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(January – June 1976)

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Chemistry Research and Development
PILOT PLANT DEVELOPMENT

Rockwell International

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

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SUBJECT DESCRIPTORS
Fluidized Bed
Incinerators
Waste Management

ROCKWELL INTERNATIONAL
ATOMICS INTERNATIONAL DIVISION
ROCKY FLATS PLANT
P.O. BOX 464
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STATUS REPORT ON THE FLUIDIZED BED INCINERATION SYSTEM FOR U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION TRANSURANIC WASTE

(January – June 1976)

Donald L. Ziegler, Lewis L. Richey, Andrew J. Johnson, Alton L. Teter, Pen K. Feng, Dave J. Peterson, and Louis J. Meile

Abstract. A fluidized-bed incineration facility is being 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. Title II engineering is at least 70 percent complete and construction work has begun.

INTRODUCTION

Fluidized bed incineration is being evaluated at the Rocky Flats Plant as an alternative to conventional incineration for processing transuranic (TRU) combustible waste. The fluidized bed concept is being pursued through several channels of activity. A 9 kg/hr (20 lb/hr) pilot plant system is undergoing operational testing with solid and liquid wastes contaminated with low levels of plutonium; an 82 kg/hr (180 lb/hr) developmental plant is being designed; and 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. Another objective is the development of an improved incineration system for processing existing or future waste from nuclear industry in general.

Through the years, operation of plutonium recovery facilities at Rocky Flats has identified a need for an improved incineration system. Conventional methods employed at the plant, though effective, have resulted in substantial maintenance problems because of equipment corrosion, short refractory life, and mechanical problems. In addition to requiring frequent maintenance, the current 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; 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 the 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 is being designed for combustion of transuranic waste. The facility is being designed for a capacity of about 82 kg/hr (180 lbs/hr), which will correspond to a heat release rate of about 1,600,000 kJ/hr (~1,500,000 Btu/hr). 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 percent 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 percent 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; high speed blowers will be used in the larger unit to provide motive force for gas flow through the process.

An air classification system is being designed into the incinerator facility for removal of tramp metal from the combustible waste. The hand-sorted waste will be shredded and fed to the air classifier, which will remove the tramp metal. The combustibles will pass through a second stage of shredding prior to introduction to the primary reactor. Pilot scale tests have shown hand sorting only about 75 percent effective in removing tramp metal. A hand-held metal detector such as that used for personnel search at airports has been tested and determined to be of little aid to hand sorting. If tramp metal is not removed, it can cause damage to the shredding and feeding equipment. In addition, accumulation of tramp metal in the reactor will have a deleterious effect on fluidization.

Product from the fluidized bed incinerator was used to evaluate pelletization for converting dust into a bulk mass form. The process resulted in a product density of about 2,000 kg/m^3, which represents a volume reduction factor of about two compared to the bulk ash volume. Some components of the mixture are water soluble, however, making a more permanent method of ash immobilization necessary.

Sintering of the pellets, bonding the ash with polymers, bonding the ash with cement, and incapsulation of the pellets were techniques conducted to impart water resistance. Some of these methods proved acceptable for imparting water resistance, but the radiolysis of the polymers was thought to be a significant detrimental effect. Consideration is being given to immobilizing the ash by vitrification into a silica based glass. The high-density product formed has excellent water resistance, and radiolysis is eliminated because no hydrocarbons remain in the waste product. A program is being initiated to develop a process utilizing this technology.

A program has been initiated to study catalyst deactivation mechanisms and the operating parameters affecting catalyst efficiency and life. Chemical and physical tests will be conducted to determine the differences between new and used catalyst.

The data acquisition system has been expanded to provide capability for on-line computer process control. The electronic hardware has been specified, and the system is expected to be operational in September 1977 when the process equipment is installed.

An administrative program group exists consisting of personnel from Facility Engineering, Finance and Administration, Maintenance, Research and Development, Operational Safety, and the local ERDA Construction Office. Expertise in these disciplines is being used to coordinate the design and installation of the facility.

Title II engineering is 70 percent complete on installation of the containment walls and the exhaust plenum, and construction has begun. Title II engineering is also 70 percent 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 at $1,332,000. The project schedule has been adjusted to keep the cost during FY 76 and FY 76A within the available funding limits. The projected start-up is in the first quarter of FY 78.

EXPERIMENTAL PROGRAM

Feed Preparations

Problems arising from the presence of tramp metal in the combustible waste became evident when the pilot-plant, fluidized bed incinerator began operating with production-generated waste. The discard of metal objects in combustible-waste receptables cannot be prevented despite regulations, labeling of receptacles, and other administrative controls. A method is necessary for handling the metal that undoubtedly is in the waste going into the incineration system.

After it was established that even careful hand sorting of waste was not sufficient to prevent problems caused by tramp metal,* methods of mechanical waste classifications were investigated. Air classifications appeared to offer the simplest method for the operation. An air classifier was tested using simulated plant waste that was mixed with various types of tramp metal and then was shredded. The classifier functioned effectively. A unit subsequently was designed, fabricated, and installed on the pilot plant incinerator.

The air classifier has been in use for several week-long incinerator runs. These runs, described here, are depicted graphically in Figure 1, which appears later in this report. Combustibles in waste bags are first dumped from 0.2-m^3 (55-gal) containers into a large, sorting glove box. The waste bags are cut open; the waste is hand sorted to remove large metal objects, and the remaining waste is then fed into a primary shredder filled with thick (16-mm) cutter blades. The coarse, shredded waste drops onto a conveyor belt that carries the material to a rotary star valve. The waste is then fed into the air classifier. Within the classifier, heavy objects fall through the upward moving air stream; lighter materials are carried by the air flow to a cyclone separator positioned over the second shredder. This shredder, equipped with thinner (6-mm) cutter blades, deposits the fine-shredded waste directly into the incinerator feed-screw hopper. The air stream from the cyclone is recycled back to the bottom of the classifier.

*See *Fluidized Bed Incineration of Radioactive Waste*. RFP-2471. Rockwell International, Rocky Flats Plant. May 14, 1976.

Modifications of the pilot classifier have proceeded as continuous operation reveal trouble points. The conveyor belt that carries the waste to the rotary valve was prone to slippage because of the high dust loading of the shredded waste. This has been corrected by providing power to both the front and the back belt rollers. A vacuum system was installed to remove dust from under the belt. The system is operated by the classifier blower and discarges into the feed hopper. Air jet agitators have been added in the rotary valve section to prevent bridging. Concurrently with the modifications, different forms of waste classifications are being investigated. Experience gained with the pilot system has pointed out possible alternate methods of waste classification for the development scale incinerator.

The amount of tramp metal found in plant-generated waste varies from run to run as shown in Table 1. Most of the tramp metal is removed from the waste by hand sorting and air classifying; the remainder is fed with combustibles into the primary bed of the incinerator. Table 2 shows the distribution of tramp metal introduced into the incineration system. Table 2 reflects data collected during the week-long periods of solid-waste incineration.

The hand sorting operation removed 47 to 68 wt % of the tramp metal, and the air classifier removed an additional 20 to 38 wt %. The efficiency of the air classifier varied from 64 to 86 percent in removing tramp metal going to the unit. The increase in tramp metal carried over by the air classifier and fed into the primary bed after Run 18 was probably due to the installation of a high differential pressure (ΔP) blower at this point. The original blower used was an old air mover for a "clean" hood and did not provide a sufficient ΔP in the classifier system. A valve has been installed to control the air flow in the classifier; this should enable an optimum amount of separation to be achieved.

Despite the effectiveness of any waste classifier, it appears certain a small amount of metal will be introduced to the bed. The metal, consisting of small, dense objects such as nuts, bolts, and overall snaps, settles to the bottom of the bed. As the

TABLE 1. Tramp Metal Contained in Production-Generated Combustible Waste

Run Number	Metal in Waste (wt %)
17	6.8
18	11.1
19	9.6
20	6.9
	Average 8.6

TABLE 2. Tramp-Metal Removal in the Incinerator System

	Run Number				
Method	17 (wt %)	18 (wt %)	19 (wt %)	20 (wt %)	Average (wt %)
Hand Sorting	58.9	64.3	67.9	47.0	59.5
Air Classifier*	35.3	28.3	20.4	38.0	30.5
Primary Bed	5.8	7.4	11.7	15.0	10.0
*Air Classifier Efficiency (%)	85.9	79.3	63.6	71.7	75.1

metal content of the bed increases, fluidization in the lower bed departs from optimum. This is noted by a temperature decrease in the lower bed section. The incinerator is equipped with a drain valve that is then opened, and the lower portion of the bed, along with the metal, is removed. This operation is repeated once or twice during a 24-hour period and is sufficient to maintain good bed fluidization.

Afterburner Gas Distribution

The continuous-loop tubular distributor for introduction of flue gas to the afterburner was discussed in a previous report.* This system was used on several liquid-waste disposal runs and performed successfully. In those runs, little or no sodium carbonate was used in the primary bed, and the solids entrained in the flue gas were chiefly fly ash plus catalyst dust. This is a mixture of free-flowing solids having a grittiness from the contained catalyst.

Solid-waste incineration differs in that sodium carbonate is the major constituent of the primary bed. The dust entrained in the flue gas has a tendency to pack solidly into any space not swept clear by a gas flow. Because of the configurations of the continuous loop distributor on the pilot plant, short radius bends are used to close the loop on two sides of the afterburner. Dust packing in these sections, following three days of continuous operation with solid waste, was significant enough to produce an excessive pressure drop in the system. A method of providing more gas sweep was needed at these points.

High-velocity nitrogen jets were installed to provide added energy and to keep the gas flow turbulent at the trouble spots. No trouble with dust packing has been noted during solid-waste runs since the gas jets were installed. The only trouble occurred when a misaligned jet did grit-blast a hole in the opposite side of the loop; this has been corrected and no further trouble has been experienced.

Ash Immobilization

Pelletizing was investigated during the prior report period as a method for immobilizing the radioactive incinerator ash for transportation and storage. The pellets were formed by adding 3.0 to 8.0 percent water to the ash and pressing it in a steel die. Compaction of the ash provided volume reduction, good mechanical strength, and improved resistance to wind dispersion; however, because of the solubility of contained sodium chloride (NaCl) and sodium carbonate (Na_2CO_3), pelletizing did not significantly improve the water resistance.

Sintering, plastic bonding, plastic coating, and cement bonding were investigated as alternate methods for immobilizing ash residues from the

*_Fluidized Bed Incineration of Radioactive Waste._ RFP-2471. Rockwell International, Rocky Flats Plant. May 14, 1976.

fluidized bed incinerator. Water leach tests have been conducted to evaluate the various residue fixation methods.

Pellets (12 mm in diameter by 18 mm high) were prepared from incinerator ash by pressing at 276 MPa (40,000 psi) in a steel die. Four percent polyvinyl alcohol (binder) and 1 percent oleic acid (lubricant) were added to the ash prior to pressing. The pressed pellets were sintered at 850 °C for 1 hour and attained a density of 900 kg/m^3 (0.9 g/cm^3). To suspend the samples for dip coating with plastics, a hole was drilled at the end of the pellets and a wire inserted. After the wire was installed, sintered pellets were reheated in a furnace at 400 °C and dip coated with vinyl plastisol. The contained thermal energy at 400 °C was sufficient to cure the 1.5-mm vinyl plastisol coating. Sintered pellets also were coated with Corvel* Vinyl and Epoxy powders. This was accomplished by heating the pellets at 350 °C and dipping them into a fluidized bed of the plastic powder.

Thermal-setting phenolic and dially phthalate (DAP) resins have also been investigated as a method for bonding the incinerator ash into pellets. Phenolic and DAP powders were blended with ash and pressed at 150 °C and 21 MPa (3,000 psi) for 8 minutes in a Beuhler** sample mounting press. Ash samples bonded with only 10 percent Phenolic or DAP resin had excellent mechanical strength.

Additional samples were molded using blends of Type I Portland cement, sand, gravel, and incinerator ash. Only blends containing cement and ash looked promising from a high-ash-loading standpoint. Combinations of cement and ash produced high strength samples containing up to 40 percent ash. Samples containing more than 40 percent ash retained water and did not produce the required high-strength bond.

Leach tests were conducted on the samples in water at 25 and 50 °C. During each cycle, the samples remained in the water for 16 hours, were then dryed for 8 hours and weighed. Clean deionized water was used for each leach cycle. It was difficult to determine the percent weight loss using this method for cement samples because cement continues to take on water of hydration and to gain strength for up to 2 years. For the cement samples, actual weight-loss data were collected by evaporating the water from the leach solution and weighing the remaining residues. Table 3 lists the results as percent weight loss for the leach tests after four cycles (64 hours) were completed. The percent weight-loss data obtained can be used for a comparison of bonding and coating techniques. The results are not comparable to Soxhlet-extraction leach test results.

As expected, the samples pressed from ash, with no further treatment, dissolved during the first cycle. Only a porous skeleton remained from the sintered pellets after four cycles. This occurred because soluble salts made up over 50 percent of the materials in the ash composition.

Samples coated with epoxy powder, vinyl powder, and vinyl plastisol showed a slight weight gain during the leach tests. That gain resulted from water leaking into the sample between the wire and the plastic coating. It appears that suitable, water resistant coatings could be applied to sintered or plastic-bonded ash pellets if the wire is not used. A suitable coating process would have to be developed, which could involve a two-step operation that would include the use of a vacuum holding fixture.

The coating on one of the epoxy-covered pellets split and failed on the fourth cycle. This also was caused by water entering the ash along the wire, which resulted in salt-crystal growth and subsequent expansion against the rigid epoxy coating. The failure indicates that if a plastic coating process is used to immobilize the ash, a pin-hole-free coating must be obtained or a flexible type barrier must be used. These alternatives will prevent destruction of the barrier by crystallization and expansion of the pellet.

The leach tests implied that samples bonded with phenolic and DAP containing a high ash loading are soluble in water and would also require an envelope type coating.

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*Corvel Coating Powders, The Polymer Corporation, Reading, Pennsylvania.

**Buehler Metallurgical Apparatus, 2120 Greenwood Street, Evanston, Illinois.

TABLE 3. Results of Water Leach Tests on Immobilized Incinerator-Ash Samples

Type Bond	Type Coating	Percent Weight Loss 64 hr at 25 °C	Percent Weight Loss 64 hr at 50 °C	Comments
Pressed	None	100	100	Dissolved first cycle.
Sintered	None	60.9	64.8	Porous skeleton remaining.
Sintered	Vinyl Plastisol	3.4 (gain)	3.4 (gain)	Weight gain from water leaking around wire.
Sintered	Epoxy Powder	0.1 (gain)	0.2 (gain)	Sample at 25 °C failed during fourth cycle.
Sintered	Vinyl Powder	5.5 (gain)	9.3 (gain)	
50% Phenolic	None	5.6	10.0	Some sample cracking.
10% Phenolic	None	100	44.7	Sample at 25 °C failed during third cycle.
50% Phenolic	Vinyl Plastisol	0	0.05 (gain)	
90% Cement	None	4.2	6.1	
80% Cement	None	5.5	7.4	
70% Cement	None	6.5	7.5	
60% Cement	None	9.8	12.5	
50% Cement	None	16.0	~ 40	Poor strength.
40% Cement	None	24.0	dissolved	Poor strength.

After 4- to 16-hour leach cycles with the cement bonded samples, the data indicated that substantial amounts of the soluble salts could be removed readily by water leaching. Samples containing greater than 40 percent ash had poor strength and high leach rates. The high leach rates in samples containing greater than 40 percent ash resulted partly from the cement bond breaking down during the leach cycle. Curves plotted from the 16-hour cycle data indicated that after a total of 64 hours, the leach rates were still high; and like the sintered pellets, leaching would continue until the soluble salts were removed and only a skeleton of cement remained.

After investigating the above alternate methods for residue fixation, it was determined that the incinerator ash should be immobilized by being melted into a glass. Glass has excellent chemical durability and long-term stability in the presence of radiation. It will stand continuous temperatures of 400 °C without crystallization from devitrification. In addition, ash prepared in the form of glass will have resulting densities of approximately 3,000 kg/m^3 (3.0 g/cm^3). By blending other, available, waste streams, it appears possible to develop a glass composition that will contain 80 percent radioactive wastes and 20 percent glass fluxing additions.

Samples prepared using cement and plastics produced densities of only 1,500 kg/m^3 (1.5 g/cm^3) and therefore would require greater storage space than glass. To produce high strengths, plastic bonded pellets can contain approximately 90 percent ash; cement bonded pellets can contain up to 40 percent ash. In addition, the sinter, plastic, and cement-bonded pellets would require a plastic coating to produce suitable chemical durability for transportation and long-term storage. All of these processes would require complicated multistep forming operations. The flammability of plastics and the flammable gases produced from them during radiation degradation also make plastics unattractive for waste immobilization. It is expected that cements may have to be used for immobilizing low-temperature, volatile salts that cannot be formed into glass.

Catalyst Studies

The catalyst plays an important role in the fluidized-bed incineration process. The catalyst facilitates combustion of hydrocarbons to carbon dioxide and water at lower temperatures (550 °C) than that required for conventional open-flame incineration (1,000 °C). By reducing the temperature of operation, longer equipment life may be realized and few oxides of nitrogen, which are pollutants, are formed. The fluidization of catalyst particles provides good gas-solid contact for efficient combustion. It also provides excellent heat transfer properties.

A catalyst of chromic trioxide (Cr_2O_3) on alumina is being used in the 9 kg/hr (20 lb/hr) pilot fluidized-bed incinerator. The particle size of the catalyst is about 1,000 microns in diameter, and the approximate surface area is 1.0 m^2/kg. Operation of the pilot plant afterburner has indicated a trend of decreasing catalyst activity with increased operating time. Visual observation of the catalyst also indicates a slow change from the greyish-green color of unused catalyst to a greyish-pink color for used catalyst.

A project to study the catalyst-deactivation mechanism has been initiated. The principal causes of catalyst deactivation are believed to be poisoning and excessive operating temperature. Differential Thermal Analysis (DTA) is being used to determine activation temperatures, combustion efficiency, and optimum temperature range for operation. Mass and emission spectroscopy will identify those trace contaminants foreign to the original catalyst. Surface area measurements will be used to determine if the deactivation is a surface-specific phenomenon. Once the problem areas are identified, optimization of catalytic efficiency and catalyst life can be accomplished, although more strict control of process variables may be required. A change in the catalyst specification may be necessary to obtain optimum performance in this application.

PLANT DESIGN

Process Description

The fluidized-bed incineration process is basically the same for the pilot plant unit now in operation and for the developmental scale unit that is still in the design stage. The process used in the developmental unit will vary somewhat from that of the pilot plant. This variation will be 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 the gas 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 used in the pilot plant system. These process modifications will reduce 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 Figures 1 and 2.

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-m^3 (55-gal) drums. The waste is first passed through an air lock into a feed preparation section of a glove box. There the waste material 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 glove box where it can be bagged out for disposal. The metal-free waste 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

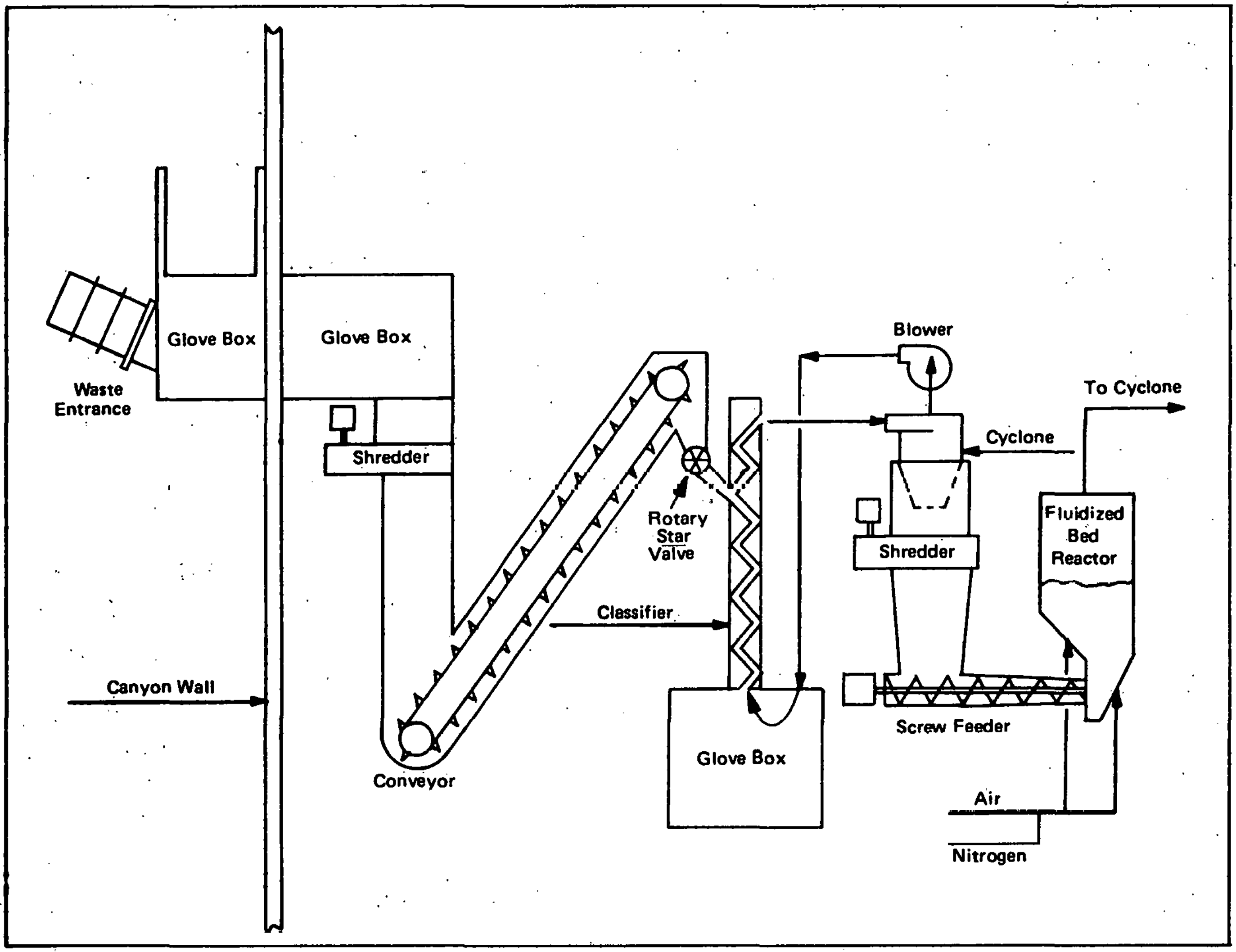


FIGURE 1. Feed End of Fluidized-Bed Incineration System for Transuranic Waste

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 polyvinyl chloride (PVC) plastic, reacts with Na_2CO_3 bed materials to produce sodium chloride (NaCl), carbon dioxide gas (CO_2), and water vapor.

Off-gas 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. Complete combustion is achieved here 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 off-gas by cyclone separation. About 75 to 85 percent of this dust is removed by

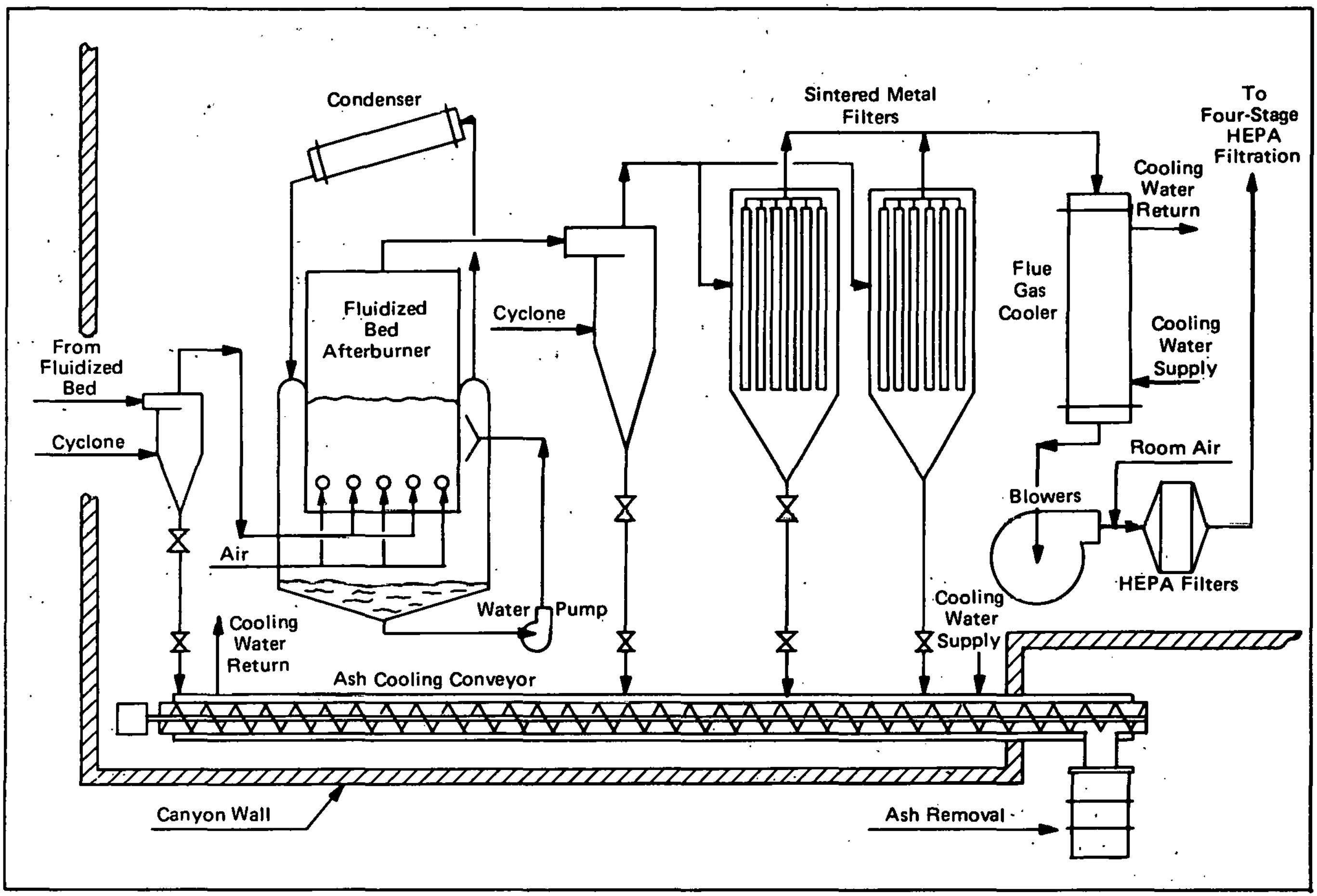


FIGURE 2. Ash End of Fluidized-Bed Incineration System for Transuranic Waste.

passing the gas stream through a second cyclone separator. The remaining material 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 negative pressure throughout the system. Off-gas 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 the 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

During the third and fourth quarters of FY 1976, design work continued on the project. The design of some process equipment has changed as more information on the pilot unit was generated and as detailed analysis of preliminary conceptual design proved cumbersome.

The containment walls, exhaust plenum, and service-related facilities for the process area will be installed by a local contractor. It is anticipated that Rockwell Maintenance will install the process equipment because of the experimental nature of this portion of the project. Because of funding and manpower limitations, the construction design was split into two parts – Phase 1A and 1B. Phase 1A involved the removal of existing ducts and piping, installation of the four-stage, exhaust, filter plenum and associated exhaust duct, and installation of conduit for the main electrical feeder lines. This portion of the design was completed, reviewed, and submitted to the local ERDA construction coordinator on May 14, 1976. The local construction company is scheduled to begin work in June. The Phase 1B package consists of erection of the block walls and doors plus installation of the motor control station, the main electrical feeder lines, and the lighting and fire sprinkler system. Design drawings for this portion of the construction work are currently being prepared and should be completed by July 1976.

Preliminary design of all equipment is complete. Table 4 represents the estimated design completion date, order placement date, and delivery date for the major items of equipment.

Materials required for equipment installation will be purchased when installation begins in FY 1977. Some instruments for pressure, flow, and temperature measurement have been ordered with delivery expected before the end of September 1976. Analytical equipment for analysis of the process off-gas stream will be purchased in FY 1977.

TABLE 4. Equipment Timetable

Item	Design Completion Date	Order Placement Date	Delivery Date
1. Entry and Sorting Glove Box	5-14-76	6-15-76	9-15-76
2. Inclined Conveyor	7-01-76	8-01-76	12-01-76
3. Air Classifier	2-01-76	6-18-76	8-15-76
4. Feed Screw	6-30-76	7-30-76	1-15-77
5. Primary Fluidized Bed	6-11-76	6-28-76	9-28-76
6. Cyclones	2-12-76	3-12-76	6-15-76
7. Catalytic Fluidized Bed	7-15-76	10-01-76	2-01-77
8. Sintered Metal Filter Housing	6-11-76	6-28-76	9-28-76
9. Condenser	5-01-76	10-01-76	2-01-77
10. Process Gas Heat Exchanger	8-15-76	9-22-76	2-15-77
11. Exhaust Blower	2-22-76	3-22-76	6-15-76
12. HEPA Filter	6-10-76	6-15-76	10-01-76
13. Ash Cooling Screw	7-15-76	10-01-76	1-15-77

The materials of construction for some of the vessels have changed. Originally two different metals were to be used in the fabrication of the primary fluidized bed and the catalytic afterburner. A stress analysis at the juncture of the different metals indicated a possible point of failure. To eliminate this possibility, it was decided that the vessels should be constructed of one metal so that differential expansions caused by temperature change would not result in undue stresses at the weld junction. To reduce the cost of fabrication, the metal selected was Type 316 stainless steel. This metal has good high-temperature strength, and pilot plant tests indicate that this metal has good corrosion resistance.

Administrative Project Control

In April 1976, an administrative program group was formed from the various disciplines in the Rocky Flats organization. Representatives from

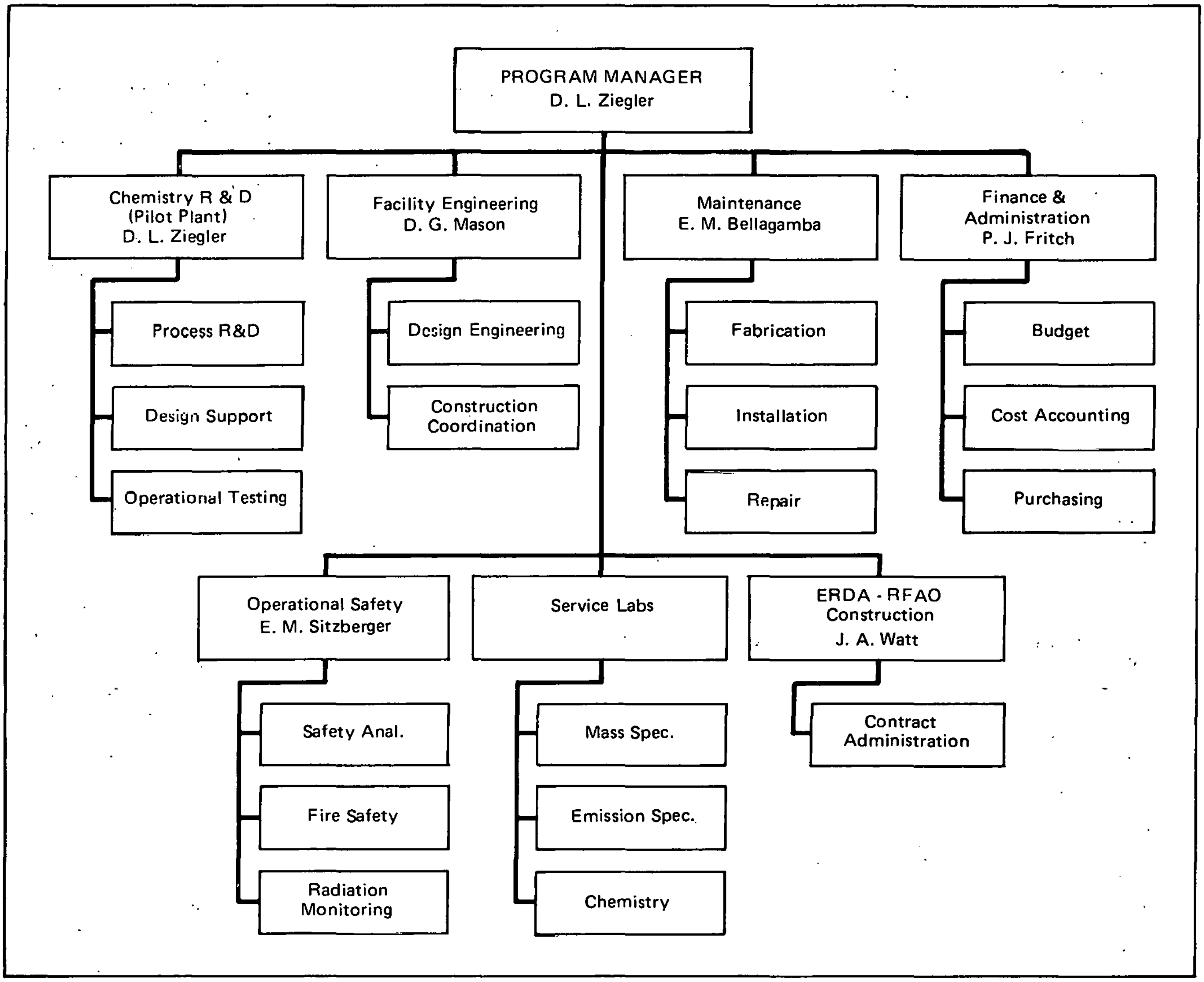


FIGURE 3. Task Responsibilities for Fluidized Bed Incinerator

Facility Engineering, Finance and Administration, Maintenance, Research and Development, Operational Safety, and the local ERDA Construction Office were assembled under the direction of a program manager from Research and Development. Using this program approach, expertise of various disciplines can be drawn upon to quickly resolve conflicts and to coordinate efforts in engineering design, procurement, fund accountability, and installation. Weekly meetings are held to inform members of the progress achieved and the problems remaining to be resolved.

Figure 3 shows the functional responsibilities of line supervision and of the communication lines for coordinating program activities. The task responsibility chart (Figure 3) shows only the primary support groups that will play the major role in completing the program. The Rocky Flats Plant is a complete, self-sustaining operation and has numerous other groups available for secondary support tasks as required. A more detailed description of the sources of primary support follows:

1. Program Manager
The program manager is responsible for overall management of the fluidized-bed incineration project and is accountable to the Manager of Chemistry R&D, Director of Research and Development, and the General Manager's office for accomplishment of this project. The program manager will direct the accomplishment of all work under the project in accordance with the ERDA-approved plan. He will be assisted by the managers, as shown in Figure 3, from Research and Development (Pilot Plant), Facilities Engineering, Maintenance, Finance and Administration, Operational Safety, and ERDA-RFAO Construction.

2. Chemistry R&D – Pilot Plant
The Pilot Plant group will provide technical manpower to conduct research, develop design criteria, operate test equipment, implement equipment modifications, and eventually operate the fluidized bed incinerator.

3. Facilities Engineering
This group will make engineering design calculations, provide engineering drawings and specifications to Maintenance, provide cost estimates, and provide design packages to the ERDA construction office. In addition, Engineering will provide inspections on purchased, contractor-fabricated, and Maintenance-fabricated equipment.

4. Maintenance
Maintenance will provide craft personnel to fabricate and install equipment, repair equipment, and modify equipment as required. Because of limited maintenance facilities in Area C, it may be necessary to fabricate some equipment in Building 334, Maintenance Area A.

5. Finance and Administration
Managers from Budget and Plans, Cost Accounting, and Purchasing will provide means for controlling all monies spent in conducting the fluidized-bed incinerator project. This will include providing an overall budget and cost accounting system to reflect, in a timely manner, manpower, materials, services, subcontracts, equipment, and construction costs.

6. Operational Safety
This group will provide design criteria to Engineering to ensure that all nuclear safety, personnel safety, and environmental safety requirements are included in the design of the fluidized-bed incineration facility. The Building-776 Monitoring group will also provide monitoring services when the equipment becomes operational with ERDA transuranic wastes.

7. ERDA-RFAO Construction
The ERDA-RFAO Construction office will provide contract administration for construction of facilities by outside contractors. This will include contract negotiation and coordination between the contractor personnel and Rockwell personnel. The Rockwell program manager, in cooperation with the ERDA-RFAO Construction office, will have the responsibility and will maintain authority as necessary to make certain construction is accomplished in accordance with the program plan and with contractual, obligational responsibilities to the ERDA Division of Nuclear Fuel Cycle and Production.

8. Service Laboratories
Chemical analysis of fluidized bed and catalyst materials, off-gases, and incinerator ash will be required for the operating pilot unit and with the development plant when it is put into operation. These services will be provided by the various analytical laboratories operated under the Service Laboratories Manager.

Computerization and Instrumentation

The basic function of the computer system remains one of process monitoring and analysis of information; however, the computer system is designed so that it can be modified to provide the function of on-line computer control of the process.

On April 15, 1976, bids were requested for a data acquisition system that would include integral functions that can be used for process control. The computer system will be able to monitor the process and will have the capability of being used for process control at a future date. Some of the minor process control functions will be provided in the integrated computer system at this time. Changes in feed rates, air-nitrogen ratios, and flue-gas flow rates will become a part of the computer process. There will be manual override switches, however, to allow for operator intervention.

The process monitoring hardware will be capable of receiving 32 Type J and/or Type K thermocouple inputs, 34 signals involving 4-20 milliamperes and 24 volts dc, and two 24-volt, dc, field-contact closures for a total of 68 inputs. The system will be expandable to a total of 120 input channels to allow for process changes and increased monitoring of highly critical variables.

Process control equipment will provide for eight control loops that will interface with the PDP-11/10 minicomputer and allow for manual, automatic, and computer control. Two manual and automatic control loops will be provided, and provisions exist for expansion of the system to a total of 16 total control loops.

Bids originally were requested on January 20, 1976. These bids were for a data acquisition system with no control functions. A change in philosophy of the computer's future function, however, necessitated canceling the original bid and soliciting a new bid that provided flexability for adaption to computer control. The bids were received on May 17, 1976 and analyzed. The decision was made to purchase the Foxboro Spec 200 analog controls and instrumentation to receive inputs and to control the process. The Foxboro Universal Interspec Communication Module (UISCM) system, which provides for communication with the PDP-11/10, was also selected for purchase. In addition to meeting the present requirements, the system, as purchased, can be expanded up to 48 more process inputs per analog input module (AIM) and eight additional control loops in the Communication Control Module (CCM). The architecture of the system is such that the system can be expanded to include 16 additional CCMs or AIMs for each UISCM; thus, the system provides a high degree of flexibility for the intended application. A hardware block diagram presented in Figure 4 shows the interaction of the data acquisition and control system with the PDP-11/10 minicomputer system.

Foxboro's Spec 200 and Interspec systems will allow for the control of the incineration process by manual means, automatic modes, set point control, or direct digital control. The system consists of a UISCM, which enables bidirectional communication between the PDP-11/10 Unibus and the Foxboro Interspec serial bus. Communication Control Modules (CCM) are used to set up eight control loops using Spec 200 input/output (I/O) modules. These loops are under manual, automatic, supervisory, or direct digital control. Control is attained completely by software configuration; thus, the system is under control of the program and programmer. Two additional loops will be under manual or automatic control only.

To better explain the monitoring and control system, assume that a thermocouple has detected a temperature of 600 °C in the primary reactor. This input signal travels into the Spec 200 input modules and into the CCM or AIM Interspec modules. The signal then flows into the UISCM, through the serial bus, and into the PDP-11/10 Unibus. The input is also recorded on the controller displays. The Remex Floppy Disk records the signal, and the PDP-11/10 compares the temperature to the maximum temperature for that location. If the upper limit on the thermocouple has been exceeded, the cathode ray tube (CRT) will display and print an alarm message alerting the operator. At the same time, a signal will be sent to the CCM to adjust flow rates to lower the operating temperatures. This message will be sent to the output modules and to the controllers, which will adjust the flow rate on the air-nitrogen stream. This will lower the burning rate and lower the temperature in the primary reactor.

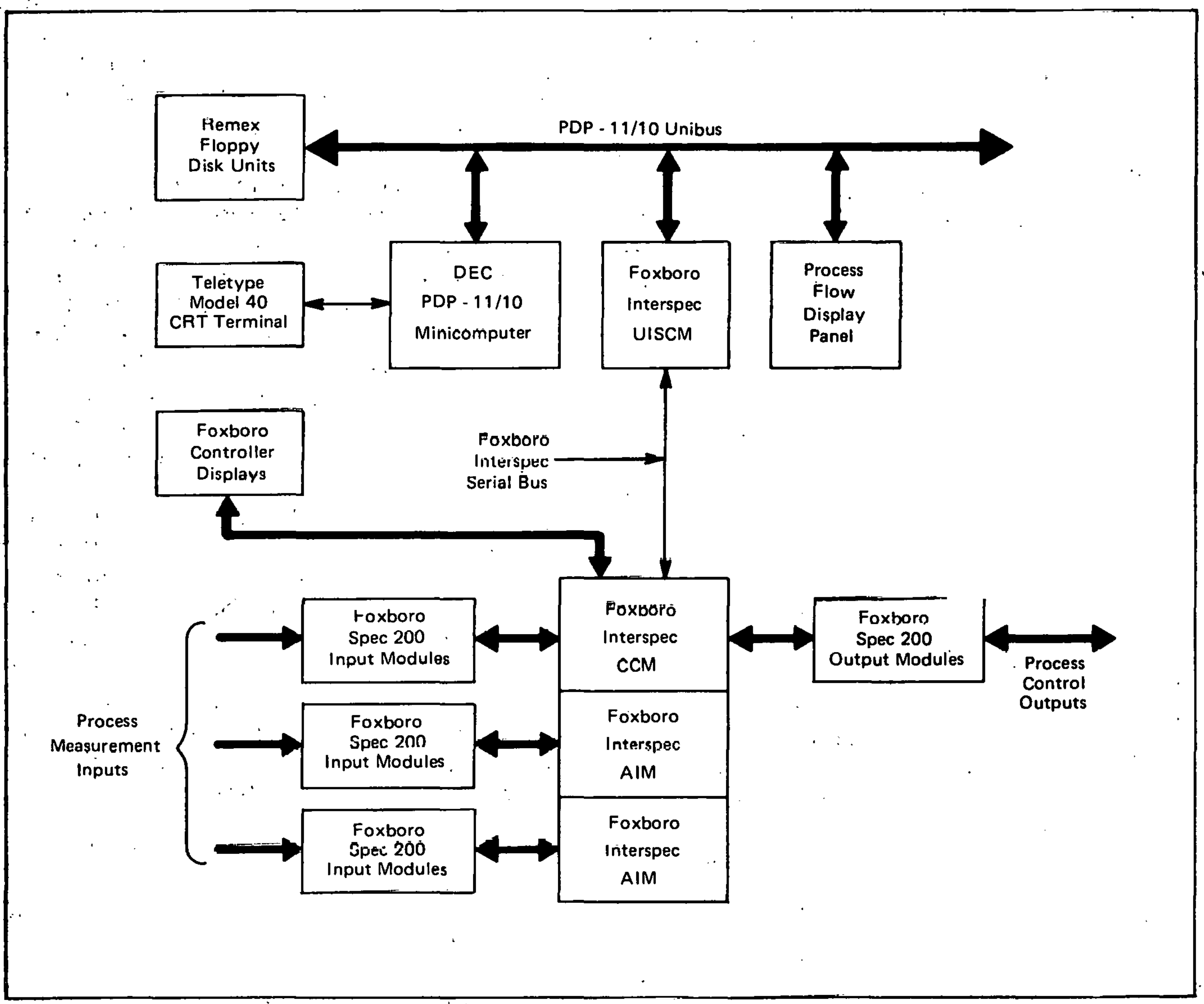
Anticipated delivery time of the analog controls and instrumentation is 16 weeks or about October 30, 1976. The Interspec modules should be delivered by June 1977.

Preliminary design work is under way for a process flow display panel. This panel will be controlled by the Unibus from the PDP-11/10. Alarm indicators will be incorporated into the display,

FIGURE 4. Process Monitoring and Control System Hardware

Legend

DEC – Digital Equipment Corporation
UISCM – Universal Interspec Communication Module
CRT – Cathode Ray Tube
PDP – Programmable Data Processor
CCM – Communication Control Module
AIM – Analog Input Module



which will graphically illustrate the process. It will be located in the control room and be observable by personnel in the working area in addition to the control center operator. The flow diagram will indicate opened and closed valves, temperatures, pressures, flow rates, and any alarm conditions that may exist.

Using information generated by the pilot plant incinerator, some preliminary programming has been done. Programs have been written in Fortran IV to calculate burning rates of drum contents introduced into the incinerator. Weight and length of burning time information is fed to the computer for each drum. The computer then calculates a burning rate for the contents of each drum in kg/hr and in lb/hr and prints a summary showing total weight of material, total weight of unburnables, total weight of burnables, total time, and average wt/hr of the run. A preliminary program has been written in which a material balance analysis is run. Based on laboratory analysis of the ash and flue gas, the resulting chemical compositions of the ash and flue gas are fed into the computer. A material balance is produced that shows the various products that were produced during processing. This program is in the developmental stage, but preliminary results are good. Fortran IV has been used for the above programming and appears effective.

There have not been any problems using Fortran on the PDP-11/10. Minimal difficulties are anticipated when programming begins for the development-plant incinerator system.

CONCLUSIONS

1. Title II design is 70 percent complete for installation of the containment walls, exhaust plenum, utilities, and process equipment.
2. Construction has begun on installation of the exhaust plenum; the remainder of the contractor work will be initiated by July 30, 1976.
3. An air classifier will be installed for removal of metal from the transuranic-waste feed material.
4. A new distribution system has been designed and tested for introduction of dust-laden flue gas into the fluidized bed afterburner.
5. Ash pelletization or incorporation of the ash in plastics and cement do not appear to provide the desired degree of fixation for transportation and long-term storage of fluidized-bed incinerator residues.
6. A study has been initiated to determine what operating conditions are necessary to optimize catalyst combustion efficiency and catalyst life.
7. An administrative project-control program has been initiated to coordinate such efforts as engineering design, procurement, fund accountability, and installation.
8. The computerized data-acquisition system is being designed to accommodate on-line computer control of the process by future modification of the system with minimal equipment or hardware changes.

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