AN INCINERATION DEMONSTRATION AT SAVANNAH RIVER

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ABSTRACT

A full-scale incineration process for Savannah River Plant (SRP) low level beta-gamma combustible waste was demonstrated at the Savannah River Laboratory (SRL) using nonradioactive wastes. From October 1981 through September 1982, 15,700 kilograms of solid waste and 5.7 m^3 of solvent were incinerated. Emissions of off-gas components (NO_x, SO_2, CO, and particulates) were well below South Carolina state standards. Volume reductions of 20:1 for solid waste and 7:1 for Purex solvent/lime slurry were achieved. Presently, the process is being upgraded by SRP to accept radioactive wastes. During a two-year SRP demonstration, the facility will be used to incinerate slightly radioactive (<900 μCi/meter^3) solvent and suspect level (<1 mR/hr @ 0.0254 meter) solid wastes. The next phase will include upgrading the facility for nonradioactive hazardous wastes such as 1,1,1-trichloroethane.

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, 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 for volume reduction since 60% of the solid waste generated is combustible. The reduced volume of the waste would extend the life of the burial ground. Also, ash residue solidified in cement and packaged in steel drums would improve burial ground practices.

Spent solvent used in the Purex process for the radiochemical separation of plutonium and uranium is also stored at the SRP burial ground in underground tanks. Currently, there are 568 meter^3 in storage with an annual generation rate of 7.6 meter^3/year. The liquid is composed of n-paraffin, a kerosene-like diluent, and tributylphosphate (TBP). The solvent is only slightly radioactive with the principal beta-gamma nuclides being ruthenium, cesium, and strontium. Burning a Purex solvent/lime slurry by spray injection is the reference 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 demonstration facility, called the Solid/Solvent Waste Incineration Facility for Testing (SWIFT), has been installed and operated at SRL.

INTRODUCTION

The incinerator has successfully completed five test runs with simulated, boxed solid waste and four test runs with uncontaminated Purex solvent. A total of 15,700 kilograms of solid waste containing paper, cotton fiber, red rubber, polyethylene, and polyvinyl chloride was burned. Tests were conducted in week-long campaigns. During the five solids campaigns, waste was burned as individual components and as a standard waste mix (Tables I and II).

A total of 5.7 m^3 of uncontaminated Purex solvent was incinerated (Table I). The solvent was sprayed into the incinerator primary chamber as a slurry with calcium hydroxide (Table II). The calcium acts as a fixative for the phosphorous that is released during TBP incineration. Without the fixative, phosphoric acid fumes would be formed that would accelerate long-term corrosion rates and cause filter blinding.

These tests demonstrated the incinerator's flexibility in burning the wide range of SRP waste, proved the operability of a dry off-gas system, and debugged the process controls, and identified and corrected several design oversights.

TABLE I - SUMMARY OF SOLID/SOLVENT WASTE BURNING CAMPAIGNS

Run Number	Duration of Incineration (hrs)	Amount of Waste Burned		Type of Waste Burned
		Weight (kg)	Volume (m^3)	
Solid 1	4	972	10	Computer Paper
Solid 2	20	3028	28	Computer Paper/Cotton
Solid 3	38	4776	43	Waste Mix w/o PVC
Solid 4	21	2724	30	Red Rubber/Waste Mix/PE
Solvent 1	7	---	0.76	n-Paraffin
Solvent 2	6	---	1.0	n-Paraffin
Solvent 3	8	---	1.1	Purex Slurry
Solid 5	32	4169	41	Waste Mix w/PVC
Solvent 4	19	---	2.8	Purex Slurry w/TCE
TOTALS	155	15,668	152 Solid 5.7 Solvent	

TABLE II - SOLID/SOLVENT WASTE COMPOSITIONS

Component	Solid Waste Mix w/o PVC (wt%)	Solid Waste Mix w/PVC (wt%)
Polyethylene (PE)	23	23
Red Rubber (SBR)	19	19
Cotton Fiber	29	25
Computer Paper	29	--
Polyvinyl Chloride (PVC)	--	8
Brown Reinforced Paper	--	25

Component	Purex Slurry (%)	Purex Slurry w/TCE (%)
n-Paraffin ($C_{12}H_{26}$)	75 volume	72.2 volume
Tributylphosphate (TBP)	25 volume	25 volume
Calcium Hydroxide ($Ca(OH)_2$)	18 weight	36 weight
1,1,1-Trichloroethane (TCE)	------	2.8 volume

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PROCESS DESCRIPTION

General

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

The incinerator is a two-stage controlled air unit manufactured by Environmental Control Products of Charlotte, North Carolina. 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 semi-pyrolyzed in the fuel rich primary chamber. The low airflow into the chamber is introduced through several underfire air ports on the side of the hearth. This airflow is low enough to avoid excessive ash entrainment.

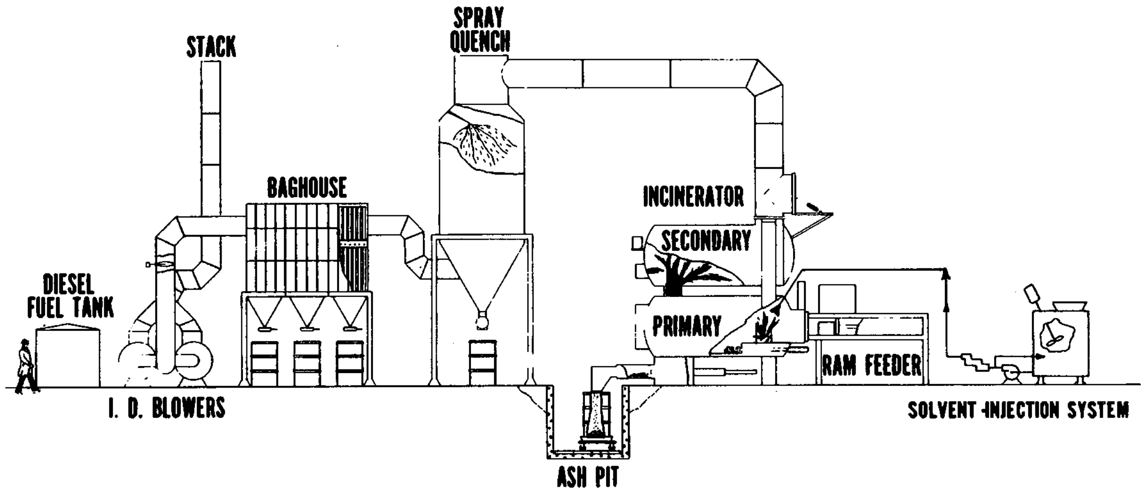

Fig. 1. SWIFT Conceptual Diagram.

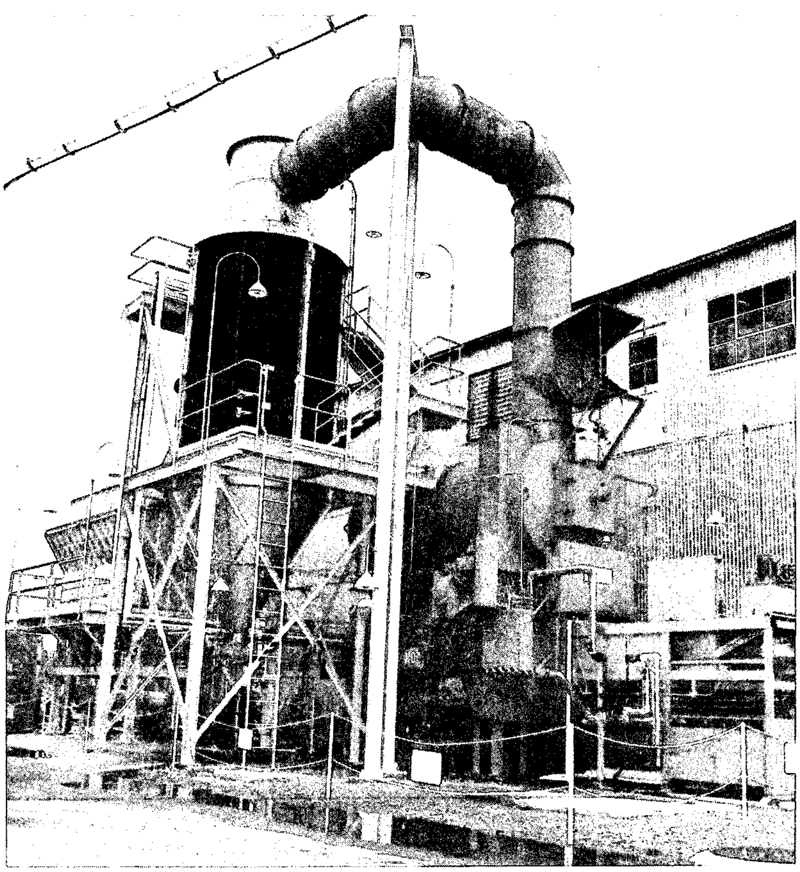

Fig. 2. Front View of the SWIFT Showing the Incinerator and the Spray Quench.

Combustion airflow (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 to 900°C in the primary chamber and 1000°C in the secondary chamber. The control system maintains these temperatures by modulating two diesel-oil-fired burners and the combustion airflows. 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.

This incinerator has two hydraulic rams for removing ash from the primary chamber. Off-gases from the secondary chamber pass through a refractory-lined duct before entering the spray quench. In the spray quench, the incinerator off-gases are cooled from 1000 to 180°C using two air-atomized water sprays. During incineration of polyvinyl chloride (PVC) and nonradioactive 1,1,1-trichloroethane (TCE), an aqueous sodium carbonate solution was tested in the spray quench. The purpose of this test was to establish the feasibility of neutralizing gaseous HCl to reduce chloride emissions and corrosion problems. The gases leaving the spray quench are maintained above the dewpoint so no secondary liquid waste streams are generated. The cooled gases are then filtered using a baghouse that contains envelope-type Nomex® (Du Pont) fabric bags. The filter efficiency is rated at 98% for particles one micron in diameter.

Two sixty horsepower induced-draft blowers maintain a negative pressure in the process and exhaust the off-gases to the atmosphere through a thirty-five foot stack.

Solids Preparation and Feeding

Solid waste was fed to the incinerator in 0.38 and 0.61 meter, cubic boxes. These boxes were prepared before each run so that the waste compositions, packing densities, and box weights were known. The boxes were then fed to the primary chamber of the incinerator with a hydraulic feed ram. Feed rates up to 180 kilograms per hour were demonstrated.

Solvent Feeding

The primary components of the solvent feed system were an agitated feed tank and two pumps. After uncontaminated Purex solvent and calcium hydroxide fixative were slurried in the feed tank, a centrifugal pump drew solvent from the bottom of the tank and recirculated it back. This recirculating pump aided in suspending the solids in the slurry and supplied solvent to the inlet of the feed pump.

A piston-type metering pump was used to feed solvent to the incinerator. The solvent flowrate was varied by manually controlling the speed of the feed pump. The solvent slurry was sprayed into the primary incinerator chamber at the reference feedrate of 0.14 $meter^3$ per hour.

SUMMARY OF RESULTS

The following key process elements were demonstrated during the one-year research program:

1. The system proved flexible enough to burn a wide variety of materials with a wide range of heat release values and instantaneous air demands at the reference feedrates.

2. Parameters for operating the dry off-gas system were optimized. With the dry system, off-gases are cooled, filtered, and maintained above the dewpoint until they are exhausted to the atmosphere. Thus, there are no secondary liquid waste streams that require treatment.

3. Process temperatures and vacuum were controlled automatically.

4. The phosphorous released by burning tributylphosphate was fixed by using calcium hydroxide as a fixative. This minimizes the formation of phosphoric acids and reduces long-term corrosion rates and filter blinding.

5. Ash was removed from the incinerator on a semi-continuous basis. The incinerator has two rams for displacing ash. The first ram moves the ash the length of the hearth and tumbles it into an ashdrop. The second ram pushes the ash the length of the removal duct and into a 0.2 $meter^3$ drum.

6. Volume reduction ratios were determined for both solid and solvent incineration. The volume reduction for solids was 20:1 for a 95% reduction in volume; solvents were reduced by a ratio of 7:1 for an 86% reduction in volume.

DISCUSSION

The system proved flexible enough to burn a wide variety of materials with a wide range of heat release values and instantaneous air demands at the reference feedrates. Pure polyethylene was burned at 180 kg/hr to determine operating characteristics of the SWIFT under the highest anticipated heat release conditions. Pure red rubber was burned at the reference rate to check if the incinerator air capacity was sufficient to maintain the exit oxygen level greater than 5%. Red rubber (SBR), which was used to simulate latex incineration, has a high instantaneous air demand. Other unique materials that were incinerated include PVC and TCE, which release hydrochloric acid, and a slurry of Purex solvent and calcium hydroxide. In all cases, the SWIFT pressure and temperature process controls functioned as designed.

The dry off-gas system eliminates secondary liquid waste streams that would require treatment. The dry off-gas system also simplifies operation. The main component of the dry off-gas system is the spray quench. The test program demonstrated that the spray quench could control the baghouse inlet temperature within design specifications. Aqueous sodium carbonate spray drying to neutralize gaseous HCl was also demonstrated. However, the ash produced during solids incineration was found to neutralize greater than 90% of the HCl released without sodium carbonate addition.

The baghouse utilized pulse blowback for removing fly-ash from the bags. The semi-continuous blowback was capable of maintaining the baghouse pressure drop below 500 newton/meter^2. In general, the material balance for ash yielded a total system DF of 1400 and a baghouse DF of 210. Particulate and gaseous (NO_x, SO_2, CO and HCl) emissions as determined by an EPA Method 5 sampling train were well below South Carolina state standards and all anticipated Federal emission regulations (Table III).

TABLE III - TYPICAL OFF-GAS AIR QUALITY

Component	Solid Waste Burning[a] Air Quality (μg/m^3)	Solvent Waste Burning[a] Air Quality (μg/m^3)	South Carolina State Air Quality Standard (μg/m^3)
NO_x	0.4	1.1	100
SO_2	4.4	2.5	1300
HCl	2.4	2.9	Not Specified
CO	<160	<160	40000
Particulates	0.02	0.04	60

[a]Values were calculated for a point one kilometer from a ten meter stack using a dilution factor of 1×10^{-4} s/m^3.

A key feature of the SWIFT design that was demonstrated is the automatic vacuum control system. This system maintains a vacuum of 249 newton/meter^2 in the secondary incinerator chamber by means of induced draft blowers and an automatic vacuum control valve. This is necessary since the incinerator will be put into radioactive service during the second phase of the incinerator program. One area of difficulty caused by vacuum operation was that air in-leakage adversely affected incinerator temperature control. After air in-leakage points were closed, temperature control via underfire air modulation was achieved.

In the burning of tributylphosphate, phosphorous is released to form phosphoric acid. Phosphoric acid would cause long-term equipment corrosion and blinding of the baghouse filters. To minimize acid formation, calcium hydroxide was slurried with the tributylphosphate/n-paraffin solvent prior to spraying the solvent into the incinerator. During incineration the phosphorous reacts with calcium and oxygen to form various calcium-phosphorous oxides. All of these products are refractory solids that primarily de-entrain in the incinerator primary chamber or are filtered from the off-gases by the baghouse.

The incinerator at Savannah River is unique in that it utilizes two hydraulic rams for ash removal. The first, an internal ram, pushes ash the length of a three-meter hearth until it falls into a rectangular ash drop in the bottom of the primary chamber. The second ram, an ash pusher, removes the ash from the ash drop, pushes it through a horizontal cooling duct, and deposits it in a 0.2 meter^3 drum. These rams are cycled by automatic timers.

Initial tests proved that the ash pusher was inadequate for removing ash from the ash drop. The original ash pusher was a short ram of hollow metal construction. The concept for this design was to displace cooled ash from the cooling duct and into a drum by pushing newly formed ash behind it. This method of ash displacement was not successful because ash compacted and plugged in the ceramic-lined cooling duct. A new ash pusher ram was designed and installed. This ram was designed to stroke all but the last 0.30 meters of the removal duct and provide positive displacement for the ash. The ram was also ceramic-filled for improved dimensional stability. The new ash pusher successfully removed ash on a semi-continuous basis during operation.

Volume reduction ratios were determined for both solid and solvent incineration. In general, the volume reduction for solids was 20:1, and solvents were reduced by a ratio of 7:1. The volume reduction data for each run can be found in Table IV. Volume reduction for solvent was less than for solid due to calcium hydroxide addition. It should be noted that the primary objective of solvent incineration is to provide a permanent means of disposal to eliminate underground tank storage. There was a wide range of volume reduction factors due to various inert contents in the simulated solid waste materials.

TABLE IV - SUMMARY OF ASH COLLECTED FROM INCINERATOR RUNS

Run Number	Ash Fraction Reaching Baghouse	Reduction Ratio Weight	Reduction Ratio Volume
Solid 1	---	22	45
Solid 2	0.07	12	22
Solid 3	0.11	9	17
Solid 4	0.10	3	15
Solid 5	0.21	8	22
Solvent 3	0.17	8	7
Solvent 4	0.17	5	8

FUTURE PROGRAM

The next phase of the incineration program involves moving the process to SRP and upgrading the equipment to accept slightly contaminated radioactive wastes in a two-year hot demonstration. The baghouse containing envelope shaped bags will be replaced by a new unit in Phase II. The new baghouse will feature tubular bags made of a fiberglass fabric for improved high temperature protection. The new baghouse will offer an overall design more amenable to radioactive service. HEPA filtration will also be added. A feed assay system comprising an airport type x-ray machine and a computer based beta-gamma multi-channel analyzer will be added for the Phase II demonstration. A development program is underway at SRL to specify an ash solidification system consistent with improved burial ground practices. The two-year Phase II demonstration will begin in June of 1983. The facility will then be used to burn slightly radioactive (<900 μCi/meter^3) solvent and suspect level (<1 mR/hr @ 0.0254 meter) solid wastes.