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SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

Technology Demonstration Summary

Horsehead Resource Development Company, Inc., Flame Reactor Technology

Under the Superfund Innovative Technology Evaluation (SITE) program, the Horsehead Resource Development Company, Inc., (HRD) Flame Reactor was evaluated during a series of test runs. The tests were conducted at the HRD facility in Monaca, PA, using 72 tons of secondary lead smelter soda slag (waste feed) from the National Smelting and Refining Company, Inc., (NSR) site in Atlanta, GA. The waste feed contained lead, zinc, iron, and many other metals and inorganic compounds. This summary includes an overview of the demonstration, a technology description, analytical results, and conclusions.

The HRD Flame Reactor technology is a patented high-temperature thermal process designed to safely treat industrial residues and wastes containing metals. The HRD Flame Reactor processes wastes by subjecting them to a hot (>2,000°C) reducing gas produced by the combustion of solid or gaseous hydrocarbon fuels in oxygen-enriched air. According to HRD, at these temperatures, volatile metals in the waste are vaporized, and any organic compounds should be destroyed. The waste materials react rapidly, producing a nonleachable slag and gases, including steam and metal vapors. Metal vapors further react and cool in the combustion chamber and cooling system, producing metal-enriched oxides that are collected in the baghouse. The resulting metal oxides potentially can be recycled to recover the metals. The HRD Flame Reactor was evaluated for effectiveness in treating waste from the NSR site to form a potentially recyclable, metal oxide product and a nonhazardous, fused effluent slag.

During the demonstration, waste feed from the NSR site produced a lead- and zinc-enriched metal oxide product and an effluent slag, which was determined to be nonhazardous, based on extraction by the Toxicity Characteristic Leaching Procedure (TCLP) and chemical analysis of the extract. Greater than 77.7% of the 5.41% weight lead and 80.0% of the 0.416% weight zinc in the waste feed were recovered in the recyclable metal oxide product, which contained 17.4% weight lead and 1.38% weight zinc. The weight of the oxide product and effluent slag was 36.6% less than the weight of the waste feed.

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 U.S. Environmental Protection Agency (EPA) has established a formal program to accelerate the development, demonstration, and use of new or innovative technologies that offer permanent, long-term cleanup solutions at Superfund sites. This program is called the Superfund Innovative Technology Evaluation, or SITE, program and is administered by the Office of Research and Development (ORD).

The SITE program has four main goals:

- Identify and remove impediments to the development and commercial use of alternative technologies.
- Structure a development program that nurtures emerging technologies.
- Conduct a demonstration of the more promising innovative technologies to establish reliable performance and cost information for site characterization and cleanup decision-making.
- Develop procedures and policies that encourage the selection of available alternative treatment remedies at Superfund sites and other waste sites and commercial facilities.

Under the SITE program, EPA solicits proposals from developers of innovative waste treatment technologies who have expressed an interest in participating in the SITE program. Based on these proposals, EPA selects technologies for the demonstration portion of the SITE program. One of the selected technologies was the Flame Reactor developed by HRD.

The HRD Flame Reactor SITE Demonstration took place at the HRD facility in Monaca, PA, using secondary lead smelter soda slag from the NSR site in Atlanta, GA, as the waste feed. The HRD technology involves a high-temperature metals recovery process that produces a potentially recyclable metal oxide product and a nonhazardous, based on the RCRA Toxicity Characteristic (TC) rule, effluent slag.

The primary objectives of the HRD Flame Reactor SITE Demonstration included the following:

- Evaluate the technology's ability to treat waste materials to form a recyclable metal oxide product and a nonhazardous, fused effluent slag
- Evaluate the system's reliability
- Develop overall economic data on the technology

Secondary objectives were also defined. These were objectives that would be of interest to potential technology users but concerned testing auxiliary systems rather than the actual Flame Reactor. Secondary objectives included the following:

- Assess airborne emissions from the process
- Verify the predictions of the HRD thermodynamic operating model so that it can be used to predict costs for other projects

Overview of the HRD Flame Reactor SITE Demonstration

The HRD Flame Reactor SITE Demonstration took place in February and March 1991. The waste material from the NSR site consisted of granular slag containing arsenic, cadmium, iron, lead, sodium, zinc, and other metals, plus carbon, chlorine, silicon, sulfur, oxygen, and other inorganic compounds. This waste material was chosen as it was readily available, it contained high concentrations of several recoverable metals (lead and zinc), it contained no organic compounds (which could not be treated under HRD's state permits), and it was representative of a waste type available in large quantities throughout the country. The waste material was dried and passed through a hammermill before treatment in the HRD Flame Reactor. The demonstration test runs included (1) a series of shakedown runs to establish optimal operating conditions, (2) a blank run with no waste feed, (3) four test runs (including one that was not used for interpretation of results because of operational problems), and (4) a series of additional runs to process remaining waste material and to try to improve the structural integrity of the effluent slag.

Process operating data and analytical samples were collected. The operating data included (1) waste feed consumption rate, (2) oxide product and effluent slag production rates, (3) natural gas and oxygen consumption, (4) electrical consumption, (5) temperatures throughout the system, and (6) flow rates throughout the system. Contaminant concentrations were measured in the waste feed, oxide product, the effluent slag, and the stack gases. The waste feed was analyzed for energy content, ash content, moisture, metals, sulfur, chloride, fluoride, carbon, and total organic carbon content. The oxide product and effluent slag were analyzed for metals. The waste feed and effluent slag were also extracted by the TCLP, and the extracts were analyzed for metals. Stack gases were analyzed for carbon monoxide, carbon dioxide, oxygen, nitrogen oxides, sulfur dioxide, total hydrocarbons, hydrogen chloride, particulate, and metals.

Technology Description

Figure 1 presents the process flow diagram for the HRD Flame Reactor process. The process consists of a (1) feed system, (2) Flame Reactor, (3) slag separator, (4) combustion chamber, and (5) oxide product recovery system. The feed system operations include fuel and waste feed storage and handling, metering and injecting of waste, fuel, oxygen, and air into the Flame Reactor.

The Flame Reactor is a two-stage system. The first stage consists of a fuel burner system composed of two separate burners; the second stage consists of a metallurgical reactor. Carbon-based combustion and gasification and metal oxide smelting reactions occur in the two-stage reactor system. The Flame Reactor is 15 ft tall, positioned vertically, with an internal diameter of 23 in.

Materials passing through the reactor discharge continuously into the slag separator, which separates molten effluent slag from reactor off-gases. The slag separator is positioned horizontally, with a slight upward angle between the reactor and the combustion chamber. The gases, particulate, and metal vapors flow toward the combustion chamber, countercurrent to the effluent slag. The molten effluent slag runs out through a tap hole on the discharge end of the unit.

The reactor off-gases are reacted with air in a refractory-lined combustion chamber. The temperature of the combustion chamber gases is typically between 600 and 800 °C.

The oxide product recovery system is designed to cool the gas stream and capture the metal oxides formed in the combustion chamber. The gas is cooled by a shell-and-tube heat exchanger and by the addition of ambient air. The oxide product recovery system includes a jet-pulsed baghouse designed to recover oxide product from the gas stream. The baghouse emits off-gas through a stack and, when pulsed, discharges the oxide product into enclosed bags for recovery. A fan between the baghouse and the stack provides an induced draft for the system.

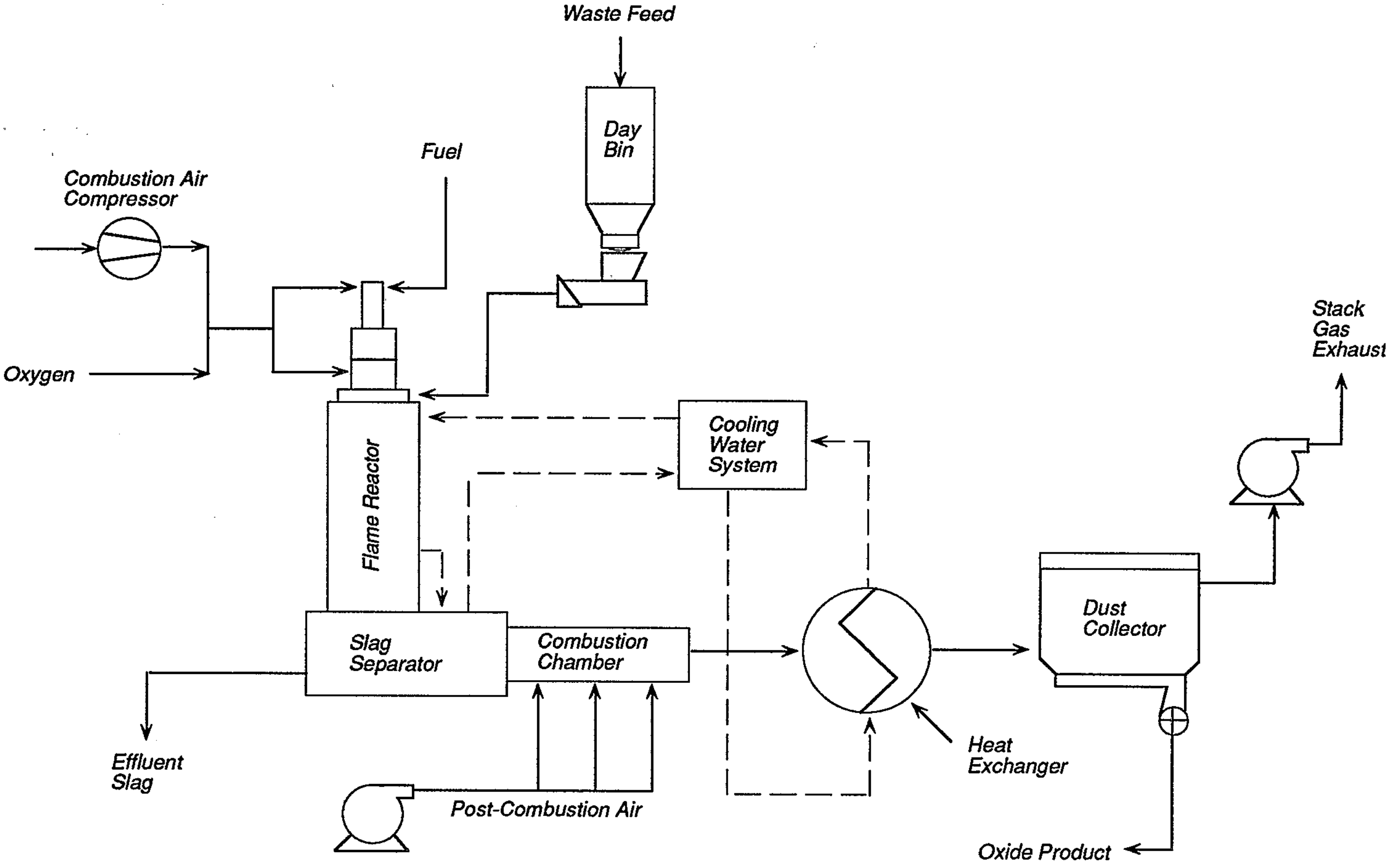

Figure 1. *HRD Flame Reactor process flow schematic.*

The HRD Flame Reactor is designed to thermally treat granular solids, soil, flue dust, slag, and sludge containing metals. After entering the reactor, the waste feed reacts in less than 0.5 sec, allowing high waste throughput. The treatment process yields two products: a metal oxide that may potentially be recycled and a nonleachable, nonhazardous effluent slag that potentially may be used as aggregate.

Volatile metals in the waste material, such as cadmium, lead, and zinc, are vaporized and oxidized, then captured downstream in an oxide product collection system. Nonvolatile metals are predominantly encapsulated in the effluent slag. According to HRD, for optimal reaction conditions, feed particles should contain less than 5% weight total moisture, and at least 80% weight of the feed should be sized smaller than 200 mesh (0.0029 in. or 75 microns). Waste material may be pretreated by drying and by physical size reduction to meet these specifications. The fusion temperature of feed materials should not exceed 1,400 °C. Deviations from these specifications are acceptable but tend to decrease throughput and reduce the recovery of metals in the oxide product.

The waste feed, after drying and size reduction, is transferred to portable storage bins. It is then transferred by a tubular drag conveyor system to the day bins. From the day bins the waste feed is metered and pneumatically transferred to the HRD Flame Reactor, where it is heated to high temperature by the fuel-rich combustion of natural gas or coal and oxygen-enriched air. Volatile metals, water, carbonates, sulfates, and other volatile inorganic compounds are vaporized; organic compounds and carbon are burned. Nonvolatile and noncombustible materials are fused into slag by the high temperatures and fall through the reactor into the horizontal slag separator. Fused, effluent slag exits through the slag tap and then cools. Volatilized matter is drawn by reduced pressure into a combustion chamber, where air is introduced and oxidation occurs. The oxidized gases are further cooled in a heat exchanger, and the metal oxides are collected in an oxide product collection system. The metal oxide product from this collection system is periodically removed by a jet-pulse and transferred by auger to enclosed oxide product storage bags for recycling.

Demonstration Results

During the HRD Flame Reactor SITE Demonstration, a comprehensive sampling and analysis program was undertaken to characterize the waste feed, the oxide product, the effluent slag, and stack gas emissions. A mass balance was performed to account for distribution of the waste feed into the Flame Reactor products and to determine the percent recovery of metals and the weight reduction of the waste feed. The HRD Flame Reactor Demonstration also assessed the Flame Reactor's operational reliability and the costs of waste treatment. The following discussion is broken down into three sections: (1) sampling and analytical results, (2) mass balance analysis, and (3) operational reliability and costs.

Sampling and Analytical Results

The HRD Flame Reactor SITE Demonstration included a comprehensive sampling and analysis program that determined the following:

- Constituents and their concentrations in the waste feed, oxide product, and effluent slag
- TCLP results
- Stack monitoring and emissions sampling

Each of these items is discussed below.

Constituent Analyses

Constituent analyses were performed on the waste feed, oxide product, and effluent slag to determine if the technology produced a potentially recyclable oxide product enriched in lead and a nonhazardous effluent slag product.

Table 1 presents the constituent analyses data for the waste feed, the oxide product, and the effluent slag. The data show clearly that volatile metals, such as lead, cadmium, and zinc, are concentrated in the oxide product, while nonvolatile metals, such as aluminum, calcium, iron, are concentrated in the effluent slag. The oxide product contains some nonvolatile species, because some unreacted feed and effluent slag particles are entrained with the off-gas stream.

The HRD Flame Reactor technology produced an oxide product enriched in lead, cadmium, and zinc. Table 1 compares the waste feed, effluent slag, and oxide product compositions. Comparison of the waste feed concentration to the oxide product concentration for lead (5.41% to 17.4% weight), cadmium (0.0411% to 0.128% weight), and zinc (0.416% to 1.38% weight) indicates a significant partitioning of these volatile metals to the oxide product.

The main constituents of the effluent slag are iron (20.4% weight), sodium (15.5% weight), aluminum (1.53% weight), and calcium (1.30% weight). HRD reports that silicon is present in the effluent slag at an average concentration of 10.2% weight. In general, the effluent slag is composed of the oxides of nonvolatile metals such as iron, calcium, and aluminum. Silicon and sodium appear in both the oxide product and the effluent slag.

TCLP Results

TCLP tests were performed on the waste feed and on the effluent slag. Table 2 presents the mean concentrations and ranges for all TCLP results and the appropriate Resource Conservation and Recovery Act (RCRA) regulatory limits for each waste code.

The waste feed processed by the HRD Flame Reactor was a RCRA characteristic hazardous waste because lead (RCRA waste code D008) and cadmium (RCRA waste code D006), when extracted by the TCLP procedure, leach above the RCRA TC rule limit. Lead leached at an average of 5.75 mg/L, compared with the RCRA TC rule limit of 5.0 mg/L. Cadmium was well above the RCRA TC rule limit of 1.0 mg/L, leaching at an average of 12.8 mg/L. The other metal extracts were well below the RCRA TC rule limits for characteristic wastes. No organic compounds were present in the waste feed. Table 2 presents the TCLP results and the RCRA TC rule limits for comparison.

TCLP extraction and analysis was not performed on the oxide product because this product is intended for recycling.

TCLP testing determined that the effluent slag was not a RCRA characteristic waste. Cadmium, chromium, lead, mercury, and silver concentrations in the TCLP

Table 1. *Composition of the Waste Feed, Effluent Slag, and Oxide Product*

Analyte	Waste Feed [1] (% Weight)	Effluent Slag [1] (% Weight)	Oxide Product [2] (% Weight)
Aluminum	0.596 (0.490-0.787)	1.53 (1.33-1.85)	0.0562 (0.0459-0.0623)
Antimony	0.0373 (0.0278-0.0455)	0.0357 (0.0100-0.190)	0.125 (0.122-0.131)
Arsenic	0.0515 (0.0428-0.104)	0.0262 (0.00921-0.134)	0.110 (0.101-0.117)
Barium	0.0861 (0.0804-0.0940)	0.165 (0.139-0.183)	0.0282 (0.0248-0.0323)
Beryllium	<0.00011	0.000101 (<0.000087-0.000110)	<0.00010
Cadmium	0.0411(0.0356-0.0512)	0.000373 (<0.00023-0.00135)	0.128 (0.108-0.138)
Calcium	0.653 (0.552-0.835)	1.30 (1.06-1.45)	0.202 (0.155-0.234)
Chromium [3]	0.00877 (0.00631-0.0113)	0.00890 (0.00339-0.0385)	0.0300 (0.0278-0.0312)
Copper	0.185 (0.146-0.259)	0.344 (0.273-0.389)	0.161 (0.138-0.178)
Iron	10.3 (9.56-13.0)	20.4 (16.7-22.8)	3.22 (2.91-3.56)
Lead	5.41 (4.82-6.17)	0.552 (0.156-1.14)	17.4 (15.9-18.4)
Magnesium	0.228 (0.163-0.346)	0.543 (0.441-0.761)	0.0327 (0.0266-0.0368)
Manganese	0.0753 (0.0672-0.0903)	0.175 (0.132-0.231)	0.0265 (0.0214-0.0300)
Mercury	0.000068 (0.000054-0.000087)	<0.000010	0.000013 (<0.000010-0.000014)
Potassium	0.244 (0.204-0.284)	0.238 (0.199-0.269)	0.707 (0.630-0.751)
Selenium	0.00727 (0.00400-0.0175)	0.00344 (<0.00226-0.0176)	0.00520 (0.00415-0.00659)
Silicon [3]	0.276 (0.176-0.444)	0.327 (0.183-0.525)	0.127 (0.113-0.137)
Silver	0.000339 (0.000160-0.000540)	0.000394 (0.000250-0.000510)	0.00269 (0.00190-0.00342)
Sodium	12.2 (11.5-13.2)	15.5 (12.8-16.8)	15.7 (13.7-16.8)
Thallium	0.0253 (0.0181-0.0317)	0.0689 (0.0535-0.0852)	0.00746 (0.00714-0.00773)
Tin	0.282 (0.261-0.314)	0.0796 (0.0544-0.111)	0.660 (0.612-0.687)
Zinc	0.416 (0.321-0.681)	0.113 (0.0709-0.168)	1.38 (1.00-1.62)
Carbon	15.0 (9.56-19.6)	NA	NA
Chloride	2.46 (2.12-2.89)	NA	NA
Fluorine as Fluoride	0.0130 (0.0106-0.0166)	NA	NA
Sulfur	5.25 (4.77-6.44)	NA	NA
Moisture	3.35 (2.26-4.07)	NA	NA
Ash	81.6 (80.6-82.4)	NA	NA

[1] Average of 18 values; the range is shown in parentheses.
[2] Average of 3 values; the range is shown in parentheses.
[3] Due to matrix interferences, analytical results are known to be lower than actual concentrations for the waste feed and effluent slag. When analyzed by HRD, chromium levels were, on average, 0.024% in the waste feed and 0.040% in the effluent slag. Silicon levels detected by HRD were, on average, 8.10% in the waste feed and 10.2% in the effluent slag.
NA = Not analyzed. < = less than.
When an analyte was not detected, the detection limit was used in calculating the average value.

Table 2. *TCLP Results of Waste Feed and Effluent Slag*

Analyte	*Waste Feed* [1] *(mg/L)*	*Effluent Slag* [1] *(mg/L)*	*RCRA TC Rule Limits (mg/L)*	*RCRA Waste Code*
Arsenic	*0.213* *(<0.210-0.264)*	*0.474* *(<0.210-0.930)*	*5.0*	*D004*
Barium	*0.0347* *(0.0177-0.0675)*	*0.175* *0.109-0.281)*	*100.0*	*D005*
Cadmium	*12.8* *(7.61-15.8)*	*<0.050* *(<0.050)*	*1.0*	*D006*
Chromium	*0.184* *(0.140-0.283)*	*<0.060* *(<0.060)*	*5.0*	*D007*
Lead	*5.75* *(4.35-6.80)*	*<0.330* *(<0.330)*	*5.0*	*D008*
Mercury	*<0.010* *(<0.010)*	*<0.010* *(<0.010)*	*0.2*	*D009*
Selenium	*0.0716* *(<0.030-0.160)*	*0.0326* *(<0.030-0.073)*	*1.0*	*D010*
Silver	*<0.050* *(<0.050)*	*<0.050* *(<0.050)*	*5.0*	*D011*

[1] Average of 18 values; the range is shown in parentheses.
mg/L = milligrams per liter.
< = less than.

extracts of the effluent slag were below the method detection limits of 0.050, 0.060, 0.330, 0.010, and 0.050 mg/L, respectively. Selenium was below the detection limit (0.030 mg/L) for all but two samples, where the TCLP extract concentrations were 0.0338 and 0.0730 mg/L. Arsenic and barium were consistently above the detection limit, with concentrations ranging from 0.210 to 0.930 mg/L for arsenic and from 0.109 to 0.281 mg/L for barium. Concentrations for all metals were well below the RCRA TC rule limits. Additionally, the waste feed was not a listed waste. Consequently, the effluent slag from the demonstration can be disposed of in a nonhazardous waste (Subtitle D) landfill.

Stack Monitoring and Emissions Sampling

During the HRD Flame Reactor SITE Demonstration, stack gases were sampled for metals, hydrogen chloride gas, and particulate emissions, and were continuously monitored for sulfur dioxide, nitrogen oxides, oxygen, carbon dioxide, carbon monoxide, and total hydrocarbons. The metals and particulate emissions were sampled using an EPA Modified Method 5, isokinetic, multiple metals sampling train. Hydrogen chloride gas emissions were determined by a single point EPA Method 26 sampling train. The continuous emission monitors used the following: EPA Method 6C for sulfur dioxide, EPA Method 7E for nitrogen oxides, EPA Method 3A for oxygen and carbon dioxide, EPA Method 10 for carbon monoxide, and EPA Method 25A for total hydrocarbons. All the standard EPA methods can be found in *40 Code of Federal Regulations (CFR) 60*, Appendix A, and the multiple metals train is discussed in the *Methods Manual for Compliance with the Boiler and Industrial Furnace (BIF) Regulations* [40 CFR 266, Appendix IX]. Emission results for metals, hydrogen chloride gas, particulate, and continuous emissions monitoring are discussed below.

Hydrogen chloride gas emissions during the HRD Flame Reactor SITE Demonstration were between 38.5 and 46.4 lb/hr. This high emission rate occurred because the Flame Reactor had no acid gas control system, and the waste feed was, on average, 2.46% chloride by weight. The BIF rule has promulgated risk-based emission limits on hydrogen chloride gas. The addition of a wet scrubber should control hydrogen chloride gas emissions to below the applicable standards.

Because the HRD Flame Reactor process uses a baghouse to capture the metal oxide product, particulate emissions from the Flame Reactor are low when the baghouse is maintained and operated properly. During analysis of the demonstration samples, problems occurred with the gravimetric analysis, preventing accurate determination of the particulate emissions. Thus, although no particulate data were obtained during the demonstration, the Flame Reactor, when equipped with a state-of-the-art baghouse (emission control system), should have more effective particulate emission control.

Emissions of sulfur dioxide, nitrogen oxides, oxygen, carbon dioxide, and total hydrocarbons were continuously monitored for the blank run and for each test run. The HRD Flame Reactor currently has an air quality permit issued by Pennsylvania Department of Environmental Resources that limits sulfur dioxide emissions to less than 500 ppm for commercial operations. During the HRD Flame Reactor SITE Demonstration test, the sulfur dioxide emissions were below 500 ppm except for a 2-minute period during one run immediately following system startup, after a shutdown was required to cool the off-gas systems. During this 2-minute period the maximum sulfur dioxide emission was 514 ppm.

Mass Balance Analysis

The HRD Flame Reactor SITE Demonstration included a mass balance analysis, which calculated (1) weight reduction of the waste feed and (2) percent recovery of metals. Each of these items is discussed below.

The HRD Flame Reactor reduced the weight of the waste feed by 36.6% (that is, the effluent slag and oxide product weighed 36.6% less than the amount of waste feed). The weight of the waste feed was reduced because carbon was essentially completely converted to carbon dioxide, moisture was converted to steam, chloride was converted to hydrogen chloride gas, and sulfur was partially converted to sulfur dioxide.

The metal recoveries, when calculated based on concentrations in the waste feed and oxide product, were less than 100%. The mass balance closure for the demonstration was also less than 100%. These values were low because of residual material buildup in the combustion chamber and heat exchanger. For lead, zinc, and cadmium, these percent recoveries are 77.7, 80.0, and 75.0, respectively. The actual percent recoveries of lead, zinc, and cadmium are expected to be higher and may range from 90% to 99% weight.

The particle size distribution (PSD) of the waste feed and the brief residence time in the reactor (between 0.1 and 0.5 sec) affect the kinetics of the treatment reactions. For the demonstration, 66.6% by weight of the waste feed particles were smaller than 200 mesh. This PSD yielded a 77.7% weight recovery of lead.

HRD Flame Reactor Operational Reliability and Treatment Costs

The HRD Flame Reactor SITE Demonstration included an analysis of the Flame Reactor's operational reliability and treatment costs. Both of these items are discussed below.

*U.S. Government Printing Office: 1992 — 648-080/60130

Information collected on the reliability of the HRD Flame Reactor during the demonstration revealed that the HRD Flame Reactor had no major operational problems; however, auxiliary systems, such as the oxide product collection system, cooling water system, and feed system, experienced problems that did not affect the operation of the Flame Reactor but impacted the overall system performance.

The oxide product collection system, consisting of a shell-and-tube heat exchanger, a baghouse, an induced draft fan, and a stack, was undersized for the demonstration. The Flame Reactor was sized to handle 20,000 tons/yr of electric arc furnace (EAF) dust, but the off-gas handling system was put together from surplus zinc smelter parts. Due to deterioration of those used parts, the off-gas handling system presently cannot handle the volume of gas generated from processing 20,000 tons/yr of EAF dust. The operating conditions required for the demonstration produced high off-gas volumes, and the Flame Reactor system was typically shut down after about 4 hr of operation because the oxide product collection system was undersized. For a commercial operation, the oxide product collection system would include a larger baghouse and a higher capacity induced draft fan to introduce a large volume of cooling air. Because of this addition, the existing heat exchanger would not be required.

The cooling water system also developed problems. The supply line to the shell-and-tube heat exchanger developed an underground leak, and makeup water was added to the cooling tower. This problem did not affect the operation of the reactor and would not occur during commercial operation because the heat exchanger would not be used.

During a test run, one of the surge hopper screw feeders in the feed system jammed. For approximately 30 min, the other day bin was used at twice the normal capacity to keep the waste feed rate constant. The operation was not adversely affected.

The estimated cost per ton for treating secondary lead smelter soda slag ranged from $208 to $932. A 50,000 tons/yr waste treatment scenario cost $208 per ton and included a more efficient waste pretreatment system than presently exists at the HRD facility; the SITE Demonstration test scenario cost $932 per ton. The estimated costs of the HRD Flame Reactor system are highly site-specific and rather difficult to identify without accurate data from a site remedial investigation report or waste profile. Variability in the waste characteristics and the costs of transporting waste to the HRD Flame Reactor, as well as the costs of transporting, shipping, and handling residuals, could significantly affect costs presented in this economic analysis. Costs presented are order-of-magnitude estimates. A more detailed discussion of the economics of this technology is presented in the HRD Applications Analysis Report.

Quality Assurance Procedures

The primary quality assurance objective of this and all SITE demonstrations is to produce well-documented sampling and analytical data of known quality. To accomplish this goal, a detailed and comprehensive Quality Assurance Project Plan (QAPP) was developed before the demonstration. This QAPP contained specific quality assurance targets for precision, accuracy, completeness, representativeness, and comparability. It also specified the (1) analytical methods to be used, (2) holding times, (3) number and type of blanks, (4) matrix spikes and matrix spike duplicates, (5) laboratory duplicate samples, (6) reference standards, and (7) method detection limits.

The waste feed and effluent slag from the reactor are both nonhomogeneous and composed of a matrix that is difficult to digest and analyze for metals. Therefore, a study was undertaken to select the best digestion method for determining metals in these matrices. Based on this study, a modification of EPA SW-846 Method 3050 using a reduced sample size was chosen. However, when this method is used, the results are known to be poor for the digestion of silicon and for the digestion of chromium in a high silicon content matrix.

Conclusions

Based on the results of the HRD Flame Reactor SITE Demonstration, the following conclusions can be made concerning the performance of HRD Flame Reactor technology:

- The HRD Flame Reactor technology processed secondary lead smelter soda slag from the NSR site and produced both a potentially recyclable metal oxide product and an effluent slag meeting RCRA TC rule criteria.
- Although the Flame Reactor stack emissions were monitored, a site-specific risk analysis is required to assess the impact of these stack emissions. Such an analysis was outside of the scope of this report. The atmospheric emissions of metals from the Flame Reactor could be a concern, however, due to data limitations, no conclusions could be reached on metal emissions.
- The HRD Flame Reactor achieved a net weight reduction of 36.6% of the waste feed when processed into oxide product and effluent slag.
- During the demonstration, the HRD Flame Reactor had no major operational problems; however, auxiliary systems such as the oxide product collection system, cooling water system, and feed system experienced problems that did not affect the operation of the Flame Reactor. HRD agrees with EPA that these systems require refinement.
- The HRD thermodynamic model can be used to set preliminary operating conditions and to determine order of magnitude estimates for parameters used in a cost estimate, such as fuel and oxygen flow rates.
- The HRD Flame Reactor system processed secondary lead smelter soda slag from the NSR site at a cost of $932/ton for the demonstration. This cost included extensive testing. Data from HRD for similar applications show that the HRD Flame Reactor can process this waste for $208/ton in commercial operation.

The EPA Project Managers, **Marta K. Richards** and **Donald A. Oberacker**, are with the Risk Reduction Engineering Laboratory, Cincinnati, OH 45268 (see below).

The complete report entitled "Technology Evaluation Report: Horsehead Resource Development Company, Inc., Flame Reactor Technology," (Order No. PB92-205 855/AS; Cost: $26.00, subject to change) discusses the results of the SITE demonstration. This report will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

A related report entitled "Application Analysis Report: Horsehead Resource Development Company, Inc., Flame Reactor Technology," (EPA/540/A5-91/005), discusses the applications of the demonstrated technology.

The EPA Project Managers can be contacted at:

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