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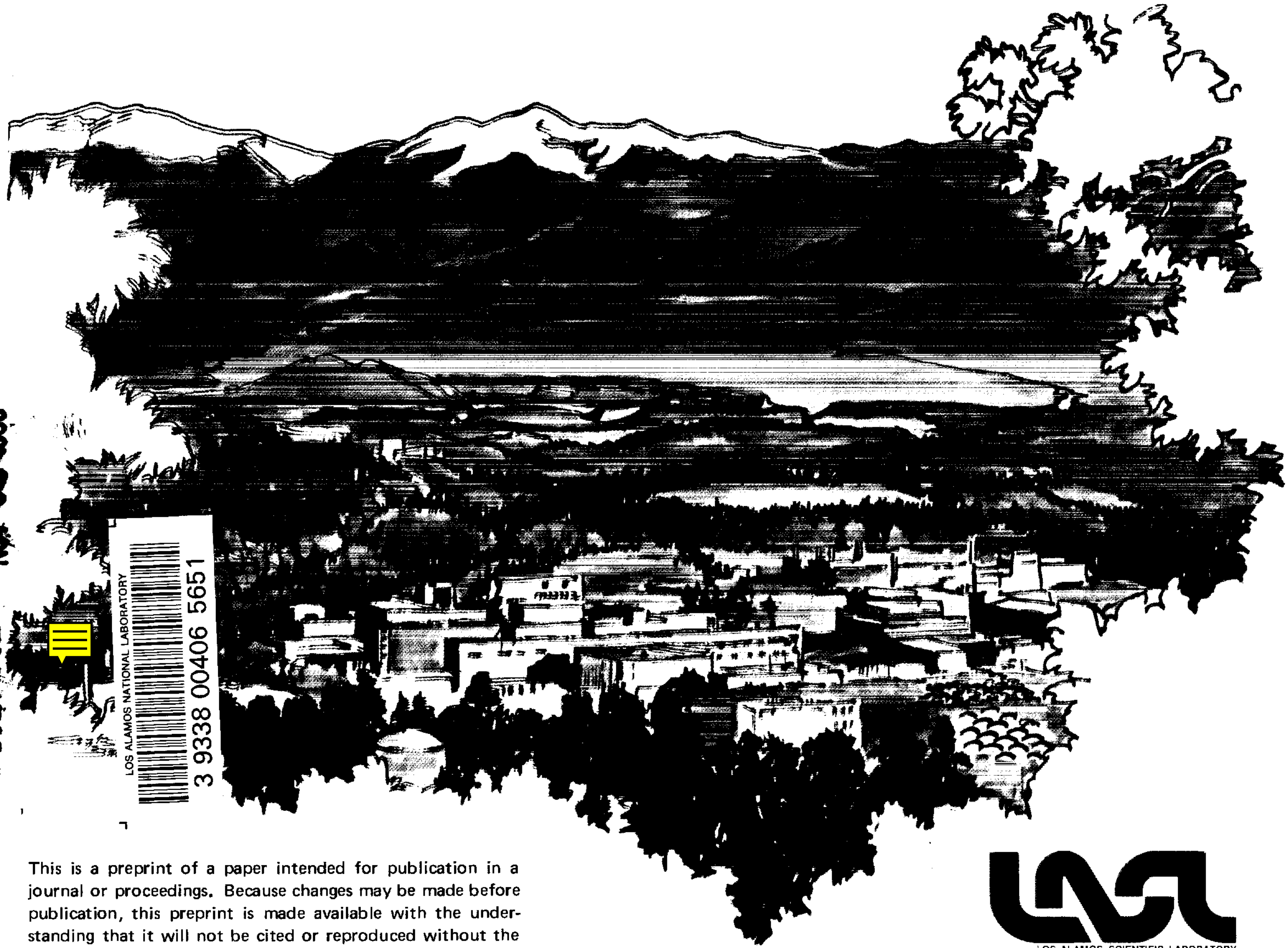

LOS ALAMOS SCIENTIFIC LABORATORY

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ABSTRACT

Development and demonstration of a transuranic (TRU) waste volume-reduction process is described. A controlled-air incinerator, based upon commercially available equipment and technology, was modified for radioactive service and was successfully tested and demonstrated with contaminated waste. Demonstration of the production-scale unit was completed in May 1980 with the incineration of 272 kg of waste with an average TRU content of about 20 nCi/g. Weight and volume reduction factors for the demonstration run were 40:1 and 120:1, respectively.

INTRODUCTION

Solid wastes contaminated with transuranic (TRU) isotopes, primarily plutonium, are routinely generated by Defense-related activities at facilities operated under contract to the U.S. Department of Energy (DOE). These materials result from laboratory, processing, and decommissioning activities, and while small compared to municipal waste volumes, they are significant due to the special handling required for safe disposal. Approximately 6900 m^3 of TRU-contaminated solid waste is generated annually by government facilities as a heterogeneous mixture of cellulosics, plastics, rubber, and a variety of noncombustible materials such as metal, glass, and concrete. The combustible portion constitutes about 45% of this volume.

Since 1970, these wastes have been segregated according to their level of transuranic contamination.[1] Extremely low-level wastes ($<10^{-8}$ Ci/g of waste) are committed to shallow earth burial in controlled areas. Materials containing enough transuranics to warrant economic recovery (approximately 0.5 g/kg of

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waste) are processed as scrap. Wastes containing in excess of 10^{-8} Ci/g but less than recoverable amounts, are placed in retrievable storage.

In 1973, the Los Alamos Scientific Laboratory (LASL) established a study program for the development, evaluation, and demonstration of production-scale (50 - 100 kg/hr) TRU waste treatment processes. The initial process investigated was to be incineration-based and utilize commercially available technology for volume reduction and chemical stabilization of low-level activity TRU-contaminated combustible materials.

This paper reviews process selection and design criteria which led to selection and modification of a Controlled Air Incinerator (CAI) system for the transuranic solid waste incineration program at LASL. The as-built process is described, and operating experience from the experimental program is presented.

PROCESS SELECTION

The overall incineration process function is to treat a combustible waste stream contaminated with transuranic nuclides to achieve volume reduction and produce an inert residue while assuring no release of contaminants to the environment, minimal exposure or hazard to operating personnel, and minimal production of secondary waste. Anticipated benefits of such processes would include reduced handling and storage hazard potentials; lower packaging, transportation, and storage expenses; reduced storage space requirements, and decreased monitoring needs. The necessary generic subsystems are feed preparation and introduction, incineration, offgas treatment, and ash removal and packaging.

Six selection criteria and related performance measures were developed for evaluating candidate processes and process components. Initially the criteria were effectiveness, flexibility, availability, health and safety, resource use, and operability.

The criteria were applied to a list of candidate processes and components using a Figure-of-Merit (FOM) selection method developed at LASL.[2] Considering the project constraint to make maximum use of existing, proven technology to develop a volume reduction process, LASL staff selected a controlled-air incineration system with an associated high-energy, aqueous, offgas cleaning system. Selection of the aqueous offgas system resulted in an additional subsystem, the scrub liquid recycle system, in order to minimize secondary waste generation.

PROCESS DESCRIPTION

The CAI process is an assembly of commercially available equipment which has been modified and otherwise incorporated into a continuous system. The more prominent features of the LASL installation are shown in Fig. 1, a greatly simplified line drawing of the CAI process. There are five subsystems in the process: a feed preparation and introduction train, incinerator, offgas cleanup system, a scrub solution recycling system, and an ash removal and packaging system. A brief description of the selected equipment and the overall processing sequence is provided in the following paragraphs. A more detailed description of individual components are contained in earlier reports.[3,4,5]

Design-Basis Waste and Capacity

The waste stream, contains low-level concentrations of transuranic nuclides. The nominal combustible waste composition, as shown in Table I, was derived from DOE surveys to serve as the incinerator design basis feed. Actual feed composition can vary and any of these components could constitute up to 100% of the feed stream at any given time.

It has been determined that processing rates need to be in the 45 to 90 kg/hr range based upon 10-month, 5 days/wk, 24 hr/day operation of a production incinerator to meet current generation rates. For this experimental model, a nominal throughput rate of 45 kg/hr was set following a review of scaleup factors, commercially available equipment sizes, and demonstration goals.

Feed Preparation and Introduction

At LASL, wastes are packaged at their source in sealed plastic bags and contained in 1-ft x 1-ft x 2-ft cardboard boxes. The boxes are transported to the Treatment Development Facility (TDF) and loaded into the receiving slotbox of the CAI feed preparation line where the packages are assayed for TRU content. Assay is performed using a multiple energy gamma assay system (MEGAS), a nondestructive assay system developed by LASL to determine TRU content near the 10 nCi/g fiducial.[6] The boxes are passed through an x-ray assembly, similar to airport security equipment, which scans for materials incompatible with the combustion process such as large noncombustible items and bottles of liquid. If necessary, the packages are opened in the sorting glovebox and these items are removed. Following inspection and necessary sorting the waste packages are transported to the storage glovebox where enough waste is accumulated for about 5 hrs of incinerator operation. During incineration, the waste packages are manually transferred from the storage box to the side ram feeder, which in turn loads the main ram feeder in preparation for waste introduction onto the incinerator hearth.

The main function of the feed preparation line is to assure safe and acceptable waste package while providing containment for radionuclides and minimizing waste handling and potential worker exposure to contamination.

Incineration

The incinerator is a conventional dual-chamber controlled-air design (Fig. 2), which has been modified to provide physical containment barriers around the combustion air fans, ash removal doors, and flanged connections to the offgas system ductwork. Similar unmodified models are frequently used for disposal of municipal, pathological, and industrial solid wastes. Both chambers are refractory lined and natural gas is used for waste ignition and supplemental heat. Wastes are charged batchwise via the main ram feeder to the lower chamber where underfire air is used to support combustion in controlled conditions. Unburned volatile components and entrained particles exit the lower chamber through an interconnecting port where excess air is introduced to promote complete combustion. The secondary, or upper, chamber provides the needed residence time for completion of combustion reactions. Supplemental heat is supplied to the secondary chamber as needed. Normal operating temperatures are 870°C in the lower chamber and 1100°C in the upper chamber. Air introduction rates and nominal chamber temperatures are varied depending on the waste combustion characteristics.

Offgas Cleaning

Exhaust from the CAI upper chamber contains both particulates and mineral acids which result from combustion of rubber and plastics present in the waste feed. Removal of these chemical pollutants and potentially radioactive particles is accomplished by the offgas cleaning system, which consists of a quench tower, a high-energy venturi scrubber, a packed-column absorber tower, a condenser, a mist eliminator, a re-heater, HEPA filters, and an induced-draft blower (Fig. 3).

The quench tower is divided into an upper contacting section and a lower separating section. Combustion gases are cooled from the incinerator exit temperature to approximately 70°C by evaporation of recycled scrub solution. Excess solution collects in the separator while the saturated gas phase is routed to the inlet of the venturi scrubber.

The variable-throat venturi scrubber, located between the quench tower and the absorber tower, removes up to 99 wt% of the offgas particulates. The venturi assembly consists of converging and diverging cones with a clamp valve throat to allow the pressure drop to be varied. Venturi pressure drop is normally controlled to 12.45 kPa. Scrub solution is injected through a nozzle located upstream of the throat. Mineral acids are removed from the gas phase by counter-current contact with process condensate, recycled scrub solution, or fresh water in the packed-column absorber tower.

The condenser, mist eliminator, and reheater are included to condition the process exhaust gases before final HEPA filtration. The condenser lowers the offgas temperature, removing the bulk of the water vapor from the scrubbed gas stream. The offgas is then reheated to approximately 17°C above the saturation temperature to avoid condensation and attendant plugging of the HEPA filters and corrosion of the plenum, exit ducting, and offgas blowers. The functional parts of each of these subsystem components are commercial equipment, which are housed in enclosures specially designed to withstand the 21.22 kPa pressure differential between this process and ambient conditions.

HEPA filtration is required for final removal of particulates. The filter module houses two frames in series; the first consisting of a prefilter and two HEPA filters, the second being similar but without the prefilter. The filter housing is designed to withstand the 20.8 kPa pressure differential capability of the process and is fitted with hatches to access the bag-out doors and in-place filter testing ports.

The induced-draft blower is capable of producing 57.2 kPa static pressure absolute at 53.8 m^3/min with a discharge pressure of 78.0 kPa absolute (to accommodate the 2255 m elevation at LASL).

Scrub Solution Recycling

A scrub solution recycle system is used to minimize liquid blowdown (waste to final treatment) from the offgas cleaning system (Fig. 4). This system consists of full-flow cartridge liquid filters, a graphite heat exchanger, two evaporative cooling towers, a scrub solution receiver tank, a condensate receiver tank, and a caustic makeup tank. Excess liquid drains from the bottom of the quench tower and combines with scrub solution and venturi blowdown in the packed-column base. This solution is pumped through 100 μm cartridge filter and a primary heat exchanger to the receiver tank. Liquid requirements for the quench tower, venturi scrubber, and absorber tower are satisfied by recycle from the receiver tank. Solution recycling through the quench tower is refiltered to remove particulates down to 20 μm.

The graphite heat exchanger cools recycling solution from 85°C to 50°C. The process (tube) side is operated at a lower pressure than the coolant (shell) side to guarantee in-leakage in the event of tube failure. The shell side fluid from the primary heat exchanger is cooled by the secondary heat exchange loop, providing isolation from the environment.

To control scrub solution acidity, 20% caustic solution is added at the receiver tank inlet. The addition rate is controlled by a pH sensor on the outlet of the receiver tank.

Condensate from the condenser/mist eliminator drains into a condensate receiver tank. The level in this tank is maintained by addition of fresh water. The solution is then pumped either to the top of the packed-column scrubber or to the receiver tank.

The blowdown rate from the scrub solution receiver tank is controlled by level and specific gravity. If the specific gravity of the scrub solution exceeds a specified value (currently 1.05), or if the tank level becomes excessive, the rate of blowdown which is sent to the liquid waste treatment plant is increased.

Ash Removal

Ash removal from the CAI is accomplished through one of two paths. A gravity ash dropout system (GADOS) is used for ash removal during operation and a vacuum ash removal system is used for thorough cleanout of both chambers of the incinerator during shutdowns.

The GADOS consists of a refractory-lined pit and door in the floor of the primary chamber of the CAI located at the end of the hearth opposite the ram feeder. As new waste is fed to the incinerator, the ash is pushed down the hearth until it drops into the ash removal pit. Periodically the dropout door is opened for a brief time to allow the ash to fall through a grate and delumper wheel into a collection hopper. The ash is then vacuumed from the GADOS hopper and collected by a high-energy cyclone and sintered metal filter system into a second hopper for removal at the ash packaging station.

The vacuum system, which is capable of producing up to 26.7 kPa suction, also is used for vacuum ash cleanout during shutdown. This is achieved by manipulating a vacuum hose in the incinerator chambers through the access doors and gloveboxes on the ends of the chambers.

The ash packaging station consists of a bagout glovebox where the ash is removed from the collection hopper through an interlocked isolation chamber. The chamber is first opened to the ash hopper and allowed to fill. The chamber is then isolated from the hopper and opened to drop the ash into a collection bag.

After the ash is packaged it is stored for future studies or immobilization processing.

Control and Instrumentation

Design and specification of the CAI process control system received priority attention throughout the planning and construction phase. As the "nerve center" for the process, the controls not only assure effective component performance, but monitor performance data to assure the safety of continuing operations. Control design considerations started with the parameters affecting operation of the incinerator and primary off-gas components. As the process design evolved, the considerations broadened to encompass the operation of ancillary equipment including back-up utility supplies. A detailed description of the complete control system is well beyond the scope of this paper, however, the incinerator control features and a general overview of the total system design are described below.

Controls on the as-received incinerator were largely limited to pre-set conditions based on combustion experience for a particular waste composition. These controls were upgraded to accept a wider range of feed compositions and to minimize thermal cycling in the lower chamber. Both air and natural gas supplies are modulated to permit proportional rather than step response to demand. The air introduction rate for each stage is controlled by feedback from oxygen analyzers located at the exit of each chamber. The pressure differential between the incinerator interior and the operating area is maintained by a valve immediately upstream of the induced draft fan. Flow measuring elements and recorders monitor air, natural gas, and steam introduction rates for energy and material balance purposes.

For the offgas cleanup, conditioning, and filtration equipment downstream of the incinerator, the controlled variables are: venturi scrubber liquid feed rate and pressure drop; absorber tower liquid feed rate; condenser gas-phase temperature decrease; re-heater gas-phase temperature increase; and HEPA filter pressure drop. The pressure drop and nominal temperature of each component is also monitored as an indication of normal vs. deteriorating performance.

In the scrub solution recycle subsystem, a pH feed-back arrangement controls neutralization of the liquid effluent from the primary offgas scrubbing components. Differential pressure is monitored across each liquid filter; process side temperatures are controlled in the graphite heat exchanger. Liquid level and specific gravity are controlled in the scrub solution receiver tank.

The primary variables, and many other secondary variables and parameters, are controlled and/or recorded at a central station. Variables considered critical to process operation and safety are tied into an alarm panel which positively identifies the off-range variable as an aid to trouble shooting. Off-range variables identified as vital to process safety will activate one of two automatic shutdown modes -- controlled or fast. Less critical alarmed variables only require operator response to correct off-range behavior.

A data acquisition system automatically records the many variable and parameter values generated during experimental CAI process runs.

Auxiliary Equipment

The backup utilities provide required services for an orderly process shutdown under abnormal circumstances. A diesel-powered generator, kept running during all incinerator operations, supplies standby power to high consumption equipment and vital motor driven equipment so as to not leave components stranded in a vulnerable phase of operation. Automatic switchgear is incorporated. An on-line, floating battery system provides electrical power for process controls, data collection, and averting potential momentary power interruptions, which could result in control relay dropout. A two-hour auxiliary cooling water supply is stored in a pressurized container for release to the quenching system in the event of a recirculation pump failure. Loss of cooling water would present an immediate threat of damage to process equipment. A backup air compressor and compressed nitrogen are available to supplement normal instrument air supply if required. Pneumatic actuators are designed to "fail safe" on loss of air pressure. Snuffing steam is injected into the primary chamber to extinguish burning waste in the event of a fast shutdown at high temperature to prevent uncontrolled burning and inefficient combustion, which can clog the offgas cleaning system with soot and heavy tars.

Radioisotope containment for the building is maintained by physical barriers and by zoned ventilation. There are four separate ventilation zones. The pressure of each zone is regulated so that ventilation air moves from the highest pressure zone (atmospheric) toward the lowest pressure zone (the volume internal to the process). The interface between each zone is controlled by physical enclosures. The zone ventilation system is shown in Figure 5.

EXPERIMENTAL PROGRAM AND RESULTS

The experimental program for the CAI development and demonstration project was divided into two phases. Phase I was the cold (nonradioactive) testing and development completed in late 1979, and Phase II was the hot (radioactive) testing and demonstration which was completed in May 1980.

Cold Testing and Development

The cold testing and development phase consisted of an initial equipment checkout period followed by six runs using noncontaminated waste materials. During the initial checkout, the incinerator module was operated for about 500 hrs in the as-received configuration. Operating experience and data obtained during the checkout were applied in designing the necessary process modifications for radioactive service.

Following initial process modifications a series of six nonradioactive test runs were made to check out the various subsystems and to establish operating parameters, identify additional modification requirements, tune control loops, and evaluate safety and containment aspects of the process. Phase I was a continuing effort of evaluating, modifying, and re-evaluating equipment performance resulting in a process with enhanced operability, improved safety in containment, and improved effectiveness.

CAI Run #4 was a cold test designed to check out process operation at designed feed rate on high plastics containing wastes. Wastes for this run included cellulosics material with up to 50% PVC, cellulosics with up to 50% polyethelene, and cellulosic with up to 20% latex.

CAI Run's #5 and #6 were made using simulated design basis feed to establish operating conditions for Phase II testing and to make a final checkout of all equipment and control system modifications.

Performance of the CAI improved steadily throughout the cold testing and development phase. Significant results include 1) attainment of designed throughput while incinerating design basis feed, 2) successful operation of all associated subsystems, 3) highly effective offgas cleanup resulting in chloride concentrations of less than 8 ppm in the condensate and sulfate concentrations of less than 10 ppm in the condensate, 4) long HEPA filter life with one set in use in excess of 230 hrs.

Hot Testing and Demonstration

Following successful completion of the cold testing and development phase, a hot test run (Run #7) was made using suspect TRU-waste consisting of room trash from the Los Alamos Scientific Laboratory Plutonium Processing Facility. Verification of the integrity and performance of the complete CAI system with actual radioactive waste as a feed material was the major objective of the test run. Other objectives were to evaluate the operation of the waste assay system, the x-ray inspection system, and the waste sorting operation in the feed preparation line.

Operation of the feed preparation line was smooth with about 15.4 kg of noncombustible materials identified in the x-ray scan and removed in the sorting operation. A total of 3.68 m^3 waste weighing approximately 213 kg was incinerated during the run. The charging rate was intentionally limited to minimize potential problems while experience was gained with incinerating contaminated materials. The incinerator system performed well with no contamination problems observed. Following the run, approximately 0.03 m^3 of ash weighing 7.26 kg was removed from the incinerator. The resulting weight and volume reduction factors were 29:1 and 130:1, respectively. These factors were somewhat higher than expected due to the low density and high plastics content of the waste material. Secondary wastes such as liquid cartridge filters, surgeons gloves, and other suspect room trash generated during the run, were also incinerated.

CAI Run #8 was a TRU-waste demonstration run during which 3.40 m^3 of design basis feed weighing 272 kg and containing an average of near 20 nCi/g of ^{239}Pu plus ^{241}Am was burned. The incinerator was operated at feed rates of 27.2 kg/hr and 45 kg/hr during the run. Operations were smooth with no contamination problems or other difficulties observed. The offgas system performed well with no significant deterioration of the final HEPA filters during the run. Ash removal and packaging was successful. About 6.8 kg of ash was removed with a volume of less than 0.03 m^3 weight and volume reduction factors for the demonstration run were 40:1 and 120:1, respectively.

Documentation and Technology Transfer

The major current effort in the CAI development and demonstration project is the preparation of detailed design and operating documentation for the system. Technology transfer to other Department of Energy contractor sites and to the commercial sector has been a continuing effort and will be emphasized in the future.

The documentation task will provide all information required for an interested user to duplicate the process including equipment specifications, drawings, calculations, and suggested modifications. Experimental results, operating procedures, and the final safety analysis will be published separately. The complete package should be available in early 1981.

Future Plans

To expand the usefulness of the process, equipment and operating procedures will be developed and tested to incinerate resins (beaded and powdered) and wide range of organic liquids. Resin combustion studies are planned for completion near the end of 1981; liquid studies will be completed in 1982.

There are a large number of potential applications of the CAI process for low level fission product wastes. However, the behavior of volatile and semi-volatile species within the process has not been addressed. Tracer level studies for ruthenium, cesium, iodine, and cobalt will begin within the next few months.

A joint commercialization program involving an equipment vendor, a utility, LASL, and DOE is scheduled to begin in June 1980. A CAI process for power reactor waste will be installed and tested at the utility site. Final reports should be published in late 1982.

SUMMARY

Modification of commercially available equipment and technology for radioactive service and production scale incineration of TRU contaminated wastes were successfully demonstrated.

Current efforts are toward documentation of the CAI process design, operating instructions, and operating data obtained during the runs. Future plans include expansion of the process flexibility to include combustion of resins and certain liquids. Technology transfer has and will remain an important objective of the project.

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Table I. Design Basis Incinerator Feed

Component	Wt%
Paper and rags	35
Plastics	
polyethylene	23
polyvinyl chloride (PVC)	12
Rubber	30
	100

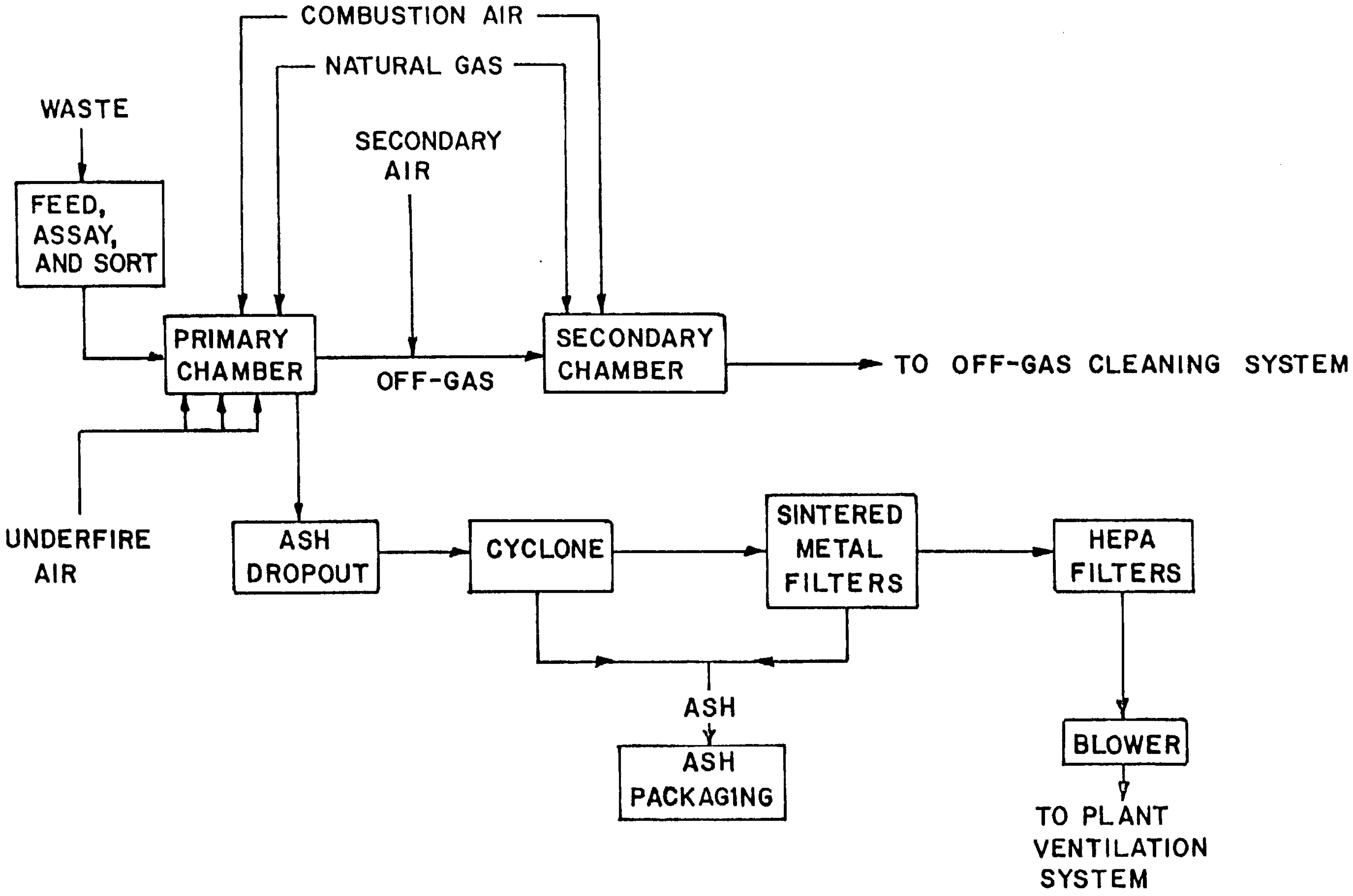

Figure 1. Simplified line drawing of Controlled Air Incineration process.

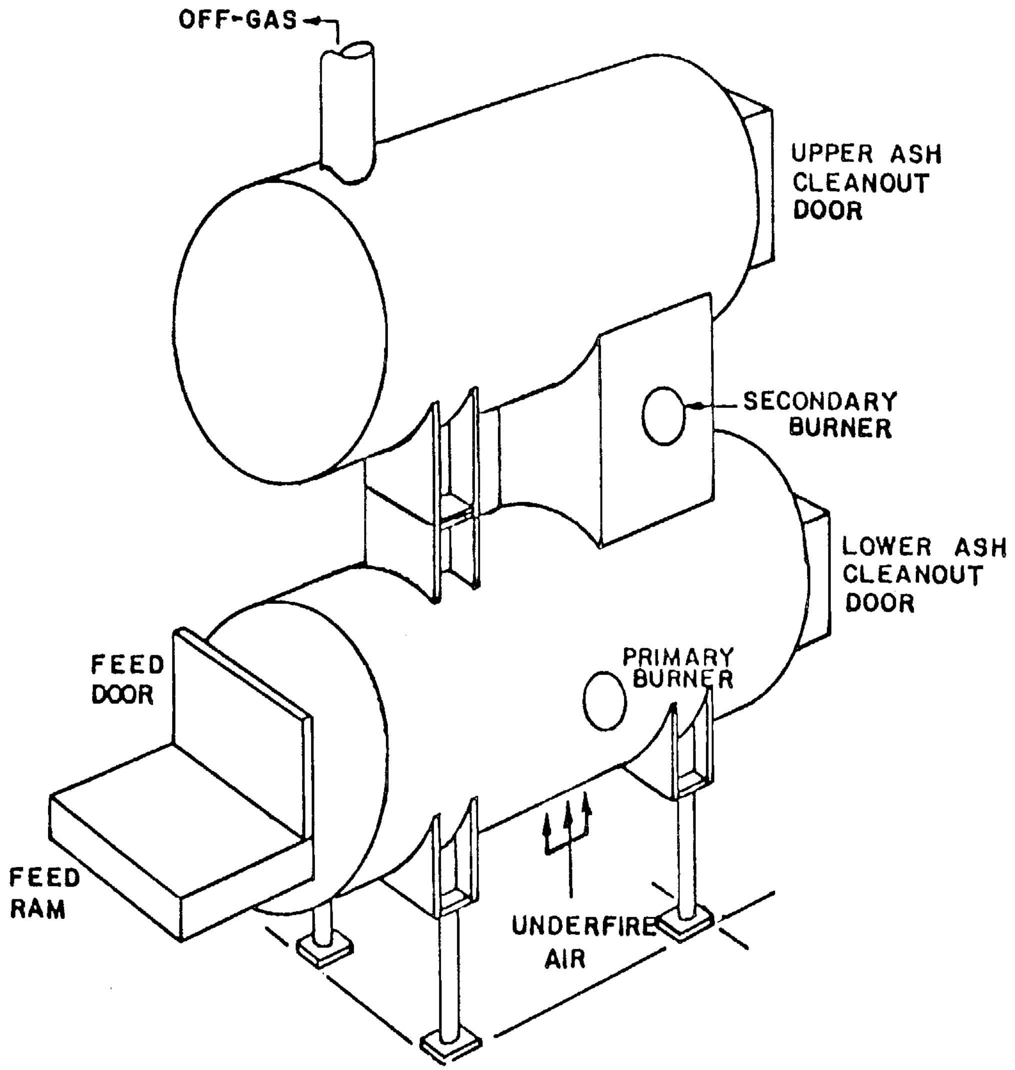

Figure 2. Basic Controlled Air Incinerator before modification.

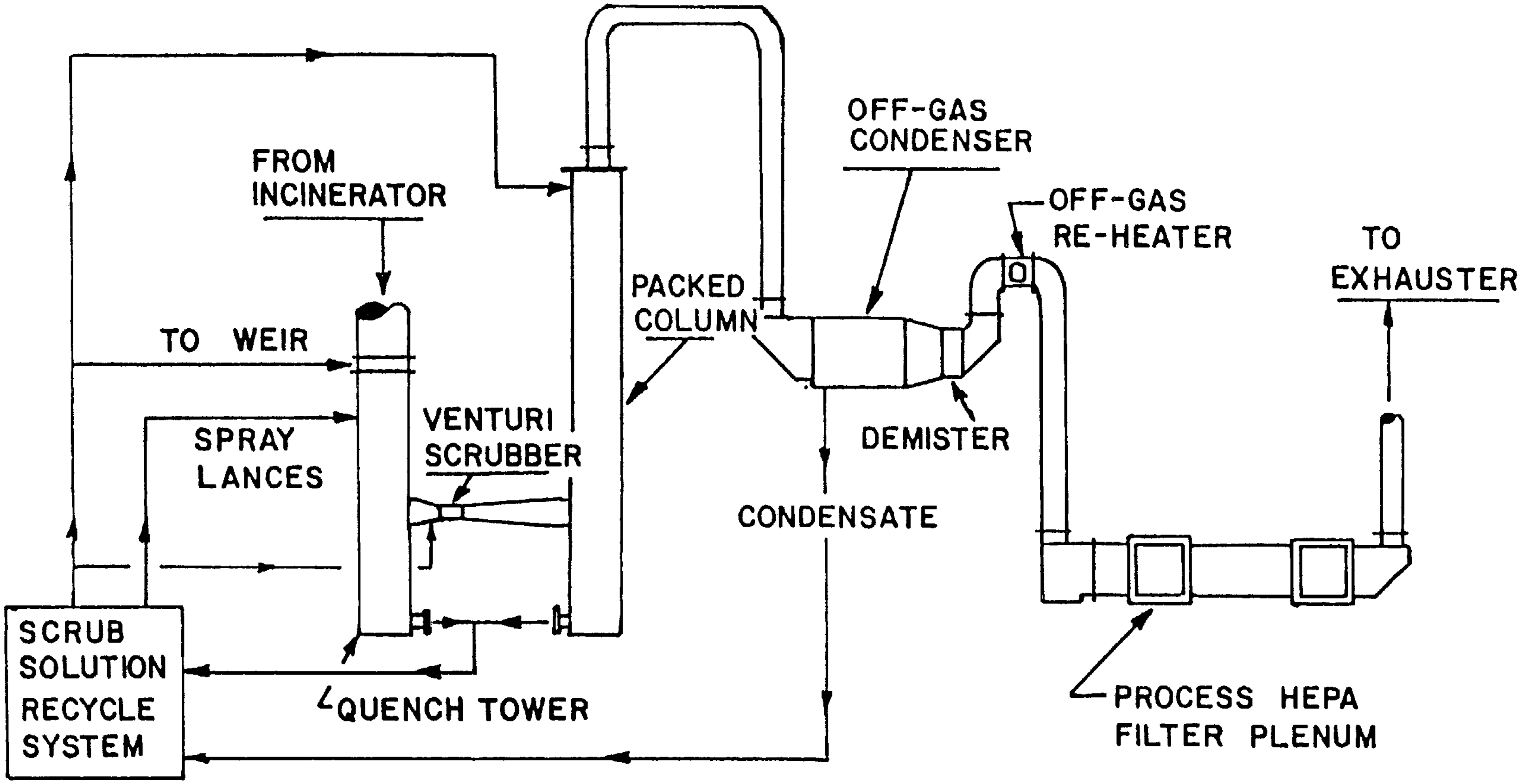

Figure 3. Offgas cleaning subsystem.

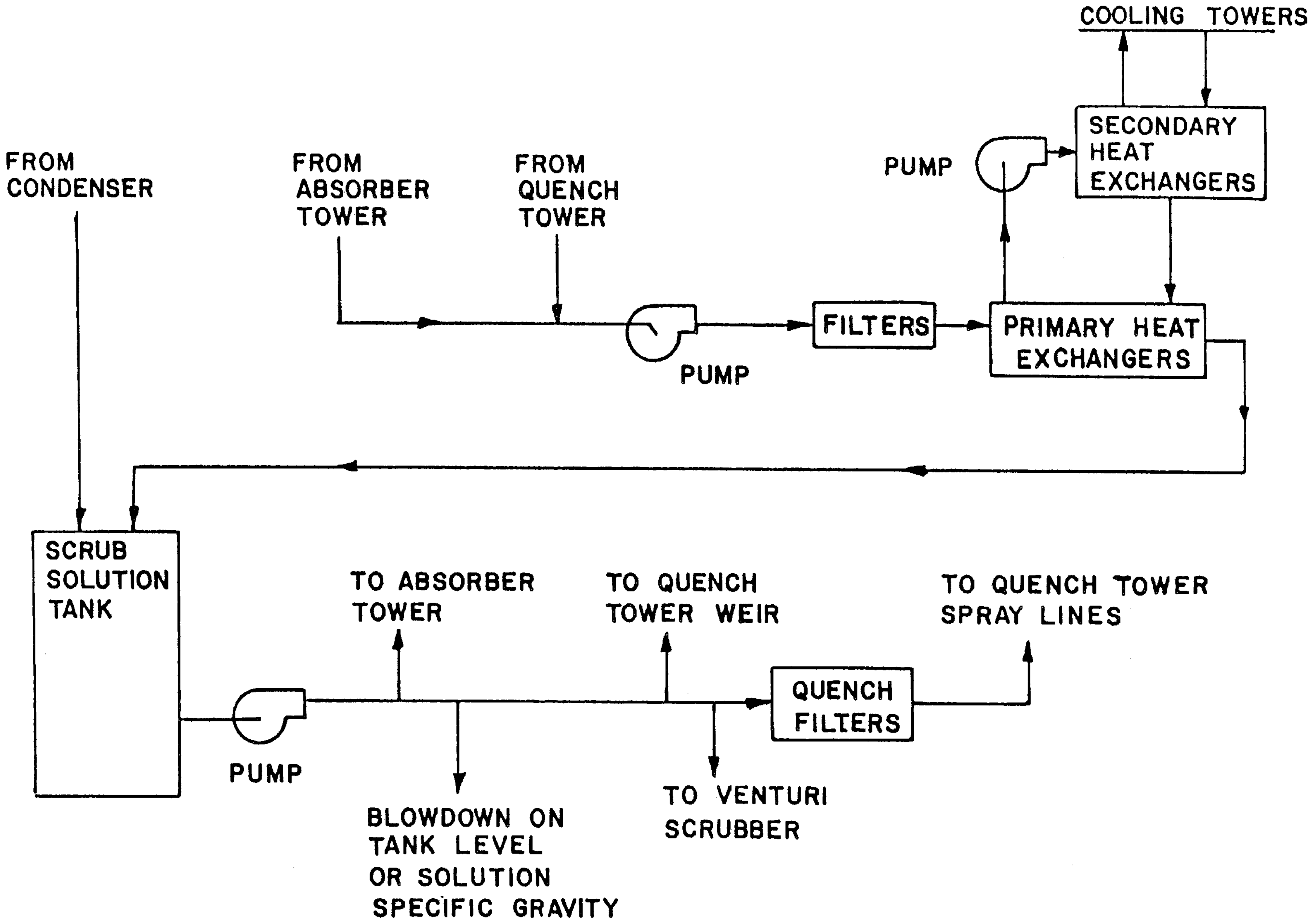

Figure 4. Scrub solution recycle subsystem.

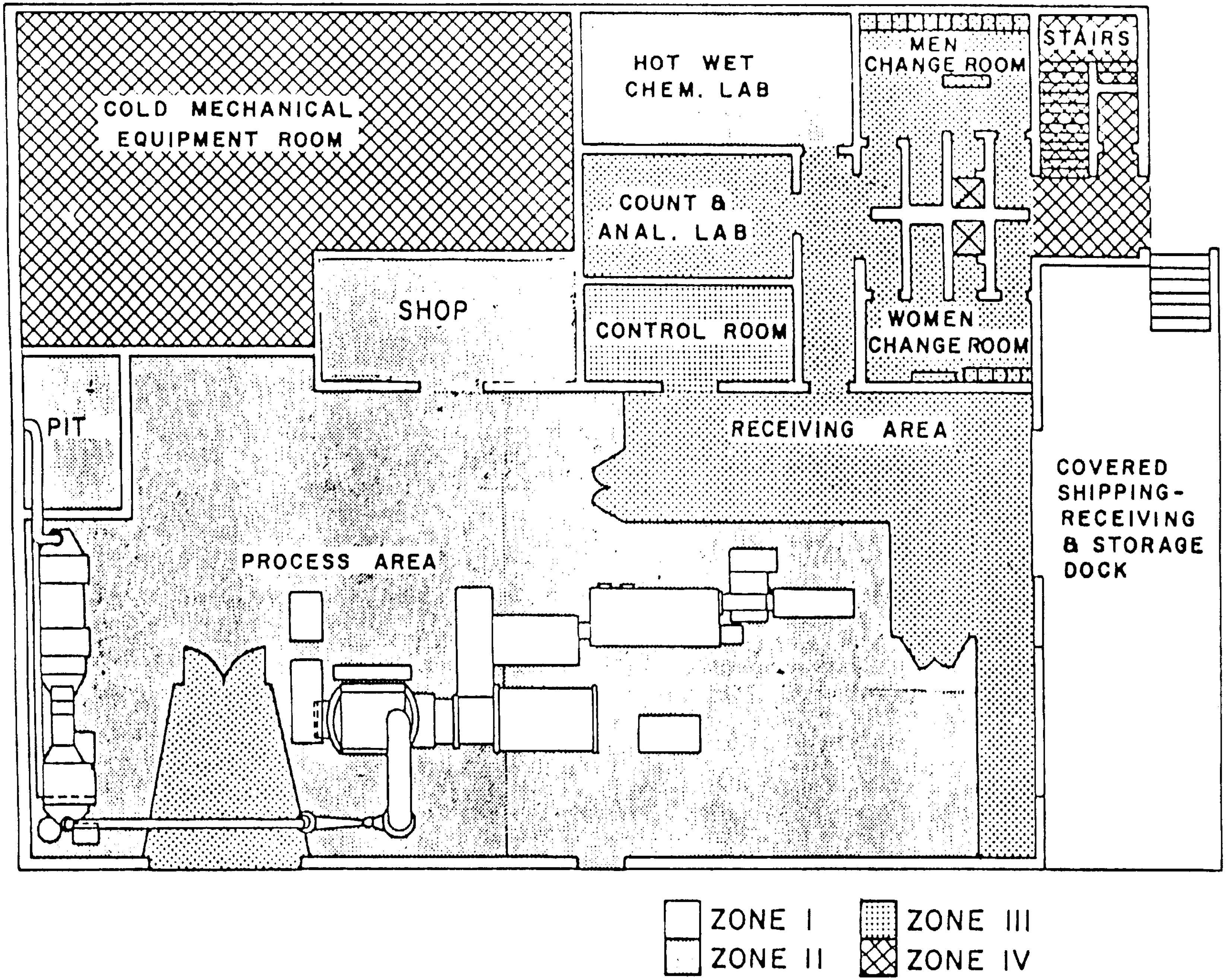

Figure 5. Building ventilation for radionuclide containment.