VOLUME REDUCTION EQUIPMENT FOR LOW-LEVEL RADWASTES

G. Quinn, Transnuclear, Inc.
J. Hofmann, Nukem GmbH
E. Schlich, Nukem GmbH

INTRODUCTION

Various low level radioactive waste streams are generated by the nuclear fuel cycle. These waste streams can be processed in volume reduction (VR) equipment to reduce transportation and burial costs and to alleviate burial space capacity problems. Volume reduction equipment in use or under development in West Germany is described in this paper. Operational results including data from tests on system improvements are also given. The waste streams and applicable VR systems are:

Waste Stream	VR System
Dry Active Waste (Trash)	Incinerator
Evaporator Bottom Slurries	Dryer
Ion Exchange Resins	Pyrolyzer

DRY ACTIVE WASTE INCINERATOR

System Description

The incinerator for nuclear power plant dry active waste is a system developed and in use for 10 years at the Karlsruhe Nuclear Research Center in West Germany. This system uses an excess air incineration process which reduces the volume of the input wastes by an average VR factor of 80 to 1. The input wastes include paper, wood, textiles and plastics which are contaminated during nuclear power plant operation and maintenance activities. A limited amount of combustible liquids can also be incinerated in the system. These wastes are reduced to a powdery inert ash suitable for solidification in a variety of agents.

The incineration system consists of a feed mechanism, furnace, high temperature dry offgas filters, induced draft fan, Hepa filters and associated instrumentation.

The original feed system at Karlsruhe, which is still available for use, consists of a sliding air-lock in a box mounted directly above the furnace chamber. The operation is completely manual and requires a lid to be opened and a bag of waste placed inside an open-ended cylinder. When the lid is closed the cylinder slides over the top of the furnace chamber opening which allows the bag of waste to fall to the bottom of the chamber where it is incinerated. The operator observes the flames through a view-glass and adds more bags of waste as needed.

To demonstrate a semi-automatic feed system which requires less operator involvement, a continuous waste feed system was installed and tested during 1981. The continuous feed system consists of a lifting and tilting device which empties a drum of bagged waste into a glove box. The bags of waste are fed to a coarse shredder at the bottom of the glove box and the shredded material fills a supply hopper which has a second shredder at the bottom. This second shredder is controlled by a pyrometer which monitors the incineration process in the furnace chamber and continuously regulates the feed rate. The waste leaving the second shredder falls into an air conveyor tube and is drawn by the main air supply into the furnace chamber.

The furnace is a vertical shaft design consisting of a carbon steel shell with several layers of refractory bricks. At any time the waste is only a small fraction of the furnace chamber volume and rapidly decomposes in the turbulent flames. After startup no fuel other than the waste is required and, therefore, the incineration process can be stopped by cutting off the waste feed.

The offgas from the waste travels up the chamber at a low velocity allowing heavy particles to settle. The offgas exits near the top of the furnace into refractory lined piping and then flows into a primary filter housing which is also refractory lined. Particulates in the offgas stream are removed by dry high temperature filters. These filters, which are called "filter candles", are made of sintered silicon carbide with a maximum pore size of 30 microns. These filter candles are one meter long, 6 cm diameter, hollow tubes closed at the bottom. They hang by a collar from a support plate at the top of the housing. The hot offgas is drawn by the induced draft fan through these glowing-hot porous filters. Any particulates are caught on the outside surface and completely oxidized to ash. Radioactive contamination which was carried on the particulates remains in the ash.

The offgas leaves the primary filter and is cooled in the offgas piping before entering the secondary filter. The secondary filter is physically identical to the primary filter, but operates at a lower temperature. The cooling of the offgas allows removal of radioisotopes which are volatile in the primary filter and contributes to the decontamination of the offgas.

Induced draft fans downstream of the secondary filter and Hepa filters complete the incineration system at Karlsruhe.

Effects of Continuous Feed System

The continuous feed system tested during 1981 at Karlsruhe demonstrated two beneficial effects in addition to the decrease in operator involvement and associated radiation exposure. These two effects were improvements in filter candle lifetimes and system decontamination factors. Although both effects resulted from the use of the continuous rather than the original type of feed system each has different origins.

The ideal situation for incineration occurs when a homogeneous fuel with a constant heat value combines continuously with air at the optimum ratio. In this ideal case the resulting offgas would be a uniform flow at a constant temperature and pressure. The continuous feed system provides a nearly steady state operating mode which approaches this ideal situation. The testing of the continuous feed system showed that it minimized the temperature and pressure fluctuations inherent in the discontinuous feed system and resulted in less cyclic stress on the filter candles and hence provided a longer filter life. The percentage increase in operating life was not determinable due to the long lifetime of the filters relative to the length of the tests which were performed. However, a substantial increase is expected based on the preliminary results.

The continuous feed system and resulting steady-state operating mode also improves system decontamination factors compared to the original discontinuous type of feed system. This results from the elimination of the momentary over feeding of the incinerator when a new bag of waste enters the furnace. The ignition of a new bag provides a relatively large fuel source for the constant air flow into the furnace chamber resulting in incomplete burning of the waste and formation of a large quantity of particulates which must be removed from the offgas by the high temperature filters. The continuous feed system eliminates over feeding and results in less particulate formation. Since less contaminants are carried away in the offgas the decontamination factor of the furnace and the overall system is increased. During the series of continuous feed tests which were performed during 1981, a system decontamination factor in the range of 10^4 to 10^5 was measured. This is approximately an order of magnitude better than that obtained with the discontinuous type of feed system.

Planned Improvements to the Karlsruhe Incinerator

Modifications to the incineration system at Karlsruhe are underway to further reduce emission rates and increase the cost effectiveness of the system.

The major change will be the addition of an afterburner between the furnace and the primary filter. It is expected that this will remove particulates from the offgas before they enter the primary filter. This removal will add an additional decontamination step to the process and should increase the effectiveness of the primary filter by decreasing the loading on the filters. The net result is expected to be an increase in system decontamination factors and in filter candle lifetime.

A second change will be the addition of a backflushing system for the filter candles. This will consist of a new design filter housing which allows the entire set of candles to be backflushed with compressed air at the same time. The backflushing system will extend the candle's useful life by a factor of 2 or 3 compared to not backflushing as it decreases the pressure drop across the filter housing allowing continued operation with the same filters.

RADWASTE LIQUIDS DRYER

System Description

The dryer for nuclear power plant liquid waste was developed by Nukem, GmbH, and is in use at RWE's Biblis nuclear power plant in West Germany. This system uses a low-temperature vacuum evaporation process which reduces the volume of the input waste by removing water. The resulting dry free-flowing product has essentially no residual water. The input wastes include evaporator bottom slurries of boric or sodium sulfate salts and also ion exchange resin slurries. The typical volume reduction factors are 8 to 1 for a 12 weight percent evaporator bottoms slurry and 2 to 1 for dewatered resins.

The dryer system consist of a hot water heat transfer system, jacketed dryer vessel with an internal stirrer, demister, condenser, vacuum pump, distillate storage tank and dry product container.

The dryer operates in a batch mode. Each batch of radwaste is processed in the incoloy vessel at a water evaporation rate of 5 to 50 gallons per hour depending on the size of the system. The dryer vessel is heated by hot water which flows through an outside jacket. The stirred vessel operates under vacuum which permits a low temperature evaporation process. At the completion of a batch, the dry free flowing product is discharged from the vessel through a pinch valve at the bottom. The product is stored on-site at Biblis in 360 liter cast iron drums. Alternatively the product could be solidified in suitable agents with substantial reduction in waste shipments when compared to solidifying the input wastes.

The water evaporated in the dryer vessel exits as vapor through a nozzle at the top and after flowing through a demister is condensed in a water cooled heat exchanger. The distillate flows down to a storage tank while non-condensable gases are drawn into a vacuum pump and exhausted to a filtered ventilation system. The distallate storage tank is emptied after each batch. The system decontamination factor of 10^5 for all nuclides except tritium is probably too low to permit discharge of the distillate without further treatment. At Biblis this water is returned to the evaporator feed stream. The dryer is used to remove radwaste salts from the power plant's operating systems for disposal.

Operating Results

Since startup of the dryer at Biblis approximately seventy m^3 of input slurries have been processed. This has reduced a 6 year accumulation of evaporator bottoms and alleviated severe storage problems. Biblis had been forced to chemically treat and then decant the waste in the storage tanks which brought the solutions up to 40 weight percent solids in the tanks. The cleanup of the sludge in these tanks was accomplished by the use of the dryer to remove the salts and store these radwastes without water in casks on-site.

ION-EXCHANGE RESIN PYROLYSIS

System Description

The pyrolysis system for volume reduction of nuclear power plant ion-exchange resins is a system under development at Nukem, GmbH. This system uses a low-temperature inert atmosphere pyrolysis process which reduces the volume of dewatered bead resins by a VR factor of 3 to 1 and the volume of dewatered powered resins by a VR factor of 5 to 1. The input resins are reduced to free flowing inert carbon granules which are suitable for disposal unsolidified in high integrity containers or for solidification in a variety of agents.

The pyrolysis system consists of a feed system, reactor vessel, afterburner and scrubber.

The feed system is a screw conveyor which meters the resins into the top of the reactor vessel which is a cylinder of stainless steel electrically heated at the wall. The resins fall onto a distribution plate which evenly spreads them across the inside of the reactor vessel. The resins fall onto ceramic balls which are stirred slowly. As the resins fall they are heated which drives off any water and pyrolyzed which releases the volatile constituents of the resin. The pyrolysis gases exit through a perforated plate at the bottom of the reactor vessel and flow through sintered metal filters in a filter housing. The filter housing has a funnel shaped bottom which collects the pyrolyzed resins as they fall out of the reactor vessel through the perforated plate. The product is discharged through a valve at the bottom of the funnel while the pyrolysis gases are incinerated in an afterburner. The offgas is then scrubbed for SO_x and NO_x and the scrub solution is neutralized.

Operating Results

Bench scale tests have been performed to determine resin volume reduction factors for both bead and powder types. Product characteristics were also investigated and cement solidification tests performed.

Average volume reduction factors from input to output are 3 to 1 for bead and 5 to 1 for powder resins. This alone is an advantage when shipping and disposing of dewatered resins in high integrity containers. Another significant advantage resulting from the pyrolysis process is that the product waste form is superior to dewatered resins. No evolution of potentially explosive gases occurs as with storage of dewatered resins. Also the chemically inert product does not swell when placed in water as compared to dried resins. This property has an advantage during cement solidification in that there is no competition for the water between the pyrolyzed resin and the setting cement. Normally a cement solidified resin product is a poor waste form since the resin loses its water to the hardening cement and ends up loose in a bubble in the cement block. Pyrolyzed resins solidified in cement are incorporated as an inert filler such as sand, resulting in a superior solidified waste form. Waste loadings per drum of product can thus be higher with pyrolyzed resins. Typically the resins in 5.5 drums of cement solidified bead resins can be cement solidified in one drum if pyrolyzed. For powered resins the similar ratio would be 9 drums to 1 drum requiring shipment and burial.

SUMMARY

Volume reduction of low-level radwaste has been used for years in Germany to reduce the on-site storage capacity which is required until an ultimate disposal site is available. The incineration of trash is a well established cost effective method for dry active waste volume reduction and now liquid radwaste treatment is gaining the operational experience which establishes it as a routine procedure. Resin pyrolysis is a promising new development which when successfully implemented will augment the other systems by safely volume reducing a radwaste which is of increasing concern.