THE COST OF ENGINEERED DISPOSAL FACILITIES

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ABSTRACT

An improved disposal trench was designed, constructed and placed into operation at the Maxey Flats Disposal Site during the period April 1985 through July 1986. With the improved trench design, the waste packages are placed in clusters and the surrounding space is filled with gravel and grouted with a sand/cement mixture to form walls and cells that surround the waste package. The walls provide structural support for a polyethylene reinforced soil beam which in turn supports a multi-layer protective cap. About 2,700 drums of waste (20,250 CF) were placed into the trench. The total cost of the improved trench was $193,500 and the unit cost was $9.56 per cubic foot not including the placement of the waste. The engineered features of the trench (i.e., sidewall infiltration barrier, grout backfill and the soil beam) cost $82,600 for a unit cost of $4.08 per cubic foot of waste. This is compared to the cost of concrete cannisters used for radioactive waste disposal. On a production basis the cannisters are estimated to cost about $1,260. Depending upon the type waste, the cost of the cannisters will range from $2 to $12 per cubic foot of waste. The slightly higher cost of the concrete cannisters is offset by certain performance advantages.

INTRODUCTION

The majority of the states and compacts planning low-level radioactive waste disposal facilities have determined that the public will no longer accept shallow land burial as it has been practiced prior to 1980. The design criteria for the facilities being planned generally state that the disposal facilities must use improved shallow land burial or some form of engineered storage. In other cases, the criteria states that all waste packages must have a minimum of one engineered barrier between the waste packages and the soil. This criterion allows the use of vaults, augered cassions or concrete cannisters. Concrete is the most generally acceptable material for engineered barriers and disposal facilities.

This paper considers two types of engineered disposal facilities and compares the cost and performance characteristics of the two facilities.

The first engineered disposal facility is the Improved Disposal Trench which was constructed at the Maxey Flats disposal site. The second engineered disposal facility is the SUREPAK module concrete cannister system designed by Westinghouse for a disposal facility to be located in California.

BACKGROUND

Both engineered disposal facilities were designed based on the experience at Maxey Flats. The Maxey Flats Disposal Facility was closed when it was found that water had filled the trenches and was migrating laterally into trenches being constructed and to other trenches filled with waste. Up until this point, the site was considered to be highly impermeable and capable of containing any water that might infiltrate the trenches.

The burial site is underlain by several sedimentary rock formations with low water transmitting capabilities. The waste was buried in a formation of shale with two discontinuous sandstone marker beds. Both standstone beds are fractured and the lower sandstone bed was found to be transmitting leachate from the closed trenches in some areas of the site.

A program for pumping water from the trenches was started prior to the closure of the Maxey Flats site in 1979 and has continued ever since. The original plan was to pump the water from the trenches and allow them to stabilize. After stabilization, the site was to be covered with a protective cover to preclude further infiltration of storm water. This plan is not practical for several reasons. Subsidence has occurred since the trenches were filled. The initial subsidence resulted from the consolidation and compaction of backfill. Because of the external radiation from the waste packages placed in the trenches, the backfill was dumped over the packages. The backfill was not vibrated into crevices nor compacted. The subsidence that is now occurring is believed to be caused by the deterioration of the waste packages. As the backfill consolidates the packages must bear the weight of overburden and failures can occur. In addition, many of the steel drums have been buried for 20 years and corrosion is and will continue to cause collapse of the drums. It has now been concluded that the waste trenches must be stabilized before the site can be covered and decommissioned. Concrete structures and grouting have been considered for the stabilization of the trenches in preparation for decommissioning.

The Maxey Flats site is located in a humid region. The construction of the burial trenches caused the surface to become more permeable than the sides and bottoms of the trench even with the fractured sandstone. Storm water enters the trenches by infiltration through the trench caps. The subsidence of the trench caps caused depressions which collected water which then flowed into the trenches. This condition is called the "Bath Tub" effect and causes the waste to be in contact with water. As the trenches fill, the contaminated water migrates to the surface and contamination can be spread during subsequent rainfall events.

When the Maxey Flats site was closed there was an estimated 7,000,000 gallons of leachate in the trenches. The rate at which leachate can be removed from the trenches is limited by the rate at which the leachate can be processed. The leachate is processed by evaporation to reduce the volume for storage and subsequent solidification and disposal. The evaporation rate is controlled by the rate at which the tritiated vapor can be released to the atmosphere. Operation of the evaporator on a three shift, five day a week basis allows about 1,000,000 of leachate to be removed and processed annually. In 1980, it was estimated that water was infiltrating the trench at a rate of 600,000 gallons annually. This caused the net removal of leachate from the trenches to be reduced to about 400,000 gallons annually.

Starting in 1981, several actions were taken to reduce the infiltration of water into the trenches. Two leachate storage ponds that were acting as recharge basins were removed. The entire site was regraded to increase the runoff of storm water. The entire burial site was graded like large domes. The covers over the individual trenches were made into single covers thereby removing the water collection areas between the individual trench covers. Improved drainage channels and buried storm sewers were installed to convey the storm water from the burial site without causing excessive erosion. This in turn necessitated the installation of outfall structures and basins to minimize downstream erosion due to the increased runoff.

In 1982, the entire burial site was covered with a plastic liner to further limit the infiltration into the trenches. The P.V.C. liner is 15 mills thick and has glued seams. Even with the installation of the liner, the water levels in the trenches indicated that about 250,000 gallons of water is still entering the disposal trenches. It appears that storm water is infiltrating the surrounding soil which creates a perched water table. This water apparently moves laterally through the soil under the plastic cover and flows into the trenches. Eventually cut off walls and rock filled gravity drainage ditches will be needed to divert the perched water around the trench area.

Based on the experience at the Maxey Flats site, it was concluded that any future disposal facility must have a high degree of structural stability. Structural stability is essential to minimize subsidence. By eliminating subsidence, protective covers can be installed over the trenches as they are filled. The protective covers will minimize the infiltration of storm water and will permit the site to be placed into a decommissioned status requiring only passive maintenance and periodic monitoring. Engineered features should not only isolate the radioactive waste from the environment, they should also create a structurally stable disposal facility.

ALTERNATIVE DESIGN CONCEPTS

The Kentucky Natural Resources and Environmental Protection Cabinet was awarded a grant by the U.S. Department of Energy to jointly sponsor the design and construction of a improved shallow land burial trench at the Maxey Flats site. In 1985, the Westinghouse contract for the operation of the Maxey Flats site was amended to cover the evaluation of various methods of enhancing the state of the art in shallow land burial. The overall goal was to design a low-level radioactive waste disposal trench that would be capable of isolating the waste at Maxey Flats and other humid sites. The trench design had to be capable of performing satisfactorily under the geological conditions now known to exist at the Maxey Flats site. Specifically, the trench had to be capable of operating in a site known to be subject to the "bath tub" effect and having a fractured geological media that could allow any water that might enter the disposal trench to ultimately be released to the environment. Finally, the disposal trench was to be demonstrated on a scale that would allow the features to be incorporated into a near term commercial or governmental disposal site. The only constraint was that the design could not use prefabricated concrete modules or SUREPAKs. This technology was considered to be adequately demonstrated and the grant funds were to be used to evaluate and demonstrate other alternatives.

The alternatives considered for providing structural stability and support for the protective cover were:

- o Reinforced Concrete Beam and Slab
- o Reinforced Concrete Arch
- o Structural Containers
- o Grouted Backfill
- o Grouted Backfill/Reinforced Slab

Figure 1 illustrates the concrete beam and slab concept. Figure 2 illustrates the reinforced concrete arch.

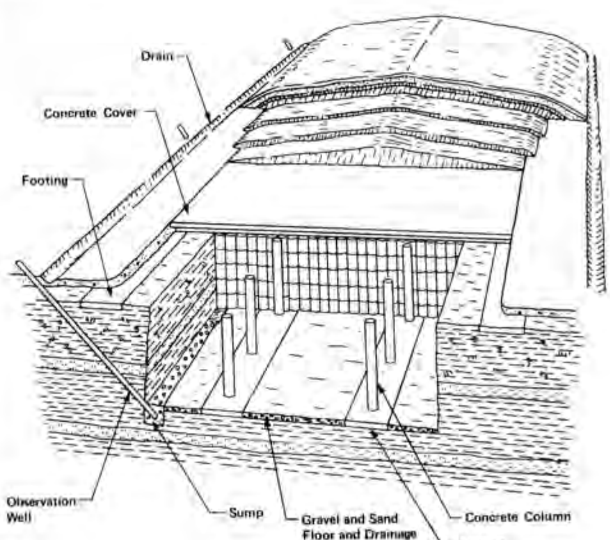

Fig. 1. Concrete Beam and Slab Concept

Figure 3 illustrates the functional components of the disposal cell. As shown, the trench cap design called for a permeability of less than 10^{-8} centimeters per second. To avoid the bath tub effect the bottom of the trench was designed to have a permeability greater than the 10^{-8} cm/second. This was done to assure that water infiltrating the concrete cap would drain from the trench at a greater rate than entering and with minimal opportunity to become contaminated.

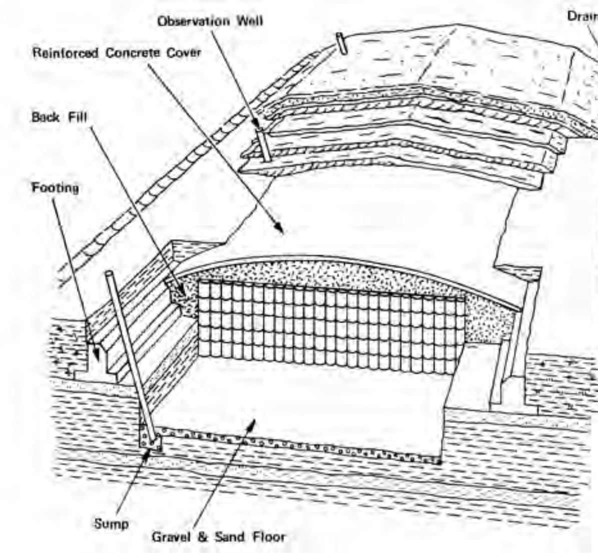

Fig. 2. Reinforced Concrete Arch Concept

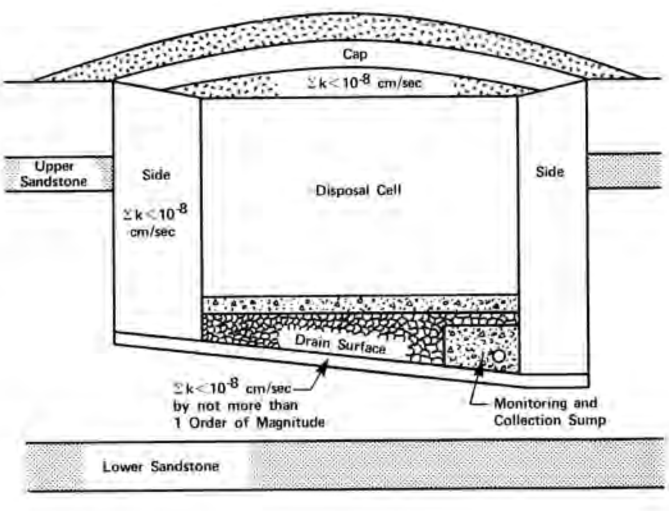

Fig. 3. Functional Components of the Disposal Cell

Using a cap designed to maximize runoff, the water will accumulate on the areas adjacent to the trench. This will create a hydraulic gradient. As shown on Fig. 4 the hydraulic gradient will cause subsurface flow back toward the trench. For this reason, the trench must also have a perimeter infiltration barrier. The permeability of the sides must be comparable to the cover but higher than the bottom of the trench.

The evaluation of alternative trench cover caps has been the subject of several published reports and papers (1,2,3,4). Based on this work, a multi-layer soil cover with a clay infiltration barrier was selected as best meeting the design requirements at the least cost. Fig. 5 illustrates the multi-layer cover used for all of the alternative designs.

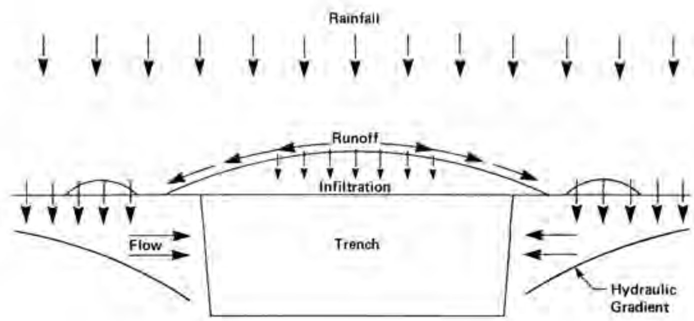

Fig. 4. Hydraulic Gradient Flow

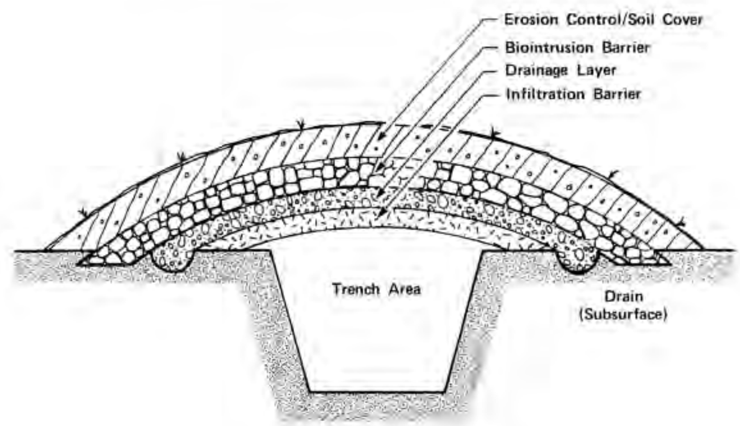

Fig. 5. Multi-Layer Cover Design

THE IMPROVED TRENCH

The selected design for the improved trench is shown on Fig. 6. As shown in Fig. 7, the drums containing the waste are placed in clusters which can also be interspersed with liners, high integrity containers and other waste packages. The drums can also be stacked in rows or horizonally with spaces not more than eight feet apart. In the improved trench, plastic pipes perforated at the bottom were placed in the spaces between the waste containers. The spaces between the containers were next filled with gravel. A sand and cement grout mixture was injected into the plastic pipes and forced up through the gravel. The grout was injected at the bottom of the gravel to allow the air to be displaced without the formation of air pockets in the grout.

With this technique, the waste containers are used as forms and the gravel and grout are used to construct walls and cells which encapsulate the waste packages. These walls provide the structural support for the trench cover. A soil beam reinforced with a polyethylene geo-grid was used over the grout/gravel walls to provide support for the protective cover. The polyethylene reinforcement was used to avoid corrosion. The soil beam was designed for a life of 300 years based upon the creep limitations of polyethylene.

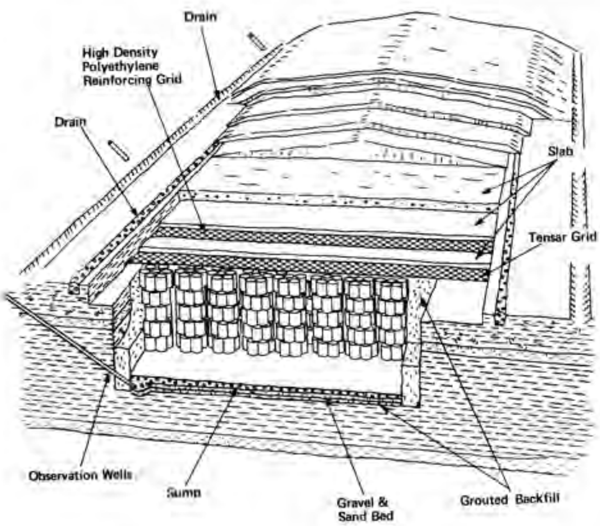

Fig. 6. Improved Trench Design

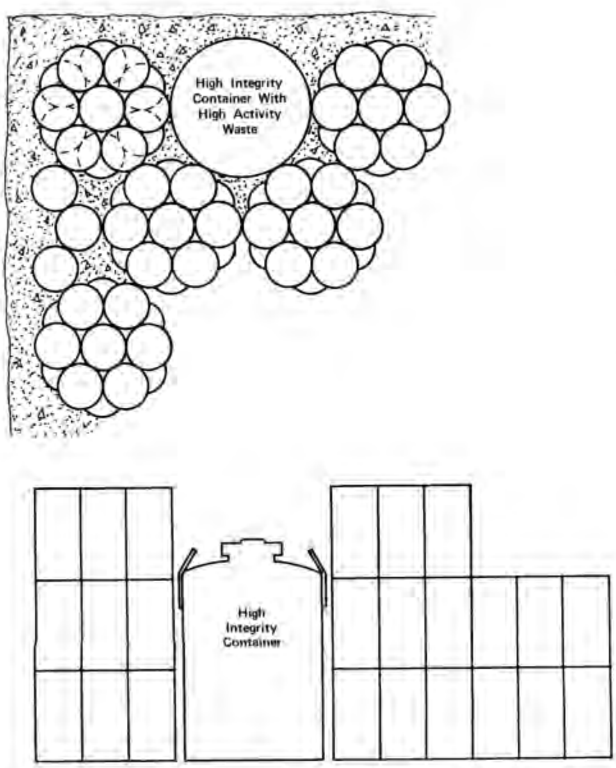

Fig. 7. Drums Containing Waste (Clusters)

At the sides of the trench an additional row of plastic pipes was installed prior to filling the trench with gravel. These pipes were used after the grout was injected to inject a bentonite slurry. The bentonite slurry was used to form a sidewall infiltration barrier having a permeability comparable to the cap.

Improved Trench Costs

The construction costs for the improved trench are shown in Table I. In Table II the costs have been broken down to show the costs associated with each of the major components.

A total of 2,700 55-gallon drums were placed in the improved trench. This equates to a volume of 20,250 cubic feet. Based on the total cost of $193,500, the unit cost for the trench construction was $9.56 per cubic foot. This covers excavation, gravel, grout backfill, the sidewall infiltration barrier, the soil beam and the balance of the cap. It does not include the cost of placing the waste drums into the trench. This unit cost is actually higher because the trench could have accommodated as many as 3,500 drums.

TABLE I

Trench Construction Cost

Subcontract		
- Excavation		$11,300
- Quality Assurance		7,160
- Grout Placement Equipment		1,800
Labor		51,340
Construction Engineering		1,600
Equipment Usage		24,480
Materials		
- Tracers	$ 2,030	
- PVC Pipe	2,240	
- Stone	20,600	
- Bentonite	7,050	
- Grout Backfill	35,640	
- Geotextile	5,000	
- Gecgrid	19,200	
- Seed-Mulch	520	
- Monitoring	1,580	
- Misc.	2,000	95,780
TOTAL		$193,550
Unit Cost (20,250 CF)		$ 9.56/CF

The engineered features of the improved trench are the sidewall infiltration barrier, the grout backfill and the soil beam. The balance of the cap would be common to all disposal facilities. As shown in Table II, these engineered features have a total cost of $82,600. This equates to $4.08 per cubic foot. This is the incremental cost of making a conventional shallow land burial trench into an engineering disposal facility.

TABLE II

Selected Major Component Costs

Component	Labor	Equipment	Materials	Total
Sidewall Infiltration Barrier	$ 7,200	$ 2,900	$ 5,000	$15,100
Grout Backfill	2,900	1,800	35,600	40,300
Soil Beam	2,600	5,400	19,200	27,200
Balance of Cap	12,100	10,900	22,700	45,700

Modular Concrete Cannister

The modular concrete cannisters achieve the same results as the grouted backfill used in the improved trench. Figure 8 shows a hexagonal concrete cannister being considered for future disposal sites. Figure 9 is an artist's concept of a disposal trench filled with hexagonal reinforced concrete cannisters.

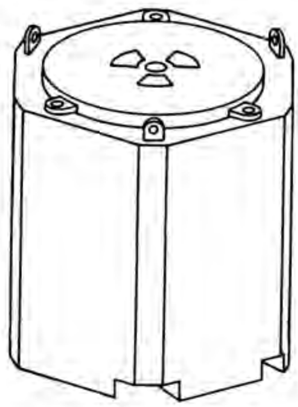

Fig. 8. Hexagonal Concrete Cannister

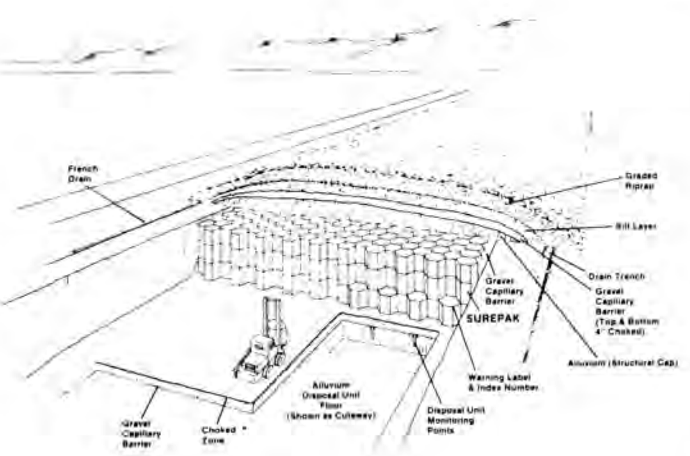

Fig. 9. Disposal Trench with Concrete Cannisters

The concrete cannisters have a minimum wall thickness of 3 inches. When placed in a closely packed array in a disposal trench, a minimum of 6 inches of wall is available to provide structural support for the protective cover. This is about the same as the thickness of the slurry walls used in the Improved Trench.

Functionally, the concrete cannister and the improved trench are nearly equal. The difference is how the structural stability is obtained. With the concrete cannisters, the waste is placed into the cannisters and the cannisters are placed into the trench. With the Improved Trench the waste packages are placed into the trench and the walls are casted around the waste packages using a grouted gravel technique.

Concrete Cannister Cost

The cost of the concrete cannisters is strongly dependent upon the quantity being produced at a given time and the cost of transporting the cannisters from the manufacturer to the point of use. In limited quantities, the cost per cannister will be about $2,500. For production in large quantities, quotes as low as $1,000 per cannister have been received.

The hexagonal concrete cannister shown in Fig. 9 has a weight of 18,000 pounds. The price of prefabricated large diameter concrete ranges from 4 to 5 cents per pound. Prefabricated concrete septic tanks generally cost in the range of 5 to 7¢ per pound. The concrete cannister should cost about $1,260 or about 7¢ per pound when produced in quantity.

The unit cost of disposal using the concrete cannisters will depend upon the type of waste placed into the cannisters. Table III lists typical waste container combinations and the unit costs based on a cannister price of $1,260.

TABLE III

Concrete Cannisters Volume and Unit Costs

Waste Combination	Waste Volume (CF)	Cannister Cost Total $	Unit $/CF
14 55-gallon drums	105	$1,260	$12.00
35 crushed drums	263	1,260	4.80
84 crushed drums	630	1,260	2.00
195 CF liner	185	1,260	6.80
Cylindrial LSA Box	200	1,260	6.30

As shown in Table III, the incremental cost of converting a conventional shallow land disposal facility to an engineered disposal facility ranges from $2 to $12 per cubic foot.

As shown in Table III, the incremental costs for disposal using the concrete cannisters are generally higher than $4.08 per cubic foot cost for the sidewall infiltration barrier, grout backfill and the soil beam used in the Improved Trench.

PERFORMANCE DIFFERENCES

The slightly higher cost of the concrete cannisters as compared to the improved trench are partially offset by improved performance characteristics. These would include:

- o Concrete cannisters are less susceptible to damage in a seismic event.
- o Concrete cannisters allow waste to be placed in the trenches with no external contamination.
- o Concrete cannisters without external contamination allows the radioactive waste to be used for monitoring.
- o Concrete cannisters provide some shielding of the waste during placement in the trench.
- o Concrete cannisters are easier to place in position in the trench.

- o Concrete cannisters will have lower radiation exposure of operating personnel.
- o Concrete cannisters are recoverable in the event remedial action is necessary.

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