EXISTING LLW TREATMENT AND DISPOSAL TECHNOLOGY OFFERS 17-TO-1 VOLUME REDUCTION AND ADVANCED DISPOSAL AT LOW COST*

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ABSTRACT

Existing technology was used to develop a conceptual design for a Waste Treatment and Disposal Complex (WTDC). The designed facility would treat nearly 100% of all solid low-level radioactive waste (LLW), regardless of waste classification. Approximately 95 vol% of all LLW would be delivered in reusable shipment containers to the WTDC, where treatment would produce a liquid-free, densely-compacted, 98 vol% inorganic waste. The treated waste would be packed with contaminated grout in uniform, smooth-sided, thin-walled, steel boxes. The boxes are stacked tightly in abovegrade, earth-mounded, concrete, disposal vaults, where they will be protected from water after vault closure. The 210-pound-per-cubic-foot waste prevents subsidence. Engineered earthen covers are placed over the vaults at the final closure and should keep water out of the waste long after vault degradation. A volume reduction factor of 17-to-1 is achieved through sorting, incineration, metal sizing operations, intense compaction, and grouting. The total cost for design, construction, testing, 30 years of treatment and disposal, administration, decontamination & decommissioning, site closure, and postclosure monitoring and maintenance will cost $13 per cubic foot in 1988 dollars for an annual incoming-waste volume of 450,000 cubic feet. In comparison, estimates of present disposal costs range from around $20 to $113 per cubic foot.

BACKGROUND

Increasingly stringent requirements for treatment and disposal of low-level radioactive waste (LLW) set forth by the Nuclear Regulatory Commission (NRC), Department of Energy (DOE), Environmental Protection Agency (EPA), and various agencies of state governments are largely a result of shallow-land burial of untreated LLW and resultant instances of groundwater, soil, and atmospheric contamination.

New direction in environmental regulations concerning acid rain, the ozone layer, hazardous waste, etc. is making nuclear energy more environmentally acceptable, if not preferable. However, we must solve the problems associated with disposal of nuclear waste if we are to establish public acceptance of nuclear power. We have sufficient data from successful and unsuccessful experimentation in both waste treatment and waste disposal techniques to act now.

DECISION TO STUDY

The Defense Low-Level Waste Management Program decided to draw from the best of the free world's waste treatment and disposal technologies and create a conceptual design for a waste treatment and disposal complex that would achieve maximum volume reduction and high-quality disposal. The design would be for "anywhere USA." This study would confirm the belief that the nuclear industry could put all of its assets together and produce a top-of-the-line disposal program at an economical price. Development of the design and cost estimate would not require an in-depth study of all the complex waste scenarios found in the USA. Rather, a decision was made to develop the design for processing solid LLW only, a waste that is typical of the national average. Volume-reduction factors were to be based strictly on known data that could be substantiated by operational LLW volume-reduction programs. If the concept were proven realistic, the conceptual design could be used by any site in the USA as the genesis for Title I and Title II design of a treatment and disposal center for the specific waste to be processed.

The design would meet or exceed the requirements of 10 CFR 61 and Chapter III of DOE Order 5820.2A, the regulations of state governments, and the perceived desires of the public. In general, the treatment and disposal concept to be developed would significantly reduce the chance of contaminating the environment, reduce future liability, and improve public perception of the nuclear industry.

COMPLETED STUDY

The study has been completed and published as an informal EG&G Idaho, Inc. report: "Application of Existing Low-Level Waste Technology Offers 17-To-1 Volume Reduction and Enhanced Disposal At Low Cost", EGG-LLW-8054, October 1988. The report is available upon request from the Defense Low-Level Waste Management Program, EG&G Idaho, Inc., from Ross Darnell, (208) 226-0516 [FTS 583-0516], or from Milo Larsen (208) 526-4225 [FTS 583-4225]. This paper summarizes that report, and references that might be listed in this paper are found in that report.

EXCLUSIONS

The conceptual design was kept simple by virtue of exclusions. The WTDC was designed to process LLW only; although, the incinerator chosen and costed for the Waste Treatment Facility (WTF) will accommodate mixed waste. The WTF was not designed to accommodate combustible liquids, but could be modified to do so at very little

* Work supported by U.S. Department of Energy, Idaho Operations Office, under DOE Contract No. DE-AC07-76ID01570.

additional cost. Pyrophoric waste and waste emitting 500 mR/h were excluded from the treatment processes and are to be stabilized in high-integrity containers (HICs) or in WTF overpacks by the generators and disposed of in the Waste Disposal Facility (WDF). Those two types of waste constituted less than 0.3 vol% of the waste analyzed for the design. Melting is a viable option, but the waste analyzed for this study did not warrant melting.

IMPORTANT DETAILS OF DESIGN AND OPERATION

Collocation of the WTF and the WDF is one of the economizing features of the WTDC. It allows a single team under a one manager to handle both waste treatment and waste disposal. Transportation of treated waste to the disposal vault is a highly automated function on a dedicated transfer system. The WTDC is in reality a one facility, one operation.

The WTF will fully treat all waste using exactly the same processes, regardless of DOE or NRC waste classification. Sorting makes it possible to incinerate nearly all organic material and to compact the inorganic material. The result of those processes is that no free liquids will leave the WTF for disposal. An estimated 98 vol% of the waste leaving the WTF will be inorganic, which minimizes the probability of rotting waste, gas generation, and subsidence after disposal.

Figure 1 shows the first-floor layout of the WTF, and will assist in understanding the treatment processes. Most current LLW operations treat a portion of the waste, and when all the available waste is considered, an overall volume reduction of 50% may be achieved. Sorting is the key to 1700% volume reduction achieved in the WTF. To achieve 1700% volume reduction, it is essential that nearly 100% of generated solid LLW to be routed through the WTF.

Unsorted Waste

Some 65 vol% of the overall waste generated will be transported to the WTF in standard-sized reusable bins. Waste in those bins will be transferred by a double-lid transfer system to a lazy-susan sorting table, which is similar to baggage claim systems found in airports. At the sorting table, approximately 25 vol% of the total generated waste consists of organic waste such as plastic bags, wipes, shoe covers, and rags that can be separated from inorganic waste and routed to the organics shredder via conveyor. After shredding, those organics are routed to the incinerator.

The remaining waste is inorganic and is routed by conveyors for plasma-arc torch sizing, shear sizing, shredder sizing, or is routed directly to the fines separator. The fines separator routes fines to the grout mixer and routes sized large-fraction waste to a puck box. Once filled, the puck box is automatically routed to the 5000-ton compactor, where it is reduced to a rectangular "puck."

Prepackaged Incinerable Waste

Approximately 30 vol% of the waste is incinerable waste packaged in cardboard boxes by the generators and is delivered to the WTF in reusable international cargo containers. That boxed waste is then routed directly to the WTF incinerator without sorting. Altogether, about 55 vol% of the total generated waste is incinerated and the ash is blended into a grout mixture for an overall volume reduction of 124-to-1.

Waste Unsuitable For The WTF

Three tenths of one percent of the waste analyzed in the development of the report was above the 500 mR/h limit established for the WTF. This waste does not enter the WTF, but is instead concreted in place in the vault's waste stack.

Waste for Sizing

The remaining 5% of the generated waste consists of large items that require sizing before incineration or compaction. That waste is delivered directly to the sizing area and is not processed through the sorting area.

Jigs, fixtures, and other cumbersome, contaminated, metal waste items too large for delivery in reusable bins are delivered directly to the sizing area through a large airlock. Once sized by torch and/or shear, those metal items can be placed in the shredder for further sizing, or in the fines separator for direct delivery to the compactor.

Railroad ties, pallets, and such are also delivered through the sizing area airlock and are then routed through the WTF to the organics shredder, whether they are in reusable bins or are specially packaged. Reusable bins filled with inorganics such as dirt, rock, pavement (usually from decontamination and decommissioning efforts) would also be delivered in this manner to bypass the sorting table and go directly to the inorganics shredder.

Grouting is the final treatment and follows compaction. A layer of grout is placed in a standard-sized 12-gauge carbon-steel box and a puck is lowered into the box. Since the puck has a smaller cross section than the box, grout oozes up around the puck. Another layer of grout is placed on top of the puck and another puck is lowered into the box and so forth, until the box is full. When the grout is screed level with the top of the box, a lid is secured and the box is placed in storage until the grout has cured. It is extremely important that the boxes be exactly the same size for void-free stacking. Therefore, a mold-form is fastened around each thin-walled box to prevent bulging. See Fig. 2 for details on this important concept.

Once the grout is cured, the mold-form is removed and the box goes through the normal package-identification procedures (weighing, contamination check, radiation analysis, classification, inventory control, and so forth). The box is then routed to the WDF vault on a small, covered railcar via a dedicated narrow-gauge rail system. The waste-box delivery zone and the entire vault are covered by a metal roof to protect the waste. See Fig. 3.

It is the use of reusable containers that provides a major cost savings in the 30-yr life of the WTDC; the WTDC will be disposing of approximately 17 times fewer containers, each of which is expensive. In contrast, the onetime procurement cost for 1600 reusable containers is small.

When a specified quantity of waste boxes has been stacked to the top of the vault (see Fig. 4), the metal roof

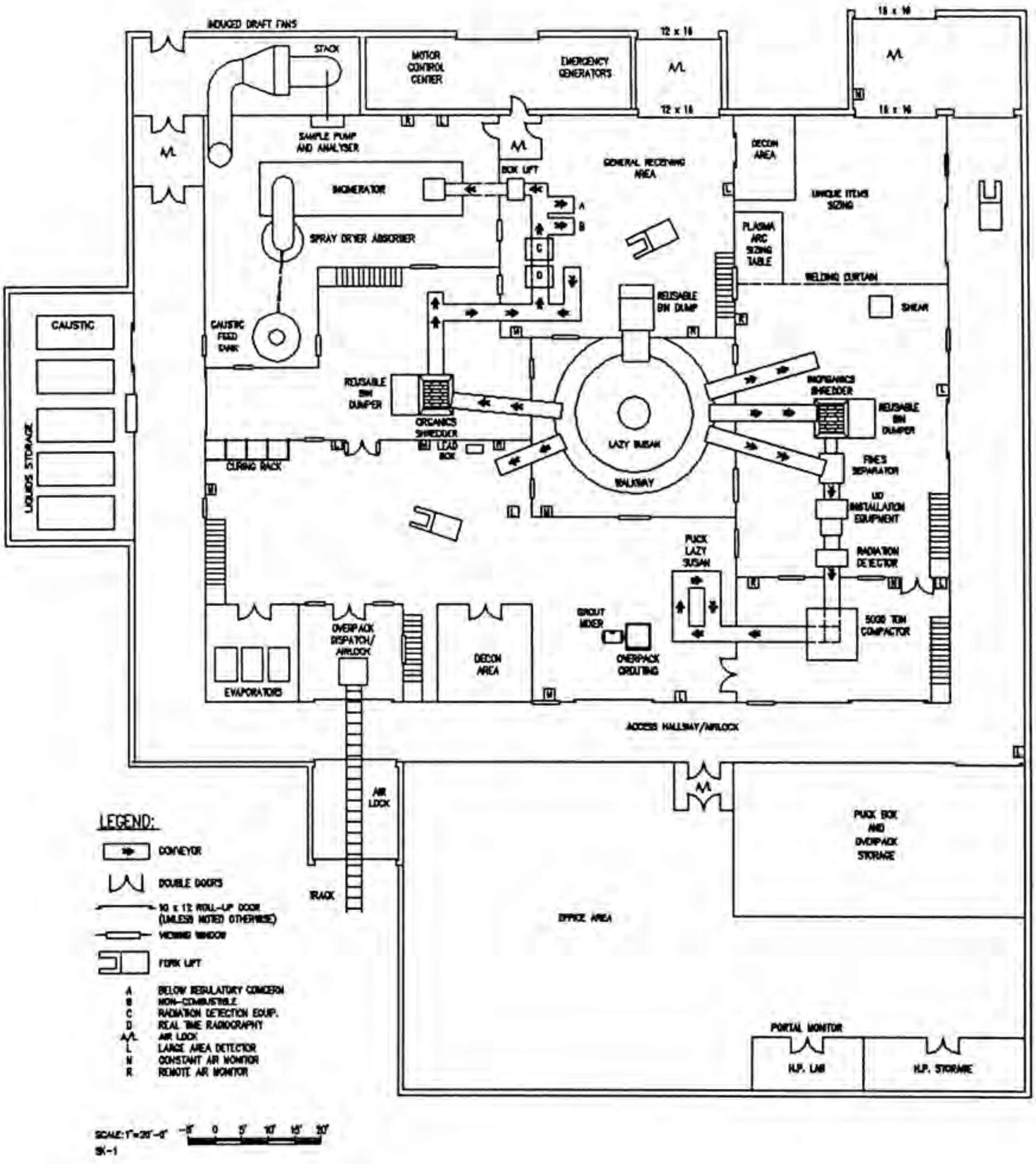

Fig. 1. WTF, Ground Floor.

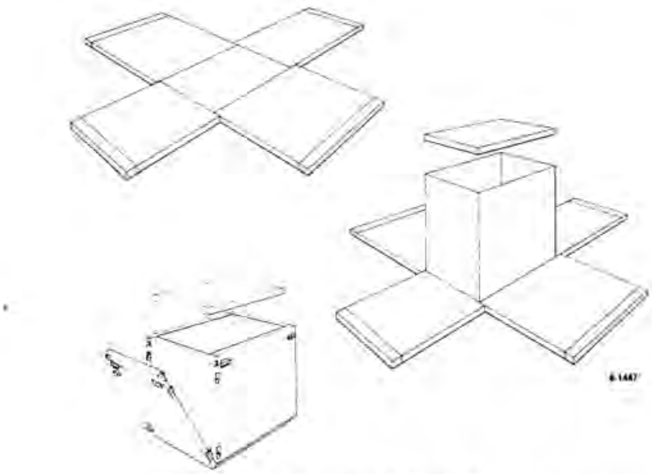

Fig. 2. Mold-form and Puck Box Interface.

View A: A mold-form is shown laid out in the horizontal position ready for a new, empty overpack box. It is constructed of 1-in. steel plate. All four side walls are joined to the central floor plate by hinges. The entire mold-form will be coated with mold release to ensure that grout does not cause the mold-form to adhere to the overpack box, and to ensure that splattered grout can be easily removed by washdown.

View B: An empty overpack box will be properly centered before the sides of the mold-form are raised to their vertical positions. The overpack lid is shown suspended above the overpack box.

View C: The heavy sides of the mold-form will be raised mechanically and locked together at the corners. The corners will overlap as shown to assure maximum radiation shielding is provided by the mold-form. Note that the top edges of the sides are hinged and can be lowered for placement of the overpack lid after the grout is in place. With the lid in place, the top edges will be raised and locked in place again for grout curing.

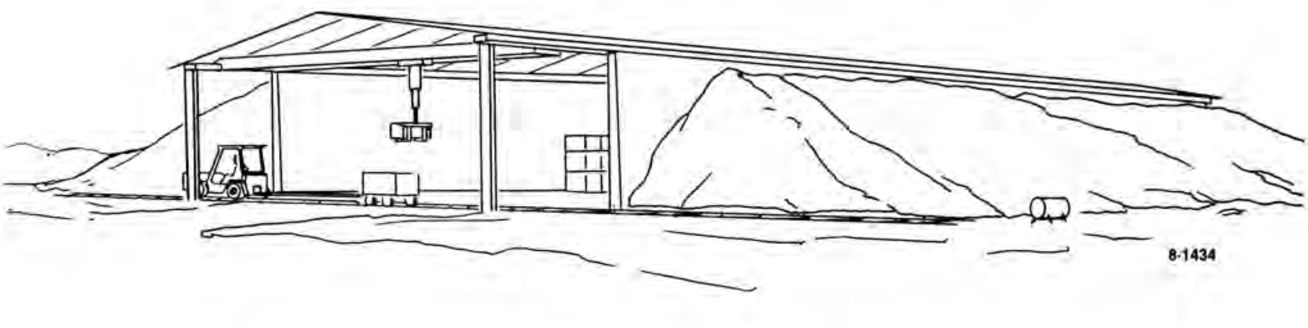

Fig. 3. WDF Vault Configuration.

A narrow-gauge railroad track that originates at the WTF will end here at the front of the vault. A bridge crane rail will be installed along the top of the vault walls, and a removable metal roof will be attached to the exterior of that rail to keep rain and snow out of the vault, off the bridge crane and rails, and off the railroad track at the overpack unloading site. Each overpack box will be lifted by the bridge crane from the railcar and placed on the stack in the vault, or stored along the wall for future permanent placement. All free liquids will have been removed from the waste during treatment. If deemed necessary, the exposed end of the vault could be closed off to further prevent water from entering the vault. The goal is to keep the overpack boxes dry during transport to the vault, during the stacking operation, and through vault closure.

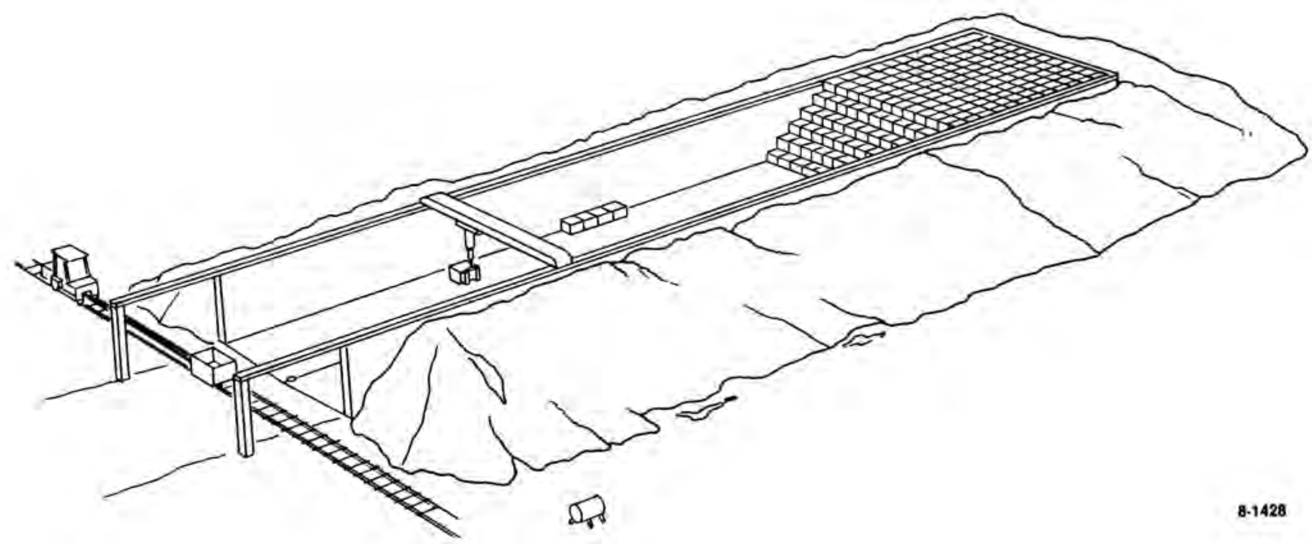

Fig. 4. WDF Vault (Tight Stacking).

covering that section is removed and a water-shedding concrete roof is poured directly on the waste stack (see Fig. 5). The waste placed in the vaults will be grouted and compacted to an average density of approximately 210 pounds per cubic foot, capable of withstanding the weight of the concrete roof and overburden with a roof subsidence of less than 0.1 in.

Upon closure, the vaults will be covered with the best combination of materials, which will be determined by the latest engineered vault-cover tests as of that date. Fig. 6 shows the vault and details a cover engineered in France that only allows 0.1% penetration by the 1-meter annual rainfall in the area. Whatever the climate, the engineered cover would be designed to prevent erosion, and biotic and water intrusion. An important feature is that the vaults will be built above grade and above the probable maximum flood plain.

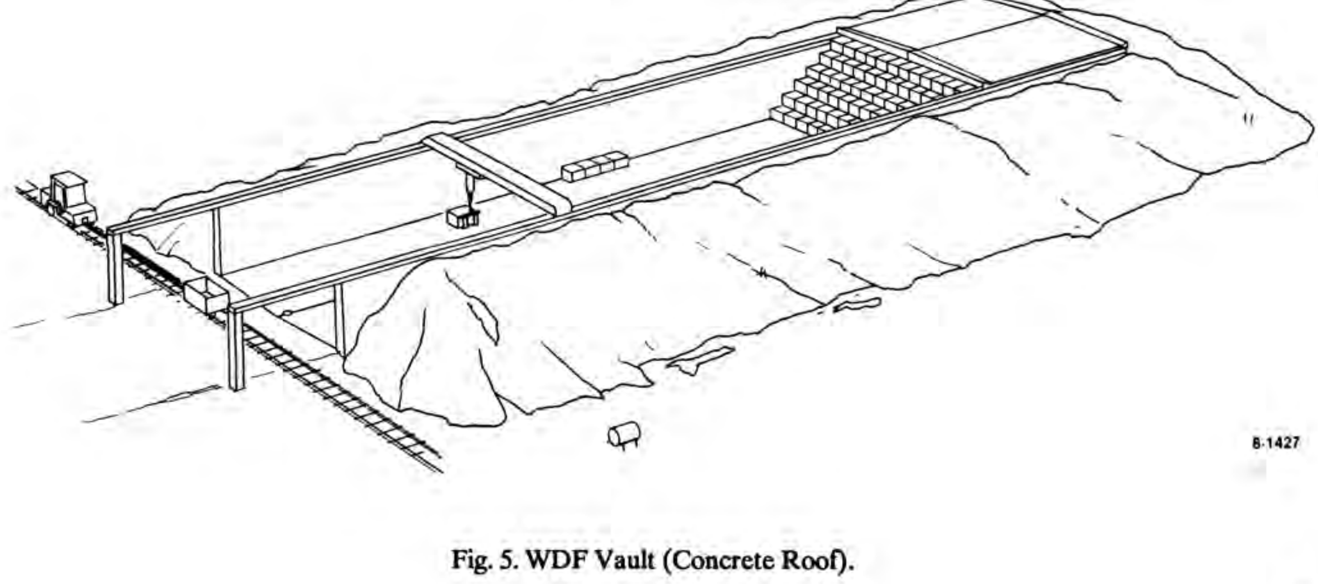

Fig. 5. WDF Vault (Concrete Roof).

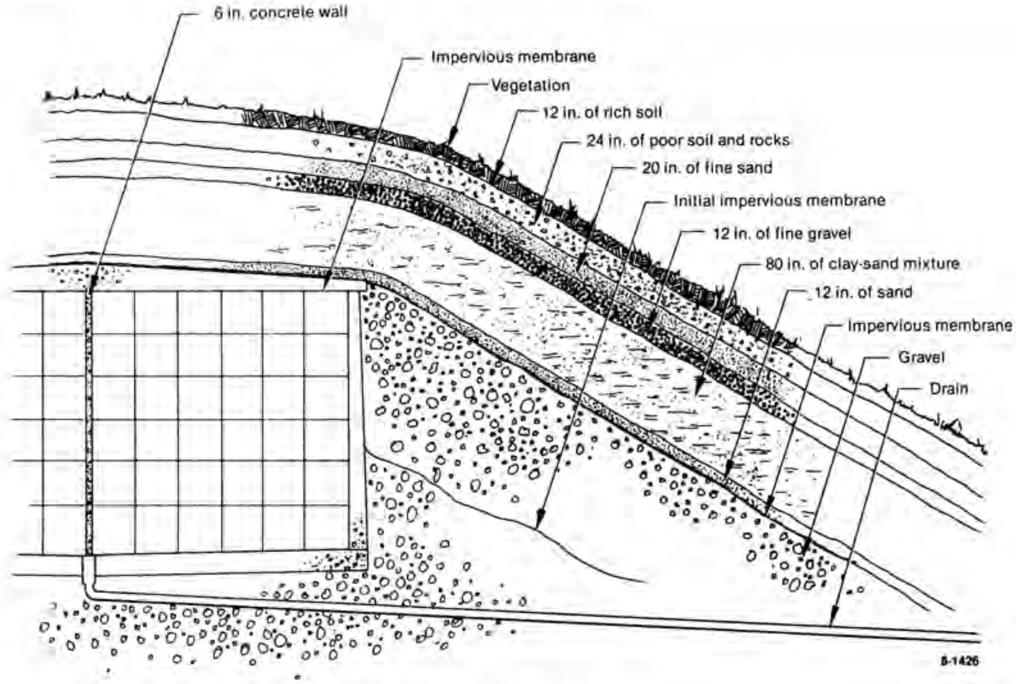

Fig. 6. WDF Vault Cover Materials.

Properly designed, the cover should require no maintenance after final closure.

Even after degradation of the concrete vault and the grout, the combination of very dense, inorganic waste and essentially no voids in the waste stack ensures that subsidence will be practically nonexistent. With subsidence eliminated, the earthen cover should continue indefinitely to function as a shield, shedding water away from the waste.

RADIATION PROTECTION

For maximum protection against intrusion, the waste packages with the highest waste classifications (first priority) and the highest radiation levels (second priority) will be placed along the center line of the vault on the bottom layer; the least hazardous waste packages will be placed along the walls and on the top (sixth) layer. That will ensure only background radiation levels at the external surface of the concrete disposal vault, and of course, only background levels at the surface of the earthen cover, thus exceeding the requirements of applicable regulations.

VERSATILITY OF THE WTDC

As designed, the WTF could accommodate extreme variations in waste composition, with no adverse impact on operations. The WTF is designed to treat waste at a rate of 450,000 cubic feet per year (the average annual volume of waste disposed of at DOE LLW disposal sites); however, it will accommodate six or seven times as much waste by increasing the operations crew and implementing a three-shift, 7-days-per-week, work schedule. As waste throughput increases, the cost of treatment and disposal decreases and of course, the opposite is true. The designed complex allows one area to close for maintenance with minimum impact on operations in other areas.

VOLUME REDUCTION POTENTIAL

Over a 30-yr period, the WTF would treat 13,500,000 cubic feet of incoming LLW and produce 790,000 cubic feet for disposal in the WDF. The technical volume reduction achieved by treatment alone is 17-to-1. The actual volume reduction for disposal is 19-to-1, which is achieved by using smooth-walled, standard-sized, rectangular parallelepiped overpacks, with no appendages. This ensures that extremely dense packing in the vaults can be achieved. See Fig. 4 and 6. (Cylindrical containers and containers with forklift cleats or lifting lugs create a lot of voids in today's waste stacks.)

Note: Volume reduction ratios of 17:1 and 19:1 are impressive, but these will increase and decrease as the waste composition changes. What is important is that, short of melting, the density for any given waste will be near the maximum achievable.

SAFETY

Streamlined treatment processes, waste stability, standard-sized disposal containers, a dedicated transportation and stacking system for disposal containers, and collocation of waste treatment and waste disposal facilities, all permit a reduction in handling and transportation. In turn, those factors improve safety and minimize radiation exposure of the technicians. Some specific examples follow. Only a portion of one technician's time will be required daily to place the two LLW overpacks in the disposal vault with remotely operated stacking equipment. Standardized disposal boxes that are relatively small lend themselves to the effective use of both permanent and temporary shielding during filling, curing, and transport to the vaults.

Tremendous reduction in disposal volume and the self-shielding waste form also reduce the overall radiation exposure of workers. By virtue of the entire WTDC concept, future intruders are less likely to encounter radiation.

COST

Based on the waste treatment and disposal concept developed, the total cost of treatment and disposal over a 30-yr period will be approximately $13 per cubic foot--considerably lower than present average disposal costs.

CONCLUSION

Even though shallow-land burial may meet existing regulations, complete treatment and enhanced disposal of LLW will surely be perceived by the public as a positive change and may well be a factor in leading the way toward public acceptance of nuclear power as a pollution-free source of energy for the nation. When all this can be achieved at a lower cost than current practices, why not do it?