Arsenic-Contaminated Superfund Site Soil," presented at the Pacific Northwest International Section of the Air and Waste Management Association 1990 Conference, Portland, Oregon, November 1990

TABLE 17. VISITORS TO THE IRF

Person	Affiliation	Date	Purpose of visit
J. Lewtas S. Harmon P. Fu K. Dooley	EPA/HERL EPA/HERL NCTR NCTR	10-11-90	Discuss possible bioassay testing
A. Shattuck O. Kitaplioglu H. Huppert E. McNicholas M. Gamboa	SAIC SAIC SAIC SAIC SAIC	11-7-89	K088 BDAT test planning, facility tour
M. Kourhedar D. Webster	ADPCE EPA/Region 6	11-8-89	Corrective action site inspection
J. Riseley E. Holan	Koch Engineering Koch Engineering	1-24-90	Facility tour
G. Mininni	National Research Council, Italy	1-25-90	Facility tour
B. Blaney E. Bates F. Freestone R. Olexsey	EPA/RREL EPA/RREL EPA/RREL EPA/RREL	1-29-90	Facility tour to assess capabilities to support START program
R. Loftus	USDA	1-30-90	Facility tour
B. Keogh	CH_2M Hill	2-5-90	Facility tour
D. Brama J. Smith	AVS Video AVS Video	2-6-90	Produce facility video
M. Abdulhafid	ADPCE	2-7-90	Facility tour
G. Carroll R. Hill	EPA/RREL EPA/RREL	3-12-90	Facility tour, project review
J. Whitney R. Gentry	Rineco Gentry & Assoc.	5-10-90	Discuss possible third party testing
B. Blackburn	S-Cubed	5-17-90	QA review
J. Frubob	ADPCE	6-1-90	Annual hazardous waste inspection
G. Carroll	EPA/RREL	6-5,6-90	Project review
S-C. Yung	Calvert Environmental	6-8-90	Discuss use of pilot scrubber in test program

(continued)

TABLE 17. CONCLUDED

Person	Affiliation	Date	Purpose of visit
M. Henderson	Burns & Roe	6-14-90	Facility tour
B. Muler	Burns & Roe		
F. Ryan	Burns & Roe		
P. Espinosa	Burns & Roe		
R. Peters	Burns & Roe		
C-L. Ku	Republic of China,	6-26-90	Facility tour
S-C. Chin	ITRI		
D-C. Lui			
M. Cramer	Arkansas	9-5-90	Facility tour
R. Sevelte	Department of		
T. McChesney	Health		
R. Mournighan	EPA/RREL	9-20-90	Drake Chemical test planning
J. I. Guzman	EPA/RREL		
R. Schrock	EPA/Region 3		
D. Johnson	USACE		
N. Narane	USACE		
C. Bisgard	USACE		
M. Fisher	USACE		
R. Wilson	JMM		
H. Wong	JMM		
J. Clayson	El Dorado Eng.		
R. Hayes	El Dorado Eng.		

SECTION 8

PLANNED EFFORTS FOR FY91

One major test program was completed in the third quarter of FY90 for which sample analyses and data evaluation efforts were underway at the end of FY90. This was the POHC incinerability ranking evaluation discussed in Section 6. Remaining test sample analyses, test data reduction and interpretation, and test reporting efforts will continue into FY91.

Most of the major facility construction and equipment upgrade efforts planned over the past 2 years were substantially completed during FY90. However, several facility and equipment improvements are planned for FY91. These include:

- Installing 5000 ft^2 of new modular office space to replace the current leased office trailers, which have served their useful life
- Completing the configuration of the automated process control system, extending its control to the entire RKS with associated scrubbers system, and bringing into operation its full data acquisition features
- Replacing the aging RKS kiln drive and drum ram feeder.

With respect to test activities, six firm test programs of varying scope are planned for FY91, as follows.

- Evaluating the capability of the IRF RKS to perform low-temperature thermal desorption studies. Scoping tests with garden topsoil were initiated in August 1990 and continued through October 1990. An additional series of tests with soil from the Caldwell Trucking Superfund site in Region 2 (E. Finerty, Region 2, and D. Hooker, USACE, coordinators). The Caldwell site soil is contaminated with high levels of volatile organics and lead. The Caldwell Trucking site soil low-temperature desorption tests are planned for December 1990.
- Residuals characterization tests to establish best demonstrated available technology (BDAT) treatment standards for spent potliners from the primary reduction of aluminum, listed waste K088 (R. Turner, J. Labiosa, L. Rosengrant, coordinators); planned for completion in January 1991.
- Incinerability testing of contaminated soils from the Drake Chemical Superfund site in Region 3 (R. Schrock, Region 3 and D. Johnson, USACE, coordinators).

Much of the planning for these tests was completed during FY90. Tests of five trace-metal-contaminated soils, two organic-contaminated soils, and two lagoon sediments are planned for completion in January and February 1991.

- Incinerability testing of PCB-contaminated marine sediments from the New Bedford Harbor Superfund site in Region 1 (M. Sanderson, Region 1 and M. Adoph, K. Howe USACE, coordinators). A parametric test program comprised of three tests at varying combinations of kiln temperatures and excess air are planned for completion in March 1991. The effect of incinerator operation on PCB destruction and contaminant trace metal fate will be evaluated.

- Testing of the fate of trace metals in the RKS using a Calvert Flux Force Condensation scrubber system for air pollution control. A test matrix similar to that employed in the ionizing wet scrubber tests discussed in Section 3 is planned for completion in May, June, and July 1991.

- Incinerability testing of arsenic- and pesticide-contaminated soil from the Chemical Insecticide Corporation Superfund site in Region 2 (J. Josephs, coordinator) using the Calvert scrubber for air pollution control. A series of three tests is planned for completion in August 1991.

Testing is expected to be initiated in December 1990 and continue relatively uninterrupted through FY91.

Other test programs currently under discussion as possible candidates for late FY91 or FY92 performance include:

- A parametric test series to evaluate the effect of feed metal form on trace metal fate in the RKS. Alternative feed metal forms other than the aqueous solution co-fed with a clay-based hazardous waste analog include an aqueous metal solution atomized into the kiln burner flame, and mixed metal oxide powders fed with the clay-based hazardous waste analog.

- A parametric field test series to evaluate a POHC surrogate "soup" for possible trial burn applications. This test series was proposed for completion during FY90, but was superseded by the incinerability ranking tests discussed in Section 6.

- Incinerability testing of contaminated materials from the SCP/Carlstadt Superfund site in Region 2

- Incinerability testing of contaminated materials from the M.W. Manufacturing Superfund site in Region 3

- Parametric testing of a synthetic Superfund soil matrix to support the Superfund Program Office

- Private sector third-party testing to be defined.

REFERENCES

1. Waterland, L. R., "Operations and Research at the U.S. EPA Incineration Research Facility: Annual Report for FY89," EPA/600/2-90/012, March 1990.

2. Barton, R. G., et al. "Development and Validation of a Surrogate Metals Mixture." Proceedings of the Fifteenth Annual Research Symposium: Remedial Action, Treatment and Disposal of Hazardous Waste, EPA/600/9-90/006, February 1990.

☆U.S. GOVERNMENT PRINTING OFFICE: 1991 - 548-187/25617