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**STATUS REPORT ON THE
FLUIDIZED BED INCINERATION SYSTEM
FOR U. S. DEPARTMENT OF ENERGY
DEFENSE WASTE
JANUARY - JUNE 1977**

Lewis L. Richey

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Chemistry Research and Development
PILOT PLANT DEVELOPMENT

Rockwell International

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U. S. DEPARTMENT OF ENERGY
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SUBJECT DESCRIPTORS

Fluidized Bed
Incinerators
Waste Management

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STATUS REPORT ON THE FLUIDIZED BED INCINERATION SYSTEM
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DEFENSE WASTE

JANUARY - JUNE 1977

Lewis L. Richey and Pen K. Feng

Abstract. A fluidized-bed incineration facility has been designed for installation at the Rocky Flats Plant to develop and demonstrate the process for the combustion of transuranic waste. The unit capacity will be about 82 kg/hour of combustible waste. The combustion process will utilize *in situ* neutralization of acid gases generated in the process. The equipment design is based on data generated on a pilot scale unit, and represents a scale-up factor of nine. Building modifications are complete and equipment installation has begun.

INTRODUCTION

Fluidized bed incineration is being evaluated at the Rocky Flats Plant (RFP) as an alternative to conventional incineration for processing transuranic (TRU) combustible waste. The fluidized bed concept is being pursued through three channels of activity at the present time: (1) a 9-kg/hour (20-lb/hour) pilot plant system is undergoing operational testing with low concentrations of plutonium contaminated solid and liquid wastes; (2) an 82-kg/hour (180-lb/hour) developmental plant has been designed and is being installed in an existing building; and (3) an integrated laboratory development program is underway to provide specific and timely data for the larger systems. This substantial amount of research is being expended in an effort to overcome inherent problems in conventional incineration of TRU wastes and to develop an improved incineration system for processing existing and/or future waste from nuclear industry in general.

Through the years, operation of the plutonium recovery facilities at RFP has identified a need for an improved incineration system. The conventional methods employed at RFP, though effective, have

resulted in substantial maintenance problems because of equipment corrosion, short refractory life, and mechanical problems. In addition to frequent maintenance requirements, the process utilizes an aqueous flue gas scrubbing system that requires additional treatment and increases the total plant waste volume. Also, the conventional open flame incinerator produces a high temperature (850 to 1000 °C) refractory type of plutonium dioxide that does not readily lend itself to the plant's aqueous recovery technique. The fluidized bed incinerator was conceived in 1971 as an alternative to the present conventional system.

Promising data from subsequent work has led to the present intensive development program to produce a production scale development plant.

The fluidized bed process incorporates three concepts that set it apart from conventional incineration. One unique concept is the *in situ* neutralization of acid gases that are produced when materials such as polyvinyl chloride plastic are burned; another is the use of a catalytic afterburner, and the third is non-flaming low-temperature combustion throughout the system. These three features are responsible for several advantages of this process over conventional methods. The most significant benefits derived are the elimination of refractory-lined equipment, the elimination of aqueous flue gas scrubbing, and minimization of equipment corrosion. These factors are expected to extend equipment life, decrease maintenance requirements, and improve overall waste volume reduction.

SUMMARY

A fluidized bed incineration system has been designed for combustion of transuranic waste. The

facility is designed for a capacity of about 82 kg/hour (180 lbs/hour) which will correspond to a heat release rate of about 1,600,000 KJ/hour (1,500,000 Btu/hour). The process equipment design is based on data generated in the pilot plant and represents a scale factor of nine based on solid waste feed rates. Approximately 45% of the heat of combustion will be extracted through the walls of the afterburner by a water spray cooling system. In the pilot unit, most of the heat is removed as sensible heat of the combustion products.

A water cooled heat exchanger in the flue gas stream will be used to remove approximately 55% of the heat of combustion from the process. In the pilot unit, the flue gas was cooled by dilution with room air. An air jet ejector was used in the pilot unit and high speed blowers will be used in the larger unit to provide motive force for gas flow through the process.

Title II Engineering is complete on the installation of the containment walls and the exhaust plenum, and construction is 64% complete. Title II Engineering of process equipment is complete and construction has begun. The project schedule has been adjusted to keep the cost in FY 1976 and FY 1976A within the available funding limits and the projected start-up is in the second quarter of FY 1978.

An air classification system is being redesigned into the incineration facility for removal of tramp metal from the combustible waste. The hand sorted waste will be shredded and fed directly to the air classifier. The classifier will remove "tramp" metal and the combustibles will pass through a second stage of shredding prior to introduction to the primary reactor.

The design for the sintered metal filter housing has been modified to reduce equipment costs and space requirements without sacrificing performance.

In order to remove trace amounts of "tramp" metal that gets into the primary fluidized bed, a discharge screw has been tested on a bench scale and scaled up for the demonstration unit. The screw will remove the more dense metal particles without removing the bed material.

To overcome some operational problems with the preheater used on the pilot plant fluidized bed system, laboratory scale tests were conducted on a new preheat system. The operational problems involved uneven heating in the catalyst preheater, causing hot spots and degradation of the catalyst. The catalyst was changed from a chromic oxide on a granular alumina support to platinum metal on an alumina honeycomb matrix support. With the larger void volume of this system, better mixing of the fuel and air resulted and more uniform heating was accomplished. The erratic ignition still continued so the fuel was changed from kerosene to methyl alcohol. The tests produced better results than the present operating system and methyl alcohol was found to be a better fuel than kerosene.

The process monitoring and control system has been better defined and effort is being directed toward completing the software configuration. A remote weighing station is also under development to impose strict inventory control on the drums of waste processed. This system is scheduled to be operational in November 1977.

EXPERIMENTAL PROGRAM

Air Classifier

As stated in RFP-2450, "Fluidized Bed Incineration System for ERDA Transuranic Waste," alternate methods of waste classification have been investigated. The air classifier installed on the pilot plant scale fluidized bed had a tendency to plug, especially at high throughput rates. The conveyor belt that fed the air classifier was also prone to slippage caused by the high dust loading of the shredded waste. To eliminate this undesirable operation, the air classifier was redesigned to reduce pluggage and eliminate the belt conveyor. The air classifier will now be positioned directly below the first shredder to accept the shredded feed directly, and eliminate the belt conveyor and feed star valve. The old air classifier also contained many sections for deflecting the shredded waste.

The principle of the operation was to cause enough turbulence to allow the lighter material to separate from the more dense material and to impact the

shredded material on the deflecting surfaces. This impaction caused the more dense material to fall counter to the rising air flow and raised the lighter material out of the unit.

The unit operated satisfactorily when the shredded waste was roughly the same particle size and shape. Severe plugging occurred when some of the shredded pieces were ribbon shaped. They would wind around the feed star valve preventing the feeding of additional material and would combine with the dense material until the unit was plugged. By placing the new air classifier directly beneath the shredder, the feed star valve could be eliminated and with only one deflection of the air flow, the tendency to plug was greatly minimized. An additional feature of the new unit is a movable vane. The vane can be positioned to give the most efficient separation of dense and light particles and in the event of a pluggage, can be moved to a position to allow total discharge of the pluggage to a receiving glovebox.

A unit with these features was tested on a laboratory scale. The tests proved successful and the unit was operated until enough information was generated to develop design criteria for a demonstration scale unit. The design criteria was then released to Engineering for the preparation of detailed assembly drawings. This unit was designed by March 1977, fabricated by May 1977, and will be installed by September 1977.

Sintered Metal Filter Housing

The design on the present pilot plant uses eight sintered metal filter housings each having isolation valves. In operation, the isolation valve on the filter housing to be blown back is closed and high pressure air is used to knock the ash fines from the filter. As the process is scaled up by a factor of nine, this method becomes expensive to duplicate because of the large number of high temperature resistant isolation valves required. To reduce the costs on this project the design was changed to an industrial type filter housing. This process will use two filter housings due to space and configuration limitations. Each filter housing will contain 96 sintered metal filter tubes, one-inch in diameter, approximately four feet long. They are arranged in eleven rows

with each row having its own blow-back header. Each blow-back header has a low temperature service solenoid valve to control the duration of the blow-back pulse. In operation, each blow-back header will pulse its associated filter tubes $\frac{1}{4}$ of a second every 22 minutes. For each filter housing containing eleven rows of filter tubes, a blow-back header will be sequentially pulsed every two minutes.

To assure successful operation of this unit, bench scale tests were conducted to determine the size of the blow-back header, pulse duration, and pulse interval. To obtain visual observation of this operation, a one-inch diameter sintered metal tube was placed inside a vertical six-inch diameter glass pipe. Dust was then loaded on the sintered metal tube at the design gas flow rate through a single tube. To remove the collected dust, a pulse of high pressure air was directed down the tube without stopping the flow discharging from the system. The tests showed that satisfactory dust removal could be accomplished with this system. Design criteria was generated for this system, tailored to the requirements for the demonstration scale plant. The two units have been fabricated and are in storage awaiting installation.

Primary Reactor Discharge Screw

In the pilot scale fluidized bed system, hand sorting and air classification are used as pretreatment methods for removal of "tramp" metal from the waste feed. As efficient as the air classifier is, trace amounts of "tramp" metal will enter the primary reactor and accumulate in the bottom of the fluidized bed. A conceptual design has been completed for a device to remove the "tramp" metal from the bed without removing the sodium carbonate bed material. The concept utilizes a screw conveyor to remove the "tramp" metal from the bed. A gas flow countercurrent to the conveyor discharge retains the sodium carbonate in the fluidized bed. To test how functional this concept is, a bench scale test was conducted using a two-inch diameter screw conveyor running through the bottom of a fluidized bed of sodium carbonate. The "tramp" metal added to the fluidized bed was carried out by the rotation of the screw while the countercurrent air flow segregated and retained the

sodium carbonate in the bed. Tests have generated design criteria for a unit large enough to handle anticipated requirements. This unit is scheduled to be fabricated by November 1977 for installation by December 1977.

Fluidized Bed Preheat System

Before the start of incineration, the fluidized bed must be raised to operating temperature with heated air. The present system on the pilot scale uses electrical preheat and catalyzed fuel heating to raise the ambient fluidizing air to about 600 °C. The catalyzed fuel heater is a fixed bed of chromic oxide on an alumina substrate in which heated air from the electric heater is mixed with fuel. In operation, local hot spots develop in the fuel heaters, causing uneven combustion and degradation of the catalyst. To overcome these problems, a laboratory scale system was tested. In this system, an electric preheater is used to raise the ambient air to about 300 °C. This heated air stream is transported to another vessel where fuel is injected with a pneumatic atomizing nozzle into a catalytic platinum on alumina substrate matrix. The matrix has more void volume and promotes better mixing than the fixed catalytic bed, eliminating local hot spots. After tests with kerosene as the fuel gave inconsistent results, methyl alcohol was tested. The methyl alcohol markedly improved the performance of the system by its uniformity of ignition and combustion. Based on these results, a fueled preheat system was designed for the catalytic afterburner fluidized bed using methyl alcohol. Although the primary reactor must also be preheated, it is smaller and electric air heating only will be used to raise the temperature of the primary bed to operating conditions. The fueled preheat system is scheduled to be fabricated by June 1977 for installation by September 1977.

PLANT DESIGN

Process Description

The fluidized bed incineration process is basically the same for both the pilot plant unit now in operation and the developmental scale unit now under

construction. The process used in the developmental unit will vary somewhat from that of the pilot plant in the method of heat removal and motive force for gas flow through the system. In the pilot plant, the heat of combustion is removed by blending the hot flue gas with a large amount of room air as it exhausts from the system. This method becomes impractical when the process is scaled up by a factor of nine for the development plant; consequently, the latter unit will be equipped with a water cooled heat exchanger for flue gas cooling. For motive force, the development unit will utilize high speed blowers to replace the air jet ejector that is used in the pilot plant system. These process modifications will reduce both equipment and operating costs of the developmental unit relative to a scaled up pilot plant system. A flow diagram of the development unit is presented in Figure 1.

The actual fluidized bed incineration process for radioactive waste differs considerably from conventional incineration techniques. The entire operation is carried out within a canyon and glovebox system for containment of radioactive contamination. Waste will be received in 0.2-cubic meter (55-gallon) drums.

The waste is first passed through an air lock into a feed preparation glovebox where it is hand sorted for removal of large size tramp metal. Sorted combustibles are then fed into a low-speed, cutter type shredder for coarse shredding. Small pieces of tramp metal that were undetected by hand sorting are shredded along with the combustibles. Coarse shredded material passes through an air classifier for removal of most of the remaining tramp metal. Metal separated by the classifier falls into a glovebox where it can be bagged out for disposal. The waste containing trace amounts of metal is pneumatically transferred into a second shredder for final sizing prior to incineration. A constant pitch tapered screw feeds the shredded waste into a primary reactor of heated sodium carbonate (Na_2CO_3) granules that are fluidized by a flow of compressed air and nitrogen gas. Within the hot fluidized bed, the waste is decomposed by partial combustion and and pyrolysis which produces sufficient heat to maintain a bed temperature of 550 °C. The air-nitrogen ratio of the fluidization gas is adjusted to promote the desired amount of combustion without

FIGURE 1. Flow Diagram of Fluidized Bed Incineration System for Transuranic Waste

open flame burning. Within the fluidized bed of Na_2CO_3 , *in situ* neutralization of acid gases is accomplished. Neutralization is achieved rapidly when nascent hydrogen chloride gas (HCl), formed during the decomposition of PVC plastic, reacts with Na_2CO_3 bed materials to produce sodium chloride (NaCl), carbon dioxide gas (CO_2), and water vapor. Offgas from the primary reactor passes into a cyclone separator where most of the entrained Na_2CO_3 , NaCl , and fly ash is removed before the gas is introduced into the catalytic afterburner. In the afterburner chamber, combustion air is added to the gas stream as it passes through a fluidized bed of oxidation catalyst. Here, complete combustion is achieved without open flame burning. A bed temperature of 600°C is maintained by a water jacket heat transfer system.

Flue gas leaving the catalytic afterburner contains fly ash, catalyst dust, and small amounts of Na_2CO_3 and NaCl fines that were not removed from the primary reactor offgas by cyclone separation. About 75 to 85% of this dust is removed by passing the gas stream through a second cyclone separator. The remainder is removed as the gas passes through a bank of sintered metal filters prior to cooling to 50°C in a water-cooled heat exchanger. The cooled flue gas is then pulled into four high-speed blowers that provide motive force for the process flow. These blowers also maintain a slightly negative pressure throughout the system. Offgas from the process passes through a bank of high efficiency particulate air (HEPA) backup filters prior to exiting through the building plenum system of four-stage HEPA filtration. Dust removed by cyclone separation and sintered metal filtration is cooled in a screw conveyor that transfers the residue into a drum for disposal.

The development plant will feature automatic control systems to regulate bed temperatures within the primary reactor and catalytic afterburner. The primary bed temperature will be controlled by the air-to-nitrogen ratio of the fluidization gas. A drop in bed temperature will activate automatic controls to increase the percent of air until the bed temperature climbs to the desired set point. Conversely, the percent of nitrogen will automatically be increased if a heat spike drives the bed temperature above a predetermined point. Catalytic afterburner

temperature will be regulated by the quantity of waste being fed into the system. Deviations in catalyst bed temperature will prompt automatic controls to increase or decrease the speed at which the screw feeder transfers waste into the primary reactor. In this manner, the amount of fuel entering the afterburner will be controlled to maintain a preset catalyst bed temperature.

Status of Engineering Work

The construction work on Phase I, erection of the containment wall, was completed in April, 1977. A beneficial occupancy inspection was conducted on April 7, 1977.

Installation of the four-stage exhaust HEPA filter plenum was completed June, 1977. Component testing and filter testing is scheduled to be completed by November, 1977.

Phase II design package, installation of process equipment, was issued to Rockwell Maintenance during February, 1977. Completion of Phase II was estimated to require 8000 man hours.

Equipment Installation

Rockwell Maintenance began Phase II work on April 11, 1977. The entry glovebox and the hydraulic drives for the low speed cutter-type shredders were installed first.

As of June, 1977, 65% of the tasks were scheduled to be completed. However, only 38% of the tasks have been completed with a schedule slippage of about one month.

A listing of the process equipment installed as of June, 1977, is included below:

1. The sorting-entry glovebox.
2. The "tramp" metal removal glovebox.
3. The feed screw.
4. The primary reactor.

5. The primary and secondary cyclones.
6. The four exhaust blowers.
7. The HEPA filter frames.
8. The "canyon" stainless steel wall.
9. The hydraulic drives for the shredders.
10. The pressure measuring transducers.

Process Monitoring and Control Systems

The fluidized bed incineration process will utilize a programmable data processor - 11/10 (PDP-11/10) minicomputer, in conjunction with the Foxboro Interspec System for process monitoring and control purposes (refer to previous Progress Report RFP-2654).

Field measurements consisting of 25 temperatures, 16 pressures, three flows, one contact closure, one weight, six analysers, and ten control loops will be brought into the Foxboro Interspec System where analog-to-digital signal conversion is performed. The resultant digital signals will be sent to the PDP minicomputer to form a process data base from which pertinent information concerning the process can be extracted. A timer will continuously transfer and update the data base at some preset interval (e.g., one minute). A real-time software package under operator keyboard control will perform the following functions:

1. Convert signals into meaningful engineering values. The Foxboro controller mode of set point operation may be automatic, manual, or computer controlled.
2. Display any process measurement or groups of measurement on the cathode ray tube (CRT).
3. Sound a bell and blink process measurements exceeding alarm conditions on-off on the CRT.
4. Allow change of alarm limits and set points of control loops by the operator.
5. Print out hard (paper) copies of data base periodically and on demand by the operator.

6. Handle all transfer of information between peripheral devices.

PRIOR WORK

Work accomplished during this period is divided into two areas:

1. Hardware
 - a. Parts for the Remote Weighing Station were specified, ordered and delivered. Handwiring of this unit was 20% complete.
 - b. Hardware hook-up diagrams of the Foxboro Interspec System were 30% complete.
 - c. Delivery of all process sensors.
2. Software
 - a. An off-line heat and material balance program in Fortran IV was complete.
 - b. Data base variables were defined.
 - c. Display format of process variables on the CRT were defined.

FUTURE WORK

1. Hardware
 - a. Delivery of Foxboro Interspec System and interfacing computer cards.
 - b. Installation, wiring, and testing of all process instrumental and final control devices.
 - c. Documentation of all hardware instrumentation.
 - d. Order and take delivery of necessary spare parts.
2. Software
 - a. Completion of data base handling routines.

- b. Completion of off-line scientific programming package that will analyze data collected during an incineration run.
- c. Generate a complete set of diagnostic routine for trouble shooting and repair of the Foxboro Interspec System.
- d. Document all software routines and prepare a process control instruction manual.
- e. Indoctrinate and train operating personnel.
- 3. Process monitoring of the FBI will be handled by a programmable data processor - 11/10 (PDP-11/10) minicomputer and Foxboro Interspec System.
- 4. Parts for the Remote Weighing Station have been delivered.
- 5. An off-line heat and material balance program in Fortran IV is complete.
- 6. The catalytic system for the secondary fluidized bed preheater was changed from chromic oxide on a granular alumina support to platinum metal on an alumina honeycomb matrix. The new catalyst improved mixing of fuel and air, resulting in more uniform heating.

CONCLUSIONS

- 1. Construction work on Phase I, erection of containment wall was completed April, 1977.
- 2. Installation of the four stage exhaust HEPA filter plenum was completed June, 1977.
- 7. Because of erratic ignition the fuel was changed from kerosene to methyl alcohol.