INCINERATION OF LOW LEVEL RADIOACTIVE WASTE AND ION EXCHANGE RESINS

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ABSTRACT

An advanced controlled air pyrolysis incinerator has been developed and placed into operation for low level radioactive wastes and has demonstrated the capability to incinerate ion exchange resin. The resin incineration program has proven the ability of the incineration process to successfully incinerate varying mixtures of low level dry active wastes and spent ion exchange resins while maintaining off-gas contamination well below limits set by regulatory authorities.

Both commercial and nuclear installations have been operated with the most recent application being a central incinerator for low level radioactive waste presently being licensed in the United States. The NRC license for this facility is expected mid 1984. This incinerator will process two million pounds of dry active waste and ion exchange resin per year.

Incinerator Description (1)

A unique incinerator for low level radioactive waste was developed and placed into commercial operation at the Jüelich Nuclear Research Center in West Germany in 1978. A wide variety of wastes are processed (typically 100 kg/hr) from general research, medical and two research reactor waste streams. For example, over 200,000 kg of low level radioactive waste have been processed including paper, rubber, plastic (PE & PVC), HEPA filters, animal carcasses from medical and pharmalogical experiments, hospital wastes, scintillation vials and ion exchange resins. The volume reduction (VR) factor has been 20 to 100 with an average VR of 40 over the operating period of the facility.

The original design objective of no pretreatment (e.g sorting, shredding, etc.) for all waste fed to the system has been sucessfully demonstrated on all of the waste forms noted above. This objective was met through the use of a two stage pyrolysis incinerator which allows a simplified dry off-gas system to be used. The incinerator consists of a thermal pretreatment, reduced oxygen pyrolysis section, separated from an excess oxygen combustion chamber by grates. The combustion off-gas is filtered and a portion is recirculated to the pyrolysis section of the incinerator after mixing with a measured amount of fresh primary air. The remaining off-gas is cooled and, after additional filtration, passed to the stack.

The details of the incinerator concept are illustrated in Fig. 1. The wastes are fed by gravity into the thermal pretreatment or pyrolysis chamber of the incinerator through an air lock arrangement. Special material handling such as sorting, shredding, and metal removal is not required. This greatly simplifies the mechanical operation, reduces maintenance, lowers exposure, and eliminates undesirable tasks. The equipment is sized to directly accept large bundles of waste, combustible drums, and bagged HEPA filters. This material is introduced through an air lock into a relatively cool area of the incinerator. The material is slowly passed downward through zones of increasing temperature while the oxygen level is intentionally restricted. As the feed material is slowly increased in temperature and the wastes break down, pyrolysis gases are produced. The remaining solid material is gradually reduced to a charcoal-like material. Tar-like residues and complex hydrocarbons are essentially "cracked" and a readily burnable material is produced. After several hours, a temperature of 800°C is reached in the glowing bed just above the grates. At this point, all burnable material has been dried, degassed, partially oxidized and reduced to a pyrolysis coke.

The pyrolysis products are then completely burned in the combustion chamber at 900°C in an excess oxygen atmosphere. Secondary air in overstoichiometric quantities is admitted through the pyrolysis bed grates which separate the pyrolysis section from the combustion chamber. This secondary air cools the hollow grates before flowing into the combustion chamber through openings in their bottom. This excess secondary air also cools the combustion process and holds the combustion temperatures at the design point of 900°C. Volatized and pyrolysis gases flow around the grates and are burned, as in a gas burner, when sufficient oxygen is present. A gentle oscillation of the grates prevents the glowing bed from "channeling" and breaks up the pyrolysis coke into small particles. These then drop into the combustion chamber for final burning. The stable and relatively low temperature combustion process ensures both a long system life and that a completely burned out but easily handled unmelted ash remains.

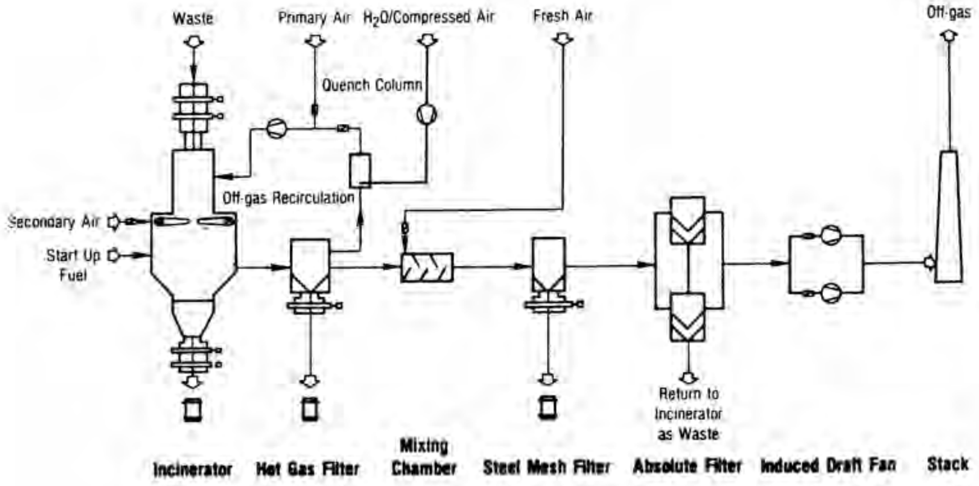

Fig. 2. Process Schematic.

The Hot Gas Filter first provides a low velocity settling plenum to drop any carry-over ash. The flow continues from this inlet plenum through disposable filter sleeves of an inexpensive ceramic fiber fleece. Perforated ceramic bricks support the filter and provide the flow channels to the clean air plenum. Solid particles, separated out by the filter bags, drop into the discharge hopper at the bottom of the inlet plenum. This plenum is coupled to the discharge hopper and ash collecting device. During maintenance operations, spent filter bags are pushed into the inlet plenum and discharged with the collected ash.

Following the Hot Gas Filter, part of the off-gas is returned back into the pyrolysis section of the incinerator via a quench cooler. Most of the clean off-gas from the hot gas filter flows through a lined duct to a mixing chamber where the off-gases are cooled to about 250°C by mixing with fresh air. A steel mesh filter, effectively a back-up safety device serving as a dust collector, spark arrester, and safety filter follows the air mixer.

Final cleaning of aerosols from the off-gases is made by absolute filter units (HEPA) which are connected downstream from the steel mesh filter. They are deisgned as two-stage parallel filters and provide 100% redundancy for change out and safety purposes. The used HEPA filters and filter frames are removed and directly recycled as incinerator feed without any crushing or shredding.

To satisfy the pressure drops in both the incinerator and the off-gas cleaning equipment, and to maintain the negative pressure of the complete system, two induced draft fans are provided at the discharge point. The induced draft discharges the cleaned off-gases to the stack and ensures a negative pressure throughout the system.

Waste feed is introduced into the pyrolysis chamber through an air lock system. As the material settles or burns down, additional feed is automatically accepted. The typical nuclear waste contains sufficient heat value to easily support the efficient incinerator operation. This typically would be approximately 5000 kcal/kg (7500 btu/lb) while the incinerator has demonstrated self sustaining operation down to 1000 kcal/kg.

Ash is removed periodically from both the incinerator and the filters in a contamination free manner via a gas tight knife valve arrangement. The ash product is reasonably heavy (not fluffy nor easily airborn) and its chemical and size uniformity allows it to be solidified by any of the accepted solidification medias.

Basic control of the incinerator is fully automatic and is based upon maintaining the combustion chamber at a preset 900°C temperature point. As variations in the heat content of the feed material occur, three control functions are automatically varied to maintain the desired temperature. These are:

- o the ratio of recirculated off-gas and primary air being delivered to the pyrolysis chamber;
- o a rate change in the motion of the grates which would vary the quantity of product delivered to the combustion chamber;
- o the amount of secondary air (combustion oxygen) introduced into the combustion chamber through the hollow grates.

Non-combustible particles accumulate in ash traps at the bottom of the combustion chamber where afterburning reactions for large particles can take place. The ash traps are periodically emptied and the ash is dumped onto a discharge gate. After cooling, it is transferred into a container for solidification and/or disposal as required.

As examples of incinerator operation, consider first the introduction of a significant quantity of flammable liquid into the system (i.e. oils, paint thinner, scintillation vials containing toluene, etc.). These would vaporize at a relatively low temperature in the upper part of the pyrolysis chamber. They would then mix with the pyrolysis gases and burn in a stable fashion when mixed with air in the combustion chamber. High heat capacity plastics or other such materials gradually break down over a period of hours and similarly burn in a controlled fashion.

Large solid sections of material, when introduced into a conventional incinerator, are normally difficult to burn without pretreatment. Such material tends to either gum or form an insulating char. However, as treated under a slow cycle, depleted oxygen condition, pyrolysis products and gases are produced and the waste is uniformly reduced to an easily burnable product.

Process Description (1)

A flow diagram of the overall incinerator system is shown on Fig. 2. The off-gas is first passed through the Hot Gas Filter which separates up to 97% of the airborne particulate from the combustion gases. A portion of the off-gas is recycled, cooled and mixed with a controlled amount of fresh air before re-introduction into the pyrolysis chamber. The balance of the off-gas is cooled by dilution in an air mixer, passed through a steel mesh filter and a redundant HEPA filter train to complete the separation of particulate from the gases. The induced draft fans maintain the complete system under negative pressure to further eliminate the leakage of any radioactive material.

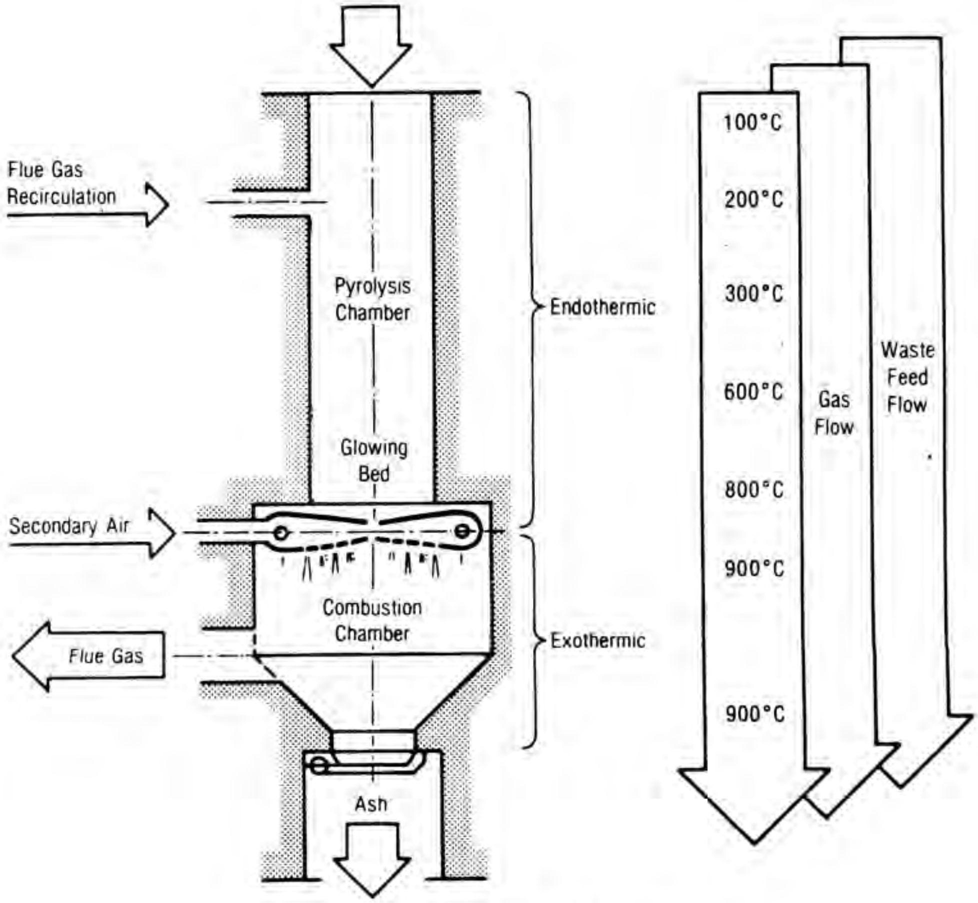

Fig. 3. Atcor Incinerator Schematic.

Both commercial operation as well as extensive development testing have demonstrated the safety and stability of this incinerator concept. It is an inherently forgiving system that does not require precise control of either its operation or feed material. The self regulation enables the system to operate unattended for long periods and with relatively unskilled personnel.

Incineration of Ion Exchange Resins (2)

There is a strong interest in the volume reduction of slightly radioactive (non-primary loop) resins from nuclear power plants by incineration. From a combustion point of view, resins are difficult to burn because of the tendency to form tars and char. A test program was initiated to demonstrate and evaluate the burning of chemically spent ion exchange resins at the Jüelich incinerator facility. During January of 1983, 7,000 kg of dry active waste was combusted along with 2,000 k of cation and anion resins. The resin content of the feed varied from 5% to 60% by weight. The resins were fed to the incinerator as a slurry with a 50% to 80% water content. The resulting VR from incineration was greater than 40.

Test Program

The test program was intended to supply values concerning type and quantity of incinerated ion exchange resins. The following items were examined in detail:

- What is the maximum proportion of ion exchange resins to dry active waste to still ensure optimum treatment and incineration?
- What is the influence and effect of type and physical properties of the ion exchange resins on the incineration process and flue gas quality?

The combustion of ion exchange resins in the Jüelich incineration process is possible without any problem. No adverse influence on the combustion process from the ion exchange resin slurry was observed, even at high resin feed ratios (up to 80%) and high moisture content (up to 80% of resin feed).

The ash produced during the test period was sampled and examined. The ash was a grey brown powder free from slag and uncombusted materials.

TABLE I

Summary of Test Values

Component	W. German Discharge Limit	Jüelich Test Average Value	Jüelich Test Peak Value
CO	1000 mg/m^3	40 mg/m^3	150 mg/m^3
NO_x	No Limit	30 PPM	58 PPM
HCl	6 kg/hr	2.5 mg/m^3	6 kg/hr
SO_2	No Limit	200 mg/m^3 to 1800 mg/m^3	
Organic Carbon	300 mg/m^3	2 mg/m^3	6 mg/m^3

Battelle Project (3)(4)

Battelle Columbus Laboratories has established a program to demonstrate the licensing and cost-effectiveness of incineration of low level radioactive waste (dry active waste, ion exchange resins, scintillation vials and medical waste). A 150 kg per hour ATCOR/Kraftanlagen incinerator has been selected by Battelle for this project. Application was made in June 1983 for the Ohio EPA permit and August 1983 for the NRC permit. The Ohio EPA has made a preliminary recommendation of approval and the NRC has completed their review of the application with no major issues remaining. A NRC license is expected the last half of 1984.

Presently, utility and institutional sponsors are being sought for the construction and operational phase of the project. ATCOR will construct the facility on a "turnkey" basis and operate the facility under the control of Battelle for a fixed toll charge. Battelle will manage the project and perform the licensing, health and safety and data collection functions.

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