RFP-2471

May 14, 1976

RFP-2471

FLUIDIZED BED INCINERATION OF RADIOACTIVE WASTE

Donald L. Ziegler

Chemistry Research and Development
PILOT PLANT DEVELOPMENT

MASTER

Rockwell International

Atomics International Division
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80401

U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT E(29-2)-3533

Printed in the United States of America
Available from the
National Technical Information Service
U. S. Department of Commerce
Springfield, Virginia 22161
Price: Printed Copy ~~$4.00~~ 3.50 Microfiche $2.25

Printed
May 14, 1976

RFP-2471
UC-70 NUCLEAR WASTE
MANAGEMENT
TID-4500-R64

FLUIDIZED BED INCINERATION OF RADIOACTIVE WASTE

Donald L. Ziegler

Chemistry Research and Development
PILOT PLANT DEVELOPMENT

SUBJECT DESCRIPTORS

Fluidized Bed
Incinerators
Waste Management

ROCKWELL INTERNATIONAL
ATOMICS INTERNATIONAL DIVISION
ROCKY FLATS PLANT
P.O. BOX 464
GOLDEN, COLORADO 80401

Prepared under Contract E(29-2)-3533
for the
Albuquerque Operations Office
U. S. Energy Research and Development Administration

DISTRIBUTION

206 – DTIE Distribution
2 – Standard Distribution
20 – TIO (Record)
8 – D. L. Ziegler
5 – A. J. Johnson
2 – D. J. Peterson
2 – H. N. Robinson
5 – L. L. Richey
2 – F. G. Meyer
1 – Library
1 – D. A. Wiederecht
1 R. H. Karlsson
1 – R. D. Howerton, Editor
1 – K. W. Calkins
1 – R. Southworth, Jr.
1 – A. R. Teter
1 – E. Jiannetti
Attn: E. Skulski
1 – H. F. Greer
1 – R. E. Lerch
Hanford Engineering
Development Laboratory
1 – C. R. Cooley
Hanford Engineering
Development Laboratory
1 – W. E. Clark and W. C. Ulrich
Oak Ridge National Laboratory
1 – B. G. Kniazewycz
Carolina Power & Light Co
1 – C. T. Sanders
Environmental Plutonium
Data Base Group
Oak Ridge National Laboratory
1 – Stanley S. Grossel
Process Design Section, Bldg. 71
Hoffman-LaRoache Inc.
1 – B. R. S. Gill, Product Manager
Douglas Engineering Company Ltd.
1 – D. E. McKenzie
Atomics Internation Division
Rockwell International
1 – J. Goodman
Westinghouse Electric Corporation
1 – S. S. Freeman
Monsanto Research Corporation
1 – Dr. L. R. Hill
Sandia Laboratories

1 – W. B. Kerr
Idaho Nuclear Corporation
1 – Lamarr Johnson
Los Alamos Scientific Laboratory
1 – Leon Fong
Atlantic Richfield
1 – R. L. Tracy
Stone and Webster Engineering Corp.
1 – Beryl Eschem
Stearns Roger Inc.
1 – J. A. Jurgile
Ryckman/Edgerley/Tomlinson
and Associates, Inc.
1 – N. C. Bradley
Oak Ridge National Laboratory
1 – J. R. McClain
Mound Laboratory
3 – J. D. Dempsey, R. W. Ramsey,
R. A. Wolfe
AEC Division of Waste Management
1 – Dr. Frank Morgan
Director Materials Division
AWRE
1 – W. Hendrickson
U.S. Energy Research & Development
Idaho Operations Office
1 – H. H. Elliot
General Electric Company
Vallecitos Nuclear Center
1 – Calvin Palmer
U.S. Energy Research & Development
Richland Operations Office
1 – Ervin H. Hardinson
U.S. ERDA
Oak Ridge Operations Office
2 – N. H. Mackay
U.S. ERDA
Albuquerque Operations Office
1 – Center for Atomic Energy
Documentation (ZAED)
Attn: Dr. Mrs. Bell
1 – Dr. Peter J. Dyne
Atomic Energy of Canada Ltd.
Whitcshell Nuclear Research Establishment

CONTENTS

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

FLUIDIZED BED INCINERATION OF RADIOACTIVE WASTE

Donald L. Ziegler

Abstract. A fluidized-bed incineration facility is being designed for installation at the Rocky Flats Plant to demonstrate a 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 unit and represents a scale-up of nine. Title I engineering is at least 70% complete.

INTRODUCTION

A conventional incinerator has been used at the Rocky Flats Plant for about 15 years to burn combustible scrap containing sufficient plutonium for recovery. The ash is subjected to aqueous processing for removing the contained plutonium. This incinerator has provided a valuable service for the plant; however, it has required frequent maintenance because of equipment corrosion, short refractory life, and mechanical problems primarily in the off-gas scrubbing equipment. Because of the high operating temperature (800 to 1000 °C), a refractory type of plutonium oxide is formed. This oxide is difficult to recover from the ash by aqueous processing.

To overcome some of the problems associated with conventional incineration, a program was undertaken to develop a fluidized-bed incineration process. A pilot plant was constructed and has been operated for about two years to develop design information and to obtain operating experience. The pilot plant initially was operated with simulated combustible scrap; it is presently burning low-level radioactive waste. This new process utilizes in situ neutralization of the acid gases to minimize equipment corrosion and to eliminate the need for an aqueous scrubbing system. An operating temperature of about 550 °C eliminates the need for refractory lined equipment and should produce a more soluble form of plutonium oxide in the ash.

In this process, the waste, which is composed of polyvinyl chloride (PVC), polyethylene, and paper, is chopped in a low speed, cutter-type shredder. The waste is then fed to the incinerator by a constant pitch, tapered screw conveyor at a rate of about 20 pounds per hour. During operation, the shredded waste is introduced into the primary combustion chamber under the surface of a fluidized bed of granular sodium carbonate ($NaCO_3$). The primary combustion chamber operates at a temperature of approximately 550 °C. Hydrogen chloride generated by PVC decomposition reacts with the bed material to form sodium chloride (NaCl). The fluidizing gas is a mixture of nitrogen (N_2) and air. The amount of air used is limited so that pyrolysis of the combustibles occurs and the operating temperature of 550 °C is maintained.

Particulates generated in this vessel are then partially removed by a cyclone, and the products of pyrolysis are intoduced into the bottom of a catalytic fluidized bed with enough air to ensure complete reaction. Flue gas dust generated in the afterburner at 550 °C is fed to a cyclone and a sintered metal filter for removal of the entrained solids. The gas stream then enters an air jet ejector. This ejector provides the motive force for gas flow through the reactors and filtering equipment and also cools the gas stream by dilution. This stream is blended with room air and passes through one stage of high efficiency particulate air (HEPA) filtration before it leaves the incineration room. It then passes through four stages of HEPA filtration before reaching the outside atmosphere.

Based on data generated by this equipment, a demonstration unit with a capacity of 82 kg/hr (180 lbs/hr) presently is being constructed for combustion of transuranic (TRU) waste.

SUMMARY

A fluidized-bed incineration system is being designed for combustion of transuranic waste. The process is being designed to have a capacity of about 82 kg/hr (180 lbs/hr), which will correspond to a heat release rate of about 1,500,000 kJ/hr (1,500,000 Btu/hr). Process equipment design is based on data generated in the pilot plant and represents a scale factor of nine based on solid waste feed rate.

The process departs from that of the pilot plant in three areas. First, 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 was removed with the combustion products. Secondly, 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. The third change involves an air jet ejector that was used in the pilot unit. High speed blowers will be used in the larger unit to provide motive force for gas flow through the process.

Title I engineering is complete on installation of the containment walls and exhaust plenum and is 70% complete on the process equipment portion of the project. The total cost for design and construction of the facility in an existing building at the Rocky Flats Plant is now estimated to be $1,332,000. At the present time, Engineering is about three to four months behind schedule. If sufficient funds are available in FY 1976 to complete planned activities, the projected start-up in the second quarter of FY 1977 is possible.

Tramp metal in the waste can damage shredding and feeding equipment. In addition, an accumulation of this metal will have a deleterious effect on fluidization. Large pieces can be removed by hand sorting; however, pilot scale tests have shown hand sorting is only about 75% effective in removing all of the tramp metal. A hand-held metal detector such as that used for security checks at airports was tested and found to be of little aid to hand sorting; consequently, an air classification system is being designed into the incinerator facility. Hand sorted waste will be shredded and fed to this air classifier, which will remove tramp metal missed during hand sorting. Combustibles then will pass through a second stage of shredding prior to introduction to the primary reactor.

A new type of flue gas distributor has been designed into the afterburner in this incineration facility. A bubble cap distributor in the pilot unit afterburner malfunctioned because of dust accumulation. This accumulation was not removed from the flue gas stream by the primary cyclone. The new design utilizes a continuous recycle turbulent flow of flue gas through the distributor tubes to keep the dust in suspension until it can pass through the orifice holes into the bed. The orifice holes provide for distribution along the tube. A tangential entry of the flue gas imparts the kinetic energy needed to accomplish the recycle flow. This system was designed, fabricated, and installed in the pilot unit, and it is presently undergoing evaluation. It has worked well on liquid waste runs. Additional tests will be made on solid waste combustion runs.

Product from the fluidized bed incinerator was used to evaluate pelletization to convert the dust to a bulk mass form. Only 3 to 8% moisture additions were required to produce pellets at pressing pressures of 140 MPa (20,000 psi) to 280 MPa (40,000 psi). Impact strengths varied from 0.13 J (0.09 ft-lb) to 0.7 J (0.5 ft-lb). This process resulted in a product density of about 2,000 kg/m^3, which represents a volume reduction factor of about two. Some components of the mixture are water soluble, however, and a more permanent method of ash immobilization is needed. Sintering was investigated as a means for forming water resistant pellets.

Development work is proceeding on the design and development of a data acquisition and computation system for the process. Computer equipment has been purchased, and activities involving design development and procurement of the process-computer interfacing equipment are in progress. The function of the computer system will be to record process data, provide on-line process calculations, perform regression analysis at the completion of the test, and provide functional history of the various process equipment components.

EXPERIMENTAL PROGRAM*

Feed Preparation

In February 1975, the pilot plant fluidized-bed incinerator was enclosed for containment of radioactive materials, and experiments began with contaminated plant-waste materials. The waste material was hand sorted for removal of tramp metal. Combustible material passed through two stages of shredding and was introduced to the primary reaction chamber by a tapered screw conveyor. The constant-pitch, tapered, screw conveyor compressed the waste by a factor of five to form a partial gas seal in the feeder.

Hand sorting for removal of tramp metal was only about 75% effective. The remaining 25%, because of its small size, passed through the shredders and screw feeder and collected in the primary bed. There was a tendency for very thin scrap to float on the surface of the bed. Most of the metal in the bed, however, consisted of objects such as buttons, nuts, and other small, dense objects that settled to the bottom of the bed.

If too much tramp metal collects in the bed, fluidization will be inhibited. This problem could be solved by periodically draining a portion of the bed, screening out the metal, and returning the bed material to the reactor. Because of the 550 °C operating temperature in the reactor, either the material would have to be screened hot or equipment would be required to cool the material.

Even if a suitable method had been provided for removing tramp metal from the bed, the metal would have had to pass through shredders and the screw feeder. On one occasion, the shredders were damaged by metal objects that were not detected by hand sorting. A contributing factor in that incident was the poor quality of welds used in fabricating the shredders. One part was broken in the primary shredder, and that caused damage to cutters and fingers in the second stage. Small objects that pass through the shredders would cause problems in the feed conveyor. At the discharge end, the clearance prevented the passage of items greater than about six millimetres (0.25 inch) in thickness. It was determined that removal of tramp metal prior to shredding is highly desirable.

Magnetic separation of tramp metal from combustible waste was impractical since a large amount of the metal was nonmagnetic stainless steel. A metal detector, similar to the hand held units used at small airports for searching passengers was then tried as a sorting aid.* The fact that waste sorting boxes are metal complicated the use of this type detector. Even in nonmetal surroundings, the detector was found to be an ineffective aid to hand sorting. This unit showed a high sensitivity to some types of metal such as foil wrappers and aluminum pieces, but it was insensitive to high grade steel. Use of the metal detector would not significantly improve hand sorting effectiveness.

An air classifier was tested to separate metal objects from shredded waste. A mixture of combustible materials simulating plant waste was mixed with various components of tramp metal and was then shredded for these tests. The trash was fed to the classifier by a rotary star valve. Within the classifier, the heavy metal objects settled against the air stream, and the lighter combustible materials were carried with the air to a cyclone separator where the combustibles were removed. The air stream was pulled through by a blower and was discharged to the atmosphere. If this unit was to be used on radioactive waste, the air could be recycled back to the bottom of the classifier.

The unit functioned well and provided a high degree of tramp metal separation. By adjusting the air velocity through the unit, it was possible to remove all of the heavy metal objects.

Under the conditions just described, some pieces of combustible material may be removed with the metal that could then be segregated by hand. Any metal that would not be removed by the classifier would tend to be light, thin sheets that would not cause major problems in the second stage of

*Andrew J. Johnson, Frank G. Meyer, and Herbert N. Robinson worked on the experimental program and prepared the related text for this report.

*A. L. Johnston. "Metal Detector Aid to Hand Sorting of Tramp Metal from Rocky Flats Plant Combustible Waste." CRDL 940780-003. Rockwell International, Rocky Flats Plant. October 2, 1975.

shredding, screw feeding, or operation of the fluidized bed.

The pilot plant will be modified to incorporate air classification of the feed, and the unit will be installed following the first stage of shredding. Classified waste will be processed through a second shredder with fine cutters prior to being fed to the primary reactor. This same type of system is being designed into the demonstration fluidized-bed incineration plant. Air classification was not included in the original scope of the project; however, it is considered necessary for satisfactory operation.

Afterburner Gas Distribution

When the pilot plant incinerator was enclosed for combustion of contaminated waste, the fluidized bed afterburner was separated from the primary reactor. Previously, two stacked beds were used in a single vessel to accomplish primary combustion of the waste and afterburning of the flue gas. Ash generated from combustion and the sodium chloride generated in neutralization of the acid gases were removed by entrainment with the flue gas stream. The dust was percolated through the afterburner fluidized bed and was collected by a cyclone and sintered metal filter downstream. When the vessels were separated, a cyclone was installed prior to the afterburner to decrease the amount of dust that had to pass through the second distributor plate. The same type of distributor plate was used in the afterburner as in the previous setup; yet, the dust settled out in an area below the bubble cap plate. Gas velocity decreased in this area because of the larger cross sectional area. The cyclone removed about 70 to 90% of the dust in the flue gas stream. The remaining dust collected below the plate until it eventually plugged the holes.

Initial plans called for using a series of horizontal tubes to distribute flue gas into the afterburner. Between each of the flue gas tubes would be tubes for introducing the air required for secondary combustion. Each of these tubes would have a series of orifices to provide the desired gas distribution throughout the bed. The diameter and number of these tubes would be sized to maintain sufficient velocity to keep the dust entrained until it could pass through these holes. It was decided to test this type of distribution system on the pilot unit.

The bottom of the pilot unit afterburner was modified to provide three 2.5-cm- (1-inch-) diameter tubes for air and two tubes for flue gas. When a run was made with this system, the tubes became blocked with dust accumulations. It appeared that the dust impacted the end of the tubes and filled them from the far end back toward the feed end. To overcome this problem, the two tubes were joined so as to provide a continuous loop through the reactor. The flue gas entered tangentially, thus imparting a continuous recirculation of gas in the tube. Flue gas was introduced at two points to help equalize the gas velocity through the two tubes, and the turbulent gas flow kept the dust in suspension until it was blown through the holes.

This system has been used successfully on several liquid-waste disposal runs. Additional tests are being made using solid waste feed to the incinerator. These changes will result in higher dust loading in the flue gas and also will produce a dust that is more difficult to handle.

The gas distribution system provides for separate introduction of flue gas and air to the afterburner. This is necessary to prevent open flame burning of the flue gas, which could produce an excessive temperature plus melting of the dust in the flue gas stream.

Providing a dependable flue gas distributor for the demonstration plant's fluidized-bed afterburner has been one of the major concerns in the design of this unit. The continuous-loop tubular distributor will be designed for the demonstration plant using information developed with the pilot plant unit.

Ash Pelletizing

The product from the fluidized-bed incineration process is a dry dust consisting of ash, catalyst fines, sodium carbonate, and sodium chloride. These products are removed from the process by two cyclones and a series of sintered metal filters. Dust from the primary cyclone is primarily ash,

TABLE I. Composition of fluidized-bed incinerator ash

Component	Percent by Weight
Sodium Chloride (NaCl)	8
Sodium Carbonate (Na_2CO_3)	42
Catalyst	45
Fly Ash	5

TABLE II. Pellet characteristics

Die Pressure [MPa (psi)]	Density (kg/m^3)	Impact Strength (J)	(ft-lb)
140 (20,000)	1,890	0.13	(0.09)
210 (30,000)	1,990	0.50	(0.36)
280 (40,000)	2,080	0.70	(0.50)

sodium carbonate, and sodium chloride. The secondary cyclone, downstream of the afterburner, removes the bulk of catalyst dust generated by the abrasion of bed material. It will also remove a small amount of the dust that passes through the primary cyclone. The flue gas passes through a bank of sintered metal filters that remove essentially all dust that is too fine to be removed by the cyclones.

Dust is an ideal form if the ash has to be processed for recovery of nuclear material; however, it has some disadvantages as a waste product for shipment and storage. Shipment of dust offers potential for rapid dispersion by wind if a shipping container should be breached in an accident. In addition, the fine particle size could increase dispersion should the material be contacted with water. Pressing the dust into a pellet was evaluated as a means of converting the material to a less dispersible form.

The pelletizing tests were performed on a sample of dust produced in the fluidized-bed incinerator pilot plant. Approximate composition of this material is presented in Table I.

Dust used in these tests represented what was generated in the process from noncontaminated, simulated, plant combustible scrap. While the dust composition may vary considerably with operating conditions and feed material composition, the product from the demonstration plant would contain the same components. It is expected that the percent ash will be significantly higher from the demonstration plant. Even though the composition tested was not representative, the material was used for the pelletizing tests because it was the only noncontaminated mixture available.

The tests were conducted on a laboratory pellet press that had a die diameter of 12.5 mm (0.5 in.) and was capable of producing a pressure of 280 MPa (40,000 psi). A moisture content of 3.4 to 8.3% in the dust was required to produce a high strength pellet. Among the several methods of moisture addition tried were steaming and fog spray of water. Fogging was found to be an acceptable method of water addition, and it was used in the preparation of experimental pellets. A die lubricant of oleic acid was used to facilitate removal of the pressed pellets.

Moisture content and pressing pressure were varied to determine the optimum pellet characteristics of maximum density and strength. The bulk density of the dust before the pelletizing treatment was 970 kg/m^3. Pellets were formed at various die pressures up to 280 MPa (40,000 psi) as shown in Table II along with other ash-pellet test results. Each of the density and impact strength results in Table II is the average of three separate experiments. The pelletizing operation produced a waste, volume-reduction factor of approximately two.

Impact strength was measured as the force necessary to break a pellet into two pieces. Impact strength increased significantly with increased pressing pressures. Pellet drop tests from a height of five metres onto a cement floor showed no breakage or chipping of pellets produced at the pressures indicated in Table II.

Pelletizing provided a significant volume reduction and improved the resistance to wind dispersion. Because of the solubility of NaCl and $NaCO_3$,

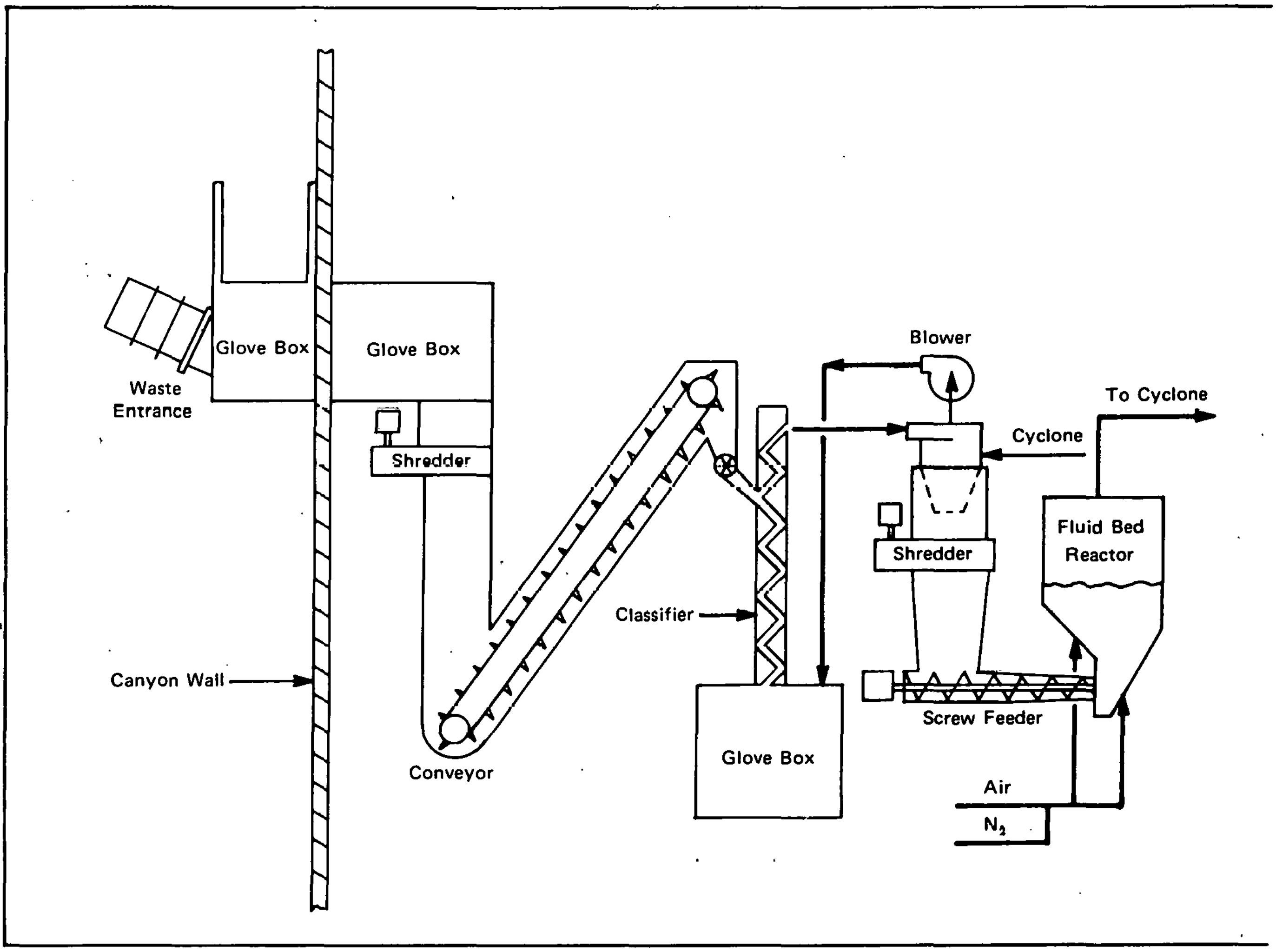

FIGURE 1. Flow diagram for demonstration plant fluidized bed incinerator

however, the pelletizing did not significantly improve the resistance to water. Sintering of the pellets at temperatures up to 950 °C also failed to add any water resistance to the pellet. To provide the desired resistance to water leaching, it may be possible to glaze the surface of the pellets by adding a fluxing agent on the surface and then heat-treating.

Pelletizing is not being designed into the demonstration plant at this time; however, space is available to add a pellet press, if necessary, at a future date. Commercially available rotary and hydraulic presses are available to produce the pressures required for ash pelletizing. While the rotary type press is significantly less costly, the hydraulically operated press may work better for this application. This latter press can automatically compensate for powder density and die filling variations that could be expected on a waste product stream. Further work on ash pelletization is being suspended until more permanent methods of ash immobilization can be evaluated.

PLANT DESIGN*

Process Description

The fluidized-bed incineration process used for combustion of transuranic (TRU) waste will depart

*Lewis L. Richey, Vito A. Trujillo, and David J. Peterson worked on plant design and prepared the related text for this report.

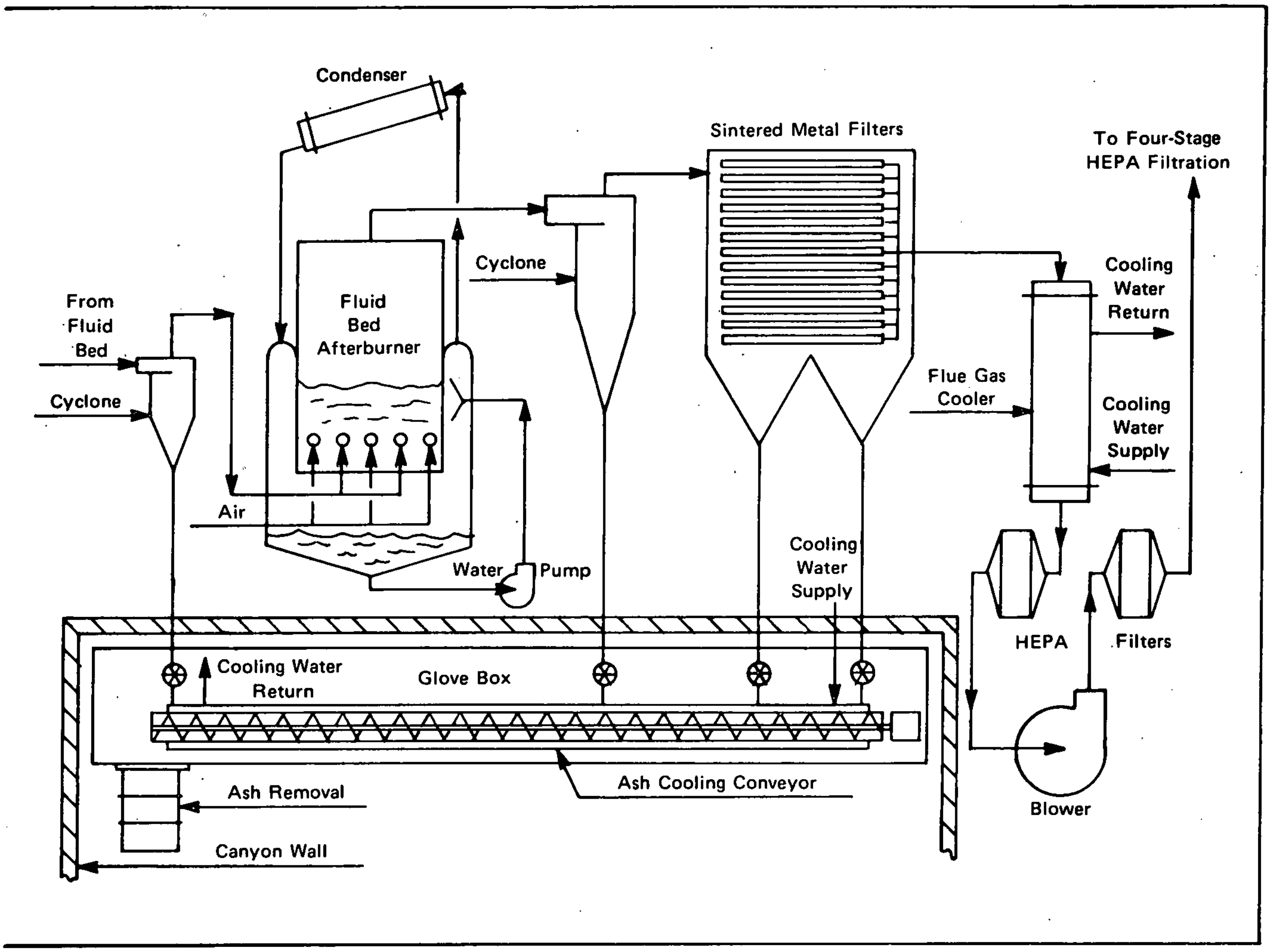

FIGURE 1. (continued)

from that of the pilot plant in the method of heat removal and the method of producing the motive force for gas flow through the equipment. In the pilot unit, the heat of combustion was removed by blending a large amount of room air with the flue gas. This becomes impractical as the process is scaled up by a factor of about nine. Mechanical blowers will be used rather than the air jet ejector that was used in the pilot unit. This will reduce both equipment cost and operating cost. The demonstration plant is being designed for a heat release rate of 1,500,000 kJ/hr (1,500,000 Btu/hr), which should correspond to a capacity of about 82 kg/hr (180 lb/hr). A flow diagram of the process is presented in Figure 1.

Waste will be received in 200-litre (55-gal) drums. The waste will be introduced from an air lock box (in an air lock room) into the feed preparation area. Large pieces of metal in the waste will be removed by hand sorting to prevent damage to the first shredder. This metal will be collected and drummed for disposal. Combustible waste from the hand sorting will then be fed to a low-speed, cutter-type shredder for coarse shredding. Associated with the combustibles will be small pieces of metal that were undetected during hand sorting. This tramp metal will be shredded along with the waste.

It is intended that discharged waste from the first shredder be conveyed to an air classifier. This classifier will allow collection of the heavy tramp metal in a glove-ported receiver. Periodically the metal can be bagged out for disposal. Light combustible waste shall then be conveyed in an air stream to a shredder that has narrower and closer spaced blades. The waste will be shredded again and be of a suitable particle size for feeding to the pyrolyzing fluidized bed.

To introduce the waste to the first fluidized bed, a constant pitch screw will be used. This should compact the waste and feed it into the bottom of the fluidized bed. The screw will be variable speed and controlled by the temperature in the catalytic fluidized bed. As the temperature in the catalytic fluidized bed increases, the feed rate of waste to the first fluidized bed will be reduced. As the temperature decreases, the feed rate is increased.

The first fluidized bed will accept the waste and a mixture of air and nitrogen. The temperature of the bed is to be controlled by the amount of air fed to the unit. If more air is required to maintain bed temperature, the amount of nitrogen will be reduced proportionately to maintain a constant flow of fluidizing gas to the unit. As with any fluidized bed, particulate matter will be entrained in the gas stream leaving the unit.

To remove a large portion of particulates, a cyclone is to be installed between the two fluidized beds. This elutriation of solids is the mechanism for removing chlorides neutralized by the sodium carbonate (Na_2CO_3). The cyclone will then pass the combustible gases and a small portion of the solids to the catalytic fluidized bed.

The second fluidized bed shall contain a granular catalyst of chromium oxide on an alumina base. This catalyst will promote oxidation of the pyrolyzed gases at about 550 °C. Sufficient air is then added to the bed to provide an excess of oxygen and to ensure uniform and complete fluidization. The combustion products and entrained catalyst are discharged from the afterburner to the dust collection equipment.

The gas stream from the catalytic fluidized bed goes through two processing steps to remove the entrained solids. The first step involves a cyclone where 75 to 85% of the solids will be removed.

The second unit is to be a bank of sintered metal filter tubes that will remove remaining dust down to a particle size of one micron. Each set of tubes in this bank shall be sequentially back-blown with air or nitrogen to remove the buildup. Gas stream temperature will be maintained above 400 °C by insulation of the dust collection equipment and process lines. As a result, should a process upset occur, the hydrocarbons produced by pyrolysis will not condense and plug the filter tubes. The as stream could then be cooled for further processing.

The discharge temperature from the filters is calculated to be approximately 500 °C. Using a water-cooled heat exchanger, this gas stream will be cooled to about 50 °C to prevent damage to the equipment downstream.

The motive force for this system shall be supplied by centrifugal blowers. The blowers will be sized to induce enough draft at flowing conditions to return the process pressure back to atmospheric pressure. Room air is to be fed to the inlet of these blowers to control the draft in the process. The pressure sensor for this control loop will be located in the first fluidized bed, and the controller can be set at about 19-cm water column (7 in.) to 25-cm water column (10 in.) below atmospheric pressure.

Blower discharge shall be filtered through a set of HEPA filters before leaving the canyon. The process gases and the canyon air then will be ducted to a four-stage HEPA plenum before being discharged to the atmosphere.

A PDP-11 computer will monitor the process and store the variables for regression analysis at the completion of the experiment. A complete description of this system is presented in a later section entitled "Data Acquisition and Computation System."

Status of Engineering Work

Engineering design work on this project was initiated in the fourth quarter of FY 1975. Some design previously had been done by Allied Chemical, and this information was transmitted to Rocky Flats and was factored into the design criteria. The present status of the design work is outlined below:

Contract Work

The contract portion of this project includes (1) removal of existing ducts and piping, (2) construction of doors, mezzanines, and containment walls, and (3) installation of the sprinkler system, the exhaust plenum, and utilities to the containment area. On October 15, 1975, the Title I package was assembled and distributed. A Title I meeting was held on October 22, 1975. The comments at that meeting presently are being incorporated in the package before transmittal to ERDA.

Utilities

The motor starter station has been designed, including the feeder lines from the existing substations, and the water supply and return, compressed air supply, and nitrogen supply have been specified.

Fire Safety

Glove boxes that contain combustible material and noncombustibles at elevated temperatures shall contain an approved fire suppression system. The containment area enclosed with mortar block will have a fire rating of four hours. A nuclear safety evaluation is being made to determine if sprinklers can be used in the canyon.

Heat Transfer System Evaluation

In the original proposal for this project, Dowtherm-G* was to be used to heat the catalytic fluidized bed during start-up of the equipment and then to remove heat generated by the oxidation reaction. With this system, a pressure relief valve would have to be used. Should pluggage and subsequent super heating of the Dowtherm occur, the associated pressure rise could be relieved by this valve and thus prevent damage to the equipment. Since all of the equipment is enclosed in a building, the vent line would have to discharge to the plenum. If this were to occur, the hot Dowtherm vapor and the air would combine to produce a flammable mixture that could not be vented to the plenum. Since this system poses a potential safety problem, a water spray system will be used to remove heat from the afterburner.

In this system, spray nozzles in an annulus at the fluidized bed level will be directed at the vessel wall, and a portion of the water sprayed shall be vaporized. The steam generated can then go to a water cooled condenser where the condensate is returned to the spray nozzles. Using spray nozzles allows more or less heat to be extracted by varying the flow of water and the spray coverage. This system is required because of the large heat flux generated at the fluidized bed wall. A conventional panel heat exchanger would extract too much heat and lower the operating temperature. This system will, of course, not heat the catalytic fluidized bed for start-up. To accomplish the heat-up, two electric air heaters and a liquid fuel burner will be used. This conceptual design is now in the equipment design stage and should be completed by December 1975.

Nuclear Safety

The process is being designed to burn TRU combustible materials that do not contain sufficient radionuclides to warrant recovery. The concentration of fissionable material in the waste shall therefore be limited. Because the process will not utilize an aqueous scrubbing system, nuclear safety limitations on the process will be somewhat less

*Product of The Dow Chemical Company, Midland, Michigan.

restrictive than that required for the conventional incinerator presently in use at the Rocky Flats Plant.

The pilot plant shall be operated with increasing concentrations of plutonium in the combustible materials. These tests will be used to evaluate the inventory of plutonium in various process equipment units under a wide range of operating conditions. This information is to be used in conjunction with suitable feed concentration and equipment limitations.

A preliminary evaluation was made using a feed concentration of 10^{-3} g Pu/g of combustible material. Using this basis, several areas of concern were identified. One was to assure that cooling water can not back up into the reactors and particulate removal equipment. Appropriate equipment features have been designed to eliminate the possibility of water introduction from both the feed and the exhaust end of the process. A second design feature is the use of a double wall on the heat transfer system used on the afterburner. This was done to eliminate any possibility of leaking heat transfer fluid (water) into the process vessel. With these design features and with nuclear materials inventory information to be generated on the pilot unit, the process can be safety operated with a suitable concentration limit on the feed.

Construction Materials

Because of the high temperature of operation, some vessels must be constructed of heat resistant alloys. To ensure a long service life, the catalytic fluidized bed will be constructed of Inconel 600. This alloy has excellent high-temperature mechanical strength and corrosion resistance. The top half of the primary fluidized bed also will be made of Inconel 600. The bottom half is to be made of Hastaloy C276. This material is presently excess from another project and will save the cost of purchasing Inconel 600 for the bottom half of the primary fluidized bed. The process piping, cyclones, and sintered metal filter housing will be stainless steel.

Purchase of Materials and Equipment

Most of the equipment has been designed, and its purchase is proceeding on schedule. Some materials for equipment to be fabricated have been purchased. As soon as the remaining equipment has been designed, the balance of the materials will be purchased.

Schedule and Cost Estimates

A 70% Title I cost estimate of the incineration facility design and construction has been made. The estimated $1,500,000 includes the installation cost of a surplus plenum and containment walls, and the purchase, fabrication, and installation of process equipment in an existing building at the Rocky Flats Plant. This cost estimate represents some escalation of a preliminary cost estimate made about one year ago. One process change contributing to this cost increase is the addition of an air classification system for removing tramp metal from the feed. This change was considered necessary for a satisfactory operation.

The engineering for this project is presently about three months behind schedule. The projected start-up date of the second quarter of FY 1977 is possible if sufficient funding is available in this fiscal year to complete engineering, purchase, and fabrication of equipment, installation of the containment walls, and installation of the exhaust plenum.

Construction of the containment walls and installation of the plenum is projected to take about three to four months and could be completed by the end of this fiscal year. Installation of the process equipment, which could begin in FY 1976A, will require about nine months for completion.

Data Acquisition and Computation System

The fluidized-bed incineration system will occupy an area of approximately 3000 square feet and will require monitoring of at least 75 data sensing points in process equipment. The large number of instruments, plus the rather large size of the operational area, requires a centrally located control area in which instrument outputs can be monitored by one operator. The system must have the capability of being expanded to greater than 75 data points input. Computerization will eliminate the manual accumulation of data and the possible paper work errors inherent in a manual system.

The function of the computer system shall be to record process data, provide on-line process calculations, perform regression analysis at the completion of the tests, and provide functional history of various process equipment components. During a run, process data such as temperatures, pressures, feed and product weights, flows, conveyor speeds, pressure differentials, and timer information will be transmitted to the computer. The process information will be converted to engineering units and stored for subsequent analysis.

The computer is to perform calculations and will display information to be used in adjusting the process operating conditions. Rather than use secondary variable such as gas flow rates to the process, the on-line calculation will allow process adjustments to be made using a primary variable such as the superficial gas velocity in the primary reactor and afterburner. Since attrition of the catalyst is a direct function of the superficial gas velocity, operating conditions can be adjusted more precisely to limit catalyst loss-rates with the aid of the on-line calculations. In the primary reactor, the sodium chloride formed in the neutralization reaction will be removed from the sodium carbonate beads by attrition. It will be necessary to adjust the operating conditions to ensure adequate neutralization of the acid gases generated in the combustion reaction.

It is anticipated that the computer would be able to calculate the proportion of combustion occurring in the primary reactor. This information will be necessary to evaluate the formation of carbon in the ash. Information is also necessary to determine operating conditions for minimizing the formation of tars that could foul the operating equipment.

At the end of a run, the regression analysis shall include a heat and material balance of the test. The operating data is to be averaged for the total run and will be used to calculate design parameters. Information will be available to correlate the heat transfer coefficient as a function of operating conditions. It is anticipated that a nuclear materials inventory in the process can be maintained by the computer. These data will be useful in both nuclear materials accountability and nuclear safety considerations.

Some process information will be stored in the computer from run to run for development of functional history of various equipment components. One example of this type of operation would be to maintain a correlation of pressure drop and flow rate through the sintered metal filters as a function of hours of operation. The filters will be subjected to reverse flow on a periodic sequential basis to remove accumulated dust. Fine dust that may not be removed by the reverse flow can partially plug pores in the filters. It is anticipated that the pressure drop through the filters will increase with increased plugging of the pores. Correlation of this information may be useful in predicting filter life or determining when the filters would have to be water washed to restore functionality.

Using the computer, it will be possible to provide a more complete analysis of the process. The computer should maximize the data obtainable and therefore reduce the number of experiments needed to obtain design and operating information.

A Digital Equipment Corporation PDP-11/10-S minicomputer, Teletype Model 40 CRT console, and Remex floppy disk units have been selected and purchased for this application. The DEC PDP-11 includes a central processing unit for performing all arithmetic and logic operations required in the system. Also included within the DEC PDP-11 minicomputer are 28,000 words of core memory for program storage and data buffers. The Remex floppy disk subsystem includes a ROS-11 Operating System (similar to DEC's Disk Operating System), which includes a macro-assembler and Fortran IV compiler. Device handlers for the data acquisition subsystem and for the display console will be written in assembly language, and application software will be generated through Fortran IV.

The Remex floppy disk units will serve as off-line storage for the DEC PDP-11 processor. This magnetic disk subsystem can store all information expected to be generated in a typical incineration run of approximately 100 hours.

The Teletype Model 40 terminal includes a CRT display, line printer, and full ASCII keyboard. (The Model 40 terminal will serve both as an entry terminal for software development and as a CRT operator's console for process monitoring.) The CRT display contains a 72 by 80 character buffer that will allow all incinerator process variables to be displayed and periodically updated.

The hardware configuration just mentioned will be capable of receiving all inputs from the instruments and can display these inputs after conversion to engineering units. Some in-process calculations will be done. If "out-of-tolerance" conditions develop, the PDP-11 will display and print out an alarm message on the display console to alert the operator.

Computer equipment purchased includes the PDP-11, the display console, and the off-line magnetic storage. All equipment has arrived and has been installed in an office area for testing and software development. Some modification work on the display terminal was required to enable it to function correctly. A regulator in the PDP-11 power supply burned out. After replacing the regulator, it was decided to power the computer continuously to avoid the power surges that occur when the equipment is initially turned on. Some programs have been written and executed to test the operating system. At present, system development activity is centered on designing data acquisition hardware between the process and the computer. Since the computer is installed and operational, some program logic development will be initiated.

Conventional control instrumentation will be used to operate the process. Calculated information from the computer system will be used to manually adjust the control set points on the conventional control. At present, no computer control is being provided; however, the data acquisition subsystem could, at some future date, be utilized for on-line control or automatic adjustment of control instrumentation.

CONCLUSIONS

1. Title I design is complete for installation of the containment walls and exhaust plenum and is 70% complete on the equipment portion.

2. An air classifier will be installed to remove tramp metal from the feed. Hand sorting is only 75% effective.

3. Ash pelletization can produce a volume reduction of about 50%. The only additive required for pelletization is three to eight percent moisture.

4. A new distribution system has been designed and tested for introduction of dust-laden flue gas into the fluidized bed afterburner.