COMPARISON OF LIQUID WASTE PROCESSING AND WASTE SOLIDIFICATION TECHNIQUES USED AT PALO VERDE NUCLEAR GENERATING STATION

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ABSTRACT

This paper covers liquid waste processing and solidification techniques utilized at Palo Verde Nuclear Generating Station (PVNGS). It emphasizes the operating experience gained on two different volume reduction techniques contrasted against the normally utilized cementation method used to solidify the resultant waste produced by waste evaporators.

INTRODUCTION

PALO VERDE (PVNGS) is a three unit Combustion Engineers pressurized water reactor. Each reactor is rated at 1270 MegaWatts electrical. Built on a site over 4,000 acres in size, PVNGS is a joint effort of seven utilities in Arizona, California, Texas, and New Mexico. The station is located approximately 100 kilometers from Phoenix, Arizona in the arid southwestern part of the United States of America.

The location of the station dictated that unique water usage and conservation methods be utilized. The units are designed to have no liquid radioactive releases generated from them.

The design of the liquid radwaste processing system includes both a liquid radwaste evaporator and a boric acid concentrator along with ion exchange demineralizers. The design of the plant includes no cross-tie capability. Each unit is a stand-alone facility. Each unit has its own radwaste equipment and control room.

LIQUID RADWASTE SYSTEM

The Liquid Radwaste System (LRS) is dependent on the operation of the radwaste evaporators as the primary processing method for radwaste solutions. After correcting several major problems with the LRS equipment that became apparent during startup of the system the waste evaporators have given good dependable service. The capacity is somewhat below design but still adequate to process all normal inleakage and produce acceptable quality distillate.

The original predicted inleakage was not attainable with the plant as originally designed and built. Extensive efforts were made to locate the sources of inleakage and to develop action plans which would reduce our inleakage to closer to the original design values.(1)

Table I shows the original design values for expected inleakage into the LRS. These values are contrasted to show the actual values at the time of initial criticality of Unit I and what efforts have been made to improve the actual values so they are closer to the original design.

Major sources of identified inleakage were the secondary sample laboratory drains, evaporative cooling units located on the roof of the radwaste and auxilary buildings, seal/cooling water supplied to several major pumps in the radwaste and main steam supply system building, and seal water supplied to the sump pump in the radwaste and auxilary building. Changes have been made and an administrative program developed which allows the tracking of inleakage and has increased the importance of work requests related to inleakage.

TABLE I

Waste Input to the Liquid Radwaste System

Inleakage Per Day Per Reactor

Expected Inleakage Liters (Gallons)	Actual 1985 Liters (Gallons)	Goal for 1991* Liters (Gallons)
7 575 (2,004)	38 745 (10,250)	17 010 (4,500)

*Expected was value included in FSAR before startup. Goal is based on 1990 actual inleakage.

The plant's water inventory is controlled by the use of the boric acid evaporator. The evaporator is operated in the atmospheric discharge mode where the steam that ordinarily would be condensed as distillate is released to the normal atmospheric plant discharge. The ability to operate in this mode was originally designed into the plant.

Even though we have not met the design inleakage value, the changes made in waste solidification, dry active waste processing and spent resin packaging have reduced our final disposal volume below the original design value. Table II shows where we have made improvements over the design values.

SOLID RADWASTE SYSTEM

Changes in U.S. federal regulations made the solidification portion of the radwaste system incapable of producing a final solidified product which would meet the new regulations without making modifications to the system. Additional changes to other U.S. regulations have forced utilities to volume reduce their waste to the maximum extent possible. Based on this knowledge it was determined that rather than spend additional funds on the modifications to the existing system a better use of funds would be to obtain the services/use of non-permanent volume reduction equipment. In late 1986 PVNGS contracted with a service company to utilize a mobile asphalt process. This system was used in late 1986 and again in 1987 and processed a total of about 76 000 liters of evaporator concentrates. Volume reduction equipment was not utilized again at PVNGS until 1990 when testing was conducted on a new blender/dryer system.

TABLE II

Solid Radwaste System Output Volumes

Per Reactor

Source	Design Volume cu. mtrs. (cu. ft.)	Actual 1990 Volume cu. mtrs. (cu. ft.)	Containers In Drums Expected/Actual
Wet Waste			
Evaporator concentrates	122 (4,299)	119 (4,187)	585/558
Spent Resin	33 (1,147)	19 (663)	158/89
Dry Active Waste			
Compacted waste	105 (3,697)	43 (1,503)	503/200
Filters			
Cartridge filters	3.5 (125)	1.5 (50)	17/7
Miscellaneous	0.1 (3.5)	9 (318)	1/43
TOTAL	263.6 (9,272)	191.5 (6,722)	1,263/897

The mobile systems used at PVNGS were designed to meet all appropriate nuclear station radwaste system requirements and the applicable regulatory codes and standards. These criteria required the system design basis to be in accordance with NRC Regulatory Guide 1.143 and ANSI 40.35.

Federal requirements were addressed for both volume reduction systems under 10 CFR 50.59, "Changes, Tests, and Experiments", which determined that there were no unresolved safety issues.

TECHNICAL DESCRIPTION OF VR SYSTEMS

The TVR-III Bitumen System

The first volume reduction system used was a one-step volume reduction and bitumen solidification concept. A Luwa Thin-Film Evaporator, operating at a waste product temperature of 140 degrees - 200 degrees C, (285 degrees to 390 degrees F), was used to evaporate all free water from the waste influents. The remaining solids were homogeneously dispersed in a bitumen matrix while inside the evaporator.

The evaporator concentrate was transferred into the Waste Batch Tank where it was chemically pretreated to prepare it for processing and to insure the solidified waste met the requirements of 10 CFR Part 61. The Waste Batch Tank was agitated to insure the contents remained a homogeneous mixture.

The prepared waste was fed at approximately 150 liters/hr (40 gph) into the Evaporator. Molten bitumen was simultaneously metered into the Evaporator through a second feed nozzle. The Evaporator was heated by means of a synthetic heating fluid circulated through an external jacket. As both the radwaste and bitumen were fed into the Evaporator, the rotor blade spread the two streams into a thin, turbulent film against the heated internal surface. The action of the rotor blades and the force of gravity created a spiral flow of the waste/bitumen mixture. As the water flowed downward through the Evaporator, water was evaporated and the vapor flowed counter-currently upward and out. The remaining radwaste mixture exited through the bottom of the Evaporator into 208 liter (55-gallon) drums. Upon cooling, the waste/bitumen mixture solidified into a free-standing, monolithic, water-free solid acceptable for storage or disposal.

The vapor leaving the Evaporator was condensed in a shell and tube Condenser and flowed into the Distillate Collection Tank. When this tank was filled the distillate was pumped through a series of filters to the plant liquid waste system. Any non-condensables from the Condenser were discharged into the process exhaust air system where they passed through HEPA and charcoal filters prior to being discharged to the plant ventilation system.

The TVR-III was a completely self-contained processing system mounted on a 3 M (10 ft.) wide by 14 M (46 ft.) long double drop, low-boy trailer. Figure 2 is a plan view of the system showing the TVR-III divided into six areas or rooms: Control, Auxiliary, Process, Waste, Distillate, and Loadout. All areas except the Control Room incorporate spill containment capable to controlling the contents of any liquid container located within the area. A spill in the Process, Waste, and Distillate Areas can be removed by a sump pump to the Waste Batch Tank or an external tank.

The Control Room contains the main control panel as well as the electrical and control equipment for operation of the entire system. The Control Room is the only normally occupied area and is separated from the radioactive process areas by the non-active Auxiliary Area and removable shield.

In addition to the areas contained within the main truck bed the system also includes a free standing Bitumen Storage Tank that sits adjacent to the trailer. This is a fully insulated tank with double shell construction to prevent possible leaks.

The bituminized end product was a free standing monolithic solid with no free liquid. Drums were filled using one, two and three passes. All drums exceeded the 85% drum fill requirement. The waste at Palo Verde was solidified using both oxidized and straight distilled asphalt. Minor surface contamination was encountered on some drums after filling. They were easily decontaminated to below the site levels (for contamination) prior to shipment for disposal.

In order to utilize the TVR-III several changes in the plant's normal operating methods were made. These changes were viewed as significant enough to warrant not utilizing the unit on a long term basis. An evaluation was made as to whether to procure a system designed specifically for PVNGS which could be backfitted into existing space rather than continue to utilize the mobile system as described. The decision was not to pursue the purchase of a specifically designed system but to continue to utilize mobile systems, preferably, a system that could fit into an existing building.

The RVR Blender/Dryer System

The RVR Blender/Dryer System is designed to provide the greatest volume reduction possible for concentrates. The system'svacuum/dryer will reduce evaporator concentrates to a dry solid, loaded into 208 liter (55 gallon) drums for shipment and disposal, with condensate for reuse.

The blender/dryer steam jacket is preheated by the steam generator. Plant evaporator concentrates are introduced through a waste feed valve to the vacuum/dryer until the proper amount of waste has been added. When a high level is indicated the inlet valve automatically closes. Vacuum on the blender/dryer is maintained at 25-28" Hg. which allows low temperature drying to take place. Steam vapor is pulled from the blender/dryer through a condenser. The condenser is cooled by a chilled water system via its 50 ton chiller skid located outside of the Radwaste Truckbay. The condensate is routed to the condensate reservoir from which it is returned to the plant or reused as the motive fluid for the jet pump.

After approximately three hours of operation, the blender/dryer will boil down to the low level addition point. The inlet valve will open and refill the blender/dryer to the proper level then close. Typically, three such batches are needed to complete one cycle.

The final drying phase begins with the end of the third transfer. Temperature indication is used to indicate that drying has been completed. Since our waste stream is a Class A waste stream per 10 CFR Part 61, we did not have to meet the stability requirements. The system was originally designed to produce an end product which was either a dried powder or a pellet when a pelletizer is incorporated into the system. At PVNGS we did not want to place unbound material into a container and felt that it was best, based on PVNGS's experience, to require binding of the end product and as a consequence a binding agent was incorporated into the process.

The final step is the adding of the binding agent to the dried material. Approximately 64 kilograms (140 pounds) of binding agent or 20-25 wt.% of the final produce is added to the blender/dryer. The blender/dryer mixes the binder with the waste powder for about 20 minutes. Then the final produce is discharged into a 55 gallon drum contained inside a drum enclosure which incorporates a HEPA filtering system.

TRANSPORTATION, SETUP AND PROCESSING

The TVR-III required less set-up time since the major components were self-contained. It normally took 3 days to setup. The RVR system took slightly longer since it had to be setup inside existing space and is of a more permanent nature.

Two campaigns of waste processing occurred with the TVR-III during which a total of about 76 000 liters (approximately 20,000 gallons) of boric acid concentrates and flush water were processed.

The boric acid concentration was significantly higher than is normal for waste evaporator systems during all the periods when volume reduction equipment were used. This higher concentration reduced the volume of waste requiring processing and also effected the volume reduction values. As a consequence, the volume reduction achieved with the bitumen process was only 3.7 versus an expected 5.4 and the volume reduction ratio achieved with the RVR was 5.0 rather than the 7.0 expected for boric acid wastes at a concentration of 12 wt.%. When dealing with varying concentrations of waste the best method of determining the system's efficiency is how much waste, in pounds of material, is contained in the final waste container. Details of the end product are given in Table III.

Any time a mobile system is used that is not specifically designed for your facility some difficulties will be encountered. At Palo Verde our difficulty with the TVR-III system was in space requirements and having to have some of the hardware located outside the radwaste facility. Additionally, the location that the system was placed in caused problems with loading and unloading drums, shielding for transfer of hotter drums, and the added length of time to set up the system when compared to a mobile cement solidification system.

In addition to the problem noted with the feedstream boron concentration several other incidents created slowdowns and reduced efficiency in processing. This was somewhat expected since each use of a mobile or transportable system is similar to the initial startup of a new system. The most significant problem encountered during the use of all the mobile systems has been the minor spills which have occurred. These have been contained and no off-site releases have occurred but they do need to be considered and planned for in advance. These spills were cleaned up within a few hours and modifications made to eliminate their recurrence either by procedural changes or by equipment changes.

TABLE III

Processing Characteristics

	BITUMEN	RVR
Volume of waste processed in liters	76 000	14 000
Solids content of feed wt.%	18-23	17-39
Number of Drums Produced	100	16
Gross Drum Weight, kgs (lbs)	250 (550)	318 (700)
Solids Content of End Product, %	50-60	75-80
Free Water, %	0	0
Fill - One Pass, %	88-97	94-99
Two Passes, %	94-99	
Surface Dose Rate, mR/Hr	60-180	60-90
Waste classification	Class A unstable	Class A unstable

ECONOMICS

While it is still too early to determine if the full advantage of volume reduction economics are being obtained, the expected savings versus other methods of processing have been shown. The economics of the volume reduction techniques used are contrasted to the standard cementation process used in the past. As can be seen, the volume reductions techniques used have shown the potential to be significant in both reducing the total cost of handling a plant's waste (processing, transportation and burial) and reducing the volume of waste requiring storage or burial. The expected savings will be dependent upon the individual

TABLE IV

Cost to Process Liquid Waste Using Mobile Vendor Services

System	Price/Liter	Liters/Yr/Rx	Cost	VRF	Disposal Vol
Cement	\$5.86 \$22.16/gal	64 260 17,000 gals	\$377,000	.7	91.96 cu. mtrs. 3,247 cu. ft.
Bitumen	\$5.40 \$20.42/gal	64 260 17,000 gals	\$347,000	3.7	17.39 cu. mtrs. 614 cu. ft.
RVR	\$3.49 \$13.20/gal	64 260 17,000 gals	\$224,000	5.0	12.89 cu. mtrs. 455 cu. ft.

Based on 64 200 liters (17,000 gallons) of concentrates generated per year per reactor. Price includes all processing charges, containers, binding agent, transportation and disposal charges in 1990 US dollars.

plant's location, amount of waste generated, and the waste processing method currently being used. Table IV is based on actual cost and final disposal volume for the various methods utilized. The minimal expected cost savings for the entire site, by using the RVR, is \$459,000 and 238 cu. mtrs. (8,400 cu. ft.) of burial volume per year. The saving are expected to double when the new Regional Disposal Site begins to operate in 1992.

SUMMARY

The economics of use of either volume reduction system were significant in both reducing the volume of waste requiring storage or burial and in reducing the total costs of handling a plant's waste (processing, transportation and burial).

The startup and operational experience from PVNGS verifies that a zero liquid release facility can be successfully operated if adequate design considerations and management techniques are utilized. However, the price for a zero release facility is constance vigilance for inleakage and equipment failure. Where design values are underestimated, a concentrated effort is required in order to successfully operate such a facility. It also requires the realization that the final wet waste volumes generated will be greater for a zero release facility, even when the maximum volume reduction techniques are utilized, than for facilities which have the ability to make liquid discharges.

REFERENCE

1. T. P. Hillmer "Operational Experience at Palo Verde Nuclear Generating Station, Phoenix, Arizona, USA" contained in the Proceedings of the 1987 International Waste Management Conference, Hong Kong, November 29 - December 5, 1987.