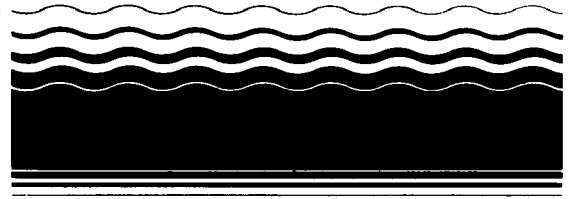




SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION



Technology Demonstration Summary

Shirco Pilot-Scale Infrared Incineration System at the Rose Township Demode Road Superfund Site

Under the Superfund Innovative Technology Evaluation or SITE Program, an evaluation was made of the Shirco Pilot-Scale Infrared Incineration System during 17 separate test runs under varying operating conditions. The tests were conducted at the Demode Road Superfund site in Rose Township, Michigan using 1,799 kg (3,967 lb) of soils contaminated with polychlorinated biphenyls (PCBs) and other organics, and lead and other heavy metals. The report includes a process description of the unit, unit operations data, sampling and analytical procedures and data, and an overall evaluation of performance and energy consumption.

The Shirco Infrared Incineration System uses electricity for infrared heating rods which heat the soil and desorb or incinerate the organic contaminants, followed by a conventional, propane-fired combustion chamber to complete the destruction of gaseous organic compounds. The system was evaluated for effectiveness in removing and destroying organic contaminants and reducing the mobility of metal contaminants under both standard

and varied operating parameters. The achievement of applicable regulatory standards and the effect of operating conditions on energy consumption were also assessed.

The results show that the unit achieved destruction and removal efficiencies (DREs) for PCBs exceeding 99.99%, based on detection limits. Several semivolatile and volatile organic compounds were measured in the stack gas at very low levels (parts per billion) and may be products of incomplete combustion (PICs). The unit achieved regulatory standards for acid gas removal and particulate emissions. Levels of residual PCBs in the furnace ash were less than 0.2 ppm under most unit operation conditions. The majority of the heavy metals remained in the furnace ash, but there was no evidence of a decrease in the mobility of lead as a result of treatment. Also, residual heavy metals were measured in the scrubber water effluent. The optimization of the heat content of the waste, retention time, and primary combustion chamber temperature can significantly reduce energy consumption and cost.

This Summary was developed by EPA's Risk Reduction Engineering Laboratory, Cincinnati, OH, to announce key findings of the SITE Program demonstration that is fully documented in two separate reports (see ordering information at back).

Introduction

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), the Environmental Protection Agency's Office of Research and Development (ORD) and Office of Solid Waste and Emergency Response (OSWER) have established a formal program to accelerate the development, demonstration, and use of new or innovative technologies as alternatives to current containment systems for hazardous wastes. This new program is called Superfund Innovative Technology Evaluation or SITE. The principal goal of the SITE program is to demonstrate new technologies in the field and develop reliable economics and performance information.

The SITE program demonstration of the Shirco Pilot-Scale Infrared Incineration System for thermal treatment developed by Shirco Infrared Systems, Inc. of Dallas, Texas, was conducted at the Demode Road Superfund Site in Rose Township, Michigan. The Demode Road site is a 12-acre waste site previously used to bury, dump, and store industrial wastes such as paint sludges, solvents, and other wastes containing PCBs, oils and greases, phenols, and heavy metals. PCBs and lead are the principal contaminants in the soil used for the test of the Infrared System.

The test was conducted from November 2-13, 1987 and treated 1,799 kg (3,967 lb) of contaminated soil under various test conditions. The major objectives of this demonstration were to determine the following:

- DRE levels for PCBs and the presence of PICs in the stack gas. The regulatory standards are 99.99% DRE under the Resource Conservation and Recovery Act (RCRA) and 99.9999% DRE under the Toxic Substances and Control Act (TSCA).
- Level of hydrogen chloride (HCl) and particulates in the stack gas. The RCRA standard for HCl in the stack gas is 1.8 kg/hr (4 lb/hr) or 99 wt% HCl removal efficiency. The RCRA standard for particulate emissions in the stack gas is 180 mg/dscm (0.08 gr/dscf).

- Level of residual PCBs in the furnace ash at normal and varied operating conditions.
- Mobility of heavy metals, particularly lead, in the furnace ash as compared to the feed.
- Mobility of heavy metals in the furnace ash as compared to the RCRA Extraction Procedure Toxicity (EP Tox) Characteristic (as measured by the EP Tox test) and the proposed Toxicity Characteristic (as measured by the Toxicity Characteristic Leaching Procedure (TCLP)).
- Level of residual heavy metals and organic compounds, and other physical and chemical characteristics in the scrubber water discharged from the unit.
- The operating conditions that reduce energy consumption without decreasing soil decontamination effectiveness.
- Effect of varying operating conditions on residual levels of heavy metals and organics in the furnace ash versus the levels in the feed.
- Adherence of the quality assurance (QA) procedures to the requirements of the RREL approved QA Project Plan (Category II), as defined by the Document No. PA QAPP-0007-GFS, "Preparation Aid for HWERL's Category II Quality Assurance Project Plans", June, 1987.

Feed Preparation

The demonstration test used soil from an area of the site that was highly contaminated with PCBs and lead, as determined in the original remedial investigations performed at the site. Pretest sampling and analysis further identified those sectors within the area most highly contaminated with PCBs and lead for excavation. Other organics and heavy metals were also present in these sectors. Soil from these sectors to be used as feed for the test was excavated and mixed into a pile using a front-end loader, and then screened to remove aggregate and debris greater than one inch in diameter. The screened soil was drummed and transferred to a designated zone adjacent to the test unit. Two drums of soil were blended with 3 wt% fuel oil to be used for several of the test runs to investigate the effect of increased feed heating value on overall unit performance and energy consumption at varying operating conditions.

Process Description

The Shirco Pilot-Scale Infrared Incineration System consists of a waste feed system, an (electric) infrared primary combustion chamber, a supplemental propane-fired secondary combustion chamber, a venturi scrubber emissions control system, an exhaust system, and a data collection and control system, all enclosed in a 45-ft trailer. The system process flow and the overall 250 ft x 100 ft test site layout are presented schematically in Figures 1 and 2, respectively.

During the test, the feed material was transferred from the drums to pails, weighed, and then fed manually to a hopper mounted over a metering conveyor belt. The waste was fed at a controlled rate through a sealed feed chute onto the incinerator conveyor (a tightly woven wire belt which moved the waste material through the primary combustion chamber). The conveyor belt speed can be adjusted to achieve feed residence times in the PCC from 6 to 60 min. Typically residence times range from 10 to 25 min. The depth of the waste on the conveyor belt ranged from one to one and a half inches.

The primary combustion chamber (PCC) is a rectangular box insulated by layers of ceramic fiber. Combustion air is supplied to the primary combustion chamber through a series of air ports at points along the length of the chamber. The gas flow in the incinerator is countercurrent to the conveyed feed material. Electric infrared heating elements installed above the conveyor belt heat the waste to the designated temperature (nominally 1600°F), which results in desorption or incineration of organic contaminants from the feed. Rotary rakes gently turn the material to ensure adequate mixing and complete desorption. When the thermally treated soil, now referred to as furnace ash, reaches the discharge end of the PCC, it drops off the belt through a chute and into an enclosed hopper and discharge storage drum. The drums of furnace ash are then stored for final disposal.

Exhaust gas containing the desorbed contaminants exits the primary combustion chamber into a secondary combustion chamber (SCC) or afterburner, where a propane-fired burner combusts residual organic compounds into CO₂, CO, HCl, and H₂O. The SCC is typically operated at 2200°F and a gas residence time exceeding 2 sec. Secondary air is supplied to ensure adequate excess oxygen levels for

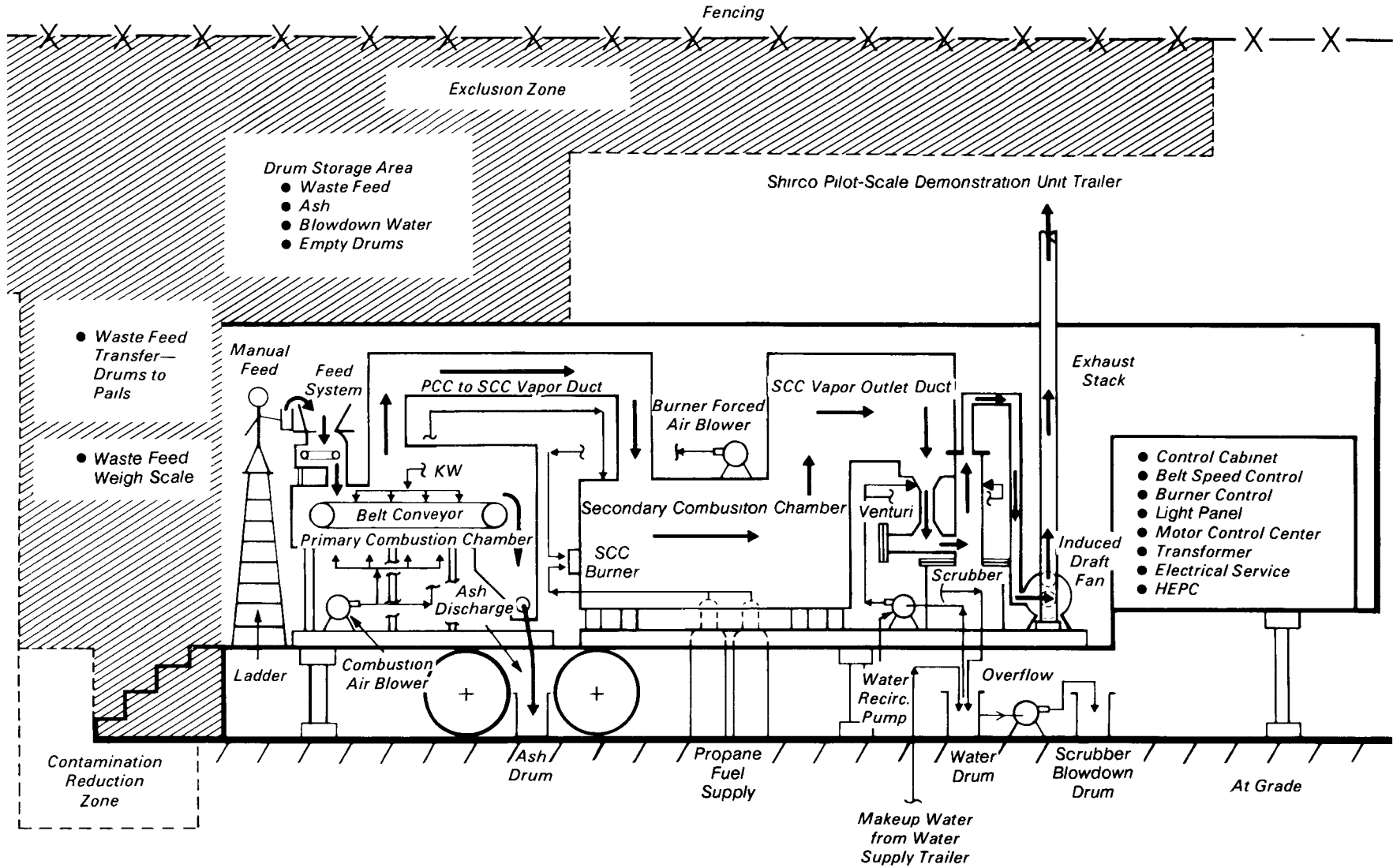


Figure 1. System process flow.

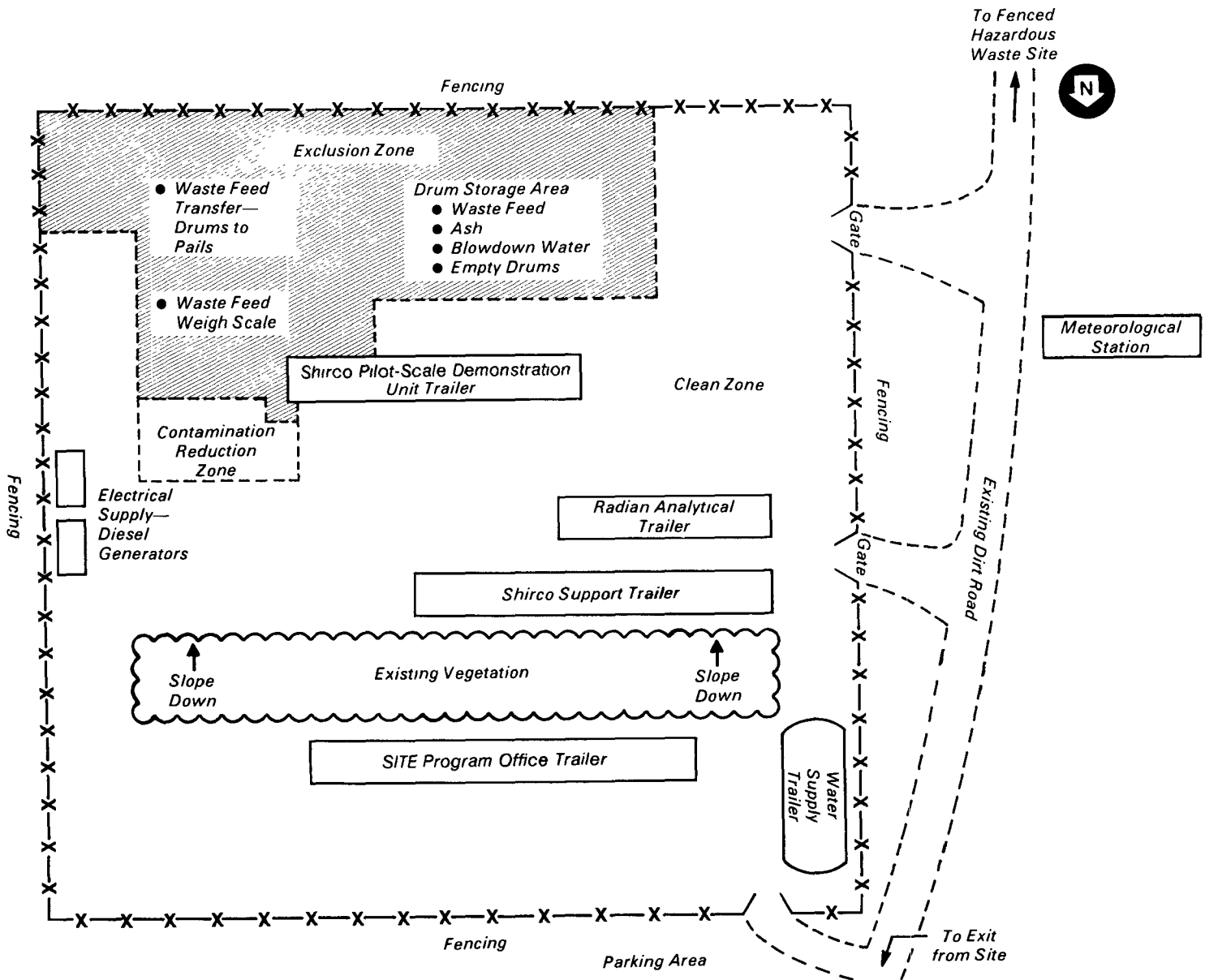


Figure 2. Overall test site

complete combustion. Exhaust gas from the secondary combustion chamber then is quenched by a water-fed venturi scrubber emissions control system to remove particulate matter and acid gases. An induced draft fan transfers the gas to the exhaust stack for discharge to the atmosphere.

The same trailer housing the thermal system also contains the control panel for the main unit, and data collection indicators and recorders. Safety

interlocks also are integrated into the trailer-mounted unit to automatically correct abnormal operating conditions, maintain system performance, and if necessary, shut down feed and heat input to the unit.

Test Procedure

In order to meet the objectives of the demonstration test (see Introduction), a total of 17 test runs were conducted. Three runs were performed under design

operating conditions to assess overall unit operation and system performance (Phase I), and 14 runs were conducted under varying operational parameters to evaluate their effect on system performance and energy consumption (Phase II).

The Phase I runs were conducted at 1600°F PCC temperature, a 2200°F SCC temperature, and a PCC residence time of 20 min. Each of the three runs was sufficiently long (six to ten hours) to

gather a large enough sample of stack gas to analyze it for PCBs. An additional run was conducted at the same operating conditions to obtain specific stack samples that had not been successfully collected during two of the previous runs.

The Phase II runs were conducted for approximately one hour under varied operating conditions that included the PCC temperature (900, 1200, 1400, and 1600°F), SCC temperature (1800 and 2200°F), PCC feed residence time (10, 15, 20, and 25 minutes), and PCC combustion air flow (on, off to simulate oxidizing or non-oxidizing (pyrolytic) PCC atmosphere).

For the Phase I runs, samples were taken of the feed, scrubber makeup water, furnace ash, scrubber water, and scrubber solids. These streams were analyzed for PCBs, dioxins and furans, metals, organics, and other physical and chemical properties and components specific to the characterization of each sampled matrix. In addition, the EP Tox and TCLP leaching tests were performed on these sampled streams (exclusive of scrubber water makeup) and the extracts were evaluated for metals. Samples were also taken of the upwind and downwind ambient air, PCC offgas, and stack gas. Ambient air upwind and downwind of the unit was monitored for PCBs and heavy metals by high volume samplers. For the stack gas and PCC offgas, several sampling methods were employed, including an EPA Method 5 for particulate matter (and subsequent metals analysis of particulates) and hydrochloric acid; a Source Assessment Sampling System (SASS) for semivolatile organic pollutants, PCBs, dioxins and furans; a Volatile Organic Sampling Train (VOST) for volatile organic pollutants; a Modified Method 5 for soluble chromium; continuous emission monitoring for oxygen, carbon dioxide, carbon monoxide, oxides of nitrogen, and total hydrocarbons; and an experimental method for vaporous lead emissions in the PCC offgas.

For the Phase II runs, samples were taken of the feed, furnace ash, scrubber water, scrubber solids, PCC offgas, stack gas, and upwind and downwind ambient air. EPA Method 5 was used again to sample stack gas and PCC offgas but was analyzed only for particulate matter. In addition, throughout the Phase II tests, the stack gas and PCC offgas were continuously monitored for oxygen, carbon dioxide, carbon monoxide, oxides of nitrogen, and total hydrocarbons. All of the remaining sampled streams were analyzed for PCBs, dioxins and furans,

metals, and other physical and chemical properties and components specific to the characterization of each sampled matrix. In addition, the EP Tox and TCLP leaching tests were performed on these samples and the extracts were evaluated for metals.

All of the sampling and analytical work was conducted in accordance with QA/QC Category II and include data quality credibility statements for the precision and accuracy of the data reported.

Results and Discussion

A detailed summary of the SITE demonstration test results is presented in Table 1. Based on the test objectives outlined in the Introduction, the following results were obtained.

• Characteristics of the Feed

Based on data from the previous remedial investigation of the site, a specific area within the site was identified with the highest concentrations of both PCBs and lead, the major soil contaminants of concern. The remedial investigation also described the soil as a dry, brown, sandy, and silty clay topsoil which upon excavation proved to be an accurate observation. Subsequent pretest sampling and analysis of the specific area of the site identified particular sectors with the highest contamination of PCBs and lead. A composite sample of all the sectors within the area indicated a 7.8 pH, 9.0 wt.% moisture, 81 wt.% ash, less than 1000 Btu/lb high heating value, and a 0.95 g/cc density. The composite sample contained 570 ppm of total PCBs and 580 ppm lead (elemental lead after digestion and conversion to inorganic form). A composite sample of the 10 sectors chosen for excavation contained 626 ppm PCBs, 560 ppm of lead, 55 ppb of tetrachlorodibenzo-p-dioxin (TCDD), and 4.2 ppb of tetrachlorodibenzofuran (TCDF). Once the feed excavation was begun, it became evident that the front-end loader could not confine its large-scale activities to the 10 specific sectors and an area comprising 14 specific sectors was excavated for the unit's feed source.

Table 1 summarizes the PCB and lead contaminant concentrations measured in the soil from the composite of the grab samples of feed taken during each of the test runs. In

addition to lead, where concentrations ranged from 290 to 3000 ppm and averaged 778 ppm, several other metals were present at average concentrations exceeding 50 ppm including barium (591 ppm), zinc (301 ppm), and chromium (85 ppm). Total PCBs concentration ranged from 10.2 to 669 ppm and averaged 272 ppm.

Several samples of the feed contained small quantities of TCDFs ranging from 0.04 to 0.1 ppb. Volatile and semivolatile organic compounds including methyl ethyl ketone, trichloroethene, and bis(2-ethylhexyl)phthalate were measured in feed samples at concentrations less than 50 ppm. Methyl ethyl ketone and trichloroethene were also detected in solvent blanks and are attributed to analytical laboratory contamination.

• Characteristics of the Furnace Ash

Table 1 summarizes the PCB and lead contaminant concentrations measured in the furnace ash from the composited grab samples taken at the conclusion of each test run. In addition to lead, where concentrations ranged from 420 to 2000 ppm and averaged 1173 ppm, several other metals were present at average concentrations exceeding 50 ppm including barium (1061 ppm), zinc (410 ppm), and chromium (81 ppm). Total PCBs concentration ranged from 0.004 to 3.396 ppm. Two samples of furnace ash contained 0.07 and 0.3 ppb of TCDF during two runs conducted at a 900°F PCC operating temperature; the normal PCC operating temperature is 1600°F. These runs were also conducted without the input of PCC combustion air to simulate non-oxidizing or pyrolytic combustion conditions. The low PCC temperature and pyrolytic environment could have led to the incomplete desorption or incineration of TCDF present in the feed or to the production of TCDF from the incomplete combustion of PCBs in the feed. Volatile compounds including methylene chloride, methyl ethyl ketone, tetrachloroethene, and trichloroethene were also measured in the furnace ash samples in concentrations ranging from 3.9 to 64 ppm with one sample containing 980 ppm of methylene chloride. Methyl ethyl ketone and trichloroethene were also detected in solvent blanks and methylene chloride is commonly employed in laboratory procedures; therefore these compounds may be

Table 1. Site Demonstration Test Results Summary

Operating Conditions PCC		Waste Feed Characteristics				Furnace Ash Characteristics			
Temp. °F	Residence Time min.	PCB ppm	Pb ppm	EP Tox (Pb) ppm	TCLP (Pb) ppm	PCB ppm	Pb ppm	EP Tox (Pb) ppm	TCLP (Pb) ppm
900 ^{a,b}	20	327	590	0.29	0.81	2 079	1,000	0.38	2.90
900 ^b	20	20.2	660	0.67	0.88	3.396	1,400	0.89	6.20
900 ^b	25	367	290	0.32	7.00	0.168	0.860	0.88	3.80
1200	20	297	640	0.05	0.56	0.115 ^d	1,100	4.10	1.60
1200	15	27.6	870	0.20	0.44	0.077	1,000	0.38	3.60
1200 ^b	25	456	590	0.12	0.53	0.108 ^d	1,200	0.14	0.05
1200 ^b	20	669	610	0.20	0.71	0.066 ^d	1,200	0.06	4.10
								4.90 ^g	2.80 ^g
1200 ^b	15	602	470	0.18	0.53	0.025 ^d	2,000	^h	^h
1200 ^{a,b}	15	309	370	0.21	0.96	0.066 ^d	1,000	0.46	0.82
1400	20	56.0	740	0.07	0.89	0.087 ^d	1,600	ND	0.15
1600	20	10.2	3000	0.15	0.67	0.037	1,100	0.05	ND
1600	20	35.2	1400	0.20	0.35	0.112	1,300	ND	ND
1600	20	20.4	550	0.23	1.30	0.003	1,100	0.13	0.05
1600	20	^f	1100	0.14	0.49	^f	0.420	0.28	1.80
1600	10	391	620	0.25	0.73	0.045 ^d	1,700	ND	1.00
1600 ^a	15	451	620	ND	0.66	0.117 ^d	0.840	0.43	0.17
1600 ^a	15 ^c	271	390	0.53	1.80	0.004	1,500	0.27	0.23
1600 ^{a,b}	15	311	500	0.07	0.55	0.061 ^d	0.800	1.10	2.40
				3.00 ^g	1.40 ^g				

^aWaste feed blended with 3 wt.% fuel oil.

^bNon-oxidizing atmosphere.

^cPCC bed depth at 1 inch. All other tests at 1-1/2 inches.

^dPCB levels below analytical detection limits. Total shown is sum of detectable limits indicated in analyses.

^eND - nondetectable value.

^fRun was conducted to make up for incomplete semivolatile organics, PCDD/PCDF, soluble chromium and stack gas particulate samplings on other runs.

^gData from additional EP Tox and TCLP tests.

^hND due to broken sample container.

products of incomplete combustion and/or the result of laboratory contamination.

• Residual PCBs in Furnace Ash

During the demonstration test, a total of 17 runs were conducted at varying operating conditions. In addition to the DRE levels, which are an indication of the performance of the Shirco Pilot-Scale Infrared Incineration System and its ability to meet RCRA and/or TSCA regulatory standards, the reduction of PCB concentration from the feed to the furnace ash is also a measure of the unit's ability to effectively destroy PCBs and produce a furnace ash with a PCB concentration below the TSCA guidance level of 2 ppm.

Based on the data presented in Table 1, two samples of furnace ash

exceeded the TSCA guidance levels and contained 3.396 and 2 079 ppm of total residual PCBs. The samples were produced during two runs conducted at a 900°F PCC operating temperature (20 minutes residence time), which is significantly lower than the normal PCC operating temperature of 1600°F. These runs were also conducted without the input of PCC combustion air to simulate non-oxidizing or pyrolytic combustion conditions. At this low PCC temperature and pyrolytic condition, these higher total residual PCB levels in the furnace ash may be the result of the incomplete combustion of PCBs in the feed. This is further substantiated by the residual TCDF present in the furnace ash samples from these same two runs, as discussed previously. The remaining

runs conducted at 1200, 1400, and 1600°F resulted in total residual PCB concentrations in the furnace ash ranging from 0.003 to 0.117 ppm. A third run, which was conducted at 900°F PCC operating temperature but with an increased PCC residence time of 25 minutes resulted in a total furnace ash PCB concentration of 0.168 ppm with no detectable TCDF. It is possible that the increased residence time in the PCC may have offset the low 900°F PCC operating temperature and provided the additional processing time for the satisfactory destruction of the PCBs in the feed.

• Mobility of Heavy Metals - Feed and Furnace Ash

In order to determine whether heavy metals, particularly lead, would leach

from the furnace ash produced in the Shirco Pilot-Scale Infrared Incineration System, EP Tox and TCLP tests were conducted to determine the mobility of heavy metals from the furnace ash as compared to the feed.

The initial EP Tox analyses for lead in the leachate ranged from 0.05 to 0.67 ppm for the feed and 0.05 to 4.1 ppm for the furnace ash. The initial TCLP analyses ranged from 0.35 to 1.80 ppm (with one sample at 7.0 ppm) for the feed and 0.05 to 4.1 ppm (with one sample at 6.2 ppm) for the furnace ash.

A comparison of the EP Tox and TCLP analyses conducted on the furnace ash and the feed do not show any trend or evidence that indicate reduced mobility of lead from the furnace ash versus the feed as a result of the thermal treatment. The comparison did reveal that the concentrations of lead in the TCLP leachates from both the feed and the furnace ash were consistently higher than the corresponding EP Tox tests on the same samples.

When several samples were retested to verify the results, the concentrations of lead in the EP Tox leachates (4.9 ppm feed, 3.0 ppm furnace ash) were higher than during the initial tests and, in direct reversal to the original data, exceeding corresponding TCLP leachate concentrations (2.8 ppm feed, 1.4 ppm furnace ash). The results of the retest again did not indicate reduced mobility of lead from the furnace ash versus the feed as a result of the thermal treatment.

- **Mobility of Heavy Metals - EP Tox and Proposed TCLP Toxicity Characteristic Standards**

EP Tox and TCLP tests were conducted on the feed, furnace ash, scrubber water, and scrubber solids. All of the results were below the EP Tox and proposed TCLP toxicity characteristic standards of 5 ppm arsenic, 100 ppm barium, 1 ppm cadmium, 5 ppm chromium, 5 ppm lead, 0.2 ppm mercury, 1 ppm selenium, and 5 ppm silver except for one feed sample at 7.0 ppm lead (TCLP) and one furnace ash sample at 6.2 ppm lead (TCLP). A comparison of the EP Tox and TCLP analyses on all the sampled streams to the above mentioned standards do not show any trend or evidence that indicate reduced mobility of heavy metals as a result of the thermal treatment.

- **Destruction and Removal Efficiency (DRE) of PCBs**

The DRE of PCBs for the first three runs (Phase I) is greater than 99.99%. In contrast, the regulatory standard for incineration under the RCRA is 99.99% DRE and under TSCA is 99.9999% DRE. The low PCB concentrations in the feed resulted in PCB levels in the stack gas that were less than the analytical detection limits for two of the runs. Therefore for these runs, DRE is calculated based on the sum of the detection limits of the PCB congeners in order to compare the DRE for the runs on the same basis. Stack gas measurements conducted during the third run did detect trichlorobiphenyl and tetrachlorobiphenyl congeners and a DRE is shown based on this measurement. The less rigorous sampling in Phase II of the test was not designed to allow calculation of DRE.

- **Other Organic Stack Gas and PCC Offgas Emissions**

Several volatile and semivolatile organic compounds were detected in the stack gas at concentrations less than 100 ppb and established standards for direct inhalation. Low levels of several phthalate compounds were also detected in blank samples and may be traced to contamination from plastic components in the process, sampling equipment, or laboratory apparatus. Several volatile organic compounds including benzene and toluene were detected in the stack gas and the scrubber makeup water and may be attributable to contamination from the makeup water although PIC formation is a possibility. Other volatile and semivolatile organic compounds, which probably represent PICs, were detected. They include halomethanes, chlorinated species including chlorobenzene and methylene chloride, other volatile organics including xylenes, styrene and ethylbenzene, oxygenated hydrocarbons including acetone and acrolein, carbon disulfide, and p-chloro-m-cresol. Dioxins and furans were not detected in the stack gas samples.

The majority of the organic compounds present in the PCC off gas samples at levels less than 500 ppb were also present in the stack gas. The additional destruction of organics that take place in the SCC and emissions scrubbing system reduced the concentration of these organic

compounds in the corresponding stack gas samples.

- **Acid Gas Removal**

During the Phase I Runs 1-3, HCl emissions ranged from 0.181 to 0.998 g/hr, which were significantly below the RCRA performance standard of 1800 g/hr that would require a 99 wt.% HCl removal efficiency. HCl removal efficiencies ranged from 97.23 to 99.35 wt.%. Acid gas removal was not measured in Phase II.

- **Particulate Emissions**

Particulate emissions were measured throughout the test and ranged from 7 to 68 mg/dscm, well below the RCRA standard of 180 mg/dscm.

- **Analysis of Scrubber Makeup Water, Scrubber Water, and Scrubber Solids**

Scrubber makeup water was transported to the site in a tank truck that may have contained some residual contamination prior to fill up. Samples of scrubber makeup water were taken at the end of each run. No PCBs, dioxins, furans, or semivolatile organic compounds were detected. Several volatile organics including benzene, toluene, and trichloroethene were measured at concentrations less than 15 ppm. The concentrations of heavy metals were all less than 0.2 ppm.

Samples of the water recirculation through the venturi scrubber system, referred to as scrubber water, were also taken at the end of each run. PCB concentrations were less than 200 ppt and no dioxins, furans, or semivolatile organic compounds were detected. Small quantities of benzene (2 ppm) and toluene (5.7 to 11 ppm) were measured in several of the samples and are attributable to the similar contaminants in the scrubber makeup water. The concentrations of heavy metals in the scrubber water were all less than 1 ppm except for barium, which ranged from 0.2 to 2.2 ppm, and lead, which ranged from 0.12 to 1.8 ppm.

Insufficient quantities of scrubber solids in the scrubber water were available for analysis.

- **Overall Disposition of Metals**

Total metals analyses of the feed, furnace ash, PCC offgas and stack gas particulates, scrubber makeup water, scrubber water, and scrubber solids showed that the majority of the detectable metals, including lead, that

entered the unit with the feed remained in the furnace ash. An overall mass balance of lead through the unit was calculated based on the analysis of lead in the samples, the measured feed rate as weighed during the runs' operating periods, the calculated furnace ash flow rate based on the ultimate analysis of ash in the feed sample, and the measured particle mass and gas volume obtained from the gas' EPA Method 5 sampling trains. Phase I results indicate an average lead mass flow rate of 28.3 g/hr in the feed, 37.0 g/hr in the furnace ash, 0.206 g/hr in the PCC offgas particulates, and 0.109 g/hr in the stack gas particulates. The quantity of lead leaving the unit with scrubber water effluent is approximately 0.204 g/hr based on the maximum measured concentration of 1.8 ppm lead in the scrubber water and an overall approximate water flow rate of 30 gph. The PCC offgas particulates sampled during the Phase I runs contained an average of 5364 ppm of lead as compared to stack gas particulates, which contained an average of 15,830 ppm of lead. By contrast, the average concentration of lead in the feed was 1550 ppm. Although the concentration of lead in the particulate matter increases as the process flow progresses through the unit, the actual mass flow of lead decreases as the gas stream is cooled and treated through the emissions control system.

For the Phase I runs sampling and analysis procedures were conducted to evaluate vaporous lead concentrations in the PCC offgas and soluble chromium concentrations in the PCC offgas and stack gas particulates. The special sampling for vapor phase lead and soluble chromium were unable to detect any of either metal at levels less than 2.7 ppb and 264 ppb, respectively; therefore the evaluations were inconclusive.

Other heavy metals, particularly barium and zinc, with average concentrations exceeding 100 ppm in the feed (barium 591 ppm, zinc 301 ppm) were also present in high concentrations, relative to other heavy metals, in the furnace ash (barium 1061 ppm, zinc 410 ppm) and scrubber water (barium 0.8 ppm, zinc 0.3 ppm).

● Optimum Operating Conditions

Phase II was designed to examine the effect on energy consumption and changes in the residual levels of heavy

metals and organics in the furnace ash versus the levels in the feed by varying operating conditions.

Based on the data obtained an analysis was conducted to compare energy consumption in the unit at operating conditions that did not affect the performance of the unit. A reduction in the PCC operating temperature from 1600°F to 1200°F reduced the average PCC power usage 48% from 0.2294 to 0.1200 kwhr/lb feed. A reduction in the SCC operating temperature from 2200°F to 1800°F reduced the average propane fuel consumption by 51% from 3997 to 1952 Btu/lb feed. The use of 3 wt.% fuel oil to supplement the fuel value of the feed further decreased PCC power usage by 26 to 67% at PCC operating temperatures of 1600°F and 1200°F, respectively, with accompanying increases in overall feed rate of 32% and 26%. The costs for fuel oil and its attendant facilities still must be examined for specific applications to determine the cost effectiveness of a fuel oil additive to the waste feed.

As discussed in previous sections the results did not provide any trend or change in the residual levels of the heavy metals and organics in the furnace ash versus the levels in the feed as the operating conditions were varied and PCC operating temperatures were maintained at 1200°F to 1600°F. At an abnormally low PCC operating temperature of 900°F, without the input of combustion air to simulate non-oxidizing or pyrolytic combustion conditions, total PCB and TCDF concentrations in the furnace ash increased. The increases may indicate that these PCC conditions led to incomplete desorption or incineration of PCB and TCDF and to the production of TCDF from the incomplete combustion of PCBs in the feed.

● QA Summary

The Phase I and II runs had a well-defined quality assurance/quality control program to ensure the collection of accurate data. This program was developed as part of the test program preparation activities and was formalized in the RREL approved QA Project Plan (Category II). All of the sampling and analytical work was conducted in accordance with this QA Project Plan and the results include data quality credibility statements and information that confirm the satisfactory

precision and accuracy of the data reported.

Conclusions

Based on the above data and discussion, the following conclusions can be made concerning the operation and performance of the Shirco Pilot-Scale Infrared Incineration System.

1. The PCC equipped with infrared heating rods reduced PCBs from an average of 272 ppm and a maximum of 669 ppm in the feed to less than 0.2 ppm PCBs in the furnace ash when PCC temperature was 1200°F or higher. PCB levels in the ash were well below the TSCA guidance level of 2 ppm of PCBs in treatment residuals.
2. The majority of the lead and other heavy metals present in the feed remained in the furnace ash regardless of operating conditions. However, the scrubber water contained levels of lead and barium (up to 1.8 to 2.2 ppm, respectively) and metals also concentrated to some extent in the furnace ash. Both residual streams may require further treatment when metals are present in the feed.
3. In most cases concentrations of metals in the extract of the furnace ash did not exceed their respective EP Tox and TCLP toxicity characteristic standards. The need for further treatment of the furnace ash to reduce or immobilize the metals is site specific, and will depend on the cleanup standards for the site.
4. Based on two leaching tests, the EP Tox and TCLP, the mobility of lead and other heavy metals was similar in the feed and the furnace ash, and there was no evidence that treatment affected metals leaching.
5. The unit achieved DREs of PCBs greater than 99.99%, based on one actual calculation and in two cases on detection limits. PCB concentrations in the feed and analytical detection limits did not allow the demonstration of 99.9999% DRE required under TSCA. However, this unit achieved greater than 99.9999% DRE in other tests, and at this time at least one full-scale infrared system has demonstrated greater than 99.9999% DRE for PCBs and is permitted under TSCA to process PCB waste. The upcoming Appli

cations Analysis Report will incorporate this additional data.

6. The unit achieved regulatory standards for acid gas removal and particulate emissions. These data apply to the operation and performance of the air pollution control system installed on this unit. Additional data on the performance of air pollution control systems on full-scale Shirco Infrared units will be

discussed in the Applications Analysis Report.

7. Several semivolatile and volatile organic compounds measured in the stack gas in the parts per billion may be PICs. These levels are much lower than established standards for direct inhalation of these compounds.

8. The unit was able to reduce the PCBs in the feed using less power

when fuel oil was added to the waste and when PCC temperature was reduced. The addition of fuel oil also increased the feed rate. Cost savings in specific applications will depend on local fuel and electrical costs, and a minimum PCC temperature must be maintained to avoid inadequate desorption of the organics in the feed and the production of PICs.