COMPARISON OF CASK AND DRY WELL CONCEPTS FOR RETRIEVABLE STORAGE OF HIGH-LEVEL WASTE

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ABSTRACT

This paper describes and compares two proposed concepts for storing high-level waste on the basis of their technical merits, technical status, research and development requirements, safety and environmental impact, and life cycle costs. This comparison indicates that although metal storage casks have technical advantages over dry wells, they are considerably more expensive and require large commitments of valuable resources.

INTRODUCTION

The deep-mined geologic repository is the reference U.S. concept for permanent disposal of high-level waste (HLW). Until this concept is licensed for operation, the waste may have to be stored in a readily retrievable storage system. The Department of Energy (DOE) has been studying such a system, the monitored retrievable storage (MRS) system, since early 1981. GA Technologies Inc. (formerly General Atomic Company) and others performed these studies under DOE contract. This paper summarizes an in-depth comparison performed in 1982 of metal storage casks and dry wells under specific scenarios for the "back end" of the fuel cycle.[1]

As the name implies, the MRS system provides equipment and facilities to contain the waste, monitor the waste containments, and retrieve the waste for repackaging, further processing, or permanent disposal. Several concepts have been proposed for the MRS system, such as casks, dry wells, vaults, and tunnels. The DOE continues to investigate new concepts. All concepts should be able to store HLW in the form of spent light water reactor (LWR) fuel assemblies, consolidated LWR spent fuel rods, and solidified HLW from reprocessed spent fuel. This study does not evaluate storage of consolidated fuel rods. Because of current interest in metal storage casks for at-reactor storage of spent fuel, the DOE studied the applicability of these casks for the MRS.

This study compares three back-end fuel-cycle scenarios. The reference scenario assumes LWR spent fuel reprocessing to begin in 1989 and disposal to begin in 1998. The other scenarios evaluated assume that either reprocessing or disposal is delayed by 10 years. With reprocessing starting in 1989, the MRS facility stores only solidified HLW. When reprocessing is delayed, the facility stores only spent fuel.

CONCEPT DESCRIPTION

The MRS facility design consists of three principal areas: (1) receiving and handling, (2) storage, and (3) support. Shipping casks are processed and unloaded in the receiving and handling area. Storage casks or dry wells are located in the storage area. All buildings, structures, and systems needed to operate the MRS facility (e.g., the administration building, the process steam plant, and the emergency vehicle/fire truck station) are included in the support facilities. This study assumed that the facility would also be used to store transuranic (TRU) wastes. The same facility is used in either the cask or dry well MRS designs.[1]

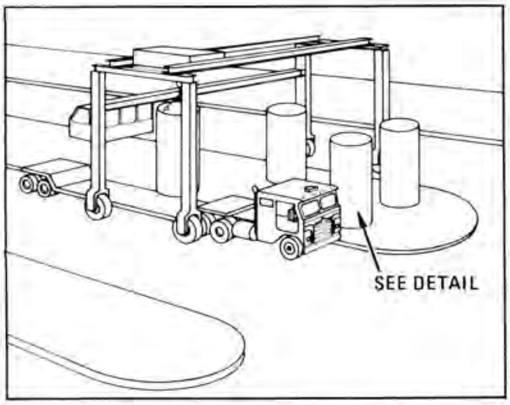
Figure 1 shows the Riddihalgh, Eggers, and Associates (REA) 2023 storage cask, which is the reference metal cask used in this study.[2] It weighs 90,710 kg (100 tons) loaded and is approximately 2.4 m (8 ft) in diameter by 4.9 m (16 ft) long. Spent fuel or solidified HLW is transferred from the shipping cask to the storage casks in water pool handling facilities. A rail transport car and a mobile crane transfer the storage casks to the outdoor storage area. The storage cask can hold 52 intact boiling-water reactor (BWR) assemblies or 24 intact pressurized-water reactor (PWR) assemblies. This cask is assumed to hold 14 solidified HLW canisters. Each HLW canister is assumed to be 32.4 cm (12.75 in.) in diameter and 3 m (10 ft) long. This study does not consider consolidated fuel rods.

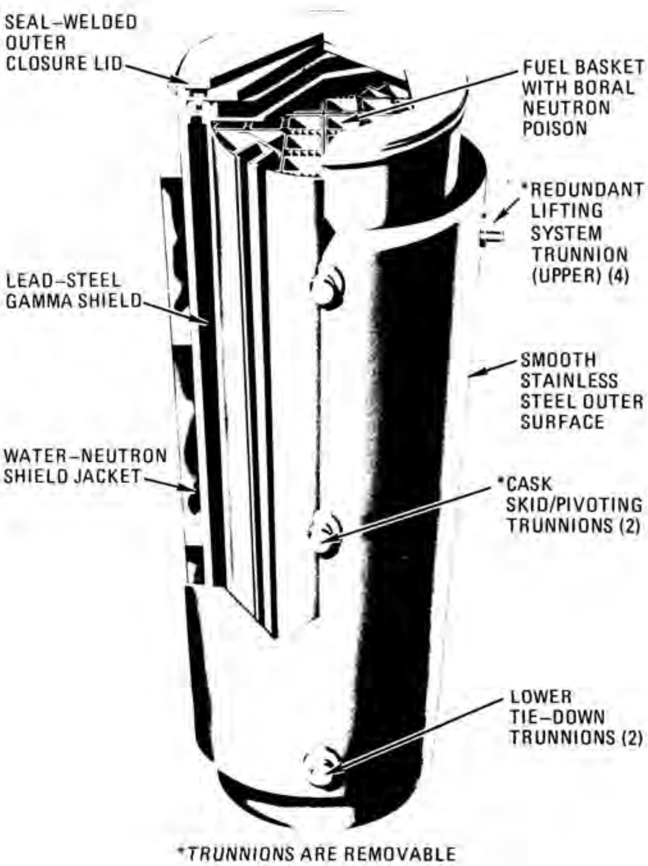
Figure 2 shows the Rockwell Hanford/Kaiser surface dry well design, which is the reference dry well used in this study for comparison with metal storage casks.[3] This concept also uses water pool handling facilities to unload the shipping cask. After unloading, solidified HLW is transferred directly to the storage field, whereas spent fuel assemblies are packaged in steel canisters prior to storage. Each canister holds one PWR assembly or three BWR assemblies. A shielded transporter, designed to load and unload dry wells, transfers individual canisters to the storage field. The dry wells in the storage field are cylindrical steel encasements placed in 7.3-m (24-ft) deep by 102-cm (40-in.) diameter ground surface holes on a pitch spacing determined by the canister heat output and the soil thermal conductivity. This spacing may vary from 3.05 to 12.2 m (10 to 40 ft). The dry well may also be surrounded by up to 30.48 cm (12 in.) of concrete. One canister is placed in each dry well, and a sand plug is added for shielding.

CONCEPT COMPARISON

Technical Merits

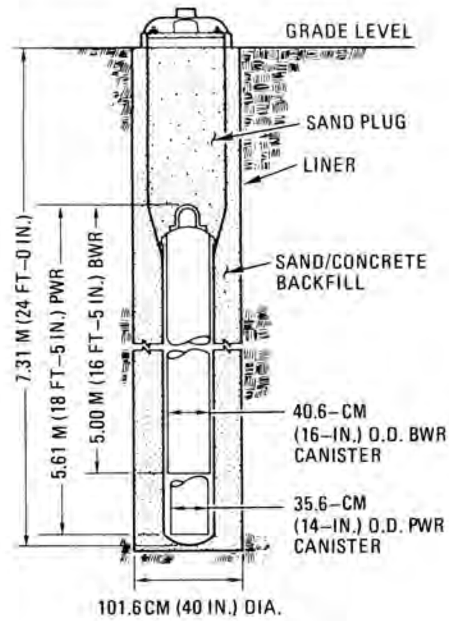
Metal casks have technical merits over dry wells. The casks do not require spent fuel assemblies to be packaged into canisters. Radioactive material is immediately transferred from the shipping cask to a shielded storage container, whereas the dry well concept involves several transfers of this material in and out of shielded systems, each with potential for malfunction. External shielding and containment surfaces can be visually monitored for casks but not dry wells. Thermal performance may be more predictable for casks, although this study did not include thermal analysis. Dry well transfer equipment moves one canister per trip to the storage area, whereas a cask holds at least 14 times as much material when it is moved to the storage area.





*TRUNNIONS ARE REMOVABLE

Fig. 1. REA 2023 Storage Cask



TYPICAL DRY WELL

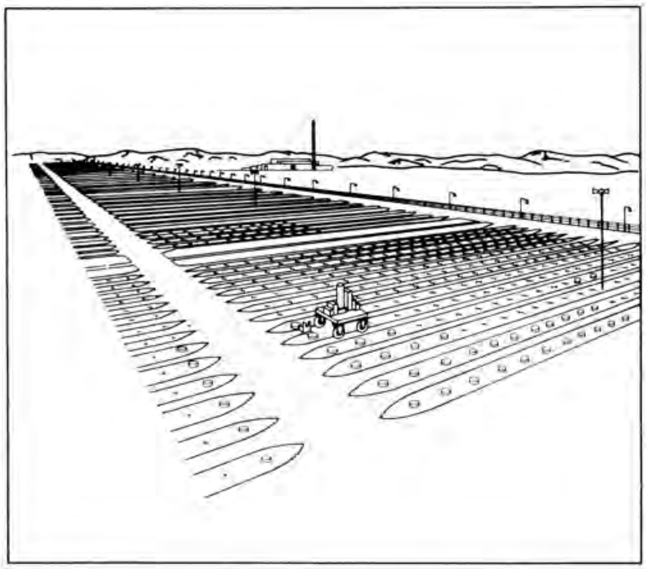


Fig. 2. Open-Field Dry Well Concept

Technical Status and Research and Development Requirements

The storage concepts are based on existing technology, existing handling equipment is utilized, and various experiments are ongoing or planned for dry storage of spent fuel or waste.[4] Several firms are developing metal spent fuel storage casks, and although this work is proprietary, metal cask technology is sufficient to produce and license prototype units. Two firms [REA and Gesellschaft fur Nuklear-Service (GNS)] have initiated licensing topical reports with the Nuclear Regulatory Commission. Research and development requirements for metal casks include experiments to demonstrate satisfactory thermal performance and to develop monitoring methods. The REA-2023 cask will be tested by the Tennessee Valley Authority.

Dry wells have stored high-temperature gas-cooled reactor and liquid metal fast breeder reactor fuel at Idaho National Engineering Laboratory. Experiments have been run with both electric heaters and spent fuel at the Hanford Laboratories and the Nevada Test Site.[5] The design of a dry well field is site specific, and thermal performance depends on conductivity of the local soil. Verification of thermal performance requires in situ testing of a typical array of dry wells. Research and development requirements for dry wells include corrosion prevention, methods to increase heat dissipation, and monitoring methods.

Safety Issues

The potential release of radioactivity during handling or storage is the main safety issue in storing spent fuel and solidified HLW. A preliminary analysis of the two concepts indicates that the risks are small compared to other nuclear facilities. For the storage cask concept, the failure modes and effects analysis (FMEA)[1] indicates two major failure modes: (1) damage to a cask containing spent fuel assemblies or (2) damage to bare spent fuel assemblies. The following initiating events are considered to have the potential to cause radionuclide releases:

1. Transporter collisions.
2. Dropping of a spent fuel assembly.
3. Airplane crash into the storage area.
4. Tornado strike.

For the dry well concept, the FMEA indicates that radionuclide release is associated with potential transporter failures or accidents. The dominant condition appears to be transporter movement while the canister is partially in place, thus shearing the canister. The following initiating events are considered to have the potential to cause radionuclide releases:

1. Transporter collision (emplacement).
2. Transporter motion while canister is partially in place (emplacement).
3. Canister drop (emplacement).
4. Airplane crash onto dry well field.
5. Large earthquake.

Environmental Issues

Because the design will control the occupational radiation dose commitment, no significant differences are expected between casks and dry wells. Public exposure to radiation is expected to be insignificant. The additional transportation required by an MRS facility will result in additional public exposure to radiation, but these levels are expected to be well below background doses.

Nonradiological environmental issues associated with an MRS facility are similar to those associated with any major industrial project, including commitment of resources, manpower, transportation, and ecological impact. The principal difference between metal casks and dry wells is that cask storage depends on the availability and usage of significant quantities of stainless steel and lead. The pollution associated with casting large quantities of lead could present a nonradiological hazard and needs to be evaluated. Large land requirements are needed for either concept; the storage field for dry wells will be considerably larger than that for casks.

Life Cycle Costs

The life cycle cost is the total of all costs incurred in developing and operating a system for a particular scenario. This study compares three back-end fuel cycle scenarios.

Figure 3 shows the back end of the fuel cycle. Reactor plants supply the spent fuel that is shipped to one of three facilities. Spent fuel goes to a reprocessing plant first, if available, until the reprocessing capacity is reached. If reprocessing is unavailable, it goes to a repository until the repository capacity is reached. If reprocessing plants or repositories are unavailable, fuel goes to the MRS facility, where it remains until capacity is available at either reprocessing plants or repositories.

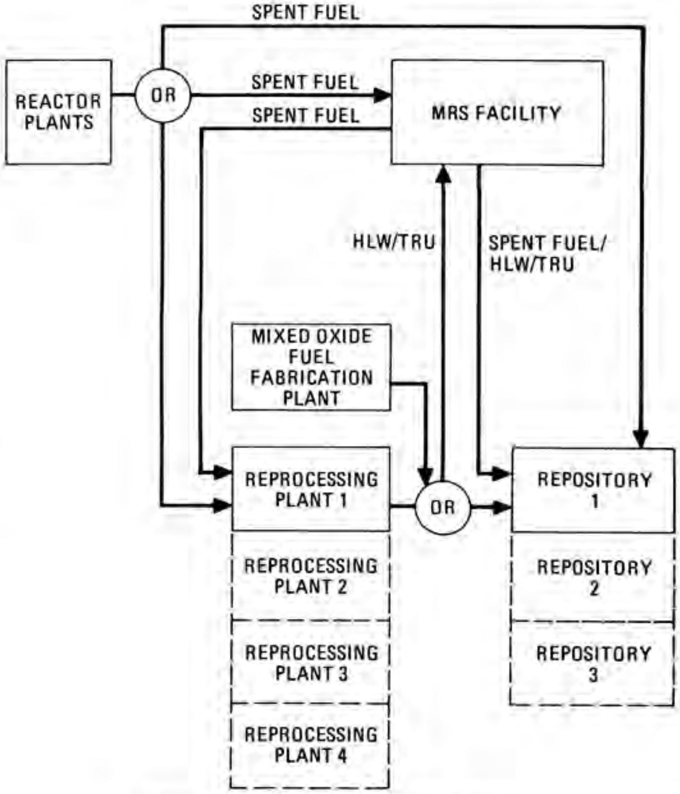


Fig. 3. Back End of Fuel Cycle

The reference scenario assumes that the first reprocessing plant will be available in 1989 and the first repository in 1998. In this scenario, the MRS facility receives only solidified HLW from 1990 to 1998. In a second scenario where the first repository is delayed until 2008, solidified HLW flows into the MRS facility until 2016 due to receiving capacity limitations at the repository. In a third scenario where reprocessing is delayed until 1999, spent fuel is shipped to the MRS facility until the repository is available in 1998. Figure 4 shows the annual handling rates for scenarios 1 and 2; Fig. 5 shows the receiving rates for scenario 3. Scenarios 1 and 2 require storage capacities of 10,500 and 61,000 equivalent metric tons heavy metal, respectively. Scenario 3 requires a capacity of 7600 metric tons heavy metal.

Capital and operating costs were estimated in mid-1982 dollars for the three scenarios.[4] These cost estimates, which have a high degree of uncertainty, were discounted at 2% to account for cash flow differences between scenarios. Table I shows the resulting total system costs, including facilities, storage, operation, and transportation. Both concepts have identical handling and storage cost for TRU wastes and identical incremental transportation cost (cost for transporting waste to the MRS). Neither cost impacts the concept comparison, but was included in the DOE study for comparison with other studies.[6]

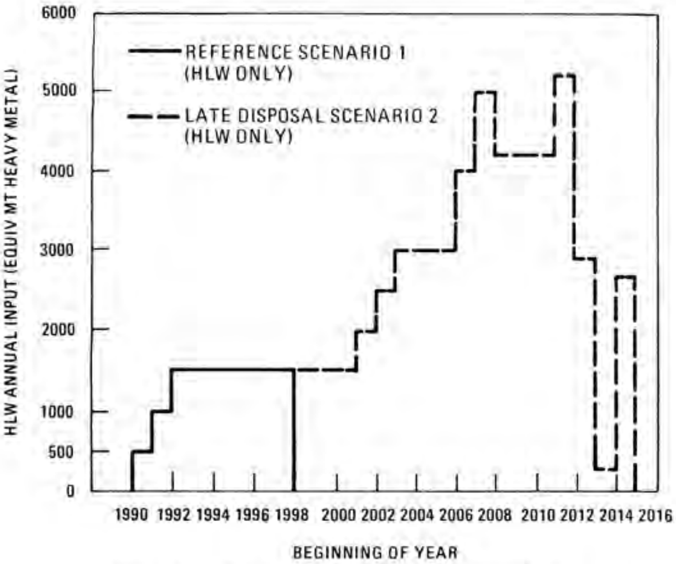


Fig. 4. Annual HLW MRS Receiving Rates

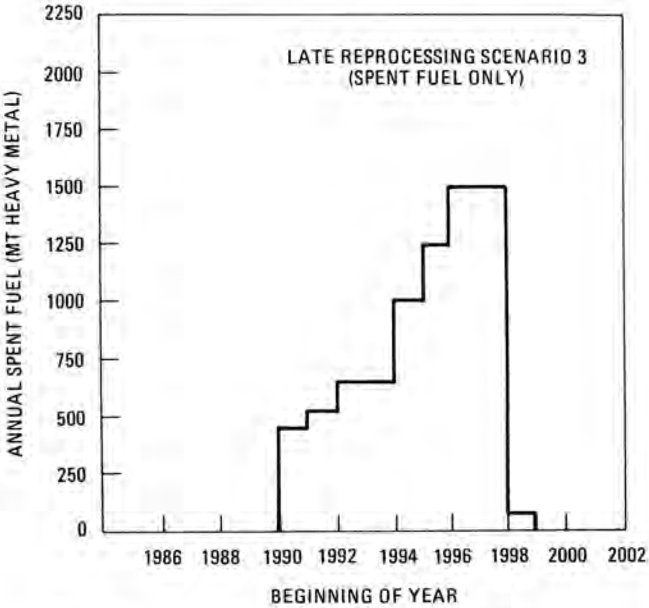


Fig. 5. Annual Spent Fuel MRS Receiving Rates

The dry well concept has the lowest life cycle cost for all cases, mainly because casks cost more than three times as much as dry wells per unit of fuel stored.

Table I also compares the operating costs of the dry well and cask concepts. In the reference scenario 1 and the late disposal scenario 2, in which only HLW is stored, operating cost differs less than 10% for the two concepts, which is within the accuracy of the estimate. In the late reprocessing scenario 3, operating costs for the dry well are about 40% higher than for casks, because added operations are necessary to package spent fuel into canisters.

The cask and dry well MRS concepts can also be compared using investment unit costs (i.e., undiscounted capital costs divided by storage capacity in kilograms of heavy metal). Table II shows that the total unit investment cost is always smaller for dry wells than for casks. Most of the unit cost difference is due to the storage unit (cask or dry well).

Because metal storage casks are assumed to be unusable as shipping casks and to require transfer facilities, Table II shows that the facility cost difference between the two concepts is negligible when the MRS facility stores only HLW. The dry well MRS facility for spent fuel is more expensive than for HLW, because it includes a packaging facility for loading and welding canisters for the spent fuel assemblies.

A sensitivity analysis was performed to determine the results for different repository schedules. When the repository schedule is accelerated by five years, the handling rate does not change, but the capacity is reduced from 10,500 to 3,000 metric tons heavy metal, which could easily be stored at the reprocessing plant. When the repository is delayed 10 years with no reprocessing, handling rates increase from 1500 to 3000 metric tons heavy metal/year, and the capacity required goes from 7,600 to 38,600 metric tons heavy metal. This results in greater life cycle costs for both casks and dry wells. However, dry wells are still less expensive, and the differences between the concepts are greater.

Another sensitivity case was evaluated where the storage casks were assumed to serve as shipping casks. Savings could be realized that would make this storage concept economically attractive below 6000 metric tons heavy metal.

TABLE I
TOTAL SYSTEM COSTS FOR MRS FACILITIES
(MILLIONS OF MID-82 DOLLARS)

Scenario	Capital Facility	Capital Storage	Operating	Incremental Transportation	Total System Costs	Discounted Total
1. Reference						
Casks	318	396	466	160	1340	1026
Dry wells	322	140	502	160	1124	846
2. Delayed disposal						
Casks	411	2225	1044	696	4376	2834
Dry wells	415	763	1116	696	2989	1994
3. Delayed reprocessing						
Casks	460	650	417	195	1722	1335
Dry wells	527	198	593	195	1513	1151

TABLE II
INVESTMENT UNIT COSTS FOR MRS STAND-ALONE FACILITY
($/KG HEAVY METAL)

Case	Spent Fuel/HLW Facilities[a]	TRU Waste Facilities	Spent Fuel/HLW Storage Unit[b]	Total Unit Investment Cost
1. Reference				
Casks	27.1	10.4	30.5	68
Dry wells	27.5	10.4	6.1	44
2. Delayed disposal				
Casks	6.2	7.1	30.3	44
Dry wells	6.2	7.1	6.3	20
3. Delayed reprocessing				
Casks	60.8	0	86.3	147
Dry wells	69.8	0	26.2	96

(a) Includes support facilities.

(b) Casks or dry wells.

A final sensitivity case assumed that the spent fuel canister could be deleted in the dry well concept. The capital cost for the late reprocessing case was reduced by $41 million and the operating costs by $3 million/year. This would make dry wells even more attractive than casks for storing spent fuel and would result in similar facilities for handling spent fuel or HLW.

SUMMARY AND CONCLUSIONS

Metal storage casks were compared with dry wells for storage of spent fuel and HLW. The following conclusions can be made from the study. The conclusions are based on the specific concepts and scenarios which were evaluated in this study.

1. Metal storage casks have technical advantages over dry wells.
2. Both concepts require little research and development, but casks are further advanced in their development than dry wells because of current efforts by private industry to market these for at-reactor storage of spent fuel.
3. Both metal casks and dry wells have similar initiating events that could lead to limited radioactivity release.
4. Metal casks require large commitments of steel and lead while dry wells require large commitments of land.
5. Storage of spent fuel and HLW in an MRS is considerably more expensive with casks than with dry wells.

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