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AGENCY FOR NUCLEAR PROJECTS/ NUCLEAR WASTE PROJECT OFFICE

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NUCLEAR WASTE MANAGEMENT SYSTEMS ISSUES RELATED TO TRANSPORTATION CASK DESIGN: AT-REACTOR SPENT FUEL STORAGE, MONITORED RETRIEVABLE STORAGE AND MODAL MIX

by
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The Nevada Agency for Nuclear Projects/Nuclear Waste Project Office was created by the Nevada Legislature to oversee federal high-level nuclear waste activities in the state. Since 1985, it has dealt largely with the U.S. Department of Energy's siting of a high-level nuclear waste repository at Yucca Mountain in southern Nevada. As part of its oversight role, NWPO has contracted for studies designed to assess the transportation impacts of a repository.

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Part I: Background

Introduction

This is one of several reports being prepared to develop background information on nuclear waste transportation issues in preparation for review of DOE designs for from-reactor shipping casks and MRS-to-repository shipping casks if a Monitored Retrievable Storage (MRS) facility becomes an integral part of the waste management system. The focus in this report is on related issues pertaining to at-reactor storage, monitored retrievable storage, and the mix of spent fuel transportation modes (railroad, highway, and waterways) that will determine impacts of spent fuel transportation to a geologic repository.

This chapter traces the evolution of the civilian radioactive waste management program from its inception through passage of the 1987 amendments to the Nuclear Waste Policy Act (NWPA) of 1982. Emphases is on those factors that will influence the configuration of the transportation system for high level nuclear waste and related cask designs.

Early history

In 1959 Congress concluded that radioactive waste management practices had not resulted in any harmful effects on the public and there was no reason to delay the development of the nuclear power industry. (It appears that this conclusion was not well founded since it has been recently disclosed that it will cost billions of dollars to clean-up defense program nuclear waste management sites.) The Federal Government sponsored the development and demonstration of commercial use of nuclear power and initiated a modest waste disposal program which led to the decision in 1970 to build a repository in salt deposits near Lyons, Kansas. The plan was to reprocess spent nuclear fuel to recover and recycle uranium and plutonium contained in the fuel, first in light water reactors then later in breeder reactors which would produce more fissionable material than they consumed, greatly expanding the nuclear fuel supply. High-level nuclear waste was defined to be the reprocessing plant liquid waste which was to be converted to a suitable solid form within five years then transferred to a federal repository within another five years.

From the mid 1960's to the mid 1970's there was a rapid expansion of electric utility commitments to build nuclear power plants. Most nuclear power plants in operation today were designed from the mid 1960's through the mid 1970's. During this period the plan was to store the fuel underwater in the reactor spent fuel storage pool for about six months to permit residual heat generation and radioactivity to decay to the point where the fuel could be shipped to a reprocessing plant. The usual practice was to design the reactor spent fuel storage pools to accommodate discharge of the full reactor core plus fuel discharged from about two operating cycles. Light water reactors discharge about one-fourth or one-third of the core at the end of each operating cycle which may vary nominally from one year to eighteen months in duration.

The rapid large scale commercialization of nuclear power became controversial during the 1970's, a period of increasing environmental awareness. Effective intervention in the licensing process established to assure safe use of nuclear power led to increasing regulatory requirements. These changes in licensing requirements combined with other factors --controversial siting decisions, high interest rates on capitol intensive projects, and construction cost overruns -- resulting in extended delays in construction and rapid escalation in nuclear plant cost. The lack of facilities for permanent disposal of high-level nuclear waste also became one of the major issues. The Lyons repository project was abandoned in 1972 due to technical, political and public acceptance problems. The government then proposed to build a Retrievable Surface Storage Facility (RSSF) at a federal site in the west to provide dry vault storage of high-level waste until a geologic repository was available. The RSSF proposal was withdrawn in 1975 due to opposition from the public, Western Governors, and the Environmental Protection Agency.

A limited amount of spent nuclear fuel was processed in the commercial reprocessing plant at West Valley, New York which was closed rather than comply with new regulatory requirements. The General Electric Company decided not operate the reprocessing plant they built at Morris, Illinois and has used the plants spent fuel storage pool to store fuel they acquired through nuclear fuel supply contractual obligations with utilities.

In 1976 the Federal Government began a comprehensive assessment of technologies for managing nuclear waste which resulted in the publication of the Intergovernmental Review Group (IRG) Report in 1978. However, in response to concerns about the proliferation of nuclear weapons the Carter Administration policy prohibiting reprocessing of spent fuel was announced in 1977. The Allied-Gulf Nuclear Services (AGNS) reprocessing plant at Barnwell, South Carolina was essentially completed but had undergone extended delays due to intervention in the licensing process and plans for operation of the plant were abandoned. In 1980 President Carter proposed that the government accept spent fuel from the utilities upon payment of a one-time fee to pay for government provided away-from-reactor (AFR) storage and geologic disposal. There was not sufficient Congressional support for this approach to proceed with implementation. In 1980 DOE completed a generic environmental impact statement that selected disposal in a geologic repository as the preferred method of spent fuel and high level waste disposal. There was strong state opposition to DOE's repository siting program. With continuing delays in the government program reactor owners had started increasing capacity of at-reactor storage pools as well as exploring other alternatives for providing additional at-reactor storage.

In most cases the reactor storage pools were conservatively designed from a structural standpoint and were generous with space provided for spent fuel storage. The racks provided to hold the fuel in the storage pools were designed to prevent the fuel from sustaining a nuclear chain reaction (criticality) by providing wide spacing between the fuel assemblies in the storage racks. Criticality calculations also assumed that the fuel had not been in the reactor. That is, credit was not taken for burnup of the fuel which results in the depletion of the fissionable content of the fuel and burnup of fission products which serve to reduce the reactivity of the fuel. These very conservative design assumptions permitted utilities to substantially increase in- pool storage capacity by better utilization of available pool space and by the installation of new storage racks that permit closer spacing of fuel assemblies.

There has, over the years, been an evolution of rack designs that utilize neutron adsorbers (poisons) as well as taking credit for fuel depletion in the spent fuel (burnup credit) to control criticality. This has permitted many utilities to expand existing in-pool storage by factors as much as ten or more times their original capacity. The extent to which reracking can be used to increase existing pool capacity is dependent on the specific design and circumstances at each individual reactor. Many reactors have undergone several changes in rack designs as the need for additional storage arose and most reactors have been re-racked at least once (1,2).

In the late 1970's and early 1980's the only proven technology with demonstrated licensibility for expanding at- reactor storage beyond the existing storage pools was to build additional storage pools (3, 4). The nuclear utilities began to study alternatives to building additional storage pools. This included various schemes to increase in-pool storage capacity and various forms of dry fuel storage. Options for increasing in-pool storage beyond what could be done by re-racking included rod consolidation and double tiering of storage racks. Rod consolidation involves taking fuel rods out of the assembly used to control spacing between the rods while in the reactor and packing the fuel rods closer together. This will permit twice as many fuel rods to be stored in the space provided for a single intact fuel assembly. Several dry storage technologies were examined ranging from large storage vaults and storage dry wells in the ground (similar to bore holes in the floor of a geologic repository) to casks designed for storage, transportation and perhaps disposal of spent fuel.

Utility industry interest has centered around rod consolidation and modular dry storage as the preferred alternatives to be developed and demonstrated as the means of providing additional at-reactor storage until the Federal Government has a geologic repository available. This preference is largely because of the flexibility they offer to provide additional storage as it is needed in the face of uncertainty about when the repository will be available. These technologies used separately or together appear to have the potential to provide life-of-plant storage capability at reasonable cost. Multi-purpose dry storage casks provide flexibility and present an opportunity for effective integration into the overall waste management system since such casks could be designed for use in transportation and could possibly serve as the disposal container. From this emerged three dry cask concepts (5):

1. Single purpose dry storage cask (metal cask or concrete modules) designed for at-reactor storage only.
2. Dual purpose cask designed for storage and transportation. Such cask could be stored at the reactor then used to ship the fuel to another location for further storage or unloaded and used as part of the transportation cask fleet. This concept was particularity useful if it should be necessary to store fuel at the reactor after the reactor has been decommissioned since it would not be necessary to return the cask to the reactor storage pool to transfer the fuel to a transportation cask.
3. Universal cask that would be designed to serve as the disposal container in the geologic repository as well as serving the storage and transportation functions in the waste management system. Conceptually, fuel could be

loaded into these casks at the reactor and go through subsequent storage transportation, and disposal operations without removing the fuel from the cask there by minimizing fuel handling operations.

The design of single purpose storage casks emerged along two separate directions. One direction was the development of large thick walled metal casks similar to transportation casks where the metal wall provided both shielding and containment for the spent fuel. The other direction was the storage of spent fuel (either intact or consolidated) in thin walled metal casks which are placed inside a concrete storage module where the cask provides the containment and the concrete storage module provides the shielding. Dual purpose casks are essentially the same as the thick walled metal storage casks except they are designed to be transportable and differ from transportation-only cask primarily in size and choice of materials. Dual purpose casks are typically larger than transportation-only casks and utilize lower cost materials with less attention to minimizing cask weight. The limited amount of study that has been given to the so called universal cask indicates that it is a viable concept that can be quite attractive from an overall waste management system standpoint (5, 6). It could, however be quite different in design than dual purpose casks due to interaction with repository design. Additional work needs to be done to fully develop and evaluate the universal cask concept.

In 1981 President Reagan removed the prohibition on reprocessing spent fuel and abandoned the Carter Administration efforts to provide a federal away-from-reactor (AFR) storage facility. By this time the decline of the nuclear power option coupled with decline in uranium prices was well underway and rerocessing spent fuel was not a viable alternative for nuclear utilities leaving them to provide for their own interim at-reactor storage of spent fuel. Expanding at-reactor pool storage became controversial in some states drawing opposition from some environmental groups and close scrutiny by state regulatory agencies.

The Nuclear Waste Policy Act of 1982

The central issue in the Congressional debate preceding passage of the Nuclear Waste Policy Act (NWPA) of 1982 was whether isolation of high-level waste should be by storage or disposal. After an extended debate geologic disposal was chosen as the primary direction of program, however, the NWPA did direct DOE to study the need for and feasibility of one or more monitored retrievable storage (MRS) facilities and to submit a proposal to Congress by June 1985, to build one or more MRS facilities. In addition to being responsible for disposal of high-level nuclear waste the NWPA also made the Federal Government responsible for transportation of spent fuel giving the government control over nuclear waste management beginning at the power plant gate.

Investor owned utilities were not successful in their lobbying effort to get a Federal AFR storage facility included in the NWPA which would be financed from the Nuclear Waste Fund. The NWPA specifically made utilities responsible for providing interim storage of spent fuel until DOE accepts it for disposal. To assure that no reactor would be forced to stop operation due to the lack of spent fuel storage space the NWPA provided for up to 1900 metric tonnes of Federal Interim Storage (FIS). However to qualify for use of FIS a utility must obtain certification from the Nuclear Regulatory Commission (NRC) that they are unable to provide their own storage and must pay the full cost of providing such storage. To date, no utility has expressed any interest in taking advantage of the FIS provisions of the NWPA. This provision of the NWPA is scheduled to expire January 1, 1990, but could be extended by Congress if there is a need to continue to have this option available.

The NWPA also placed the responsibility on the Federal Government (DOE and NRC) to encourage and expedite the effective use of existing and needed at-reactor storage facilities to prevent disruptions in the orderly operation of nuclear power plants. DOE was directed to establish a cooperative program with utilities to demonstrate one or more dry cask storage technologies which NRC may, by rule approve for use at reactor sites without the need for additional site specific approvals to the maximum extent practical. Promulgation of such a rule would limit the scope of issues to be considered when utilities apply for storage expansion limiting delays from siting and environmental controversies. DOE was also authorized to conduct unlicensed research and development at Federal facilities in support of these demonstrations to collect necessary data to assist utilities in the licensing process.

DOE-utility contracts

It appears that the intent of Congress in the NWPA was for the owners of spent nuclear fuel to have the primary responsibility for providing interim storage by making maximum effective use of existing on-site storage capacity and adding new capacity in a timely manner where practical.

This, however, may have been compromised due to other provisions in the NWPA. As a condition of continued operation of nuclear power plants owners were required to enter into contracts with the DOE which provided for payments into the Nuclear Waste Fund of one mill per kilowatt-hour, subject to adjustment, to pay the full nuclear waste disposal program cost. In return for these fees DOE was required to begin accepting high-level radioactive waste or spent fuel not later than January 31, 1998. The NWPA provided a detailed schedule of milestones leading to the beginning of disposal in the first repository. (2)

The DOE-Utility contract obligated DOE to begin accepting spent fuel on an orderly schedule not later than January 31, 1998, but, provides no remedy if DOE fails to perform. Some utilities have interpreted the contract to mean that DOE is obligated to start accepting their fuel whether or not the repository is ready to began disposal operations. This situation has led to some posturing by utilities to keep the pressure on the government and tends to obscure the situation with regard to the need for additional at reactor storage beyond what can be accommodated in existing storage pools.

Some belive DOE exceeded their authority under the NWPA in making the obligation to began accepting fuel by 1998 (2). This issue could be litigated, but may well be a moot question since any compensation the utilities might realize would likely come from the Nuclear Waste Fund since it appears clear that Congress intended owners of the fuel to pay the full cost of the program. In this case any judgment against DOE would most likely be passed back to the utilities through resulting increases in the Nuclear Waste Fund fees to be paid by the utilities. This could lead to unfairly penalizing the utilities that acted responsibly in providing for their own spent fuel storage by subsidizing those that did not.

There are several other provisions in the contract between DOE and the utilities that have important implications for at-reactor storage and subsequent transportation of spent fuel. That is:

- Only fuel that has been discharged from the reactor for at least five years will be accepted by DOE.
- Acceptance priority for standard fuel is based on oldest fuel first.
- Acceptance criteria will be developed with regard to non- standard fuel which has a lower acceptance priority.
- Non-standard fuel is fuel that is defective, or may require special packaging or handling.
- Utilities have the right, subject to DOE approval, to trade acceptance rights.

The standard contract (10 CFR 961) was developed and executed over a very short period of time and does not adequately address the fuel transfer interface between DOE and the utilities. Utilities can do anything that NRC will allow to accommodate at-reactor storage which could have serious impacts on subsequent DOE transportation, handling, and packaging of the fuel. The utilities, however, run the risk of having DOE classify such fuel as non-standard resulting in loss of acceptance priority by the utility. As an example fuel consolidated at the reactor for storage would currently be classified as non-standard fuel and there are no standards for packaging the fuel and non-fuel bearing scrap produced by consolidation to meet as yet to be defined acceptance criteria. DOE acknowledges that they are obligated to accept and dispose of the scrap from rod consolidation but utilities have no guidance as to when it would be accepted or how the scrap must be packaged. The lack of standards in this situation can adversely impact DOE and the utilities. Little if any real progress has been made in this area.

DOE'S monitored retrievable storage proposal

Until Bernard Rusche became the first permanent director of DOE's Office of Civilian Radioactive Waste Management (OCRWM) DOE viewed MRS strictly as a backup to the geologic repository program. Under Rusche's direction DOE proposed that the MRS become an integral part of the waste management system. In the concept as originally proposed all fuel would be shipped to the MRS where it would be consolidated and inserted in repository ready disposal packages for storage and/or shipment to the repository for disposal. These packages would then be shipped to the repository in multiple cask shipments by special dedicated trains. The MRS would provide buffer storage between the reactors and repository, as needed, using large concrete storage casks. DOE proposed to began MRS operation in 1996 ahead of the repository that was scheduled, at that time, for operation in 1998. All three sites selected by DOE for the MRS facility were located in the State of Tennessee near the center of a region that DOE claimed would minimize spent fuel transportation impacts. The preferred site was in Oak Ridge, TN at the former Clinch River Breeder Reactor site.

DOE provided funding at the local and state level for evaluation of their MRS proposal. The local level evaluation focused primarily on local impacts (7). The prospects for jobs and payments equivalent to taxes provided important incentives at the local level. They, however, had from previous experience a deep distrust of the Federal Government and insisted that there be some local control over facility operation and that linkages in the use of the facility be tied to progress on the repository to prevent the MRS from becoming a defacto repository. DOE agreed to include, in their proposal to Congress, linkages between MRS use and the repository and to provide for local participation in oversight of MRS operations but considerably short of local control. Local support appeared to be slightly in favor of the proposed MRS facility.

The State of Tennessee conducted a comprehensive technical and economic evaluation of DOE's MRS proposal (8, 9). The evaluation was conducted by scientists from the University of Tennessee, Vanderbilt University, and Oak Ridge Associated Universities; and by state health radiological and environmental professionals. The study group was advised by national experts who served on a technical advisory panel. The State of Tennessee found that while a MRS facility is technically feasible and could be operated safely there is no need for a MRS in Tennessee or any place else since a better and cheaper solution could be readily designed to meet the legitimate needs of the nations waste management system.

The State's evaluation showed that DOE had underestimated the system cost and had exaggerated the potential at-reactor storage benefits related to having a MRS facility as an integral part of the waste management system. The State's evaluation questioned the desirability of including unproven dry rod consolidation technology as part of the system and challenged transportation benefits that DOE attributed to having a MRS facility in the system. Dry rod consolidation was seen as a potential source of problems and the most likely source of accidents, but, did suggest that DOE encourage at-reactor consolidation and provide incentives to encourage its utilization.

The State concluded that fuel rods can be stored indefinitely at nuclear power plants until a permanent repository is ready and that DOE had not adequately considered optimization of at-reactor storage as an alternative to the proposed MRS facility. An independent study by the Congressional General Accounting Office also concluded that DOE had failed to optimize the at-reactor storage alternative to the proposed MRS facility.

As in previous environmental assessment studies DOE assumed that from-reactor spent fuel shipments would be 70% by rail and 30% by truck by common carrier using single cask shipments. Shipments from the MRS facility to the repository would be by multiple cask shipment using special dedicated trains. DOE's initial MRS studies were based on using nominal 25-ton truck casks and 100-ton rail casks for from reactor shipments that were designed to accommodate 180 day old spent fuel. Later MRS studies assumed that improved cask designs with increased capacity that could be achieved by shipping older fuel. For MRS-to-repository shipments DOE assumed large specially designed nominal 150-ton casks would be used and five of these casks would be included in each cross country shipment. By using the MRS to marshal large shipments of consolidated fuel the impacts related to spent fuel transportation would be greatly reduced in the vicinity of the repository state and the western transportation corridor compared to direct shipment from reactors.

The State conducted a preliminary investigation of the use of a family of dual purpose casks in conjunction with an improved from-reactor transportation scheme which they believed to be superior to the system configurations evaluated by DOE. By deploying a new family of casks and increasing the proportion of from-reactor shipments by rail, transportation impacts were reduced below levels associated with a MRS. The from-reactor transportation system improvements would involve upgrading the cask handling and shipping capability of some reactors in conjunction with multiple cask shipment by special dedicated train.

A transportation scheme developed by the Nuclear Assurance Corporation for the State of Tennessee indicated that 87% of the reactors could ship fuel by rail by readily achievable upgrading of reactor access and handling capability. When used in conjunction with a family of transportation casks consisting of nominal 125, 100 and 70-ton rail casks with 40-ton and 25-ton truck cask could greatly reduce transportation impacts of from-reactor shipments to a MRS or repository. Of the 119 reactors considered 75 were limited to using 125-ton casks, 25 would be limited to 100-ton casks and four would be limited to 70-ton casks for rail shipments. The remaining reactors would ship by truck, 10 using 40-ton casks and 4 using 25-ton casks. Plants that were limited to 25, 40 and 70-ton casks models because of crane capacity, could use a transfer cask to load larger 100 or 125-ton casks further reducing transportation impacts. The State concluded that improvements in the from-reactor transportation system need to be made irrespective of the decision to include a MRS facility as part of the system.

The conceptual design of the proposed MRS facility was a moving target throughout the States evaluation. DOE decided to ship fuel from western reactors directly to the repository rather than to an eastern MRS. Unable to define the disposal package configuration DOE decided to canister the fuel at the MRS then overpack it in the disposal container at the repository.

The State of Tennessee had no prior warning when DOE announced the three potential MRS sites in Tennessee. The State felt that DOE should have conferred with them during the selection process as provided for selection of potential repository sites in the NWPA which were extended to the MRS. The State of Tennessee obtained a Federal Court restraining order enjoining DOE from submitting their MRS proposal to the Congress. The restraining order was eventually overturned after delaying the submission for over a year.

The MRS fight then moved to the Congress. There was strong support for the MRS in the Senate but strong opposition in House of Representatives. This led to a stalemate since the House blocked efforts to authorize or provide any funds for the MRS.

NWPA implementation

The NWPA required geologic disposal to began by January 1, 1998 and prescribed a number of milestone dates for siting and licensing the repository to meet this very ambitious schedule. This date was intentionally selected to be optimistic in hopes of providing motivation to get the job done on a timely basis. By necessity, DOE established a success oriented program that focused narrowly on meeting NWPA milestones with little flexibility to study alternatives or to take a systems approach to overall optimization of the waste management system. DOE's task was further complicated by the intent of the NWPA to establish an open and cooperative partnership with the affected states and Indian tribes.

The NWPA also placed all civilian nuclear waste facilities to be managed by DOE under the regulatory jurisdiction of the Nuclear Regulatory Commission (NRC). Cooperating with the states and being subject to NRC regulation was an area in which DOE had little or no practical experience. Most observers, that were aware of the complexities involved, believed that at least an additional ten years would be required to get the first repository into operation. DOE's efforts to expedite meeting their NWPA schedule created friction with the affected states which felt that DOE was more interested in meeting the schedule than they were in the technical quality of the work. DOE was not successful in getting any potential repository state to enter into a cooperative agreement as required by the NWPA and wound up trying to deal with the states through the courts.

DOE's management style and processes for making and justifying their decisions did not instill the trust and confidence necessary for successful implementation of a program of this type. In fact, the Alternative Means of Financing and Management (AMFM) Panel, commissioned by the NWPA recommended that the program should be taken out of DOE and placed in a newly created independent government/private organization (12). This was, however not seriously considered since it would have required reopening the NWPA and would have resulted in a major disruption in the program. Many observers, including this author, believe some action similar to this will, most likely, be necessary to develop the credibility and trust essential to successful implementation of a program of this type.

By the beginning of 1987 the program had become hopelessly bogged down. In five years, DOE had delayed the repository five years to 2003 and had managed to make waste disposal a more sensitive high profile issue. It appeared that the fragile coalition that made the NWPA possible had unraveled. While the general situation contributed to the problem the most immediate cause was the way DOE selected the three potential first repository sites for detailed characterization and the deferral of the program for siting a second repository. From a technical standpoint neither of these were, necessarily, poor decisions. The problem was the appearances created by the way DOE went about them, creating a loss of confidence in DOE's credibility.

DOE'S transportation cask development program

The NWPA of 1982 requires DOE to accept title to spent nuclear fuel at the reactor site and be responsible for shipment, subject to licensing and regulation by NRC and DOT, to a MRS facility or geologic repository. The NWPA provided little direction to DOE related to transportation beyond requiring DOE to use, by contract, private industry to the fullest extent possible in each aspect of transportation. The 1987 NWPA Amendments clarified that the casks are also to be licensed by NRC.

To facilitate having the spent fuel transportation fleet available to began shipments to the MRS facility by 1996 DOE initiated a cask development program. The initial phase of the program was to developed improved cask designs for from- reactor shipments and development of the MRS-to-repository casks would be deferred until after the MRS was authorized by Congress. It is generally agreed that one of the most effective ways to minimize spent fuel transportation impacts is by increasing the capacity of the cask. The spent fuel to be shipped to a MRS facility or repository will have been discharged from reactors over five years. This allows the radioactivity in the spent fuel to decay to the point that active cooling systems are not required and the amount of radiation shielding can be reduced.

These circumstances permit a new generation of transportation casks to be designed with greatly increased capacity for the same gross shipment weight. DOE also sought proposals from industry for innovative design features and use of materials to optimize cask capacity. In comments to DOE the NRC expressed concern about innovation in cask design and cautioned DOE about the use of new cask technology and materials (12).

The nuclear transportation industry's initial response to DOE's plans to carry out a program to develop new cask designs was that such a program was not necessary. They felt that the existing industry could provide the necessary services. One of their major concerns was that DOE would deprive existing transportations services contractors from supplying casks and providing transportation services. It now appears that their concerns may have been well founded.

DOE's program has two major components; cask development and technology development. The cask development program is managed by EG&G Idaho, Inc. through DOE's Idaho Operations Office and the technology development activities are being performed by Sandia National Laboratory and involves resolution of such technical issues as burnup credit, source term evaluation, and cask contamination.

Initially the DOE from-reactor cask development and demonstration program included the following four types of casks:

- Legal weight truck cask (loaded weight about 25 tons),
- Overweight truck cask (loaded weight about 40 tons),
- Rail/Barge cask (loaded weight about 100 tons), and
- Dual Purpose storage/transport cask (loaded weight about 100 tons).

DOE decided to drop the overweight truck and dual purpose casks from program and proceed with the legal weight truck and rail/barge casks.

DOE's decision to drop the dual purpose cask from the development program appears to have been motivated by the desire to reduce competition to their proposed system configuration with an integral MRS facility. They used a very narrow study by H&R Technical Associates and E. R. Johnson Associates (14) to justify their action. An extension of the DOE study sponsored by Electric Power Research Institute (EPRI) system showed that the results of the DOE study were very sensitive to assumptions used (15). The EPRI study concluded that substantial cost savings and reduced handling of cask and spent fuel can be achieved by effective and broader use of dual purpose casks. Neither of these studies optimizes the use of dual purpose casks into the transportation system through the use of multiple cask shipments by special dedicated train as has been suggested in studies for the State of Tennessee (2). With large numbers of dual purpose casks in the system a completely different basis for optimization of the transportation system is available.

DOE awarded five contracts between February and July of 1988 for two legal weight truck casks (with options for development of an overweight truck cask) and three rail/barge casks (16). DOS's original plan was to have ten cask prototypes (two of each design) certified, acceptance tested and ready to go in 1995.

The following is a brief description of the five cask designs:

140-B Rail/Barge Cask by Nuclear Packaging Inc (17). The nominal loaded weight of the cask is 100 tons and uses separate basket designs to accommodate 21 PWR or 48 BWR intact fuel assemblies. The cask body is stainless steel clad lead with a borated silicone neutron shield that utilizes copper fins to transfer heat to the exterior stainless steel surface. The fuel baskets are constructed from high strength stainless steel and uses boron dispersed in copper heat transfer plates in conjunction with water gaps to control criticality. A bolted closure with two elastomer "O" ring seals on the bore is used for containment.

BR-100 Rail/Barge Cask by B&W Fuel Co. (18). (See Figure 1) The BR-100 rail barge cask has a nominal loaded weight of 100 tons and uses separate basket design to accommodate 21 PWR or 52 BWR intact fuel assemblies. The cask body is a multi-layered structure of lead and stainless steel with a borated concrete neutron shield with copper fins embedded in the concrete to enhance heat transfer. (See Figure 2) A unique feature of the design is the release of steam formed on the outside of the concrete to retard heat flow into the cask during an accident involving a fire. The fuel baskets will be constructed of aluminum to expedite heat transfer and will be clad with boron carbide dispersed in aluminum as the neutron poison for criticality control. A bolted two piece closure is used.

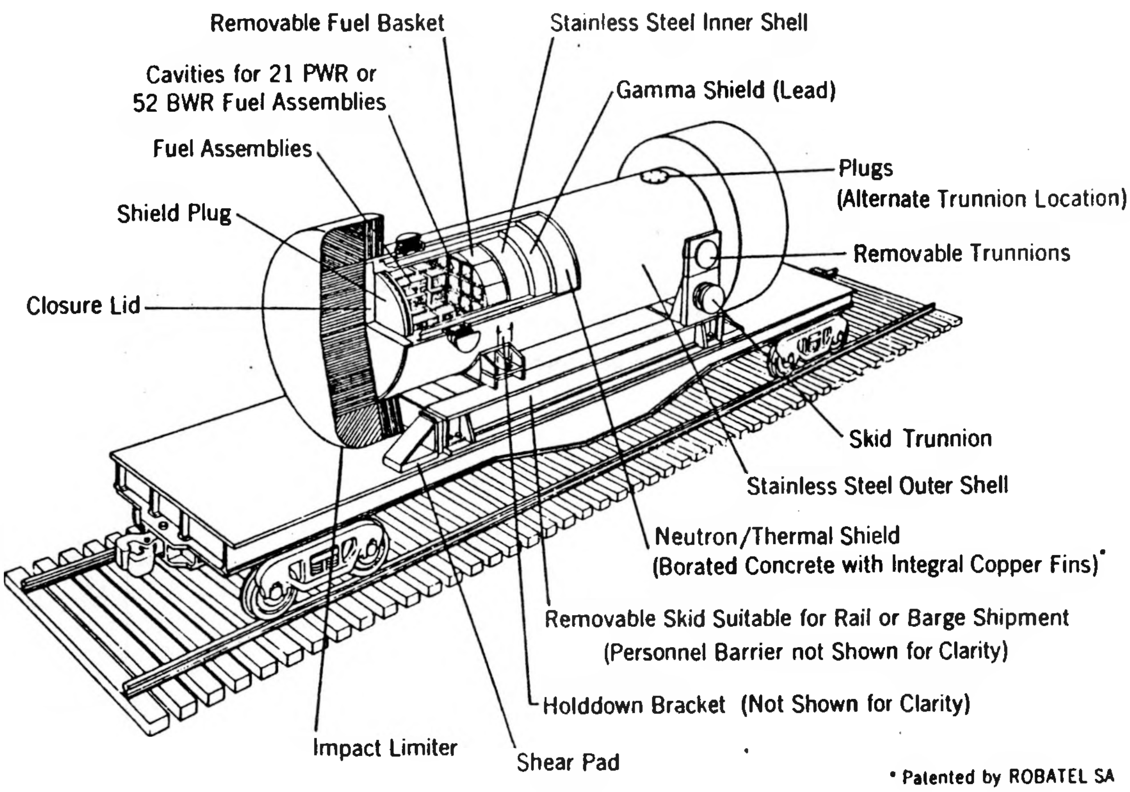

Figure 1. Babcock & Wilcox BR-100 100 Ton Rail/Barge Cask, mounted on Rail Car (Source: B&W Fuel Company, February, 1990)

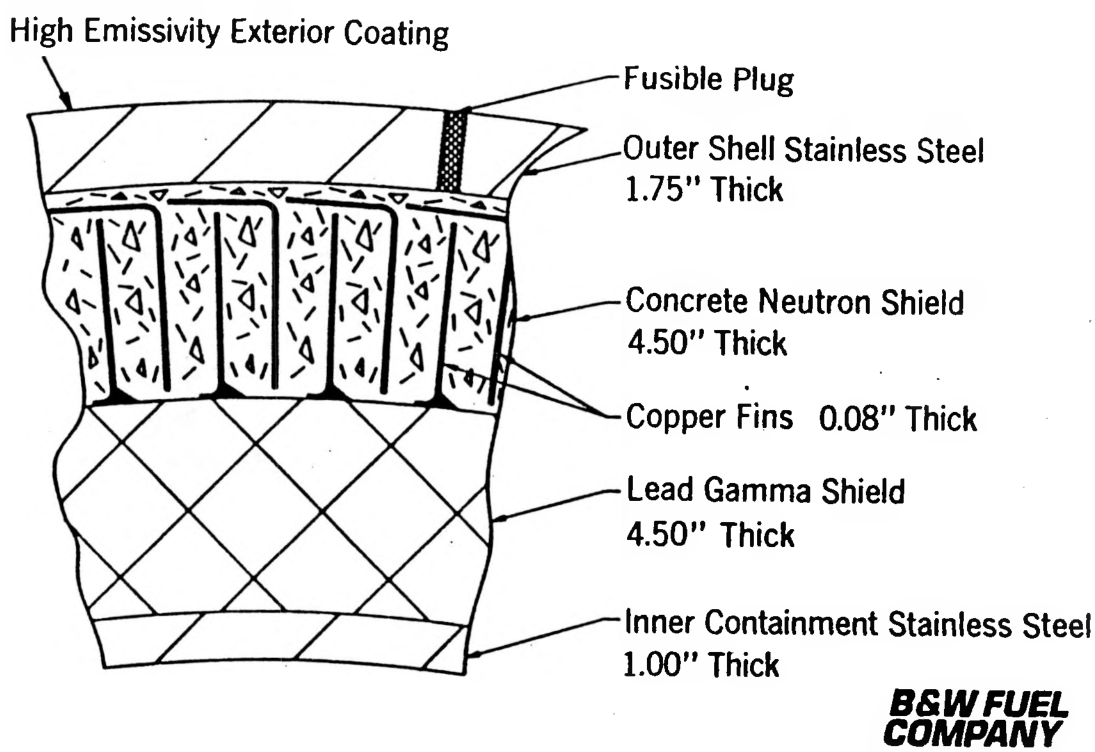

Figure 2. BR-100 Cask, Multi-layer Cask Wall (source: B&W Fuel Company, February, 1990)

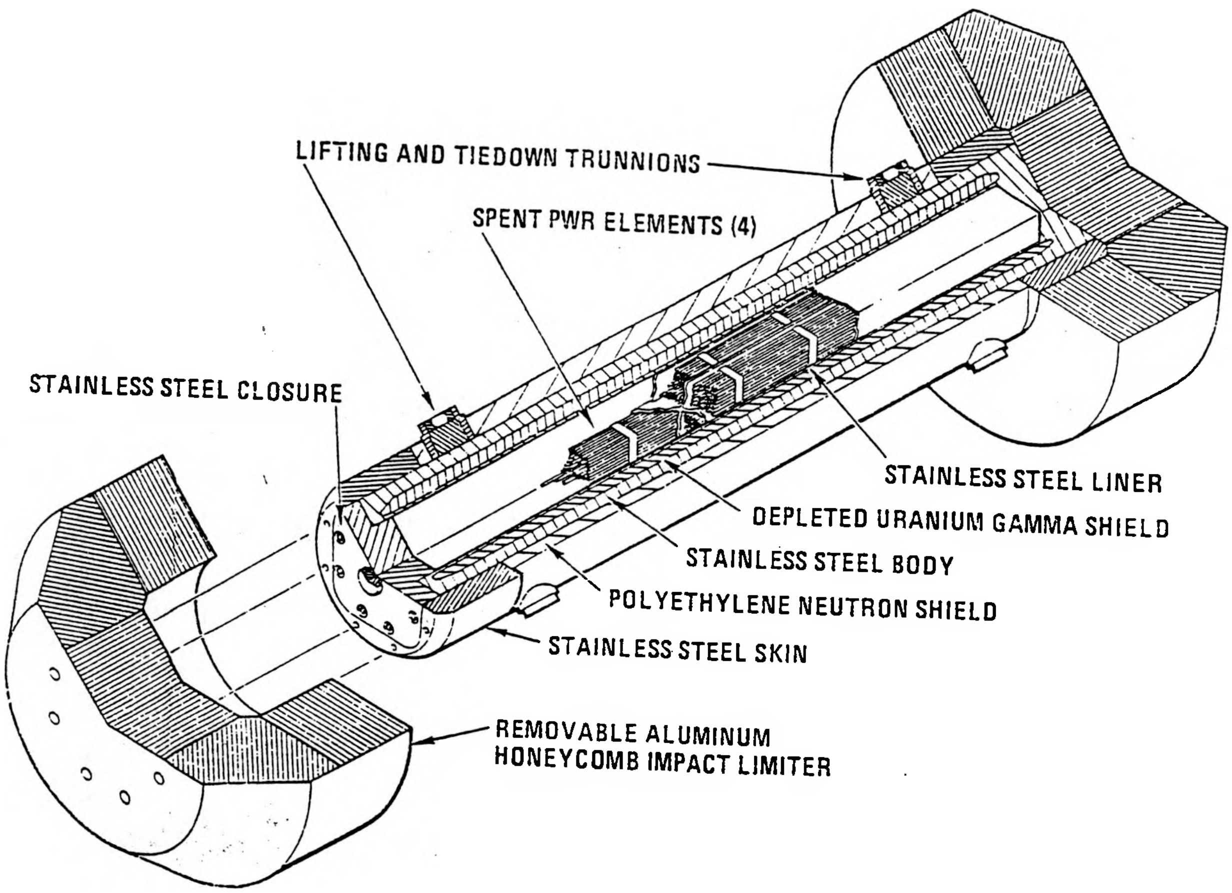

Figure 3. GA-4 legal weight truck cask (source: General Atomics, April, 1990)

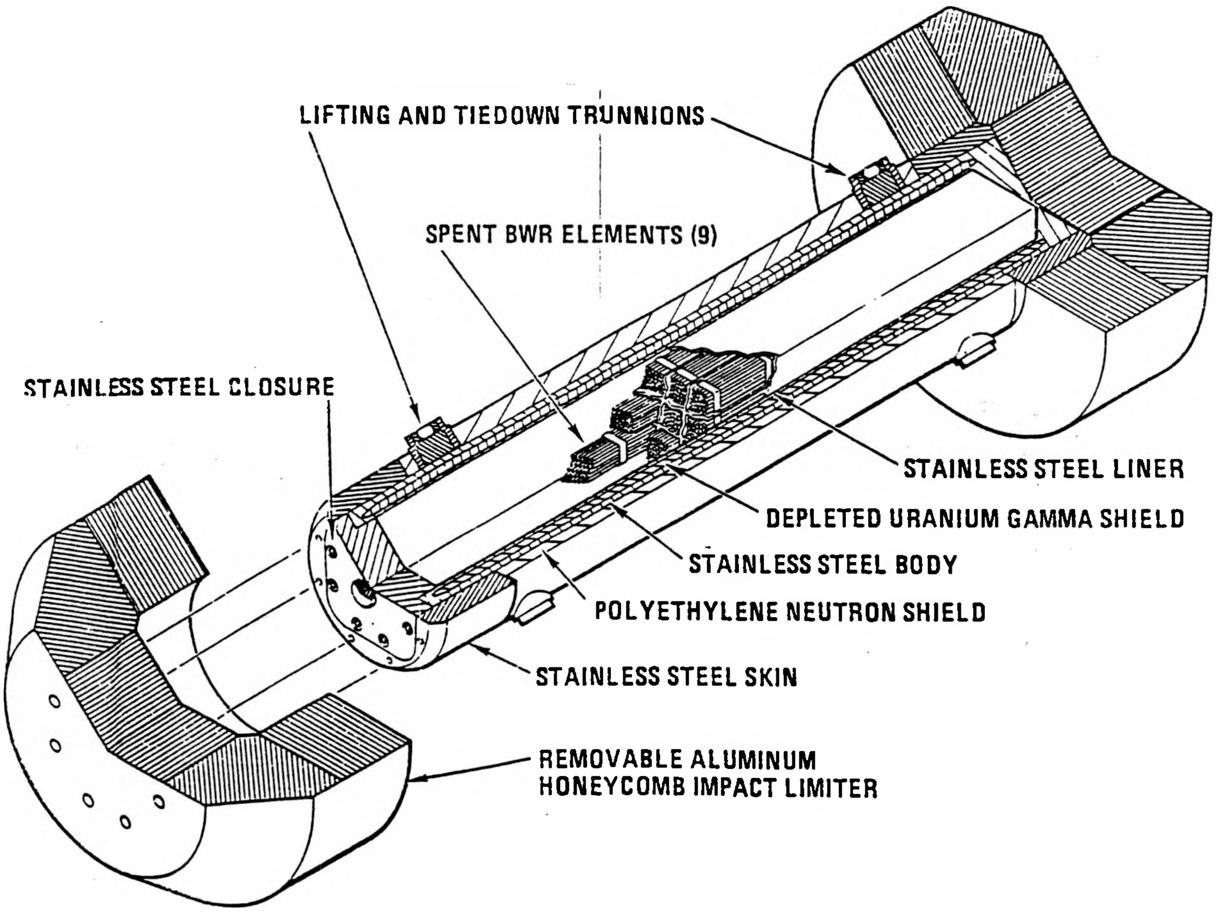

Figure 4. GA-9 legal weight truck cask (source: General Atomics, April, 1990)

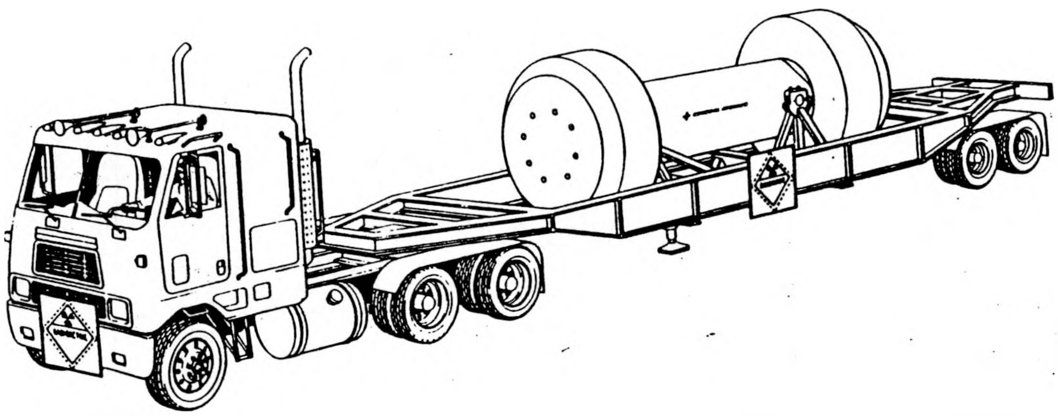

Figure 5. General Atomics Cask and Transporter (source: General Atomics, April, 1990)

NAC-CTC Rail/Barge Cask by Nuclear Assurance Corp (19). The body of the NAC-CTC cask is constructed of ferritic steel and depleted uranium. The cask uses interchangeable fuel baskets that can accommodate 26 PWR or 52 BWR intact fuel assemblies within a loaded weight of 100 tons.

Legal Weight Truck Cask by Westinghouse (20). The loaded nominal weight of the cask is 27 tons with a gross legal vehicle weight of 40 tons and has interchangeable fuel baskets that can accommodate 3 PWR or 7 BWR intact fuel assemblies. The cask body is constructed of titanium alloy and uses depleted uranium for gamma shielding and boron silicone for neutron shielding. Fuel baskets are constructed of stainless steel with neutron poison plates and aluminum honeycomb encased in stainless steel is used for impact limiters.

GA-4 and GA-9 Legal Weight Truck Cask by General Atomics (21). GA's technical approach was to optimize separate cask designs for PWR and BWR fuel to maximize payload capacity. Their GA-4 and GA-9 cask designs have a capacity of 4 PWR and 9 BWR intact fuel assemblies respectively. (See Figures 3 and 4) The casks have a nominal loaded weight of 27 tons and a gross legal vehicle weight under 40 tons. (See Figure 5) The cask has a nominal square cross section built around integral fuel baskets constructed from stainless steel sandwiched around boron carbide neutron poison plates. The cask inner liner, main structure and outer skin are stainless steel that enclose a depleted uranium gamma shield and a borated polyethylene neutron shield.

In December, 1989, OCRWM cancelled the Nuclear Packaging contract and scaled-down the Westinghouse and Nuclear Assurance contracts. The General Atomics and Babcock and Wilcox contracts remain fully funded through 1991.

All casks are to be designed to meet NRC 10 CFR 71 regulatory requirements assuming 10 year old fuel and fuel burnup of 35,000 megawatt days per metric ton for PWR fuel and 30,000 megawatt days per metric ton for BWR fuel with corresponding enrichment levels. Cask designs are optimized to minimize life cycle cost.

It should be noted that the cask design criteria is inconsistent with 5 year old acceptance criteria and the industry trend to higher fuel burnups and related enrichments. While there will be a large at-reactor inventory of fuel that is over ten years old it is not the fuel that many utilities will want to ship first. Utilities will most likely consolidate or place their oldest fuel in dry storage first when they must use additional at-reactor storage. It would make little sense to incur the additional economic and radiation dose penalties associated with unnecessary removal of this fuel from storage to ship it to DOE which must be replaced in storage to make room in the storage pool. The assumption that DOE will receive the oldest fuel first from utilities may not be valid. Many utilities interpret the oldest fuel first as a basis for entitlements to ship fuel to DOE not the actual fuel to be shipped. Forcing utilities into unnecessary fuel handling operations is not consistent with NRC regulations to keep radiation doses as low as reasonably achievable (ALARA).

Currently there are six cask designs certified by NRC for transporting light water reactor fuel. Two are rail casks, one legal weight truck cask and three overweight truck casks. The capacity of cask designs currently in use are compared in Table I.1 to the new cask designs being developed by DOE (16).

The basic design of most of the new rail/barge casks is not as dramatic a departure from traditional cask design as are the new truck cask designs. The use of new materials and complex geometries for the highly optimized new truck cask designs are likely to encounter more difficulty in obtaining NRC certification than the new rail/barge cask designs. While NRC formally contends that the design criteria test conditions contained in 10 CFR 71 are adequate to assure cask safety there seems to be additional unpublished criteria used by NRC to provide additional safety margins. These design criteria are adequate to assure safety in the vast majority of accidents that are likely to be encountered during shipment. There is, however, the possibility and some believe the likelihood that extra severe accidents can occur that can result in cask failures. NRC embodies a "quality product" principal in its regulations to assure that the cask performance will be acceptable in the extra severe accident range but is vague on specific guidance on how this might apply to new and innovative cask designs that depart from previously certified designs (27). If, in NRC's eyes, the cask design departs too far from currently accepted designs or may not perform satisfactorily in the extra severe accident range NRC can decline to certify the cask design. It is difficult to say, at this time, how this will be applied to the new generation of transportation casks being developed by DOE.

Table I.1 Comparison of currently-certified casks to casks being developed by DOE

CASK TYPE	CURRENTLY CERTIFIED CASK			NEW DOE CASK DESIGNS		
	Weight (tons)	Fuel Elements		Weight (tons)	Fuel Elements	
		PWR	BWR		PWR	BWR
Legal truck	25	1	2	27	3-4	7-9
OW truck	40	3	7	--	--	--
RAIL/BARGE	70-100	7-10	18-24	100	21-26	48-52

DOE did not perform waste management systems analysis to develop an optimized transportation system design in conjunction with optimization of the overall waste management system configuration. The transportation system serves to connect at-reactor storage with the repository and the MRS facility if it becomes part of the system. The effectiveness of integration of these system components to meet overall system objectives should have been the basis for developing the transportation system configuration including the mix of transportation modes and the numbers and types of cask designs needed.

The from-reactor transportation system configuration being developed by DOE is an adaptation of the traditional approach to spent fuel transportation that was being used in the 1960's when the emphasis was on quickly reprocessing and recycling spent fuel, but, with improved cask designs made possible by the older fuel. In this approach single cask shipments would be made in general commerce depending on the availability of rail access to the power plant site. This has also been the traditionally accepted basis for estimating the impacts related to transporting spent fuel to the repository or MRS. Optimization of this type of transportation system configuration is dependent on maximizing cask utilization and cask capacity. The economics of this transportation system concept are driven primarily by demurrage or use charges on the casks. Transportation impacts would be controlled primarily by the number of shipments which result from the modal mix between rail and truck shipments.

The Tennessee Valley Authority did some transportation systems studies to address the problems related to integration of at-reactor storage into the overall waste management system (22) and from their work concluded that a government sponsored cask development program would be necessary, but it was premature from a systems design perspective to start the cask development program until the configuration of the overall system was better defined. That is, it is too early to decompose the overall system into components until a better understanding is achieved of the interactions between at-reactor storage options, the geologic repository, and MRS facility if it should become an integral part of the system, with the transportation system which must effectively interface with these other sub systems. With the delays that have occurred in the repository program the nuclear utility industry believes it is desirable to delay cask development program as an unnecessary expense (23).

There seems to be general agreement in the nuclear industry technical community that spent nuclear fuel can be safely transported with a very low level of risk to the public. DOE estimates that there would be less than 0.5 latent-cancer deaths associated with radiological impacts from all spent fuel shipments for the range of system configurations they have considered which compares to roughly 5,000 latent-cancer deaths per year in the United States (24). Nuclear utility industry representatives have suggested that transportation impacts are so low that any reductions that might be achieved through system optimization would be so small that they would be insignificant (25). DOE has taken a somewhat similar position by arguing that differences in transportation impacts should not be a discriminatory in determining the waste management system configuration (26). These views, however, are not shared by all the waste management system stakeholders.

The general public and public officials appear to be more concerned about the potential risk related to spent fuel transportation than any other aspect of nuclear waste management. Whether or not there is a well founded basis for this concern is, however, less important than their perception that nuclear waste transportation is very dangerous. The difference in these views are due to different perspectives and values. Reviews of the technical literature conducted for the State of Nevada Nuclear Waste Project Office suggest considerable uncertainty about several important issues related to nuclear waste transportation safety (28). The nuclear industry and DOE have tended to arrive at what they believe to be the best solution based on their own perspective and values then attempting to gain acceptance in an adversarial process. Their proposed solution may be very sound, but the other stakeholders have no ownership in the solution and might often have a basic distrust of the proposer.

The primary customer for the nuclear waste management system is the general public, therefore, it is important to take their perceptions and values into account when optimizing the design of the transportation system. To achieve public acceptance it is important to be able to demonstrate that the proposed approach is both technically sound and optimized to be responsive to public concerns. Transportation systems studies conducted by the Tennessee Valley Authority suggest that major improvements can be made in this regard and with lower impacts and cost than the transportation system configuration being pursued by DOE (22). This work will be discussed in detail in connection with the chapter on analysis of transportation modal mix.

Nuclear Waste Policy Amendments Act of 1987

Congress had cut funds for DOE below-ground site characterization work at the three potential repository sites DOE had selected and efforts to authorize the MRS DOE had proposed were blocked. Congress was not eager to take up the contentious nuclear waste issue before the 1988 elections. It appeared that the program would be in limbo for several years until a new administration was in office and ready to take up the nuclear waste issue. Senator Johnson (D-La), who has been a strong nuclear industry supporter and proponent of MRS as an alternative to geologic disposal, succeeded in attaching amendments to the Omnibus Budget Reconciliation Act of 1987 as a cost cutting move without reopening the NWPA for debate. The principal provisions of these proposed amendments would: allow DOE to select one site for characterization, authorize the proposed MRS without restrictions and provide for compensation to states that host the repository and MRS facility ($100 million per year for the repository and $50 million per year for the MRS).

There was no companion legislation in the House and it appeared that efforts in conference to reach any compromise had failed. However, at the last moment in a surprize move compromise was reached with support of the House Leadership, including ranking members from Texas and Washington which were also potential repository sites. The principal provisions of this compromise were: Yucca Mountain in Nevada would be the single site to be characterized, the MRS was conditionally authorized subject to stringent linkages to progress on a permanent geologic repository, compensation to host states was reduced to $20 million/year and $10 million per year for the repository and MRS respectively, and the concept of using a negotiator to work out acceptable arrangements with host states was adopted.

This legislation avoided open debate on the nuclear waste issues and provided a new lease on life for the program which should allow it to proceed in the chosen direction for several years. It, however, did not deal with the underlying problems in the program which will most likely surface again. The best prospect for success in this new direction probably depends on the skill and wisdom of the negotiator.

The Nuclear Waste Policy Amendments Act (NWPAA) of 1987 established a MRS Review Commission to evaluate the need for a MRS facility as a part of the Nations's nuclear waste management system. DOE's selection of Oak Ridge, TN as the preferred site for the proposed MRS was annulled and revoked. The following restrictions or linkages were place on MRS siting and use:

- DOE may not begin site selection until after the MRS Review Commission reports their findings to Congress and DOE can not select the MRS site until DOE recommends to the President the approval of a site for development as a repository,

- No MRS may be located in Nevada,
- Construction may not begin until NRC issues a license for construction of a repository,
- The quantity of nuclear waste stored at the MRS may not exceed 10,000 metric tons until the repository begins accepting waste,
- The quantity of nuclear waste in storage may not exceed 15,000 metric tons, and
- MRS construction or acceptance of nuclear waste shall be prohibited during any time a repository license is revoked by NRC or construction of the repository ceases.

The NWPAA also directed DOE to conduct a study evaluating the use of dry-cask-storage technology for the temporary storage of spent nuclear fuel at the sites of civilian power reactors until a geographic repository is available for receiving the spent fuel.

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Part II: At-reactor storage

Introduction

The manner in which at-reactor storage is performed can have a significant impact on spent fuel transportation to a monitored retrievable storage (MRS) facility or to a geologic repository. Transportation impacts in the repository state and nearby transportation corridor states will be minimized if there is a MRS facility in the waste management system similar to the one that has been proposed by the Department of Energy (DOE). In this case special dedicated trains would be used to move fuel from the MRS facility to the repository in multiple cask shipments of large casks up to 150 tons each. If such an MRS is located in the east DOE will most likely ship about 10 percent of the fuel from western reactors directly to the repository which would increase impacts in the vicinity of the repository. Without a MRS facility, there will be a large increase in transportation impacts in the repository state and nearby transportation corridor states due to the relatively inefficient from-reactor transportation system configuration that DOE is developing. Most of the impact will be due to the large number of legal weight truck shipments that will be required to move from 30 percent to 50 percent of the fuel from reactors to a western repository over greater distances than shipments to an eastern MRS facility. It is possible to greatly improve the efficiency of the from-reactor transportation system by minimizing truck shipments and the maximum use of multiple cask shipments by special dedicated trains using the largest cask practical (1). This will be discussed in greater detail in the chapter on transportation modal mix.

Prior to the Nuclear Waste Policy Act (NWPA) of 1982 utilities were responsible for arranging for shipments of spent fuel using commercially available services. The NWPA made DOE responsible for shipments of spent fuel from the reactors. Since the transportation system interfaces with the reactors, repository and MRS facility, if one is in the system, there is an opportunity to take a systems approach to developing the transportation system configuration. DOE has control over the transportation interface with the repository and MRS but has very limited control over the interface with the reactors. Utilities are responsible for providing at- reactor storage until DOE accepts the fuel for disposal. There is a wide range of storage options available to the utilities, subject to approval of the Nuclear Regulatory Commission (NRC), which can have major transportation implications. Since DOE does not have control over at- reactor storage DOE has taken a simplistic approach to the at-reactor transportation interface.

DOE's from-reactor transportation system configuration is an adaptation of the traditional approach to spent fuel transportation developed in the 1960's, but using new higher capacity cask designs made possible by shipping older fuel. In this approach transportation system optimization strives to minimize the number and different types of casks required and to achieve high utilization of the transportation fleet. DOE takes a lowest common denominator approach by using two basic cask sizes to accommodate nearly all of the reactors. One, is the nominal 25-ton legal weight truck cask, and the other is a 100-ton rail cask that would have unrestricted movement on the railroads. A few special casks would also be required to accommodate a relative small amount of fuel that will not fit in these casks. This is an expedient but inefficient approach to from-reactor transportation which will be discussed further in the chapter on modal mix. DOE's approach seems to overlook several important principles.

1. The electric rate payers are going to pay the full cost of spent fuel management through utilities at- reactor expenditures and the fees paid by utilities to DOE. Therefore, there should be cooperation and effective integration of at-reactor storage into the overall transportation system.
2. Transportation of spent fuel is that part of the waste management system that comes into closest contact with the public and public officials, and is perceived as the greatest risk. While the perceptions of the risk might be much greater than the absolute risk from a technical standpoint it is a reality to which DOE should be responsive by being able to demonstrate that they have minimized the risk.
3. DOE and the utilities have an obligation, under NRC regulations to keep radiation exposure to the public and workers "as low as reasonably achievable" (ALARA). An inefficient from-reactor transportation system that does not effectively integrate into at-reactor storage violates the ALARA principal by requiring many more shipments and an unnecessarily large amount of fuel and/or cask handling operations at reactors and in DOE facilities.

In addition to expanding normal pool storage, at-reactor storage options include consolidation of fuel into a more compact configuration and various forms of dry storage. The dry storage options favored by utilities that have important implications for interfacing with the transportation system and integration into the overall waste management system are:

1. Concrete storage modules which use large metal canisters (thin-walled casks) to contain intact or consolidated fuel,
2. Large metal (thick-walled) casks similar to large rail transport cask that are designed only for storage of intact or consolidated fuel, and
3. Dual purpose metal casks that are designed for storage of intact or consolidated fuel and can also be used for transportation.

Other options such as additional pool facilities, dry storage vaults, storage dry wells, and concrete casks are possibilities, but do not appear to have broad interest among the utilities, at this time. Reference 1 to this chapter, a report prepared for the State of Tennessee, provides detailed background information on at-reactor storage options (1). The reader is referred to that report for those details which are not repeated here. This chapter provides an updating and extension of that work.

At-reactor storage needs

Over the years DOE has consistently overestimated the amount of additional at-reactor storage that will be needed (2).

This is due to overestimating how much spent fuel will be produced by commercial nuclear power plants and underestimating utilities ability to expand storage capacity in existing storage pools. Both of these parameters are subject to a great deal of uncertainty and are very important considerations in the design and implementation of the overall waste management system. DOE Office of Civilian Radioactive Waste Management (OCRWM) relies on nuclear power forecast and data collected from utilities by DOE's Energy Information Agency (EIA) as a basis for planning the high level nuclear waste management program. EIA has maintained an unrealistic outlook for the growth of nuclear power which is reflected in their forecasts (3). EIA has also made optimistic assumptions about nuclear plant performance and service life as well as not taking the trend to increased fuel burnup into account, all of which results in overestimating the amount of spent nuclear fuel that will be produced. Utilities take a conservative approach to reporting their ability to store spent fuel in their reports to EIA since they general report their licensed storage capacity and do not want to speculate about what they could do or what NRC might approve if necessary. Moreover utilities would like to keep pressure on the Federal Government to perform their responsibilities and began accepting the fuel on a timely basis.

There is no independent review or oversight of the forecasts that OCRWM uses for planning the waste management program. In 1985 as part of a metallic cask systems study for DOE the Tennessee Valley Authority (TVA) used the available data and TVA's experience to prepare an independent probabilistic forecast of spent fuel production and the ability of utilities to store spent fuel in existing storage pools (4). The results of this study showed that the expected value of spent fuel production would be slightly less than the 70,000 metric ton capacity authorized for the first repository and that with extensive use of high density storage racks less than 5,000 metric tons of additional at-reactor storage would be needed by the year 2010 and if rod consolidation could be used this would be reduced to a few hundred tons. These results were substantially below DOE's forecast and were the source of some controversy. The State of Tennessee MRS evaluation team conducted an independent forecast which produced results intermediate to the DOE and TVA results (5). DOE has subsequently revised their forecast to be more in line with these independent forecasts.

The most recently available independent spent fuel production forecast was prepared in 1988 at the University of Tennessee as part of a "Probabilistic Assessment of Nuclear Waste Fund Fee Adequacy" (6). The results of that analysis is shown in Table II.1.

Table II.1 Uncertainty in spent fuel production forecast

Year:	2003	2008	2020
Cumulative probability in percent	Cumulative production in thousands of metric tons		
2.5	42.0	46.9	52.3
15.0	43.6	51.7	62.3
50.0	45.4	56.3	73.5
85.0	47.6	58.3	80.2
97.5	48.5	59.6	96.4

This is believed to be a realistic probabilistic estimate of spent fuel production. The expected value for this distribution through the year 2020 is about 74 thousand metric tons compared to DOE's estimate of 88 thousand metric tons. The Nuclear Waste Policy Act Amendments of 1987 defers consideration of the need for a second repository until 2007-2010. Unless there is a revitalization of the nuclear option, which seems unlikely at this time, or there are severe physical restrictions on the capacity of the first repository, it appears likely that all of the spent fuel will be transported to the first repository for disposal.

Reactor pool storage

Most reactor pools were designed in the 1960's or 1970's when the plans were to ship spent fuel to a reprocessing plant after its radioactivity was allowed to decay for about six months. (See figures 6 and 7). Reactor spent storage pools were usually designed to provide for storage of one or two discharge batches of fuel plus being able to discharge the full reactor core. The spent fuel storage pools were, in general, designed very conservatively from a structural standpoint and wide spacing between fuel in the storage racks were used to assure that the fuel in storage can not support a nuclear chain reaction (criticality) by maintaining the fuel sub-critical. (See Figure 8). As an extra precaution it was assumed that fresh fuel was stored in the racks with no credit being taken for the depletion of the enriched uranium and build-up of fission products that occurs during burnup of the fuel during reactor operation.

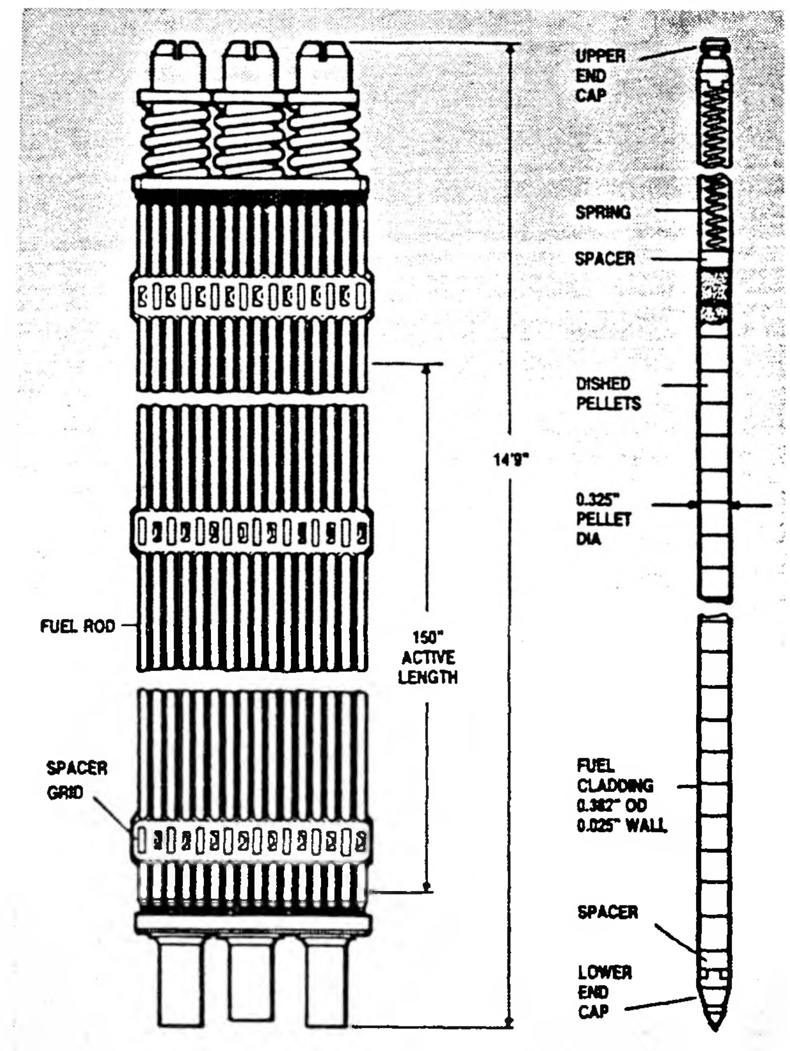


Figure 6. Fuel Assembly and Fuel Rod (Source: Nuclear Regulatory Commission)

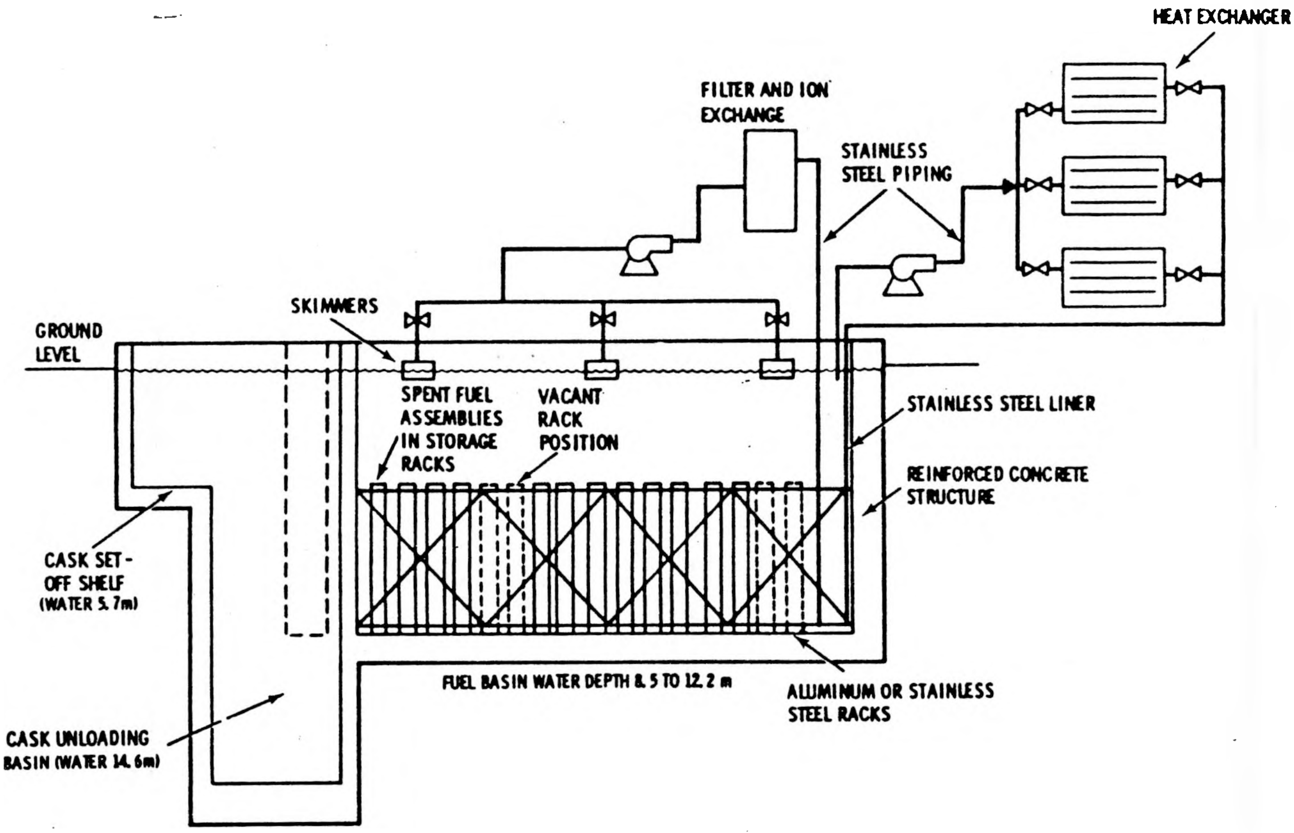


Figure 7. Schematic of Typical Spent Fuel Storage Pool (Source: Pacific Northwest Laboratories)

Maintaining Full Core Reserve (FCR)

For planning purposes, avoiding encroachment on FCR at a nuclear power plant is the generally accepted criterion used in determining when additional storage capacity will be needed in the absence of the ability to ship the fuel off- site. A reactor might continue to operate for five years or more by encroaching on FCR before being forced to shut down due to the inability to discharge fuel from the reactor for the lack of spent fuel storage space.

Maintaining the ability to discharge the full reactor core is not a specific regulatory requirement, but is considered to be a prudent practice. If it should be necessary to discharge the fuel from the reactor to perform inspections or make repairs in the reactor vessel this full core reserve (FCR) storage capacity is needed. Where reactors at the same site share common spent fuel storage facilities the usual practice is to maintain only one FCR since it is not likely that it will be necessary to discharge more than one core at the same time.

If it should be necessary to discharge the full core from the reactor the utility will usually be able to plan this operation at least a few months and perhaps several years in advance. Utilities may temporarily encroach on FCR while additional storage capacity is being provided with little risk of being forced into an extended reactor shutdown due to the lack of spent fuel storage space.

The commercialization of dry storage technology, since the NWPA was passed in 1982, has made additional options for utilities faced with loss of FCR. With ready availability of dry storage casks in the market place in conjunction with promulgation of NRC rules to expedite dry cask use, additional at-reactor dry cask storage can, at the present time, be provided in a few months. Another possibility that has been suggested is the use of dry storage casks to provide a portable FCR that could be shared by several reactors.

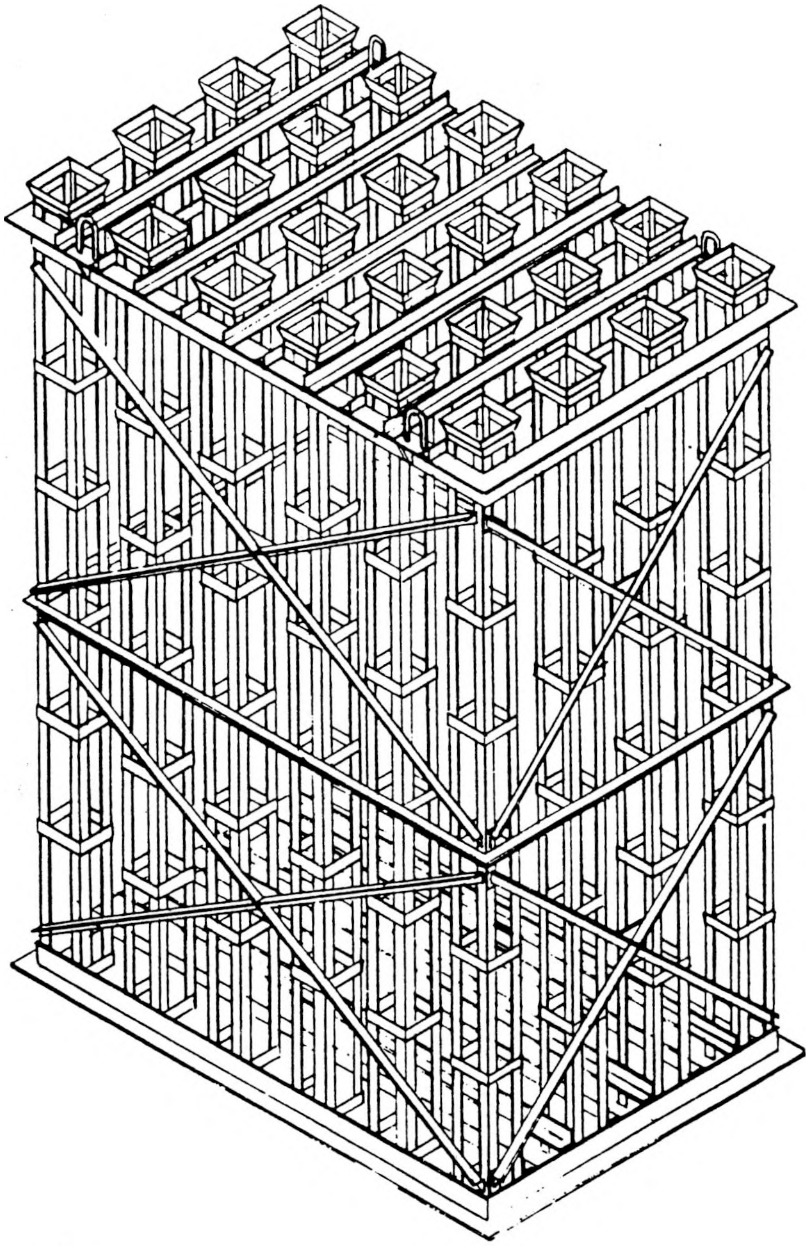


Figure 8. Typical Open Frame Storage Rack for PWR Fuel (Source: Nuclear Regulatory Commission)

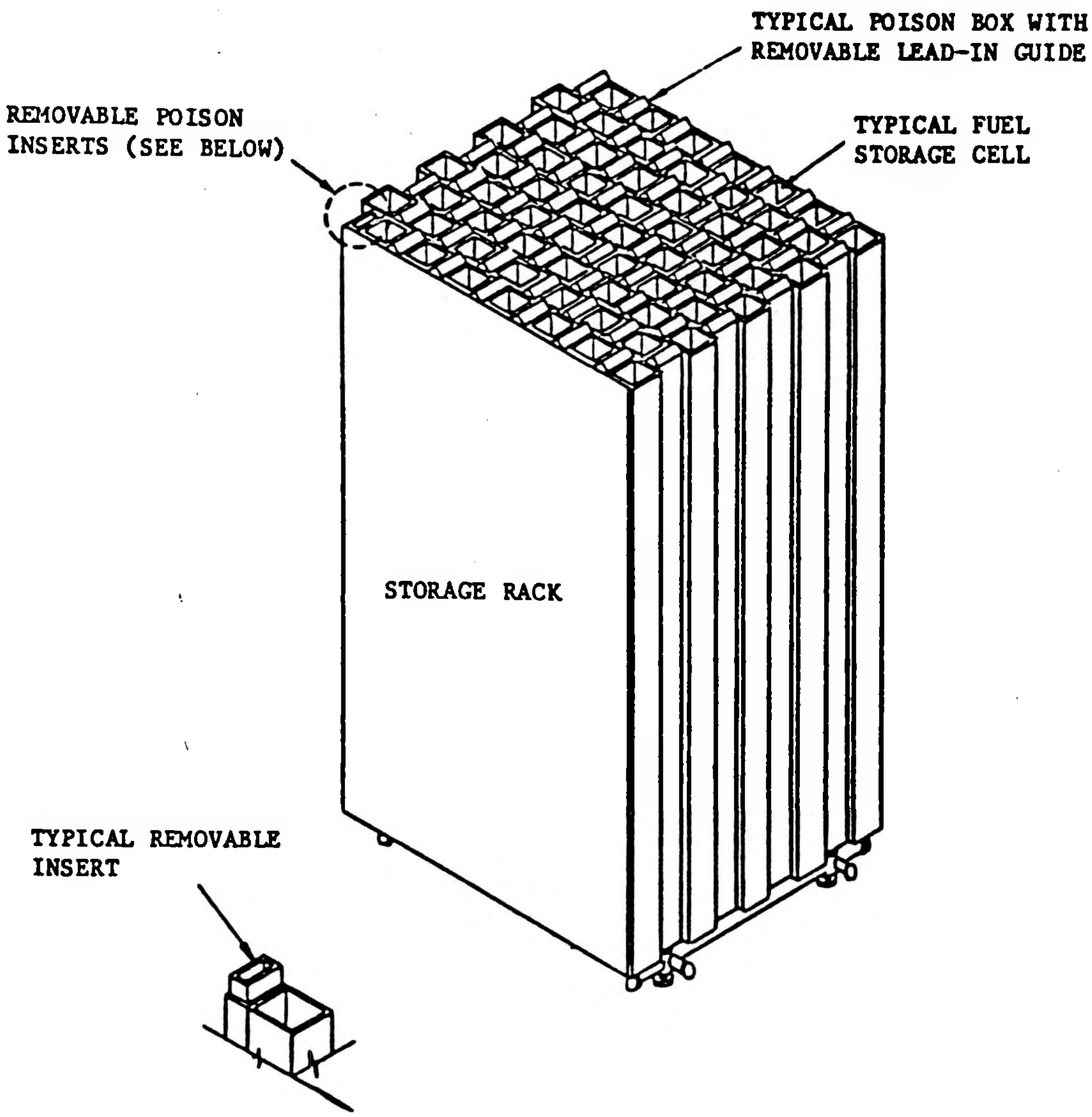


Figure 9. Typical High Density Storage Rack for PWR fuel (Source: Allied General Nuclear Services)

Pool re-racking

As delays in reprocessing spent fuel for recycle into the reactors mounted, utilities found that they could expand existing pool storage by installing new storage racks that permit closer spacing of fuel assemblies in the racks. See Figure 9). Several generations of storage rack designs with increasing storage efficiency have evolved. Initially closer spacing of the fuel was achieved by building neutron poisons into the racks to control criticality. In later designs NRC permitted burnup credit (accounts for depletion of the fissionable material during fuel use in the reactor) in the design of storage racks. Reracking is the lowest cost option for expanding at reactor storage costing in the order of five million dollars. Most reactors have been reracked at least once and some have been reracked several times. By reracking utilities have been able to extend pool storage of intact fuel to accommodate 10 to 20 years of storage while maintaining FCR.

Reracking requires amendment of the reactor's operating license under NRC regulations (10 CFR 50) to increase pool storage capacity. Since the pools were, in most cases, conservatively designed, refined computational methods have been able to demonstrate that pool structures can safely carry the additional structural loads as well as accommodate design basis accidents. NRC has routinely approved expanded pool storage by reracking. There has been opposition in the licensing process in only a few cases. The off-site shipment and return shipment to accommodate reracking and/or expansion have occasionally generated public controversy, for example in the Genoa (LACBR) and Point Beach cases (31).

The extent to which reracking can be used is dependent on the particular reactor pool design and other unique circumstances which must be considered on a case by case basis. Other storage options that a utility may be considering can also influence the extent to which they might elect to utilize reracking. There is no authoritative independent source of information on the extent to which reracking can or should be used to expand at-reactor storage which contributes to the uncertainty in how much additional at-reactor storage capacity will be needed. Another consideration is the way reracking costs affect utility ratemaking, which varies from state to state.

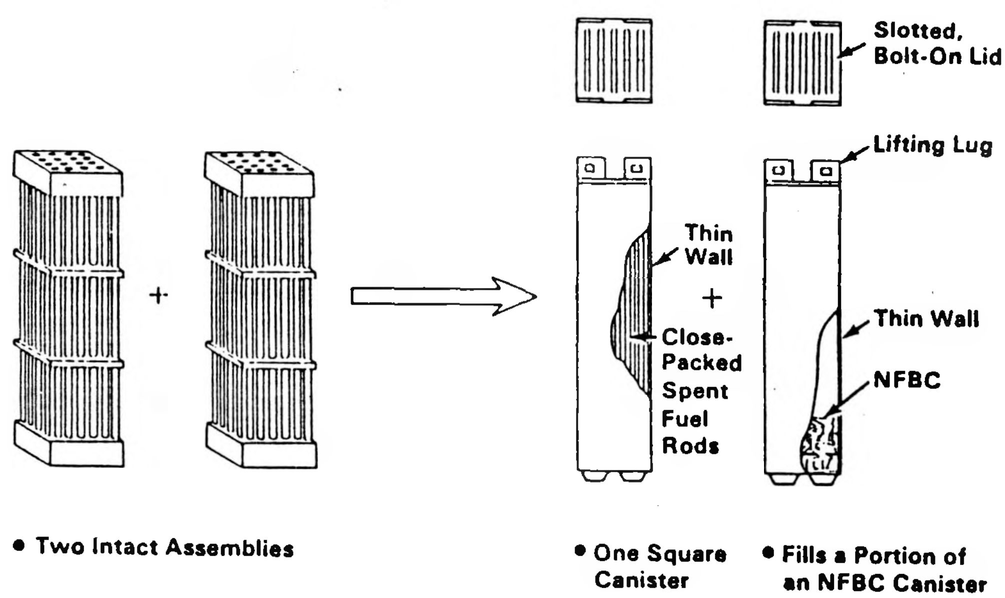


Figure 10. Rod Consolidation (Source: U.S. Department of Energy)

Rod consolidation

After spent fuel has been stored in reactor pools for several years the radioactivity of the fuel has decayed to the point that the water cooling channels in the fuel assembly are no longer necessary to maintain adequate cooling of the fuel. The fuel rods can be removed from the fuel assembly and packed closer together (consolidated) permitting as much as twice the amount of fuel to be stored in the same physical space. (See Figure 10) Since packing the fuel closer together reduces the nuclear moderator effect of the water, consolidated fuel is less reactive than intact fuel from a nuclear criticality standpoint. By reducing the spent fuel volume rod consolidation can:

- provide additional at-reactor in-pool storage capacity,
- reduce the number of casks and related cost of providing dry storage at the reactors, at a MRS facility, or at the repository,
- reduce the number of casks that must be handled and transported to the repository and/or MRS facility with corresponding reductions in related cost and radiological impacts,
- reduce the fuel packaging and handling operations at the repository and/or MRS facility with corresponding reductions in related cost and radiological impacts.(1)

DOE has traditionally assumed that fuel would be consolidated prior to disposal and that the repository benefits would outweigh the economic and radiological cost of performing the consolidation operations. The assumption appears to be based on a superficial study conducted by E. R. Johnson Associates in 1984 (1, 32, 33). This assumption was challenged by the State of Tennessee in their evaluation of DOE's MRS proposal noting that it is the most likely source of accidents related to MRS operations (5). DOE studies have not been able to show any clear systems advantage to justify consolidation for disposal (7). Studies have, however, shown that the benefits of consolidation are greater the further back in the system the operation is performed since the cumulative benefits in storage, handling, and transportation would be greatest (4). Recognizing that at-reactor consolidation technology is simpler than the dry process that DOE is developing for use at the MRS or repository, the State of Tennessee recommended that DOE provide incentives to encourage at-reactor fuel consolidation.

The maximum system benefits of fuel consolidation would be realized when consolidation is performed at the reactors. Extensive at-reactor fuel consolidation would, however, undermine DOE's preferred waste management system configuration including the need or desirability of having a MRS facility in the system. DOE has not only been reluctant to support efforts to demonstrate and solve the problems related to at-reactor consolidation but has undertaken to discourage such efforts. DOE has not been cooperative in working with the utilities to provide timely resolution of the DOE-utility interface problems and has actively tried to persuade utilities that they really do not want to get involved in spent fuel consolidation and packaging operations. DOE conducted a limited survey of eight utilities about their attitude towards performing consolidation and packaging operations at multiple reactor sites not designed for such activities (8). The questions were crafted to emphasize potential interference with reactor operations and might be roughly comparable to asking the man on the street "how would you like to volunteer for AIDS research". Predictably utilities would prefer to do as little as possible at the reactors and would like for DOE to take their fuel as soon as possible. It may, however, in the public and ratepayers interest, be desirable to have utilities conduct some at-reactor operations that are practical and effective in the overall optimization of the waste management system. It would not be inappropriate or unreasonable to expect the utilities to do more than the absolute minimum to help reduce the cost and impacts related to a problem they created.

At-reactor underwater rod consolidation in reactor storage pools is an adaptation and extension of the at-reactor practice of removing defective fuel rods from fuel assemblies and reconstituting the assembly for further use in the reactor for which there is extensive experience. Several vendors offer rod consolidation service and a few small scale demonstrations have been conducted. Rod consolidation is potentially the lowest cost option for providing additional at-reactor storage beyond what can be accomplished by reracking storage pools. Estimated costs range from about $5 to $40 per kilogram of fuel consolidated with an assessed median value of $17.50 (9). For a target 2:1 consolidation ratio the incremental cost of providing additional in pool storage would be twice this amount since at least two assemblies must be consolidated to provide storage space for one additional assembly. If the nonfuel-bearing scrap produced in the fuel consolidation operation is stored in the reactor pool in space that would normally be occupied by spent fuel the effective consolidation ratio will be reduced and the cost of providing additional storage will be increased accordingly.

The NRC does not specifically license fuel consolidation as a means of providing at-reactor storage. The utility must, however, obtain an amendment to their operating license under 10 CFR 50 to increase spent fuel storage capacity using consolidated fuel. The utility must also show that there are no unresolved safety issues or technical specification violations related to consolidation operations. NRC has granted license amendments to Rochester Gas & Electric Co. and Northeast Utilities to store consolidated fuel beyond that produced in limited demonstrations.

Limited demonstrations of at-reactor fuel consolidation technology have been sponsored by Duke Power Co. (10), Rochester Gas and Electric Corp. (11), Northern States Power Co. (12), and Northeast Utilities (13, 14). These have been part of the learning experience necessary to establish the practicality and viability of this technology as an option for providing at-reactor storage on a large scale. These projects have demonstrated the ability to achieve the target 2:1 consolidation ratio but have been disappointing with regard to:

- production rates that have been achieved, and
- compaction of nonfuel-bearing scrap from the consolidation operations.

Radiation exposure to workers has been low during these demonstrations and is essentially from the background level in the storage pool area. Two utilities, Northern States Power Co. (12) and Baltimore Gas & Electric Co. (15) have decided to utilize dry storage to provide additional at- reactor storage. The most serious problem is the operating burden placed on reactor pool utilization by the slow pace of consolidation operations. Improvements in equipment design and consolidation operations as well as the interface with DOE will be required before rod consolidation will be accepted for widespread at-reactor use.

The decision of whether or not to pursue rod consolidation may largely depend on the degree to which technology is developed and demonstrated to efficiently treat, package and store the nonfuel-bearing components (NFBCs) or scrap from the consolidation operations (16). To date, the range of alternative technologies that have been applied to these tasks have not been well investigated and the challenges and opportunities involved have not been well qualified. While the scrap is technically low level waste most of which could be disposed of at a low level waste disposal facility, it is quite likely that utilities would keep the scrap on-site until removed by DOE. DOE has indicated that they plan to accept this responsibility at no added cost to utilities.

The Rochester Gas and Electric Co., with support from the EPRI and ESEERCO, is conducting research on the "Treatment, Packaging and Storage of Bundle Scrap Hardware" (16). The scope of work includes NFBC processing, storage and disposition related to:

- interim in-pool wet storage,
- interim on-site dry storage, and
- disposal options.

The evaluations will include:

- NFBC volume and mass, by material, present in several of the most currently used fuels,
- determination of waste classification of specific components and materials,
- packaging alternatives,
- degree of processing required,
- cost for packaging, storage, transport and disposal,
- optimum degree of component segregation,
- existing licensing requirements and potential licensing concerns,
- compatibility of the waste form with future DOE disposal concepts, and
- quality assurance requirements.

Results of this study are scheduled to be available in 1990 and should help better define the problems and options related to dealing with NFBCs from consolidation operations.

The following preliminary results of this study have been made available (16):

1. Characterization of activated materials indicate that different isotopes are controlling for different options.

- Cobalt-60 in stainless steel guide tubes and end fittings is a strong gamma emitter and is the controlling isotope for shielding which is most burdensome for dry storage. These components are within limits for low level burial, except that it must be transported in heavily shielded casks.
- Niobium-94 is the controlling isotope for low level waste disposal. The Class C limits for burial are so low that very little is needed to exceed the limit (0.2 curries per cubic meter). The source of niobium-94 is high nickel inconel alloys. Inconel grids are clearly out of limits for low level burial, and even grids containing small inconel springs are questionable. Since the primary activity is beta emissions, inconel is not a particular problem for dry storage.

- Zirconium components are the least bothersome and do not present a particularly difficult problem for either disposal or shielding.

2. The studies have evolved into to two basic configurations for packaging: the 55-gallon drum and the square fuel geometry. For in-pool storage it is very important to minimize the amount of spent fuel storage space occupied by the NFBCs. The industry has had a target 10:1 NFBC compaction ratio to permit storage in the fuel racks in full length canisters. Under this condition it would be necessary to consolidate 10 fuel assemblies to gain 4 storage spaces by producing 5 canisters of 2:1 consolidated fuel and one canister of NFBC. The best the demonstrations have been able to achieve, to date, is in the range of 5-6:1 NFBC compaction ratio that produces 3 storage spaces for consolidating 10 assemblies, a questionable return for the effort. The preferred approach appears to be evolving towards alternatives that do not consume any fuel storage space and rely less on achieving high NFBC compaction ratios. In such cases it appears that the increased cost of achieving high compaction ratios might not be not justified. A 4:1 compaction ratio can be achieved by simply cutting up the fuel assembly skeleton with no crushing of components. Two alternative approaches to in-pool storage that do not consume fuel storage space are being considered.

- On-rack storage of NFBCs in 55-gallon drums placed on a platform placed over the fuel racks containing consolidated fuel canisters. Hardware compacted to 5:1 into such containers will occupy a rack area slightly less than the consolidated fuel. In this manner life- of-plant fuel and NFBCs can be stored in an area 28 feet square for a 1000 MW PWR and a somewhat larger area for a BWR.
- NFBCs are compacted in a short canister that is mounted on top of the consolidated fuel canister in the fuel storage rack. To allow shipment of both canisters in space for a long intact fuel assembly (Westinghouse) in DOE spent fuel transport cask the combined length of the canisters can not exceed 207 inches. The consolidated fuel and NFBCs from two intact fuel assemblies can fit in such a package with a 7-8:1 NFBC compaction ratio which should be achievable with some improvement in the technology.

3. On-site dry storage of NFBCs in metal and/or concrete shielding structures is being considered based on storage in 55-gallon drums. Shielding of stainless steel components will require about 40 inches of concrete or 8 inches of lead. Zirconium components and low burnup fuel that has decayed for some time may need as little as 25 inches of concrete or 4 inches of lead.

The study will keep in mind the longer term impacts on the ultimate interface with the DOE waste management system. However, in the absence of a DOE defined system, the task of setting packaging standards has fallen upon the utilities and the existing waste industry. Some utilities have already began packaging of hardware and many are soon to follow. DOE will need to design the waste management system to accommodate the packages used by industry.

Shipment of spent fuel between reactors

Shipment of spent fuel from a reactor that has near term storage needs to a reactor that has available storage space can provide some relief in solving near term storage problems. DOE has done studies of this approach assuming that fuel would be shipped between plants owned by the same utility and between plants of different utilities. The institutional problems of transshipment of spent fuel between utilities appear to be insurmountable. It can, however, be practical in some circumstances to ship fuel between a utility's reactors, but can be controversial.

In the 1970's TVA was conducting spent fuel management studies including transshipment and offered to assist DOE in implementing President Carter's plan for a Federal away-from-reactor (AFR) storage facility. This resulted in swift and strong public opposition to unnecessary spent fuel shipments. In response, TVA decided to plan for on-site life-of-plant storage for their nuclear power plants.

The Virginia Power Co. (VPC) owns two Westinghouse PWR nuclear plants. Their strategy was to rerack their North Anna plant with high density storage racks suitable for storage of consolidated fuel and ship fuel from their Surry plant for storage at North Anna. In 1982 VPC applied to NRC to allow them to rerack North Anna and ship spent fuel from Surry. There was strong public opposition which resulted in intervention in the NRC licensing process as well as litigation. Opposition to reracking North Anna was withdrawn when VPC agreed to limit shipments to North Anna by providing additional storage at Surry.

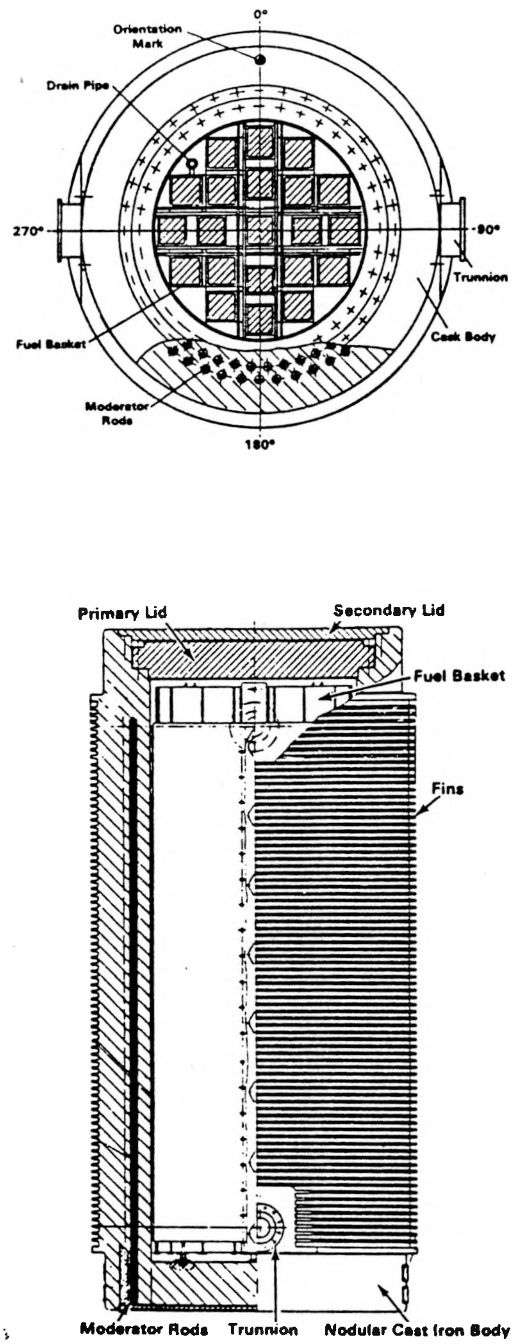
On the other hand the Duke Power Co. and the Carolina Power and Light Co. have shipped fuel between plants on their respective systems with little apparent difficulty. This is a limited temporary fix and both of these utilities are proceeding with plans to provide additional on-site dry storage.

Dry storage

While dry storage of spent fuel has not, until recently, been licensed by NRC for use in the United States, there has been considerable experience at DOE facilities and abroad.

General

Generically there are four types of dry storage: 1) silos, 2) dry wells, 3) metal casks, and 4) vaults. Utilities have favored passive storage in concrete silos or metal cask since they can be readily accommodated at reactor sites and provide flexibility to add storage essentially as it is needed. In the late 1970's TVA in a cooperative program with DOE began a program to demonstrate the licensing of dry at- reactor storage in metal casks. Two casks were to be used in this demonstration: 1) the CASTOR-1C which had been designed and licensed in the Federal Republic of Germany as a dual purpose cask, and 2) the REA-2023 storage-only cask designed especially for this project. While this project was never completed it was instrumental in laying the groundwork for the dry storage demonstration projects that were carried out under the NWPA provisions.



<u>Figure 11. Metal Storage Cask: CASTOR - V/21 (Source: Electric Power Research Institute)</u>

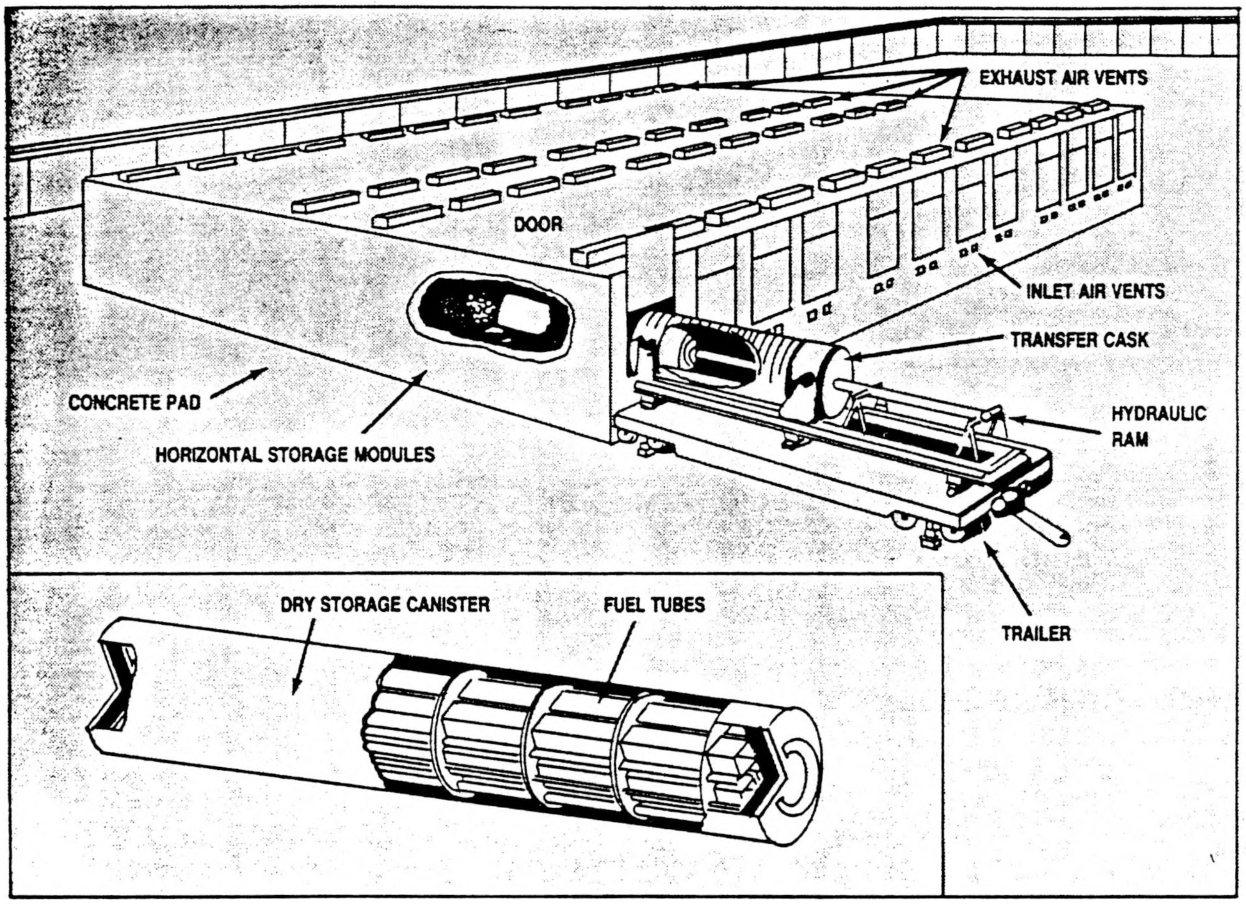


Figure 12. Horizontal Modular Storage System: NUHOMS (Source: U.S. Department of Energy)

The following sections provide some brief background information on the current status of dry cask use for: storage only, dual purpose for storage and transportation, and a universal cask that would also serve as the waste disposal container.

Storage-only cask

The only real success story that can be reported under implementation of the NWPA is the cooperative program between DOE and utilities to demonstrate the use of at-reactor dry storage technology. Very successful programs with the Virginia Power Company (VPC) and the Carolina Power and Light Company (CP&L) to demonstrate the use of large metal storage casks (See Figure 11) and concrete storage modules (See Figure 12) respectively have been carried out in cooperation with the Electric Power Research Institute (EPRI). This success was primarily due to the leadership and control over these projects that was exercised by the participating utilities.

In the program with VPC topical reports for cask designs by four different vendors have been approved by NRC. Unlicensed demonstrations using intact and consolidated fuel were conducted at DOE's Idaho National Engineering Laboratory (INEL) to obtain design verification data. This data has also been very useful in the design of transportation casks. VPC now has about ten such casks in use at their Surry Nuclear Plant. All these casks were designed with the intent of being dual purpose casks. The current demonstration in cooperation with DOE deals only with the storage. VPC has indicated their intent to pursue certification of these cask designs for transportation.

The project with CP&L demonstrates the use of the NUTECH NUHOMS-7 concrete storage module, designed to use an IF-300 rail cask owned by CP&L as the transfer cask, which limits the capacity of the demonstration module to seven PWR fuel assemblies. A larger version of the design, NUHOMS-24, with a capacity of twenty four PWR fuel assemblies has been recently approved by NRC which will have storage capacity comparable to the large metal cask used by VPC.

NRC REGULATION

NRC regulations, 10 CFR 72, for independent spent fuel (ISF) facilities apply to at-reactor storage and to a MRS facility. A major difference is that the license period is 20 years for at-reactor storage and 50 years for a MRS facility. This difference is due to NRC's perception of need rather than any inherent difference in the dry storage technology that would be used. For at-reactor dry cask storage the ISF facility is essentially concrete pads for parking the casks enclosed in a fenced security area within the plant site boundary. Most of the important safety aspects of such a facility are embodied in the cask design. The approach that has been taken is for the cask vendor to develop a comprehensive topical safety analysis report which encompasses the range of conditions for cask use which is reviewed by NRC. When the NRC is satisfied with design a letter of approval is issued noting any NRC limitations that might be applicable to the use of the cask. The utility applies to NRC for a Part 72 license in which they address site specific considerations and incorporate the vendor topical report, by reference, for the cask(s) they intend to use.

To date there has been little evidence of any real opposition to the use of dry storage. In fact, in testimony before the MRS Review Commission, representatives of environmental and public interest groups supported at-reactor storage as an alternative to the MRS facility proposed by DOE. While this provides a climate favorable to expanding at-reactor storage in general and dry storage in particular it provides_no assurance that opposition will not develop in some situations.

NRC DESIGN REVIEW

In early 1989 the NRC had reviewed and approved the following topical reports for referencing in site-specific license applications under 10 CFR 72:

CASTOR-1C by General Nuclear Systems. This nodular cast iron cask has a capacity of 16 BWR intact fuel assemblies and a loaded weight of 81 tons. It has been licensed in the Federal Republic of Germany as a dual purpose storage/transportation cask which will be loaded at reactors and transported to a central storage facility. This cask was on loan to TVA from a German utility and was the first dry storage cask to be reviewed by NRC as part of a DOE-TVA demonstration project. While it was never used in the United States it served a useful purpose.

CASTOR-V/21 by General Nuclear Systems. This nodular cast iron cask has a capacity of 21 intact PWR assemblies and a loaded weight of 117 tons. This cask is based on the technology used in West Germany for their dual purpose cask and is also designed to be transportable. Several of these casks are now in service at the Virginia Power's Surry Nuclear Plant.

NUHOMS-7 by NUTECH. This is a concrete and stainless steel storage module and has a capacity of 7 intact PWR fuel assemblies. This design is used in the demonstration project at Carolina Power and Light's H. B. Robinson Plant. The capacity was dictated by the use of the IF- 300 rail cask owned by CP&L to transfer the storage canister from the reactor pool to the concrete storage module.

MC-10 by Westinghouse. This cast ferretic steel cask has a capacity of 24 intact PWR fuel assemblies and a loaded weight of 120 tons. It was used in the unlicensed experiments at DOE's Idaho National Engineering Laboratory (INEL). It was also designed as a dual purpose cask.

Modular Vault Dry Store by FW Energy Applications. Thisdesign has been approved for up to 5 concrete modules in which each module has a capacity of 83 PWR or 150 BWR intact fuel assemblies.

NAC-S/T by Nuclear Assurance Corp. This lead and stainless steel dual purpose cask has a capacity of 26 intact PWR fuel assemblies and has a loaded weight of 100 tons. Its capacity can be expanded to 31 intact PWR assemblies with NRC approval of burnup credit. It is also designed to accommodate consolidated fuel and has the capacity for 56 PWR or 122 BWR consolidated fuel assemblies. One of these casks is in use at VPC's Surry plant. VPC is working with NAC to get this cask licensed for transportation. Spain has recently selected the dual purpose cask as the basis for their national spent fuel management program and has contracted with NAC to design and license the NAC-S/T for their program (19).

The Following dry storage systems were under review by NRC in early 1989:

Dry Cap by Combustion Engineering. This ferretic steel cask has a capacity of 24 PWR or 60 intact fuel assemblies with a loaded weight of about 112 tons. It is designed to accommodate 48 PWR or 100 BWR consolidated fuel assemblies.

TN-24 by Transnuclear. This ferretic steel cask has a capacity of 24 PWR or 52 BWR intact fuel assemblies and a loaded weight of 100 tons. It is designed to store consolidated fuel assemblies and has a capacity of 48 PWR or 104 BWR consolidated fuel assemblies. This cask was used in the unlicensed demonstrations at INEL with intact and consolidated fuel. It was designed as a dual purpose cask, but the vendor has not pursued a transportation license.

CP-9 by Nuclear Packaging. This storage only concrete cask has a capacity of 9 intact PWR fuel assemblies and a loaded weight of 88 tons. It is also designed to have a capacity of 18 consolidated PWR fuel assemblies. This cask may be dry loaded.

NUHOMS-24P by NUTEC. This concrete storage module design has a capacity of 24 intact PWR fuel assemblies. The design may rely on burnup credit for criticality control. A special transfer cask is required to move fuel in a stainless steel container from the reactor pool to the storage module. The fuel container is too large to be moved in the rail/barge transportation cask being developed by DOE (20). A special cask or a dual purpose cask can be designed to transport the container without returning it to the reactor pool and transferring the fuel to the DOE rail/barge cask. This design has been selected by Duke Power, Carolina Power and Light, and Baltimore Gas and Electric. for expanding at-reactor storage (20).

CASTOR-X by General Nuclear Services. This is a cast iron cask similar to the CASTOR-V21 but designed for 10 year old fuel. It has a capacity of 28 intact PWR fuel assemblies which can be expanded to 33 assemblies with approval of burnup credit for criticality control. VPC will work with the vendor to get this cask licensed for transporting spent fuel.

NRC has concluded that dry storage is an option now available to utilities to expand at-reactor storage (17). NRC has modified Part 72 regulations to make dry cask storage more easily available to utilities, reducing cost to them, and increasing NRC licensing efficiency in the late 20th through the early 21st century.

NRC DRY STORAGE RULEMAKING

Based on the experience with these dry storage demonstration programs and in response to the NWPA directive, NRC proposed (May 1989) by rule to authorize nuclear power plant licensees to store spent fuel on reactor sites in NRC-approved dry storage cask under a general license, without submitting an application for a specific license to store the fuel.(21) In this arrangement NRC would review the vendors cask design and the application envelope for its intended use. If it meets NRC's approval NRC would issue a Certificate of Compliance similar that those already issued for transportation casks. To use these certified casks for at- reactor storage under the general license the utility need only ensure NRC, through written evaluations, that there are no unreviewed safety questions or changes needed in association with the use of the cask at the particular reactor site as well as show compliance with conditions of the cask's Certificate of Compliance and develop operating procedures for use of the dry storage casks. In July 1990, the NRC approved a final rule which is not specifically different from the proposed rule. (34) Under this rule it appears that use of dry cask storage will be greatly expedited under conditions that will be very difficult to block by those that might oppose expansion of at-reactor storage. Nearly all nuclear power plants in the United States should have adequate space on site to accommodate dry cask storage of spent fuel. As indicated in the previous section NRC has already approved several dry storage designs and has several more under review. Dry cask storage is an option currently available to utilities for at-reactor storage and several utilities have announced their intentions to use the larger NUHOMS-24 concrete storage module design.

BURNUP CREDIT

Burnup credit as a means of criticality control is of interest for storage and transportation casks. Several storage cask vendors as well as DOE transportation cask designers have indicated an interest in using this method which can increase the capacity of large casks by 15 to 20 percent and can have important effects on spent fuel storage and transportation costs. NRC has approved the use of burnup credit in spent fuel storage rack design and is beginning to consider the issues related to its application to dry storage cask design (22). The Virginia Power Company will conduct a "proof-of-principal" testing program, with support from EPRI and DOE, to measure neutron multiplication factors of spent fuel in storage racks and storage cask for comparison with computed values (23). It is anticipated that NRC will eventually approve the use of burnup credit in the design of storage and transportation cask subject to administrative controls.

DOE'S DRY CASK STORAGE STUDY

The Nuclear Waste Policy Amendments Act (NWPAA) of 1987 authorized the MRS and established the MRS Review Commission to compare the proposed MRS to the alternative of at-reactor storage and to report on the need for a MRS facility. The NWPAA also directed DOE to:

"conduct a study and evaluation of the use of dry cask storage technology at the sites of civilian nuclear power reactors for the temporary storage of spent fuel until such time as a permanent geologic repository has been constructed and licensed by NRC and is capable of receiving spent nuclear fuel".

It appears that the Congress intended for DOE to study and evaluate at-reactor dry cask storage as an alternative to the proposed MRS, but did not explicitly spell this out in the legislation. DOE published the draft report "Initial Version: Dry Cask Storage Study" in August 1988 for comment as required by the legislation. In the report DOE elected to narrowly interpret Congress's direction and placed primary emphasis on the status of dry cask technology rather than taking a systems approach to examining the integration of dry cask technology effectively into the overall waste management system. DOE did a good job of reporting on the status of the technology and came to the conclusion that had precipitated Congress's interest in the study in the first place. That is:

"The DOE concludes that these existing technologies are technically feasible, safe, environmentally acceptable options for storing spent fuel at the sites of civilian nuclear reactors until such time as a Federal facility is available to accept the spent fuel".

Note that DOE took the liberty of changing the scope of at-reactor storage in the study from when a "permanent geologic repository has been constructed and licensed by NRC and is capable of receiving spent nuclear fuel" to when "a Federal facility is available to accept spent fuel". Presumably the Federal facility DOE has in mind is the MRS.

The lack of a systems approach was noted by NRC in their comments on the report and NRC writes that DOE should apply systems analysis to the entire spent fuel management system to "achieve cask design compatibility to the greatest extent possible". NRC charges that:

"inadequate attention is being given to ensure the compatibility of the various steps in storage, transport, and disposal of spent fuel and thereby to enhance the safety and efficiency of fuel handling."

It was clear that NRC recognized the potential benefits that can be gained from effective integration of multipurpose cask technology into the overall waste management system. NRC presented the following argument:

"With a proliferation of storage options, it appears likely that fuel to be removed from reactor sites in some instances may have to be returned to reactor pools to unload and then load into transportation casks for shipment to site. In addition subsequent operations at the repository, or a monitored retrievable storage (MRS) site, may be needed to repackage the fuel for ultimate disposal. The Commission believes that radiation exposures and other handling risk should be minimized in the entire process, from removing the fuel from the reactor pool the first time, to its ultimate disposal. System analysis and action at this early stage could result in minimizing these handling risks, and we suggest that DOE proceed on this course of analysis and action to achieve cask design compatibility to the greatest extent possible."

The "Final Version Dry Cask Storage Study" was published In February 1989 along with the comments received and DOE's response. The final report included some editorial and clarification changes but no substantive change in content. (24).

STORAGE COST

The DOE estimates for providing at-reactor dry storage of intact fuel are shown in Table II.2 for a range of capacity additions.

These costs appear to reasonably reflect uncertainty in at- reactor dry storage cost based on the current status on the technology and limited experience available. With the use of larger cask capacity, high volume production, and the storage of consolidated fuel there is a potential for achieving lower dry storage unit cost by, perhaps, as much as 50 percent.

TABLE II.2 Estimated cost of providing at-reactor dry storage of intact fuel in dollars per kilogram stored

Metric tons stored:	100	300	1000
Storage technology:			
Metal cask	$60-115	55-105	55-100
Concrete cask	50-110	45-95	45-85
Horizontal concrete module *	60-80	45-60	40-85
Modular concrete vault	105-155	70-105	45-70

* NUHOMS concrete storage modules

Transportation storage casks

The dual purpose cask concept was developed by West German nuclear utilities as a means of managing their spent nuclear fuel until it can be reprocessed or placed in a geologic repository. Since their nuclear plant sites do not have the space available for on-site storage of the casks they are transported to a central facility for storage. The need for an cost effective dual purpose cask led to the development of the nodular cask iron cask manufactured by economically pouring the cask body as a single part requiring minimal finish machining. Unlike grey cast iron, nodular cast iron is ductile and is suitable for use in transportation casks. Nodular cast iron casks have been tested and routinely licensed to the same international criteria contained in NRC transportation cask regulations. NRC has been reluctant, however, to approve nodular cask iron for transportation casks in the United States due primarily to the lack of appropriate standards to assure quality of the material in the castings.

The TVA and DOE program to demonstrate licensibility of dry storage cask technology also included a second phase to license dual purpose casks for transportation. This program predated the NWPA and was abandoned when TVA's nuclear power program encountered major difficulties. The dry storage demonstration program authorized by the NWPA led to the Virginia Power Company demonstration project at their Surry nuclear plant. This project has become the principal vehicle for establishing the dual purpose cask concept in the United States.

Dual purpose casks are, as has been indicated in the previous section on storage cask, essentially the same as large dry storage casks. (See Figure 13) The cost of manufacturing these large casks would be about the same if it is used for storage or used for storage and transportation. There would be an increase in cost due to licensing the cask for transportation and the additional ancillary equipment required for shipment of the cask. Licensing costs can be very high when spread over a few casks, but can be almost insignificant when spread over many casks of the same design.

DOE has consistently refused to perform systems transportation studies that depart from the concept they adopted as a matter of expedience as a basis for design and optimization of the from-reactor part of the transportation system. The traditional transportation system concept that DOE is pursuing is based on improved cask capacity made possible by shipment of older fuel. DOE has proceeded on the basis of optimization

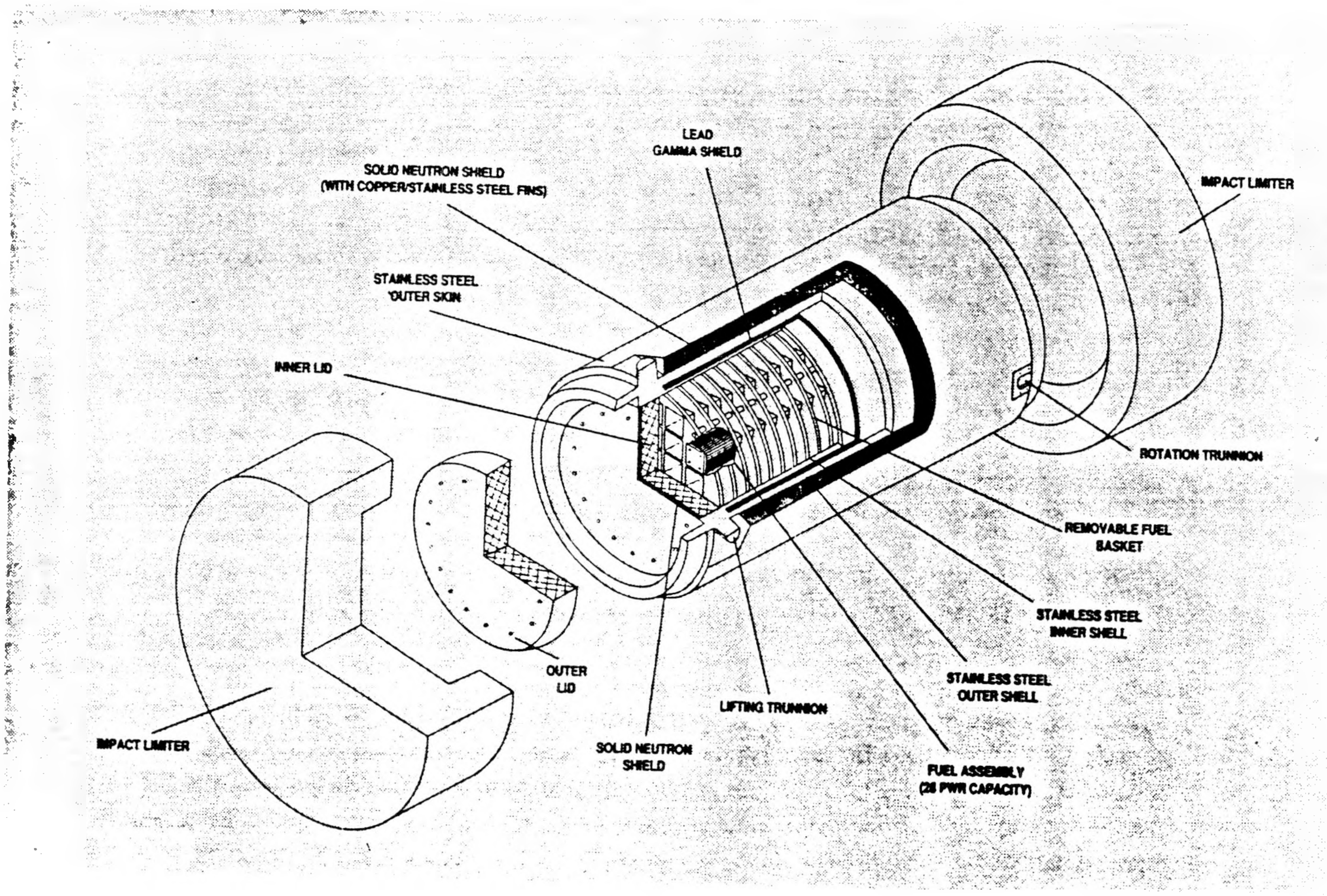


Figure 13. Dual-Purpose Cask (Source: Nuclear Assurance Corporation)

of the cask design without defining the system in which it must operate on the theory that such casks will be needed in any event. This is inconsistent with systems engineering principles and can result in forgoing overall system optimization. These problems are discussed in greater detail in other sections of this report.

Until DOE became committed to justifying a MRS facility as an integral part of the system, DOE supported development of the dual purpose casks concept. When it became apparent that the dual purpose cask effectively integrated into the waste management system could undermine their MRS strategy DOE became hostile to the concept. At one time DOE had included dual purpose cask development as part of their transportation cask development program.

DOE's decision to drop the dual purpose cask from the development program was justified using a very limited study conducted for DOE by H&R Technical Associates and E. R. Johnson Associates (25). This study assumed a rigid interface between at-reactor storage and the transportation system in which a limited number of dual purpose casks would substitute for part of DOE's transportation fleet. Under the particular cask capacity and cost assumptions used in this study the use of dual purpose casks in this manner was shown to be slightly more expensive than use of transportation only cask.

An extension of the DOE study was performed by the Nuclear Assurance Corporation for the Electric Power Research Institute (EPRI). The EPRI study examined several options for more effective integration of dual purpose casks into the overall waste management system and showed that the results of the DOE study were very sensitive to cask capacity and the cost assumptions used (26). The EPRI study used a larger number of higher capacity dual purpose casks for at- reactor storage which were also used for transportation to a MRS or repository, lag storage at the MRS, interim storage of consolidated fuel, storage at the MRS and to transport fuel from the MRS to the repository indicating that substantial cost savings and reduced handling of cask and spent fuel can be achieved.

Neither of these studies optimizes the use of dual purpose casks into the transportation system through the use of multiple cask shipments by special dedicated train which becomes practical with large numbers of dual purpose casks in the system as has been suggested in studies for the State of Tennessee (27). With large numbers of dual purpose casks in the system a completely different basis for optimization of the transportation system is available. Minimizing the transportation fleet size and maximizing cask utilization are not major optimization factors as they are in the type of transportation system DOE appears to be developing.

The position that DOE has taken with utilities interested in using dual purpose casks put the utilities in an untenable position. DOE would expect the utility and/or cask vendor to assume all the cost and risk of getting the dual purpose cask licensed for transportation up front and then DOE might be willing to buy it, if they can use it as part of their transportation fleet. This is best illustrated by DOE's response to comment on their Dry Cask Storage Study (24).

"The observation in the report that the impact of dual purpose casks on the transportation system is expected to be slight is based on two premises. First, the beneficial impact of dual purpose cask on the transportation system requires a commitment by the utility to deliver certified casks sufficiently far in advance for DOE to avoid the purchase of transportation cask for its transportation fleet. However, studies to date indicate that, if the entire transportation fleet were composed of dual purpose cask, only 28 to 34 such cask would be required. Second, it is doubtful that a utility would want to ship the spent fuel stored in dry storage earlier than the spent fuel stored in the spent fuel storage pool."

Studies for the State of Tennessee indicate that the principal benefactor of integration of dual purpose casks into the overall system is the electric rate payers and the general public not DOE or the utilities (27). DOE appears to be erecting an artificial barrier between them and the utilities that forgoes effective integration of at-reactor storage into the overall waste management system including transportation.

DOE's position on the dual purpose cask was clearly articulated in response to a question in the following testimony before the MRS Review Commission (28).

CHAIRMAN RADIN: "I think there have been some rather significant developments that have been brought fourth by the State of Tennessee in its studies subsequent to 1987, and it would seem to me that they would merit your consideration, particularly in the development of dual purpose cask".

MR. ISAACS (DOE): "Let me just state, I think it is a mistake to mix considerations over dual purpose cask with whether or not there is an MRS. I think those are two separate and distinct issues. You can decide whether or not dual purpose cask, which are actually principally for storage at reactor sites, and then transportation is a separate and distinct issue from whether or not an MRS helps to achieve the strategic objectives of the program.

I think they are both important objectives. We plan on looking at both of them, but don't believe, to a first order effect, they have any impact on one another."

CHAIRMAN RADIN: "You don't think it is relevant to the

question of whether or not there should be an MRS"?

MR. ISAACS: "No".

Unfortunately this exchange characterizes DOE's overall approach to design and optimization of the waste management system. Contrary to good systems engineering practice they separate the system into subcomponents for optimization based on DOE's internal criteria and strategic objectives ignoring external input and avoiding effective integration of system components if it does not serve to support DOE's predetermined position.

Universal cask

The universal cask concept evolved from a Westinghouse study for DOE of a thick walled disposal container concept which provided shielding to facilitate emplacement and recovery of spent fuel disposal packages. The similarity of this self- shielding disposal package to a dual purpose cask for storage and transportation cask came to TVA's attention. TVA and EEI jointly sponsored a feasibility study which indicated that the universal cask concept was technically feasible and economically competitive. This lead to a DOE sponsored systems engineering study of integration of various metal cask concepts into the overall waste management system. The results showed that the universal cask concept warranted further study. DOE abandoned this program and has declined to give further consideration to the universal cask concept since they have become committed to a system configuration with an integral MRS.

The Canadians are developing a universal cask concept based on the use of a concrete cask. The universal cask concept is also under study in the Federal Republic of Germany.

NRC waste confidence rulemaking

One of the issues in contention during nuclear power plant licensing proceeding was the question as to whether nuclear power plants should be built with no assurance that disposal of the high-lever nuclear waste they produce will be provided. Rather than address this issue on a plant by plant basis NRC chose to address the issue through formal rule making procedures. In 1984 NRC issued their Waste Confidence Rule (29). In this rule NRC found that there is reasonable assurance that one or more geologic repositories for commercial high-level radioactive waste and spent nuclear fuel will be available by the years 2007-2009. It was also found that, if necessary, spent fuel generated in any reactor can be stored safely and without significant environmental impact for at least 30 years beyond expiration of that reactor's operating license, either on-site or off-site, and that safe independent spent fuel storage capacity will be made available if needed. NRC committed to revisit the question in five years.

In April 1989 the NRC Staff presented their proposed recommendations to the NRC Advisory Committee on Nuclear Waste. In recognition of delays in the first repository and other program changes the principal NRC Staff recommendations were:

- At least one mined geologic repository will be available within the first quarter of the 21st century, and that sufficient repository capacity will be available within 30 years beyond the scheduled expiration of operating licenses for the bulk of nuclear power reactors to dispose of spent fuel generated in those reactors.
- If necessary, spent fuel generated at any reactor can be stored safely and without significant environmental impact for at least 100 years.

The staff recommendations were adopted by the NRC in its final revision of the Waste Confidence decisions in September, 1990. (35)

Extending the repository dates is justified based on increased confidence in long term storage and recognizes the possibility that the Yucca Mountain Site might not be found suitable. The technical basis for increased confidence in long tem storage is based on the reliability of hardware and engineering structures and the lack of any failure modes of significant concern for storage pools or dry casks. Some believe this will reduce the pressure on DOE to put a repository in operation allowing more time for site selection.

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Part III: MRS Status

Introduction

The issues involved in the MRS debate can have greater effect on transportation impacts in the repository state and nearby transportation corridor states than any other issue. If spent fuel is shipped to an MRS facility as DOE has proposed a very efficient transportation system would be used between the MRS and the repository that would minimize impacts. Without a MRS spent fuel would be shipped directly from the reactors to the repository. The from-reactor transportation system being developed by DOE is by comparison very inefficient.

The State of Tennessee found in its evaluation of DOE's MRS proposal that substantial improvements in the from-reactor transportation can and should be made whether or not a MRS is in the system (1). Moreover, dual-purpose casks integrated into the system result in a from-reactor transportation system that approaches the efficiency of the MRS-repository transportation system (2). A study sponsored by the State of Tennessee has also shown that with improvements in the from- reactor transportation system the optimum location for a MRS facility to minimize transportation impacts is as near the repository as possible (3). The modal mix issue is intimately involved in realizing these improvements and will be discussed in the next chapter. Recent studies indicate that the current approach to repository licensing may not be achievable and it might be desirable or necessary to incorporate MRS features into the repository (4, 8).

This chapter reviews the MRS status starting with the NWPAA of 1987. The principal studies that have been done relating to the MRS are by the State of Tennessee, the DOE, and the MRS Review Commission. The Tennessee and DOE studies were prepared as input to the MRS Review Commission's deliberations and are reviewed in this chapters as are the activities of the Commission.

1987 NWPAA amendments and MRS

The 1987 amendments to the Nuclear Waste Policy Act (NWPA) of 1982 annulled and revoked DOE's proposal to build a MRS in Tennessee and authorized DOE to site, construct and operate one MRS facility subject to the following conditions:

- Site selection may not begin until a MRS Review Commission reports to the Congress on the need for a MRS facility,
- No MRS may be located in Nevada,
- Construction may not begin until NRC issues a license for construction of a repository,
- The quantity of nuclear waste stored at the MRS may not exceed 10,000 metric tons until the repository begins accepting waste,
- The quaintly of nuclear storage may not exceed 15,000 metric tons, and

- MRS construction or acceptance of nuclear waste shall be prohibited during any time a repository license is revoked by the NRC or construction of the repository ceases.

A three member commission was established for the purpose of reporting to the Congress by June 1 (changed to November 1), 1989 on the need for a MRS facility as a part of the Nation's nuclear waste management system that achieves the purposes of the NWPA. In preparing their report the MRS Commission was directed to:

- review the status and adequacy of DOE's evaluation of the systems advantages and disadvantages of bringing such a facility into the national nuclear waste disposal system,
- obtain comment and available data on monitored retrievable storage from affected party, including States containing potentially acceptable sites,
- evaluate the utility of a MRS facility from a technical perspective,
- make a recommendation to Congress as to whether such a facility should be included in the national nuclear waste management system in or to achieve the purposes of the Act, including meeting needs for packaging and handling spent nuclear fuel, improving the flexibility of the repository development scheduled, and providing temporary storage of spent fuel accepted for disposal.

In preparing the report and making its recommendations the MRS Commission is required to compare the MRS facility to the alternative of at-reactor storage. This comparison was to take into consideration the impact on:

- repository design and construction,
- waste package design, fabrication and standardization,
- waste preparation,
- waste transportation systems,
- reliability of the national disposal system,
- ability to fulfill contractual commitments to accept fuel for disposal, and
- economic factors, including the impact on the cost to be imposed on ratepayers for temporary at-reactor storage as well as cost likely to be imposed due to the building and operation of a MRS facility.

After the MRS Commission submits its report to the Congress DOE may conduct a survey and evaluation of potentially suitable MRS facility sites. The MRS site, however, can not be selected until the DOE Secretary recommends to the President the approval of a site for development as a repository. An environmental assessment, based upon available information, is to be submitted to the Congress at the time the MRS site is selected. In conducting the survey and evaluation DOE is to consider the extent to which siting a MRS facility at each site surveyed would:

1) enhance the reliability and flexibility of the waste disposal system,
2) minimize the impacts of transportation and handling of such fuel and waste,
3) provide for public confidence in the ability of the such system to safely dispose of spent fuel and waste,

4) impose minimal adverse effects on the local community and local environment,
5) provide a high probability that the MRS facility will meet applicable environmental, health, and safety requirements in a timely fashion,
6) provide such other benefits to the system as the Secretary deems appropriate, and
7) unduly burden a State in which significant volumes of high-level radioactive waste resulting from atomic energy defense activities is stored.

At least six months before selecting a MRS site the Secretary must notify the Governor and legislature of the State in which the site is located, or the governing body of the affected Indian tribe, as the case may be, of such potential selection and the basis for such selection. The State or Indian tribe can submit a notice of disapproval of such site with 60 days of site selection. The selection of the site will not be effective unless both houses of the Congress override the State disapproval.

Once selection of the MRS site is made by the Secretary the State or Indian tribe is eligible to enter into a benefits agreement with DOE. The benefits agreement provides for annual payments of $5 million and $10 million respectively for a MRS or repository until receipt of waste. These are increased to $10 million and $20 million annually respectively from receipt of waste until the closure of the facility. States or Indian tribes entering in such agreements must wave their rights to site disapproval and impact assistance. The agreement is to provide for participation in a Review Panel to advise the Secretary on matters relating to design, construction, operation, and decommissioning of the facility.

The 1987 NWPAA established the Office of the Nuclear Waste Negotiator. The Negotiator is to attempt to find a State or Indian tribe willing to host a repository or MRS facility at a technically qualified site on reasonable terms and conditions. Any proposed agreement is to be submitted to the Congress and shall have no effect unless enacted into Federal law.

The I-No-MRS alternative to DOE'S MRS

The Integrated No-MRS (I-NO-MRS) waste management system configuration was developed at the University of Tennessee in a State of Tennessee sponsored study as an alternative to the configuration proposed by DOE with an integral MRS facility (4). This I-NO-MRS concept was based largely on ideas developed at the Tennessee Valley Authority (5). The concept was refined in DOE's Westinghouse PRDA project (6) and by the State of Tennessee's evaluation team in the course of reviewing DOE's MRS Need and Feasibility Study (1). The concept is based on the use of dual purpose casks integrated physically and institutionally into at-reactor storage, transportation and repository operations to provide a high degree of flexibility and reliability while minimizing fuel handling and shipments. It is the product of an effort to apply a systems engineering approach to the optimization of a technically sound waste management system configuration to be responsive to the stakeholders values. The stakeholder value structure used was developed in the PRDA project (6) and is discussed in the following chapter on transportation modal mix which is a major factor in determining the best system configuration.

The universal cask concept in which the cask would also be used as a disposal container is compatible with the dual purpose casks concept up to disposal and is also an attractive basis for system integration. This concept, however, has not been developed to the point where interaction with repository performance is well understood. Therefore, with current uncertainties, greater confidence can be placed on a system configuration based on dual purpose casks. A comprehensive evaluation of alternative system configurations should include the universal cask concept which was beyond the scope and resources available in the studies performed by the University of Tennessee for the State of Tennessee.

The I-NO-MRS concept is based on a family of dual purpose casks suitable for transportation which can be utilized for at-reactor storage of intact and/or consolidated fuel assembles and is compatible with concrete storage modules to provide efficiency and flexibility in at-reactor storage. Standardized dual purpose casks would be used by utilities for long term at-reactor storage and/or as a temporary portable full core reserve permitting better utilization of available pool storage. DOE would provide incentives to utilities for use of dual purpose casks for storage and transportation and encourage at-reactor rod consolidation. At-reactor consolidation would improve the effectiveness of pool storage and cask utilization. The casks would be designed for 10 year-old fuel and would be available in up to five standard sizes ranging in nominal loaded gross weights of 25 to 150 tons. Casks would be designed to interface with concrete storage modules using standardized fuel storage canisters. The dual purpose cask would be used to transfer canisters to the concrete storage module and to ship canisters to the repository without returning fuel to the reactor pool. DOE would work with individual utilities to upgrade access and cask handling facilities to accommodate the largest cask practical. In some cases a special transfer cask could be used to move fuel from the reactor pool to a larger dual purpose cask that cannot be handled inside the plant (7). DOE would work with the utility industry to establish fuel acceptance criteria and packaging standards as soon as possible.

Multiple cask from-reactor shipments would be made periodically by special dedicated trains with special crews under conditions that provide close control over all aspects of spent fuel transportation. Barge or heavyhaul transfer would be used, as appropriate, to move large casks to a nearby railhead where the plant does not have rail access and it is not practical to provide rail access. The few small casks (25 or 40 tons) that might be required would be moved to a nearby railhead by legal weight or overweight truck short haul. Upon receipt and unloading at the repository the dual purpose casks become the transportation cask fleet for removal of additional fuel from reactor storage pools and concrete storage modules.

There is a real possibility that the start of large scale disposal will be delayed beyond the time when it becomes desirable to decommission nuclear power plant sites. This could become a pressing problem by about the year 2020 if decommissioning should begin within ten years of the end of commercial operation of a nuclear power plants. In this event, the fuel could be shipped in the dual purpose cask to one or more centralized temporary storage sites to accommodate decommissioning until the repository is ready for operation. This simple buffer MRS would be a cask storage facility in which the casks would remain sealed with no processing or packaging of the fuel at the site. Since it is not necessary to return dual purpose casks to the reactor pool to transfer the fuel to transport casks, dual purpose casks can be use for at-reactor storage after the pool is not available. It is not necessary to open the dual purpose cask before shipment from the reactor or from a simple buffer MRS. It, however, will not be necessary to make a decision to include this form of MRS as part of the system until after the turn of the century when better information on the prospects for repository operation should be available. It is important to recognize the flexibility available in the I-No-MRS system to use this option if it becomes necessary or desirable.

DOE's transportation technical experts , Sandia National Laboratory, indicated before the MRS Review Commission that it may be necessary to unload fuel from dual purpose casks every five years to inspect them as required by NRC regulations (10 CFR 71) applicable to transportation casks (17). Sandia, also questioned the feasibility of being able to transport dual purpose storage casks due to potential deterioration of the cask or fuel after long periods of storage (18). These rather shallow arguments, the best technical arguments DOE can muster against dual purpose casks, should present no unusual problems in a systems approach to the design and regulation of dual purpose casks. First, dual purpose casks should not be certified separately for storage (10 CFR 72) and transportation (10 CFR 71) under existing NRC regulations. To facilitate effective integration of dual purpose cask into a systems approach waste management system NRC would be requested to promulgate regulations appropriate to the application (4). The seal on the cask closure is the only critical cask component subject to deterioration during long term storage. This can be easily accommodated in the design of dual purpose cask by adding a redundant additional closure with transportation seals just before shipping the cask. It is possible that even in an inert atmosphere some deterioration of fuel from such mechanisms as internal corrosion could take place. There is no evidence that this will be a significant problem. In fact NRC in its pending waste confidence rulemaking, see previous chapter, specifically notes that the technical basis for increased confidence in long term storage is based on the reliability of hardware and engineering structures and the lack of any failure modes of significant concern for storage pools or dry casks (19). Moreover, if there should be some significant deterioration of the fuel in long term storage, the radiological exposure associated with recovering the damaged fuel and decontamination of the cask probably can be dealt with most effectively, after shipment, at a central facility that has appropriate recovery facilities.

Dual purpose casks would also be used to provide buffer storage of spent fuel at the repository site. They would be used to provide buffer storage at the fuel receiving facilities as well as buffer storage of disposal packages to accommodate normal perturbations in repository operation or major disruptions of the balance of the waste management system. The I-No-MRS system configuration is not dependent upon any firm repository schedule or continuous repository operation, providing great flexibility in overall operation of the waste management system.

Since large scale disposal is not likely to begin much before 2008 or probably later, the repository would be designed to accept 20 year old fuel rather than the current design basis for 5 year old fuel. This would simplify system design, reduce impacts and increase the capacity of the repository as well as reduce disposal cost.

The I-NO-MRS concept provides an effective and reliable means of providing interim storage at-reactor sites that is less vulnerable to disruption than storage at an I-MRS or FIS facility. The spent fuel generated at reactors must be stored, and passive storage in dual purpose casks provides the greatest flexibility in accommodating the many uncertainties while minimizing the risk related to handling, storing, and transporting spent fuel. The I-NO-MRS system configuration provides a high degree of flexibility and reliability with regard to:

- providing wet and/or dry storage of intact or consolidated storage at reactor sites,
- reducing at-reactor fuel handling since it is not necessary to move these casks back into the reactor pool to remove the fuel and load it into transport casks,
- serving as a portable full core reserve allowing increased storage in reactor pools,
- providing long-term at-reactor storage after the reactor and pool have been decommissioned, if necessary,
- reducing from-reactor transportation costs and radiological dose commitments (occupational and public from routine operations and accidents) by making multiple cask shipment by dedicated train,
- reducing state and public concerns by more effective security, control, and emergency response made possible by use of dedicated trains for spent fuel shipments,
- preserving the option for simple buffer MRS facilities to allow decommissioning of reactor plant sites if there is an extended delay in the availability of a geologic repository by moving dual-purpose casks to one or more central locations where they would continue to provide monitored dry storage until shipped to a repository without removing fuel from the cask,
- providing temporary buffer storage of spent fuel at the repository site to facilitate optimum fuel flow to the packaging facility and continued operation of the transportation system when there are disruptions in packaging or disposal operations, and
- providing temporary buffer storage between packaging operations and disposal if there are disruptions in disposal operations.

The number of dual purpose casks in the system is a function of the amount of dry storage needed at the reactors which depends on when large-scale geologic disposal begins. The beginning of large-scale disposal is likely to be delayed at least ten years beyond the 1998 target date set in the NWPA and it is anticipated that there would be several hundred dual purpose casks in the system. DOE could provide incentive credits based on sharing avoided system cost to encourage utilities to consolidate fuel and to use the largest practical dual purpose cask or compatible concrete storage module to meet their additional storage needs. Responding positively to these incentives will be important to utilities since they must show their public utilities commission that they have acted prudently to be allowed to recover their storage cost. It is important to have some leverage to encourage utilities to act in the ratepayers interest.

Utilities would buy standardized dual purpose casks to DOE specifications with assurance that they would be purchased by DOE when the fuel is conveyed to DOE.

Alternatively, DOE could develop a competitive supply system and make volume purchases to obtain the lowest possible price. DOE could then lease casks to utilities based on investment interest cost. Utilities would pay all other at-reactor storage costs for facilities and operations.

The dual purpose cask can also be readily adapted for providing Federally financed at-reactor storage if Congress determines such assistance is desirable. In this event DOE would provide utilities with standard dual purpose casks without lease charges. DOE would not, and should not, be directly involved in conducting any activities at the reactor site. However, with Congressional approval, DOE could go as far as paying for the cask storage facilities and reimbursing the utility for related operation cost. This would not be different in principal than paying a contractor to operate a centrally located I-MRS. It probably is not desirable to remove all incentives for utilities to keep some pressure on DOE to get the repository in operation.

The I-NO-MRS concept could assure that no reactor will be forced to suspend operation due to lack of storage, or inability to ship fuel to an MRS or repository. This would allow repository characterization, selection, licensing and construction to proceed at the pace required to do-it-right taking fuel acceptance off the critical path to repository operation. The I-NO-MRS system configuration based on dual purpose casks is very robust with regard to its flexibility to perform effectively and reliably under a wide range of institutional and technical uncertainties in the overall waste management program.

Tennessee studies and position

The NWPA Amendments of 1987 set aside DOE's selection of a MRS site in Tennessee. If Congress should decide to proceed with a MRS after receiving recommendations from the MRS Review Commission DOE will be required to initiate a new site selection process. Tennessee could still be a candidate for a MRS site, however, more important is the State's conclusion that a MRS is not needed since better solutions are available. The State has been an active participant in the MRS Review Commission proceedings and sponsored two studies at the University of Tennessee as input to the process.

1) The first, is primarily a technical study (4) which takes a systems approach to development of an optimized NO-MRS waste management system configuration based on integration of a family of dual-purpose cask into the overall system. This Integrated-NO-MRS (I-NO-MRS) system concept is then used in a comparative evaluation to DOE's Integral-MRS (I-MRS) system concept, and
2) The other, is a broader public policy study (8) that evaluates a wide range of MRS options including the I-NO-MRS as a decentralized-MRS concept.

These studies are the result of independent work by the authors and do not necessarily represent positions by the State of Tennessee or the University of Tennessee.

University of Tennessee technical study

Figure 14. provides a summary comparison of the evaluation of DOE's I-MRS system configuration and the I-NO-MRS system configuration on a relative basis. A single

star (*) indicates that the system is somewhat better than the other configuration. Two stars (* *) indicate that the system is clearly better and three stars (* * *) indicates that the system is decisively better (4).

The evaluation criteria used is based on a composite stakeholder value criteria structure developed in a PRDA project workshop with groups representing Public, Government and Technical interest for use in optimization and evaluation of alternative waste management system configurations (6). It is an appropriate basis for design and evaluation of waste management system configurations. The first two criteria lend themselves to quantitative comparison. The remaining six are compared in more subjective qualitative terms based primarily on stakeholder testimony before the MRS Review Commission with deference to those views closest to the public.

Health and Safety is divided into public and occupation components which can be addressed as impacts related to transportation and those related to spent fuel handling operations. Table III.2 shows a relative comparison of transportation impacts in terms of the following four proxy measures:

TON-MILES is an indicator of freight charges for gross shipping activity.

CASK-DAYS is a measure of radiological dose commitments to the public and transportation occupational workers.

CASK SHIPPED is a measure of transportation related occupation radiological dose commitments at nuclear facilities.

TRIP-MILES is a measure of apparent shipping activity, risk of a shipment being in an accident, and the cost of security, monitoring and emergency response.

It was assumed that the I-MRS would be located in the east as DOE has proposed. The I-NO-MRS concept significantly reduces CASK SHIPPED, TRIP-MILES, and CASK-DAYS while achieving some reduction in TON-MILES compared to DOE's I-MRS concept. Results are also shown for no at-reactor fuel consolidation and for full at-reactor rod consolidation for both system configurations. At-reactor rod consolidation dramatically reduces transportation impacts which will be discussed in the modal mix chapter. At this time, it is not possible to accurately predict the amount of at-reactor rod consolidation that will take place.

Figure I4. Comparison of value criteria for I-MRS and I-NO-MRS system configurations

NOTE: * Somewhat better
* * Clearly better
* * * Decisively better

Criteria	DOE's I-MRS concept	Dual purpose cask I-no -MRS concept
1. Health and Safety:		
Public		* * *
Occupational		* * *
2. Economic		* * *
3. Environmental:		
Near-term		*
Long-term		* *
4. Political:		
Acceptability		* *
Public Confidence:		
In DOE		* *
Political will		* * *
Local and State Attitudes		* *
5. Social (Fears and Anxieties)		* *
6. Fairness:		
Liability		*
Equity:		
Geographic		* * *
Intergenerational		* *
Interutility		* *
Utility-Ratepayer		* * *
Government-Utility	* *	
7. Scheduling (Repository)		* * *
8. Flexibility:		
Technical		* * *
Institutional		* * *

Table III.2 Reduction in transportation system impact measures for the I-No-MRS compared to DOE's integral MRS

Proxy measure:	No at-reactor consolidation	Full at-reactor consolidation
Cask shipped	72% less	74% less
Trip-miles	88% less	88% less
Ton-miles	16% less	42% less
Cask-days	50% less	58% less

Economic costs are compared in Table III.3 as total system life cycle cost including compensation payments to the states and the cost of providing at-reactor storage in terns of nominal cost and expected value assuming the repository starts operation in 2008. These cost are in undiscounted 1986 dollars. The expected value cost reflects uncertainty in the cost estimates. The nominal cost and expected value of DOE's NO-MRS system configurations are about $1.2 billion more than the I-NO-MRS concept. Assuming the MRS operation is linked to the repository and starts operation in 2008 the nominal cost and expected value of DOE's I-MRS concept is about $3.4 billion and $5.0 billion more than the I-NO-MRS respectively. If the linkage to the repository were removed and the MRS starts operation in 1998 the corresponding increase in cost over the I-NO-MRS would be reduced to about $2.2 billion and $3.4 billion.

Table III.3 Comparison of nominal and expected total system life cycle cost for repository operation in 2008 in millions of 1986 dollars

	Nominal cost		Expected value	
	Amount	Increase	Amount	Amount
DOE's No-MRS	23,150	1,236	24,777	1,239
DOE's I-MRS (2008)	25,326	3,412	28,530	4,999
DOE's I-MRS (1998)	24,106	2,192	26,974	3,436
I-NO-MRS	21,914	BASE	23,538	BASE

If there is an MRS in the system removing the linkages to the repository would save about $1.2 billion in nominal cost or about $1.6 billion in the expected value of total system life cycle cost, however, it would still cost $2.2 billion and $3.4 billion more than for a I-NO-MRS system. The disproportionate increase in expected value of total system cost indicates that there is greater uncertainty in cost associated with an MRS than with at-reactor storage cost.

Environmental comparison in the near-term slightly favors the I-NO-MRS due to better use of resources, but this does not appear to be a major issue. Long-term environmental concerns are related to the I-MRS becoming a defacto repository.

Political considerations are divided into ACCEPTABILITY, PUBLIC CONFIDENCE, and LOCAL AND STATE ATTITUDES. From an overall ACCEPTABILITY standpoint stakeholders closest to the public oppose the I-MRS concept. From the PUBLIC CONFIDENCE perspective the I-NO-MRS minimizes reliance on DOE and removes the possibility of political will erosion allowing the I-MRS to become a defacto repository.

LOCAL ATTITUDES may be accommodating to the I-MRS due to benefits in jobs, compensation and related economic development, however, STATE ATTITUDES tend to take a broader perspective related to need, impacts and public perceptions, that clearly favors the I-NO-MRS concept.

Social considerations are primarily related to fears and anxieties associated with transportation. This clearly favors the I-NO-MRS concept for the same reasons discussed in the HEALTH AND SAFETY evaluation.

Fairness is a complex issue that is divided into LIABILITY and EQUITY considerations. The language of the NWPA clearly intended for generators of the high-level nuclear waste to be responsible for providing interim storage and paying the cost of disposal. While DOE might have exceeded their authority by contracting to accept fuel by 1998 it appears to be a moot question. There are several EQUITY issues. From a GEOGRAPHIC perspective it is most equitable to leave fuel where the benefits were derived from its generation until it can be moved to the repository. INTERGENERATIONAL considerations require the current generation to not allow the I-MRS to become a defacto repository. INTERUTILITY equity is best served by requiring each utility to provide for their own fuel storage. UTILITY-RATEPAYER equity favors the I-NO-MRS concept since it is expected to save the ratepayers about $5 billion. GOVERNMENT-UTILITY equity favors the I-MRS since the utilities should be entitled to some at-reactor storage assistance due to the Federal Governments failure to deal with their high-level waste disposal responsibility over the past 30 years. This inequity can, however, be mitigated in less expensive and more acceptable ways in the I-NO-MRS concept.

Scheduling of disposal in a geologic repository at the earliest possible time favors the I-NO-MRS concept since it keeps the pressure on DOE, the utilities and everyone involved to get on with the repository program. The I-NO-MRS concept also avoids the distraction and diversion of resources from the repository program.

Flexibility is the ability of a system to continue to perform reliably under a wide range of conditions and uncertainties. From a TECHNICAL standpoint the I-MRS creates a bottleneck in the system making it vulnerable to failure from a wide range of causes while the I-NO-MRS provides diversity reducing the vulnerability to shutdown of the entire system. The I-MRS concept is also very fragile and difficult to define since it is too dependent on undefined interfaces with other system components. The I-NO-MRS concept is, on the other hand, very robust in that it can perform very effectively under a wide range of uncertainties independent of decisions yet to be made on geology, rod consolidation, and disposal packaging. INSTITUTIONALLY the I-MRS is very vulnerable since there is not now and unlikely to be a strong supporting consensus necessary for effective implementation.

No effort is made to apply weights to the individual criteria to provide an overall rating or ranking since this would require a value judgment of the relative importance of the criterion. The I-MRS concept is judged to be better than the I-NO-MRS concept for only one fairness criteria which can be easily mitigated within the I-NO-MRS concept. Therefore, there is no need to get into the difficult task of evaluation that would be required if extensive trade-offs between important criteria were required. This could, for example, be a very difficult in an evaluation of system configurations based on dual purpose cask and universal cask concepts.

In conclusion it appears that there is no "need" for a MRS in the system and compared to the I-NO-MRS concept DOE's I-MRS concept has very limited utility.

University of Tennessee public policy study

Various options for utilizing monitored retrievable storage of civilian spent fuel were compared using criteria of maximizing the likelihood of implementing successfully a comprehensive U.S. nuclear waste management system (taking into account scientific and institutional uncertainties) and minimizing the cost, risk and other impacts. The purpose of the study was to state clearly the goals and objectives of the options, to evaluate and compare them using well-defined and reasonable criteria, and to assess their robustness to deal with a wide range of future scenarios (8). The seven options considered are described below.

Backup-MRS as an alternative or backup to the repository, which would be available to accept spent fuel in a timely manner even if the repository is deferred indefinitely, which was the concept of the MRS envisioned in the NWPA.

I-MRS (1987) as DOE proposed to Congress in 1987, with the MRS carrying out consolidation, packaging, and storage functions as an integral part of the overall repository system.

I-MRS (1989) as the modified Integral-MRS proposed by DOE to the MRS Review Commission without consolidation of fuel and relaxed linkages to the repository.

Constrained-MRS as authorized in the NWPAA of 1987, with linkages that tie construction of the MRS and acceptance of spent fuel to progress on the repository.

Co-located-MRS which would be located on the Nevada Test Site, currently forbidden by law, Regional-MRS's located on government property around the country.

I-NO-MRS as a decentralized form of MRS with storage at the reactors until shipped directly to the repository, which in optimized form is called the Integrated-NO-MRS.

In order to compare options in a simple manner, two criteria were selected. The first is to maximize the likelihood of successfully and timely implementation of a comprehensive nuclear waste management system. The other criterion is to minimize the cost, risk, and other impacts to people and the environment for this and future generations. Evaluating options based on these two criteria requires considerable subjective judgment. The issues examined help to illuminate some of the conflicting objectives and opinions held by different stakeholderS in the MRS debate were:

- the linkage of the future of nuclear power to the nuclear waste management system,
- the linkage of the MRS to the repository,
- the likelihood of licensing the repository with no more than a slight delay from the original schedule,

- the political problems in siting the MRS,
- the definition, optimization, and integration of the overall waste management system,
- the flexibility of the system to deal with uncertainties and different future scenarios,
- the potential economic and equity impacts on utilities and ratepayers, and
- the role of compensation, incentives, and different management schemes to deal with perceived impacts.

To facilitate comparison seven proxies were used to represent the two criterion. The first criterion was divided into the following four categories:

1) technical feasibility of the storage and packaging part of the system,
2) technical feasibility of the disposal part of the system,
3) institutional feasibility associated with storage and packaging part of the system, and
4) institutional feasibility associated with the disposal part.

The second criterion was divided into three categories:

1) cost of the system,
2) risk associated with the system, and
3) other socioeconomic impacts associated with the system in addition to those associated with the repository.

A simple scoring method was used in the evaluation. A grade ranging from an "A" to "F" was given for each of these seven categories which reflect the authors' subjective evaluation. The grade of "A" is intended to imply system performance about as good as realistically achievable. The grade of "D" is intended to imply an obstacle that very likely cannot be overcome. An equal weighting was assigned to each category to produce a simplistic overall rating for each option. The resulting MRS Report Card is given in Table III.4 ranked in the order of their overall rating

Table III.4 – MRS Report Card: The Authors's Subjective Evaluation of Waste Management System Alternatives

Note: The grade of "A" is intended to imply system performance about as good as realistically available. The grade of "D" is intended to imply an obstacle that very likely cannot be overcome.

		TECHNICAL FEASIBILITY		INSTITUTIONAL FEASIBILITY		SOCIETAL IMPACTS			
RANK	OPTION	STORAGE & PACKAGING	DISPOSAL	STORAGE & PACKAGING	DISPOSAL	COST	RISK	OTHER IMPACTS	FINAL GRADE
1	I-NO-MRS	A	C	A	B–	A	A	A	A–
2	Co-located-MRS	A	B+	C–	B–	A–	A	A–	B+
3	I-MRS (1989)	A	C	D+	B+	B–	A–	C+	B–
4	Constrained-MRS	A–	C	D+	B–	C–	A–	C	C+
5	I-MRS (1987)	B+	C	D	B+	C	B+	C	C+
6	Regional MRS	A	C	D–	B	C	A–	C–	C+
7	Backup-MRS	A	B+	D–	D	B–	A–	C	C+

The two highest ranked systems are the I-NO-MRS and Co-located-MRS options. The I-NO-MRS system suffers from not dealing with the difficulties in overcoming technical problems in unprecedented licensing of a repository facility for geologic disposal. The Co-located-MRS system suffers from difficulties in overcoming the institutional problems in siting a centralized federal storage facility that is not absolutely necessary. The national strategy that appears to be most robust for dealing with the uncertainties caused by these two problems is one that combines the two highest ranking systems, that is, a strategy that preserves the option of going in ether direction after more information is available. While there are many advantages to a Co-located- MRS it has serious difficulties because of Nevada's intense opposition, the promise by the Secretary of Energy that DOE would not pursue this option, and the existing law prohibiting co-location.

Tennessee's position

In transmitting the State of Tennessee's position: on the MRS, final comments, and studies sponsored by the State to the MRS Review Commission the Governor indicated that the MRS concept should once again be rejected with a finality that will allow DOE to regain a proper focus in the nuclear waste program on permanent isolation in a deep geologic repository. He noted that in the final analysis the Commission must decide if the considerable MRS cost and associated burden to utility ratepayers can be justified by claims of rather subjective system efficiency and public policy benefits (9, 10).

The State's position and comments are summarized below:

1. The State of Tennessee stands by and advocates its original position that the MRS is not needed, that it is too expensive, and that a better solution -- the Integrated NO- MRS system -- exists for managing the nation's spent nuclear fuel and high level nuclear waste.
2. The Tennessee Valley Authority position on the MRS (11) and two recent studies conducted by the University of Tennessee (4, 8) validate the States position and document that:
   a) the Integrated-NO-MRS system is technically feasible. cost--effective, and has many advantages;
   b) the MRS is significantly more expensive than the Integrated-NO-MRS system; and
   c) the Integrated-NO-MRS system is by far the most preferred system taking into account all public policy issues including technical feasibility, institutional feasibility, cost, risk and impacts.
3. The State commends DOE for some of the positive changes in the departments's revised position on the MRS (agreeing in part with the State's earlier assessments on rod consolidation and transportation, and favoring negotiated approaches to siting), but the State criticizes significant shortcomings that remain in the DOE analysis including:
   a) underestimating cost of the MRS,
   b) failing once again to optimize the NO-MRS system,

c) insufficiently assessing dual-purpose casks,

d) underestimating the institutional difficulties in siting the MRS and in mitigating socioeconomic impacts, and

e) rationalizing the MRS with highly subjective and questionable judgements which ignore the increased cost and institutional feasibility problems associated with the MRS.

4. If the MRS Review Commission should favor some type of MRS based upon its evaluation of public policy issues, then the Commission should recommend to the Congress that the following requirements be mandated in law:

a) a negotiated siting approach, whereby the MRS is located in a state, if and only if, the host state finds it acceptable and agrees through a signed and legally enforceable agreement with the federal government,

b) the increased cost to the nuclear waste management system attributed to the MRS are paid by, and only by, those utilities that (by choice) directly use the MRS for storage, and

c) the strong linkages of the MRS schedule to the repository schedule contained in the Nuclear Waste Policy Act Amendments of 1987 remain in force.

DOE'S MRS studies and position

After Congress amended the NWPA in 1987 to authorize an MRS facility as an integral part of the waste management system, subject to strong linkages to progress on a geologic repository, DOE decided to conduct a study of alternative system configurations with and without a MRS. The purpose of what has become known as the MRS SYSTEMS STUDIES was to assist DOE in re-assessing their position on the MRS and to provide input to the MRS Review Commission.

DOE'S MRS system studies

To assist the MRS Review Commission in considering the need for a MRS, DOE conducted a series of systems studies that examine several variables in design of the high level waste management system (12). Nine cases were examined which included the following variables:

- system configurations with and without a MRS in the system and whether western reactor fuel should be shipped to an eastern MRS,
- system configurations in which rod consolidation is performed at the repository or at a MRS prior to disposal or no rod consolidation, and
- system configurations that perform packaging for disposal at the repository or at a MRS.

DOE's MRS SYSTEMS STUDIES were documented as ten tasks as follows:

Task A	Assumptions for MRS Systems Studies
Task B	Facility Design Reference Analyses of Alternatives Designs and Operating Approaches for a Monitored Retrievable Storage Facility
Task C	Storage Concepts for the MRS-Facility Re-evaluation of Monitored Retrievable Storage Concepts
Task D	HLW Packaging Location
Task E	Waste Package Design
Task F	Transport Impacts of a Monitored Retrievable Storage Facility
Task G	The Role and Functions of Surface Storage of Radioactive Material in the Federal Waste Management System
Task H	Licensing
Task I	Waste Management System Reliability Analysis
Task J	MRS System Study Summary Report

The full set of documents contain several thousand pages much of which is not relevant to the issue of whether to have a MRS in the system.

The MRS SYSTEMS STUDIES is not the application of systems engineering to develop, optimize, and evaluate alternative system configurations as the name might suggest. It is actually a comparative evaluation of nine pre-defined system configurations which evaluates the split of fuel packaging functions between the MRS and the repository with a strawman No-MRS system configuration included for comparison. The primary focus from a systems standpoint is on the question of whether to consolidate fuel prior to disposal and if it is to be consolidated should the operation be performed at the MRS or the repository. Whether to perform final waste packaging at the MRS or the repository is also examined. The study is useful in examining these questions but is of no value for considering alternatives to a central MRS.

DOE's justification of their position in support of the MRS is based primarily on strategic considerations rather than technical aspects of the waste management system. DOE has stated (12):

> "The decision on whether or not an MRS facility should be pursued rest more on the vision of how its program objectives can best be achieved, and this decision is supported, but not driven by considerations of technical optimization and cost."

It has been difficult for others to grasp a clear view of DOE's vision and the values DOE has used in designing and managing the waste management system. Many of the stakeholders apparently do not share DOE's vision or values and continue to believe that objective technical optimization and cost trade-offs should play an important role in developing the overall systems design of the waste management system (4). This will be essential in gaining and maintaining public acceptance.

The most useful result from DOE's MRS SYSTEMS STUDIES is the inability to justify consolidation of fuel rods based on disposal benefits in the repository. The transportation analysis appears to be the best DOE has done to date. The problem with it was the assumptions they made. See reference 4 for specific comments on DOE's MRS SYSTEMS STUDIES.

DOE'S MRS position

On May 25, 1989 DOE made the MRS SYSTEM STUDIES available to the MRS Review Commission and presented DOE's MRS position in hearings before the Commission (13). DOE continues to support an MRS facility as an integral part of the waste management system, because it would help meet DOE's strategic objectives. The MRS concept that DOE now favors is a phased approach which would not initially include rod consolidation or preparation of the final disposal package at the MRS. The MRS would receive, store and stage shipments of intact fuel to the repository, and could be later expanded to perform additional functions that may be found to be beneficial or necessary as the system design matures. To fully realize the benefits of an MRS it would be desirable to reduce the linkages between the MRS and the repository, which DOE hopes to be achieved by the Negotiator established by the Congress. However, DOE supports the MRS facility, even if the linkages are not modified.

Based on initial operation of the MRS and repository, as currently scheduled (2003), DOE estimates that with the proposed MRS the DOE's part of the waste management system would cost $2.1 billion more than the system without a MRS. DOE estimates that availability of the MRS would reduce at-reactor storage cost by about $400 million resulting in a net system additional cost of about $1.7 billion. If the linkages to the repository were relaxed and the repository was delayed 10 years to 2013 the increase in net system cost would be reduced to about $1.3 billion based on MRS operation starting in 2000.

Evaluation of traditional criteria:

- Health and safety,
- Environmental impacts,
- Socioeconomic impacts, and
- Transportation impacts,

discriminate between system configurations with and without a MRS, according to DOE. DOE's MRS justification relies on strategic benefits related to:

- Institutional and regulatory experience with an MRS to facilitate timely disposal in a repository,
- Acceptance of fuel from utilities at the earliest possible time allowing utilities to:
  - reduce their storage cost,
  - avoid interference with plant operations, and
  - not delay reactor decommissioning,
- Providing confidence that the Federal Government is using all available means to ensure timely assumption of it responsibility to accept waste for disposal and by providing the earliest possible demonstration of acceptance, transportation and handling of spent fuel at high annual rates, and by
- Providing flexibility with respect to later decisions about waste aging and the preferred location of waste packaging functions and to the extent

allowed by repository linkages provide the flexibility to adapt to an uncertain future and reduce at-reactor impacts.

The MRS system configuration proposed by DOE does not correspond to any of the options specifically analyzed in the MRS SYSTEMS STUDIES. These studies provided useful insights which were used in conjunction with analysis of other qualitative factors to assist DOE in reaching its final decision. DOE feels that the MRS decision is primarily a public policy question in which the value of the strategic benefits obtained with an MRS outweigh the increased system cost.

Critique of DOE'S MRS position

The basis for DOE's MRS position is highly subjective. Since they could not justify the MRS in terms of traditional criteria they turned to strategic considerations to try to make their case. However, the appropriateness and value of many of these considerations are very questionable and in some instances not supported by their MRS SYSTEMS STUDIES (4).

It appears that DOE has elevated waste acceptance from utilities to be of equal or greater importance than progress towards disposal. There is no justification for this based on the NWPA which clearly places the responsibility for interim storage on the waste generators.

DOE places great value on confidence building by accepting, transporting, and handling waste and the experience that would be gained from building and operating a MRS. Some utility executives might be encouraged by this, but, many of the other stakeholders would see centralized storage at a MRS as a prelude to accepting defeat on the repository program. DOE's emphasis on relaxing the MRS linkages to the repository and the direction of some of the MRS SYSTEMS STUDIES suggest that DOE recognizes that the repository program is in real trouble and the MRS is being positioned as a holding action which many fear could become a defacto repository.

The same basic technology available for use at the proposed MRS with a wide range of adaptability to particular situations is available to permit utilities to reliably, safely and economically provide for life-of reactor storage if necessary. The Integrated-NO-MRS system configuration developed for the State of Tennessee offers a higher degree of overall system reliability and flexibility than the MRS option proposed by DOE at a lower cost and with greater public acceptance.

While cost should not be the determining factor in selection of the preferred waste management system configuration, it is not unimportant to the electric ratepayer. DOE's cost estimates are based on preliminary conceptual designs for facilities that have never been licensed, built, or operated. Experience with such nuclear related facilities of a controversial nature suggest that there is a real possibility of major cost increases after it is decided to proceed with the facility. DOE acknowledges that there might be 10 to 20 percent uncertainty in their estimates. More realistically the MRS system is more likely to cost two or three times DOE's estimates.

DOE may also be overestimating the MRS storage benefits to utilities since DOE appears to be overestimating the amount of spent nuclear fuel that is likely to be produced and underestimating the utilities ability to expand in-pool storage capacity, if they find it necessary. DOE also appears to be overestimating the differential cost between providing storage at the MRS and at-reactor storage.

DOE has not adequately considered system configurations based on at-reactor storage as an alternative to the proposed MRS system configuration. In testimony before the MRS Review Commission DOE represented that their comparisons were base on the optimum No-MRS case. Examination of the MRS SYSTEM STUDIES indicate that none of the system configurations were optimized.

One of the MRS Commissioners asked if DOE had given any consideration to the work brought fourth by the State of Tennessee in studies since 1987, particularly related to systems based on use of dual purpose casks. DOE indicated that they think it is a mistake to mix up considerations of dual purpose casks with whether or not there is an MRS. DOE sees these as separate distinct issues, which are both important objectives, but don't have any impact on one another. That clearly is not the case as has been shown in the report for the State of Tennessee. DOE has consistently refused to give any meaningful consideration to this approach or to optimization of a No-MRS system configuration.

MRS review commission

The MRS Commission has was officially commissioned in June, 1988, after a six month delay. This delay was due to political wrangling over the appointments and the time the MRS Commission had to complete its work was extended to November 1, 1989. The Commission members were:

Mr. Alex Radin who served as Executive Director of The American Public Power Association for more than 35 years and now serves as a consultant,

Dr. Dale E. Klein an associate professor at the University of Texas where he serves as Associate Dean for Research and Director of the Nuclear Engineering Teaching Laboratory, and

Dr. Frank L. Parker a Professor of Environmental and Water Resources Engineering at Vanderbilt University who also serves as Chairman of the Board on Radioactive Waste Management at the National Academy of Sciences.

The Commission functioned as a collegial body with Mr. Radin serving as Chairman. The Commission hired a small staff of professionals to perform research, supervise contracts, and advise the Commission in the preparation of its report.

The Commission visited dry storage demonstration projects in the United States and spent fuel management facilities in Europe.

The Commission worked to make its evaluation as professional and unbiased as possible by reading and reviewing work that has been done on the subject, by gathering first-hand information about work being done by utilities and others, and where necessary, by conducting its own studies (14).

Public hearings

The Commission has held extensive public hearings in Washington DC and several other locations across the country to obtain the views of a broad spectrum of people and organizations. A Public Document Room was established at the Commissions's offices in Washington, DC to house transcripts of public meetings, routine correspondence with outside persons and data that the Commission is accumulating (15).

In July 1988, DOE, NRC, GAO, members of Congress and Congressional staff, State of Tennessee, nuclear industry and environmental groups briefed the Commission on the work done on monitored retrievable storage that had been done prior to creation of the Commission. A series briefings on specific subjects was then presented by DOE and NRC at the Commission's request. The Commission held a series of public hearings from December 1988 through February 1989 in different sections of the country. DOE briefed the Commission in March 1989 on the preliminary results of their MRS Systems Studies and returned in May to present their position on the MRS to the Commission. These briefings and hearing have been well attended and produced a wealth of information for the Commission to consider in it's deliberations. The following is an effort to briefly characterize input by various interest.

Members of Congress that testified or submitted written statements were primarily representatives of areas that might be a candidate for locating a MRS facility and generally opposed the MRS and indicated that the linkages to the authorized MRS are sacrosanct.

Congressional staff involved in activities leading up to the 1987 NWPA Amendments indicated that there is no broad based support for a MRS facility in the Congress.

States that considered themselves as a candidate for a MRS opposed the MRS while other states declined to take a position but expressed concerns related to spent fuel transportation. The State of Tennessee was the most prominent opponent of the MRS and funded the technical and public policy evaluations previously described which were presented to the Commission.

Local officials in areas that might be candidates for a MRS facility did not take a position on the merits of an MRS. They were interested in the local benefits of such a facility but were concerned about mitigation of adverse impacts, local control and supported linkages to assure that such a facility does not become a defacto repository.

Environmental and public interest groups supported at-reactor dry storage (expressed concern about fuel consolidation) and opposed the MRS. They strongly support, and would oppose any weakening of, the linkages of MRS operation to progress on the repository.

Private citizens generally opposed the MRS on a wide variety of grounds with some expressing the view that no additional nuclear wastes should be generated until a safe method of disposal has been generated.

Individuals and organizations interested in local economic development promoted the location of an MRS in their area citing the need for economic growth and stating that the an MRS would not endanger the community overall health and safety.

Nuclear utilities were divided in their support of the MRS.

The majority appeared to support having an MRS in the system so DOE can meet contractual obligations to start accepting spent fuel by 1998. This is conditional on relaxing linkages to the repository since the MRS would be of limited value if delayed until the repository is in operation. They also expressed concern that environmentalist and local interest groups would oppose attempts to increase at-reactor storage. Other utilities opposed the MRS preferring instead to provide their own at-reactor storage. The Tennessee Valley Authority indicated that they intend to provide their own at-reactor storage, but suggested that a MRS facility funded by those utilities that elect to use it could be an acceptable approach.

Nuclear industry suppliers electing to take a position supported the MRS if they were closely affiliated with DOE's waste management program. Those suppliers involved in development of at-reactor storage technology supported the use of the technology indicating their readiness to provide the necessary services.

DOE, as previously discussed, justified continuing support for a MRS based primarily on strategic considerations and would like to see linkages relaxed but would continue to support the MRS with the linkages.

Federal agencies such as NRC, DOT, GAO and OTA provided information about their activities related to the MRS but did not take a position on the overall merit of the MRS or other alternatives.

Evaluation

The Commission synthesized four generic waste management system strategies from the views expressed during public hearings:

(1) At-reactor storage until repository ready to accept fuel (No-MRS),
(2) Hybrid systems with a mix of at-reactor storage and MRS storage at regional MRS facilities until repository ready to accept spent fuel (Mix of at-reactor and one or more MRSs),
(3) Storage at central facility until repository ready to accept fuel (MRS-storage only), and
(4) Handling and storage at central facility until repository ready to accept spent fuel (Multi-function MRS).

The Commission decided to evaluate these strategies under a variety of scenarios depending upon the postulated scheduling of waste acceptance at the repository, fuel burnup, emerging technologies such as rod consolidation and dual purpose or universal cask, and other related factors. The following ten criteria were to be used in their evaluation:

(1) Overall safety and environmental impacts,
(2) Effect on safe, efficient preparation of spent fuel for safe, permanent disposal (impact on repository design construction; waste preparation; waste package design; fabrication; and standardization),
(3) Transportation impacts (will include consideration of dual purpose and universal casks),
(4) Flexibility and reliability of the national nuclear waste management program,
(5) Economic efficiency,
(6) Effects on public confidence in the national nuclear waste program,
(7) Likelihood of meeting applicable regulatory requirements,
(8) Likelihood of adverse impacts on reactor operations,
(9) Equity of the system (e.g., regarding distribution of costs and benefits), and
(10) Likelihood that DOE will be able to meet its contractual obligations.

Contracts totalling more than $850,000 were awarded for five technical tasks to provide data and tools the Commission needed to perform its evaluation. Three of the tasks involved reviews of the existing literature, assembling data bases, and developing models to allow the staff to evaluate the strategies with regard to economic cost, transportation impacts, and the need for storage and at-reactor storage capacity. The fourth task involved examining the issue of rod consolidation and quantifying the risk, benefits, economic cost and the need for use of this technology. The fifth task involved the development of an integrated systems model to incorporate the results of the other studies and assess the overall risk, benefits, and economic cost of alternative strategies.

Report

In November, 1989, the Commission released its report, entitled "Nuclear Waste: Is There A Need For Federal Interim Storage?" (20)

The Commission reached five conclusions:

1. From a technical perspective, both the No-MRS and MRS options are safe. ... the degree of difference in risks between the No-MRS and MRS options is so small that the magnitude of difference should not effect whether there should be an MRS.

2. The net cost of a waste management system that includes an MRS would be lower than previously estimated because of delays that have already occurred in the expected date of repository operation and the likelihood of further slippages of that date.

   ... the economics of an MRS would become more favorable if the repository were delayed and the MRS were to accept fuel as early as possible. The economic effects would be especially significant if the repository operation were to be delayed beyond 2013...

   ... the possibility of further delay in the repository opening therefore places the economic benefits of an MRS in a different and more favorable light than previously reported.

3. There are no single discriminating factors that would cause the MRS alternative to be chosen in preference to the No-MRS alternative. However, the Commission finds that an MRS whose schedule of operation and capacity is not linked to the repository would serve the following purposes:

   a) Supplying storage for emergencies, such as after a nuclear power plant accident, when it would be advantageous to have the plant's spent fuel pool available for decontamination of affected reactor parts and storage debris.

   b) Providing storage for utilities that have insufficient space in their spent fuel pool or on-site, or that cannot obtain licenses for additional at-reactor storage, thus preventing the shut-down of otherwise satisfactorily operating nuclear power plants.

c) Furnishing storage for spent fuel from shutdown reactors, especially at sites where utilities no longer operate nuclear power plants.

d) Creating economies in the waste management system if an MRS could be completed substantially in advance of the repository, especially if the repository were delayed beyond 2013 and an MRS were in operation by 2000.

e) Allowing greater redundancy in the system in the event of unforeseen circumstances.

f) Offering more surge capacity to facilitate the flow of spent fuel to the repository.

g) Providing more flexibility in storage operations and future waste preparation functions.

h) Assisting in standardization.

i) Initiating Federal responsibility for taking possession of spent fuel.

<u>None of these factors alone would warrant an MRS, but cumulatively they justify a facility not limited in capacity or linked to the repository schedule and operation. (Emphasis Added)</u>

4. An MRS linked as provided in current law would not be justified, especially in light of uncertainties in the completion of the repository. consequently, the Commission does not recommend a linked MRS as required by current law and as proposed by DOE.

...The schedule linkage presently in the law (MRS construction may not begin until the Nuclear Regulatory Commission (NRC) issues a license for the repository's construction) would make it impossible for an MRS to become operational more than three years before the repository. Because of delays already experienced in the scheduled repository opening and continued uncertainty surrounding the repository's location and date of operations, the value of the MRS would be greatly diminished if its construction were tied to the schedule of the repository. Most of the need for an MRS would have disappeared because the utilities would have had to make other arrangements for storage.

...[the linkages] would significantly reduce the benefits of providing backup to on-site storage or for operational emergencies, surge capacity, early waste acceptance, institutional experience in siting and licensing, and standardization. The benefits of removing spent fuel from shutdown reactors would also be reduced, especially if the repository opening were delayed beyond about 2013.

5. Some interim storage facilities, substantially more limited in capacity and built under different conditions than the DOE-proposed MRS, are in the national interest to provide for emergencies and other contingencies.

   The Commission recognizes the need to provide certain services that would be in the national interest, but that could not be provided by an MRS restricted by the schedule linkages currently in the law. The Commission concludes that spent fuel storage for emergency and other purposes and storage necessary to prevent utilities from shutting down otherwise satisfactorily operating nuclear power plants would be in the national interest. Facilities to fulfill this national interest could be more limited in scope and could be built under different conditions than the DOE-proposed MRS. (p.101)

The commission submitted these recommendations for "improving the flexibility of the repository development schedule, and providing temporary storage of spent fuel accepted for disposal":

1. Congress should authorize construction of a Federal Emergency Storage (FES) facility with a capacity limit of 2,000 metric tons of uranium (MTU).

   ...the Commission believes it would be in the national interest to have available a safety net of storage capacity for emergency purposes, such as an accident at a nuclear power plant, which would make it advantageous to have the plant's spent fuel pool available for decontamination of affected reactor parts and for storage of debris.

2. Congress should authorize construction of a User-Funded Interim Storage (UFIS) facility with a capacity limit of 5,000 MTU. Such a facility would provide storage only, and would be used in addition to the Federal Emergency Storage facility proposed in Recommendation No. 1.

   Although spent fuel can be stored safely at reactor sites for as long as 100 years, some utilities may not have space at their reactor sites for life-of-plant storage or may not be able to obtain a license for additional storage.

3. congress should reconsider the question of interim storage of spent fuel by the year 2000, taking into account, among other things, the following factors:

   a. Status of the repository;

   b. Status of nuclear power plants, i.e., number that shut down early, license extensions, utilization of extended burnup, etc.;

   c. Availability of at-reactor storage;

   d. Utilization and adequacy of the 2,000 MTU Federal Emergency Storage facility;

   e. Utilization and adequacy of the 5,000 MTU User-Funded Interim Storage facility;

f. Status of rod consolidation, dual-purpose casks, and other technological developments in spent fuel storage;

g. System optimization; and

h. The fee schedule established for the user-funded facility.

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Part IV: Modal mix

Introduction

The massive shielding required to reduce radiation doses and the potential for release of radioactivity in accidents limit the choice of transportation modes available for shipment of spent nuclear fuel and high-level nuclear waste. Shipping containers are designed and certified for use in general commerce based on criteria contained in Nuclear Regulatory Commission (NRC) regulations (10 CFR 72). Different aspects of the shipment of these containers is regulated by NRC, states and the Department of Transportation (DOT).

Transportation modes

The three transportation modes applicable to shipment of spent nuclear fuel and high-level nuclear waste are highway, railroad, and marine which are briefly described below (1, 2).

HIGHWAY shipment would be primarily on the interstate highway system avoiding routing through metropolitan centers. The interstate highway system is adequate to provide fairly direct routing from reactors to a MRS or geologic repository facility located in the east or west. Highway shipment by truck is the most visible means of transportation and will bring spent fuel shipments into the closest proximity to the public. With a high volume of truck shipment there will be many minor accidents that have little potential for radioactive release, but will cause major disruptions in traffic creating a great deal of public inconvenience and apprehension. These types of accidents will also place a large burden on police and other emergency response services.

The gross weight and other aspects of spent fuel trucks allowed on the highways is regulated by individual states and may differ substantially from state to state. Generally what is refer to as a "legal weight" truck shipping cask is designed to be carried by on a vehicle with a gross weight not exceeding 40 tons which can travel through all states in general commerce without special permits. Allowing for the weight of the tractor-trailer and ancillary equipment results in a nominal loaded cask weight of about 25 tons. Heavier loads are allowed by special permits issued by states for specific shipments allowing shipment of cask with a loaded weight up to 40 tons which are referred to as "overweight" truck shipping cask. States are concerned about the damage to highways by these heavier loads and there is a lack of uniform regulations pertaining to their use.

RAILROAD shipment in general commerce is restricted to casks that have a loaded weight of about 100 tons in order to accommodate interchange standards for transfer of rail cars between different rail lines. However, casks with a loaded weight up to 150 tons and 10 feet in diameter are allowed through special arrangements where the route to be used can accommodate the shipment (3). DOE's proposed MRS-repository transportation system uses these very large cask in conjunction with multiple cask shipments by special dedicated trains. Some reactors do not have rail access or have other constraints that will not permit them to load spent fuel into large rail cask in the reactor spent fuel storage pools.

Direct contact with the public is much lower for rail shipment than truck shipment. However the nature of how the rail network evolved results in shipment through major metropolitan areas. There is an extensive railroad network throughout the United States for moving spent fuel from reactors to a MRS or geologic repository. The quality of a large part of this system, however, is questionable for use in shipping spent fuel.

DOE and the nuclear utilities have tried to force the railroads to accept spent fuel and high level waste for shipment in general commerce like other commodities that are routinely shipped by rail. The railroads have resisted, expressing concerns about (4):

1) the adequacy of NRC's cask design criteria to account for the railroad operating environment,

2) inadequate attention to preparing for emergencies such as train derailments which will inevitably occur which will involve major emergency response efforts regardless of whether cask are breached, and

3) the liability aspects of expenses associated with accidents have not been adequately addressed.

The railroads are willing to ship spent fuel and high- level nuclear waste subject to restrictions which include:

- the use of dedicated trains,
- limiting speeds to 35 mph, and
- requiring one train to stop when passing.

MARINE transportation of spent nuclear fuel has found very limited use in the United States. It has been used extensively by Sweden and Japan using special ships designed for this purpose. In the case of Japan fuel has been shipped to France and the United Kingdom for reprocessing. There is an extensive navigable waterway system in the United States in which there are routes from the vicinity of most reactors in the east to a MRS located in the east or to rail transfer points as far west as Texas for multi-modal transport to a western repository. Available data suggest that about 40 to 50 percent of the fuel could be shipped directly from reactors by barge. Barge transportation appears to have the following characteristics that enhance its potential as a desirable transport mode:

- less potential for high impact accidents,
- less proximity to people, and
- low public visibility.

However, for traditional approaches to spent fuel transportation, truck and rail shipment have been more economical than barge shipment due to the longer routes and slow shipment. There is also the potential for contamination of a major waterway in the event of an accident that results in breaching the cask containment.

Modal mix is one of the major parameters that determine the impacts related to the transportation of spent nuclear fuel. The spent fuel capacity of rail casks can range from five to twenty times greater than the capacity of legal weight truck casks and both are designed to meet the same radiation shielding standards. It is generally accepted that transportation cask designs should be optimized to maximize payloads for their nominal weight class in order to minimize the number of shipments required. It also follows, that the number of truck shipments should also be minimized to reduce transportation impacts. In environmental impact statements and program planning documents DOE has assumed that 70 percent of the fuel shipped from reactors would be by rail and 30 percent would be by truck. DOE's most recent MRS transportation systems study, however, assumes the split will be 55 percent by rail and 45 percent by truck. This is the first major adjustment DOE has made in their modal mix assumptions in many years and appears to clearly be in the wrong direction if minimizing transportation impacts is important.

Early studies by the Tennessee Valley Authority (TVA) indicated that the public was very concerned about the transportation of spent nuclear fuel and other high-level nuclear waste (5). This lead TVA to the conclusion that highway transportation of spent fuel should be avoided and TVA began to explore options for minimizing truck shipments that are compatible with at-reactor storage of spent nuclear fuel (6). It is also noteworthy that all other countries that have major commercial nuclear power programs have opted to avoid highway shipment, to the extent possible, in favor of rail and/or marine shipment. In reviewing DOE's MRS proposal the State of Tennessee recommended improving the from-reactor transportation system by use of multiple cask shipments by special dedicated trains of the largest cask practical and minimizing truck transportation irrespective of whether a MRS facility is part of the system (7). This concept was extended to 100 percent rail shipment using a family of dual-purpose (storage and transportation) casks in a study for the State of Tennessee to develop an I-NO-MRS system configuration (8). This concept was optimized by taking a systems approach to integrate these casks into at-reactor storage, transportation, and utilization at the repository as an alternative to DOE's proposed system configuration with an integral MRS facility. These were discussed and compared in the preceding chapter on MRS status.

In 1985 one of the sessions in DOE's "Transportation Institutional Plan Workshop" was "Type of Service/Mixture of Transportation Modes" (9). After one and one-half days of wide-ranging discussions the 20 participants reached a consensus that the important considerations in determining the desired modal mix are:

- safety,
- security,
- public acceptance,
- environmental protection, and
- cost *.

* cost was included in list only as a concession to utility industry representatives since most of the others felt that cost was not important enough to be included on the list.

The group delineated the following basic principals that should be used in defining the modal mix:

1) maximize cask payload,
2) make multiple cask shipments,
3) maximize use of dedicated trains and/or truck convoys, and
4) minimize transit time.

While not explicit stated above the group also felt that there may be a need to adjust spent fuel acceptance schedules to accommodate a better optimized system.

Transportation system interfaces

The from reactor transportation system must interface with the reactors and the repository and with the MRS if one is in the system. Since the final design of repository and/or the MRS are not fixed there is flexibility to design their interface to best fit the transportation system. There, however, is less flexibility in interfacing with existing nuclear power plants with the transportation system. Over the past 25 to 30 years nuclear power plants have been designed with different pool storage arrangements, cask handling capability, and transportation access. NRC has also imposed restrictions on cask handling and crane capacity at some nuclear power plants. As utilities expand at-reactor storage using a variety of technologies other interface requirements and constraints will develop (see chapter 2 on at-reactor storage).

The Nuclear Waste Policy Act (NWPA) of 1982 makes utilities responsible for providing interim at-reactor storage until DOE accepts the fuel for disposal in a geologic repository. The balance of the waste management system including transportation are DOE's responsibility. This creates an institutional interface or barrier across which it may be difficult to effectively integrate components of the waste management system. The full cost of the whole system, however, will be paid for by the utilities ratepayers through recovery of at-reactor storage expenses directly by the utility and by utility payments into the Nuclear Waste Fund. While this provides a great deal of independence to DOE and the individual utilities to "do their own thing" it can and most likely will result in a poorly integrated, inefficient and more expensive waste management system configuration than could be achieved with an effective institutional interface to facilitate integration and standardization. Coordination and cooperation across this important institutional interface has been very poor and there appears to be little prospects for improvement. The nuclear utility industry has tried to work with DOE but has not been very successful in their efforts to develop an effective working relationship.

There are many options available as to how the transportation system could be interfaced with reactors, the repository and a MRS facility (8, 10). DOE appears to be taking a traditional approach to transportation of spent fuel from the reactors in which single cask shipments are made by common carrier by truck or rail depending on reactor transportation access and cask handling capability. This approach evolved in the early days of nuclear power when emphasis was on fast turn-around of reprocessed fuel for recycle into the reactors. Optimization of this type of transportation system depends on minimizing number and types of casks used to achieve high cask utilization. However, with the use of large numbers of multipurpose cask in the system (that were purchased primarily for storage) cask utilization in transportation becomes unimportant and opens other approaches to transportation system optimization.

The use of multiple cask shipments by dedicated train has been shown to have the potential for greatly reducing transportation impacts (11). Since the number of casks needed for storage exceeds the number needed for transportation cask utilization for transportation is not a dominant factor in transportation system economics. This also allows the use of the largest cask practical for shipment using heavy-haul vehicles and barge shipments to move the large casks to a nearby railhead where rail access to the reactor site is not available.

Table IV.1 compares the traditional transportation system with a nominal 70 percent rail and 30 percent truck modal mix scenario to an all-rail transportation scenario in terns transportation access to the reactor and reactor crane capacity (2). In the traditional scenario shipment would be made by rail in 100 ton casks for those reactors that have rail access and can handle a 100 ton cask with all other shipments being made by truck. In the all-rail scenario the largest cask that can be handled inside the reactor building containment would be used for shipment by multi-modal transport where direct rail access is not available. About 70 percent of the fuel going to the first repository has unrestricted rail access and adequate crane capacity which could be increased to about 74 percent by upgrading crane capacity or using a transfer shield (no containment) to move fuel from the reactor pool to the cask located inside the reactor containment. About 15 percent of the fuel would be moved to a railhead by barge with another 11 percent being moved by heavyhaul vehicle. In this all-rail scenario it would be necessary to ship less than 3 percent of the fuel in casks smaller than 100 tons and 81 percent could be shipped in casks larger than 100 tons which would substantial reduce the number of cask shipped and related transportation impacts relative to the traditional system that DOE has assumed. The use of these few small casks could be eliminated altogether by using a transfer cask concept being studied by the Electric Power Research Institute (12). This type of transfer cask could be used to move fuel from the reactor to a large storage or to a transportation cask located outside the reactor containment.

The data used in the preceding analysis was based on data provided to DOE by the utilities and compiled by DOE's Pacific Northwest Laboratory and was used in I-NO-MRS system configuration concept previously discussed. There is, currently, very limited data available on what could be done to upgrade storage and spent fuel handling capability at individual nuclear power plants. DOE has contracted with the Nuclear Assurance Corporation to perform a Facility Interface Capability Assessment to determine and document existing and planned facility capabilities to store and ship spent fuel and will identify where possible interface changes could result in benefits to the Federal Waste Management System (13). This study is scheduled to be completed in 1991 and should provide better information on transportation system reactor interface.

Need for a systems approach

DOE has not done any comprehensive systems engineering studies to determine the combination of modal mix and other important parameters that result in the best configuration for the from-reactor transportation system taking into account the reactor interface and integration with at-reactor storage options. DOE has been rather vague about the from- reactor transportation system configuration but has prematurely proceeded with development of transportation casks as described in the introduction chapter to this report. It appears that DOE is taking the traditional transportation system approach to development of the from- reactor transportation system based on use of a nominal 100-ton rail/barge casks and 25-ton legal weight truck casks optimized to take advantage of higher capacity that can be achieved through shipping older fuel. DOE's plan was to have the from-reactor transportation fleet ready to start moving fuel from the reactors to a MRS facility in 1996. Beyond optimizing the design of these casks to maximize payload it is not apparent that DOE has paid much attention to outside input into shaping the transportation system (8).

TABLE IV.1 - COMPARISON OF MODAL MIX AND REACTOR INTERFACE ASSUMPTIONS USED IN DOE STUDIES TO AN ALL-RAIL SCENARIO USING THE LARGEST CASK PRACTICAL FROM A FAMILY OF CASK

DOE'S NOMINAL ASSUMPTIONS (70% RAIL/30% TRUCK)	ALL-RAIL SCENARIO ASSUMPTIONS (100% RAIL/0% TRUCK)							
	REACTOR CRANE CAPACITY (TONS)	150	125	100	60	40	25	TOTAL
		(PERCENT OF FUEL TO BE SHIPPED FROM REACTORS)						
RAIL (100 TON CASK)	UNRESTRICTED RAIL ACCESS	14.3	40.0	14.3	–	–	–	68.6
TRUCK (25 TON CASK)	UNRESTRICTED RAIL ACCESS	–	–	–	–	0.9	0.1	1.0
" "	BARGE TO RAILHEAD	2.1	11.4	–	–	1.0	–	14.5
" "	HEAVYHAUL TO RAILHEAD	0.6	5.3	–	–	–	–	5.9
" "	UPGRADE CRANE	–	0.8	–	–	–	–	0.8
" "	UPGRADE CRANE AND HEAVYHAUL	0.7	2.4	–	–	–	–	3.1
" "	TRANSFER CASK	–	1.5	0.9	–	<0.1		2.5
" "	TRANSFER CASK AND HEAVYHAUL	0.5	1.4	–	1.1	–	–	3.6
	TOTAL	18.2	62.8	15.2	1.1	2.6	0.1	100.0

Another important aspect of transportation system design should be the effective interfacing with the dry storage options that will be used by utilities. NRC called attention to this need in their comments on DOE's Dry Storage Cask Study (14) mandated by the NWPAA of 1987 as discussed in the chapter on at-reactor storage. The inefficient interfacing of the transportation system to at- reactor dry storage can result in unnecessary fuel handling operations that are contrary to NRC's commitment to keep radiological dose commitments as-low-as-reasonably-achievable (ALARA). NRC suggested that DOE take a systems approach to addressing this problem. Rather than taking a systems approach to defining the transportation system DOE has opted for a transportation system configuration based on choosing the lowest common denominator and expedience without imposing on the utilities to improve the system configuration. It appears that the general public and public official are more concerned about spent fuel transportation than other aspect of high-level waste management. In order to gain public acceptance of this critical part of the waste management system it is essential that DOE make a creditable effort to take a systems approach to determining the best transportation system configuration within the context of overall optimization of the high-level nuclear waste management system..

The high-level nuclear waste management system is made up of several major components which are themselves interrelated systems working towards a common objective. In the systems approach components or sub-systems are viewed as part of a larger system and is explained in terns of their role in the optimization of the larger system. This way of thinking is based on the observation that, when each part of a system performs as well as possible, the system as a whole may not perform as well as possible. This follows from the fact that the sum of the functioning parts is seldom equal to the functioning of the whole.

The design of a large complex system should be performed by a team possessing the necessary knowledge integrated into an effective project organization and assigned the responsibility of developing the type of system that will be responsive to the need. The system designers must be cognizant of the interfaces between their respective specialty areas and economic factors, political factors, ecological factors, societal factors and the like which is the systems environment in which the system must operate. The design of the system must also take into account public policy and institutional considerations as well as technical considerations. Decisions that shape the system design require consideration of these factors in the early stages of system design and development, and the results of such decisions have a definite impact on acceptability of the proposed system design.

Once the purpose of a system has been explicitly defined and understood it is possible to establish measures of effectiveness indicating how well the overall system performs in the systems environment in which it is intended to function. Systems engineering is the process employed in the evolution of systems from the point when a need is identified through production and/or construction and ultimate deployment of that system. It involves the following steps or phases (15):

Phase 1. Transformation of an operational need into a description of system performance parameters and a preferred system configuration through the use of an iteration process of functional analysis, synthesis, optimization, definition, design, test, and evaluation.

Phase 2. Integration of related technical parameters to assure compatibility of all physical, functional, and program interfaces in a manner that optimizes the total system definition and design.

Phase 3. Integration of performance, producibility, reliability, maintainability, manability, supportability, and other specialties into the total engineering effort.

Initially systems engineering is concerned with defining a mission statement that defines a set of objectives that grows out of a need or set of needs. It should precisely define the desired condition to be created rather than describing a system imagined to be adequate to fulfill the need. Fundamental to mission definition is the expression of the customers values by which the customer will evaluate the acceptability of a proposed solution. If properly defined, the mission statement does not usually change during design, development and construction of the system. The mission statement provides:

- a consistent, unifying objective for all conceptualization and design activities,
- the driving force and guiding light for all planning, and
- the rational for scope, cost, schedule, approach, design, research, development, testing, reviews, decision-making, quality assurance, and documentation.

From a systems approach standpoint the key to successfully designing, developing and implementing a system is satisfying the customer.

Value criteria

The system designer must understand customers values and use these values in: developing conceptual approaches, evaluating alternatives and optimization of the system configuration to be responsive to those values. DOE and DOE's contractors have viewed DOE as the principal customer for the waste management system and has employed DOE's internal values to their work. The real customer for the waste management system, however, is the general public with DOE serving as the steward of a public trust in managing the program at the expense of the utilities who pass the cost on to their ratepayers. There are, however, many stakeholders who have a vested interest which should help shape the best solution since their acceptance if not support will be necessary for successful implementation. The Congress, as elected representatives, is and should be the final arbitrator of what best serves the general public.

An effort was made in a DOE Program Research and Development Announcement (PRDA) project to develop a stakeholder value structure appropriate for designing and evaluating spent fuel management system configuration alternatives (10). The value criteria shown in TABLE IV.2 was developed in a PRDA project workshop in early 1984. Separate value structures for groups representing Public, Government, and Technical interest were developed then combined to produce this composite structure. The value structure for each group was developed by getting the participants to identify "what is important". In the process, two concepts were utilized repeatedly. One concept is the separation of means and ends to the degree possible, and the other is specification of impacts that can be minimized or maximized as appropriate. When a concern or issue was identified, the question of why is that important" was pursued until the end effects were identified. This is not intended to indicate that means are unimportant, but rather that they are important for the effects on the ends. The results from the three panels were then integrated and modified into one overall hierarchy of value criteria, taking care not to loose important points brought out in the workshops. The letters P, G, and T indicated in the right margin indicates criteria emphasized by the Public, Government, and Technical panels respectively.

The scope of waste management considered in developing this value criteria included all components of the system from generation of waste at the reactor through disposal in the repository but excludes performance of the geologic disposal media. Therefore, this value structure is appropriate for developing and evaluating transportation system configurations in the context of evaluating overall waste management system alternatives with or without a MRS in the system. This basic value structure was in the development and evaluation of the I-NO-MRS systems concept developed for the State of Tennessee as an alternative to DOE's propose configuration with an integral MRS (8).

Overview

The preceding discussion indicates that DOE has not given adequate attention to optimization of the transportation system and appears to be proceeding to prematurely develop a fleet of transportation cask without defining the system in which they will operate. DOE's transportation cask development program should be placed on "hold" and a creditable systems engineering study conducted to define the transportation system configuration before proceeding with cask design. It does not now appear that there is a pressing need to rush into transportation cask development since it is unlikely that there will be a need for such cask before about 2003 at the earliest. NRC should take an active role in carrying out their responsibility to keep radiation doses to the public and worker as-low-as-reasonably-achievable (ALARA) rather than taking a passive role through piecemeal responses to DOE initiatives, which is not working to produce an effective and efficient system design.

The balance of this report is devoted to the review of studies that, when taken together, illustrate the very poor job DOE has been doing in developing an effective transportation system that is responsive to the overall waste management system needs. The potential for optimization is examined, which can be compared to DOE's current thinking and DOE's efforts toward meeting NRC's ALARA criteria.

Potential for transportation system optimization

The following transportation analysis is based on a parametric systems study (11) conducted at TVA in 1986 to examine the potential for optimization of various transportation system concepts to minimize transportation impacts. Five different transportation system configurations with varying degrees of integration into the overall waste management systems were examined with and without at-reactor rod consolidation and with and without a MRS facility in the system. An effort was made to bracket the full range of transportation system configurations and to make them responsive to public values, yet be technically sound and meet practical functional requirements. The five transportations system configurations are described below.

1. Traditional transportation system which corresponds to the technology and nominal 70 percent rail and 30 percent modal mix being assumed in, then current, DOE spent fuel transportation studies. Single cask shipments are made from the reactors in general commerce by rail using nominal 100 ton casks for rail shipment or nominal 25 ton casks for truck shipments. Improved cask designs are assumed that has capacities equivalent to 14 and 2 intact PWR fuel assemblies for rail and truck casks respectively. For consolidated fuel the capacity of casks are doubled. Consolidated fuel in disposal packages is shipped from the MRS facility to the repository by special dedicated train with five nominal 140 ton casks per shipment. Each cask accommodates the equivalent of 18 PWR fuel assemblies.
2. Improved traditional transportation system is the same as the traditional system described above except shipment by truck cask is minimized by multi-modal shipment of rail cask. The use of heavyhaul or barge shipment to a nearby railhead results in a 90 percent rail and 10 percent truck modal mix for from-reactor shipments.
3. Integrated mixed dual-purpose system uses a family of dual purpose-purpose casks that are designed for both storage and transportation of spent fuel. This is the forrunner of the I-NO-MRS waste management system configuration developed by the University of Tennessee for the State of Tennessee as an alternative to DOE proposed MRS as an integral part of the system. The dual-purpose cask family consist of five nominal cask sizes, 150, 125, 100, 40, and 25 tons which has capacities equivalent to 28, 22, 15, 4, and 2 intact PWR fuel assemblies respectively. The casks are assumed to have double this capacity for consolidated fuel. The largest possible cask is always used consistent with the nuclear plants handling capability. All from-reactor shipments are by rail using special dedicated trains with five casks per shipment. As in the previous case multi-modal transport by barge or heavyhaul are use to move the cask to a railhead where necessary. Each from- reactor shipment consist of five fuel casks. The MRS to repository transportation system is the same as that used in the previous cases.
4. Integrated large size dual-purpose cask system is the same as the previous mixed dual-purpose cask system except a single 125 ton cask size is used at all reactors. A transfer cask is used to load fuel into this large cask at those reactors that do not have crane capacity or other limitations to permit loading of fuel into the large cask in the reactor pool.
5. Universal cask system uses a cask designed for storage, transportation, and use as the disposal container in the geologic repository. The nominal cask size is 85 tons with an intact fuel capacity equivalent to 9 intact PWR fuel assemblies. The capacity would be doubled for consolidated fuel. A transfer cask would be use to load the cask at the few reactors that can not accommodate a cask this large. The preferred application for this concept would be to load fuel into the universal cask at the reactor and never open it again. With an MRS in the system the universal cask would be used for

Table IV.2 Value structure for evaluating metal cask systems for spent fuel management

1. Health and Safety	P
from Radiation Exposure	
Public	PGT
Worker	PGT
from Transportation Accidents	
Public	PGT
Worker	PGT
Future Generations	
Genetic	P
Cancer	P
2. Economic	G
State Governments	G
Federal Government	PGT
Utility Companies	PGT
3. Environmental	G
Visual	PG
Land Use	PG
4. Political	G
Public Confidence in the Technical System	PG
Public Confidence in Government	G
Local and State Attitudes	G T
5. Social	P T
Fears, Anxieties	P
Transport System (inconvenience)	T
6. Fairness	PG
Equity	G
Transportation Workers, Industry Workers, Public	G
Geographical	G
Beneficiaries of Nuclear Power	P
Intergenerational	P
Liability	P
7. Scheduling	T
Timely Availability of System	GT
Ability to Handle Appropriate Quantities	T
8. Flexibility	T
Technical:	
with respect to Consolidation	T
with respect to Reprocessing	T
with respect to Plant Types	T
with respect to Retrievable	G
with respect to Repository Media	GT
Institutional:	
with respect to Transport Regulation Changes	T
with respect to Regulation Changes	PGT
with respect to Political Changes	P

storage at the MRS and would also be used to transport fuel from the MRS to the repository. All shipments would be by special dedicated train with five cask per shipment.

The comparisons are based on the following uniform conditions:

1) the quantity and distribution of spent fuel was based on the expected lifetime discharges for individual reactors that are currently in operation or under construction,
2) the availability of rail, barge, and truck access, as well as cask handling constraints at individual plants, was based on the data utilities have provided to DOE, and
3) the distance between reactors and the geologic repository or an MRS facility is based on 1.3 times the great circle distances computed from geographic coordinates. The average distance from reactors to an MRS facility at Oak Ridge, Tennessee or to a geologic repository was 807 miles and 2,041 miles respectively. The distance from the MRS to the repository was 2,059 miles based on the average distance to the three sites DOE had recommended for characterization (Deaf Smith County in Texas, Yucca Mountain in Nevada, and the Hanford site in Washington).

Transportation impacts are quantified in terms of four proxy measures below together with a discussion of their transportation impact implications. At this stage of comparison and evaluation of alternative system configurations this approach provides the system designer a faster and better understanding of interactions of components than can be achieved by performing detailed impact calculations which tend to obscure the basics due to the large number of often questionable assumptions that must be made.

<u>TRIP-MILES</u> - This is the sum (one-way) of the individual trip-miles required to move the fuel from the reactors to the geologic repository (via MRS if applicable). A single cask shipped by truck or rail counts as one trip. Shipments that include several cask on the same train also count as one trip. The following transportation impacts are directly related to TRIP-MILES:

- The potential for a shipment to be involved in an accident,
- The cost of security, monitoring and emergency response, and
- Public perceptions of shipping activity.

The obvious means by which TRIP-MILES can be reduced is through the use of larger capacity cask, minimizing truck shipment, making multiple cask shipments, and by shipping consolidated fuel.

<u>CASK-DAYS</u> - This is the total number of days cask loaded with fuel are in transit. Since transportation cask are designed to meet the same radiation protection standard (ten millirem per hour two meters from the surface of the conveyance vehicle), the nominal radiation exposure is essentially independent of how much fuel is in the cask. Therefore the radiological dose commitment to the public and transportation occupational workers is related to their proximity to the casks and the exposure time. Exposure time depends on the distance shipped and the speed of transit. The following typical average speeds for the indicated conveyance were used in this analysis:

Truck Shipment	35 MPH
Rail-Dedicated Train	25 MPH
Rail-General Commerce	7.5 MPH

Under these conditions CASK-DAYS is a proxy measure for radiological dose commitment to the public and transportation workers for the transportation system concepts being compared. The radiological dose commitments can be reduced by reducing the number of cask shipped and distance traveled, and by increasing the average speed of conveyance.

CASK-SHIPPED - This is the number of cask that must be loaded, shipped, and unloaded related to transportation. This does not include operations related to the use of storage-only casks for at-reactor storage or storage at a MRS facility. The following transportation impacts are directly related to the number of CASKS-SHIPPED:

- Capital and operating cost of cask handling and transportation equipment, and
- Occupational radiological dose commitments related to handling, decontamination, and inspecting cask at the reactor and other facilities in the waste management system.

CASK-SHIPPED can be minimized by using the largest capacity casts possible and reducing the number of times the fuel must be shipped.

TON-MILES - This is based on gross weight of round trip shipments including the fuel one way and is an indicator of freight charges related to transportation of spent fuel. The effectiveness of transportation casks in terns of payload per ton of gross weight decreases dramatical as cask size decreases. Therefore, to minimize TON-MILES, the largest cask practical should be used.

Results of this study are shown graphically in figure IV.1 on a relative basis normalized to the maximum value for each of the proxy measures. The maximum values for all proxy measures occurs with the traditional transportation system which is similar to the transportation system configuration that has been assumed by DOE in their studies. The maximum values for TRIP-MILES and CASK-DAYS occurs in the NO-MRS configuration without at-reactor rod consolidation and is the basis of DOE's claims that including a MRS in the system reduces transportation impacts. This, however, is due to the relative inefficiency in the from-reactor transportation system compared to the MRS-repository transportation system. The transportation benefits associated with the MRS vanish as improvements are made in the efficiency of the from-reactor transportation system. The maximum value of the number of CASKS and TON-MILES proxy measures also occurs in the traditional transportation configuration with no at-reactor consolidation, but, with the MRS in the system.

The following general observations can be drawn from this study:

- at-reactor rod consolidation always produces reductions in all transportation impact measures,
- The integrated large size dual purpose cask system has the lowest overall impacts which are significantly better than either of the traditional transportation system configurations but not substantially better than the mixed dual-purpose cask or universal cask configurations.

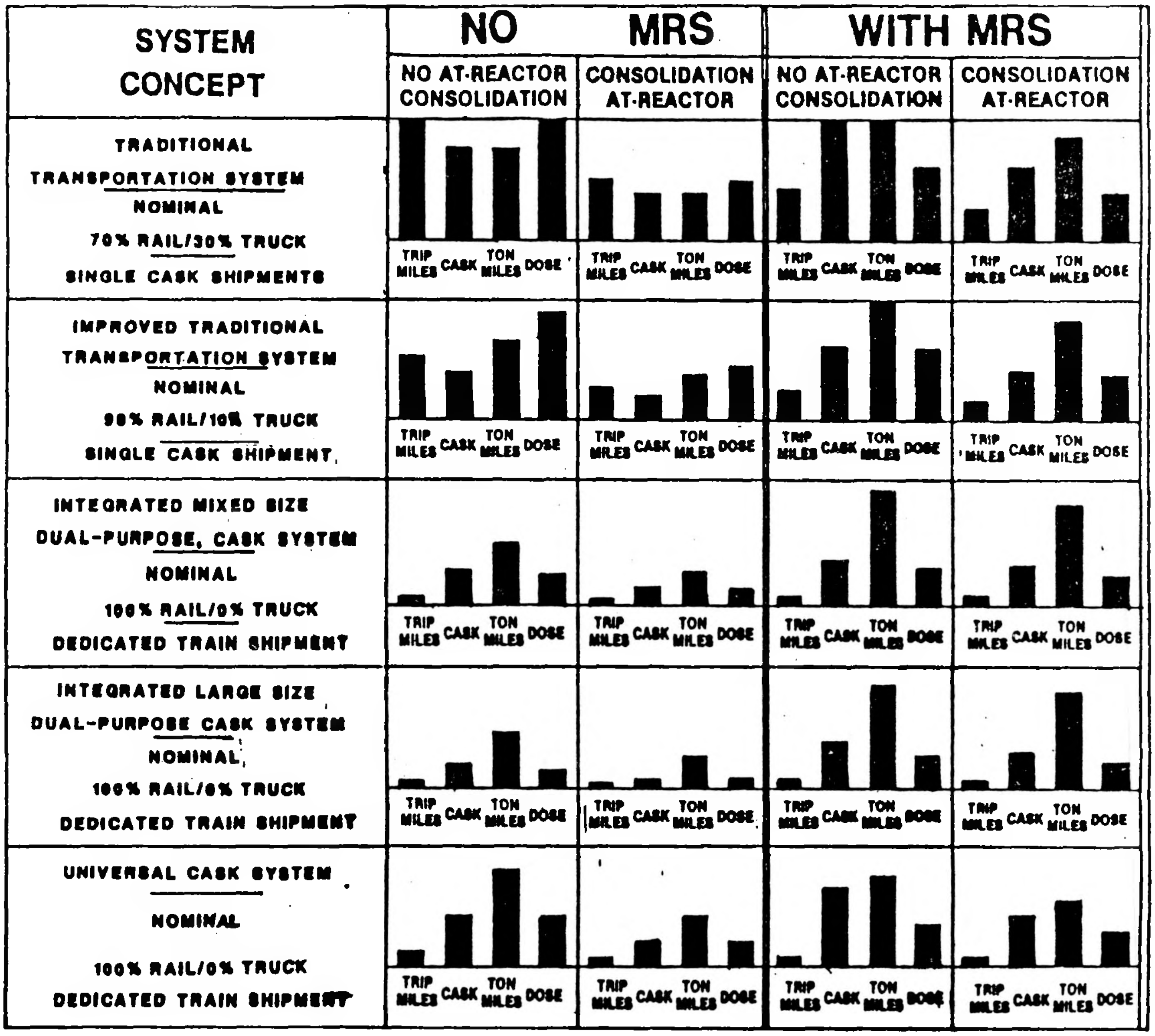

FIGURE IV.1 PARAMETRIC RELATIVE COMPARISON OF IMPORTANT ATTRIBUTES OF OF SPENT FUEL TRANSPORTATION SYSTEMS

- the universal cask system configuration has the lowest overall impacts for a system configurations that includes a MRS facility,
- all alternative transportation system configurations considered are superior to the traditional transportation system DOE has assumed in their transportation studies,
- the traditional transportation system configuration is the only configuration that shows any significant reduction in impacts when an MRS facility is included in the system.

The methodology used was extended in a study performed at the University of Tennessee to study the effects of transportation system design on the optimum location of a MRS facility to minimize transportation impacts. The following conclusions were drawn from that study (2):

- major reductions in transportation impacts can be achieved through using the largest cask practical and multiple cask shipment of fuel from reactors to the MRS by dedicated trains,
- the reduction in transportation impacts that can be achieved by improving transportation technology are greater than can be achieved by geographic location of the MRS and should be vigorously pursued without regard to the MRS or its location,
- the optimum MRS site location to minimize transportation impacts is a function of the relative efficiencies of the reactor-to-MRS and the MRS-to-repository components of the transportation system,
- as the efficiency of the repository-to-MRS component improves relative to the MRS-to-repository component the minimum values of all proxy measures converge into the sane area as near the repository as possible.
- over 90 percent of the potential reductions in transportation impacts can be achieved by the integrated mixed dual-purpose cask system compared to the integrated large dual-purpose cask system which has the lowest impacts. and
- the integrated mixed dual-purpose cask system would have the greatest flexibility to accommodate a wide range of physical and institutional considerations.

These studies provide some useful insights into modal mix and other transportation considerations and clearly indicate that there is a need to take an integrated systems approach to defining the transportation system. The optimization should take into account public values criteria and final judgment on the preferred transportation system configuration should be reserved until appropriate systems engineering studies are performed that take into account interaction with at-reactor storage and handling of fuel as well as other packaging, storage and disposal operations in the waste management system.

DOE'S MRS transportation systems studies

In May of 1989 DOE completed a number of systems studies which examined alternative waste management system configurations as input to the MRS Review

Commission and to Assist in DOE's reassesment of their MRS position (16). One of these studies, Task F - Transportation Impacts of a Monitored Retrievable Storage Facility, provides the most recent glimpse of DOE's transportation system configuration thinking (17). DOE continues to support an MRS facility as an integral part of the waste management system, but now favors a phased approach which would not initially include rod consolidation or preparation of the final disposal package at the MRS. The MRS would receive fuel, provide storage and stage shipments of intact fuel to the repository, and could be later expanded to perform additional functions that may be found to be beneficial or necessary as the system matures (18). The presence of a MRS and the functions performed at the MRS as well as the location of the MRS and result in major differences in transportation system impacts. DOE contends that differences in transportation impacts do not significantly discriminate between system configurations. As previously indicated this is a value judgment with which all stakeholders do not agree.

The study considered two basic waste management system configurations, one without an MRS and one with an MRS. MRS functions considered were:

1. intact fuel would be received for storage and/or shipment to the repository,
2. intact fuel would be received, consolidated and packed in canisters for storage and/or shipment to the repository for placement in a disposal container,
3. intact fuel would be received and packed in a disposal container for storage and/or shipment to the repository, and
4. intact fuel would be received, consolidated and placed in a disposal container for storage and/or shipment to the repository.

Generic eastern and western MRS locations were considered. For a western site it was assumed that all fuel would go through the MRS. For the eastern site shipment of fuel from western reactors to the MRS or directly to the repository was examined. In all cases it is assumed that shipments from the MRS to the repository is by special dedicated trains which carry five fuel cask on each trip. The cask size and capacity depends on the fuel form being carried as indicated in table IV.3.

Table IV.3 MRS to repository transportation casks capacity

Fuel form	Loaded cask (tons)	Capacity (PWR/BWR)
Intact bare assemblies	150	34/80
Consolidated in storage canister *	150	56/140
NFBW *	120	*
Intact assemblies in disposal package	133	12+16
Consolidated in disposal package *	138	24/72

* Non fuel bearing waste (NFBW) from rod consolidation operations would be compacted into 55 gallon drums and shipped to the repository in 20 drum cask with two cask per dedicated train shipment. When consolidated fuel is shipped in disposal packages the NFBW is shipped in the central void in 138 ton cask. It is also assumed that 5% of the fuel would not be consolidated and would require special handling.

The transport mode for from-reactor shipments to the MRS or to the repository depends on:

1. cask handling capability (which is primarily constrained by crane capacity), and
2. rail access to the loading bay.

Reactors that have adequate crane capacity and rail access to the loading bay is assumed to be served by rail using a 100 ton rail cask that has a capacity of 21 PWR or 48 BWR intact fuel assemblies. Otherwise, the reactor is assumed to be served by truck using a 28 ton cask that has a capacity 3 PWR or 7 BWR intact fuel assemblies. Truck shipment sensitivity analysis is performed assuming a 40 ton overweight truck cask that has a capacity of 5 PWR or 12 BWR intact fuel assemblies. The modal mix used in this analysis was 55% rail and 45% truck, by weight, based in data compiled by the Oak Ridge National Laboratory. This is a major departure from the previous DOE transportation system modal mix assumptions of 70% rail and 30% truck. In this study, DOE has for the first time assumed that from-reactor rail shipments would be by multiple cask shipment by dedicated train and is also major departure from previous DOE assumptions. It was assumed that an average amount of fuel removed from-reactor in annual re-fueling is about 30 MTU which represents about 3 rail cask loads which was assumed as the shipment size.

Results from the MRS Systems Study Transportation Analysis is shown below in terms of estimate total transportation cost and transportation dose for a 24 year shipping campaign in the following table.

Table IV.4 Summary of life-cycle transportation costs and doses from DOE'S MRS system studies

CASE	Total cost ($million)	Total dose (1000 person-REM)
No-MRS:	832	2.6
Store only:		
Eastern MRS	835	1.6
Eastern MRS/western strategy	741	1.5
Western MRS	896	1.6
Consolidate and canister:		
Eastern MRS	718	1.5
Eastern MRS/western strategy	634	1.4
Western MRS	862	2.4
Containerize intact fuel:		
Eastern MRS	1,120	1.9
Western MRS	996	2.6
Consolidate and containerize:		
Eastern MRS	965	1.8
Western MRS	942	2.5

Based on the assumptions made for this study MRS packaging function is an important determinant of transportation cost. Regardless of MRS location, the least cost option is where the MRS consolidates fuel and places it in canisters for storage and/or shipment to the repository since this provides the most efficient cask loading followed by a store-only MRS. The least attractive MRS option from a cost perspective is an MRS that containerizes intact fuel assemblies because cask capacity is greatly reduced requiring more shipments. The transportation cost for an MRS that consolidates fuel and prepares loads the disposal container falls between these depending on location.

The cases that involve shipping repository containers incur a transportation cost penalty due to the inefficiency of packing repository containers in a transportation casks. The repository container is a cylinder with a larger diameter than the square boxes of fuel pins transported in the consolidate and canister cases or the intact fuel elements carried in the store only case. The large cylindrical repository containers do not pack efficiently into the shipping cask, resulting in reduced capacity. A cask carrying intact fuel in a repository container has a double penalty in that the square fuel assemblies does not efficiently use the space inside the container and the containers do not efficiently fit into the shipping cask.

According to this analysis an eastern STORE-ONLY or CONSOLIDATE & CANISTER MRS, with or without shipment of western fuel to the MRS, would have lower transportation cost than a NO-MRS system. Since the assumed transportation system is more efficient between the MRS and repository than the from-reactor transportation system all western MRS location cases have a higher cost than the NO-MRS case. This is due to the large number of truck shipments between the reactors and the MRS.

The total radiological dose related to transportation of spent fuel in this analysis did not include fuel and cask handling operations at the reactors and at the MRS and/or repository and is not directly comparable to the ALARA study results. The MRS location is the dominant factor in total radiation dose for the assumptions used in this study. Dose estimates for the cases where the MRS is located in the east fall in a narrow band. The NO-MRS and western MRS cases also fall in a narrow, but higher, band. The dose is related to the cask miles traveled which explains the higher dose for the NO-MRS and Western MRS options. It is assumed that all cask operate at the regulatory dose limit of 10 mrem per hour at 2 meters from the vehicle regardless of the payload. Under these conditions dose per cask mile is essentially independent of cask type.

As low as reasonably achievable?

The NRC and the Department of Transportation (DOT) have regulations pertaining to cask design and shipment which establish radiation dose limits. In January 1986 NRC proposed regulations (19) which also requires that every reasonable effort be made to maintain radiation dose as low as reasonably achievable (ALARA) below the regulatory dose limits. The proposed NRC regulations require application of the ALARA principal to the extent practical:

- consistent with the purpose for which the licensed activity is undertaken,
- taking into account the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and
- in relation to utilization of nuclear energy in the public interest.

Guidance on the application of ALARA principals are contained in NRC's Regulatory Guide 8.10 and DOE's Order 5480.1B

In August of 1988 DOE announced the availability of a transportation ALARA study (20) by the Pacific Northwest Laboratory (PNL) that analyzed radiation doses to the public and workers during normal transportation activities that might occur in a postulated transportation system for shipment of spent fuel from reactors to a repository. DOE indicated that they will meet regulatory limits for radiation doses and will also consider meeting NRC's ALARA principals (21). DOE's language appears to suggest that DOE believes that they are not required to meet NRC's ALARA principals.

The NWPA is explicit in requiring NRC licensing of facilities, certification of cask, and notification of shipments, but, does not appear to require compliance with other regulatory requirements.

The PNL study is described as one of a series of systems studies which will be considered with numerous other factors in DOE's value judgements in making overall system design and operational decisions leading to specifications describing an optimal transportation system for deployment in the late 1990's. PNL is careful to specify that the study is not intended to specify the reference DOE transportation system, nor form the basis for final system design characteristics or operational procedures. The analysis encompasses spent fuel loading at the reactor (not part of the DOE waste management system), transportation to a repository, and unloading of the fuel at the repository. It provides cost/dose trade-off analysis of selected potential alternatives to the postulated reference transportation system which is based on using current technology. The principal assumptions that define postulated reference system and determine its radiological dose characteristics are:

- a single 30/70 percent (by weight) split between truck and rail transport mode respectively,
- shipping cask just meet DOT regulatory limits for external radiation levels (10 mrem/hr at 2 meters from the edge of the vehicle),
- all truck shipments are by legal weigh (25 tons) cask that has a capacity of 2 PWR or 5 BWR fuel assemblies that are shipped in general commerce an average distance of 1780 miles to the repository at an average speed of 24.1 miles per hour,
- all rail shipments are by unrestricted (100 tons) cask that have a capacity of 14 PWR or 36 BWR fuel assemblies that are shipped by general freight an average distance of 1910 miles to the repository at an average speed of 7.3 miles per hour,
- 3,000 metric tons of fuel would be shipped each year which would, under these conditions, correspond to 320 rail shipments and 971 truck shipments each year,
- the radiation source is 10 year old PWR fuel with a burnup of 35,000 megawatt days per metric ton, and
- radiation doses to workers is based on current practices and assumes that workers at a facility are not rotated to reduce individual doses.

The underlying rational for this transportation system configuration appears to be based on a snapshot of current technology in which the number of different cask sizes is minimized by having one rail and one truck cask size to accommodate unrestricted transport in a modal mix dictated by no special provisions for reactor site access or improvements in at-reactor cask handling capability. Estimated annual radiation doses in thousands of person mrem. to the public, to workers and the total are shown in table IV.6 by system segment for rail and truck for the postulated reference system activities.

There is essentially no dose to the public from activities at the reactor or at the repository. Overall the workers receive over twice as much radiation as the public which comes primarily from activities related to fuel loading at the reactors and at the repository. While only 30% of the fuel is shipped by truck, truck shipment contributes over two thirds of the total dose, with dose to the public from the truck shipments being 37 times greater than for the rail shipments.

Table IV.6 Collective radiation doses for the postulated reference transportation system activities

(Thousands of Person mrem. per year)

	At-reactor	In-transit	at-repository	Total
Public:				
Rail	0	12	0	12
Truck	0	447	0	447
Sub-total	0	459	0	459
Worker:				
Rail	141	21	150	312
Trail	270	207	270	747
Sub-total	411	228	420	1,059
Total	411	687	420	1,518

In this system configuration the number of truck shipments is three times the number of rail shipments, but truck shipments require significantly shorter in-transit time than rail shipments because of the higher average speed. However, with rail cask payload 6 to 7 times greater than for truck cask the public dose per unit of spent fuel shipped by rail is 10-fold lower than for truck shipments, primarily because of the fewer but larger shipments made by rail and the fewer public members near enough to rail shipments to be affected by them. Collective doses to the workers are higher than to the public for either shipment mode. It is noted that collective doses to the public is spread over millions of people while doses to workers are spread over a few hundred people. Under the assumed conditions dose to some workers exceeded allowable limits. Individual doses to the average affected members of the public are at least one-thousand-fold lower than those to the average worker.

A large number of alternatives for reducing radiation doses were considered which involved:

1. increasing cask shielding,
2. decreasing the time an individual is exposed, and/or
3. increased separation between cask and people.

Table IV.7 lists 17 alternative system configurations that were identified and evaluated along with the estimated reduction in total transportation system dose that would be achieved with the indicated change in the postulated reference system design.

The most dramatic improvements result from reducing the number of truck shipments through the use of higher capacity casks achieved through advanced designs and/or use of overweight casks. Improved truck operations by shorter stop times and remote parking also significantly reduce the dose from truck shipments. Improvements in the rail cask capacity through the use of uranium shielding and/or advanced design produce much smaller but significant dose reductions than for truck cask. Increased cask end shielding is effective in reducing worker exposure at both the reactors and the repository. Remote handling at the repository is also very effective. Dose reductions to workers is also achieved by the use of special tools and features. A number of these alternatives would be combined to minimize the overall system dose.

Table IV.7 Dose reductions for alternative transportation system configurations

Alternative	Percent Reduction
1. use of overweight truck cask	36.0
2. uranium-shielded rail cask	8.5
3. increased rail and truck cask end shielding	41.9
4. increased side shielding for truck cask	12.2
5. increased side shielding for rail cask	1.5
6. advanced legal weight cask design	37.0
7. use of advanced overweight truck design	52.5
8. advanced rail cask design	9.6
9. special impact tool to remove closure bolts	15.8
10. single-action cask lid fasteners	15.2
11. built-in cask lid-lifting fixture	3.6
12. integral cask impact limiters	4.0
13. quick release cask impact limiters	1.9
14. quick-release cask tiedowns	3.2
15. total remote handling at the repository	27.4
16. remote cask lid operations at the repository	19.8
17. improved truck operations	25.1

Generally the NRC promulgates regulations as they are needed to assure public safety. The current regulations have been developed over a number of years in a compartmentalized fashion to deal individually with operation of reactors, operation of fuel preparation facilities, transportation of radioactive materials, and for the storage of spent nuclear fuel. Each set of these regulations appears to be adequate to provide for accepted standards of public protection when applied independently to their respective component of the spent fuel management system. This can, and does in the case of DOE's I-MRS concept, result in the situation where radiological dose commitments are much greater from the sum of the individual components of the system than for a system that is designed as system to minimize radiological dose commitments. In fact, some very conservative aspects of the regulations which were intended to deal with other circumstances can when applied to one component to obtain marginal improvements can force conditions in other components that result in much greater dose commitments in the overall system than the marginal reduction achieved in the individual component. This is the classical situation that justifies the use of the "systems approach" to designing a system. NRC's responsibility to the public, however, is to keep the radiological dose commitment for the whole waste management system as low a reasonably achievable (ALARA). NRC presently does not have an effective mechanism for integration and optimization of waste management system from an overall safety standpoint. The current partitioned approach is counter productive in achieving this objective and NRC needs to take a "systems approach" to carrying out their responsibility to the public.

NRC has traditionally taken the approach that it not their responsibility to propose how something should be done but to dispose of specific proposals that the licensee proposes. Under this approach NRC is relying on DOE and the utilities to somehow put together an overall system configuration which NRC can regulate piecemeal that will fulfill NRC's responsibility to the public. NRC has recognized, as indicated in their comments on DOE's report "Dry Cask Storage Study" that it is not happening and has pushed DOE for compatibility in spent fuel cask designs for storage and transportation (14). Cask compatibility is an important aspect of the overall problem but is only the tip of the iceberg. NRC is aware that there does not appear to be anyone in charge but appears to be reluctant to take the initiative to provide leadership in integration of the spent fuel management system components to achieve overall system ALARA dose commitments. NRC is not likely to take an integrated systems approach to regulation of the waste management system unless DOE formally proposes to use multipurpose casks that cut across traditional internal NRC regulatory boundaries or public pressure placed on NRC. Opportunities for public participation in NRC regulation of the spent fuel management system up to the repository may be very limited since it will be conducted largely through materials handling licensing and cask certification that do not provide for the type of intervention available for facility licensing.

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