A COMMERCIAL REGIONAL INCINERATOR FACILITY

FOR TREATMENT OF LOW-LEVEL RADIOACTIVE WASTE

Richard E. Sauer
US Ecology, Inc.
Louisville, Kentucky

Dale Jessop
Associated Technologies, Inc.
Charlotte, North Carolina

ABSTRACT

In 1981, US Ecology, Inc. began studies on the feasibility of constructing and operating a regional radioactive waste incinerator facility. In December, 1982, US Ecology requested turnkey quotations from several vendors for engineering, procurement, and construction of the new facility. After technical and commercial evaluations, a contract was awarded to Associated Technologies, Inc., of Charlotte, North Carolina, in June, 1983. In June, 1984, US Ecology made a public announcement that they were studying two sites in North Carolina for location of the facility. This same month, they submitted their permit application for a radioactive material license to the North Carolina Department of Human Resources. The facility will accept wastes from power reactors, medical and research institutions and other industrial users, and will incinerate dry solid waste, pathological waste, scintillation fluids, and turbine oils. The incinerator will be a dual chamber controlled air design, rated at 600 lbs/hr, with a venturi scrubber, packed column, HEPA, and charcoal filters for pollution control. The stack will have a continuous monitor.

INTRODUCTION

Incineration is a proven method of reducing the volume of waste products and is a well established technology in non-nuclear industrial applications. The use of incinerators for the processing of radioactive waste while not widely in use is not new. A number of government laboratories and research facilities have used incineration as a means of volume reduction for many years. In 1981, US Ecology, Inc. began a study to determine the feasibility of applying available incinerator technology to the disposal of commercially generated low-level radioactive waste materials. The intent of this feasibility study was to determine whether a properly designed and stringently regulated incinerator could be a safe and efficient means for volume reduction of certain types of low-level radioactive wastes. As envisioned by the company, the incinerator facility would be a permanent regional incinerator located in an appropriate market intensive location.

The feasibility study investigated the following:

- Incinerable LLRW generated commercially
- Activity of these materials
- Types of LLRW to be incinerated
- Incinerator technology available
- Location of the facility
- Economics of the facility
- Anticipated permitting problems
- Project schedule

FEASIBILITY STUDY

Types of Materials to be Incinerated

It was decided that the facility should be designed to handle a combination of waste from power reactors, medical and research institutions and other industrial generators. The facility would process dry active waste (DAW), scintillation fluids, biomedical waste and turbine oils. Low activity dried resins, filter cartridges and filter media were also considered but eliminated at a later date because of their higher activity.

Activity of These Materials

The type and quantity of radionuclides present in the waste to be incinerated must be known with reasonable accuracy to design and permit the facility. This is difficult for a facility receiving wastes from a wide range of various types of generators. However, typical waste streams were developed through a detailed analysis of the waste received at US Ecology's Richland, Washington site.

When screening the waste, different constraints were used to eliminate waste that should not be incinerated at the facility. Since US Ecology's data base does not differentiate between combustible and noncombustible materials, the activity of the waste streams was generated utilizing the density of the waste (DAW only), the radiation readings, the shipping package volumes and waste characteristics. All containers reading greater than 200 mrem/hr were eliminated; also, containers with high levels of tritium were eliminated (level was set at 13.3 mCi/ft^3). Waste characteristics, container surface readings, container sizes, and DAW density are shown in Table I through IV for waste shipped to Richland during 1983.

TABLE I

Waste Characteristics Shipped to Richland Site

Waste Type	Percent by Volume
a) Vials	4.2%
b) Solid Dry (DAW)	82.8%
c) Solidified Liquids	4.4%
d) Biological	1.6%
e) Absorbed Liquids	5.4%
f) Resin Materials	1.2%
g) Filter Media	0.4%

TABLE II

Radiation Reading at the Container Surface Shipped to Richland Site

Radiation Reading (mrem/Hr RLS)	Percent by Volume
a) 0.0 to 0.20	21.8%
b) 0.21 to 1.00	23.7%
c) 1.01 to 2.00	8.4%
d) 2.01 to 5.00	9.7%
e) 5.01 to 10.00	6.8%
f) 10.01 to 20.00	6.5%
g) 20.01 to 40.00	6.6%
h) 40.02 to 60.00	4.3%
i) 60.01 to 80.00	2.5%
j) 80.01 to 100.00	1.8%
k) over 100.00	7.9%

TABLE III

Shipping Container Size Shipped to Richland Site

Container Size	Percent by Volume
a) Less than 7.5 ft^3 container	2.1%
b) 7.5 ft^3 (55 gal.) drums	46.6%
c) Overpacks (80 to 85 gals.)	0.9%
d) 15.0 ft^3 to 50 ft^3 boxes or liners	1.9%
e) 50.1 to 100.0 ft^3 boxes or liners	31.1%
f) 100.1 to 200 ft^3 boxes or liners	16.7%
g) Greater than 200 ft^3 boxes	0.7%

TABLE IV

Density of DAW Shipped to Richland Site

Density (Package Included)	Percent by Volume
a) 0 to 26.5 lbs/ft^3	40.0%
b) 26.6 to 33.3 lbs/ft^3	16.4%
c) 33.4 to 40.0 lbs/ft^3	9.5%
d) 40.1 to 46.8 lbs/ft^3	6.6%
e) Greater than 46.8 lbs/ft^3	27.5%

Based upon the information generated, a separate isotopic list was developed for three of the waste streams that would be processed at the proposed facility: 1) scintillation fluids; 2) dry active waste; and, 3) pathological waste. Turbine oils usually have a low activity, thus their isotopic list was not developed. Each list contained the radionuclides that were present, the total activity of each radionuclide and the percent of the total waste volume that contained each radionuclide. A portion of this list is shown as Table V, along with a typical power plant activity for trash type waste.

TABLE V

Dry Active Waste

Isotope	Activity Typical Power Plant (mCi/lb)	Activity US Ecology Analysis (mCi/lb)	Isotope Frequency
Co (-60)	.03400	.00580	65.0%
H (-3)	.00085	.02430	17.4%
C (-14)	.00003	.01401	12.0%
I (-131)	--	.00310	14.4%
Cs (-137)	.00878	.00396	63.0%

Incinerable Materials Generated

A marketing and literature survey was conducted to determine the potential waste scenario and volumes that could be expected at the incinerator. One study utilized was NUREG-0782, Nuclear Regulatory Commission (NRC) Study of the projected LLRW commercially generated from 1980 to 2000.

Also, from US Ecology's Data Base the combustible fraction of all waste types shipped to Richland was estimated to be from 32% to 44% of the total waste volume received.

Incinerator Technology Available

Various combustion technologies were investigated along with different combinations of off gas treatment and filtration subsystems. Primary consideration was given to three types of incineration technologies: controlled air, fluidized-bed, and excess air. Both dry, wet or combination of both flue gas filtration systems were considered.

Information published discussing the viability and reliability associated with LLRW incineration, indicates that the technology was available.

Location of the Facility

First, the facility needed to be located close to the source of the generation of waste. Second, access to main highways was considered very important.

North Carolina was selected because of its location within the low-level radioactive waste compact region which produces the highest amount of waste, approximated 1/3 of the nation's total.

In addition, the state of North Carolina is interested in incineration as an alternative to a low-level radioactive waste landfill. Under the terms of the compact, the Barnwell site is scheduled to close in 1992. North Carolina is the second largest generator of waste in the Southeast Compact region with South Carolina being the largest generator. North Carolina may not have to host a LLRW landfill if the state does its share of disposal through incineration.

Economics of the Facility

Based upon an internal evaluation, supplemented by information from several equipment manufacturers, an economic study was completed. This study showed that a regional incinerator processing from 140,000 to 190,000 ft^3 of LLRW per year would be competitive with shallow land burial facilities. The incinerator process volume will be dependent upon waste type, density, BTU rating, and volume of non-combustibles; a conservative estimate was assumed for DAW waste materials for both density and percent non-combustible.

Anticipated Permitting Problems

Licensing of the radioactive waste incinerator was considered the most critical controlling factor in the development of the facility. The basic incinerator technology was considered sufficiently developed to answer most technical questions. It was the negative public perception associated with radioactive waste and hazardous waste that was considered the biggest obstacle to the location of the facility. Public reaction can influence local and state officials plus the regulators involved.

Project Schedule

The initial schedule was optimistically projected to show an eighteen-month time frame from start of engineering through facility start-up. This was based upon a six-month initial engineering time frame for permit preparation. A six-month period was scheduled for review, public hearings and issuance of the permit. This was considered optimistic but attainable. Finally, the facility could be constructed within six months from issuance of the radioactive materials license.

CONTRACT AWARD

The feasibility study showed that a LLRW incinerator could be both feasible and economically viable. So in December, 1982, US Ecology requested turnkey quotations from several vendors for engineering, procurement and construction of the incinerator facility. The vendors represented the three types of combustion process evaluated earlier: controlled air, fluidized bed and excess air. Air pollution control systems bid were both of the dry and wet type designs. The specifications were written based upon a performance type contract allowing for each vendor to propose his specific type equipment. For this reason, equipment, pricing and scheduling varied dramatically.

After completion of the technical and commercial evaluations, a two-phase contract was awarded to Associated Technologies, Inc., (ATI) of Charlotte, North Carolina, in June, 1983. The incinerator system selected is a dual chamber controlled air design, with a venturi scrubber, packed column, HEPA, charcoal filters for pollution control. The controlled air system allows for combustion to take place without excessive turbulence, thus minimizing carryover of flyash particles. However, because the waste will be bulk-loaded into the primary chamber, proper mixing of the air and waste would be difficult if the waste is compacted or in a container. For this reason, a shredder was included prior to the incinerator ram feed for processing the DAW.

A wet system for off-gas primary filtration was selected in lieu of a dry system because of the projected higher decontamination factor that could be achieved. The scrub solution can absorb gases such as radioactive iodine and can achieve acid gas neutralization. The disadvantage is that the scrub solution must be handled as a liquid, requiring evaporation by means of radiant heat.

The contract that was awarded to ATI divided the project into two phases. The first phase included engineering up through design and equipment selection. This information would be used for inclusion in US Ecology's permit application which would be submitted to the state of North Carolina's Radiation Protection Section. The initial project schedule reflected a December 31, 1984 facility start-up.

FACILITY TECHNICAL DESCRIPTION

Facility Layout

The facility will include office space, site laboratory, storage area, feed preparation area, and process area. It will be located on approximately 20 acres of land, with the stack at the center of the acreage (see Fig. 1).

Process Building

The incinerator and the off gas scrubbing equipment and ash storage will be contained in a separate process building. The building will be constructed of 12-inch-thick concrete block and the interior of the building will be maintained at a negative pressure of a minimum of 1 inch of water column with respect to atmospheric conditions. This will minimize fugitive emissions from the facility. (See Fig. 2).

The process building will be ventilated using a combination of outside and recirculated air. The ventilated air will be filtered through a dry filter system consisting of a prefilter, High Efficiency Particulate Air (HEPA) filter, two carbon filters and a final HEPA filter. The filtered air will then be returned to the building or exhausted up the stack.

Operations Area

The operations area will include the drum storage areas, the receiving and shipping area, control room and feed preparation area. These areas will be housed in a pre-engineered building with the exception of a portion of the feed preparation area which is housed in an extension of the process blockhouse to provide sufficient overhead space for maintenance of the shredder and feed system. The feed preparation room houses the DAW conveyor feed system, shredder, a decant room for processing drummed shipments of scintillation fluid and turbine oil, and a room to house the vial breaker used to remove liquid from the scintillation vials (see Fig. 3).

There will be a dedicated area for storage of drums of DAW for incineration. There will not be an area allocated for storage of scintillation fluids or turbine oil. Due to their flammable nature, they will be processed as received by decanting into the site storage tanks.

There will be a freezer building attached to the pre-engineered building for storage of pathological waste.

Also, a portion of the building will be dedicated to short-term temporary storage of waste in transit to an out of state shallow land burial facility.

A hood will be placed over the DAW shredder to contain particulate emissions, and the decant and vial breaker rooms will be ventilated to remove both flammable organic vapors and radioactive particulates. The ventilated air will be passed through a dry filter assembly consisting of a prefilter, HEPA filter, dual activated carbon filter and a HEPA filter prior to discharge to the stack.

Office Area

The office portion of the facility will include offices, a reception area, lunch room, laboratory, decontamination room and locker room facilities. This section of the building will be separated from the operations area by a 12-inch-thick concrete block wall. The block will be filled with grout to increase its shielding capacity. The wall will also be sealed at the roof to minimize air from the operations area from infiltrating into the office area. Also, due to the nature of the operations performed in the decontamination room (i.e., emergency shower, etc.) and the laboratory, these rooms will have separate heating, ventilation and air conditioning (HVAC) units from the rest of the office areas.

Fire Protection

The entire facility, with the exception of the control room, decant room, vial breaker room and liquid waste storage room, will be protected with a

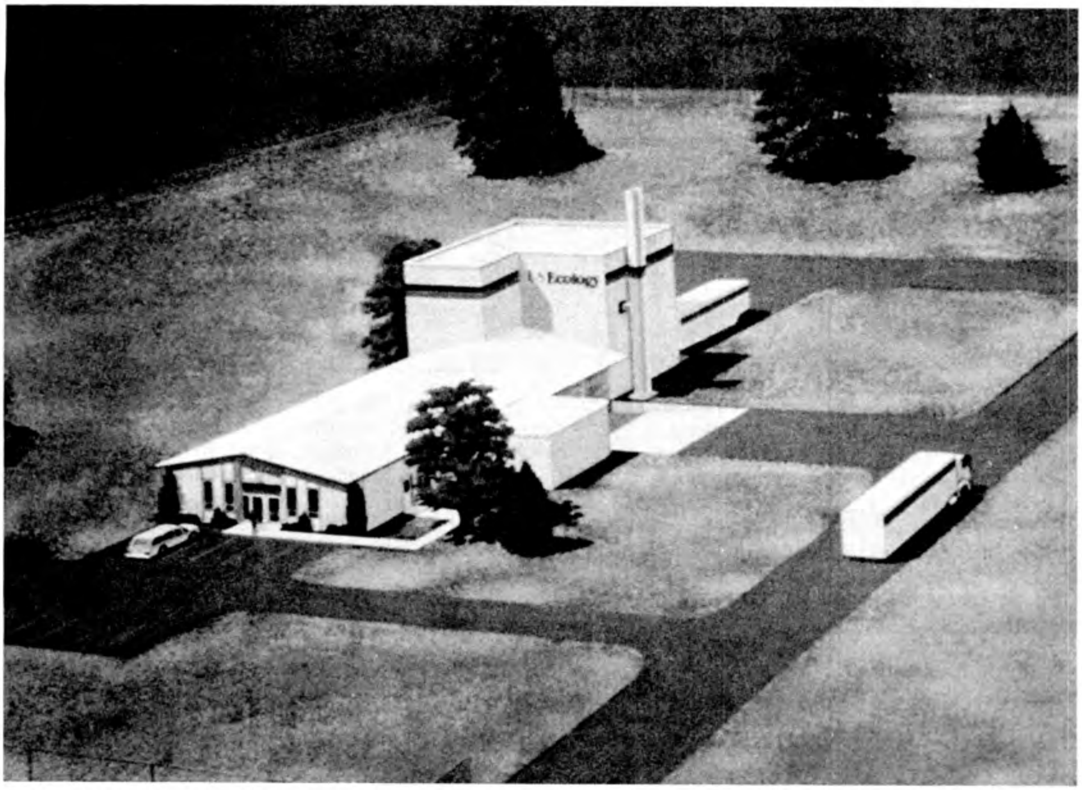

Fig. 1. Facility Layout.

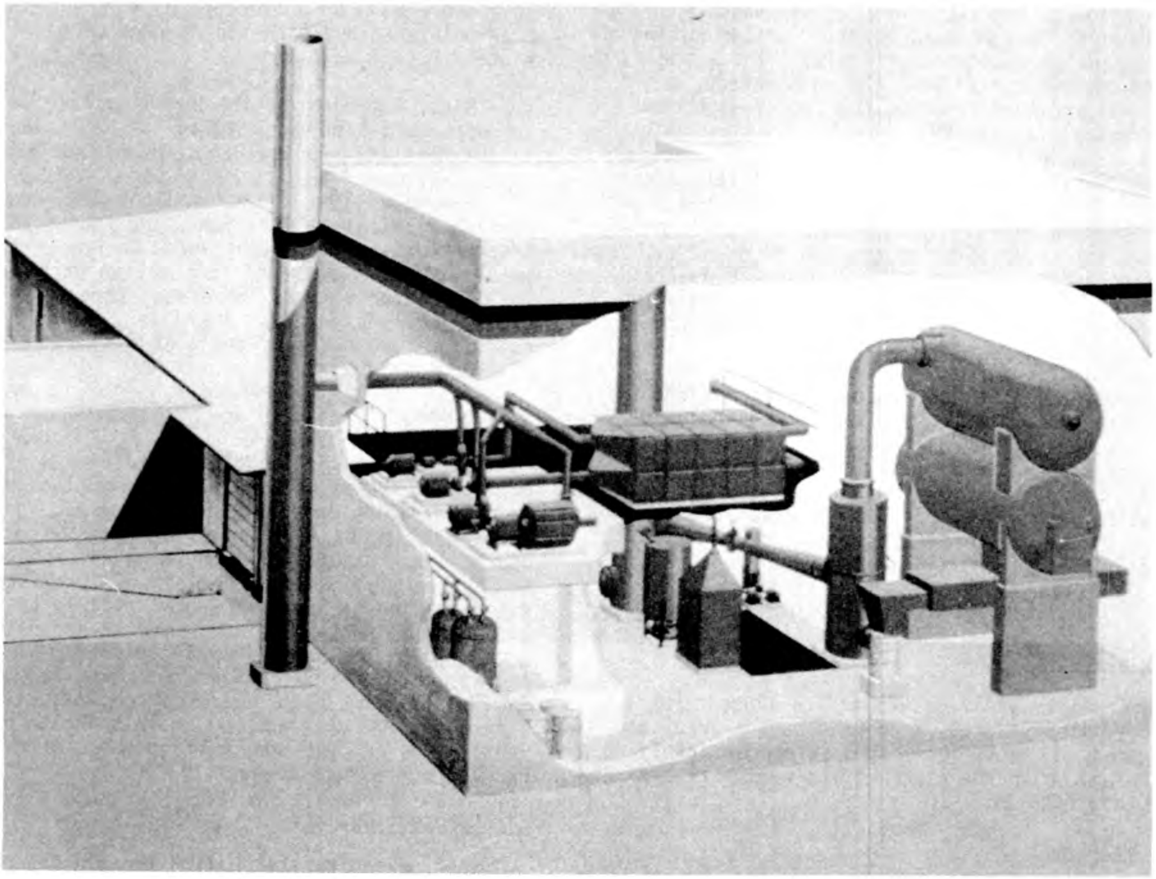

Fig. 2. Process Building Including Incinerator Pollution Control Equipment.

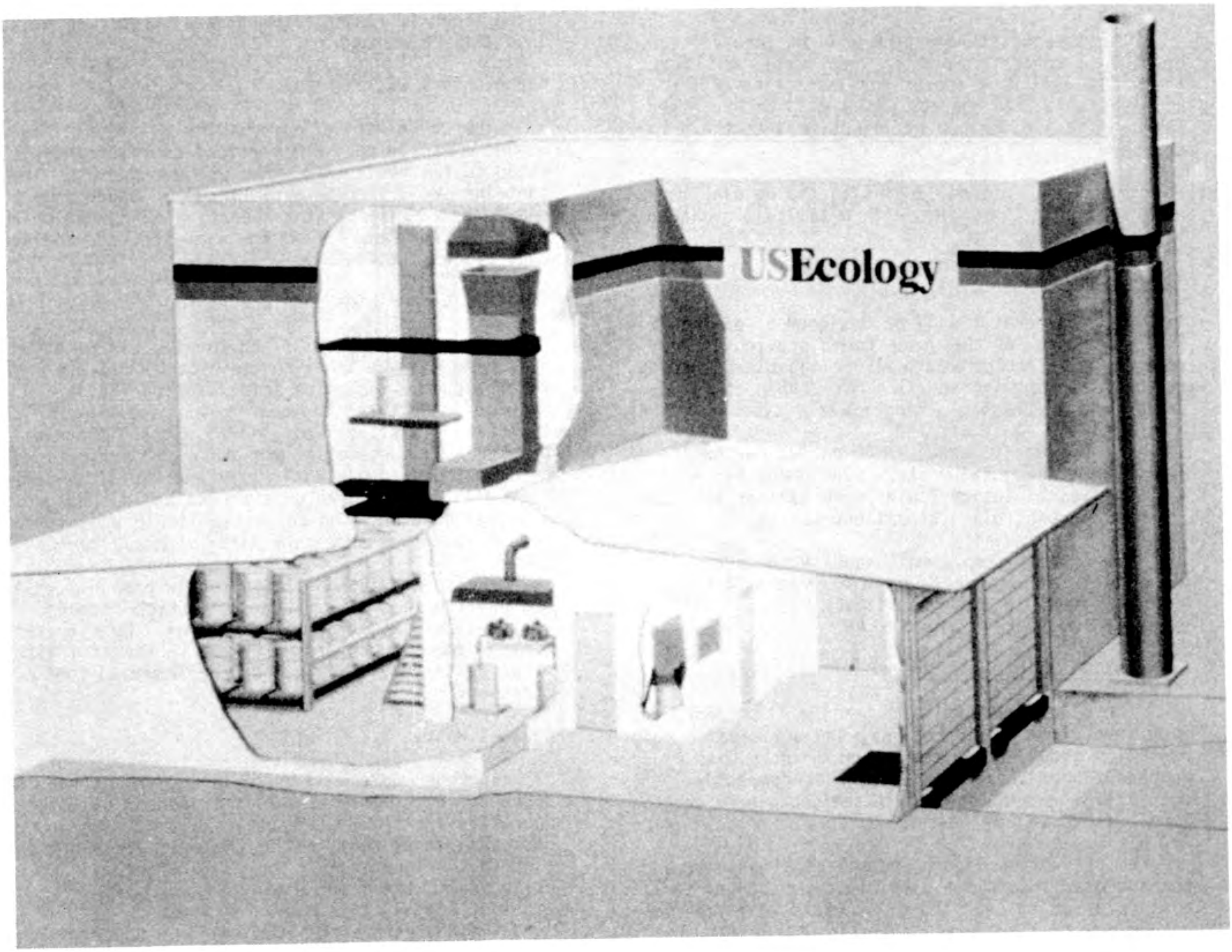

Fig. 3. Storage and Feed Preparation Area.

wet sprinkler system. The decant, vial breaker and liquids waste storage rooms will be protected by a Halon fire suppression system due to the flammable liquids that will be processed in these areas. The control room will be protected by manually operated portable units due to the disruptions that would occur should either one of the above systems discharge inadvertently.

Sewers and Drains

The emergency decontamination shower and sink, the laboratory sink, and all floor drains in the storage facility will drain to the storage tank located in the process building.

The aqueous storage tank will be located below grade in a concrete vault in the process building. The vault will have access for inspection of the holding tank. The aqueous waste will be processed through the incinerator by injection into the primary chamber.

Also, all external drains to the holding tank will be double lined pipe with a telltale drain for leak protection.

Incinerator Capacity

The incinerator will be designed to efficiently incinerate each of the waste forms previously described. The incinerator will be capable of operating at the following incineration rates when at full capacity and processing a single waste type.

a. Dry active waste - 600 pounds per hour
b. Pathological waste - 600 pounds per hour
c. Scintillation fluids - 40 gallons per hour
d. Turbine oil - 34 gallons per hour

The facility can simultaneously incinerate all waste types in any combination as long as the total heat released, including auxiliary heat, does not exceed 4.9 million BTU per hour.

Anticipated Volume Reduction

The volume reduction achieved will be dependent upon several factors. For DAW, the anticipated volume reduction should be in the range of 20:1; this will be dependent upon the initial degree of compaction, the volume of non-combustibles in the container, and the level of PVC in the waste.

Scintillation liquid, pathological wastes, and turbine oils should see a volume reduction of 99:1; this is assuming that the glass vials have been separated from the liquid scintillation materials which will require separate disposal off site.

Feed Systems

The incinerator facility will be designed to process the four waste types described previously: 1) DAW; 2) pathological; 3) scintillation fluids and turbine oil; and 4) aqueous waste. The facility will be able to incinerate all four waste types simultaneously. With the exception of the pathological waste, which must be manually fed, the charging will be automated (see Fig. 4 for the system flow diagram).

DAW Feed System

DAW will be received in fiber or polyethylene drums. The drums will be loaded by forktruck onto a drum storage conveyor with a total capacity to hold 60 drums. The storage conveyor will be two levels high with three lanes on each level. When a drum is loaded, the controller will advance the conveyor to provide adequate space for the next drum. As required, a vertical conveyor will stop at the appropriate storage conveyor level. A drum will then be fed from one of the six lanes onto the vertical conveyor. The drum will be transported to the shredder where it will be automatically fed into the shredder receiving hopper. The waste is shredded prior to charging to increase burning efficiency and minimize temperature fluctuations.

The shredded waste will discharge into the incinerator ram feeder. Upon a signal from the incinerator control system that additional waste can be introduced, the ram feeder automatically feeds the waste into the incinerator.

Pathological Waste

The containers of pathological waste will be loaded directly onto the vertical conveyor and elevated to the ram feeder intermediate opening. The container will then be automatically loaded into the ram feeder. The charging operation will then be automatically completed using the same sequence and safety controls as for the DAW.

Scintillation Fluids and Turbine Oil

Scintillation fluids and turbine oil received in bulk form will be taken to the decant room where they will be pumped out. The scintillation fluids and oils will be transferred to separate storage tanks. Scintillation vials received will be placed in a vial breaker. Once the vials are broken, the liquid will be discharged into a small tank and the glass particles will be collected on a screen and discharged into a 55-gallon drum. The collected liquid will then be pumped to the storage tank using a decant pump.

The scintillation fluids and turbine oil will be incinerated in the secondary combustion chamber. Flow of the liquids to the incinerator will be temperature controlled. These fluids will be incinerated with other waste types to minimize supplemental fuel consumption.

Aqueous Waste

Aqueous waste will be collected from three major sources: 1) floor drains in the process building and operation areas; 2) the safety shower drains in the decontamination room; and 3) the contaminated wash sink in the laboratory. The waste water will be collected in the floor drain tank.

The contents of the tank will be pumped to the incinerator and injected into the ignition chamber where the liquid will be evaporated.

Incineration

Ignition Chamber

The DAW and pathological waste charged into the ignition chamber is burned at less than stoichiometric conditions for a sufficient time to reduce it to mixture of ash and non-combustible materials. The underfire air system provides combustion air to the ignition chamber. It consists of a fan, a control valve, and air distribution to underfire air ports located along both sides of the hearth. This air entering at the base of the burning bed promotes complete and reliable incineration. The air flow rate is controlled based on the temperature in the ignition chamber in order to promote the most efficient burning

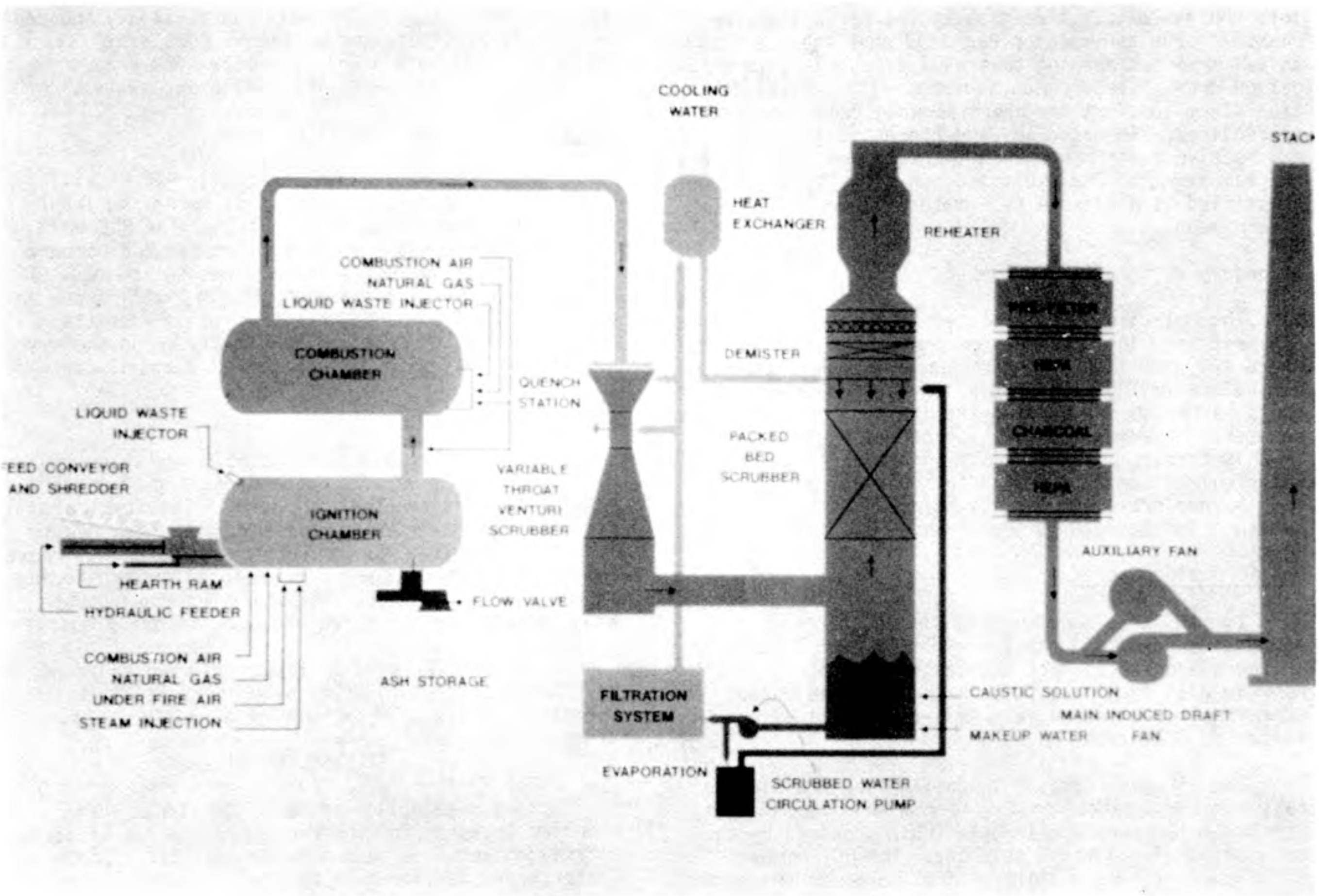

Fig. 4. System Schematic Diagram.

with the temperature limitations of the incinerator. The ignition burner is also controlled based on the temperature in the ignition chamber. After the chamber has been preheated and the first waste has been charged and ignited, the ignition burner shuts down and comes back on only when the waste burning in the ignition chamber has insufficient BTU value to maintain the temperature.

The ash will be removed from the incinerator with a hearth ram. The hearth ram is placed in the floor of the ignition chamber below the ram feeder and it has the capacity to stroke the full length of the hearth. The hearth ram is actuated to push the ash into the ash drop out opening at the far end of the chamber. The ash ejector ram will push the ash into an ash drop out opening that will discharge into a 55-gallon drum. The drum is equipped with a level detection alarm to alert the operator when drum change-out is required. The ash rams are hydraulically operated and receive their power from the same unit that powers the ram feeder. The estimated ash activity should be classified as a Class A type material per 10 CFR 61 requirements.

Secondary or Combustion Chamber

The volatile gases produced in the ignition chamber pass into the secondary or combustion chamber where they are completely oxidized. Secondary air equivalent to 100% excess air is introduced through ports in the throat between the ignition and secondary chambers. The main burner, located at the discharge of this throat, provides additional heat to maintain the required temperature. Both secondary air and the main burner are controlled to maintain a stable temperature in the secondary chamber.

Wet Scrubbing System

Immediately downstream of the incinerator, the combustion gases will be lowered from 1800^{o}F to 172^{o}F in the quench section of the venturi scrubber. The off-gas will then pass through the variable throat venturi scrubber where extremely fine particulate matter will be removed.

The off-gas from the venturi scrubber will then pass through a packed column to remove mineral acids, particularly hydrochloric acid (HCl) produced by the combustion of polyvinyl chloride. The HCl removal efficiency will be a minimum of 99% down to one part per million by volume. The packed column will be equipped with a demister to minimize liquid carryover.

The salt concentration level in the scrubbing solution will be controlled with a density meter. The turbidity of the solution will also be monitored to minimize particulate build-up.

The scrubbing solution pH will be maintained by the addition of sodium hydroxide. The addition will be automatically controlled by a pH meter. The sodium chloride generated by the reaction between the HCl and sodium hydroxide will be controlled by blowdown of the scrubber solution. The same scrubbing solution will be used in the quench, venturi scrubber, and the packed column. Ash particles, larger than 100 micron, in the scrubbing solution will be removed by cartridge filters. The heat will be removed from the scrubbing solution with a tube and shell heat exchanger and by makeup water.

The blowdown will be pumped to a 55 gallon 17H drum. The liquid portion of the blowdown will be evaporated using 35 kW drum heaters. The evaporated water will be discharged to the scrubbing system.

Final Filtration

The off-gas from the packed column will pass through a final dry filter system prior to discharge. The temperature of the saturated off-gas will be raised by 30^{o}F to prevent condensation inside the filter assembly. The filter assembly will consist of a prefilter, HEPA filter, two stage carbon filters and a HEPA filter. Each HEPA filter has a 99.97% particulate removal efficiency for particulate larger than .3 microns.

Stack

The exhaust from the main and auxiliary induced draft fans passes to and up the 55 foot metal stack. The stack will have a velocity meter and probes for the continuous radioactivity monitoring system.

Programmable Logic Controller

The programmable logic controller (PLC) will monitor the incinerator process by receiving input from instruments shown on the P&IDs. The PLC will continually check the process parameter and compare these readings against predetermined set points. If these set points are exceeded, the PLC will issue an alarm and take a course of action to correct the process deviation or to automatically bring the system off-stream in a safe and controlled manner.

Stack Monitor

The facility will have a continuous stack monitoring system for simultaneous measuring of gross beta/gamma particulates and iodine. This system will be continuous duty, high capacity, with both remote and local alarms. The incinerator operator will have full readout in the control room to allow monitoring of the stack discharge. The stack monitoring data will be fed into a recorder to log the daily outputs.

A gas sampler will be installed downstream of the continuous sampler to allow site personnel to batch the stack. This will be done on a routine basis.

SITE SELECTION

With the selection of North Carolina as the proposed location for the facility, the job of identifying an actual site was begun. A list of site criteria was developed to be used in ranking general areas and individual sites. This turned out to be one of the more difficult problems to resolve and has resulted in extensive delays in the overall project schedule. There is no such thing as the "ideal" site.

Two sites were finally selected, and in June, 1984 US Ecology made a public announcement that it was proposing to site a LLRW incinerator in North Carolina. Although extensive conversations had been held on both the state and local level, this was the first public announcement. This same month, US Ecology submitted its permit application for a radioactive materials license to the North Carolina Department of Human Resources. The site identified is in rural Bladen County, off I-95 just south of Fayetteville, North Carolina.

PRESENT PROJECT STATUS

Since making the announcement, US Ecology personnel have been active on both the state and local levels attempting to educate the public concerning the project. The problem of alleviating the public's fears concerning radiation and controlling the rumors and exaggerations within the county has become acute. This problem must be solved through education by both US Ecology and the State.

The public's fears, though unwarranted, concerns the impact that this facility will have on the community both economically and personally. The facility will not have a great enough economic impact upon the community for them to accept the perceived risk associated with its location. Their main concerns deal with accidents from transportation, exposure to individuals from the stack discharge, radioactive isotope accumulation in their crops, devaluation of the property surrounding the facility and overall contamination of their environment. The stack dose model shows that a child who spends his entire time living, eating and drinking at the site boundary will be less than 2% of the allowed dose rate under 10 CFR 20 for an individual in an unrestricted area.

USE has responded to the second round of questions from the state of North Carolina. The project engineering is presently on hold awaiting the outcome of the state's permit review.