DESIGN, FABRICATION, TESTING, AND STARTUP OF A MOBILE VOLUME REDUCTION AND SOLIDIFICATION SYSTEM

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ABSTRACT

The modular concept was utilized in the design and fabrication of the low-level radioactive waste Transportable Volume Reduction and Bitumen Solidification System, the TVR-II. This concept has been taken one step further with the design and construction of a mobile unit, the TVR-III. The new unit is designed to move onto a plant site, process waste, and move to the next plant site. A portion of the TVR-III's capacity is being used to fulfill a five year contract for volume reduction and solidification services at Illinois Power Company's Clinton Power Station.

Many challenges were met and overcome in the design and fabrication of this system into a compact unit while complying with all applicable codes, standards, and design criteria. This paper discusses some of these challenges and how they were met.

DESIGN CRITERIA

Based on a review of nuclear station radwaste system requirements, and the applicable regulatory codes and standards for radwaste system design, criteria were developed for the design of the TVR-III. These criteria required the system design basis to be in accordance with NRC Regulatory Guide 1.143 and ANSI 40.35.

PROCESS DESCRIPTION

The TVR-III system process was developed in France in the early 1960's. The one-step volume reduction and bitumen solidification process is proven and has been operating in both BWR and PWR nuclear power plants in Europe and Japan for a number of years. The concept is a physical process for reliability and economy. A Luwa Thin-Film Evaporator, operating at a waste product temperature of 285°F to 390°F, is used to evaporate all free water from the waste influents. The remaining solids are homogeneously dispersed in a bitumen matrix while inside the evaporator.

Figure 1 is the Basic Flow Diagram for the TVR-III system.

The waste to be processed is charged into the Waste Batch Tank. There it may be chemically pretreated to prepare it for processing and insure the solidified waste meets 10CFR61. When processing resins or sludges, water is decanted or added as required to obtain the desired feed concentration for improved pumping characteristics and optimizing of processing rate. The Waste Batch Tank is agitated to insure the contents remain a homogeneous mixture.

The prepared waste is fed at a controlled rate to the Evaporator. Molten bitumen is simultaneously metered into the Evaporator through a second feed nozzle. The Evaporator is heated by means of a synthetic heating fluid circulated through an external jacket. As both the radwaste and bitumen are fed into the Evaporator, the rotor blades 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 creates a spiral flow of the waste/bitumen mixture. As the waste flows downward through the Evaporator, water is evaporated and the vapor flows counter-currently upward and out. The remaining radwaste mixture exists through the bottom of the Evaporator into 55-gallon drums. Upon cooling, the waste/bitumen mixture solidifies into a free-standing, monolithic, water-free solid acceptable for storage or disposal.

The vapor leaving the Evaporator is condensed in a shell and tube Condenser and flows into the Distillate Collection Tank. When this tank is filled, the distillate is pumped through a series of filters. The cleaned distillate is pumped to the plant liquid waste system.

Any non-condensibles from the condenser are discharged into the process exhaust air system where they pass through HEPA and charcoal filters prior to being discharged.

SYSTEM DESCRIPTION

The TVR-III is a completely self-contained processing system mounted on a 10 ft. wide by 46 ft. long double drop low-boy trailer. Figure 2 shows a typical arrangement of the TVR-III set-up for operation. Figure 3 is a plan view of the system.

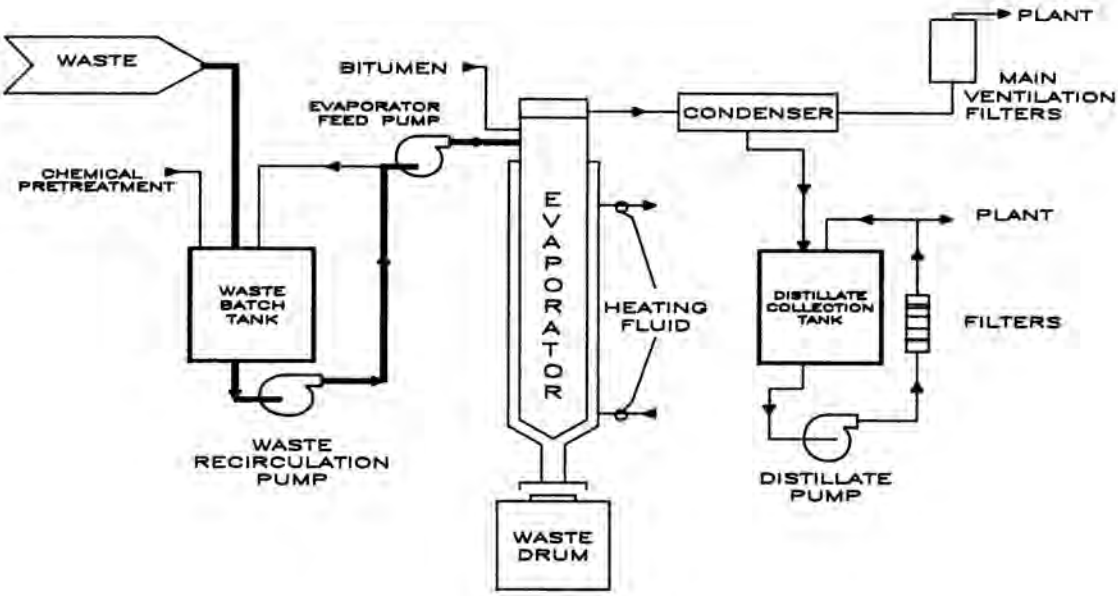

Fig. 1. Basic Flow Diagram, TVR III System

The TVR-III is divided into six areas or rooms: Control, Auxiliary, Process, Waste, Distillate, and Loadout. All areas except the Control Room incorporate spill containment capable of 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 (Fig. 4), the motor control center, the system programmable logic controller and computer, and the video monitor for the closed circuit TV system. The TV System is for viewing the filling and movement of the 55-gallon waste product drums in the Fill Area. The Control Room is the only normally occupied area and is separated from the areas containing radioactive materials by both shielding and the non-active Auxiliary Area.

The Auxiliary Area contains such support equipment as the Heating Fluid Subsystems, the Chemical Addition Subsystem, the Bitumen Feed Pump, and the Chilled Water Subsystem Compressor. This area contains no radioactive or potentially radioactive materials. Any liquid spills in this area can be drained to containers outside of the containment wall.

The Process Area is divided into an upper and lower or Fill Area. The upper Process Area contains the Evaporator (Fig. 8), the Condenser, and the Waste Feed Pump. The lower Process/Fill Area contains the conveyors used to move empty and filled product drums, and a TV camera for viewing the drums. The Fill Area is also the holding area for filled drums while they cool and solidify. The heat from the cooling drums is removed by the TVR-III HVAC System.

The Waste Area contains the Waste Batch Tank (Fig. 5) and Agitator, the Waste Recirculation Pump (Fig. 7), the Resin Decanting Pump, and the Waste Sample Station. The location of the Sample Station is adjacent to the exterior wall so a sample can be taken through an access door in the wall without entering the Waste Area. The Waste Batch Tank and the waste lines are electrically heated to prevent crystalization during the processing of sodium sulfate waste.

The Distillate Area contains the Distillate System Collection Tank, Filters and Transfer Pump, and the main ventilation filters and exhaust fan. A connection box containing the TVR-III input/discharge connections for waste, decant water, flush water, distillate and ventilation exhaust fan discharge is located in this area. However, the access to this connection box is from outside the trailer.

The Loadout Area contains a conveyor for product drum movement, closed circuit television cameras for product inspection, and load cells for weighing the filled drums. This area is also used for capping, swiping, labeling and monitoring the contact dose rate of the filled drums. The capability also exists to overpack drums.

The free standing Bitumen Storage Tank (Fig. 9) sits adjacent to the trailer. The fully insulated tank is double shell constructed to prevent any

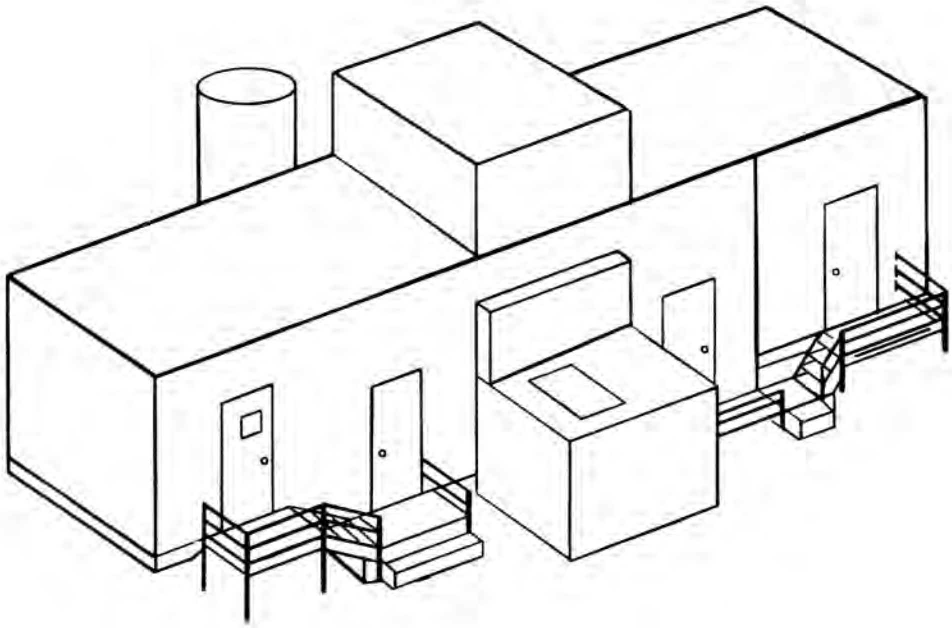

Fig. 2. Typical Operating Arrangement

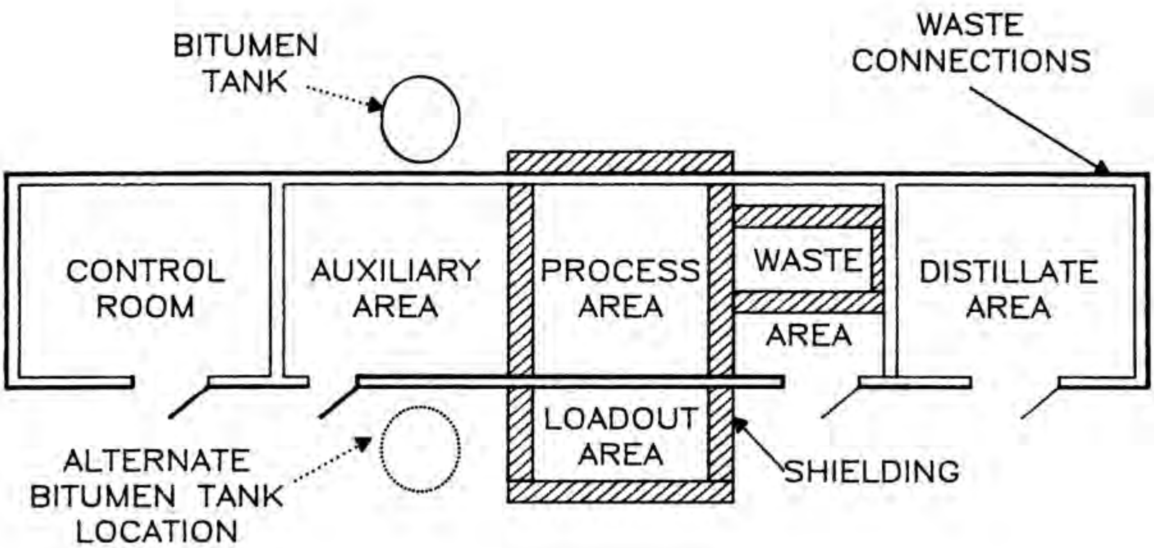

Fig. 3. System Plan View

Fig. 4. Section of Control Panel, Note Ease of Reading

Fig. 5. Waste Batch Tank, Insulated

leakage of the contents. Low watt density electric heaters maintain the bitumen at the correct processing temperature. A vent prevents any pressure buildup in the tank. The vent incorporates a charcoal filter to remove organics in the exhaust. The bitumen is pumped from the tank and metered to the Evaporator by the Bitumen Feed Pump located in the Auxiliary Area. The interconnecting pipe is jacketed and heated by one of the Auxiliary Area Heating Fluid Subsystems.

The TVR-III includes its own completely self-contained heating, ventilation and air conditioning systems. The Control Room and the Auxiliary Area are each served by a unit dedicated only to that respective area.

The main Ventilation and Air Conditioning System serves the Process, Waste and Distillate Areas, all of which are potentially contaminated areas. The air from this system is drawn through the HEPA and charcoal filters (Fig. 6) prior to being exhausted to either the plant's ventilation system or to the atmosphere. The interior of the trailer is maintained at a negative pressure with respect to the outside atmosphere to prevent the uncontrolled release of air.

The TVR-III System includes a completely self-contained fire protection system. This system includes redundant fire detection devices and automatic fire suppression equipment. The trailer and Loadout Area are equipped with Halon systems while the Bitumen Storage Tank is equipped with a water deluge system. The lower Process/Fill Area is also

Fig. 6. Access Doors, Bag-In/Bag-Out HEPA and Charcoal Filters

Fig. 7. This Waste Recirculation Pump is Typical of the Diaphragm Pumps Used Throughout for Waste Except Waste Metering

Fig. 8. Luwa Thin-Film Evaporator in the Operating (Elevated) Position

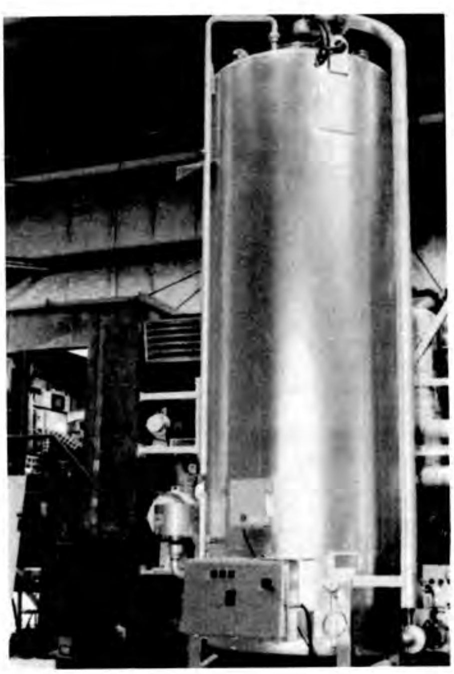

Fig. 9. Bitumen Storage Tank Showing Electric Controls

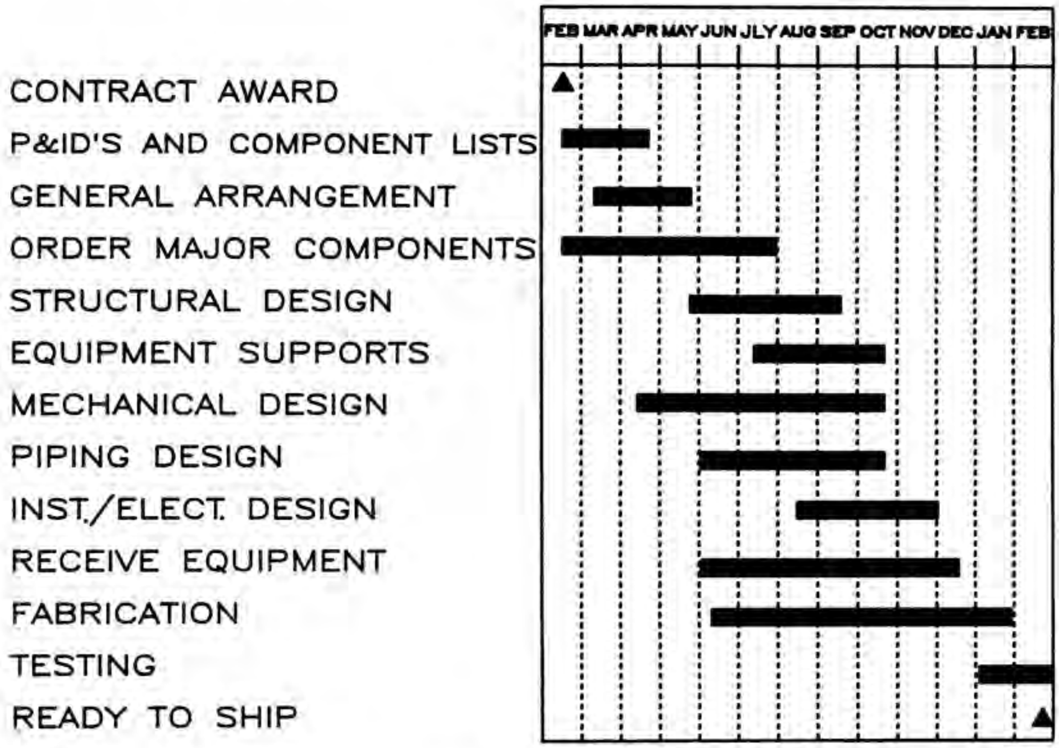

Fig. 10. Project Schedule Summary

equipped with a water deluge system as a backup. These fire protection systems have been reviewed by the American Nuclear Insurers (ANI). The roof and exterior wall panels are constructed of two metal plates separated by insulation resulting in a flame spread rating of at least 15.

The TVR-III System is equipped with shielding designed to allow for the processing of typical PWR and BWR radwaste types. This shielding consists of steel plates located around the Waste Batch Tank, Fill and Loadout Areas. The shielding is removed when transporting the system. In addition the design permits it to be installed in increments to satisfy the activity level of the waste being processed.

PROJECT SCHEDULE

A contract was awarded and engineering initiated in February 1985 with a system on-site requirement of January 1, 1986. The on-site requirement was contingent upon fuel loading at Clinton. However, with the delay of fuel loading, the on-site date was changed to February 28, 1986. Therefore, the design, procurement, fabrication, testing, and delivery of a "first of a kind" system required only 12 months. Figure 10 is a bar chart summary of the schedule for this project.

During January a series of component and subsystem tests were performed to verify that fabrication was in accordance with design and to meet specification and code requirements. During the month of February, a complete system functional test was performed using various simulated waste types. Upon completion of these functional tests the unit was readied for shipment to Clinton.

FABRICATION

The fabrication of the unit on both a short schedule and into such a compact unit required careful planning of construction sequences and scheduling the number of concurrent activities in any area.

The initial work upon receipt of the trailer frame was installing the floor and sealing this entire area against future damage by the environment during transport.

Work was next begun on the superstructure followed by installation of equipment and piping. As equipment and piping was completed, instrument and electrical work began. Installation of the external wall and roof panels was the last step of the fabrication phase.

One method used to help alleviate the problem of the limited work areas was to do as much bench welding as possible. Pipe spool sections created on the bench could then be welded into place on the unit with a minimum of field welds. The large amount of bench welding made possible a shorter fabrication time since much work could be performed concurrently.

Many of the challenges encountered during the design phase were solved by using special fabrication techniques. The containing of any possible spills in the unit was solved through the addition of short containment walls around the bottom of each area of the trailer. These walls range in height from 6 inches to 14 inches and provide a containment capacity greater than the maximum expected liquid inventory in each area. The walls were fabricated from 1/4 inch stainless steel.

The overall height of the trailer was another challenge. In order to allow the unit to be easily transported over the road, the height of the trailer during transportation had to be kept at 13 feet 6 inches or less. However, during operation it is necessary for the Evaporator to be above the product drum, with the result that the top of the Evaporator is 18 feet above ground. Therefore, the Evaporator was mounted on a movable platform with telescopic support legs to allow for the Evaporator to be raised or lowered as required for both transport and operation.

To allow easy access to components for maintenance during operation of the unit, it was necessary to fabricate and install specially designed removable wall and roof panels. These panels allow the removal of single panels for access to components which are not readily accessible from the interior of the unit.

One of the design requirements was that the TVR-III system should allow for the processing of waste from many different sources. Therefore, the radioactivity levels for the waste might range from very low at relatively new or clean plants to rather high at older or dirty plants. However, it was not desirable to incorporate a large amount of shielding into the unit since the weight of this shielding would preclude transportation by normal methods. Therefore, it was desired to make the shielding removable so that it could be transported separately. It was decided to fabricate the shielding from multiple steel plates for both economic and operational reasons. Using multiple plates allows for using only as much shielding as is actually required at a particular plant or site. For example, one plant site might require the full 8 inches of shielding around the Fill Area which contains the product drums, whereas, another site with lower activity waste might require only one or two inches of steel. Therefore, it would not be necessary to ship the remainder of the shielding to such a site.

PREOPERATIONAL TESTING

The next step after fabrication was to perform operational testing of the system to meet code requirements, verify that fabrication was in accordance with design, and ensure that equipment was operable for startup.

This testing included the inspection and testing of all fabricated piping in accordance with the requirements of ANSI 40.35 and Regulatory Guide 1.143. Equipment was run and monitored for noise, vibration, binding, loose parts, and misalignment. Safety devices and features were tested for proper operation.

Electrical equipment was tested to verify that all electrical interconnections were made correctly, that all equipment was functioning properly, and that the equipment could be properly calibrated.

Some of the above testing was performed during the last stages of fabrication. This was accomplished by scheduling the completion of entire subsystems at different times during fabrication, thereby allowing the testing of these completed subsystems while work was being performed on other subsystems. This allowed for an accelerated testing schedule.

FUNCTIONAL TESTING

A shop functional test was performed. This included individual testing of major subsystems followed by a series of integrated system process tests.

The subsystems tested included the Heating Fluid Subsystems, the Bitumen Storage and Metering Subsystem, the Distillate Collection Subsystem, the Waste Preparation and Feed Subsystem, and the Evaporator Subsystem.

The integrated system tests involved the actual processing of simulated waste for various waste types, including bead/powdered resins, evaporator concentrates, and Solka Floc. The binder used was a straight distilled, viscosity graded asphalt, commercially available as AC-20.

These integrated system tests were designed to demonstrate that the TVR-III system produced an acceptable waste product identical to that produced by the earlier TVR-II system. The tests were also a verification of the Process Control Program (PCP) for the TVR-III. This PCP is designed to produce a product which is acceptable for burial at the operating burial sites.

Process optimization and product stability (in relation to 10CFR61) testing was not necessary for the TVR-III because of previous testing. The product produced by TVR-III is identical to that produced by the earlier TVR-II and it underwent complete testing and qualification.

TRANSPORTATION, SETUP AND STARTUP

After all testing was completed on the TVR-III, the unit was prepared for shipment to Clinton Power Station. This involved lowering the Evaporator platform to its lower position, installing the wheels on the trailer, and loading all accessory items onto separate trailers. These accessory items included the Bitumen Storage Tank, the Loadout Area enclosure, the steel shielding plates, and other supplies.

Setup at the site requires raising of the Evaporator platform, placement of the Loadout Area enclosure and the Bitumen Storage Tank, and hookup of the systems' utility interface connections.

LICENSING OF THE TVR-III SYSTEM

The U. S. Nuclear Regulatory Commission (NRC) has stated that the licensing of volume reduction and solidification systems for a facility with an operating license could be addressed under 10CFR50.59 "Changes, Tests and Experiments." After a determination by the utility that there are no unresolved safety issues, ATI can operate the TVR-III System under 10CFR50.59.

ATI has submitted a topical report for the TVR-III system to the NRC for review. This review resulted in questions and requests for further information, which have now been addressed and ATI is awaiting final approval at the time this paper is written.

The TVR-III system has also been reviewed by the American Nuclear Insurers (ANI). Their review resulted in acceptance of the system's design.

ECONOMICS

In periods of tight capital and high interest rates, many utilities defer decisions regarding the addition of permanently installed volume reduction and solidification systems. When the above conditions exist, the advantages of a mobile system becomes more pronounced. The TVR-III allows a utility to reduce operating costs as delineated below while foregoing a large outlay of capital. The utility pays only for the amount of waste that is processed. Additional advantages are as follows:

1. Significant savings in transportation and burial costs (see Table I).
2. Eliminates high risk factor on capital due to changing NRC, DOT, or burial site requirements.
3. Trained operators provided, thereby reducing plant staff requirements.
4. Total system maintenance provided.
5. Equipment is provided on a trailer which can be located inside existing truck bays or outside in the plant yard, thereby eliminating need for new facilities.
6. Assist in complying with burial site volume allocation restrictions as covered by House Bill 1083.
7. Assures compliance with no free water requirements.
8. Accelerate schedule to achieve volume reduction.

TABLE I

ECONOMIC EXAMPLE CASES

	EXAMPLE CASE 1 1100 MWe BWR 600 MILES FROM BARNWELL		EXAMPLE CASE 2 1100 MWe PWR 2500 MILES FROM HANFORD	
	CEMENT	TVR-III	CEMENT	TVR-III
CHEMICAL Na_2SO_4*	10,000 ft^3/yr.	10,000 ft^3/yr.	5,000 ft^3/yr.	5,000 ft^3/yr.
CONC. LIQUIDS**	2,000 ft^3/yr.	2,000 ft^3/yr.	2,000 ft^3/yr.	2,000 ft^3/yr.
RESINS/SLUDGES DEWATERED	5,000 ft^3/yr.	5,000 ft^3/yr.	2,000 ft^3/yr.	2,000 ft^3/yr.
COST OF SERVICE	\$ 55/ft^3	\$ 125/ft^3 (Including Drums)	\$ 55/ft^3	\$ 125/ft^3 (Including Drums)
TREATMENT COST (INCL. EQUIP. LEASE)	\$ 1,188,200/yr. (Including Liners)	\$ 2,125,000/yr.	\$ 848,200/yr. (Including Liners)	\$ 1,125,000/yr.
CONTAINER SIZE	178 ft^3 Liner	55 gal Drum	178 ft^3 Liner	55 gal Drum
SOLIDIFIED WASTE VOLUME	22,590 ft^3/yr.	4,460 ft^3/yr.	11,960 ft^3/yr.	3,338 ft^3/yr.
BURIAL VOLUME	25,276 ft^3/yr.	4,598 ft^3/yr.	13,350 ft^3/yr.	5,400 ft^3/yr.
NUMBER OF SHIPMENTS	142/yr.	44/yr.	75/yr.	52/yr.
TRANSPORTATION COST	\$ 915,790/yr.	\$ 142,000/yr.	\$ 675,000/yr.	\$ 300,820/yr.
BURIAL COST	\$ 1,137,420/yr.	\$ 206,890/yr.	\$ 467,250/yr.	\$ 189,000/yr.
TOTAL ANNUAL COST	\$ 3,241,410/yr.	\$ 2,473,890/yr.	\$ 1,990,450/yr.	\$ 1,614,820/yr.
ANNUAL SAVINGS:	\$ 767,500 and 20,678 ft^3 burial volume		\$ 375,630 and 7,950 ft^3 burial volume	

* For BWR: 12 wt. %
For PWR: 25 wt. %

** *For BWR:* 10 wt. % dissolved solids
For PWR: 12 wt. % H_3BO_3