SELECTION AND PROTOTYPE TESTING OF A RADWASTE VOLUME REDUCTION AND SOLIDIFICATION (VRS) SYSTEM

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ABSTRACT

Tennessee Valley Authority was the first utility to implement the EPRI VR Tech computer code to evaluate radwaste volume reduction systems. TVA used the code to assist in the development of a radwaste management strategy and selection of the process system.

Inputs to the code included guaranteed performance data from the vendor. As part of its bid request, TVA required the VR systems suppliers to propose a prototype test program to confirm the guaranteed performance data. This paper describes the results of the economic and testing evaluations.

INTRODUCTION

In 1983, TVA adopted a radwaste management plan that provides significant volume reduction, requires minimal capital expenditures and has a positive cost benefit. TVA utilized the VR Tech computer code developed by EPRI to evaluate candidate VR technologies for TVA plants. The results of those studies were reported at Waste Management '84.

In 1984, TVA began implementation of their radwaste management plan by electing to replace the cement system at the Bellefonte Nuclear Power Plant, a twin 1100 MWe pressurized water reactor. TVA evaluated several VR systems using criteria which included the following:

1. The system must have operating experience.
2. The system must fit in available plant space with minimal modifications to the existing facility.
3. A positive cost benefit must result from the purchase, installation and operation of the system.
4. Significant volume reduction must be achieved.
5. Solidified products must be demonstrated to meet 10CFR61 requirements.

VRS SYSTEM SELECTION

TVA solicited bids in August 1984. Proposals were evaluated with the assistance of the EPRI VR Tech computer code. Input to the Code included the bidder's guaranteed volume reduction performance data and TVA generated installation costs, operating and disposal costs and escalation. In December 1984, TVA selected WasteChem's Volume Reduction and Solidification (VRS™) System for installation at Bellefonte. The VRS system utilizes an extruder-evaporator to simultaneously volume reduce radwaste and solidify them in an asphalt binder.

The VRS system is being installed in an area previously planned for a cement solidification system. Modifications to the facility were limited to four wall penetrations, one for process equipment, one for a shield window and two for drum transfer.

Table I provides the results of the VR Tech computer code for systems evaluated by TVA. The VRS system installation at Bellefonte has a potential $40 million present worth cost advantage over the cement solidification system for the life of the plant. This is equivalent to annual savings of over $1.5 million.

These cost benefit calculations were based on the system being installed prior to anticipated commercial operation of Bellefonte in 1988. However, since that time, Bellefonte has been delayed to approximately 1995. The delay results in a reduced, but still substantial positive cost benefit.

PROTOTYPE TESTING

TVA required in its bid request that vendors propose prototype testing to confirm the guaranteed performance data provided by the vendor in his proposal and to establish a base line for development of system start-up and operating procedures. Prototype testing was performed at WasteChem's pilot plant facilities in Ramsey, New Jersey. Full compliance with 10CFR61 was required by the contract. Testing to demonstrate compliance was underway at the time of contract award.

The prototype tests were specifically intended to identify the following performance characteristics for each waste influent:

1. Volume reduction factor including a determination of product shrinkage.
2. Compressive strength of solidified products.
3. Homogeneity of the solidified product.
4. Lack of free standing water in the solidified product.
5. Condensate (distillate) water quality.
6. Concentration of particulates in the off-gas and the species of volatile organics present in the off-gas.

Five Bellefonte-specific waste simulates were prepared in accordance with requirements of the contract. These were spent cation bead resins, spent mixed bed bead resins, boric acid, sodium sulfate and oil. The properties of the simulated wastes are shown on Table II.

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TABLE I

Cost Benefit

WasteChem
Avg. Escalation Rates - Book Life = 27 Years
Cost of Money = 15%
Present Value Costs In 1985 Dollars -
27 Operational Year(s)

Escalation for VR/Solidification = 0.060
Escalation for Storage = 0.000
Escalation for Transportation = 0.080

Escalation for Burial Before 1986 = 0.150
Escalation for Burial After 1986 = 0.100

OPERATION	COTRASH	CVCSRESIN	SULFATE	BORIC	NCTR/C/NC	SUBTOTALS
Chemical Additives	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Containers	1.54E+05	1.14E+04	5.97E+04	2.31E+04	2.57E+05	5.05E+05
Solidifying Agents	0.00E+00	1.36E+04	7.11E+04	2.75E+04	0.00E+00	1.12E+05
Utilities	0.00E+00	1.08E+03	5.67E+03	2.19E+03	0.00E+00	8.94E+03
Transportation	1.65E+06	9.98E+05	3.46E+05	2.00E+06	1.01E+05	5.09E+06
Burial	4.36E+06	5.87E+06	1.49E+06	9.07E+06	2.94E+06	2.37E+07
Miscellaneous	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Operation Labor	********	********	********	********	********	8.29E+05
Maintenance	********	********	********	********	********	1.37E+06
Subtotals	6.16E+06	6.89E+06	1.98E+06	1.11E+07	3.30E+06	3.16E+07
Savings	0.00E+00	4.95E+06	1.25E+07	2.52E+07	0.00E+00	4.09E+07
Volume (ft^3)	6.89E+03	5.10E+02	2.68E+03	1.04E+03	9.17E+03	2.03E+04

TABLE II

Simulated Waste Feed Properties

	Spent Resins		Boric	Sodium	
	Cation	Mixed Bed	Acid	Sulfate	Oil
Bulk Resin Density (lb/ft^3)	44	42	N/A	N/A	N/A
% Moisture Content	48.6%	51.4%	N/A	N/A	N/A
Sample Weight before drying (g)	18.194	24.023	N/A	N/A	N/A
Sample Weight after drying (g)	9.352	11.737	N/A	N/A	N/A
Specific Gravity	N/A	N/A	1.066 @ 63.3°C	1.28 @ 58°C	1.53 @ 23°C
Solids Content (by weight)	51.4%	48.6%	12%**	25%	55.1%
Feed Temperature (°F)	Ambient	Ambient	150	171	72
Feed pH	6.5	6.5	9.5	7.0	7.5

Prototype testing of the Radwaste Solidification System for Bellefonte was conducted in accordance with TVA approved procedures. One 30 gallon drum of solidified waste product was produced for each of two (2) resin feeds (cation and mixed bed), a boric acid (sodium borate) feed, a sodium sulfate feed and an oil feed. Multiple smaller samples of each product were also taken for analytical testing. The following parameters were quantified during the test program.

1. Simulated Waste Feed Properties

   a. Bulk density and moisture content (spent resin feeds)
   b. Specific gravity (liquid feeds)
   c. Solids content (boric acid and liquid sodium sulfate feeds)
   d. Feed temperature and feed pH (boric acid and liquid sodium sulfate feeds)

2. Operating Data

   a. Waste feed rate (volumetric or gravimetric)
   b. Asphalt feed rate (volumetric or gravimetric)
   c. Drum fill time
   d. Product temperature
   e. Extruder-evaporator temperature profile
   f. Off-gas flow rate

3. Solidified Waste Product Properties

   a. Free standing water (absence of)
   b. Uniformity/homogeneity
   c. Specific gravity
   d. Weight of product per drum
   e. Compressive strength
   f. Product shrinkage
   g. Performance in 90 day immersion test including post-test compressive strength (oil waste form only)
   h. 10CFR61 testing for oil waste only

4. Off-Gas Properties

   a. Volatile organics (species)
   b. Particulate content

5. Condensate (Distillate) Properties

   a. pH
   b. Total dissolved solids
   c. Total suspended solids
   d. Total organic carbon (before and after filtration)

6. Asphalt Properties

   a. Specific gravity
   b. Compressive strength

Process data was recorded and used either directly or indirectly (through calculation) to produce the performance characteristics summarized in Tables III and IV. These tables contain a compilation of process variables/characteristics which have contractual significance and a comparison of actual system performance vs. contractual acceptance criteria for each process variable.

TABLE III

Volume Reduction Factors/Waste Loadings

Simulated Waste Feed	Volume Reduction Factor		Waste Loading	
	Actual	Guaranteed	Actual (lbs/drum)	Guaranteed (lbs/drum)
Spent Resins (dewatered)				
o Cation	1.7	1.7	344	N/A
o Mixed Bed	1.88	1.7	381	333
Boric Acid (12 wt%) (as sodium pentaborate)	6.39	6.3	278	267
Sodium Sulfate (40 wt%)	Not Determined	1.65	497	400
Oil	Not Determined	N/A	23	23

TABLE IV

Solidified Waste Product Properties

	Spent Resins		Boric Acid	Sodium Sulfate	Oil	Acceptance Criteria
	Cation	Mixed Bed				
Free Standing Water	None	None	None	None	None	None
Uniformity/Homogeneity	(1)	(1)	(1)	(1)	(1)	(1)
Specific Gravity	1.27	1.12	1.4	1.71	1.03	N/A
Compressive Strength	166 to 228 psi	187 to 197 psi	226 to 296 psi	130 to 161 psi	-	50 psi min.
Product Shrinkage %	3.7%	3.7%	4.5%	4.1%	6.2%	N/A
Distillate pH	6.5	10	8.5	6.5	1.5	6-9
Off-Gas Properties	(2)	(2)	(2)	(2)	(2)	N/A

NOTES: (1) No separation or stratification of waste from the binder; no voids.

(2) No volatile organics were detectable for cation resins, boric acid, sodium sulfate or oil and only trace amounts were detected on mixed bed resins.

Based on data available at this time, the following conclusions can be drawn:

(1) All solidified waste products were uniform, homogeneous and free of voids.

(2) There was no free water in any solidified waste product.

(3) For each simulated waste stream, the volume reduction factor or waste loading per drum exceeded that guaranteed in the contract.