OPERATIONAL EXPERIENCE OF THE PALISADES STATION VOLUME REDUCTION SYSTEM - THE FIRST TWO MONTHS

B. B. McKercher
Consumers Power Company
Palisades Nuclear Plant
Route 2 Box 154
Covert, Michigan 49043

C. C. Miller
Sargent & Lundy
55 East Monroe
Chicago, Illinois 60603

M. D. Naughton
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

ABSTRACT

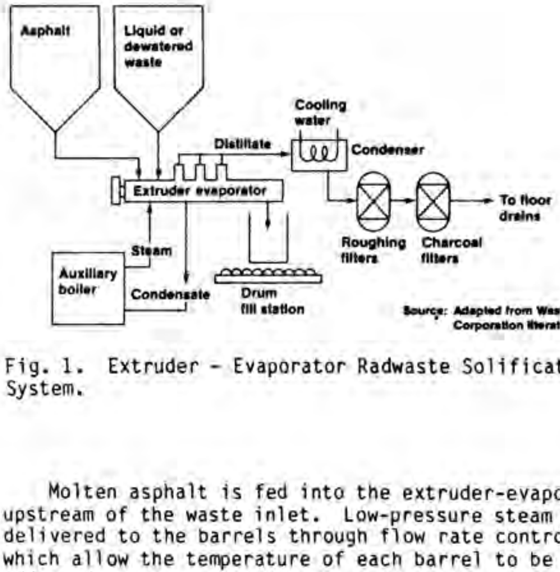
The startup and operational experience of an extruder-evaporator volume reduction and solidification system are discussed. A description of the system and the retrofit installation of the system is included. The operating parameters for processing wastes and the results of waste processing are presented.

INTRODUCTION

The volume reduction system at Consumers Power Company's (CPCo) Palisades Nuclear Plant is the first operational system of its type in the United States. The Palisades plant is an 811.7-MWe pressurized water reactor which began commercial operation in December 1971. A WasteChem Volume Reduction and Solidification (VRS[a]) system was retrofitted at the station and began startup testing in late 1982. Startup testing was completed in December 1983 and the system commenced operation in February 1984. This paper is the second progress report on operating volume reduction systems and is part of a study on "Advanced Low-Level Radioactive Waste Treatment Systems" carried out under EPRI Contract RP-1557. The first report covered in detail the installation and initial startup of the VRS system. This paper will present the results of startup testing which served as the basis for the selected operating process parameters. The operating data as of this writing is also presented.

VOLUME REDUCTION SYSTEM DESCRIPTION

The VRS system consists of an extruder-evaporator which simultaneously evaporates water from liquid wastes while encapsulating the residual solids in an asphalt binder (see Fig. 1). The extruder-evaporator consists of seven connected Nitroloy (deep-nitrited carbon steel) barrels. Within the barrel walls there are closed-loop passages for cooling water and process heating steam. Two corotating kneading and conveying screws are contained within the connected barrels. These screws are driven by a 100-hp variable-speed d-c motor.



Source: Adapted from WasteChem Corporation literature.

Fig. 1. Extruder - Evaporator Radwaste Solification System.

Molten asphalt is fed into the extruder-evaporator upstream of the waste inlet. Low-pressure steam is delivered to the barrels through flow rate controllers which allow the temperature of each barrel to be adjusted.

The process heating steam does not come in contact with the waste and is condensed and returned to the boiler.

As the asphalt/waste mixture is conveyed through the extruder by the screws, water is evaporated. This vapor leaves the extruder through three volatilization

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[a] VRS is a registered trademark of WasteChem Corporation

domes located along the top of the barrels. This vapor is condensed, filtered, passed through an oil separator, and sent to the plant floor drain system. The asphalt/waste mixture exits the end of the extruder and flows into a 200-liter (55-gallon) drum, solidifying upon cooling.

SYSTEM INSTALLATION

Due to inherent difficulties with the original urea formaldehyde solidification process, CPCo began evaluating alternative solidification processes including volume reduction in 1976. This evaluation resulted in the selection of the VRS asphalt solidification system. WasteChem was awarded the design and engineering contract. Engineering and equipment procurement began in the fall of 1979.

The volume reduction system was retrofit into two existing rooms in the plant, the radwaste packaging area and an adjoining storage room (see Fig. 2). Vikem Industries, Inc. was contracted by WasteChem to perform the decontamination of the radwaste packaging area. The decontamination project began on February 10, 1981 and was completed on September 22, 1981.

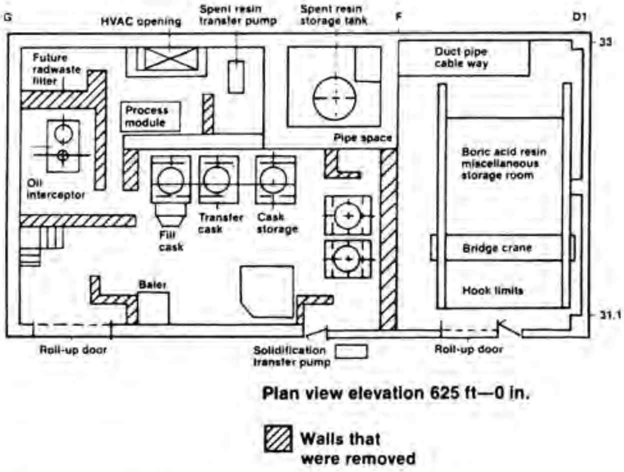

Fig. 2. Existing Radwaste Packaging Area.

Besides removing the original solidification process equipment, several shield walls were demolished to provide a 6.1-meter by 14.3-meter (20-foot by 47-foot) clear area for the VRS system.

The major processing equipment, including the extruder-evaporator feed pumps, fill station, drum handling system, distillate treatment skid, and vent filters, was installed in the packaging area. High-density concrete walls were poured to consume a minimum amount of space and yet provide adequate shielding of the process components (see Fig. 3). Due to the limited available space, a conveyor line was installed for drum handling in the fill area. The conveyor system required that, normally, drums be filled in one pass. At other extruder-evaporator installations, a turntable has been used which allows drums to be filled in multiple passes.

A portion of the adjoining storage room was used to house the VRS system control room. A metal sided building, 6.1 meters by 15.2 meters (20 feet by 50 feet), was constructed adjacent to the storage room to house the asphalt storage tank, the electric boiler and other auxiliary equipment (see Fig. 3).

The retrofit installation was completed by spring 1982.

SYSTEM STARTUP

The system startup procedures included hydrostatic piping tests, wiring continuity checks, and instrument calibration. The auxiliary system startup testing began in July 1982. The extruder-evaporator was first operated with pure asphalt in September 1982.

Startup testing of the process was conducted with simulated nonradioactive wastes. The simulated wastes tested included boric acid, bead resin, and powdered resin. Four separate startup test programs were conducted. WasteChem conducted the startup program until February 1983.

Consumers Power Company conducted an operator training session and process parameter optimization program from mid-March to mid-April 1983 and performed further tests in August 1983. WasteChem returned to Palisades in early December 1983 to provide further system parameter optimization.

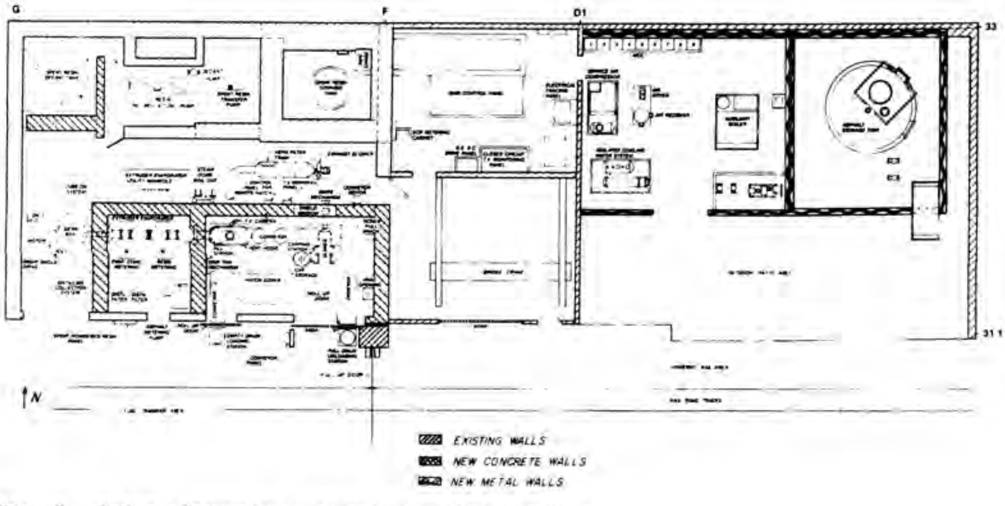

Fig. 3. Volume Reduction System Equipment Location.

PROCESS PARAMETERS AND WASTE FORM

The major concern of startup testing was the determination of the process parameters for boric acid concentrates, the major waste stream at the plant. The capability to solidify bead and powdered resin was also desired along with filter encapsulation.

The waste and asphalt feed rates to the extruder are determined by the solids content of the feed and the desired waste loading in the product. A process evaporative rate of 120 liters/hr (0.53 gpm) was desired for all waste streams at Palisades. The simulated waste forms produced by the system were freestanding monoliths with no freestanding water.

Boric Acid

Boric acid waste generated at the Palisades plant averages about 20,000 ppm of boron, which corresponds to approximately 12 wt. % boric acid. The boric acid is neutralized with sodium hydroxide prior to processing in the extruder. The amount of sodium hydroxide added for neutralization will determine the final sodium borate salt formation in the product. Pentaborate, tetraborate, and metaborate are possible products of the neutralization process. By monitoring the pH of the solution during neutralization, the waste formation can be determined. Pentaborate formation is predominant at a pH of 7.8, tetraborate at a pH of 9.3, and metaborate at a pH of 11.0. As the extruder-evaporator is made of carbon steel, a pH below 7.0 is not recommended. During startup testing, it was determined that the metaborate salt resulted in a product texture which was foamy or grainy. Of the two remaining formations, pentaborate is preferred as it has a lower saturation temperature and requires less sodium hydroxide than tetraborate. Due to this consideration, process optimization work was only performed for the pentaborate formation. Accordingly, CPCo placed the high and low set points on the divert valve for the concentrates feed line at 8.5 and 7.3, respectively. The assumed salt formation in the product is sodium pentaborate dihydrate.

The waste forms for concentrated boric acid were homogeneous, without voids, contained no free water and provided a large drum fill fraction of approximately 94% in a single pass. Evaporative rates as high as 140 to 150 liters/hr have been achieved (see Fig. 4).

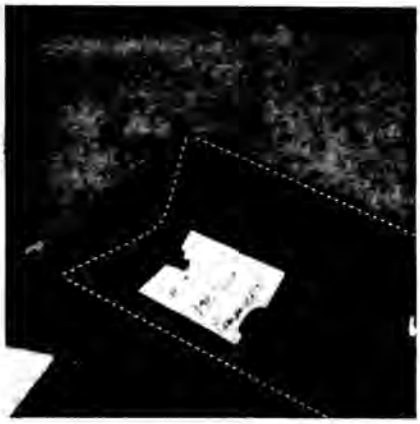
Fig. 4. Solidified Boric Acid at 140 liters/hr.

To ensure a sufficient operating margin, boric acid is processed with an evaporative rate of 120 liters/hr, a waste feed rate of 125 liters/hr (0.55 gpm), and an asphalt feed rate of 18 liters/hr (0.08 gpm). The mass flow rates are 129 kg/hr (284 lb/hr) of concentrates solution and 18.6 kg/hr (41 lb/hr) of asphalt. These feed rates result in a final waste form containing about 45% waste solids.

Spent Resin

The startup tests for spent resin processing proved more difficult than the concentrates testing. Previous European experience with resin processing was used to develop the initial startup set points. The European experience, however, was gained on systems which utilized multiple-pass drum filling with turntables. The one-pass drum fill was performed at Palisades for the first time. This required that the process be optimized to produce a high quality product with a single pass.

In the initial WasteChem tests, both bead and powdered resin were tested. The bead resin slurry formulated for processing contained 33 wt. % wet resin or about 15 wt. % bone dry resin. The powdered resin slurry formulated contained 30 wt. % wet resin or about 13 wt. % bone dry resin. The simulated waste forms for bead and powdered resin were also free-standing monoliths. These initial products, however, contained voids and/or exhibited significant shrinkage.

It was determined from these initial resin tests that the bulk temperature of the waste mixture was ultimately determined by the waste feed rates. To provide sufficient heating, the steam flow controllers were required to be in a fully open position. To compensate for insufficient heating, the extruder screws were exchanged to incorporate more kneading and fewer conveying elements. This modification increased the asphalt waste mixture residence time inside the extruder allowing the waste to "cook" longer.

Process runs performed after the modification showed little improvement for bead resin. The bead resin product produced from a 120-liters/hr run shrank to about two-thirds of its original size and contained large interior voids. The net effect was a drum fill of approximately 50%. The product produced from a 90-liters/hr run contained a void space near the top of the monolith; the region above the void consisted of a honeycombed lattice. For an 80-liters/hr run, the lattice contained a small amount (less than 2 ml) of encapsulated water.

It should be noted that for all of these products, the lower portions of the monoliths were homogeneous and contained no voids.

Fig. 5. Solidified Bead Resin at 80 liters/hr.

The powdered resin products produced from a 120-liters/hr run shrank to half their size in 1 day with about 50% of the shrinkage occurring within the first 2 hours. A good product was obtained from a 90-liters/hr run. The product was homogeneous, contained no voids, and provided a good fill fraction. Powdered resins were not tested further as their use was discontinued at the plant.

In an effort to overcome the problems with the initial results, several strategies were employed during CPCo's parameter optimization program. The major goals of the program were to establish operational set points and obtain a good bead resin product.

At first, several runs were performed with an increased temperature profile. Although improvements in the product were made, a small void remained, even for process runs as low as 70 liters/hr. A run with a cold temperature profile was also attempted. The lower temperature increased the viscosity of the asphalt and the torque on the extruder. As the initial torque set point was approached in this run, no further runs were attempted.

WasteChem returned to Palisades in December 1983 to perform further resin optimization runs. The torque set point was increased from 50% to 70% of capacity. The temperature profile was adjusted to a setting similar to that previously used for concentrates except that the last barrel was reduced to 87.8$^{\mathrm{C}}$ (190°F). The bulk temperature of the product exiting the extruder was measured with a probe at 115.6°C (240°F), about 5.5°C (10°F) cooler than in previous runs. Several 80-liters/hr resin runs and a 105-liters/hr resin run were performed. The 105-liters/hr run contained a small void of about 0.4 liter in volume. The products produced from the 80-liters/hr runs contained no voids and a fill fraction of 90% or greater was achieved in each case (see Fig. 5).

Small homogeneously distributed pores were contained in the product. These pores did not contain any water and were spaced relatively far apart, 3 mm (1/8 in.) to 6 mm (1/4 in.). The operating feed rates for acceptable resin processing with an 80-liters/hr evaporative rate are 77 liters/hr (0.34 gpm) of resin slurry (50 vol. % or 33 wt. % resin) and 16 liters/hr (0.07 gpm) of asphalt. The mass flow rates are 89 kg/hr (196 lb/hr) of resin slurry and 15.2 kg/hr (35 lb/hr) of asphalt.

Cartridge Filter Encapsulation

Simulated cartridge filter encapsulation tests were performed in August 1983. One filter was encapsulated in each drum. These tests determined that the filters should be allowed to drip dry before loading into a drum. A perforated PVC tube was initially used as a support basket for the cartridge filters. Test results showed that the PVC tube could not withstand the high asphalt temperatures, and a wire mesh basket was used instead. The examination of the final product revealed that the filter was well coated and that the asphalt had penetrated the pleated paper.

At present, filter encapsulations are not planned at Palisades because there is no area currently available in which filters may be allowed to dry. Filters will continue to be packaged in high integrity containers until such time as provisions for filter drying are made.

Operational Experience

Radioactive concentrates were first processed by the VRS system on February 1, 1984. As of this writing, three waste boric acid batches have been processed resulting in six drums. One drum has been produced from approximately every 300 gallons processed. This corresponds to the previous cement process of approximately 10 drums for every 300 gallons of boric acid solidified. The external dose rate from these drums has ranged from 170 mR/hr to 770 mR/hr. Measurements taken from four of the drums were under 300 mR/hr and one drum showed a reading of 330 mR/hr. Only Class A waste has been solidified to date. Curie contents will not be determined until the waste is shipped. The curie content will be determined from the waste samples taken from each batch prior to processing.

CONCLUSION

Several important items relevant to the industry have been identified as a result of the VRS system installation at the Palisades Plant.

First, plant space occupied by obsolete or abandoned equipment can be utilized to house volume reduction equipment. The cost benefit, if any exists, of decontaminating such spaces for reuse is site specific.

Second, the extruder-evaporator has been demonstrated to process boric acid powdered resin and bead resin. Dry filter encapsulation has also been demonstrated.

Third, the results of the startup testing point out the need for future comparisons of the single-pass fill station versus a multipass turntable, especially for resin processing.

Further monitoring of the system will continue under EPRI Contract RP-1557 to determine the operational performance and maintenance requirements of the system.