POSTER SESSION

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ADVANCED LOW LEVEL RADWASTE VOLUME REDUCTION AND SOLIDIFICATION SYSTEMS

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ABSTRACT

Disposal of radioactive waste produced by the many operating nuclear power plants represents an increasingly significant problem to the nuclear utility industry. Westinghouse is responding to this need by use of technology developed over the years. Today Westinghouse offers to the utilities a means of volume reducing both liquid and solid waste. Westinghouse systems to accomplish this are the Radwaste Volume Reduction/ Solidification System and the Controlled Air Incineration System.

The Radwaste Volume Reduction/Solidification System employs a vacuum cooled crystallization process to effect volume reduction, coupled with high speed, high shear mixing of the waste with cement to achieve solidification. The final mixture is a homogeneous, high strength matrix containing no residual water. The end product, automatically packaged in waste disposal containers, is consistent with current and currently anticipated regulatory requirements for the shipment and disposal of radioactive wastes.

Incineration is becoming increasingly popular among nuclear utilities. To assist utilities and defense waste generators with upgraded incinerator design, the Department of Energy funded a program at Los Alamos National Laboratory (LANL) and developed the "Controlled Air Incineration" concept. Westinghouse Electric's Nuclear Fuel Division at Columbia, South Carolina adopted the Los Alamos concept and implemented a radwaste incineration system for their uranium contaminated wastes. Westinghouse Technology Division took the Nuclear Fuel Division design and upgraded it for application to commercial nuclear power plant wastes with fission products. The following write-up describes upgraded Westinghouse radwaste systems.

BACKGROUND:

RADWASTE LIQUID VOLUME REDUCTION/ SOLIDIFICATION

Westinghouse Radwaste Volume Reduction/Solidification System system development has been ongoing for several years, incorporating both Westinghouse design experience and continuing nuclear utility feedback. Prototype testing of the major system components was conducted over a 3-year period, with successful system design and end product results obtained. Not only were Westinghouse research and engineering resources employed in the development of the system, but extensive participation by the Cement and Concrete Association of England, in cooperation with Westinghouse, was also integrated into the testing efforts. In addition, information exchange programs with utilities have enabled Westinghouse to more fully understand the needs of the nuclear utility industry regarding waste management, and to recognize those key areas in which system design improvements were necessary.

As a result of extensive development efforts, Westinghouse has applied the proven technologies of evaporative cooling crystallization and high-speed cement shearing for the optimization of an integrated waste volume reduction and solidification system. This combined system is comprised of the Radwaste Volume Reduction Subsystem and Cement Solidification Subsystem.

RADWASTE LIQUID VOLUME REDUCTION/SOLIDIFICATION SYSTEM

Technical Description

The Westinghouse Radwaste Volume Reduction/ Solidification System is designed to perform the volume reduction and solidification of radioactive plant wastes by utilizing proven, basic technologies. Volume reduction of concentrated evaporator bottoms, which may include boric acid wastes, laundry wastes, chemical wastes, and other floor drain wastes, is accomplished in the Radwaste Volume Reduction Subsystem. This subsystem also incorporates the potential for volume reduction of secondary-side sodium sulfate wastes for plants equipped with regenerative condensate polishers. Solidification of the volume-reduced waste and other low-level radioactive wastes, such as spent resins, filter cartridges, contaminated tools and clothing, is performed in the Cement Solidification Subsystem. Although discussed separately, the two subsystems have been designed in harmony such that the volume reduced output serves as optimal input to the solidification process. Each system, however, can be operated independently of the other.

The following paragraphs in this section give a brief discussion of the crystallization and high-shear mixing technologies, and include a description of each subsystem within the Radwaste Volume Reduction/Solidification System.

RADWASTE VOLUME REDUCTION SUBSYSTEM

Radwaste Crystallization Process

The evaporative cooling crystallization process of the Radwaste Volume Reduction Subsystem is performed using a forced circulation crystallizer. The forced circulation crystallizer is widely utilized in the commercial production of a large variety of commercial salts and is the most commonly employed type of crystallization equipment.

To achieve crystallization, the concept of boric acid solubility as a function of temperature is applied to produce crystals from a hot waste feed solution. The solution is gradually cooled in the crystallizer to ambient temperature by means of evaporative cooling under vacuum. When the concentration of the waste feed solute reaches a supersaturated state, crystallization is initiated and proceeds according to a solubility-temperature curve as cooling is continued. At ambient temperature, supersaturation is totally relieved and a stable solid-liquid slurry obtained. The precipitation and growth of crystals occurs in the bulk fluid, rather than in the evaporation zone, with the temperature of the bulk fluid remaining constant by evaporative cooling and continuous feed of the hot solution. The incoming hot waste stream crystallizes in the cooler bulk fluid by using existing crystals as seeds for the initiation of new nuclei. Volume reduction is accomplished by recycling the diluted waste solution for further evaporation while discharging the waste solute in crystalline slurry form.

The central theory underlying the analysis of the crystallization process is the population balance theory of crystal size distribution. Crystal size distribution so determined, coupled with the actual process configuration and physical parameters, was used to study crystallizer scale-up and product handling characteristics of the Westinghouse-developed radwaste volume reduction process.

RVRS System Description

A semicontinuous, vacuum-cooled crystallization process is employed in the Radwaste Volume Reduction Subsystem to concentrate primary-side liquid wastes. The system contains a forced-circulation crystallizer, circulating pumps, condenser, vacuum pump package, return pump, valves, instrumentation, piping, and miscellaneous equipment. The crystallizer chamber consists of a vertical tank with a conical bottom and an inner circular baffle to separate solids from a clear recycle stream.

The system is initially filled with subsaturated waste to a preset level in the crystallizer. The liquid in the system is then circulated through the crystallizer and circulating pump, and reenters the crystallizer tangentially.

Vacuum is then applied to the crystallizer until the bulk fluid temperature has stabilized at ambient conditions. At this time, hot waste feed from an upstream evaporator is fed continuously into the recirculation loop at 3 gallons per minute. Thermal input of the hot evaporator bottoms is balanced by evaporative cooling so that system operation is maintained at ambient temperature. The presence of an overflow line ensures constant level in the crystallizer chamber.

The precipitation and growth of crystals occurs in a controlled manner in the bulk fluid phase within-the crystallizer chamber. A high fluid flow rate maintained in the recirculation loop prevents solids deposition on system equipment. In addition, the low-speed circulating pump is used to reduce particle attrition.

Water evaporated to maintain bulk fluid temperature is condensed and returned, along with the overflow stream, to the plant liquid waste evaporator. Noncondensible gases that may be produced during the crystallization process are returned to the plant vent system by way of the vacuum pump package.

The Radwaste Volume Reduction Subsystem is operated until the concentration of solid crystals reaches a predetermined limit which is typically 25 v/o in the bulk fluid. Operation is then terminated and the crystals are allowed to settle in the chamber. The settled slurry which is typically 50-60 w/o waste solids is then pumped to the Cement Solidification Subsystem.

Volume reduction is accomplished by discharging the waste solute produced in crystalline slurry form, while recycling the diluted waste solution from the crystallizer back to the evaporator for further concentration of radioactivity, miscellaneous contaminants, and remaining boric acid. In this manner, a two-phase volume reduction process is employed, namely, the vacuum-cooled crystallization process in conjunction with reevaporation of the crystallizer recycle output stream. The primary objective of the Westinghouse two-phase process is to provide for clean operation of the crystallizer and to optimize the crystallization-process in order to achieve maximum, controlled precipitation of boron-containing evaporator concentrates. By removing most of the boric acid content from the evaporator bottoms through crystallization, the evaporator can then be utilized more efficiently to concentrate any remaining radioactivity and contaminants in the recycle stream. Based on the extremely low concentration of radioactivity and chlorides typically found in evaporator bottoms compared to the limiting criteria for operation, extensive recycle operation is anticipated without hindering overall system efficiency.

After discharging the major portion of the crystalline slurry, additional feed from the evaporator is added to the liquid remaining in the crystallizer to prepare for processing the next batch. Crystals remaining in the crystallizer act as seeds for the initiation of new crystals.

The Radwaste Volume Reduction Subsystem is designed to accept evaporator concentrates at 12 w/o boric acid and a temperature of 165°F; however, the actual temperature and concentration may be allowed to vary within a wide range. The system is highly flexible and the operator is generally not required to adjust for varying input conditions.

The system is likewise only minimally sensitive to the presence of other constituents in the input stream. The capability of the system to handle suspended solids is inherent in the design criteria for the processing of slurries. The concentration of halogens is not critical, as the crystallizer operates at a temperature below that necessary for the initiation of chloride-induced cracking.

Detergent wastes would require the use of anti-foam agents, but these are routinely added in the waste evaporator. In summary, the crystallizer and associated equipment are designed to operate reliably regardless of the composition of the input stream, as the system input is only that which has already been processed in an upstream evaporator.

In addition, the recirculation loop contains a heat exchanger for periodic cleaning. To boil out the system, the vessel is first emptied and refilled with clean water. The system is heated by injection of steam on the secondary side of the heat exchanger. Circulation for several hours will dissolve the deposits, and slow evaporative cooling to ambient temperature will then crystallize the waste stream. The solids can then be disposed of or used as seeds for the next crystallization operation.

CEMENT SOLIDIFICATION SUBSYSTEM

High-Shear Mixing and Solidification Process

Based on research and development conducted by Westinghouse in conjunction with the Cement and Concrete Association of England, the close-gap high-shear mixing technology applied in the production of commercial, high-strength concrete was adapted specifically for use in the Cement Solidification Subsystem.

The recurrence of problems associated with the encapsulation of nuclear power plant borated waste has demonstrated the necessity to review the design of cement solidification systems in order to eliminate existing deficiencies. Westinghouse's investigations performed to date have indicated that a more sophisticated technique of mixing must be employed to overcome the chemical and physical impediments inherent in the waste liquor. The cement grains must be sheared during the preparation of the cement paste so as to induce a greater hydration of the cement in the presence of boron retarder.

Among the different types of mixers commercially available, the one exhibiting optimum shearing potential and further developed by Westinghouse for radwaste application is the colloidal mixer. The high-shear capability of the colloidal mixer is provided by the high speed of the mixer impeller mechanical shear and the rapid displacement of solid particles against the other solid constituents of the mix, hydraulic shear, which result in continuous shearing action.

Because the properties of the radwaste cement and the phenomena that occur during the solidification process are highly dependent on the chemistry of the constituents, knowledge of the boron and cement chemistries was developed jointly with the mixing technique to optimize the Westinghouse radwaste solidification technology.

CSS System Description

The Cement Solidification Subsystem features in-line batch, high-shear mixing of volume-reduced liquid slurry wastes with cement, and automatic packaging in waste disposal containers. This system also incorporates the dewatering of spent resin slurry, followed by solidification of the resin with nonreduced liquid waste in cement. Other wastes, such as spent filter cartridges or contaminated articles may be placed directly into containers for encapsulation. The major components of the Cement Solidification Subsystem include the Westinghouse-patented high-shear radwaste mixer, waste dispensing system, flushwater recycle system, cement storage and feed system, and the container handling system.

To initiate the waste solidification process, volume-reduced slurry waste is collected and stored in the waste dispensing vessel prior to mixing with cement. Volume reduction of spent resin slurry is performed at this time by screen dewatering inside the dispensing vessel, and transport water is returned to the plant liquid waste system for reuse. The dispensing vessel is a cylindrical tank with a conical bottom and is steam heated. Other process equipment that may at some point be exposed to evaporator concentrates are heat traced to prevent boric acid precipitation.

Homogeneity of the waste is provided by the action of an agitator on top of the dispensing vessel as well as by recirculation through the waste metering pump. The waste feed is then discharged to the high-shear radwaste mixing vessel using the waste metering pump.

The cement storage and feed system is used to store and meter the feed of Portland cement into the high-shear mixing vessel where it is combined with the contents of the waste dispensing vessel.

Cement is gravitationally fed to the high-shear radwaste mixer from the day bin and is measured gravimetrically. The mixer is vented through a dust filter which is located in an area remote from the mixer, typically on the roof of the radwaste building. By this arrangement, the entire system can be operated with no in-plant release of cement dust.

The radwaste mixing vessel is a small, drum-shaped tank which houses the mixer, and in which the waste feed and cement are mixed and sheared: The small size of the mixing vessel was intentionally designed to minimize the volume of flushwater required and to facilitate disposal at the end of its service life. The mixer is driven by a 40-horsepower induction motor, which is shielded from the mixer itself. The essential parts of the high-shear mixer are the rotating impeller and its housing. The shape of the impeller, together with its high rotational speed (3000 rpm) and the small gap between the impeller and its housing, results in the mixer imparting high shear to the mix and providing a discharge head sufficient to pump the mix. By this mechanism, a homogeneously mixed paste is created in which rapid hydration of the cement particles occurs.

Batch control in the high-shear mixer is automatic. The operator sets the panel controls for the type of waste to be drummed and initiates the process. The process parameters (feed rates, mixing time, etc.) are selected automatically. The waste feed and the cement are metered into the mixer, which runs continuously during operation. The batch is sheared for a short period of time, typically 1 to 3 minutes. Depending on the type of waste, then discharged into the disposal container. The process is repeated and continues until the container is filled.

WASTE INCINERATOR:

Background and History:

Nearly 60 percent of the total low level wastes generated in a nuclear power plant is combustible. Due to the recent shortage of burial grounds and cut back of allocated quotas, volume reduction of these low level wastes is a major concern of utilities. Additional concerns are the ever increasing costs of waste transportation from power plant site to the remaining two federally approved burial grounds and the sky-rocketing costs for their disposal at the burial sites.

The history of the Westinghouse Radwaste Incinerator goes back to the early 70's. In the fuel fabrication plant in Columbia, South Carolina, a one stage incinerator was operated from early 70's to 1979. The incinerator was small and was not capable of handling the ever increasing volume of combustible wastes generated from various manufacturing operations. In 1979 Westinghouse installed a controlled air incinerator, the design of which was based on that developed and tested by the Los Alamos National Laboratory. During the process of operation over a 3-1/2 year period Westinghouse engineers have upgraded and modified various components and subsystems of the design.

Technical Description

The basic objective of the Westinghouse Radwaste Incinerator is to volume reduce the low level combustible wastes generated during operation of commercial nuclear power plants. Typical wastes that can be processed include the following:

Cellulosties	Cloth	Volume
Polyethylene	Booties	Dioxane
P.V.C.	Machine oil/cutting oil	Ketones
Rubber	Kerosene	Mineral Spirit
Wood	Benzene	HEPA filter

Any mixture of the above materials in any proportion can be accommodated. The Westinghouse Radwaste Incinerator is broadly divided into several systems, including the following:

- -Waste Inspection/Preparation
- -Waste Feed and Controlled Air Incineration
- -Off-gas Quenching and Scrubbing
- -Ash/Non-Combustible Removal
- -Scrub Water Filtration
- -Off-gas Filtration

Following are brief descriptions of each subsystem.

Waste Inspection/Preparation

The basic objective of this subsystem is to minimize exposure and release of radionuclides during inspection, preparation and handling of the charge. The necessary provisions for detecting large metal pieces and non-combustibles are provided. If highly compacted waste is to be burned, a shredder for size reduction is incorporated.

The mechanical components of the system include an electric hoist, two sets of conveyors, an x-ray machine and a shredder (optional).

Waste Feed and Controlled Air Incineration

The basic components of the subsystem are the dual chamber, refractory lined incinerator and horizontal hydraulic driven ram. Waste feed after inspection and preparation is boxed into the ignition chamber (bottom chamber) of the dual chamber incinerator by a hydraulically driven horizontal ram. The waste in the ignition chamber is set aflame by a gas or oil burner. Inside the chamber a starved oxygen environment is maintained to minimize turbulence and maximize the dwell time of the burning process. The waste undergoes decomposition in the bottom Chamber and the gaseous products, partially oxidized, pass to the combustion chamber (top chamber) where they undergo complete combustion with 50-100% excess air. Most of the ash and radioactive contaminants remain in the ignition chamber.

Off-Gas Quenching and Scrubbing

The incinerator exhaust is cooled and cleaned by a quench tower, a venturi scrubber, and an absorber column. The combustion chamber is highly effective in particulate combustion; however, minute particulates become entrained in the incinerator effluent. Undesirable combustion gases are also contained in the exhaust along with the particulates. The incinerator exhaust is drawn into the quench tower where it is cooled and partially scrubbed by a water spray. The quenched gas then passes through a venturi scrubber where most of the remaining particulate matter is removed. Water is injected into the throat of the venturi where turbulent mixing and wetting of particulates occur. Undesirable combustion gases are removed by the absorber column. A counterflow water spray absorbs the soluble gases and wets most unscrubbed particles.

Ash/Non-Combustible Removal

The ash from the bed of the incinerator is removed periodically by a ram pusher to the ash pot, screened for particles larger than 1/16", cooled in a water jacketed pot, and finally mixed with transport water to prepare a slurry for transportation to the Westinghouse Cement Solidification System.

The equipment comprising this subsystem is a 1/16" vibratory screen, water cooled jacketed pot, screw feeder and an agitated tank for slurry preparation, and a slurry transport pump.

The scrub water filtration subsystem consists of neutralization and storage tanks, a cross-flow high velocity cleaning filter, a shell and tube heat exchanger, and several transfer pumps. The scrub water containing combustion acids is neutralized with a caustic solution, filtered for removal of particulates, cooled in a shell and tube heat exchanger, and recycled back to the off-gas scrubbing equipment. This recycle process continues until the salt concentration in the water nears the solubility limit, in which case the recycled water is sent directly to solidification, and/or solidification preparation.

Off Gas Filtration

The combustion gases drawn from the absorber column are condensed to remove water vapor, passed through a coconut charcoal/silver zeolite column for removal of iodine vapor, superheated above its dew point, drawn through HEPA filters for removal of particulates, and finally released to the atmosphere or plant ventilation system via a centrifugal blower. This blower maintains a negative pressure throughout the radwaste incinerator. Thus, should any leakage occur, it would be into the system. This subsystem consists of a condenser, an adsorption column, a superheater, HEPA filters, and a centrifugal blower.

Instrumentation and Control

The entire incineration system contains instrumentation for measuring and automatically controlling process parameters such as pressure, temperature, flow rates, concentrations, pH, and radioactivity levels. The process parameters are controlled from a remote control panel and digital instrument readouts will give the process status at any given time.

BENEFITS AND ADVANTAGES

The Westinghouse Radwaste Incinerator features the following benefits and advantages:

- High volume reduction of combustible low level radioactive wastes is achievable.

- The Radwaste Incinerator utilizes a proven system design developed at the Los Alamos National Laboratory and successfully operated by Westinghouse at the Westinghouse Columbia Fuel Fabrication Plant.

- Only one operator is required during normal incinerator operations.

- Low maintenance requirements provide for low maintenance costs and low occupational radiation exposure.

- A remote control panel monitors and automatically controls most system operations.

- In addition to process design, detailed engineering, and hardware, Westinghouse can also provide installation services and training support for operators.

- The incinerator ash and brine can be solidified with the Westinghouse high speed, high shear Cement Solidification System to give a homogenous cement matrix that will satisfy the low level radwaste packaging, transportation and long term storage criteria.