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Project Summary

Trace Metal Retention When Firing Hazardous Waste in a Fluidized-Bed Incinerator

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This report describes a bench-scale fluidized-bed incinerator that will capture trace metals on the bed material when firing hazardous waste. The design is based on limited tests at an existing laboratory facility. Operating conditions, operating procedures, and equipment design are established for greater than 90 percent trace metal capture on the bed material. A surrogate hazardous waste, paint containing lead chromate, was used in the tests. Other trace metals were identified that can be captured by agglomeration on a silica bed material. The design provides the capability of operating in either a single- or double-stage configuration so that various bed materials or operating conditions can be used to capture different trace metals or to provide more effective capture. The bench-scale fluidized-bed incinerator will have the flexibility to operate with several fuels, bed materials, and fluxing agents, over a wide range of operating conditions.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Emissions of trace metals from the combustion of hazardous waste material is of primary concern to EPA's Office of Solid Waste. Organic material in such waste can be disposed of by incineration; however, many trace metals are emitted into the atmosphere from most conventional incinerators. This study was undertaken to evaluate the potential for fluidized-bed incinerators to capture the trace metals.

The major activity of this work assignment was to provide a design package for a versatile bench-scale fluidized-bed incinerator. This design was to be based on general experience in fluidized-bed combustion, with particular attention to operating conditions expected for trace metal capture. The bench-scale testing was preliminary in nature to establish the feasibility of the system. A detailed performance analysis of the fluidized-bed incinerator was not necessary to design the bench scale unit. Starting with a feasible system, EPA plans to conduct subsequent work using the versatilely designed bench-scale facility to thoroughly test the trace metal capture performance on specific waste materials.

The project objective was to design a bench-scale fluidized-bed combustor (FBC) to capture trace metals in the bed material during hazardous waste incineration. Special designs (e.g., cascading FBCs or a spouted bed) and selected bed materials were evaluated for capturing the trace metals in the FBC. Preliminary tests were run in an existing laboratory facility, firing a surrogate hazardous waste to establish system feasibility and performance. Samples were collected to determine collection efficiency and to provide design data for the bench-scale FBC.

Procedure

Four tasks were identified for conducting the required project work: waste characterization, testing, FBC design, and reporting.

Battelle's background in fluidized-bed combustion, waste management, and environmental control technology provided a starting point in planning the project. The waste characterization task evaluated different types of waste materials (e.g., paint, paint sludge, or used lubricating oil) that could be used as the surrogate for testing. All of these wastes contain trace metals of interest to EPA. Candidate bed materials (e.g., silica, limestone, alumina, or glass beads) were evaluated for chemical absorption and physical adsorption of the trace metals onto the bed material. The operating conditions of the FBC were selected to match the trace metal(s) of interest and the bed material. It was generally preferred to capture the trace metal as an oxide, but consideration was given to cascading beds so that another chemical species of the trace metal can be captured.

A limited amount of experimental testing was done to verify the behavior of the candidate materials in the FBC. After evaluating the available existing facilities at Battelle, the 6-in. Spouted Bed Facility (after modification to operate as a conventional FBC) was chosen as most suitable for this work. Modifications included installing a perforated plate distributor, reactivating the liquid feed system and the flue gas cyclone, and installing a particulate filter. Sample points were provided for the bed material, cyclone capture, and filter capture so that a material balance and capture efficiency could be calculated.

The bench-scale FBC was designed for use by EPA to test a variety of hazardous waste streams. A detailed design of the FBC and its integral components (e.g., the distributor, instrumentation, and materials of construction) are provided. Specifications of auxiliary components (e.g., air supply, start-up burner, and control and analytical instrumentation) are also provided so that existing off-the-shelf equipment can be purchased by EPA. The design is of such quality that a mechanical contractor can provide a fixed price bid for building the facility.

Discussion and Results

Waste Characterization

Consistent with the project objective of trying to capture trace/heavy metals on the bed material in a FBC, a review was conducted to characterize the hazardous wastes and trace metals of concern. Based on toxicity and OSHA threshold limit values (TLVs), six metals were selected as priority concerns: mercury, lead, cadmium, chromium, nickel, and cobalt. Other metals which were considered are: antimony, arsenic, barium, beryllium, selenium, silver, and tellurium. It is thought that all of these metals, except mercury, can be captured as a stable oxide at conventional operating conditions for a FBC. The relatively high vapor pressure of elemental mercury presents a special problem that must be addressed separately.

The mechanism for capture of these trace metals, except for mercury, is to agglomerate the metal oxide with silica in the fluidized bed. The addition of a small quantity of sodium carbonate (Na_2CO_3) to the fluidized bed of silica results in a "tacky" surface. This approach utilizes the chemistry of glass formulations on the surface of the bed material. At near the softening temperature, the particles within the fluidized bed have a tacky surface and thus can stick to other particles.

This is the proposed basis for capture of trace metals in the FBC. First, particles of the trace metal oxides are trapped by the sticky surface of the bed particles, and the trace metal oxides are incorporated into the glass composition. In favorable circumstances, the trace metals are trapped as insoluble glasses, greatly easing the problem of disposing of the material.

Nearly all of the trace metals in th form of their oxides react with th sodium silicate to form glasses of low water solubility than that of the sodiu silicate glass.

Experience with particle agglomeratio has shown that fine particles tend t attach to the relatively large bed particle in a FBC operating at an agglomeratin temperature. The small particles coat th large particles with a tacky surface. If th temperature is too high or the surface to tacky, a point will be reached where th bed particles stick to each other an defluidize the bed. An empirical correlatio between bed temperature and superficia fluidizing velocity establishes a range c stable fluidization.

Paint containing lead-chromate pigmer was chosen as the surrogate hazardou waste to be used in testing this captur mechanism in the laboratory. Paint is common material which typically contair one or more metallic pigments and solvent that is the fuel to be incinerate

Experimental Test Facility

Figure 1 shows the FBC and auxiliar equipment used during the testing phas of the project. The FBC has insid dimensions of 6 in. (0.15 m) diameter an 84 in. (2.13 m) overall height, and is line with 2 in. (0.05 m) of castable refractor

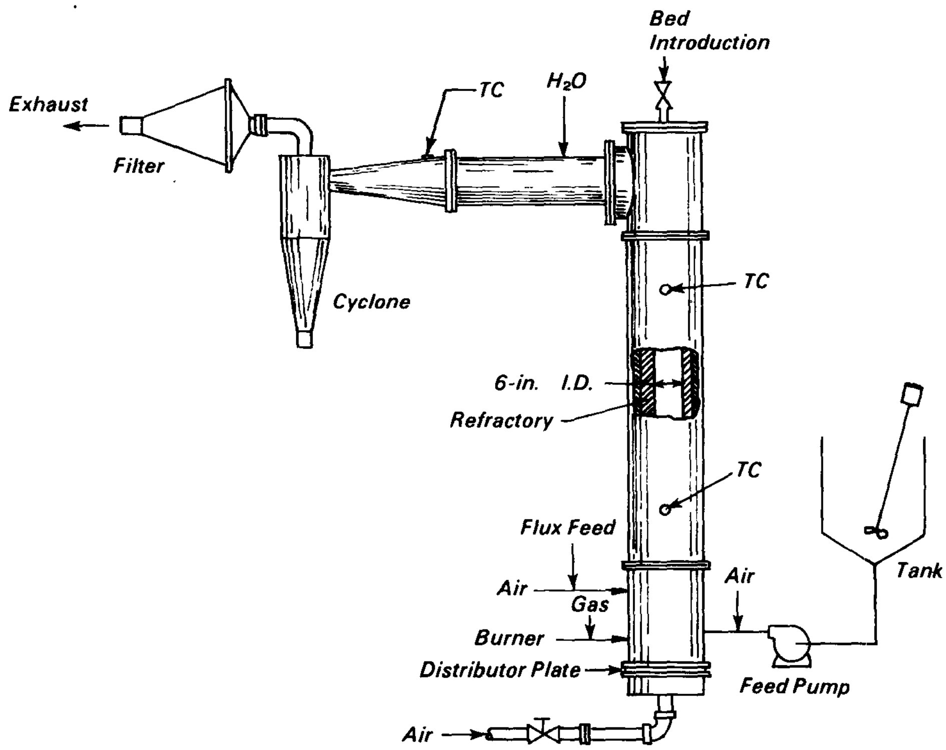

Figure 1. *Six-in. fluidized-bed combustor.*

The unit is flanged near the top and bottom: a number of nozzles in both the sidewalls and the top are for bed introduction, feed introduction, and temperature and pressure indicators.

A natural gas burner in the FBC's bed area heats the bed material prior to introduction of the waste feed. The fluidizing air, after passing through the distributor plate and bed material, is exhausted from the unit via a water-cooled stainless steel, 6-in. diameter line which discharges the dust-laden gases into a cyclone dust collector. After the cyclone, the gases pass through a high-purity glass fiber filter and into the building exhaust system.

The surrogate waste material was pumped to a pneumatic feed tube in the side of the combustor, 4 in. (0.1 m) above the distributor plate, using a peristaltic pump. The single-barrel (1/4-in. diameter) water-cooled feed tube allowed dispersion of the feed by varying the amount of air to the tube.

Test Results

Seven tests were made in the 6-in. FBC while feeding surrogate hazardous waste. Six of the tests used paint as the source of trace metals, and one test was with used motor oil. A preliminary test, without trace metals in the fuel, was used to check out the equipment and establish baseline operating conditions before testing the surrogate hazardous wastes. The primary variables were temperature, velocity, and the use of sodium carbonate (Na_2/CO_3) as a fluxing agent. The combustion temperatures ranged from 1300 to 1600°F (700 to 850°C), and the superficial velocity varied from 3.3 to 4.0 ft/sec (1.0 to 1.2 m/sec). During the preliminary test, a shallow, 6-in. bed depth was tried: considerable difficulty was encountered in burning mineral spirits. Therefore, a 12-in. deep bed was used to get more complete combustion in all the tests with surrogate hazardous waste as the fuel. This amounted to 20 lb (9 kg) of minus 20 plus 100 mesh sand.

Approximately 90 percent of the trace metals were captured on the bed material in a fluidized-bed incinerator. These tests established the operating conditions and verified the capture mechanism. A significant amount of the trace metals were captured with the bed material in one of the tests without the fluxing agent. Thus the requirement for the fluxing agent is less critical, depending on the waste material and the operating conditions. Adding a fluxing agent to the system is more certain and controllable. Further testing would maximize the capture of trace metals and extend the operation to more materials.

Design

The bench-scale FBC was designed to burn hazardous wastes containing trace metals. The system can burn either solid or liquid waste materials. A fluxing agent can be added to the fluidized bed to improve capture of the trace metals on the bed material. The FBC temperature can be controlled by modulating the fuel feed and fluidizing air rates. The 6-in. diameter combustor is designed for a heat release rate of about 32,000 Btu/hr (34 MJ/hr), corresponding to a superficial velocity of 3 ft/sec (0.9 m/sec) at 1400 °F (760°C). The design is based on a 12-in. (0.3-m) deep bed of silica sand, 20 x 100 mesh, for this fluidization condition.

Considerable flexibility is designed into the system so that a wide range of operating conditions are possible. Single-stage operation is possible, using one FBC. Two FBCs can be operated in series to provide two separate operating stages. This feature provides the ability to operate with two different bed materials, or fluxing agents, to capture distinct trace metals in each bed. The FBC design is the same for both stages. Figure 2 shows the system with two stages in series.

The upper section of the combustor is expanded to facilitate solids disengagement from the flue gas. After exiting the combustor, the flue gases are quenched to 300°F (150°C) by spray injection of cooling water. The gases then pass through a cyclone and filter before being exhausted from the system.

When operating two FBCs in series, the gas condition into the second FBC affects the distributor plate and bed behavior. For this reason, a cyclone was specified in the duct between the two units to minimize plugging caused by dust from the first stage FBC. Gas temperature into the second stage FBC may need to be controlled separately from bed temperature, but this depends on the conditions being tested.

Conclusions and Recommendations

A FBC can capture on the bed material over 90 percent of the trace metals from the incineration of a surrogate hazardous waste. To maximize this trace metal capture, operating conditions are set at less than 1350°F (750°C), 4 ft/sec (1.2 m/sec) superficial velocity, and bed material containing up to 0.5 percent sodium carbonate (Na_2CO_3) as a fluxing agent. These conditions are based on limited testing to establish a design basis for this project. More extensive testing would optimize the system and to extend the operation to a wide range of wastes.

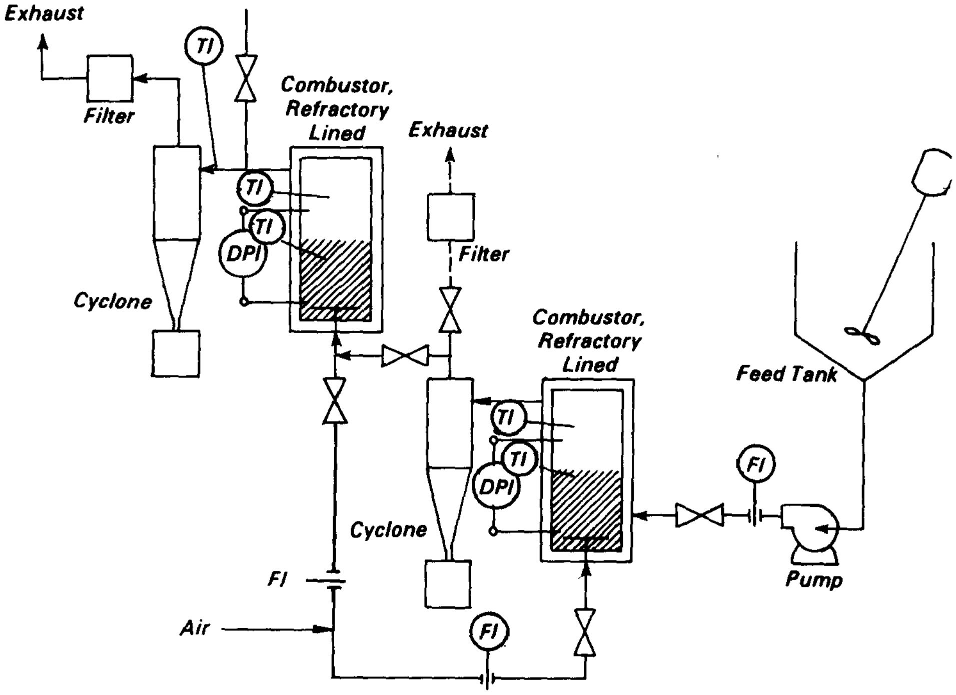

Figure 2. Six-in. fluidized-bed combustion facility (two-stages in series).

A bench-scale FBC has been designed to operate in either a single- or double-stage mode so that testing can be conducted. Such a facility, built to operate on a variety of hazardous wastes, could be used to determine the trace metal capture efficiency and operating conditions for a variety of wastes. It would also be possible to evaluate the capabilities of a two-stage operation. Some wastes may require higher operating temperatures than those tested in this work to achieve complete combustion; testing under a variety of conditions would more fully capitalize on this work.

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***Robert E. Hall** is the EPA Project Officer (see below).*

The complete report, entitled "Trace Metal Retention When Firing Hazardous Waste in a Fluidized-Bed Incinerator," (Order No. PB 85-138 618; Cost: $8.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
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