EXPERIENCE WITH THE TUMULUS TECHNOLOGY FOR THE DISPOSAL OF SOLID LOW-LEVEL RADIOACTIVE WASTE* **

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ABSTRACT

As part of the development of a long-range plan for the disposal of solid low-level radioactive waste, Martin Marietta Energy Systems, Inc., has built a full-scale tumulus facility as a technology demonstration. This aboveground facility consists of a concrete pad on which the waste is placed, a synthetic underpad liner, concrete disposal vaults to contain the waste, a performance monitoring system, and a multilayered cap to be constructed after the pad is filled. Waste has already been placed on the pad, and the suitability of the design, the construction, and the operating procedures has been assessed. The facility appears to be acceptable with the exception of the underpad liner, which will be eliminated in subsequent tumulus facilities. Radiation monitoring of the workers and environmental monitoring have shown essentially no impacts above background. Although a final assessment of the tumulus technology must await an evaluation after construction of the cap, plans are proceeding to construct additional tumulus facilities.

INTRODUCTION

Martin Marietta Energy Systems, Inc. (Energy Systems) operates research and production facilities in Oak Ridge, Tennessee, under contract to the U.S. Department of Energy. As part of the development of a long-range plan for the disposal of the solid low-level radioactive waste (LLW) generated by these facilities, promising disposal technologies are selected for demonstration at a scale sufficient to assess performance adequately. One technology selected for demonstration is the aboveground tumulus (Fig. 1), which consists of a concrete pad on which the LLW is placed, a synthetic underpad liner, concrete disposal vaults to contain the LLW, and an engineered multilayered cap to be constructed after the pad is filled.

The aboveground tumulus technology was selected because it offers advantages over the past practice of shallow land burial:

- The concrete disposal vaults confine the waste and provide structural stability.
- The concrete pad collects any leachate, thus serving as a barrier to radionuclide migration to groundwater and allowing any water that comes into contact with the waste containers to be monitored.
- Water contacting the waste containers is minimized through the use of a multilayered cap.
- Waste recovery will be easier if it becomes necessary.
- Waste disposal is possible at shallow groundwater depth, a feature that extends the amount of land usable for disposal.

At this time, the tumulus facility is being loaded with the concrete disposal vaults. This paper describes the waste acceptance criteria for the demonstration facility and its engineering, operational, and monitoring aspects. Experiences and findings to date are also related.

WASTE ACCEPTANCE CRITERIA

The development of waste acceptance criteria (WAC) is a key element in the overall strategy for disposing of LLW generated by Energy Systems. These WAC will be based on a site-specific pathway analysis that predicts potential doses of radiation to the public, the environment, and the inadvertent intruder. Since the pathway analysis model is not finalized, the following interim WAC were developed for the tumulus demonstration facility:

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- Incoming waste is in primary containers, chiefly sealed 0.22-m^3 drums and 1.2 X 1.2 X 1.8 m wooden or metal boxes.
- Contact radiation at the surface of the primary containers is < 200 mrem/h, and transferable surface contamination of the primary containers is < 200 dpm/100 cm^2 for beta gamma and is < 20dpm/100 cm^2 for alpha radiation.
- Incoming waste is certified to contain no liquids, to be free of materials regulated by the Resource Conservation and Recovery Act (RCRA), and to contain < 100 nCi/g of transuranic materials.

The waste generators certify that all WAC are met by completing the documentation that accompanies all LLW packages. When the disposal strategy is fully implemented, the types of LLW that can be disposed of in the tumulus facility will be those that result in acceptable doses to the environment and the public after an institutional control period of 100 yr. While the acceptable dose is not yet defined, preliminary pathway analyses use 10 mrem/yr as the effective dose equivalent to any member of the public or to an inadvertent intruder.

ENGINEERING

The engineering aspects of the tumulus facility described here are the site selection criteria, design criteria, and construction experience.

Site Selection Criteria

The major site selection criterion was the requirement that the demonstration facility be located within an existing LLW disposal area so that it could be operated with LLW rather than with a surrogate waste. The following criteria (1) were then used in selecting the specific demonstration site within an existing LLW disposal area:

- The site must be located above the 500-yr flood plain.
- The highest recorded groundwater elevation must be at least 0.6 m deep.
- The site must not be located on top of closed disposal sites or on fill areas.
- The site must not be located in areas suitable for

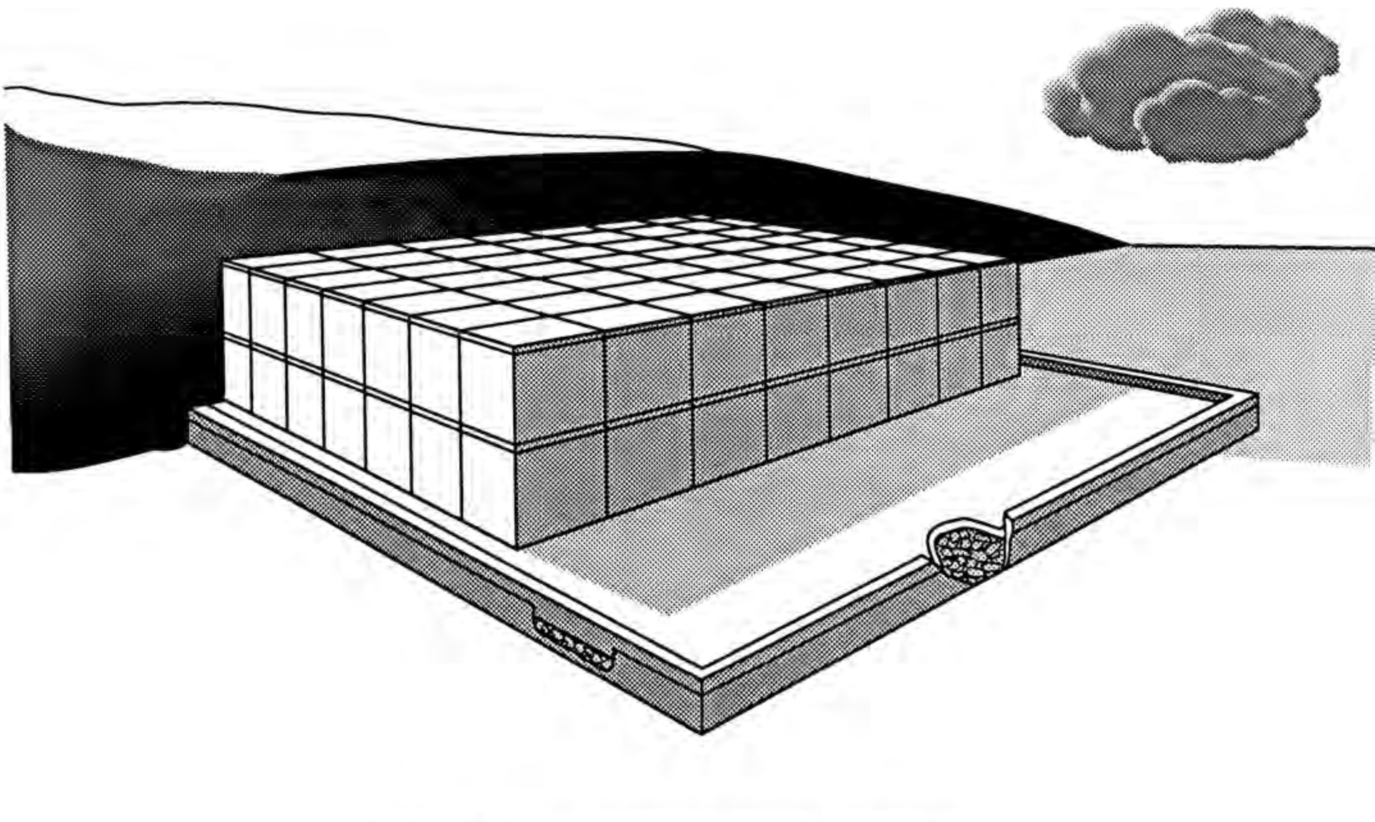

Fig. 1. A Conceptual Sketch of the Capped Tumulus.

below-grade disposal.

- The land area must be large enough to accommodate an earthen cover 1.8 m thick with a 4:1 side slope.
- The site must be accessible by forklift and crane from the staging area.
- The site should be located on a level area where the slope is < 10%.
- The site should be located as far as possible from surface drainage features.
- The site should not interfere with the overall surface water monitoring scheme.

Design Criteria

The chief objectives of the tumulus design were to provide multiple, engineered barriers to isolate radionuclides and allow for complete monitoring of leachates. These barriers are provided by the primary containers, disposal vaults, concrete pad, and underpad liner. A concrete disposal vault (2) was designed to receive a 1.2 X 1.2 X 1.8 m steel or metal box, to provide a 7.6-cm annular space, and to provide structural stability for the waste to reduce the potential for cap subsidence. The vault was designed with epoxy-coated rebar and wire, a concrete mix almost identical to that specified for the pad, and a waterproofing additive. The vaults have forklift slots cast in the bottom for ease in handling.

The following design criteria (2) were used for the pad:

- The lifetime of the pad will be approximately 300 yr.
- The pad must support 3 to 5 m of LLW contained in disposal vaults, a soil overburden of 1.2 to 1.6 m, a concrete cover of 0.6 m, and earth-moving equipment.
- The pad shall contain and collect all rainwater during loading operations and leachate after closure.
- The pad shall be sized to hold approximately one year's generation of LLW from Oak Ridge National Laboratory.

The most difficult design criterion to satisfy was the 300-yr lifetime. The approach taken was the use of high-strength concrete (415 kg/cm^2) with two layers of No. 6 (2.1-cm) epoxy-coated reinforcing steel to minimize the potential for corrosion. The steel reinforcing is spaced on 15.2-cm centers, a considerably narrower interval than conventional practice. The 32-m by 19.8-m concrete pad varies in thickness from 20.3 cm in the center to 40.6 cm at the thickened footer along the sides. A 15.2-cm curb surrounds the entire perimeter of the pad, which slopes to the west at 1%, to a gutter with two floor drains. The two drains empty into a single line connected to the monitoring station.

The 30-mil plastic liner is sealed to the pad to ensure collection of leachate in the event of leakage through the pad. The liner is sloped to the west, where any drainage flows through a pipe to the monitoring station.

Approximately 3 months after the pad was constructed, water flow was noted in the underpad liner drain. Investigations have identified three possible sources of the water. First, flood tests strongly suggest that the underpad liner/liner drain seal is leaking from the outside to the inside from a perched water table but not vice versa. Consequently, the underpad liner still acts as a qualitative leak detection system. Second, a poor seal where the underpad liner is fastened with a batten strip to the concrete pad creates a potential for rainwater to enter the liner. Third, a rubber boot used to provide the seal between the liner and the two surface drain pipes failed during construction and again after construction.

A drain will be constructed to eliminate the perched water table, and the poor seals have been corrected. However, since drainage from the underpad liner has continued, the liner will be eliminated in the future for the following reasons:

- There are sufficient barriers to contaminant migration without the liner.
- There is no evidence that a synthetic liner will last for the 300-yr design life.
- The problems with liner installation and testing outweigh any advantages.

The design for the cover of the tumulus facility has not been completed, but the proposed conceptual design includes a multilayered cap with drainage layers, an impermeable layer, inadvertent intruder protection, and a vegetative layer. The cover design will not be finalized for several years so that it can be incorporated into the overall closure of the disposal area. In the meantime, an interim plastic or canvas cover will be used.

Construction Experience

The pad was constructed during the period October 1986 to May 1987 (2). Approximately 1 month after the concrete pour, hairline cracks appeared at several locations. The cracks do not appear to be caused by loads imposed on the pad by the stacked vaults, but because the rebar cover is as much as 1.3 to 2.5 cm thinner than specified (5.1 cm) at several locations, and the concrete shrank during curing. Fortunately, structural calculations have confirmed that structural strength is adequate to support the pad loads, and pad surface flood tests have shown no leakage. In the future, rebar elevations prior to the concrete pour will be compared to those during finishing operations, and an improved concrete mix will be designed to minimize cracking potential.

OPERATIONS

As part of the operational planning, the unit operations were identified and described (3). Briefly, the packaged LLW is brought to the staging area; the packages are placed into the disposal vaults; the annular space between the vault and the package is grouted; a lid is sealed to the vault; and the vault is placed on the concrete pad. Following is a summary of the operating experience to date (2).

Continuous loading operations on the tumulus pad started in April 1988, and as of the end of December 1988, 120 of its 250 disposal vaults (800 m^3) had been loaded. Concrete block spacers are placed on the bottom of the disposal vault. The primary LLW packages are placed in the concrete vaults by a crane, centered in the cavity to achieve a uniform annular space around the waste container, and then backfilled with grout. During initial operations, the containers "floated" as the grout was added. A mechanism was constructed to hold the containers down, and only enough grout was added to fill the vault halfway. After a curing period, the containers are held in place by the backfill, and the remainder of the grout can be added. After a bitumen sealant is placed on the upper vault edge, the concrete lid is placed and held in position with steel bands.

The completed vaults weigh 9900 to 13,500 kg with an average of 10,800 kg. The vaults are moved to the pad by forklift or low-boy truck. Choker cables are placed around the vault through the forklift slots, and the vault is lifted by crane onto the pad. The choker cables are removed, and the vault is pushed into final position with the forklift. During these operations, surface damage was being caused to the vaults, so pipe and wood buffers were fabricated to protect them. In the future, an overhead crane may be used for positioning the vaults. Vault loading has created a very uniform stack; the maximum space noted between vaults is about 2.5 to 3.0 cm.

MONITORING

Two types of monitoring are conducted to assess the performance of the tumulus facility environmental and worker exposure. The monitoring programs were developed to meet the following objectives:

- comply with regulatory monitoring requirements,
- develop a data base for evaluation of the performance of the tumulus facility,
- develop monitoring cost data,
- collect sufficient data for use in future environmental assessments and pathway analyses,
- evaluate work procedures to maintain worker exposures As Low As Reasonably Achievable (ALARA),

TABLE I
Environmental Monitoring Program Tumulus Disposal Demonstration Facility.

Monitoring activity	Frequency	Constituents
Groundwater elevation	Every 15 min	Level
Groundwater quality	Quarterly	Gross alpha, gross beta, gamma scan, tritium, pH, ^{60}Co, ^{137}Cs
Pad runoff and underpad quality	Quarterly	Gross alpha, gross beta, gamma scan, tritium, pH
Pad runoff and precipitation quantity	Every 5 min	N/A
Underpad drainage volume	Every 15 min when flow occurs	N/A
Meteorological data	Hourly	Wind speed, wind direction, relative humidity, solar radiation, temperature
Soil	Quarterly	Gross alpha, gross beta, gamma scan

- determine what components of the monitoring programs used for the demonstration are suitable for a full-scale facility, and
- assess worker and public safety.

Environmental Monitoring

The environmental monitoring plan currently includes the characterization of groundwater, pad runoff, underpad drainage, meteorology, and soils. After the tumulus pad is filled and capped, the above parameters will continue to be monitored, while the measurement of cap subsidence and pad settling, infiltration through the cap, and soil moisture will be added. This paper addresses only the monitoring during the operations phase. Parameters being monitored and the frequency of monitoring are shown in Table I.

The two pad drain lines and the underpad drain line are routed to the monitoring station where flow is measured with a Parshall flume, and samples are collected by a flow-proportional composite sampler. The pad runoff flow rate is small, and there has been difficulty in calibrating the Parshall flume at low ranges. In the future, another flow monitoring device such as a V-notch weir will be used. When the cap is constructed over the tumulus pad, the flow rates will decrease significantly, and a more accurate flow measurement device for low flows will be necessary.

After each storm event, a pad runoff sample is collected. In the event that runoff from the pad is contaminated, a contingency plan defines three action levels, the actions to be taken, and those responsible for the actions. The action levels are shown in Table II.

To date, Action Level I, the lowest concentration requiring action as part of the contingency plan, has been exceeded only once for total suspended solids.

One deficiency identified with the groundwater monitoring system was the lack of a shallow piezometer to measure perched water levels under the pad. Although the groundwater elevation has remained below the underpad liner, the liner has nonetheless come into contact with perched water as discussed previously. Therefore, a piezometer was installed at the edge of the pad to monitor this water level.

The groundwater monitoring indicates that the concentration of gross alpha, gross beta, tritium, ^{60}Co, and ^{137}Cs are in the range of the blanks. The large number of past and present waste disposal operations in the area makes it difficult to establish a good reference data set for the tumulus facility because the cause of any water quality change is difficult to identify. Therefore, if a facility to be monitored is in the proximity of other waste disposal facilities, the groundwater monitoring network must be carefully designed to meet the objectives of the monitoring program and to distinguish between upgradient and downgradient water quality.

TABLE II

Contingency Plan Action Levels Tumulus Disposal Demonstration Facility.

	Contaminant concentration					
Action Level	Alpha (pCi/L)	Beta (pCi/L)	O&G[a] (mg/L)	TSS[b] (mg/L)	pH	Action
1	100	500	10	30	<6.0 <9.0	Increase monitoring
2	200	1000	15	50	<6.0 <0.9	Inform appropriate parties
3	2500	7500	NA	NA	NA	Determine cause and take remedial action
4	Exposure rate = 2.5 mR/h above ambient					Cease operations except to remediate the problem

[a] Oil and grease.

[b] Total suspended solids.

Worker Exposure Monitoring

To assess the radiological exposure of the workers, a worker exposure monitoring program is conducted. This monitoring program includes site surveys, particulate air sampling, worker exposure rate surveys, and primary waste container surveys. At least 20% of all incoming primary waste containers and unit operations are monitored.

The site surveys on the tumulus pad show average exposure rates of approximately 0.44 mR/h on the vacant portions of the pad, which is typical of preoperational values, and 0.18 mR/h at 1 m from the sides of the outer rows of vaults.

Particulate air sampling shows the maximum concentrations of gross alpha emitters (0.5×10^{-12} $\mu Ci/cm^3$) and beta-gamma emitters (4.8×10^{-12} $\mu Ci/cm^3$) to be below the maximum permissible concentrations for unidentified emitters in air, which are 1×10^{-12} $\mu Ci/cm^3$ and 1×10^{-10} $\mu Ci/cm^3$, respectively. Based on the radionuclide distribution, it appears that this activity in air is natural, not man-made and is due to the daughter products of the gaseous isotopes radon^{-222} and thoron^{-220}. Thus far, the tumulus activities have not increased the ambient background activity associated with the particulates in air.

The exposures to personnel performing the unit operations are monitored as follows. Each individual routinely wears a thermoluminescent dosimeter (TLD) as part of the standard occupational health program. In addition, a self-reading pocket dosimeter is worn by the workers who enter the tumulus area. Finally, a third dosimeter is issued to a representative number of workers for each unit operation. After the completion of the task, the third type of dosimeter is removed and processed, and the readings from the self-reading pocket dosimeter are reported. In addition, a continuous air sample is collected during each unit operation to document the level of airborne radioactivity that might occur from undiscovered loose surface contamination or from undiscovered leaks.

The total collective dose received by the disposal crew in preparing and placing a disposal vault onto the pad is approximately 225 mrem, and it takes approximately 1 h to perform the job. The vault filling unit operation is responsible for 76% of this dose; vault grouting is responsible for 21%; vault sealing is responsible for 2%; and vault loading onto the pad is responsible for 1%. The riggers receive the highest collective dose because they work in the closest proximity to the disposal vaults; they comprise 50 to 80% of each disposal crew.

COSTS

It is estimated that the design, construction, operation, and closure costs for the tumulus facility are approximately $1950/m^3 on an "as disposed" basis (2). Costs on an "as generated" basis could be much lower, depending on the degree of waste compaction achieved. The manufacturing and operating costs are based on actual costs but are extrapolated to a filled pad. The cost of the cover is based on an estimated cost for a conceptual cover design.

CONCLUSIONS

This demonstration is being conducted to assess the suitability of the tumulus technology for the disposal of those LLW that result in acceptable doses to the environment and the public after an institutional control period of 100 yr. While it is impossible to document that the facility will remain intact for 100 yr to contain the LLW, there is sufficient general experience with concrete to expect it to do so.

The environmental and worker exposure monitoring programs, the design, and the operational procedures appear to be acceptable with the exception of the underpad liner. In the future, the underpad liner will be eliminated from the design because there are already sufficient barriers to contaminant migration, there is no evidence that the synthetic liner will last for 100 yr, and there has been difficulty making the liner watertight. Based on these findings, Energy Systems intends to incorporate the tumulus technology into its long-range plans for the disposal of LLW.

The design, construction, and performance assessment of the cap remain to be done. While the ability of the cap to minimize contact between the waste forms and infiltrating rainwater is critical to the success of the tumulus technology and while the demonstration of this ability will take many years, immediate use of the technology should not be delayed.

REFERENCES

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