VOLUME REDUCTION SERVICES -

THE ALTERNATIVE TO PERMANENT SYSTEMS

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ABSTRACT

Interest in radwaste volume reduction/solidification services has increased dramatically in the past two years. This increase is due in part to the increasing complexity of selecting a permanent low-level radwaste system for installation at a nuclear power plant. This paper examines the viability of a volume reduction/solidification service as a short and long-term alternative to a permanent system. Issues examined in comparing services to permanent systems include capital versus operating funds, time required for start up, space requirements, licensing, technology obsolescence, and regulatory changes. A portion of this paper focuses on one specific aspect of the evaluation of alternatives - the acceptability of the product. To illustrate the evaluation of product acceptability, a bituminized waste form produced by a volume reduction system is examined for leach resistance.

INTRODUCTION

Operational nuclear power plants generate varying quantities of liquid and solid wastes that require solidification prior to shipment and disposal at shallow land burial facilities. The rapid and continuing escalation of the transportation and burial charges has caused the power plant operator to consider the use of volume reduction equipment to bring down this high annual cost. However, the problems in the adoption of volume reduction at the plants have kept all but a few utilities from making a permanent change.

Currently in the United States the nuclear power utilities use cement as the major method of solidification of the wastes prior to their shipment and disposal. The liquids may be volume reduced through the process of evaporation. However, this volume decrease is far overridden by the volume increase of the cement solidification process which follows.

The rapid rise in the charges by the burial ground operators would appear to give, at the first glance, reason for the immediate installation of volume reduction equipment at every nuclear installation in the country today. But when examined in closer detail the actual cost of facility modification coupled with the high cost of money in today's market make the payback of volume reduction equipment viable for large waste generators. In fact, the burial charges may appear to stay just below the point where a utility could find an attractive payback in installation of a new permanent volume reduction system. The effect of a burial ground rate change may make a life of plant decision for a permanent volume reduction or solidification retrofit invalid. An example is the recent 1983 rate change at Barnwell which in effect reduced the difference in cost between volume reduced waste and non-volume reduced waste.

The high installed costs have also kept the utilities from retrofitting permanent solidification systems. A large new business area has developed to provide mobile solidification services to the operational nuclear power plants. The recent development of transportable volume reduction now presents the utilities with an alternative to the use of a volume increasing solidification service.

At the present time, one Transportable Volume Reduction System (TVR) is being fabricated. The TVR system will be tested and put into operation at a U. S. nuclear power plant in the summer of 1983. The TVR consists of four skids installed together. They have an overall length of 80 feet and a width of 12 feet.

The TVR sytem is self-contained in a totally enclosed structural steel module. The system, which is a complete and operable volume reduction and bitumen solidification system, is prewired and prepiped to the maximum extent possible to minimize the number of field connections required. A material handling system is provided for handling empty and filled drums. Radiation protection is provided by lead and concrete shielding.

The vendor is providing the TVR equipment, supervisors, operators and materials necessary to receive, process, drum and prepare for shipment radioactive wastes generated from plant operations.

Maintenance of the system is the responsibility of the vendor. The vendor is also responsible for procuring chemical reagents, solidification agent, 55-gallon drums, and all other material required for waste processing and packaging.

The process used in the system was developed in France in the early 1960's. The process, a one-step volume reduction and solidification in bitumen, is proven and has been operating in both Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) plants for a number of years. In addition to the operation at nuclear power stations, the system is being used in research, military and fuel reprocessing centers. The process has years of experience in volume reducing and solidifying both bead and powdered resins, sodium sulfate concentrates, boric acid concentrates, equipment and floor drain wastes, decontamination wastes and laundry wastes.

ECONOMIC COMPARISON

Before the costs of using a TVR system can be compared to other methods of waste processing, a base line of plant waste volumes and plant parameters are required. The parameters used in this evaluation are shown in Table I.

TABLE I - INPUT ASSUMPTIONS

Parameter	Value
Plant distance to Burial Ground	1000 miles
Shield Rental Charge	$250/day
Burial Ground Charges (Barnwell)	1983 Prices
Shipment Time	5 days
Input Waste Streams	
Chemical Wastes (12% Boric Acid)	10,000 ft^3/yr
Concentrated Liquids (10% dissolved solids)	2,000 ft^3/yr
Resins (dewatered volume)	1,750 ft^3/yr
Sludges (dewatered volume)	500 ft^3/yr
Radiation Levels	
Final Cement Product	1.0 R/hr(liner)
Final Bitumen Product	.1 R/hr (drum)
Specific Activity of Product	
Cement	2.0 uCi/ml
Bitumen	5.0 uCi/ml
Waste Packages	
Cement	170 ft^3 liners
Bitumen	7.35 ft^3 drums
Lease Charges	
Cement	$15,000/mo*
Bitumen	$75,000/mo**
Processing Costs	
Cement	
Resins	$125/$ft^3$
Liquids	$65/$ft^3$
Bitumen	$25/$ft^3$

*Typical 1 year lease value.
**Typical 3 year lease value.

With the input values established, the following economic comparison can be made. The cost of TVR can be compared to the costs associated with a permanently installed cement solidification system excluding the original capital and installation costs. The TVR costs can also be compared to the charges for use of a mobile cement solidification system. Finally, the TVR service costs can be compared to the cost of the retrofit of a new volume reduction solidification system.

The evaluations of the permanent system costs include the cost of power, labor, materials and an expected annual maintenance cost.

The final solidified volumes for each waste processing method are shown in Table II. These volumes form the basis for the transportation and burial charges for each system.

TABLE II - WASTE DISPOSAL VOLUMES
(ft^3/year of solid product)

Waste Type	TVR	Permanent VR	Mobile Cement	Permanent Cement
Chem. Waste	2100	2100	15000	15000
Conc. Liquids	400	400	3000	3000
Resins	1000	1000	2500	2500
Sludges	250	250	700	700
TOTAL	3750	3750	21,200	21,200

A capital cost of $7.50 X 10^6 (1983 dollars) is used for the permanent volume reduction system. This figure is the cost of a new volume reduction/bitumen solidification system and the costs of engineering, design, plant modifications and equipment installation. For the purposes of this analysis, we will use a fixed charge rate of 17% and a ten-year-investment life period for the capital cost. First we will translate the capital cost into an annual charge for the ten-year period through the use of a Capital Recovery Factor (CRF).

$$CRF = \frac{i(1+i)^n}{(1+i)^n-1} \quad = \text{ in this case } \quad \frac{.12(1+.12)^{10}}{(1+.12)^{10}-1} \qquad \text{Eq. (1)}$$

$$CRF = .81716/3.80683 = .21465$$

The annual capital cost is therefore:

$$\$7.5 \times 10^6 \times .21465 = \$1.61 \times 10^6.$$

Table III compares the costs of the four different options.

The differential cost to TVR service shows the amount of money a utility could save over the use of the other options. The table shows that a saving of $260,000/year could be realized by a utility having waste volumes similar to the input values over the costs to operate a permanent cement solidification system without any recovery of the original equipment and installation costs.

For cement solidification, the largest costs are the burial charges. Since these charges have been escalating at a rate of over 100% a year, the future savings for use of a TVR service should be even larger.

TABLE III - Annual Cost Comparison
(Dollars multiplied by 10^3)

	Permanent TVR	Mobile VR	Permanent Cement	Cement
Annual operating Costs per ft^3	360	100	1,060	360
Capital Equip. Cost or Lease Fee	900*	1,610	180	--
Cask Rental & Transportation Cost	150	150	500	500
Burial Charges	180	180	980	980
TOTAL	1,590	2,040	2,720	1,850
Differential To TVR Service	--	+450	+1,130	+260

*This value is for a typical three year lease period. A significant cost reduction is seen over longer lease periods.

The use of a lease service for volume reduction and solidification offers a $450,000/year savings over the retrofit of a new volume reduction/solidification system. In addition, the lease offers the flexibility of changing the equipment after the lease period, if the waste volumes or burial ground regulations should warrant without having to lose a large capital investment.

The use of TVR services presents several other advantages over a permanent system installation. Some of the major advantages are:

- Defers large capital outlays
- Meets burial site volume allocation restrictions
- Reduces transportation and burial costs
- Complies with "no free water" requirements
- Evaluates volume reduction technology
- Accelerates the schedule to achieve volume reduction
- Provides a hedge against future regulatory changes
- Having trained operators reduces plant staff requirements
- Total maintenance program eliminates plant downtime.

Because the equipment comes either skid-mounted or on a rail car, the system does not require a new facility. Further, the modifications to the power plant are held to the absolute minimum. The plant requirements are a waste supply line and a distillate return line. Auxiliary services requirements are 480 volt power supply, 90 psig instrument air, cooling water and flush water. The entire TVR system is contained in structural steel modules and is completely compatible with location ouside of the existing plant buildings. The entire space envelope is 15 feet times 56 feet or 86 feet. The system can be at a plant site ready for operation within ten months of a contract. This time frame makes TVR very interesting when compared to a retrofit of a volume reduction/solidification system to a power plant. These complete retrofits typically take up to three years, from start to finish.

By choosing a service contract, a utility can begin saving at a minimum over two years before the permanent system. The services also reduces the regulatory requirements. The equipment in a service can be reviewed under 10CFR50.59 for a plant with an existing operating license. As long as the utility review finds no unresolved safety questions with the service at their plant, no licensing amendments are required.

These advantages should provide the utility with the type of waste volumes previously discussed with a definite option to cement solidification either permanent or service.

PROCESS DESCRIPTION

The concept is a simple chemical and physical process for reliably and economically reducing the volume of radwaste and for incorporating radwaste into a solidified bitumen matrix. The process uses a LUWA Thin-Film Evaporator, which operates at a waste product temperature of 320°F (160°C). This results in the evaporation of all free water from the waste influents. The remaining solids are homogenously dispersed in a bitumen matrix. Solidification of the end product occurs upon the natural cooling of the binder. Figure 1 is the Basic Flow Diagram for the TVR System.

Waste to be processed is charged into one of the waste batch tanks. There it is sampled and chemically pretreated to prepare it for processing. Water is decanted or added as required to obtain the desired concentration for processing.

When the waste has been conditioned for processing, it is fed at a controlled rate to the LUWA Thin-Film Evaporator. Molten bitumen is also fed into the evaporator by means of a hot thermal fluid flowing through an external jacket.

The evaporator rotor rotates within the cylindrical, heated body, maintaining the waste and bitumen in a thin, turbulent film against the heating surface. The action of the rotor and the force of gravity create a spiral flow path of waste/bitumen mixture as it flows from the top to the bottom of the evaporator. As the waste flows through the evaporator, the water is evaporated and the water vapor flows countercurrently upward and out of the evaporator. The waste solids, which are mixed with molten bitumen, exit the bottom of the evaporator, flowing into a waste container. Upon cooling, the waste/bitumen mixture solidifies into a free-standing, monolithic, water-free solid.

The water vapor leaving the evaporator is condensed in a shell-and-tube Condenser and flows onto the Distillate Collection Tank. When this tank is filled, the distillate is pumped through a series of activated carbon filters to remove any light oils that may have been vaporized from the bitumen in the Evaporator. The cleaned distillate then enters the plant's liquid waste system.

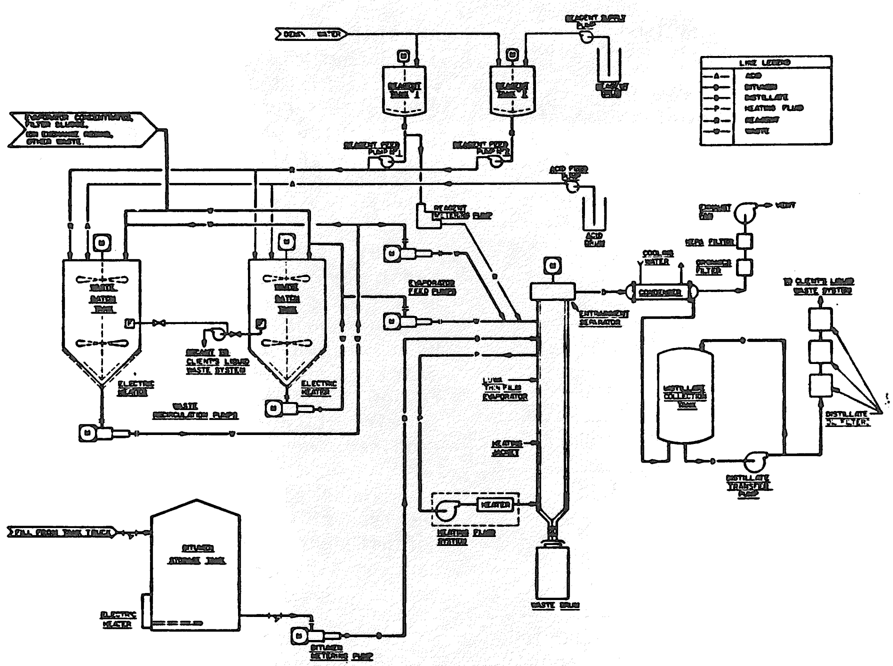

Fig. 1. Basic Flow Diagram, ATI Transportable Volume Reduction System.

RADIOACTIVE LEACHIBILITY

To evaluate the leaching characteristics of a radioactive waste material, the IAEA developed a standard leach test procedure.[a] This procedure establishes standard parameters for leach testing, including materials of construction of the test equipment, dimensions of the test specimen, volume of leachant, conductivity of leachant, temperature of leachant, frequency of sampling and replacing leachant, and other parameters. This procedure specifies that the results of the leach testing should be reported as a plot of the cumulative fraction of radioactivity leached from the specimen as a function of the total time of leaching.

$$\left(\frac{\Sigma a_n}{A_o}\right) \left(\frac{V}{F}\right) \text{ versus } \Sigma t_n \qquad \text{Eq. (2)}$$

where:

a_n = Radioactivity leached during the leachant renewal period.

A_o = Radioactivity initially present in specimen.

F = Exposed surface area of specimen, cm^2

V = Volume of specimen, cm^3

t_n = duration of leachant renewal period, days.

From this plot a cumulative leach rate R_c can be determined,

where:

$$R_c = \left(\frac{\Sigma a_n}{A_o}\right) \left(\frac{V}{F}\right) \left(\frac{1}{\Sigma t_n}\right) \text{ cm/day} \qquad \text{Eq. (3)}$$

Using the IAEA test procedure, the French have done extensive testing of the bituminized products of the TVR process. The results of their tests are discussed below for the various types of waste.

In 1978, Brookhaven National Laboratory published the results of tests that indicated a low leach resistance for bituminized sodium sulfate concentrates.[b] Tests performed by the French confirm these results.

The French have developed a chemical pretreatment that transforms the sodium sulfate into a non-swelling form, so that this tendency to swell is eliminated. In a recent test[c], a 200 gram/liter solution of sodium sulfate was treated with a reagent and the resulting suspension was bituminized in a LUWA Evaporator to yield a product containing approximately 40 wt % solids and 60 wt % bitumen. The product was tested for resistance per the IAEA test procedure. After three months, the percentage of solids leached was only 0.93%. This demonstrates the high leach resistance of bituminized sodium sulfate concentrates that have been properly pretreated.

[a] E. D. Hespe, "Leach Testing of Immobilized Radioactive Waste Solids, a *Proposal for* a Standard Method," Division of Health, Safety and Waste Management, International Atomic Energy Agency, Atomic Energy Review, 9, No. 1, pp. 194-207, 1971.

[b] P. Colombo and R. M. Neilson, Jr., "Properties of Radioactive Wastes and Waste Containers, Progress Report No. 7," BNL-NUREG-50837, Nuclear Waste Management Research Group, Brookhaven National Laboratory, Upton, N. Y., May 1978.

In a recent test performed at the Cadarache Research Center[a], a 117 gram/liter boric acid solution was neutralized with caustic to produce a sodium borate solution, which was then bituminized in a LUWA Thin-Film Evaporator per the SGN Process. The bituminized product, containing approximately 40 wt % sodium borate and 60 wt % bitumen was then tested for leach resistance per the IAEA test procedure. After two months, the percentage of sodium borate leached was only 0.4% for a specimen the size and shape of a 55 gallon drum (but without the drum itself), totally immersed in demineralized water per the IAEA procedure.

Tests have shownthat the leach rates of the specific nuclides Cs 137, Sr 90, Ru 106, Co 60, Pu 238, Pu 239, and Am 241 are significantly lower than the leach rates of the salts reported above for boric acid concentrates and sodium sulfate concentrates, typically by a factor of 100. In other words, it is much more difficult to leach the radioactive nuclides than it is to leach the non-radioactive solids.

Leach tests on bituminized ion exchange resins (40% resins, 60% bitumen), performed per the IAEA procedure, have shown that after 974 days of testing, the cumulative leach rates of Cs 137 and Sr 90 were as follows:

Cs 137: 3.7×10^{-5} cm/day

Sr 90: 3.1×10^{-6} cm/day

The results of leach tests performed in the past ten years have consistently yielded cumulative leach rates for bituminized resins and sludges, as follows:

Cs 137: 10^{-5} to 10^{-8} cm/day

Sr 90: 10^{-5} to 10^{-7} cm/day

Ru 106: 10^{-5} to 10^{-6} cm/day

Co 60: 10^{-5} to 10^{-6} cm/day

Total gamma activity: 10^{-5} to 10^{-7}

Alpha emitters (Pu 238, Pu 239, Am 241): 10^{-5} to 10^{-7}

To put these leach rates into perspective, using the results of the recent leach test performes on bituminized ion exchange resins, the Cs 137 leach rate of 3.7×10^{-5} cm/day means that after 974 days (2.7 years) of immersion, only 0.34% of the Cs 137 initially present in the specimen will have leached out. This very small percentage illustrates the high leach resistance of the bituminized product.

[a] G. Lefillatre, et al., "Bituminizing of BWR and PWR Type Concentrates by Means of a Thin-Film Evaporator LUWA L-150," Department of Chemical Applications and Analytical Studies, CEA, Cadarache, France, November 1979.