VERIFICATION OF VOLUME REDUCTION DATA FROM THE VOLUME REDUCTION & SOLIDIFICATION (VRS^{TM}) SYSTEM AT THE PALISADES NUCLEAR PLANT

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ABSTRACT

At the Palisades Nuclear Power Plant, low-level radwaste was solidified with urea formaldehyde until 1978. Technical difficulties and regulatory restrictions prompted Consumers Power Company (CPCO) to replace the UF system with a Volume Reduction and Solidification (VRS^{TM}) system supplied and installed by Werner & Pfleiderer Corporation (WPC). The VRS system uses an extruder to simultaneously evaporate water from the waste while encapsulating the waste solids in a thermoplastic binder, asphalt. Installation of the VRS system at Palisades was completed in 1982. Functional testing and startup on simulated waste streams have now been completed. Results demonstrate a solidified product which meets all acceptance criteria while reducing the volumes of borate, bead resin and powdered resin wastes by factors of 5 to 11 over previous practice. A substantial drop in annual waste shipments, processing manhours, and man-rem exposure is projected for Palisades when radioactive material processing commences in 1983.

INTRODUCTION

The Palisades nuclear power plant is an 821 MWe pressurized water reactor. The original radwaste solidification system used a urea formaldehyde process (UF). The well-known difficulties with UF solidification prompted Consumers Power Company (CPCO) to evaluate alternative solidification processes including volume reduction technology. Werner & Pfleiderer Corporation (WPC) was selected to provide and install its Radwaste Volume Reduction and Solidification (VRS^{TM}) system. The VRS system uses an extruder to simultaneously evaporate water from the waste while encapsulating the waste solids in an asphalt binder.

The solidified product meets all federal requirements for shipment and burial including the essential requirement of "no free water". Additionally, the removal of water from the waste results in substantial volume reduction for evaporator concentrates and ion exchange resins.

The Palisades retrofit included the design and delivery of all process equipment and auxiliaries. Engineering and equipment purchasing began in the fall of 1979 with delivery of all equipment concluded by April 1981. Removal of the UF system and decontamination of existing building surfaces was completed during the first six months of 1981. Modification of the existing structure, installation of a new process building and all equipment, and sealing and painting of surfaces was completed a year later. Initial operator training, functional testing and startup were concluded by the end of 1982. The system has been operated extensively to process simulated radwaste. Details on the system design, installation and performance are summarized herein.

SYSTEM DESCRIPTION

The basic VRS system process involves simultaneous feeding of the liquid waste or waste slurry and the asphalt binder to the extruder. Water is evaporated from the waste in the steam-heated extruder. The evaporated waste is condensed and returned to plant waste system. Simultaneously, the residual waste solids are mixed with asphalt in the extruder. The resulting homogeneous product is discharged to a container. Solidification of the waste solids in the thermoplastic asphalt is achieved as the mixture cools. No chemical reaction is required to achieve a solidified product.

At Palisades, the process and auxiliary systems were provided as a complete radwaste facility. The process flow diagram is shown in Fig. 1.

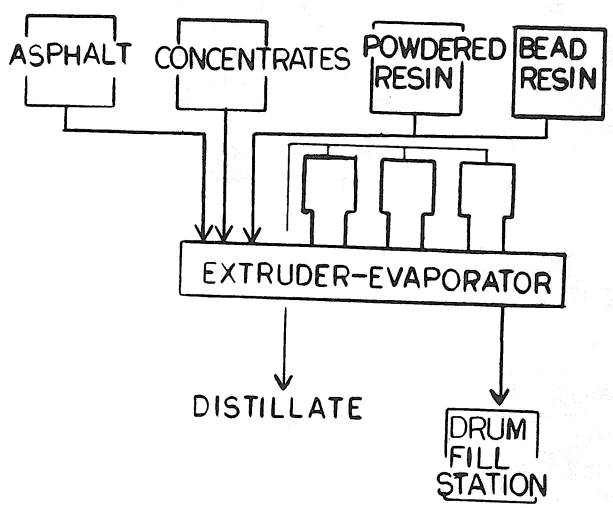

Fig. 1

Waste Feed Systems

The major source of radwaste to be processed at Palisades consists of evaporator concentrates from the liquid waste system. The waste contains 12 weight percent boric acid (in borate form). Piping tie-ins were made between existing plant collection tanks and the VRS system. An existing pump was used to supply a VRS system metering pump. The metering pump controls the waste flow to the extruder. The second source of radwaste is bead form ion exchange resin. This material is used in the reactor cleanup system, the spent fuel pool cleanup system, and the liquid waste system. For this waste source, a resin batch and decant tank system was installed and interconnected with existing storage tanks. A feed, recirculation and metering system was also provided. This system assured that a uniform resin slurry would be maintained and fed to the extruder at a controlled rate.

In addition to the liquid radwaste sources, contaminated filter cartridges are generated at Palisades. Provisions were made in the remotely operated drum handling system to position filter cartridges, in drums, at the fill station. The cartridges are encapsulated with either pure asphalt or an asphalt and waste mixture.

Another potential source of radwaste at Palisades is the powdered ion exchange resin used in the plant condensate polishing system. This condensate polishing system is physically distant from the radwaste building. To transport powdered resin slurries, a truck mounted batch feed tank was provided. The batch tank is filled at the condensate polishing building and transported to the VRS system building. Piping and electrical tie-ins to the bead resin metering system were included. The powdered resin is then processed in the same manner as the bead resin slurry.

Asphalt Binder System

Asphalt is utilized as the binder in the Palisades radwaste system. It was selected because of its burial site and regulatory acceptance, compatibility with the waste streams, and low price.

An asphalt and storage and feed system was provided at Palisades. The atmospheric storage tank has a working capacity of 9,000 gallons and is maintained at ~325°F by steam heating coils. An asphalt pump recirculates the tank contents in a closed loop to maintain uniform temperatures. A metering pump obtains suction pressure from the recirculation line and feeds asphalt to the extruder. Strainers are provided to remove any foreign matter from the asphalt. All piping is steam heat traced and insulated to maintain uniform temperature and eliminate hot spots.

Extruder-Evaporator

Waste and asphalt are continuously and simultaneously fed to the extruder-evaporator by variable capacity pumps. The extruder's process section consists of modular barrel sections bolted together by support plates and mounted on the frame. Inside the barrel sections are two co-rotating and self-wiping shafts fitted with screw conveying elements and kneading blocks. These screw elements reduce the waste particle size and mix the solids with the asphalt binder. Three barrels of the extruder-evaporator process section are fitted with devolatization domes. The water evaporated from the waste is discharged from the extruder into the devolatization domes. The domes contain integral coolers which condense the distillate. The distillate is then returned to the plant waste system.

The process section of the extruder-evaporator is heated with steam. The steam provides the driving force for evaporation of the water from the waste. Each barrel of the process section has its own steam supply and condensate return and is equipped with a temperature (steam flow rate) controller. The steam is generated by an electric boiler at 250 psig. The steam system is closed loop with condensate returned to the boiler.

The extruder-evaporator screw shafts are driven by a 100 HP variable speed D.C. motor. The motor's variable speed allows control of the residence time and mixing intensity. The drive motor operates the screw shafts through a combination reduction distribution gearbox. The output from the gearbox drives each shaft. Oil lubrication is provided to the gearbox by an independent lube oil system.

Container Handling System

At Palisades, standard 55 gallon drums are used to collect the solidified waste product. A remotely operated conveyor system is used to perform the major drum handling operations. Lids are mechanically placed on the drums and then automatically seamed. After seaming, the drums are swiped and then conveyed to a pickup point. There, a shielded forklift truck is used to remove the drums for shipment or storage. Closed circuit television and a shield window are available for visual monitoring of the process and all drum movements.

Process Controls

All system functions for the VRS system are controlled from a full graphic panel located in a control room adjacent to the process room. A companion panel is provided for control of drum handling operations. The panels each contain a programmable logic controller (PLC). The PLC contains all of the logic functions needed to automatically control systems operation. A separate controller is provided to automatically regulate the asphalt flow rate in response to changes in waste flow rate. This assures that a uniform solidified product is achieved.

INSTALLATION

The process and material handling equipment were installed in an area previously occupied by the UF system. This necessitated decontamination of the building and removal of equipment that could not be reused. Modification of both seismic and nonseismic structural components were performed. Shield walls, of high density concrete, were poured to segregate radiation zones. The process equipment was installed in a Seismic Class I portion of the auxiliary building.

FUNCTIONAL TESTING

Startup

Initial testing activities included piping hydrostatic tests and flushes, wiring continuity checks, instrument calibration and energization. The usual difficulties with instruments, wiring errors and leaky fittings were encountered and rectified. Auxiliary system startup began in July of 1982. The progression was to complete the auxiliaries most necessary to operation of the VRS system first. For this reason, the load center, motor control center, instrument air system, extruder lube oil system, cooling water system and auxiliary boiler were the first systems operated. After all the auxiliaries were functionally tested, startup of the drum handling, fire protection, asphalt and resin feed systems began. Finally, the extruder-evaporator was operated with pure asphalt in September 1982. Once the entire system was functional, all logic requirements and automatic sequencing controls were tested and verified. The remaining systems such as the HVAC units were checked out.

SIMULATED WASTE PROCESSING

Initial operation of the VRS system was performed with simulated radwaste. The simulated (nonradioactive) waste streams were formulated from chemical constituents normally used at Palisades. Three major waste streams were studied during the startup testing: bead resin, powdered resin and boric acid. The system was operated in a normal configuration insofar as practical.

Boric Acid

Simulated evaporator concentrates were prepared in a heated batch tank. Temporary piping was connected between the tank and the VRS system's concentrates metering pump. The temporary feed system was necessary because the actual piping is tied into the plant concentrates system. This section of the system was isolated during startup to prevent contamination of the VRS system components.

A 12 weight percent boric acid mixture was prepared in the batch tank and neutralized to pH 7.4 by the addition of sodium hydroxide. The resultant mixture had 21,460 ppm boron and an equivalent solids content of 12.1% boric acid. Results of an extended test run are given in Table I.

TABLE I

BORIC ACID

Waste:	Dissolved Borates - 21,460 ppm boron (equivalent to 12.1 wt % boric acid)
	pH - 7.4
	Concentrates Feed Rate - 290 lbs/hr. (equivalent to 26 lbs/hr. of solids)
Binder:	Asphalt Feed Rate - 33 lbs/hr.
Evap.Rate:	265 lbs/hr. or 120 liters/hr.
Product Loading:	44 wt % Concentrates 56 wt % Asphalt
VR:	6.3 : 1 Input Waste Volume : Product Volume

The reported data is from a long duration test run. The product was homogeneous, without voids, contained no free water and flowed smoothly to fill the container. Other test runs indicate both higher loadings and higher evaporative rates are attainable. Testing at these conditions is continuing.

Powdered Resin

The powdered resin batch tank was used as the feed source during testing. An anion/cation mixture of 3:2 (by volume) and water were combined to make a 30% slurry (12.8 weight percent bone dry resin). The mixture was processed with a normal system line-up. The results of an extended run are shown in Table II.

TABLE II

POWDERED RESIN

Waste:	Mixed Anion/Cation Powdered Resin - 30% slurry (12.8 wt % bone dry resin)
	Slurry Feed Rate - 260 lbs/hr. (33.3 lbs/hr. bone dry)
Binder:	Asphalt Feed Rate - 51 lbs/hr.
Evap.Rate:	227 lbs/hr. or 103 liters/hr.
Product Loading:	40 wt % Resin 60 wt % Asphalt
VR:	4.0 : 1 Input Waste Volume : Product Volume

The data was taken during a long duration run. The product was homogeneous, without voids, contained no free water and flowed smoothly to fill the container. Other test runs indicate both higher loadings and higher evaporative rates are attainable. Testing at these conditions is continuing.

Bead Resin

Mixed bed bead resins were processed during the system startup. The resin slurry was prepared in the system's batch tank. A premixed Graver bead resin (2:1 by volume, anion/cation) and sufficient water to make a dilute slurry were added to the batch tank. The slurry was decanted with the installed pump and screens to a 33% slurry (15.3 wt % bone dry resin). The results of an extended test run are given in Table III.

TABLE III

BEAD RESIN

Waste:	Mixed Anion/Cation Bead Resin - 33% slurry (15.3 wt % bone dry resin)
	Slurry Feed Rate - 227 lbs/hr. (34.6 lbs/hr. bone dry)
Binder:	Asphalt Feed Rate - 52.4 lbs/hr.
Evap.Rate:	192 lbs/hr. or 87.2 liters/hr.
Product Loading:	40 wt % Resin 60 wt % Asphalt
VR:	2.5 : 1 Input Waste Volume : Product Volume (1.8 : 1 for Dewatered Resin)

The reported data is from a long duration test run. The product was homogeneous, without voids, contained no free water and flowed smoothly to fill the container. Other test runs indicate both higher evaporation rates and higher binder loadings are attainable. Testing at these conditions is continuing.

During each test run, a material balance was made on the VRS system. Known feed concentrations and timed samples of the feeds and extruder-evaporator discharge were utilized to calculate volume reductions and waste loadings. Evaporative rates were determined from timed samples of the distillate. The instrumentation provided to characterize the waste and monitor extruder-evaporator feeds was consistent with the material balance.

Of major importance was the fact that no free water was detected in the product samples. Samples were allowed to cool and cut into sections. No free water was found. The product homogeneity was verified during the sample sectioning. Additionally, solidification always occurred upon cooling. In summary, significant volume reductions were achieved and a suitable solidified product produced.

PROJECTED PLANT OPERATION

The projected volumes of radwaste to be generated at Palisades were reviewed in conjunction with the VRS system performance. The comparison with present solidification techniques is shown in Table IV. It is concluded that the VRS system will substantially reduce the volume of waste shipped from Palisades and the number and time of container handling operations. At least 1200 fewer containers will be required on an annual basis. This reduction should result in substantial cost savings and reduced operator radiation exposure.

TABLE IV

PROJECTED PERFORMANCE OF VRS SYSTEM AT PALISADES

WASTE TYPE	WASTE VOLUME	CEMENT SOLIDIFIED VOLUME	VRS SOLIDIFIED VOLUME	PROCESS TIME	VOLUME REDUCTION FROM CURRENT PRACTICE
Bead Resin	3000 gal/yr	5400 gal/yr	1200 gal/yr	100-200 hr/yr	4.5
Powdered Resin	4800 gal/yr	8600 gal/yr	1200 gal/yr	130-160 hr/yr	7.2
Boric Acid	29920 gal/yr	53856 gal/yr	4749 gal/yr	750-900 hr/yr	11.3
Total	37720 gal/yr	67856 gal/yr	7149 gal/yr	980-1180 hr/yr	
Containers		1358 drums/yr	127 drums/yr		10.7