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FLUIDIZED BED INCINERATION SYSTEM FOR U.S. DEPARTMENT OF ENERGY DEFENSE WASTE JULY–DECEMBER 1977

David L. Anderson

Frank G. Meyer

Pen K. Feng

Chemistry Research and Development
PILOT PLANT DEVELOPMENT

Rockwell International

Energy Systems Group
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80401

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Incinerators
Waste Management

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ENERGY SYSTEMS GROUP
ROCKY FLATS PLANT
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FLUIDIZED BED INCINERATION SYSTEM FOR U.S. DEPARTMENT OF ENERGY DEFENSE WASTE JULY–DECEMBER 1977

David L. Anderson, Frank G. Meyer, 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/hr 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 the 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 if 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.

The four stage HEPA exhaust plenum is now operational and is undergoing final adjustments. Phase II equipment installation was 84% complete as of November, 1977. Completion is now scheduled for February, 1978. Operational testing of completed sub-systems will proceed concurrent with the construction effort.

The process monitoring and control system diagnostic and operating software packages are 50% complete. The hardware and software development of the inventory control remote weighing station was complete as of November, 1977.

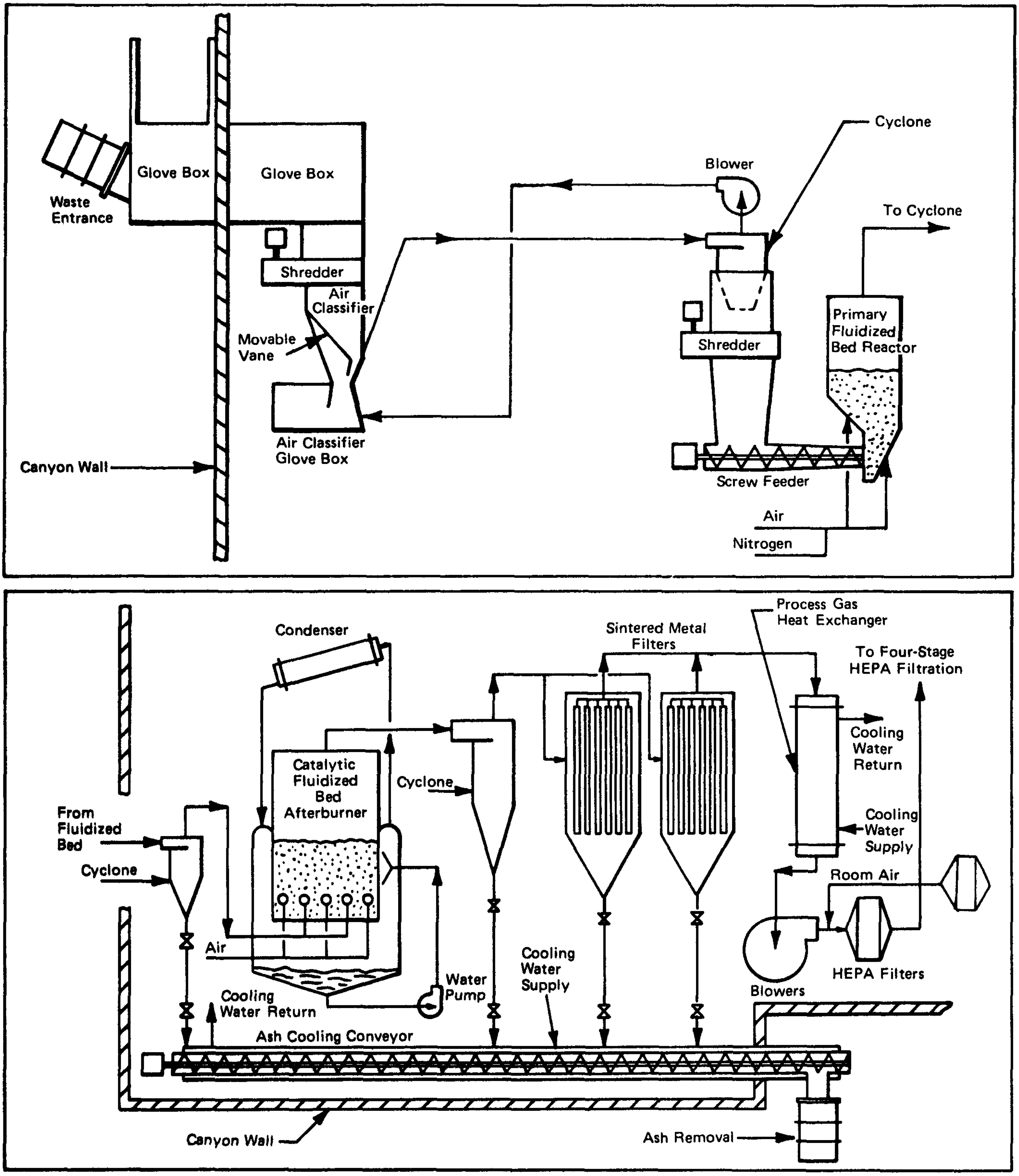
PLANT DESIGN

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 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 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

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



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 and maintain a slightly negative pressure throughout the system. Offgas from the process passes through a bank of high efficiency particulate air (HEPA) roughing filters prior to exiting through the building plenum system of four-stage HEPA filteration. 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 four stage HEPA filter plenum is now operational and undergoing final adjustments. This plenum will be placed in service as soon as roughing filters are installed in the processing area. The filters are required to prevent a spread of contamination in the processing area should a flow reversal occur.

Equipment Installation

Phase II, equipment installation, was 84% complete as of November, 1977. Scheduled completion of the installation will be delayed beyond December 31, 1977. Phase II completion was scheduled for the end of February, 1978. To minimize the impact on later milestones, testing of individual components and systems will be initiated before total installation is complete. Testing was previously scheduled to begin at the completion of installation.

Process equipment installation tasks completed to date include process items previously reported plus the equipment listed below:

1. Catalytic afterburner
2. Sintered metal filter housings
3. Air classifier
4. Hydraulic shredders
5. Flue gas heat exchanger
6. Exhaust blower intercoolers
7. Process cooling water lines
8. Catalyst-carbonate transfer box
9. Preheater fuel storage tank
10. Preheater fuel pump
11. Canyon ventilation ducting and roughing filters
12. Water cooled ash cooling screw
13. Primary fluid bed preheaters
14. Afterburner preheaters
15. Process control valves

Equipment installation tasks in progress as of the end of November, 1977:

1. Process control field wiring
2. Process instrumentation field wiring
3. Process flue gas ducting

Equipment installation tasks remaining in addition to those listed above:

1. Afterburner spray cooling water condenser
2. Afterburner spray cooling water pump
3. Process insulation
4. Feed drum hoist

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-2733). 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 conversion will take place. These 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).

The incorporation of computer process control will take place in two steps. During Phase I, the computer will perform strictly process monitoring and data acquisition operations. As more experience is gained from the operation of the Fluid Bed Incinerator, Phase II will be implemented. It will consist of programming into the computer the control logic necessary for direct digital control (DDC) or supervisory set-point control (SCC). The advantage of such a computerized control system with the correct analog-digital interface is the great flexibility it offers the user. Once the hardwares (computer, instrumentation, peripheral and interphase equipment, etc.) are in place, any field measurement can control any one or more actuating device by changing the system software (computer programs) environment. Little or no hardware change is necessary.

Prior Work

Work accomplished during this period is divided into two areas:

1. Hardware
   a. The Remote Weighing Station was completed.
   b. Hardware hook-up diagram of the Foxboro Interspec System was completed.
   c. Installation of process sensors was 70% completed.
   d. Control panel wiring diagram was completed.
2. Software
   a. Remote weighing station software package was completed.
   b. Hardware diagnostic routine and operating system routines are 50% finished.

Future Work

1. Hardware
   a. Testing of all process instrumentation and final control devices.
   b. Procure and build Graphics Display Panel.
   c. Order and take delivery of necessary spare parts.

2. Software

   a. Completion of operating system routines with detailed documentation.

   b. Prepare a process control instruction manual.

   c. Indoctrinate and train operating personnel.

   d. Continue to upgrade and increase a package of off-line scientific programs that will analyze data collected during an incineration run.

CONCLUSIONS

1. The four stage HEPA filter plenum is now operational and undergoing final adjustments.

2. Phase II, equipment installation, was 84% complete at the end of November, 1977.

3. The Remote Weighing Station has been completed.

4. The hook-up diagram of the Foxboro Interspec System has been completed.

5. The control panel wiring diagrams have been completed.

6. Installation of process sensors was 70% complete.

7. Hardware diagnostic routine and operating system routines were 50% complete.