RADIOACTIVE WASTE INCINERATION

David Dalton
Science Applications International Corporation
Idaho Falls, Idaho

ASME RW Systems Committee Radwaste Short Course - 1991

THE BENEFITS OF RADIOACTIVE WASTE INCINERATION ARE:

- Volume Reduction
- Improved Disposal Form
- Toxic Organic Destruction (if Present)

COMBUSTION REACTIONS:

WASTE	+	***AIR*** ------›	***FLUE GAS***	+	***RESIDUE***
-Carbon		-Oxygen	-Oxygen		-Hearth Ash
-Hydrogen		-Nitrogen	-Nitrogen		-Flyash
-Oxygen			-Carbon Dioxide		-Scrubber Brine
-Sulfur			-Water Vapor		
-Chlorine			-Sulfur Oxides		
-Metals			-Nitrogen Oxides		effluent
			-Hydrochloric Acid		
			-Carbon Monoxide		
			-Products of Incomplete Combustion		

IMPROVED DISPOSAL FORM

- Residue is not subject to biological decay
- Residue can be physically and/or chemically stabilized by compaction, solidification, epoxy encapsulation, vitrification, disposing in a HIC, etc.

MATERIALS THAT CAN BE INCINERATED

- Textiles
- Paper
- Wood
- Oil
- Plastics
- Resins
- Sewage
- Animal Wastes

IDEAL INCINERATOR SYSTEM

Waste ---»

Fuel -----»

Air-------»

INCINERATOR CHARACTERISTICS

-Long Residence Time

-Complete Mixing of Air and Combustibles

-Large Equipment

-Low Heat Losses

-Easy Controlled Temp and Pressure

-Low Maintenance

OFF-GAS

------------»

OFF-GAS SYSTEM CHARACTERISTICS

-Low Maintenance

-High Particulate Removal Efficiency

-High Acid Gas Removed Efficiently

-Long Life

ASH ↓

ASH CHARACTERISTICS

-Low Unburned Carbon

-Minimum Volume

-No Clinkers

-Minimum Airborne Fines

OFF-GAS ↓

OFF-GAS CHARACTERISTICS

-Minimum CO

-Minimum Particulate

-Minimum Acid Gases

-Minimum Products of Incomplete Combustion

INCINERATOR TYPES

STANDARD DESIGNS

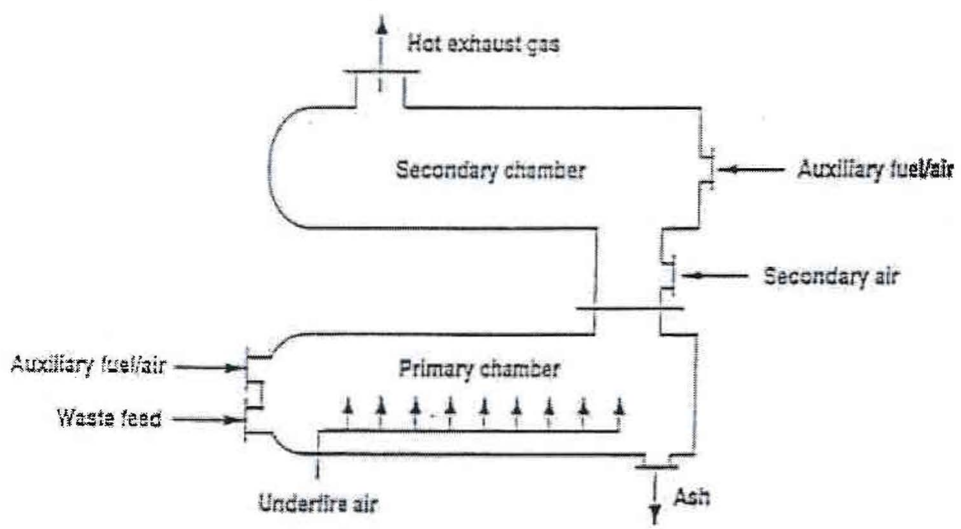
- Controlled Air
- Excess Air
- Rotary Kiln
- Fluidized Bed
- Vertical Shaft
- Multiple Hearth

NON-STANDARD DESIGNS

- Microwave
- Molten Glass
- Molten Salt
- Plasma Cyclonic
- Electric Infrared

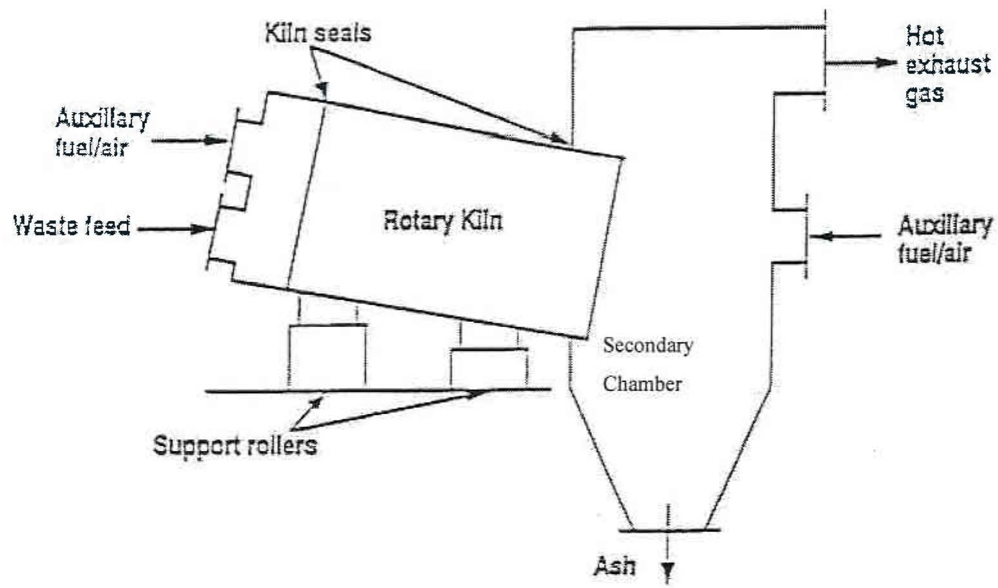
Controlled Air Incinerator

A controlled air incinerator is the name often used for the stationary hearth class of incinerator. This type of incinerator is usually designed as a two-stage combustion process with some systems using three chambers. Radioactively contaminated waste is fed into the primary chamber and burned at roughly 30 to 50 % of the stoichiometric air requirement (starved air condition). This pyrolizes the waste, thus emitting a volatile fraction with the required heat supplied by partial combustion and oxidation of the fixed carbon. The resultant smoke and pyrolytic products, consisting primarily of volatile hydrocarbons and carbon monoxide along with some combustion products, which pass to the secondary chamber. Excess air is provided in the secondary changer to assure complete combustion. Liquid waste can be incinerated in either the primary or secondary chambers.



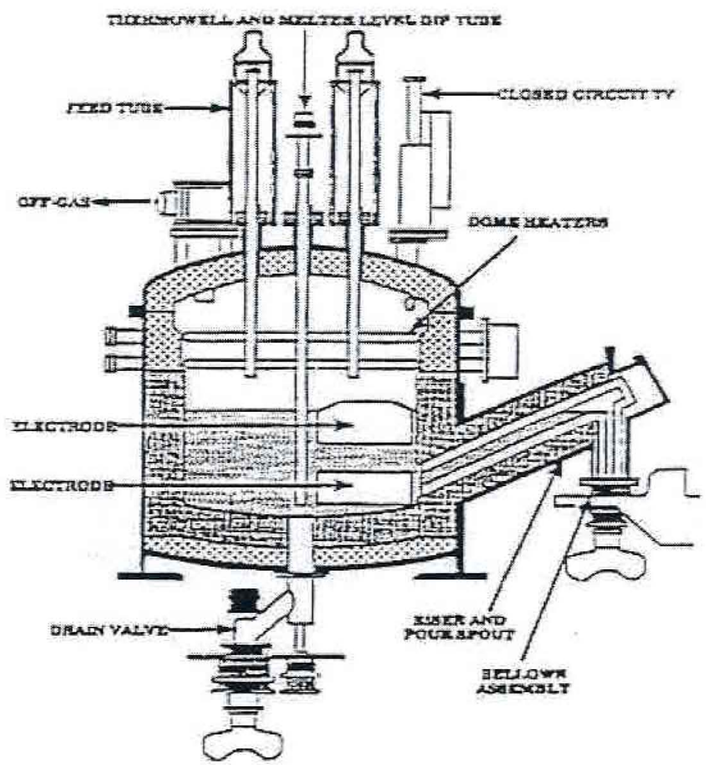
Rotary Kiln Incinerator

The rotary kiln is a cylindrical refractory-lined shell mounted on a slight incline. The rotation and incline of the kiln provide for movement of waste through the kiln as well as for enhancement of radioactivley contaminated waste mixing. Rotary kilns normally require a secondary combustion chamber to assure complete destruction of hazardous constituents. The primary chamber functions to pyrolyze or combust solid waste to gases. The gas-phase combustion reaction is completed in the secondary chamber. Both primary and secondary chambers are generally supplied with auxiliary fuel systems. An extensive offgas system is generally required to control the high volume of emissions.



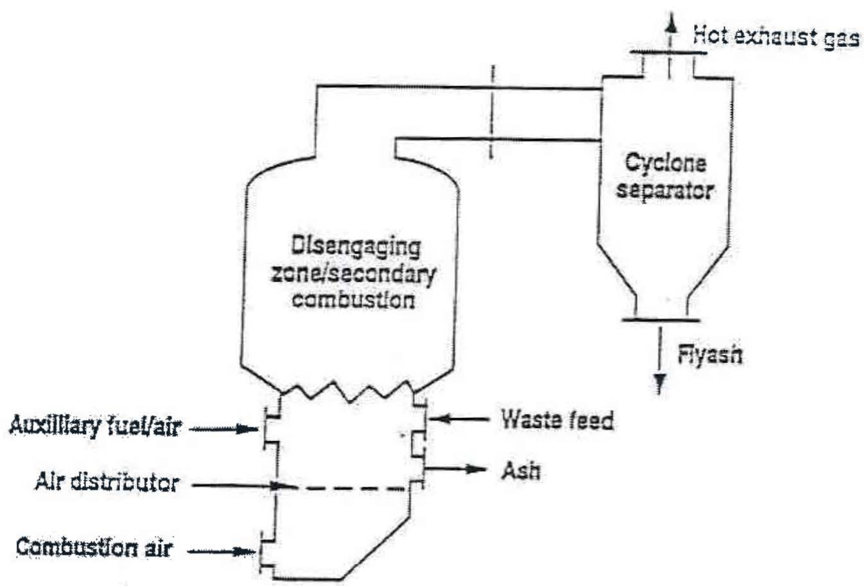
Liquid Fed Ceramic Melter

A special application of glass furnace technology developed by the DOE for conversion of high-level liquid commercial and defense wastes to borosilicate glass. Radioactively contaminated waste slurries are prepared by blending liquid wastes and glass-forming chemicals which are fed to the melter cavity. The melter cavity is refractory lined and contains an overflow system which discharges molten waste to steel canisters. Temperatures in the 2000° - 2200° F range are maintained by joule heating which occurs when an alternating current is passed between electrodes in contact with the molten glass in the melter cavity.



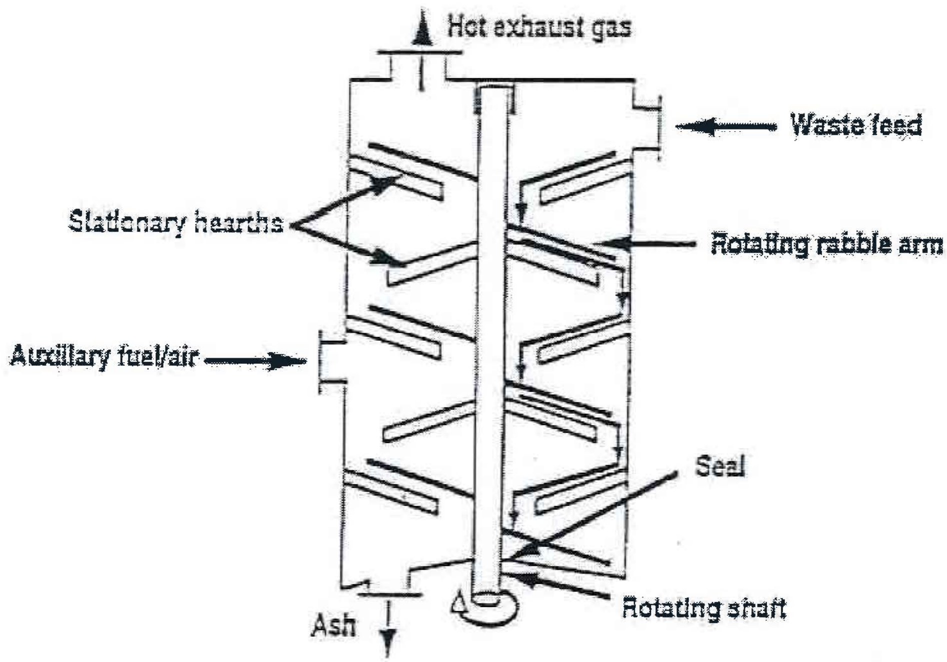
Fluidized Bed Incinerator

A Fluidized Bed Incinerator is comprised of a vertical refractory lined vessel containing a bed of an inert material. The bed is "fluidized" by passing air, which serves as combustion air, through a perforated air distribution plate at the bottom of the vessel. Radioactively contaminated waste is fed to the hot bed for combustion, where the high thermal mass and turbulent mixing action of the bed material rapidly transfers heat to the waste. Auxiliary fuel is often used to maintain bed temperature. A secondary chamber may be required to ensure complete combustion for hazardous wastes. Limestone is usually added to the bed to provide in-bed acid gas scrubbing capability (no scrubber required). A cyclone separator is often required in the off-gas system to help handle the higher generation of particulates. A variation of fluidized bed technology is a circulating bed system, where higher air velocities cause high carryover rates. The carryover material is recovered and returned to the system.



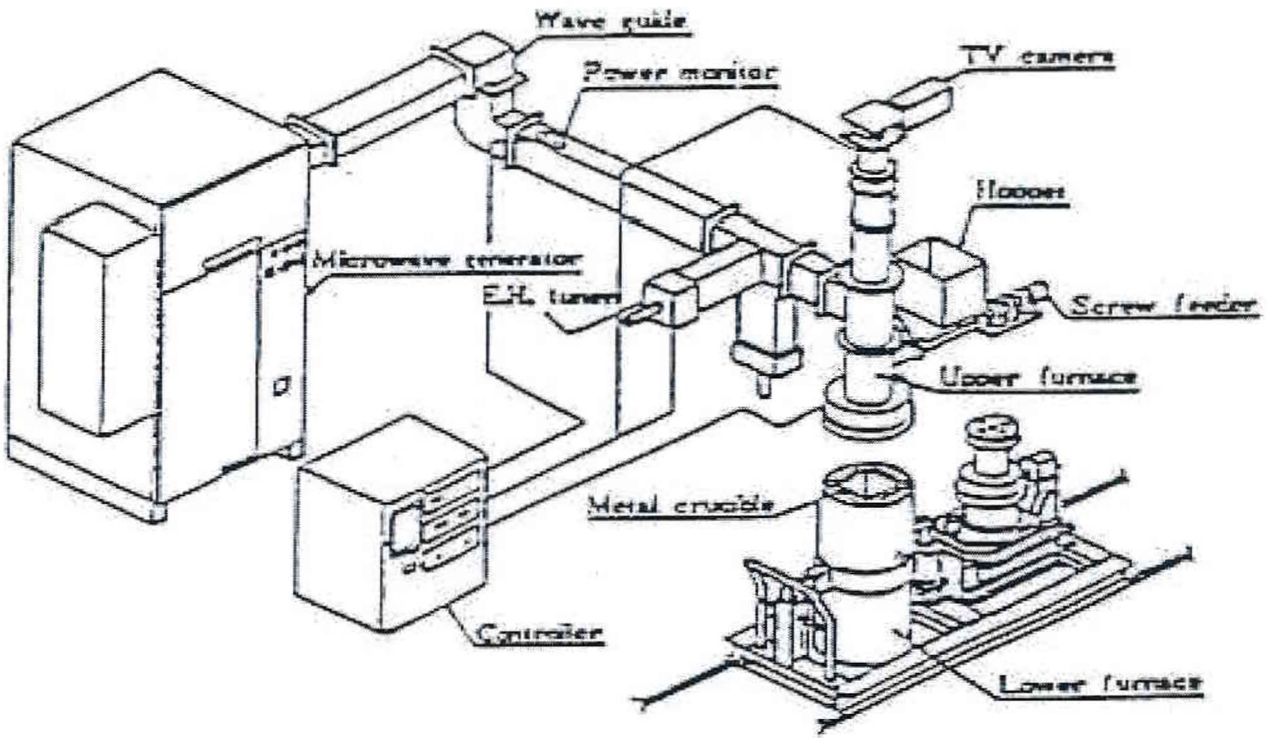
Multiple Hearth Incinerator

A multiple-hearth incinerator consists of a refractory-lined steel shell with a series of circular hearths arranged in a vertical design. A series of rotating, air-cooled rabble arms convey the solid waste from upper to lower hearths. As the radioactively contaminated waste is conveyed down through the incinerator, the successive hearths are used for drying, heating, combustion, burnout, and cooling of the radioactivley contaminated waste. Fuel burners are mounted on the side of the vessel in the hearths where combustion and burnout occur. These burners can be used for high heat value hazardous liquid if desired. A secondary chamber may be required for complete destruction of hazardous wastes. This type of incinerator has been used principally for sludges, tars, or other low hear value solids requiring long solids retention times, and has been commonly used for disposal of de-watered activated waste-water treatment sludges.



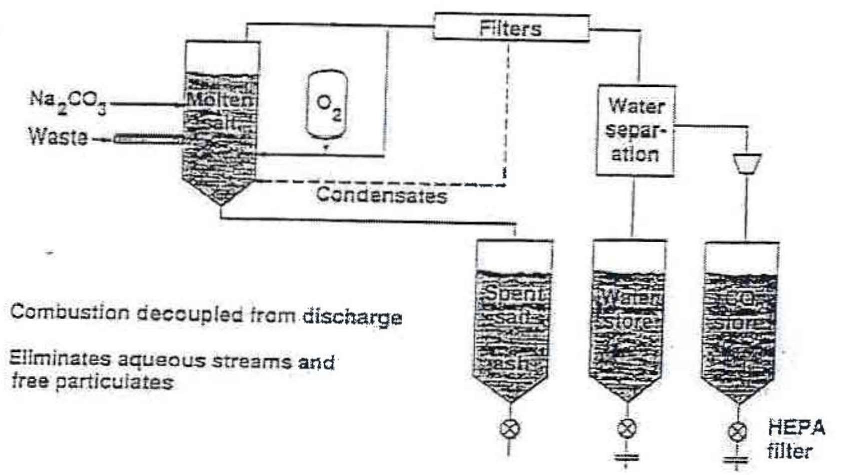
Microwave Melter

This process utilizes microwave energy for in-container solidification/stabilization of radioactively contaminated non-organic wastes such as incinerator ash, sludges, or soils, Waste moisture is removed in a belt-driven microwave dryer prior to treatment. The dry waste materials are vitrified inside a metal disposal container in either a batch or continuous feed mode. Melt temperatures range from 1800-2600 F and the resulting product is a glassy monolith that meets radioactive disposal criteria for liquid, particulate content and RCRA LDR requirements for leaching of toxic hazardous constituents. The process results in volume reductions on the order of 80% with waste-to-glass loading on the order of 60%.

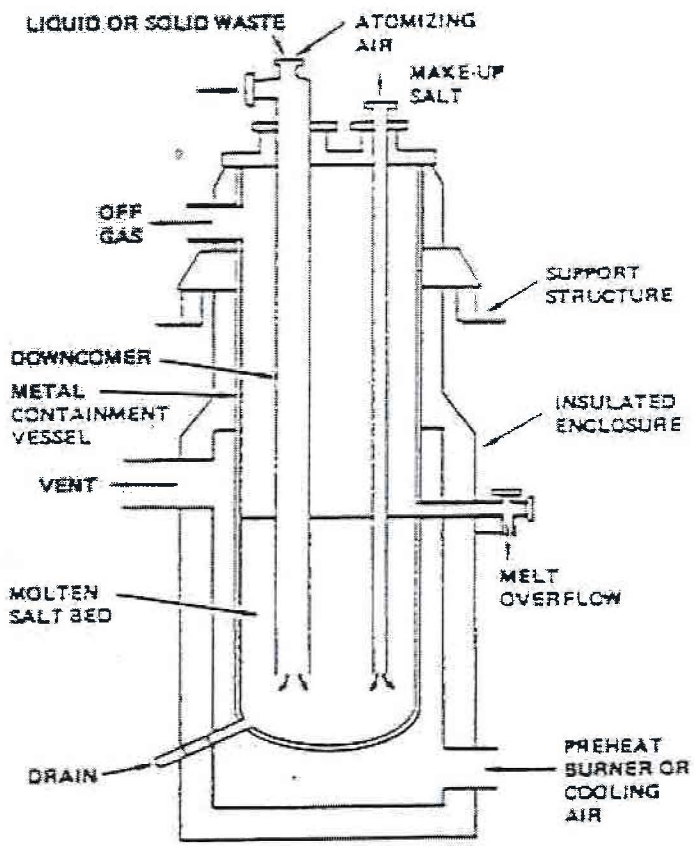


Molten Salt Furnace

In the molten salt (MS) process, waste and air are continuously introduced beneath the surface of a sodium carbonate (Na2CO3) melt at a temperature of 750 to 1000 C. Supplemental fuel may be required to be added to the radioactively contaminated waste, if the stand alone waste stream is not sufficiently combustible. Rapid destruction of the waste results from the catalytic effect of the salt, and from the intimate contact of the waste with air and the hot molten salt, which provides rapid transfer of heat to the waste. The molten salt forms chemical complexes with toxic metals and radionuclides to retain them in the salt. Sodium carbonate is used because it prevents emissions of acidic gasses, such as HCI (ordinarily produced from organic chloride compounds) and SO2 (from organic sulfur compounds). Also, it is stable, nonvolatile, inexpensive, and nontoxic. The carbon and hydrogen in the waste are converted to CO2 and steam; halogens form corresponding sodium halide salts; phosphorus, sulfur, arsenic, and silcon (from glass or ash in waste) form oxygenated salts; and the iron from metals forms iron oxides. The ash is trapped in the melt. The melt is removed periodically or batch-wise to prevent exsessive build-up of halide salts or ash. If required, the melt can be immobilized prior to disposal in the appropriate burial facility.

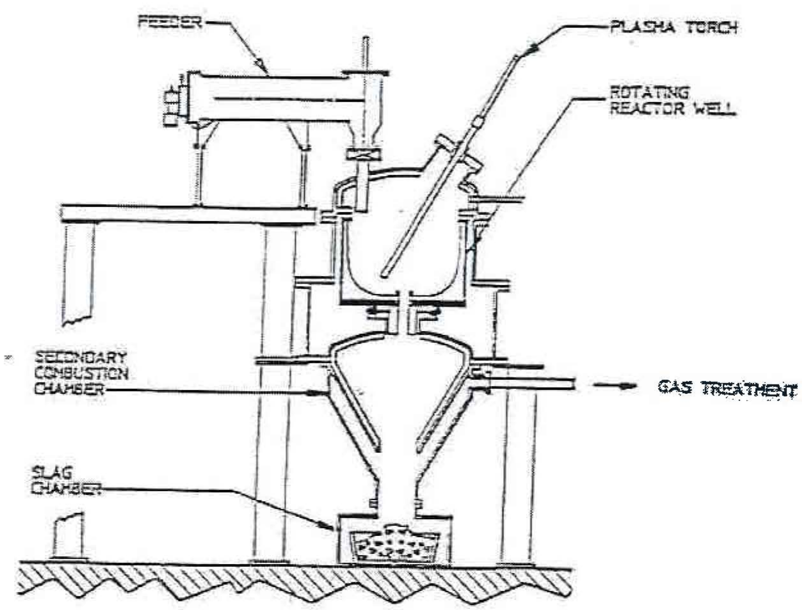


Molten Salt Furnace



Plasma Centrifugal Reactor

The Plasma Centrifugal Reactor (PCR) uses heat from a plasma arc torch to assist the radioactively contaminated waste incineration process. The additional energy allows melting of the inert components to produce a solid vitrified product. The PCR is a two-chamber incinerator that operates semi-continuously. Waste material is fed to a rotating primary chamber where sub-stoichiometric operation results in pyrolysis of the organic fraction. The plasma arc discharges in the primary chamber melts the inert fraction of the waste, and rotation at 50rpm forces the liquid slag toward the outer walls. Gaseous products are fully combusted in a secondary combustion chamber. The use of an air plasma and pure oxygen for combustion results in very low offgas volumes. After feeding approximately 1000 lbs of inert material, the primary chamber rotation speed is decreased; the molten slag flows to the center of the chamber; the slag pours through a hole in the center of the primary chamber, falls through the secondary chamber, and is collected in a mold below the secondary chamber.



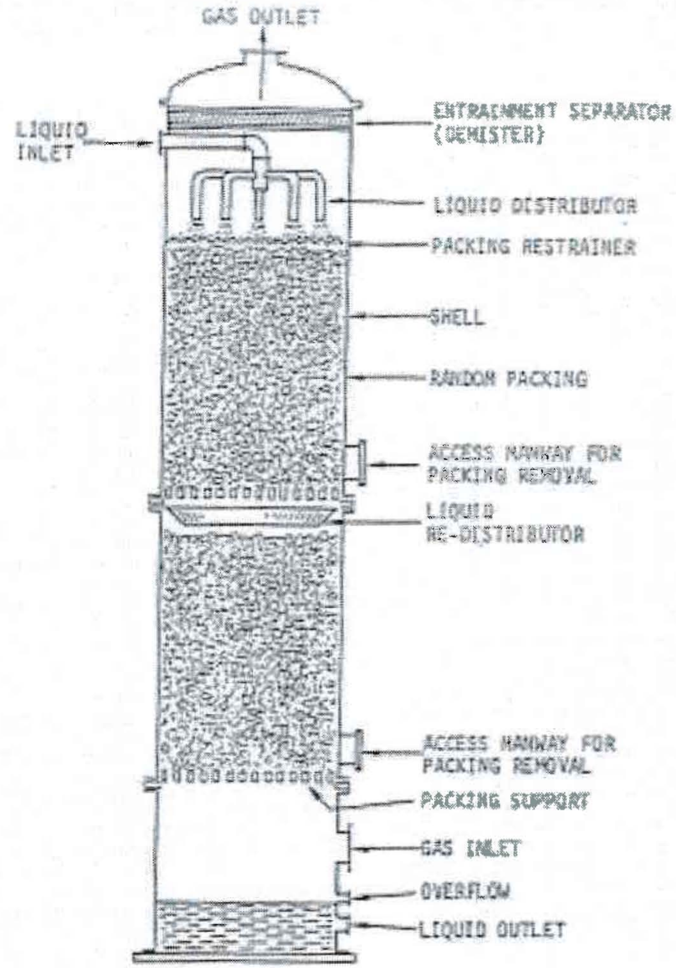
CHARACTERISTIC

- Stoichiometric vs. Excess Air
- Batch vs. Continuous
- Method of Ash Transport

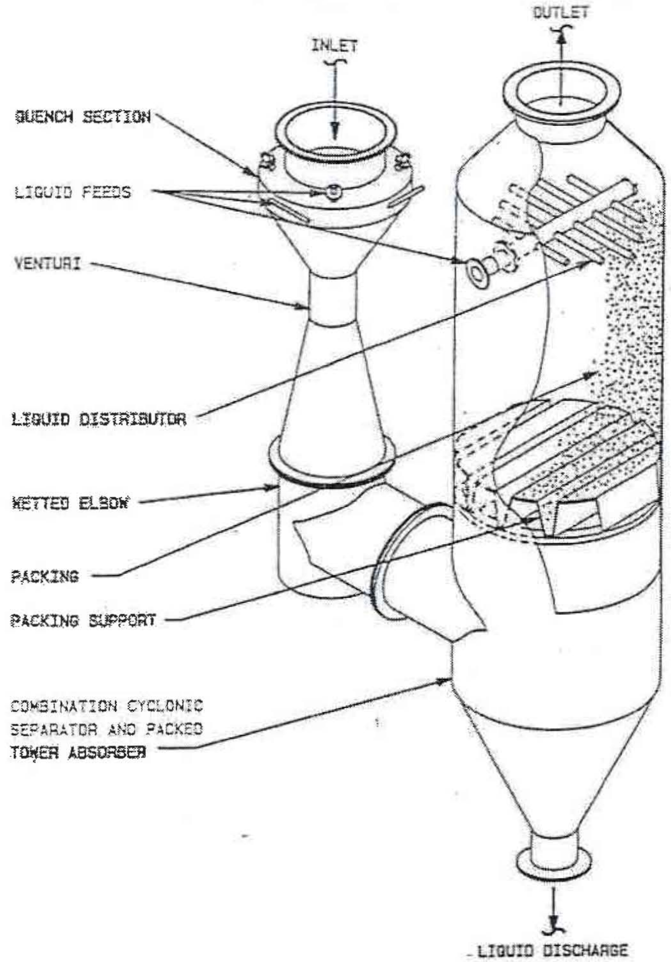
OFF-GAS SYSTEMS ARE GENERALLY CATERGAORIZED AS "WET" OR "DRY"

AIR POLLUTION CONTROL EQUIPMENT

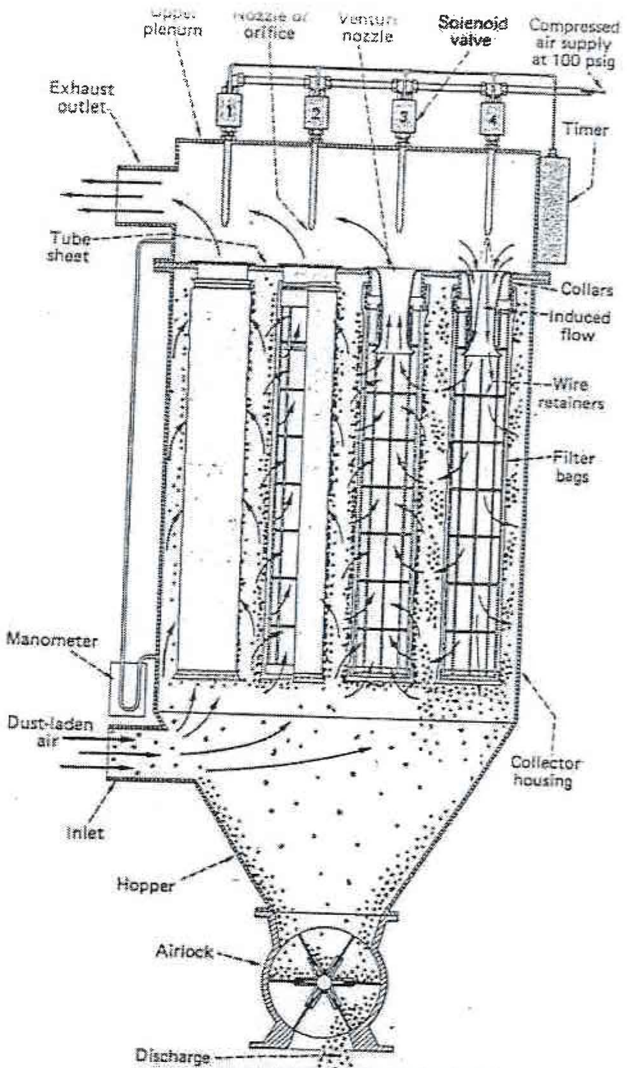
WET COMPONENTS	***DRY COMPONENTS***	***WET OR DRY COMPONENTS***
-Ionizing Wet Scrubber	-Absorber	-Cyclone
-Packed Tower Scrubber	-Baghouse	-Electrostatic Precipitator
-Plate Column Absorber	-Ceramic Filters	
-Spray Dryer Absorber	-Dry Caustic Injection	
-Venturi Scrubber	-Hepa Filters	



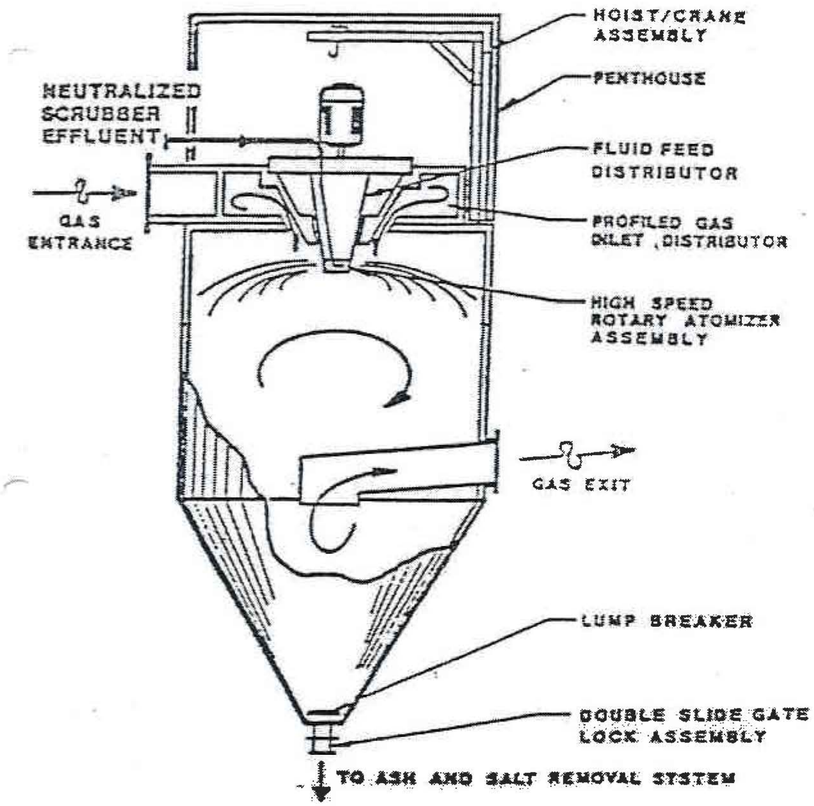
PACKED TOWER SCRUBBER



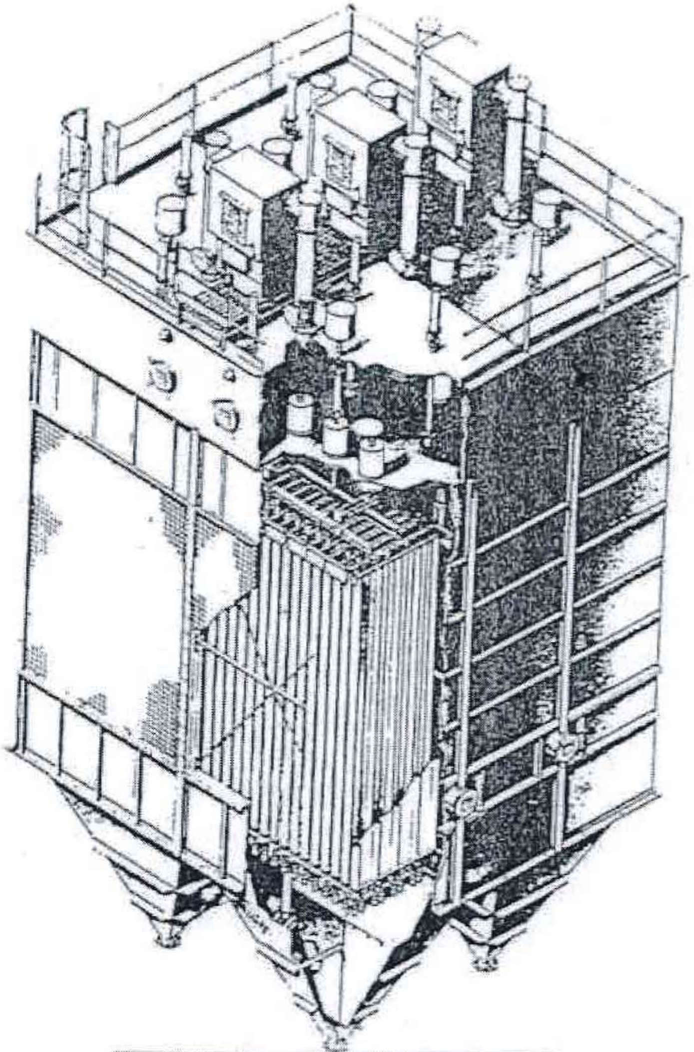
VENTURI SCRUBBER AND PACKED TOWER COMBINATION



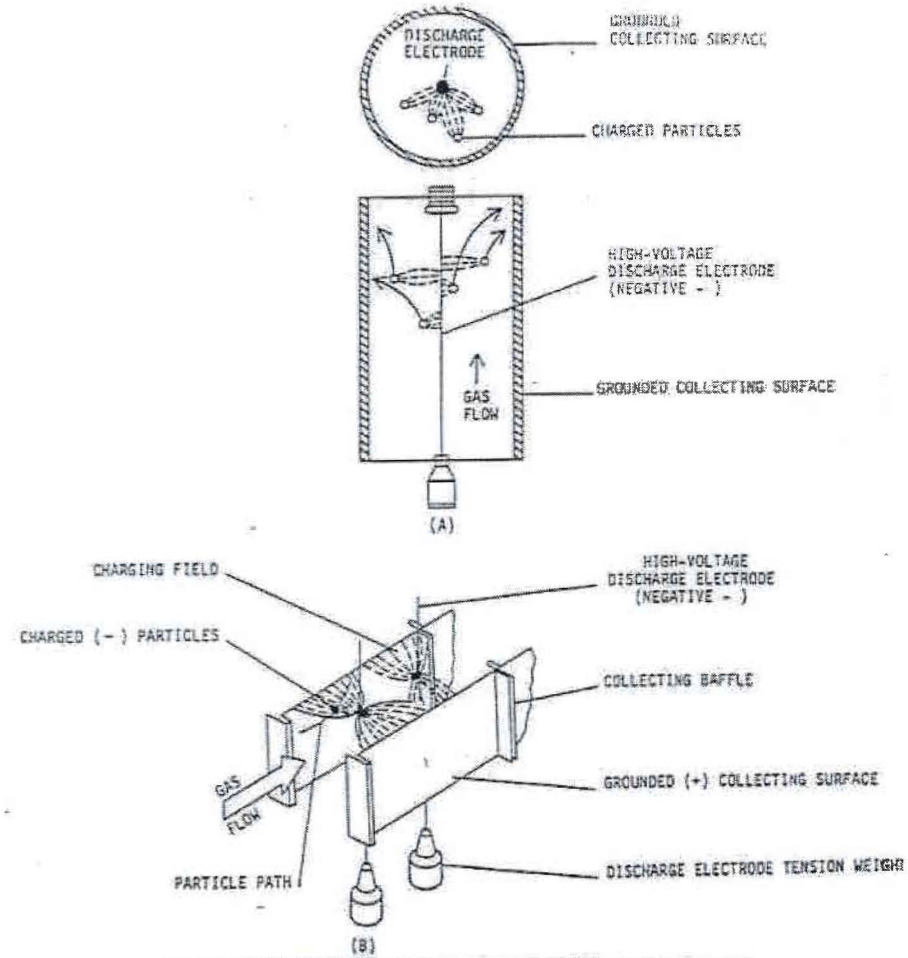
BAGHOUSE



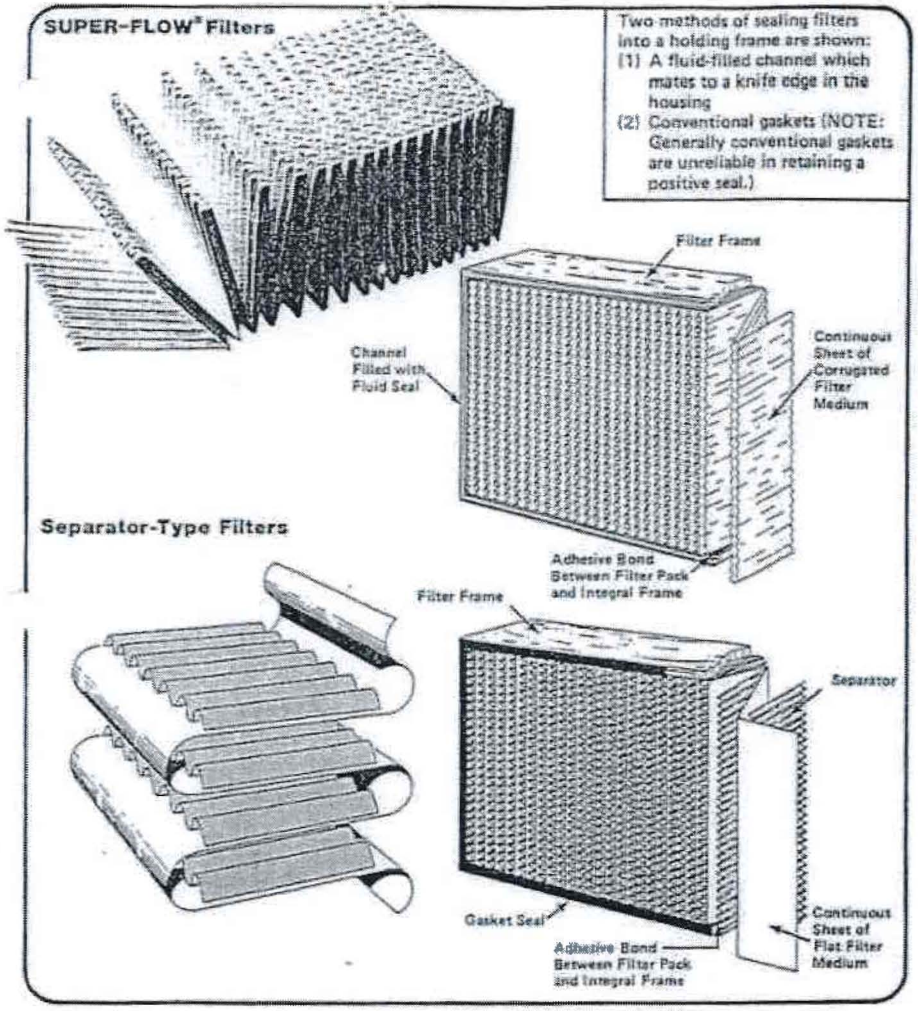
SPRAY DRYER ABSORBER



ELECTROSTATIC PRECIPITATOR

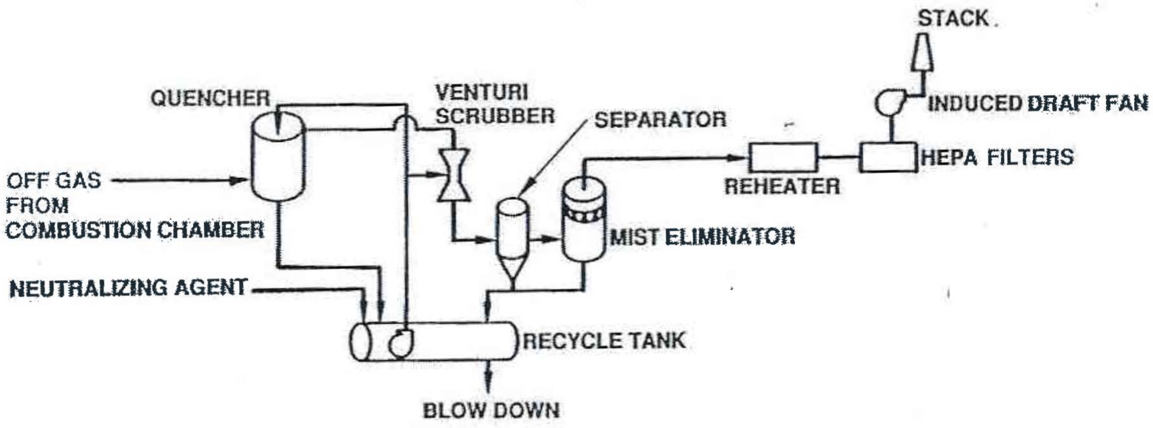


ELECTROSTATIC PRECIPITATOR ELECTRODES
(A) TUBE ELECTRODE
(B) PLATE ELECTRODE

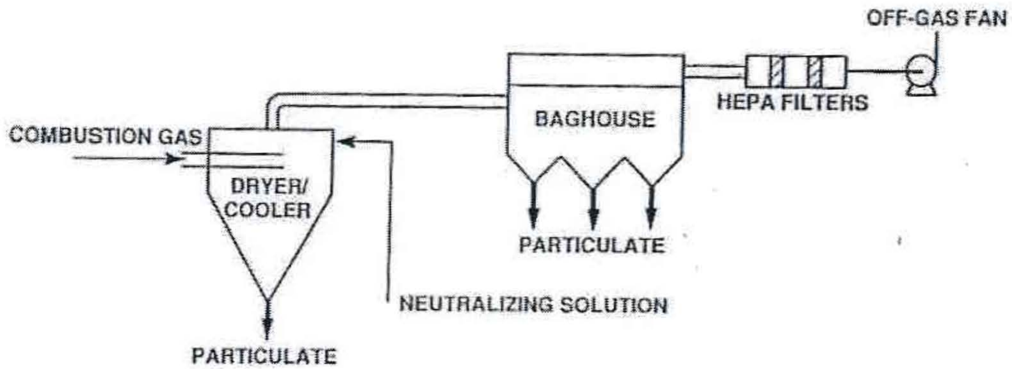

SUPER-FLOW® Filters
Two methods of sealing filters into a holding frame are shown:
(1) A fluid-filled channel which mates to a knife edge in the housing
(2) Conventional gaskets (NOTE: Generally conventional gaskets are unreliable in retaining a positive seal.)
Filter Frame
Channel Filled with Fluid Seal
Continuous Sheet of Corrugated Filter Medium
Adhesive Bond Between Filter Pack and Integral Frame
Separator-Type Filters
Filter Frame
Separator
Gasket Seal
Adhesive Bond Between Filter Pack and Integral Frame
Continuous Sheet of Flat Filter Medium

HEPA FILTER

WET OFF-GAS SYSTEM FLOW SCHEMATIC



DRY OFF-GAS SYSTEM FLOW SCHEMATIC



Unique Aspects of Radioactive Waste Incineration

A) WASTE ACCEPTANCE CRITERIA

-Size and/or Weight Limits

-Radionuclide Activity Limits (concentrated in ash)

-Types of Materials

-Limit the Amount of Halogens and Sulfur to Protect Materials of Construction and to Minimize Salt Generation which Reduces Volume Reduction

•

Unique Aspects of Radioactive Waste Incineration (con't.)

B) WASTE TRACKING

C) WASTE TRANPORTATION

D) WASTE STORAGE

E) WASTE FEEDING

-Prepare Waste by Sorting or shredding
-Examine Waste Using Metal Detectors
-Waste is Fed to Incinerator Through an Air Lock

Unique Aspects of Radioactive Waste Incineration (con't.)

F) INCINERATOR OPERATION AND MAINTENANCE

- -Redundant Instruments for Critical Measurements
- -Larger Vacuum to Prevent Contamination of Surrounding Facility
- -Airborne Contamination in Refractory
- -Fixation of Contamination Concerns when System is Breached
- -Higher Operation and Maintenance Costs

G) ASH PROCESSING

- -Ash Removal Requires Air Locks
- -Radionuclides Concentrated in the Ash May Result in a Class B Waste Even Though the Waste Fed to the Incinerator was Class A
- -Metals Concentrated in the Ash may Result in a Mixed Waste and Require Processing such as Cement Solidification or Vitrification to Render the Ash non hazardous
- -Ash may be Processed to Recover Uranium or Plutonium

•

Unique Aspects of Radioactive Waste Incineration (con't.)

H) AIR POLLUTION CONTROL

- -Highest Possible level of Particulate Removal Required
- -Gaseous Radionuclide Pollutants, Which are not Easily Scrubbed or Filtered, such as H-3 (in the form of Tritiated Water), C-14 (in the form of Carbon Dioxide), and Radionuclides (in the form of Organic Iodines and Elemental Iodine)
- -Particulate Removal from Equipment Requires Air Locks
- -Residuals may be a Mixed Waste and Require Further Processing such as Cement Solidification or Vitrification
- -Liquid Residuals must be Treated by Evaporation, Solidification or Vitrification
- -Extensive Emissions Monitoring

References:

1) BRUNNER, CALVIN, R., "INCINERATION SYSTEMS SELECTION AND DESIGN, "VAN NOSTRAND REINHOLD CO., NEW YORK, NY.
2) THEODORE, LOUIS, AND REYNOLDS, JOSEPH, "INTRODUCTIN TO HAZARDOUS WASTE INCINERATION," JOHN WILIEY AND SONS, NEW YORK, NY.
3) ANDERSEN 2000 INC., PEACHTREE CITY, GEORGIA, BULLETIN TR-89-900239, FEB. 1989.
4) STEVENSON, MALONE, THE 1989 INCINERATION CONFERENCE, INCINERATION BASICS COURSE NOTES, SPONSORED BY THE UNIV. CALIF AT IRVINE.
5) FLANDERS FILTERS, INC., WASHINGTON, NORTH CAROLINA, SALES CATALOG.