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by

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EXPERIMENTATION WITH A PROTOTYPE INCINERATOR FOR BETA-GAMMA WASTE*

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ABSTRACT

A test facility for the incineration of suspect and low-level beta-gamma waste has been built and operated at the Savannah River Laboratory. The processing steps include waste feeding, incineration, ash residue packaging, and off-gas cleanup. Demonstration of the full-scale (180 kg/hr) facility with nonradioactive, simulated waste is currently in progress. At the present time, over nine metric tons of material including rubber, polyethylene, and cellulose have been incinerated during three burning campaigns. A comprehensive test program of solid and liquid waste incineration is being implemented. The data from the research program is providing the technical basis for a phase of testing with low-level beta-gamma waste generated at the Savannah River Plant.

BACKGROUND

An incineration development program is in progress at the Savannah River Laboratory in support of waste management objectives of the Savannah River Plant and the Department of Energy. Currently generated solid waste contaminated with low levels of beta-gamma emitters is buried in shallow trenches in an onsite burial ground. Incineration has been proposed as the primary method of volume reduction, since 70% of the solid waste generated is combustible. The reduced volume of the waste would extend the life of the burial ground. Ash residue packaged in steel drums would improve burial ground practices.

Spent solvent used in the radiochemical separation of plutonium and uranium is also stored at the SRP burial ground in underground tanks. The liquid is composed of n-paraffin, a kerosene-like diluent and tributyl phosphate (TBP), which acts as a complexing agent. The

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solvent is only slightly radioactive (<90 nCi/gm), with the principal beta-gamma nuclides being ruthenium, cesium, and strontium. Burning the solvent by spray injection into the solid waste incinerator is being studied as a method for final disposal.

After a survey of the incineration processes being tested and demonstrated at nuclear installations in the United States and Europe, a full-scale facility based on a two-stage, controlled air incinerator and a dry off-gas system was designed. The test unit, called the Solid/Solvent Waste Incineration Facility for Testing (SWIFT), is being used to evaluate uncertainties in design including the following areas:

- Flexibility to burn a wide variety of materials
- Operability of a dry off-gas system
- Efficacy of process controls for temperature and pressure
- Ability to fix phosphorous released during solvent burning.

DISCUSSION

PROCESS DESCRIPTION

Processing steps in the Solid/Solvent Waste Incineration Facility for Testing (SWIFT) are waste preparation and feeding, incineration, ash residue packaging, and off-gas cleanup. Figure 1 shows a conceptual flowsheet of the solids test facility. The incinerator installation is shown in Figure 2.

The incinerator is a two-stage, commercially available unit with controlled air. The term "controlled air" denotes the incinerator design feature that permits control of the quantity and location of combustion air. In two-stage combustion, waste is semipyrolyzed in the fuel rich primary chamber. The low air flow into the chamber is introduced through several underfire air ports on the side of the hearth. The airflow is sufficient to char the waste by slowly oxidizing the fixed carbon, but it is low enough to avoid excessive ash entrainment. Combustion air (100-200% excess) is supplied at the entrance to the secondary chamber in order to oxidize the partial combustion products to H_2O and CO_2. The oxygen concentration in each chamber is continuously measured with online analyzers.

Normal operating temperatures are 800°C to 900°C in the lower chamber and 1000°C in the upper chamber. The control system maintains these temperatures by modulating two diesel fired burners and the combustion airflow. The burners are used mainly to heat the incinerator to minimum burning temperatures. When waste feeding begins, the heat of combustion released from the burning material serves as the primary heat source. The amount of air entering the chambers is then used to control the temperatures and pyrolysis/oxidation rate.

The incinerator off-gas system reduces the temperature of the gas from 1000°C to 180°C in a spray quench chamber with an air atomized water spray. Two nozzles provide a fine mist that is totally evaporated by the incoming gas. The flow rate of the water is controlled by the temperature of the spray quench outlet. At 180°C, the exhaust gas is completely in the gas phase, but below the maximum operating temperature of the baghouse.

When HCl or SO_2 is present in the gas, an aqueous neutralizing solution of Na_2CO_3 is sprayed into the chamber. This reduces the corrosion problems from HCl generated during the incineration of chlorinated polymers and SO_2 formed from the sulfur in rubber and fuel oil.

The cooled off-gas from the spray quench is drawn through a fabric filter baghouse, which removes particulates and dried salts. The structure contains 96 envelope-shaped Nomex® (DuPont) filter bags that have a total surface area of 190 m^2. Envelope type bags are being tested because of their suitability in "bag out" techniques used in radiation zones. The removal efficiency of the filters is 98% for particulates with a diameter of one micron. Particulate cake on the filter surface is removed with intermittent reverse air pulsing. The caked particulates fall into a hopper for gravity discharge into steel collection drums.

Two induced draft (I.D.) blowers pull the off-gas through the system and maintain a constant negative pressure. A 0.6 m butterfly valve in the process line throttles the draft pulled on the system to control the pressure in the incinerator between 0.05 kPa and 0.25 kPa. A smaller valve located downstream from the throttling valve regulates the amount of ambient dilution air added to the stack gases. This dilution air reduces the temperature of the exiting gases to 100°C before they are released to the atmosphere.

OPERATING HISTORY

The SWIFT has been operated 300 hours during three weeks of campaign runs. A total of 9200 kg of waste material composed of polyethylene, rubber (syrene-butadiene), cotton fiber, and computer paper has been incinerated during the test program. The operating history to date includes a checkout period for equipment testing, a startup run that was used to cure the incinerator refractory, and two production-type runs.

Prior to operating the incinerator, each component and subsystem of the facility was tested. The checkout requirements included operating the control valves, I. D. blowers, spray quench pump, controller, and baghouse pulse cleaning system. During this period, the instrumentation was calibrated.

The goal of the startup run was to cure the ceramic liner of the combustion chambers and high temperature stack. A field engineering representative of the incinerator manufacturer was present to assist in curing the refractory. The incinerator is shipped with the refractory in a green condition, i.e., the ceramic still has considerable water content. The curing cycle was used to slowly drive the water from the refractory without causing excessive cracking or steam explosions. During the cure, the incinerator was held at 100°C for 8 hours, heated for 8 hours at a rate of 40°C/hr, and idled at 540°C for 16 hours. Figure 3 shows the incinerator temperature during the curing cycle. The startup was completed by burning 990 kg of cellulose in the form of boxed computer paper to increase the incinerator temperature to 950°C. The emphasis of this run was to determine the normal operating conditions of the incinerator.

The second run was used to obtain information on off-gas system operation. The incinerator was heated during a 12-hour period to 650°C at a nominal rate of 50°C/hr. About 3000 kg of cotton fiber and computer paper packaged in 23 kg and 10 kg boxes were incinerated. A total of 210 kg of ash was removed from the incinerator and 17 kg from the baghouse. The mass and volume reduction ratios were 13:1 and 15:1, respectively. Since computer paper contains large amounts of clay filler, the ratios are somewhat low.

The spray quench was operated at a constant outlet temperature of 180°C. Small amounts of dry particulates were removed from the bottom of the quench vessel. The rest of the fine particulates were entrained in the unsaturated gas and pulled into the baghouse. The pressure differential over the baghouse, which is directly related to the amount of solids accumulating on the bags, slowly increased from 0.12 kPa to 0.37 kPa. Even though the baghouse could be run at a pressure drop of 1.2 kPa, the pulse cleaning system was tested. After pulsing the bags during the cleaning cycle, 17 kg of material was removed and the pressure differential decreased to 0.17 kPa.

During the third campaign, nearly 4800 kg of material was incinerated. The purpose of this run was to establish steady state burning with a waste mix that contained rubber and polyethylene, which have high heats of combustion. The total heat value of the waste which also includes computer paper and cotton fiber is 29,000 kJ/kg. Continuous feeding of waste at 180 kg/hr was unable to be sustained because the incinerator temperature increased over 1100°C. (Operating at temperatures higher than 1150°C could have damaged the ceramic in the incinerator.) Uncontrolled air in-leakage into the incinerator probably caused the temperature control based on air modulation to be ineffective. Over the thirty-six hour burning period, the average waste feed rate was 130 kg/hr.

During the third run, the residence time of the ash in the hearth area of the primary chamber was controlled by adjusting the cycle and stroke of an internal ram. A plug of ash moved through the chamber in approximately five hours. This residence time produced a free flowing, whitish-brown ash that contained less than 5% carbon. The ash removed during the run was packaged into twelve 200-liter drums, for a volume reduction ratio of 17:1. Inspection of a drum of ash removed from the incinerator revealed a few clinkers of solid, partially charred rubber. Localized areas of insufficient combustion air and frequent movement of the ash bed may have produced the unburned material.

When waste burning approached steady-state, the exhaust gas was isokinetically sampled with an EPA Method 5 stack sampler. The gas was pulled through a fiberglass filter and a series of caustic bubblers and then collected in a sample bag. Only trace amounts of particulates were captured on the filter indicating that the baghouse efficiently removed even fine particles. The caustic scrub solution was analyzed for SO_2 and SO_3 with ion chromatography. Results indicate that the concentrations of sulfur oxides were below the state and EPA limits for release to the atmosphere. The gas collected in the sample bag was analyzed by gas chromatography for carbon monoxide, and the concentration was below the detection limits of the instrument (<100 ppm). The excess air in the secondary combustion chamber oxidized the CO to CO_2 and reduced its presence in the off-gas.

RESEARCH PROGRAM

The research program has been divided into Phase I for nonradioactive testing and Phase II for a radioactive demonstration. Phase I is currently underway and will continue through September 1982. Testing will then be temporarily halted and the equipment will be modified for radioactive service. Phase II of the test program will begin in early 1983. The remaining tests are discussed in more detail in the following sections.

Solids Burning

Future solids burning includes incinerating single waste components that will demostrate the limits of the process. The program will test the ability of the incinerator to meet the high oxygen demands of burning rubber and also the system's ability to control temperatures while burning polyethylene with its high heat of combustion. While the composition is held constant, the weight of each box and the feed rate will be varied.

A run will be conducted to burn waste mix with polyvinyl chloride. During this run, corrosion caused by the HCl produced from burning PVC will be minimized by neutralizing with Na_2CO_3. This will be accomplished by spraying the hot off-gases with the carbonate solution in

the spray quench. The efficiency of this neutralizing method will be determined.

The system will be demostrated in a final solids burning campaign requiring five days of continuous incineration. This run will simulate actual plant operation by varying the feed rate, waste composition, box size, and packing density and observing the system's response.

Solvent Burning

Exhausted solvent from plutonium and uranium extraction is currently stored in underground tanks at the Savannah River Plant. The inventory of solvent in these tanks is 570,000 liters. The spent solvent contains fragmented alkanes and di- and monobutyl phosphates, which are formed by the radioactive and thermal degradation of tributyl phosphate and n-paraffin.

Phase I of the testing includes determining the optimum method of solvent incineration by burning nonradioactive materials. Two methods will be tested, spray burning and dripping solvent onto the hearth of the incinerator. The effectiveness of fixing the phosphorous produced in burning TBP will be determined using calcium-based fixatives. Phosphorous fixation is desired to prevent phosphorous pentoxides produced during TBP burning from forming phosphoric acid and corroding the equipment materials. Tests will be conducted which vary the TBP concentration in n-paraffin, flowrate, fixative concentration, chemical fixative, and spray nozzle type.

The solvent incineration tests will utilize the dual-chambered in cinerator and off-gas equipment that is presently undergoing solids testing. Additional equipment to inject solvents into the incinerator is presently being specified and will be installed in April 1982.

A 1900-liter agitated tank will serve as the feed vessel for solvents. Solvent and fixative slurry will be pumped through a recirculating line fed from the bottom of the tank. The flowrate of solvent to the incinerator will be controlled by a metering pump feeding off the recirculating line. In the reference process, solvent will be injected into the primary incinerator chamber through an atomizing spray lance. Process lines will be kept short to minimize the possibility for powdered fixatives to settle.

Phase II

At the conclusion of the cold test period, the entire incineration facility will be moved from its present location in a clean area of the Savannah River site to the SRP burial ground. The equipment will be modified for radioactive service by upgrading the ash

handling system and sealing the process for radionuclide containment purposes. At this time, a bank of absolute (HEPA) filters will be added downstream of the baghouse. The experimental program will continue with test burns of suspect solid waste and campaign runs to incinerate the inventory of radioactive spent solvent. The major emphasis of the research program will be to determine the intensity and type of radioactivity remaining in the ash, system decontamination factors, and nuclide uptake into the ceramic material.

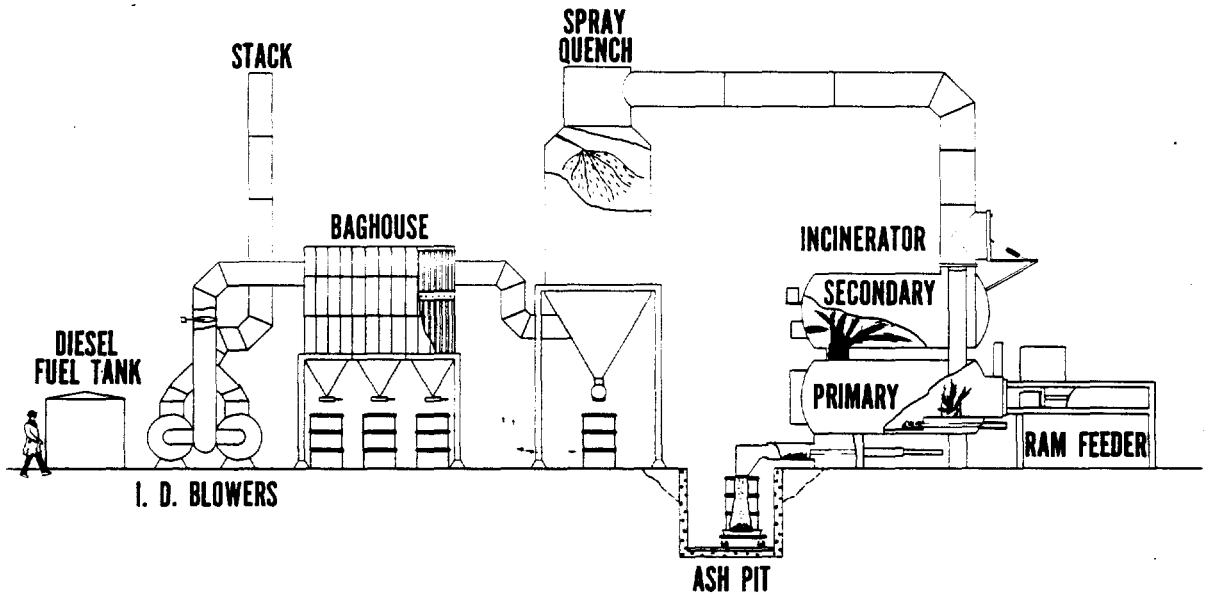

FIGURE 1. Conceptual Diagram of the SWIFT.

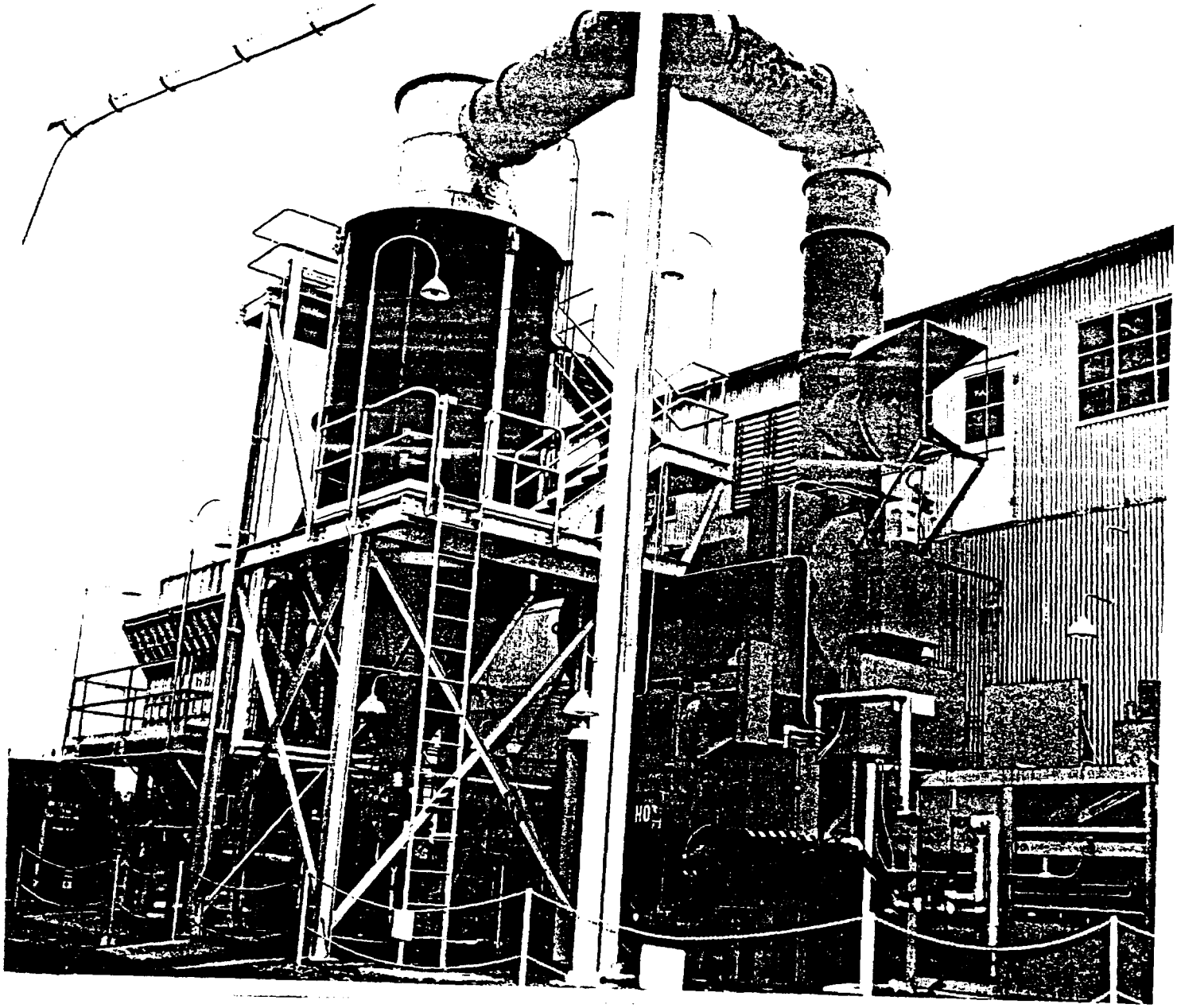

FIGURE 2. Incinerator Installation at SRL.

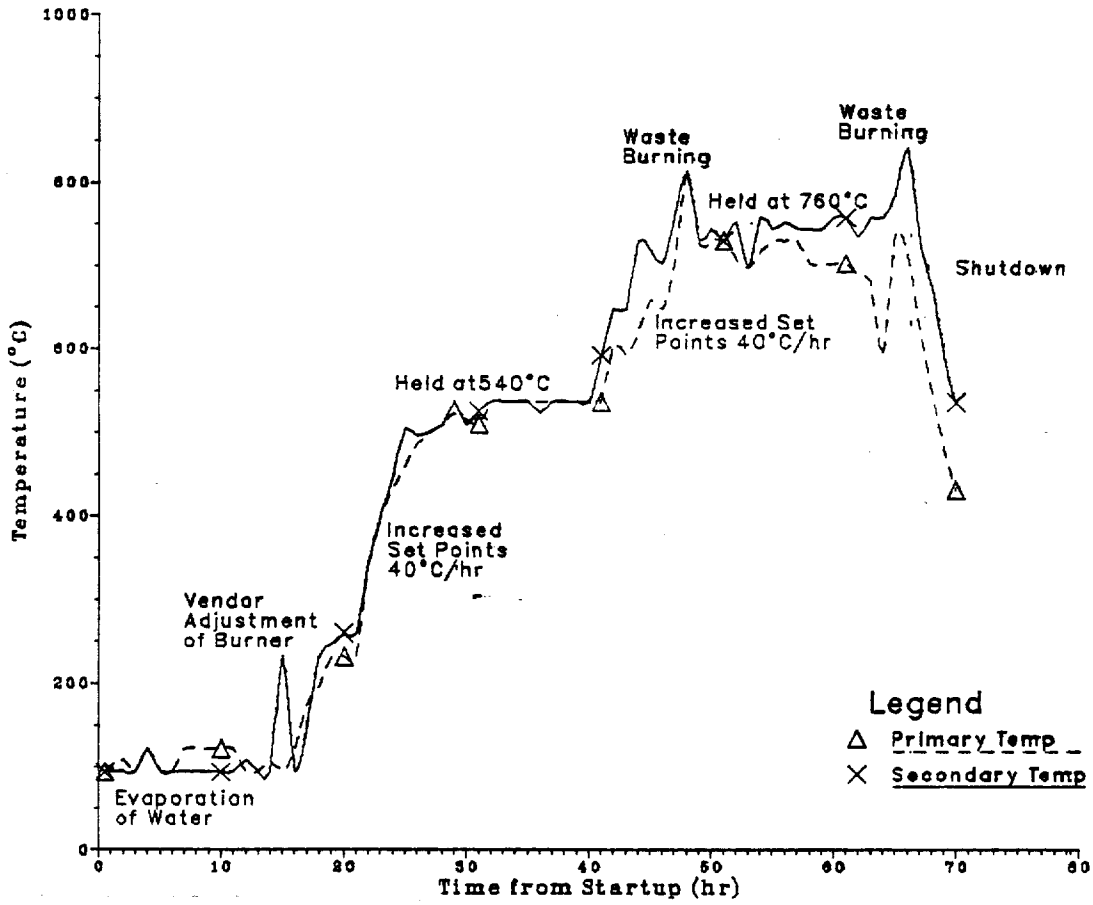

FIGURE 3. Temperature Curve for Curing Refractory.