Rw 311

OCRWM Backgrounder

United States Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

DOE/RW-0034

January 1987

THE STATUS OF THE NUCLEAR WASTE FUND

The Nuclear Waste Fund was established to provide financing for activities mandated under the Nuclear Waste Policy Act of 1982 (NWPA). These activities include the siting, design, construction, and operation of deep, geologic repositories for the permanent disposal of spent nuclear fuel and high-level radioactive waste; preparation of a proposal to Congress on a monitored retrievable storage facility; development of a transportation system; and additional related activities.

The NWPA's key financial concept is that the Government's cost for these activities should be fully recovered from the generators and owners of spent nuclear fuel and high-level radioactive waste.

Under the NWPA, it was determined that nuclear utilities, through contracts with the U.S. Department of Energy (DOE), would pay a 1 mil (one-tenth of a cent) per kilowatthour disposal fee for electricity generated beginning April 7, 1983. At the present time, there are 80 contracts in effect with 66 purchasers to provide disposal services for 150 reactors.

For electricity generated prior to April 7, 1983, utilities would pay a one-time fee based on assembly status and burnup. Three payment options were available to the utilities:

(1) pay in 40 quarterly installments with accrued interest;

(2) pay in a lump sum with accrued interest prior to the first scheduled delivery of spent fuel to DOE for disposal;

(3) pay in a lump sum prior to June 30, 1985, with no interest.

With receipt of the $1.4 billion received from utilities for these one-time fee payments, DOE has paid off an appropriated debt of $264 million inherited from disposal-related activities prior to establishment of the Nuclear Waste Fund. Remaining funds are invested in a mix of Treasury bills and notes intended to maximize interest earnings. Investment strategy is developed in conjunction with the cash flow plan such that investments are termed to mature at the time required to meet program outlays.

As a result of a Federal court ruling in the case of *Wisconsin Electric Power Company et al. v. Secretary of Energy Donald Hodel*, the one-mil per kilowatthour for electricity generated after April 7, 1983, must be redefined. DOE has issued a Notice of Proposed Rulemaking to amend the standard disposal contract for utility fee calculations from "gross" generation of electricity to "net" generation (the total power produced less the amount used onsite) lowering the utilities' assessment under the NWPA. Several utilities have submitted comments on the proposed rule, stating that the definition of "net" generation should be further defined to eliminate the charges on electric generation that is not sold, including transmission line losses.

Regardless of the results of the proposed rule in defining net generation, DOE will be rebating overpayments the utilities have made to the current level of fee calculations. When the revised definition is adopted it will be added to the DOE standard Nuclear Waste Fund contract.

In addition, the April 30, 1985, Presidential decision to dispose of defense high-level waste (DHLW) in the civilian repository system requires an allocation means be developed to assess the DHLW disposal. The payments for DHLW disposal in a combined civilian defense waste repository will be made by the DOE Office of Defense Programs and will be sufficient, in the aggregate, to cover the full cost of DHLW disposal. Since the NWPA does not specify a methodology for assessing a fee to cover this type of waste, DOE has proposed three options for determining the total fee:

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- *Full cost recovery using a sharing formula.* Costs for facilities and activities carried out solely for defense waste, such as transportation, would be charged directly to the Government, together with the appropriate percentage of shared costs for facilities and activities used for both defense and civilian disposal. As calculated by DOE, this option will produce $2.60 to $3.43 billion in defense contributions (1985 dollars).

- *One mill electric-generation equivalent.* Defense fee based on DOE estimates of the electric-generation equivalent (thermal output multiplied by the estimated thermal efficiency for electric generation) of defense radwaste to past and future reactor operations. Amounts to $1.75 billion.

- *Cost sharing proportional to avoided costs.* Both defense and civilian contributions to the Nuclear Waste Fund are equivalent to the avoided costs of each sector from not having separate repositories. This brings in about $5.30 billion in defense contributions.

On December 2, 1986, DOE published a Notice of Inquiry in the *Federal Register*. This Notice invites public comment on a tentative decision to employ the "full cost recovery" option in determining the defense contribution to the Nuclear Waste Fund.

Beginning this year, DOE's annual evaluation of program costs and revenues required by the NWPA will encompass both defense and civilian fees—meaning that both will be subject to change in the future.

— DOE —

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Office of Civilian Radioactive Waste Management
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SHIPMENTS OF SPENT NUCLEAR FUEL IN SUPPORT OF NUCLEAR WASTE POLICY ACT RESEARCH AND DEVELOPMENT PROGRAMS

The Nuclear Waste Policy Act of 1982 (NWPA) assigns responsibility for development of a national system of nuclear high-level waste disposal to the U.S. Department of Energy (DOE). However, until the disposal system begins to operate (expected in 1998), the utilities are responsible for spent fuel storage. To accommodate the growing inventory of spent fuel prior to system operation, many utilities must increase their storage capacity or face the possibility of shutting down their nuclear electric plants.

To alleviate this problem, the NWPA directs DOE to establish a demonstration program, in cooperation with the private sector, for the dry storage of spent fuel at civilian nuclear power reactor sites. The purpose of these research and development (R&D) projects is to collect data to assist utilities in obtaining Nuclear Regulatory Commission (NRC) approval of various dry-storage technologies. The demonstration programs may take place at nuclear power reactors or at Federal facilities. The NWPA also tasks DOE to undertake a cooperative program with utility owners of nuclear power reactors to encourage development of the technology for spent nuclear fuel rod consolidation. Additionally, DOE will be conducting a repository-related program to characterize the spent fuel and test its behavior in various rock types.

DOE will be making a number of shipments over the next 5 years in support of these R&D programs. Approximately 50 shipments will be made from Virginia Power's Surry Power Station to DOE's Idaho National Engineering Laboratory (INEL). Initial shipping campaigns, involving 23 shipments, began in July 1985 and have been completed. It is anticipated that additional shipments (24 shipments or less) of consolidated fuel from the Surry Power Station to INEL could begin as early as the spring of 1987. Four spent fuel shipments to INEL were conducted in August 1986 from the Engine Maintenance Assembly and Disassembly (EMAD) facility at DOE's Nevada Test Site. Spent fuel shipments to INEL from the Nuclear Fuel Services facility at West Valley, New York, are also planned, pending cask certification. Shipments of spent fuel were made to the Hanford facility in Richland, Washington: in September 1985 from the Calvert Cliffs Power Station in Maryland (two shipments), and in February 1986 from General Electric's facility in Morris, Illinois (one shipment). Finally, tentative plans are being made for shipments in the next several years from yet-to-be-determined power stations to Richland, Washington, in order to conduct laboratory tests of fuel and waste-package interactions, and to INEL to test prototype fuel-rod consolidation equipment.

Over the past 30 years, more than 6,000 spent fuel assemblies have been shipped in the United States. Federal policies and procedures regulating the shipment of spent fuel were established under authority of the Hazardous Materials Transportation Act and are implemented under regulations of the Department of Transportation (DOT). In addition, DOT and the NRC, by agreement, have established roles for regulating transportation and packaging of radioactive material. DOT has developed safety standards that encompass transportation activities such as regulating radiation exposure; placarding; labeling and marking transport packages; loading, unloading, and handling transport packages; driver training; and highway routing. All DOE shipments comply with DOT requirements, therefore, spent fuel shipped under the NWPA, including these R&D shipments, will be conducted according to DOT requirements.

The NRC has developed safety standards for the design and performance of packages for shipment by NRC licensees of certain specified quantities of radioactive materials, including spent fuel. Under the governing DOT regulations, DOE also has authority to certify its own radioactive materials packages using standards that are

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equivalent to NRC requirements. Requirements for packaging and transporting radioactive materials are contained in 10 CFR 71 for the NRC and in DOE Order 1540.1 for DOE.

Consistent with the authority established under DOT regulations, both the NRC and DOE have implemented physical protection requirements to protect spent fuel shipments from acts of theft and sabotage. DOE requirements cover shipments made by DOE contractors, while similar NRC requirements apply to NRC licensees (generally involved in the operation of electric utilities).

Existing DOT, NRC, and DOE policies and procedures concerning nuclear materials shipments were established prior to enactment of the NWPA. When the disposal system is fully operational, the number of spent fuel shipments to repositories and other facilities developed under the NWPA is expected to increase significantly. This increase has prompted DOE's Office of Civilian Radioactive Waste Management (OCRWM) to begin a process of establishing procedures that will be uniquely applicable to shipments carried out under the NWPA. As an element of this process, OCRWM has announced their intent to comply with all DOT and NRC regulatory requirements that are in effect at the time of shipment to NWPA facilities [i.e., a geologic repository and if approved by Congress, a monitored retrievable storage (MRS) facility]. Pursuant to this intent, DOE and the NRC have signed a Procedural Agreement concerning certification of spent fuel and high-level waste transportation packaging under the NWPA. This agreement states that DOE will use packaging that has been approved by the NRC in accordance with 10 CFR 71 (rather than DOE-certified packaging) for DOE shipments performed under the NWPA from NRC-licensed facilities to an NRC-licensed repository, MRS, or interim storage facility. In addition, OCRWM and DOE's Office of Defense Programs signed an interagency agreement on July 1, 1986, that provides that OCRWM ship defense waste to a repository in casks certified by the NRC. DOE has also determined that NRC-certified packages will be used for the R&D shipments to support NWPA programs.

The procedures that will support transportation within the waste disposal system are in the formative stage. Several factors will influence the decisions on what these procedures will be and on what schedule they can be implemented. The NRC has released for comment proposed modifications to its current physical protection requirements. Any modifications will affect OCRWM's future procedures. In addition, OCRWM is committed to a program of involving the States, Tribes, utilities, industry, and other interested parties in its program planning. Accordingly, the viewpoints of these groups will be considered in OCRWM decisions regarding appropriate procedures for NWPA shipping.

Prior to the time when new procedures for a fully operational system can be developed, DOE shipments of spent fuel in support of OCRWM R&D programs are being conducted under existing DOE procedures with some modifications. For example, all Surry-to-INEL shipments are being made exclusively in NRC-certified casks. It is the intent of OCRWM to make the transition to NRC requirements on an incremental basis for the R&D shipments as the new procedures are developed and approved.

— DOE —

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ADDRESSING CONCERNS ABOUT WATER THROUGH REPOSITORY SITING AND DESIGN

INTRODUCTION

The U.S. Department of Energy's (DOE's) siting guidelines[1] are designed to ensure the selection of repository sites that will safely isolate high-level nuclear waste from the accessible environment. The accessible environment is the atmosphere, the land surface, surface water, oceans, and the lithosphere outside the repository-controlled area. The objective of several repository siting and design requirements, developed to meet these final guidelines, is the protection of water from all sources: surface, ground, and precipitation. U.S. Nuclear Regulatory Commission (NRC) licensing procedures[2] require protection of water resources. The NRC mandates a minimum waste emplacement depth of 300 meters (about 1,000 feet) to protect surface water and precipitation from the repository. Subsurface water or ground water occurring within the repository setting is given primary consideration for protection when siting and designing a repository.

GROUND WATER

Ground water is water that occupies spaces between rock grains or in fractures in rocks. Such openings tend to be larger and more abundant near the land surface; at depth, the openings (pore spaces) tend to be smaller and fewer due to the greater pressure of overlying material. The source of ground water is the fraction of rain and snowmelt or seepage from streams and lakes that percolates down through the soil and rock. Plants consume much of the water that enters the soil, and a small amount is held on the soil grains by capillary forces; any surplus percolates downward to the "zone of saturation" (rock in which every available space is filled with water). The top of the zone of saturation is the "water table." Candidate repository sites both above and below the water table are being evaluated.

Ground water is usually in motion, flowing under the force of gravity to lower areas. The volumetric rate of ground water flow is determined by the "hydraulic gradient" (inclination of the water table or the pressure surface) and the "permeability" (ease of conducting water). Flow rates of ground water have a wide range. For example, rock salt has an absence of, or extremely low rate of, ground water flow. On the other hand, a permeable sandstone "aquifer" (rock that contains sufficient saturated permeable material) will yield significant amounts of water to wells or springs (e.g., thousands of gallons per minute) and will not be considered for a repository.

REPOSITORY SITING AND GROUND WATER CONDITIONS

The study of ground water (geohydrology) is of primary importance in siting a repository since ground water has the potential for transporting radionuclides from the repository to the accessible environment. The "geohydrologic setting," defined as a composite description of all the major geologic and hydrologic factors that affect and control ground water movement into, through, and out of an area, requires thorough investigation before site recommendation and NRC licensing of a repository. Repository siting with respect to water is addressed in both the preclosure and postclosure siting guidelines. Surface water and ground water are preclosure considerations under technical guideline section 960.5-2-10 (hydrology). The ease and cost of siting a repository is directly influenced by the presence of water. Therefore, surface and ground water evaluations will be conducted when comparing sites under the preclosure guidelines. The presence of surface-water systems will be investigated with respect to potential flooding of the repository during construction, operation,

[1]/ U.S. Department of Energy, 10 CFR 960, "General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines," 1984.

[2]/ U.S. Nuclear Regulatory Commission, 10 CFR 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories; Licensing Procedures," 1983.

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and closure. Ground water aquifers between the land surface and the repository depth will be examined with respect to conditions that could require complex engineering measures beyond reasonably available technology for repository construction, operation, and closure.

Ground water is also a postclosure consideration in repository siting. The geohydrologic setting must permit compliance with requirements as specified by the NRC and the U.S. Environmental Protection Agency (EPA). The existence, therefore, of ground water (in saturated or unsaturated rock), the "porosity" (percent of void space in rock), permeability, hydraulic gradient, and ground water flow direction will be evaluated during site characterization. The first favorable condition in the postclosure siting guidelines under geohydrology is that the pre-waste emplacement ground water travel time along any path of likely radionuclide travel from the repository to the accessible environment would be more than 10,000 years. This is in compatible with the EPA release rates noted in the Environmental Standards for Disposal (40 CFR 191, Subpart B).

REPOSITORY DESIGN AND GROUND WATER CONSIDERATIONS

One of the factors addressed in repository design is ground water saturation or resaturation of the repository after closure. The isolation qualities of the "engineered barrier system" (i.e., the manmade components of a disposal system designed to prevent the release of radionuclides from the underground facility into the geohydrologic setting), including the waste packages and the repository seal system, will be designed to deter ground water from coming in contact with the waste. In the event that ground water contacts the waste package during postclosure, the waste package will be designed to deter ground water from contacting the radioactive materials within the waste package. The NRC specifies that the waste package must substantially contain the waste for 300 to 1,000 years. Additionally, the engineered barrier system and the repository seals will be designed to inhibit radionuclide transport away from the repository. In total, the combined isolation requirements of repository siting and design will, in principle, ensure that releases of radioactive materials to the accessible environment are within EPA limits for 10,000 years.

— DOE —

Rw 34

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United States Department of Energy
Office of Civilian Radioactive Waste Management
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TRANSPORTATION ROUTING ISSUES RELATED TO THE SHIPMENT OF HIGH-LEVEL NUCLEAR WASTE

INTRODUCTION

In accordance with the Nuclear Waste Policy Act of 1982 (NWPA), the U.S. Department of Energy's (DOE's) Office of Civilian Radioactive Waste Management (OCRWM) is responsible for the transportation of spent nuclear fuel[1] and high-level radioactive waste[2] from various storage sites to a geologic repository or other facility. Spent nuclear fuel may be transported from commercial nuclear powerplants to a repository, or transported to a monitored retrievable storage (MRS) facility[3] for subsequent shipment to a repository. Under current planning assumptions, high-level radioactive waste from defense activities will be transported directly to a repository. OCRWM is developing plans for the transportation system that will be needed to handle radioactive shipments, scheduled to begin in the late 1990s. In providing for transportation, the NWPA requires OCRWM to contract with private industry to the fullest extent possible.

Three modes of transportation are being evaluated by OCRWM—highway, rail, and barge.[4] Routing issues related to these modes of transportation will be addressed by OCRWM in close cooperation with Congress, other Federal agencies, States, affected Indian Tribes, local governments, industry, utilities, and the public. The following discussion reviews major highway and rail routing issues identified by OCRWM and parties having an interest in the development of the NWPA transportation system. Further discussion of these issues is included in OCRWM's "Transportation Institutional Plan" (DOE/RW-0094, August 1986).

[1]/ Spent nuclear fuel refers to fuel that has been removed from a nuclear reactor core because it can no longer sustain an efficient chain reaction.

[2]/ High-level radioactive waste, generated from the reprocessing of spent nuclear fuel to extract plutonium and the remaining usable uranium, results largely from defense nuclear activities.

[3]/ If authorized by Congress, the MRS facility would serve as a centralized spent fuel and nuclear waste consolidation and packaging facility.

[4]/ The feasibility of barge transportation is currently being studied. If found to be an appropriate transport mode for NWPA shipments, specific barge routing issues will be addressed by OCRWM.

HIGHWAY ROUTING ISSUES

In 1982, the U.S. Department of Transportation (DOT) established final routing regulations, commonly known as HM-164,[5] for highway transportation of specified types and quantities of radioactive materials, which include the spent nuclear fuel and high-level radioactive waste shipped to NWPA facilities. Under DOT regulations, carriers must use preferred highway routes selected to reduce time-in-transit. Preferred routes consist of (1) an interstate highway system route, using an interstate bypass or beltway around a city where available and (2) alternative routes selected by a "State routing agency." Indian Tribal authorities, having police powers to regulate and enforce highway routing requirements, are included within the definitions of "State routing agency." Routing designations by State and Indian Tribal governments must be preceded by substantive consultation with affected jurisdictions (including local governments).

Understanding DOT Highway Routing Regulations

Based on the responsiblity placed with the State and Indian Tribal authorities in designating routes, participants at the OCRWM Transportation Institutional Plan Workshop held in Atlanta, Georgia, November 1985, noted that the States and Indian Tribes need to fully understand the requirements of DOT routing regulations and available options. Workshop participants recommended that OCRWM furnish financial support for an information program responding to the concerns expressed. DOT and OCRWM are evaluating a variety of mechanisms to disseminate such information.

[5]/ The Hazardous Materials Transportation Act of 1974 (HMTA) specifically grants DOT the authority to prescribe routing regulations by any mode of transportation. HM-164 is the docket number assigned to the rule making procedure.

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Reviewing Highway Route Selection Methodology

When evaluating and then designating highway routes as alternatives to the interstate highway system for transportation of highly radioactive materials, DOT regulations require State and Indian Tribal routing authorities to apply a route selection methodology suggested in DOT guidelines, or an equivalent route selection methodology, that adequately considers overall risk to the public. Some participants at the Workshop recommended a careful review of DOT guidelines and suggested supplementing the methodology with additional guidelines that address such issues as high hazard areas, the need for detailed assessments of transportation risks, and the effect of transportation on environmentally sensitive areas. Workshop participants also suggested OCRWM take a lead role in developing a route selection methodology applicable to *all* routing decisions associated with NWPA shipments.

OCRWM will participate with DOT, States, and Indian Tribes in a review of route selection methodologies for State and Indian Tribal alternative route designation.As an initial step, OCRWM will support the review of route selection methodology through financial arrangements with regional organizations. (Such activities are currently conducted through contractural arrangements with the Western Interstate Energy Board and the Southern States Energy Board.) Plans are for OCRWM to extend similar assistance to organizations of the northeastern and midwestern States and to Indian Tribes.

Assisting States and Affected Indian Tribes in Highway Route Designation

Upon request, OCRWM will provide technical assistance to States and Indian Tribes for the evaluation and designation of routes under DOT regulations. Assistance will take the form of mechanisms such as:

- providing access to a highway routing model (HIGHWAY) that is maintained by Oak Ridge National Laboratory[6]
- providing access to computer codes that estimate the risk associated with waste transport (developed specifically for OCRWM)
- providing access to computer codes developed for OCRWM to derive transportation cost estimates (also developed for OCRWM)

OCRWM will work with States and Indian Tribes, on both an individual and regional basis, to provide access to future codes involving transportation analyses, and to determine other forms of technical assistance that may be appropriate.

[6]/ The highway network data base used in the model was developed by Logistics Systems, Inc.; user fees may be required.

States and Indian Tribes have requested that OCRWM provide financial as well as technical assistance for route evaluation and designation activities. Grants will be provided under the NWPA to support route evaluation activities directly related to the siting of the repository within State borders or Indian Tribal lands. Financial arrangements with regional transportation organizations will support routing activities of non-host States and Indian Tribes affected by NWPA transportation.

Routing Highway Shipments to NWPA Facilities

Other issues relate to whether OCRWM will develop the routing procedures for waste shipments to NWPA facilities, and what degree of control OCRWM will exercise in determining the selection of specific highway routes.

Some comments to OCRWM have urged the development of NWPA shipping procedures that would instruct carriers to use specific highways within the DOT system of "preferred routes." OCRWM's policy is that its oversight role must be balanced with the need to allow carriers to make routing decisions during individual shipments in order to avoid adverse transportation conditions (such as local weather conditions and traffic delays). To implement this policy, OCRWM will develop NWPA route planning criteria that will conform to all DOT routing requirements. The criteria will further require the selection of routes that avoid operational delays (such as road construction and/or repair activities) and adverse weather conditions. Route planning criteria will also address such factors as:

- the preferred time of day for travel through urban areas
- the appropriate stopping places for rest, vehicle refueling, and vehicle repair

Applying Sanctions for Carrier Violations of Highway Routing Requirements

As recommended by participants at the Workshop, contracts between OCRWM and carriers providing transportation Services will specify all OCRWM and DOT procedures and regulations, formally directing the use of preferred highway routes. Transportation service contracts will include incentives for performance, and will specify sanctions for routing violations. Such sanctions may include the suspension and termination of contracts.

Analyzing Highway Routing Factors in Future Transportation Studies

Transportation cost and risk analyses will be conducted by OCRWM for the environmental impact statement (EIS) required in the selection of a repository site. To assist in determining what routing factors should be considered in such transportation analyses, OCRWM is considering the use of regional routing workshops.

RAIL ROUTING ISSUES

The routing of rail shipments of radioactive materials differs from the routing of highway shipments.

- Federal rail routing regulations have not been promulgated, in contrast to established DOT regulations governing highway shipments of radioactive materials.
- Rail transportation offers fewer routing alternatives than does highway transportation since fewer alternative rail routes are available, and the condition of rail tracks can limit the number of acceptable routes.
- In contrast to the public highway system, rail lines are generally privately owned and maintained.

Reviewing the Need for DOT Rail Routing Regulations

When developing highway routing regulations, DOT considered whether routing rules should be established for other types of hazardous materials and other modes, including rail transportation. It was decided at that time not to proceed with development of additional routing rules. Now, OCRWM will work with DOT to review needs for Federal rail routing regulations for transportation of radioactive materials. OCRWM will also consult with the NRC, other affected DOE offices, railroad companies, and the Association of American Railroads during the review process. Mechanisms for addressing the potential need for Federal rail routing regulations may include the following:

- technical studies, to evaluate the need for rail routing regulations
- workshops specifically designed to solicit views and comments from the rail industry
- petitions to DOT for a formal rule making if, after review, OCRWM concludes that the routing of shipments of radioactive materials by rail requires regulation

Analyzing Rail Routing Factors in Future Transportation Studies

As with highway routing, the issue has been raised as to what routing assumptions and what data will be used in the rail transportation cost and risk analyses for the EIS. OCRWM will also consider the use of regional workshops on rail routing.

Developing Routing Procedures for NWPA Shipments by Rail

Some comments received by OCRWM have urged development of NWPA shipping procedures under which OCRWM would direct the use of specific rail routes for shipments to NWPA facilities. Similar to the policy for highway shipments, OCRWM's role will involve balancing an oversight role with the need to allow carriers flexibility, necessary to avoid unique or adverse local conditions (track repair or train derailments). OCRWM plans to develop NWPA route planning criteria for rail shipments that will parallel certain features of highway shipment criteria. At a minimum, OCRWM's route planning criteria for rail shipments will (1) require the selection of rail routes that limit shipping costs and transit times, (2) avoid population centers (where possible), and (3) avoid adverse seasonal weather conditions.

— DOE —

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The procedures that will support transportation within the waste disposal system are in the formative stage. Several factors will influence the decisions on what these procedures will be and on what schedule they can be implemented. The NRC has released for comment proposed modifications to its current physical protection requirements. Any modifications will affect OCRWM's future procedures. In addition, OCRWM is committed to a program of involving the States, Tribes, utilities, industry, and other interested parties in its program planning. Accordingly, the viewpoints of these groups will be considered in OCRWM decisions regarding appropriate procedures for NWPA shipping.

Prior to the time when new procedures for a fully operational system can be developed, DOE shipments of spent fuel in support of OCRWM R&D programs are being conducted under existing DOE procedures with some modifications. For example, all Surry-to-INEL shipments are being made exclusively in NRC-certified casks. It is the intent of OCRWM to make the transition to NRC requirements on an incremental basis for the R&D shipments as the new procedures are developed and approved.

— DOE —

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OCRWM Backgrounder

United States Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

DOE/RW-0127

February 1987

FEDERAL AGENCIES INVOLVED IN THE IMPLEMENTATION OF THE NUCLEAR WASTE POLICY ACT OF 1982

INTRODUCTION

The U.S. Department of Energy (DOE) has the primary responsibility for siting, constructing, and operating the elements of the radioactive waste management system mandated by the Nuclear Waste Policy Act of 1982 (NWPA). The U.S. Nuclear Regulatory Commission (NRC) has the primary regulatory responsibility for review of the nuclear safety aspects of certain DOE actions and for licensing the elements of the radioactive waste management system.

The Environmental Protection Agency (EPA) is responsible for developing generally applicable environmental standards for the management and disposal of spent nuclear fuel and high-level waste. EPA is also responsible for environmental review of various DOE actions pertaining to the siting of geologic repositories. The Council on Environmental Quality (CEQ) and the Department of the Interior (DOI) also have review responsibilities specified under the NWPA.

Four other Federal agencies—whose roles are not directly specified in the NWPA—have responsibilities by law with respect to certain actions required to site, construct, license, and operate the NWPA-mandated radioactive waste management system. They are the Department of Agriculture (USDA), Department of Defense (DOD), Department of Justice (DOJ), and Department of Transportation (DOT).

Of these other Federal agencies, the Department of Transportation (DOT) has a major role in that it has general responsibility for regulating safety in the transport of hazardous materials, including radioactive waste.

This backgrounder describes the regulatory responsibilities of the NRC and the EPA in siting and developing the Nation's first repository. It also outlines the responsibilities of DOT and the NRC in establishing a system for transporting spent nuclear fuel and high-level radioactive waste. In addition, it identifies the NRC's role in licensing a monitored retrievable storage (MRS) facility, if the facility is approved by Congress. Finally, it provides an overview of DOI and CEQ review responsibilities under the NWPA.

REPOSITORY SITING AND DEVELOPMENT ACTIVITIES

Nuclear Regulatory Commission

The NRC is centrally involved as the primary regulatory agency in the repository siting, construction, operation, and decommissioning phases. At the beginning of the siting process, the NWPA required NRC concurrence on DOE's siting guidelines[1] before adoption. The NRC is also required by the NWPA to adopt DOE's environmental impact statement (EIS) "to the extent practicable" in connection with issuance by the NRC of a construction authorization and a repository license.

The NWPA also requires that the NRC promulgate technical requirements and criteria to be used in licensing a repository (10 CFR 60). These regulations consist of procedural rules for the licensing of geologic repositories and technical criteria used in the evaluation of license applications submitted under the procedural rules. The procedural portion of 10 CFR 60 sets forth the basic steps of the licensing process for the repository, and also provides specific requirements for a site characterization program and the associated site characterization plan. The technical criteria of 10 CFR 60 stipulate a number of performance objectives. The NRC has issued (June 1986) a proposed rule to amend 10 CFR 60 to conform existing NRC regulations to the standards promulgated by the EPA in 40 CFR 191.

[1]/10 CFR 960, "Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines," U.S. Department of Energy, December 6, 1984.

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To provide current background information on program facts, issues, and initiatives. For further information write to: Information Services Division, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Mail Stop RW-40, Washington, DC 20585, Telephone (202) 586-5722.

The most intensive level of NRC involvement occurs during the site characterization and license application phases of the repository program, where the NRC has considerable oversight authority. The NRC's activities during each phase are discussed in the following sections.

Site Characterization. Prior to the selection of a site for the first repository, the three candidate sites—Yucca Mountain, Nevada; Deaf Smith County, Texas; and Hanford, Washington—will undergo site characterization pursuant to the requirements of the NWPA. Before sinking exploratory shafts at the three sites, DOE must prepare a site characterization plan (SCP) that summarizes information collected to date about the geologic conditions at the site, describes conceptual designs for the repository and the waste package, and presents plans for obtaining the data necessary to demonstrate the suitability of the sites for a repository.

Specifications for the content of the SCP are presented in Section 113(b)(1) of the NWPA and in Section 60.17 of 10 CFR 60. To facilitate compliance with these requirements, the NRC has developed regulatory guidance on the format and content of the SCP for geologic repositories (Regulatory Guide 4.17, Standard Format and Content of Site Characterization Plans for High-Level-Waste Geologic Repositories, Proposed Revision 1). The NRC also has the authority pursuant to the NWPA to require additional information in the SCP. When the SCP is released for public review, the NRC will review it and provide comments in the form of a Site Characterization Analysis, as required by 10 CFR 60.

Before proceeding with site characterization, DOE has agreed to have a quality assurance (QA) program in place. Audited by the NRC, the QA program will provide demonstrable evidence that both the public's health and safety are adequately protected. Structures, systems, and components important to public safety; barriers important to waste isolation; and engineering and technological data will be subjected to QA methods and procedures.

Pursuant to the NWPA, the NRC will also review and comment on the National Environmental Policy Act (NEPA) and the EIS (draft) for the site selected for the first repository. The NRC will also review and comment on the adequacy of site characterization studies for inclusion in the license application for the first repository [Sections 114(a)(1)(b) and (E) of the NWPA].

Licensing. After the President recommends a site for the first repository to Congress and the site designation becomes effective, the Secretary of Energy is required by the NWPA to submit a license application to the NRC. If the NRC approves the application as required by 10 CFR 60.31, it will then issue DOE a construction authorization.

Between the time a license application is submitted and the construction authorization is granted (approximately 27 months are planned for NRC review and the required adjudicatory proceedings), the NRC is required by the NWPA to submit annual reports to Congress that describe the progress made in processing the license application [Section 114(c) of the NWPA]. Once the NRC grants authorization, construction can begin.

Environmental Protection Agency

The NWPA charges the EPA with responsibility for promulgating generally applicable standards for geologic repositories to protect the health and safety of the public from potential hazards due to the disposal of spent nuclear fuel and high-level radioactive waste. On August 15, 1985, the EPA promulgated standards (40 CFR 191) for protecting the public from the offsite release of radioactive materials pursuant to Section 121(a) of the NWPA. The key provisions of these standards are: (1) limits on the radiation dose equivalent to any member of the public as result of preclosure operations; (2) a limit on the amount of radioactivity that may enter the environment for 10,000 years after disposal; (3) limits on the radiation dose that can be delivered to any member of the public for 1,000 years after disposal; and (4) requirements for the protection of certain sources of ground water for 1,000 years after disposal. Compliance with EPA standards will be enforced, as noted above, by the NRC.

Pursuant to the NWPA, the EPA has reviewed and commented on DOE's siting guidelines (10 CFR 960), as well as environmental assessments (EAs), for the first repository. The EPA must also review and comment on DOE's EIS. In this regard, DOE has requested that the EPA serve as a "cooperating agency" during development of the EIS. When the draft EIS is complete, the EPA will review and comment on the document, pursuant to Section 309 of the Clean Air Act.

NWPA TRANSPORTATION ACTIVITIES

DOT and the NRC are responsible, by law, for regulating safety in the development and operation of a radioactive waste management transportation system serving the repository and an MRS facility, should one become part of the waste management system.

In June 1979, the NRC and DOT signed a Memorandum of Understanding that delineates the respective responsibilities of each agency under law for regulation of safety in the transportation of radioactive materials. Generally, DOT is responsible for regulating safety in receipt, use, and transfer of radioactive materials as specified in 10 CFR 171. The NRC is responsible for review and approval of package designs for the transportation of radioactive waste.

Department of Transportation

DOT signed a Memorandum of Understanding with DOE in August 1985. The document outlined the agencies' responsibilities under the NWPA pertaining specifically to the transportation of spent nuclear fuel and high-level radioactive waste. The memorandum stipulates that "management of the transportation of spent fuel and high-level radioactive wastes under the NWPA resides with DOE's Office of Civilian Radioactive Waste Management." However, this task will be performed in full compliance with all applicable DOT regulations. The memorandum also states that DOE and DOT will exchange information, consult with each other, and provide appropriate support within the areas of their responsibilities. Both DOT and DOE will interact as well with public and intergovernmental agencies to identify transportation-related impacts and acceptable transportation routes.

Nuclear Regulatory Commission

In November 1983, DOE signed a procedural agreement with the NRC concerning the planning assumptions and procedures that each agency will observe for development of transportation packaging under provisions of the NWPA. DOE has agreed to use packaging that has been approved by the NRC in accordance with 10 CFR 71. Under this agreement, the NRC will be responsible for reviewing safety analyses (called the "Safety Analyses Report Packages") on transportation casks for spent nuclear fuel and high-level radioactive waste. The NRC will also be responsible for inspecting and certifying casks before use by the Office of Civilian Radioactive Waste Management for transporting radioactive waste.

MONITORED RETRIEVABLE STORAGE FACILITY

The NWPA, in addition to authorizing DOE to develop and operate a geologic repository, directs DOE to complete a study of the need for and feasibility of an MRS facility, and to submit a proposal for the construction of the MRS facility to Congress. If Congress authorizes construction of the MRS facility, then the NWPA requires the facility be subject to licensing by the NRC. In May 1986, the NRC published a proposed rule to amend its existing regulations under 10 CFR 72 that covers licensing of an MRS.

OTHER AGENCIES HAVING RESPONSIBILITIES UNDER THE NWPA

The DOI and CEQ also have responsibilities specified under the requirements of the NWPA. Both agencies were consulted during development of DOE's siting guidelines (10 CFR 960), and both are charged with review of DOE's EIS for a geologic repository.

FEDERAL AGENCY CONTACTS

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Council on Environmental Quality (CEQ)
Washington, DC 20006

U.S. Department of Defense (DOD)
Washington, DC 20330

U.S. Department of Energy (DOE)
Washington, DC 20585

Environmental Protection Agency (EPA)
Washington, DC 20460

U.S. Department of the Interior (DOI)
Washington, DC 20240

U.S. Department of Justice (DOJ)
Washington, DC 20530

Nuclear Regulatory Commission
Washington, DC 20555

U.S. Department of Transportation
Washington, DC 20590

Rm 311

OCRWM Backgrounder

United States Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

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QUALITY ASSURANCE FOR NUCLEAR WASTE REPOSITORIES

INTRODUCTION AND DEFINITION

The Office of Civilian Radioactive Waste Management (OCRWM) is dedicated to achieving quality management through a formal documented quality assurance (QA) program. QA is commonly defined as a set of planned and systematic actions that ensure satisfactory performance of a system, component, or structure.

During the site characterization phase for nuclear waste repositories, systematic actions are focused on providing adequate confidence in the validity and integrity of the data and other activities used in the site investigations.

This Backgrounder briefly discusses:

- the types of activities subject to the QA program requirements
- the specific requirements of the program
- the types of activities carried out by QA personnel and the parameters of their authority
- the type of interactions with the Nuclear Regulatory Commission (NRC)

HISTORICAL BACKGROUND

The concept of QA evolved from early quality control (QC) activities, such as acceptance testing and product inspection. In the 1970s, QA was formalized as a discipline in the nuclear industry to deal with the growth of nuclear power. Under commercial nuclear powerplant programs, emphasis was placed on assurance of quality in the design, construction, and operations activities. These activities gave rise to a series of national consensus QA standards that defined QA program requirements and QC practices.

REGULATORY DOCUMENTS

The Nuclear Waste Policy Act of 1982 (NWPA) states that, for work performed under OCRWM, the NRC must approve plans for the design and operation of a high-level nuclear waste repository. To this end, the NRC has directed [10 CFR 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," and 10 CFR 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI)"] that the general quality assurance criteria in 10 CFR 50, "Quality Assurance Criteria for Nuclear Power Plants," are to be applied. Also, in 10 CFR 71, "Packaging and Transportation of Radioactive Material," the NRC has established QA criteria similar to those in 10 CFR 50, Appendix B, "Quality Assurance for Nuclear Power/Fuel Reprocessing Plants." The NRC staff will use the NRC Review Plan for reviewing the DOE QA program for site characterization activities during the prelicensing phase.

Basic policies and requirements for establishing and implementing QA programs are contained in the following documents which amplify and are consistent with the above regulations: *Program Management System Manual*, DOE/RW-0043, published January 1986; *Quality Assurance Management Policies and Requirements*, DOE/RW-0032, published October 1985; *Quality Assurance Plan for High-Level Radioactive Waste Repositories*, DOE/RW-0095, published August 1986; and *Office of Storage and Transportation Systems Quality Assurance Directive*, DOE/RW-0103, published October 1986.

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ACTIVITIES SUBJECT TO QUALITY ASSURANCE REQUIREMENTS

In a major and continuing commitment to achieve and ensure quality at all levels, OCRWM's QA program is applied to the following types of activities:

- the designing, constructing, testing, operating, maintaining, and closing/decommissioning of waste management facilities and all associated components, systems, and structures
- the processing, treating, packaging, handling, transporting, storing, and monitoring of high-level radioactive waste and spent nuclear fuel
- the transfer of technology development and demonstration data and the collection of data
- the licensing/certifying of systems, structures, components, and processes
- the preparing, reviewing, approving, and finally distributing technically significant data and documents (e.g. studies, analyses, computer codes, test results, and reports)

OCRWM and its other program participants are required to have established QA program plans and implementing procedures in place so that all personnel will know their responsibilities and authorities for ensuring quality. Participants are to have access to the necessary levels of management to resolve any difficulties in implementing QA policy and requirements. Personnel are to be indoctrinated and trained for adequate proficiency in their work and familiarity with the requirements of the QA program. The QA program must be reviewed regularly to determine its adequacy.

At the present time, one of the primary program requirements is the quality control of project documents, including procedures, instructions, and drawings, so that work is accomplished according to the latest revisions of the documents.

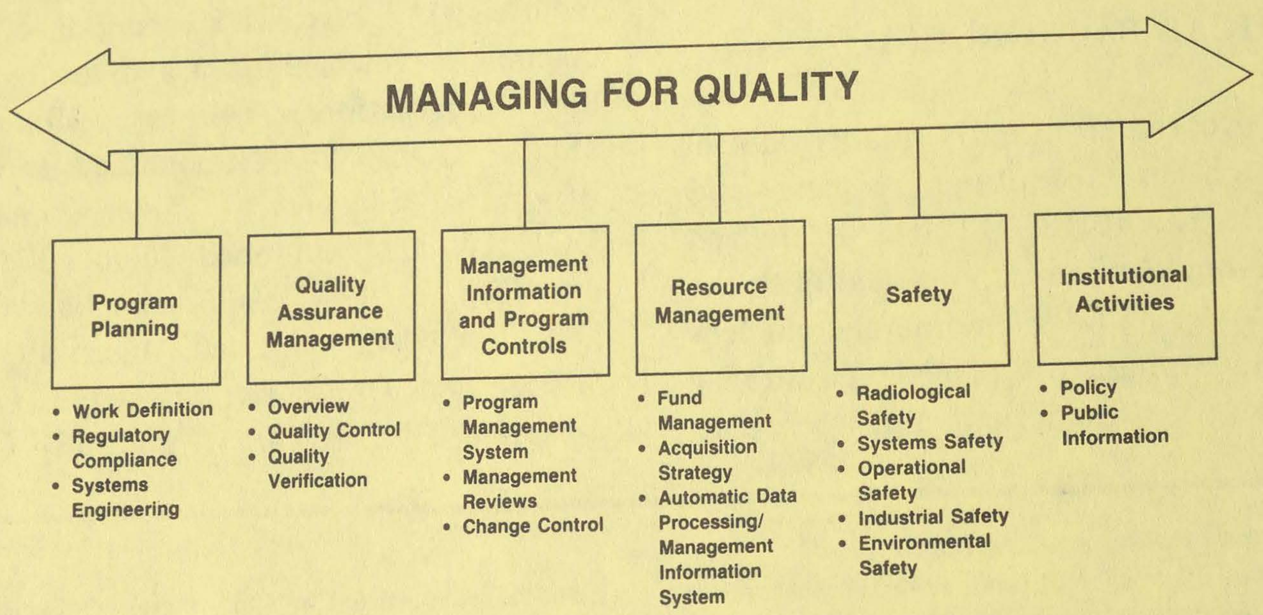
As the development of the repository progresses, additional QA program requirements will include quality controlled design of facilities and specification of materials and equipment.

INDEPENDENCE

The achievement of quality is a primary responsibility of line management, and it will be independently verified using various methods by OCRWM and the contractors' line and QA organizations. A full-time QA management position is to be established within all levels of the organization—from Headquarters, through Project Offices, to participating contractors. This position is to have direct channels of communication with senior management (at the same or higher levels within the organization), and have the authority and responsibility to verify the adequacy and effectiveness of the QA plan, requirements, and activities. All QA management levels will have the authority to order work stopped by line managers.

The organizational relationships for the performance of quality overview and audits and the feedback of quality status and problems are shown in the chart.

CIVILIAN RADIOACTIVE WASTE MANAGEMENT PROGRAM



AUDITS

QA personnel are trained and authorized to audit ongoing activities to ensure that work is planned, implemented, and documented on a timely and continuing basis. Significant results of audit activities are reported to management. Planned and scheduled internal and external audits are performed regularly to verify compliance and measure effectiveness of the overall QA program. Audit results are analyzed for (1) quality trends and (2) possible QA management improvements. Any deficiencies noted during audits are to be tracked until closure. "Stop Work" orders on technical activities (e.g., investigation, design, parallel construction, test, or installation) have been imposed due to findings of insufficient data collection or inadequate QA procedures.

GRADED QUALITY ASSURANCE

The QA requirements and procedural controls are applied selectively and judiciously on the basis of how important the items or activities are to safety, waste isolation, and overall mission performance criteria. A "graded approach" to QA is implemented to provide demonstrable evidence that the health and safety of the public are protected and that components and barriers important to waste isolation are subjected to appropriate QA methodology.

INTERACTIONS WITH OTHER AGENCIES

To facilitate the prompt resolution of licensing issues, participating organizations are to provide for continuing interaction with the NRC and other involved agencies on QA matters. This procedure is intended to keep the NRC informed of ongoing activities and to provide for timely input from the NRC on any QA problems that might otherwise delay licensing of the repository or any other facility.

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OCRWM Backgrounder

United States Department of Energy
Office of Civilian Radioactive Waste Management
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ACTIVITIES DURING THE SITE CHARACTERIZATION PHASE OF THE GEOLOGIC REPOSITORY PROGRAM

BACKGROUND

The site characterization phase of the geologic repository program includes two kinds of activities: (1) a program of extensive field and laboratory testing and studies to collect and evaluate geologic, hydrologic, and geochemical information (in this backgrounder, the studies are referred to as site characterization); and (2) environmental and socioeconomic studies that assess the potential impacts of repository development and operation. The site characterization phase is expected to last about 5 years and cost as much as $1 billion for each site (in 1985 dollars). As many as 200 to 500 persons will be employed at each site at the peak of site characterization activity.

The Nuclear Waste Policy Act of 1982 (NWPA) became law (P.L. 97-425) in January 1983. The U.S. Department of Energy (DOE) formally identified nine sites as being potentially acceptable sites for the first repository. The nine sites are: Vacherie Dome in Louisiana [salt dome]; Richton Dome and Cypress Creek Dome in Mississippi [both salt domes]; Yucca Mountain in Nevada [tuff (compacted volcanic ash)]; Deaf Smith County and Swisher in Texas [bedded salt]; Davis Canyon and Lavender Canyon in Utah [bedded salt]; and Hanford in Washington [basalt (a very fine-grained rock that is formed by the solidification of lava)].

Using the repository siting guidelines (10 CFR 960) developed by DOE and concurred by the U.S. Nuclear Regulatory Commission (NRC), DOE issued for public comment and review the draft environmental assessments (EAs) on the nine potentially acceptable sites in December 1984. In those draft EAs, DOE identified five of the nine sites for nomination as suitable for site characterization and proposed three of the sites for recommendation to the President for site characterization.

As a result of the public comment period, DOE received over 20,000 comments and has incorporated those comments into the final EAs, as appropriate. Following consideration of the comments and other information, Secretary of Energy John S. Herrington issued a *Federal Register* Notice nominating five sites that he determined suitable for site characterization. Herrington recommended to the President in writing Yucca Mountain, Deaf Smith County, and Hanford for site characterization. The President approved the recommendation on May 28, 1986. Two sites, Richton Dome and Davis Canyon, were nominated but not recommended for site characterization.

SITE CHARACTERIZATION

Overview

The objectives of the site characterization program are to (1) determine the geologic, hydrologic, and geochemical conditions at a candidate site; (2) provide information needed to design a package for the disposal of spent fuel and high-level radioactive waste that will meet the licensing requirements of the NRC; (3) provide information for the design of the repository facility; and (4) evaluate whether the site can meet the requirements of the NRC and the Environmental Protection Agency (EPA).

The program will consist of surface-based investigations (e.g., geologic mapping; geophysical surveys; and seismologic, paleoclimatologic, and hydrologic studies) as well as subsurface investigations conducted by deep and shallow boreholes that will be used for ground water monitoring; core extraction; laboratory testing; and stratigraphic, tectonic, geochemical, and geohydrologic studies. Most importantly, investigations will be conducted in the host rock at repository depth through the construction and use of exploratory shafts and underground test facilities. Geochemical studies of the host rock and surrounding strata will assess the effect

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of the *insitu* environment on the waste package, the ability of the host rock to contain radionuclides, and the ability of surrounding units to retard radionuclides by chemical interaction.

Hydrologic testing and monitoring of surface and subsurface water flow systems will assess surface flooding potential and help in the construction of computer models to analyze subsurface hydrologic flow systems and their potential for transport of radionuclides.

Although site evaluation studies comparable to the site characterization activities in the repository program are commonly conducted in preparing environmental impact statements for large construction projects such as dams and powerplants, site characterization for a repository departs from those studies in that it requires the sinking of a deep exploratory shaft to conduct preliminary tests in the repository host rock. However, there is considerable experience with deep shaft construction. The mining industry frequently constructs deep shafts to extract minerals. For example, the Stripa Mine in Sweden was excavated to a depth of 1,150 feet in saturated rock. Furthermore, the Climax Stock mine, near the Nevada Test site, was excavated to a depth of 1,400 feet in unsaturated rock.

Exploratory Shafts

DOE is planning to sink two exploratory shafts at each candidate site. Having a second shaft is necessary for the safety of operating personnel.

At the Deaf Smith County site, shafts will be constructed by drill-and-blast techniques. They will be sunk to depths ranging between 2,600 and 3,000 feet, with horizontal workings (subsurface facilities and ventilation tunnels) extending about 5,400 feet from the base of the shafts. The shafts will penetrate the Ogallala and Dockum aquifers as they are sunk to repository depth. To control water migration and to stabilize the ground during this operation, portions of the ground will be frozen to ensure isolation of the aquifers. Ground freezing is a well-documented procedure used in the mining industry. The frozen ground will be maintained until the final concrete lining is emplaced.

At the Hanford site, shafts will be drilled using a large drill rig. Shafts will be sunk to the candidate repository depth, or approximately 3,000 and 4,000 feet. The shafts will be lined with watertight steel casing and sealed in place with a cement grout. Effectiveness of the seal to prevent water intrusion will be verified before beginning horizontal excavations at repository depth.

At the Yucca Mountain site, the planned exploratory shaft will use drill-and-blast techniques. Shaft depths will be approximately 1200 and 1500 feet. The Yucca Mountain site is different from the other sites in that, from the surface to repository depth, the rock is unsaturated. Water will be used sparingly during shaft construction so that tests to characterize the unsaturated zone will not be affected. The liners for the first shaft will be concrete, with steel possibly used for the second shaft. Underground test facility rooms will be excavated at about the 500-foot level and at the shaft bottom.

The exploratory shafts will be incorporated into the repository design after a site is found suitable and is selected for development as the repository. If a site is not selected for further development, then the shafts will be filled and sealed, and the site will be restored as nearly as possible to its original condition.

Site Characterization Plans

Prior to exploratory shaft construction at each candidate site, the Secretary of Energy will submit a Site Characterization Plan (SCP) to the NRC, the Governor and legislature of the State in which such candidate site is located, the governing body of affected Indian Tribes, and the public. The site plans are scheduled to be issued for Hanford and Yucca Mountain in December 1986 and Deaf Smith County in April 1987. A 3-month public comment period, including public hearings, will follow the issuance of each SCP.

The "Annotated Outline" for the SCP, derived from the NRC's Regulatory Guide 4.17 (*Standard Format and Content of Site Characterization Plans for High-Level Waste Geologic Repositories*), was approved by the NRC and distributed to other recipients. The outline is divided into Part A describing the candidate site, the waste package, and the repository; and Part B presenting the site characterization program. Part A will present existing information pertaining to geology, geoengineering, hydrology, geochemistry, climatology, and meteorology. Part B will be the heart of the SCP. It will be composed of (1) the rationale for the planned site characterization program; (2) issues to be resolved and information required during site characterization; (3) planned tests, analyses, and studies; (4) planned site preparation activities; (5) milestones, schedules, and decision points; (6) quality assurance activities; and (7) the decontamination and decommissioning activities related to the repository.

ENVIRONMENTAL AND SOCIOECONOMIC STUDIES

In parallel with the site characterization program, DOE will conduct environmental and socioeconomic studies to assess the potential impacts of repository development and operation. The studies will support the preparation of the environmental impact statement (EIS) for the site that is ultimately selected and the development of plans to mitigate any significant adverse impacts. The environmental studies will also evaluate whether repository development and operation can be conducted in compliance with environmental regulatory requirements.

Environmental data collection and analysis will focus on (1) land use and mineral resources, (2) terrestrial and aquatic ecosystems, and (3) ecology, threatened and endangered animal species, air quality and meteorology, surface waters and water quality, soils, and noise. Aesthetic, archeological, cultural, and historical resources, background radiation, and transportation systems affected by repository development will also be studied. Socioeconomic studies will address potential demographic and economic impacts, as well as changes in community services, social conditions, fiscal conditions, and government organization.

Plans will be developed and implemented to detect significant adverse environmental and socioeconomic impacts resulting from site characterization activities. These plans, developed in consultation with the affected States, Indian Tribes, and local governments, will also identify procedures for developing and implementing programs to mitigate significant adverse impacts.

Following site characterization, DOE plans to send a site selection report to the President in late 1994 and submit the license application to the NRC in early 1995, as soon as the site designation becomes effective. Construction of the geologic repository could begin in 1998, with initial operation commencing in 2003.

— DOE —

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Rm 311

OCRWM Backgrounder

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April 1987

CHARACTERISTICS AND INVENTORIES OF NUCLEAR WASTE

The purpose of this paper is to describe the characteristics and inventories of the various forms of nuclear waste that are generated during the production of electricity in nuclear powerplants or during the production of nuclear materials for national defense.

Radioactive waste is broadly classified as spent nuclear fuel, high-level radioactive waste, transuranic (TRU) waste, low-level waste, and uranium mill tailings.

Nuclear fuel that has been removed from a nuclear reactor core because it can no longer sustain an efficient chain reaction is referred to as "spent nuclear fuel." At this point, the spent nuclear fuel is highly radioactive and thermally hot. Spent fuel is stored temporarily in water pools adjacent to the power reactors. The water removes heat generated by the spent fuel and keeps the fuel cool. It also serves as an effective shield to protect workers at the reactor site from radiation.

High-level radioactive waste is generated from the reprocessing of spent nuclear fuel. Reprocessing is a chemical separation process that can extract plutonium, which is formed during the fission process, and the remaining usable uranium from the spent fuel. Although in some other countries reprocessing is a means of extracting usable fissile material for subsequent use in new fuel elements, in the United States reprocessing is only utilized in the production of nuclear materials for national defense.

Transuranic waste is material contaminated with certain alpha-emitting radionuclides in concentrations greater than 100 nanocuries per gram. Transuranic waste is generated primarily from defense reprocessing and fabrication operations. Almost all of the existing inventory of TRU waste was generated under the Nation's atomic energy defense programs. TRU waste is further classified as either "contact handled" waste in which little or no shielding is required, or as "remote handled" waste in which shielding and remote handling are required.

Low-level waste is defined by the U.S. Department of Energy (DOE) Order 5820.2 as all wastes which are not classified as spent nuclear fuel, high-level radioactive waste, TRU waste, or byproduct material. Low-level wastes, which are produced by many commercial, industrial, and medical processes, may require special handling although extensive shielding is not usually required. The U.S. Nuclear Regulatory Commission (NRC), which regulates the commercial low-level waste, has developed a classification system that groups part of the low-level waste into three separate categories, depending on the level of radioactive contamination. These categories are designated as Class A, B, or C.

The Low-Level Radioactive Waste Policy Amendment Act of 1985 has directed DOE to provide for the disposal of greater than Class C low-level waste and has directed that a report of recommendations for implementation be developed by DOE and presented to the Congress within one year of the passage of the Act. This report, which was submitted to Congress in February 1987, concludes that "Until the time that greater than Class C low-level wastes can be disposed, DOE plans to accept such wastes as necessary, after adoption of appropriate waste acceptance criteria, and to safely manage such wastes until disposal options are developed."

Uranium mill tailings are radioactive rock and soil that are the byproducts of uranium ore mining and milling. Tailings are produced in very large volumes and contain low concentrations of naturally occurring radioactive materials.

The following table depicts current and projected quantities of nuclear waste.

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Table 1. Quantities of Nuclear Waste[1] (in Thousands of Cubic Meters)

Type	Year			
Defense Waste	1985[2]	2000	2010	2020
High-Level[3]	355	346	370	379
Transuranic[4]	286	376	437	497
Low-Level	2,181	4,043	5,159	6,256
Commercial Waste[5]				
Spent Nuclear Fuel[6]	5	16	25	39
Low-Level[7]	1,160	2,441	3,545	4,972
Mill Tailings	100,000	146,500	197,300	265,900
High-Level[8]	2	—	—	—

The Nuclear Waste Policy Act of 1982 (NWPA) authorizes activities leading to the safe, permanent disposal of commercial spent nuclear fuel and of commercial and defense high-level waste. These forms of waste[9] contain relatively high concentrations of elements that remain radioactive for thousands of years and are potentially harmful and, hence, require isolation from the public and the environment for very long periods of time. Therefore, spent nuclear fuel and high-level waste will be disposed of in deep, geologic repositories that will be licensed by the NRC.

Defense-generated TRU waste will be sent to the Waste Isolation Pilot Plant (WIPP) in New Mexico for the demonstration of safe disposal. Low-level waste may continue to be disposed of by shallow land burial, although alternative methods, including engineered facilities and waste treatment, will be considered. Uranium mill tailings will be treated, stabilized, and stored near the uranium mines.

This paper focuses on the two forms of nuclear waste that will be disposed of in the civilian repositories authorized by the NWPA.

Spent Nuclear Fuel

Nuclear fuel is the heart of the reactor. For a commercial, light-water nuclear powerplant, the fuel consists of pellets of ceramic uranium dioxide that are sealed in hundreds of metal rods bundled together within a rigid metal structure called a "fuel assembly." The fuel rods are carefully spaced in the fuel assembly to allow coolant to flow between them as they irradiate during the fission process. Each assembly is about 14 feet long and weighs about 1,200 pounds. It is designed to be readily handled with suitable hoists and cranes at the reactor site. After about 3 years of use, the fuel assembly is removed, or discharged, from the reactor.

DOE uses forecasts of commercial spent fuel discharges published annually by the U.S. Energy Information Administration (EIA) as one of the principal planning variables in the formulation of waste management program and funding requirements. These projections are generated from predictive macroeconomic computer models and other data sources, including industry surveys. These data sources are used by EIA to assess the status of commercial nuclear powerplants as they move from the planning phase to operational status.

In developing its waste acceptance schedules for program planning purposes, DOE uses EIA's "Upper Reference Case"[10] forecasts of commercial spent fuel discharges that assume "increasing burnup" of fuel assemblies. Under this assumption, the irradiation levels[11] of fuel assemblies removed from reactor cores increase gradually, exceeding the 1979-1983 historical average levels by 30 percent in 1998 and then stay constant thereafter. The following table depicts cumulative projections of inventories of commercial spent fuel discharges from 1986 through 2020.

Table 2. Projections of Cumulative Commercial Spent Fuel Discharges - EIA Upper Reference Case[12]

Year	Extended Burnup Metric Tons	Extended Burnup Cubic Meters
1986[13]	13,800	5,900
1990	21,200	8,500
1995	31,500	12,500
2000	41,600	16,200
2005	52,400	20,200
2010	66,600	24,800
2015	85,600	31,300
2020	106,000	38,200

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1 DOE, *Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics* (DOE/RW-0006, Rev. 2), September 1986.
2 Actual. Subsequent data are projections.
3 Includes future immobilized and other forms of waste.
4 Includes previously disposed suspect transuranic waste and stored waste.
5 Assumes no reprocessing of spent nuclear fuel.
6 Volumetric data for intact assemblies calculated from data contained in referenced document. Cubic meters are used for convenience and consistency. However, spent nuclear fuel quantities are usually expressed in terms of metric tons of uranium (MTU). See Table 2. In 1985, the inventory of spent nuclear fuel reached about 13,750 MTU.
7 Includes waste from the decommissioning and decontamination of nuclear reactors, which may have higher than Class C concentrations of radioactivity. Exclusive of reprocessing.
8 Less than 200 cubic meters of solidified high-level waste will be produced from reprocessing waste stored at a facility near West Valley, New York.
9 For brevity and convenience, the term "waste" may be used in this paper to mean both spent fuel and high-level waste from reprocessing.

10 The "Upper Reference Case" is one of four projection series devised by EIA. The others are the "No New Orders Case," "Lower Reference Case," and "Optimistic Case." DOE selected the Upper Reference Case series as its reference planning case because it typified a moderate growth condition in which projected demand for additional nuclear power is satisfied by new orders of light-water reactors, as well as taking into account industry practice to extend the fuel cycle.
11 Fuel assembly irradiation (or burnup) is measured in units of megawatt-days thermal per metric ton of uranium (MWDT/MTU).
12 EIA, *World Nuclear Fuel Cycle Requirements 1986* [DOE/EIA 0436(86)], September 1986. The post-1985 volumetric data computed by OCRWM were based on the projected mix of commercial boiling water and pressurized water reactors.
13 Data are projections.

High-Level Radioactive Waste

Radioactive waste produced from the reprocessing of either commercial or defense spent fuel accounts for the other type of nuclear waste that DOE is required to accept and dispose of under the provisions of the NWPA and subsequent Presidential actions. High-level waste is distinguished from spent nuclear fuel by its much greater volume, substantially lower radioactivity, and variety of forms ranging from liquids to solids.

A small quantity of liquid high-level radioactive waste was generated during the commercial reprocessing of power reactor spent fuel at a facility near West Valley, New York, from 1966 through 1972. No additional commercial liquid high-level waste from reprocessing is being generated in this country. The liquid waste stored at the West Valley facility is scheduled to be solidified into glass and encapsulated in stainless steel canisters for eventual disposal in a geologic repository.

The preponderant share of immobilized high-level waste from reprocessing that is scheduled to be emplaced in geologic repositories comes from the Nation's nuclear defense materials production.

Defense high-level waste is generated and stored at three DOE sites: (1) the Savannah River Plant (South Carolina), (2) the Idaho National Engineering Laboratory (Idaho), and (3) the Hanford Reservation (Washington).

Neutralized defense high-level waste in the form of liquid, salt, and sludge is stored in underground tanks at the Hanford and Savannah River Plant sites. At the Idaho National Engineering Laboratory site, acidic liquid high-level waste is stored in stainless steel tanks. It is routinely converted to a dry, granular solid called calcine for storage in bins in underground concrete vaults. As a result of the President's decision in April 1985 to accept the Secretary of Energy's recommendation that defense waste be emplaced in a civilian geologic repository, high-level waste stored at the three DOE sites will be converted to a solid waste form for ultimate disposal in a combined defense-commercial repository. The ultimate disposal of waste at Hanford is the subject of a draft *Environmental Impact Statement*. The following table depicts cumulative inventories of defense high-level waste from 1986 through the year 2020.

Table 3. · Inventories of All Forms of High-Level Defense Waste[14]

Year	Cubic Meters (in Thousands)
1986[15]	340
1990	342
1995	340
2000	343
2005	361
2010	365
2015	371
2020	374

[14] DOE, *Spent Fuel and Radioactive Waste Inventories, Projections and Characteristics* (DOE/RW-0006, Rev. 2), September 1986.

[15] Data are projections and exclude high-level waste incorporated in borosilicate glass.

— DOE —

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OCRWM Backgrounder

United States Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

DOE/RW-0138

April 1987

COOPERATIVE DEMONSTRATION PROJECTS FOR SPENT NUCLEAR FUEL

INTRODUCTION

The U.S. Department of Energy (DOE) is implementing, in cooperation with the nuclear power industry, several technology demonstration projects designed to assist utilities in enhancing spent fuel storage capacity at primary nuclear reactor sites.[1] Objectives of the cooperative demonstration projects, in accordance with Section 132 and Section 218 of the Nuclear Waste Policy Act of 1982 (NWPA), are to encourage and to expedite the efficient use by the utilities of existing storage facilities and to provide technologies for adding new storage capacity.

Until DOE accepts the spent fuel for disposal at a geologic repository, nuclear utilities have the primary responsibility for the storage of their spent fuel and for the effective use of that storage capacity. By focusing on cooperative demonstration projects with utilities that have expressed a high degree of interest in specific technologies, the storage concepts developed will be those which most appropriately address the needs of the utilities.

STORAGE OF SPENT FUEL

Spent fuel assemblies removed from nuclear reactors are stored temporarily in water pools that cool the spent fuel rods and shield workers and others at the site against radiation. Many of these storage pools were intended originally for short-term storage, and their capacities are generally limited. Some utilities, faced with potential spent fuel storage problems, have developed and subsequently obtained approval from the U.S. Nuclear Regulatory Commission (NRC) for various methods of extending their onsite storage capacity.

[1]Spent nuclear fuel refers to fuel that has been removed from a nuclear reactor core primarily because it can no longer sustain an efficient chain reaction. High-level radioactive waste, generated from the reprocessing of spent nuclear fuel to extract plutonium and the remaining usable uranium, results largely from defense nuclear activities.

One method employed by the utilities is the "reracking" of fuel assemblies in storage pools to obtain greater storage densities. By changing the configuration of the racks that hold the spent fuel in the storage pools, and by adding neutron-absorbing material, it is possible to store more than double the fuel that had been held in the originally designed racks. Another method, called "transshipping," involves transporting spent fuel from reactor sites with storage limitations to other reactor sites of the same utility that have available storage capacity.

CURRENT DEMONSTRATION PROJECTS

DOE's Office of Civilian Radioactive Waste Management (OCRWM) is implementing the provisions of the NWPA that are designed to establish, in cooperation with the utilities, new technologies for onsite dry storage and consolidation of spent fuel. The efficient use of existing storage facilities and the addition of new at-reactor storage capacity will be enhanced through the following activities:

- a cooperative demonstration program with the private sector to
  - — demonstrate spent fuel rod consolidation in existing storage pools and in a dry environment, and
  - — develop dry storage technologies that the NRC may, by rule, approve for use at civilian reactor sites;
- consultative and technical assistance to utilities on a cost-shared basis to assist each utility in obtaining NRC licensing and construction authorization for the application of new technologies; and
- a cost-shared research and development (R&D) program at Federal facilities to collect the necessary data to assist the utilities in the licensing process.

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OCRWM is currently supporting cooperative demonstrations of rod consolidation and dry storage with several utilities. In addition, OCRWM is conducting spent fuel research and development to provide data to the utilities for obtaining licenses for these new technologies. These cooperative R&D activities are intended to establish one or more technologies that the NRC may approve by rule for use at reactor sites without, to the maximum extent practicable, the need for additional site-specific approvals.

Rod Consolidation Cooperative Demonstration Projects

Rod consolidation differs from reracking in that rod consolidation involves dismantling the fuel assemblies and placing them in canisters, whereas reracking places the intact assemblies in reconfigured storage racks that are designed for higher storage densities. Rod consolidation may be done in a storage pool, or it may be done in a dry environment. Rod consolidation increases the capacity of spent fuel storage pools which have sufficient structural strength to safely support a more compact array of spent fuel rods that have been separated from their associated hardware components.

In 1981, DOE successfully completed a "cold" (nonradioactive) demonstration of prototypical rod consolidation equipment. In May 1983, DOE issued a solicitation for cooperative agreement proposals for in-pool rod consolidation demonstrations that could provide a basis for future licensing by the NRC. A cooperative agreement for a rod consolidation demonstration project has been negotiated with the Northeast Utilities Services Company of Hartford, Connecticut. After the completion of the cooperative demonstration project, DOE expects to assemble a data base that will provide sufficient data to enable the utilities to apply for licensing of rod consolidation.

OCRWM has initiated R&D of equipment and methods for dry rod consolidation of spent fuel at the Idaho National Engineering Laboratory (INEL). The purpose of this demonstration, which is known as the Prototypical Consolidation Demonstration Project (PCDP), is to show that dry rod consolidation is feasible on a production line scale for use at NWPA facilities, including the repository or the monitored retrievable storage (MRS) facility, if authorized by Congress. The PCDP consists of four sequential phases that will lead to a planned demonstration of the process in 1989.

OCRWM has two new rod consolidation projects that are in the planning phase. The first one is known as the Nonfuel-bearing-component Volume Reduction Demonstration. The objective of this project is to design new equipment that will reduce the overall bulk of residual nonfuel hardware and other parts. The second project will be a canister welding project to test various methods of sealing canisters containing spent fuel rods from a rod consolidation process. These two projects are to be initiated in fiscal year 1989 and are expected to be completed several years later.

Dry Storage Cooperative Demonstration Projects

Dry storage systems provide a fuel storage alternative whenever reracking or rod consolidation cannot be undertaken because of economic, seismic, or structural limitations of spent fuel storage pool systems. Systems for dry storage include casks, drywells, silos, and vaults. Casks are large metal containers with radiation shielding that are stored aboveground. Drywells are below-grade wells with steel and concrete linings that are designed to hold one or more spent fuel assemblies; the surrounding earth provides an additional radiation barrier, as well as a medium for conducting heat from the drywell. Silos are concrete cylinders built aboveground that provide sealed secondary containment for spent fuel. Vaults are large concrete structures that use natural air convection for cooling. All of these dry storage systems are designed to have low maintenance requirements and to be modular in order to provide additional capacity as required.

DOE has extensive experience in conducting demonstrations of dry storage systems for spent fuel. Drywell, silo, and vault storage systems have been demonstrated at several DOE facilities in Nevada. However, dry storage systems demonstrated under DOE's auspices have never been licensed by the NRC for commercial use.

A solicitation for cooperative agreement proposals for licensed dry-storage demonstrations was issued by DOE in May 1983, leading to cooperative agreements that were negotiated with the Virginia Electric Power Company and the Carolina Power & Light Company in March 1984. At Virginia Power's Surry Nuclear Plant, construction of an independent spent fuel storage installation has been completed, and NRC issued a license for the system in July 1986.

DOE's agreement with Carolina Power & Light (CP&L) provides for a licensed demonstration of dry storage in horizontal, modular concrete silos at the site of the H.B. Robinson plant in South Carolina. On March 28, 1986, NRC approved the topical report prepared on CP&L's demonstration. Licensing of CP&L's Independent Spent Fuel Storage Installation is upcoming, and construction is expected to begin in the near future.

OCRWM has also initiated dry storage technology R&D activities at DOE's Idaho National Engineering Laboratory (INEL). Spent fuel assemblies from the Surry plant were shipped to INEL for an unlicensed demonstration of dry storage casks and to conduct tests under situations that approach the bounding parameters and limiting conditions of dry storage. Initial testing has been completed at INEL on dry storage casks of three different designs and manufacture; long-term monitoring is now in process.

— DOE —

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Rm 311

OCRWM Backgrounder

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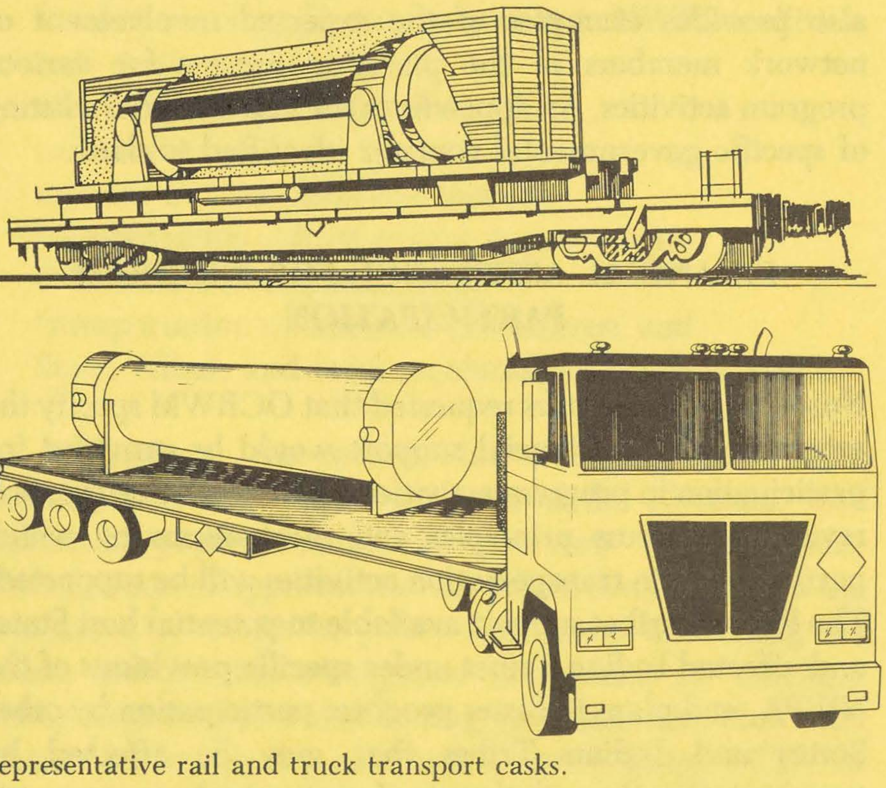
PUBLIC PARTICIPATION IN THE DEVELOPMENT OF THE TRANSPORTATION INSTITUTIONAL PLAN

In cooperation with the public, the Office of Civilian Radioactive Waste Management (OCRWM) has developed the *Transportation Institutional Plan* (DOE/RW-0094, August 1986). This document lays the foundation for interaction among all interested parties in addressing and working to resolve issues related to the establishment and operation of a transportation system. This transportation system supports the requirements of the Nuclear Waste Policy Act of 1982 (NWPA) to develop a national capability for disposal of spent nuclear fuel.

The Plan is divided into three chapters. Chapter 1 provides background information, discusses the purposes of the Plan and planning principles, and describes the projected NWPA transportation system and plans for its integrated development. Chapter 2 describes the major participants with whom OCRWM expects to interact to build the transportation system. Chapter 3 suggests mechanisms for interaction that will foster wide participation in program planning and implementation, and provides a framework for managing and resolving transportation issues. Appendices to the Plan include discussion of specific transportation issues, detailed information on Federal roles in regulating transportation, and a directory of organizational contacts.



Representative rail and truck transport casks.

When developing the Plan, OCRWM made a special effort to address comments received on the *Draft Transportation Institutional Plan* (DOE/RW-0031, September 1985) and at the Transportation Institutional Workshop in Atlanta, Georgia, in November 1985. The most frequently received comments called for:

- development of a comprehensive transportation plan to provide integrated guidance on major elements of the NWPA transportation system;
- definition of the roles of various offices of the Department of Energy (DOE) in planning for NWPA transportation and Federal agency responsibilities for regulating nuclear waste transportation;
- clarification on planned interactions with interested parties;
- definition of the degree to which OCRWM will provide financial assistance to support participation in transportation planning activities;
- discussion of the potential use of conflict-resolution procedures; and
- detailed discussion of OCRWM's plans to address specific transportation issues, and the expected timing of related OCRWM policy decisions.

In response to such comments, the draft Plan was significantly revised and supplemented by a Comment/Response Document. The following discussion provides a synopsis of major comments and OCRWM's effort to effectively address such comments in the Plan.

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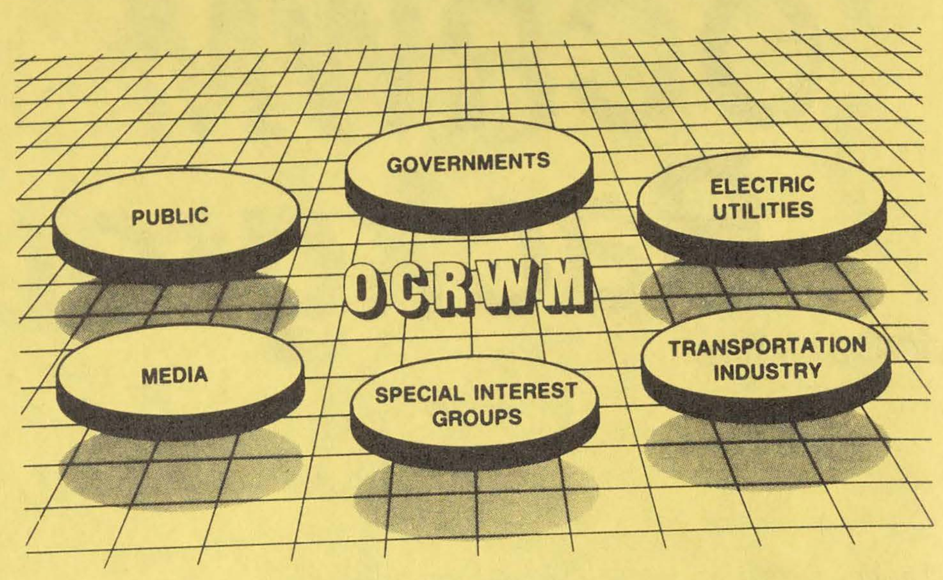
DEVELOPMENT OF COMPREHENSIVE TRANSPORTATION PLAN

The most frequent comment received by OCRWM was that the *Transportation Institutional Plan* should be combined with the *Transportation Business Plan* (DOE/RW-0046, January 1986) and an operations plan, yet to be developed, to provide integrated guidance on major elements of NWPA transportation planning. In response to such comments, OCRWM accelerated its schedule to produce a comprehensive transportation plan. As a first step, discussion papers on specific transportation issues that were originally intended to be published separately were incorporated into the *Transportation Institutional Plan* as an appendix, and an overview of OCRWM's preliminary plans for the technical development of the NWPA transportation system was provided.

A second major step toward integration of the transportation plan is expected in 1988 with the release in draft form of the first iteration of a comprehensive document containing three planning elements for: (1) institutional interactions and related planning principles; (2) business activities related to cask and equipment design and development, and the study of service and management options; and (3) operational procedures and activities. The operational element in the first version of the comprehensive plan will be a preliminary outline of operational activities and procedures. When the comprehensive plan is fully developed, the operational element will provide an overview of the basic procedures under which nuclear waste will be transported to NWPA facilities. The draft comprehensive plan will, of course, be issued for public review and comment.

FEDERAL AGENCIES INVOLVED IN TRANSPORTATION PLANNING AND REGULATION

Some commenters requested that OCRWM include in the *Transportation Institutional Plan* a discussion of various DOE offices now involved in planning for NWPA transportation, and a review of the roles of Federal agencies having responsibility for regulating nuclear waste transportation. A discussion was added to the Plan to define the roles of offices within OCRWM as well as the support that is provided by DOE Operations Offices and the repository program project offices. In addition, an appendix to the Plan provides a detailed summary of Federal agency roles in regulating nuclear waste transportation.



Six major groups will interact with OCRWM in the *Communications Network*.

INTERACTION WITH INTERESTED PARTIES

Many commenters suggested that the *Draft Transportation Institutional Plan's* discussion of planned interaction with interested parties was vague. The revised Plan therefore contains an expanded discussion of a network whose members OCRWM expects will actively participate in establishing a system for NWPA transportation. This network is comprised of six categories of participants: (1) Federal, State, Indian Tribal, and local governments; (2) the electric utilities; (3) the transportation industry; (4) special interest groups; (5) the media; and (6) the public at large. The Plan provides detailed information on methods OCRWM will use to facilitate interactions with members of the network, including information exchange; active participation in meetings, briefings and workshops; the potential use of issue-resolution mechanisms; and the support of program participation through various funding mechanisms. The Plan also provides examples of the expected involvement of network members in the planning process for various program activities. An appendix to the Plan includes a listing of specific governmental contacts identified to date.

FINANCIAL ASSISTANCE FOR PROGRAM PARTICIPATION

Numerous commenters requested that OCRWM specify the extent to which financial support would be provided for participation in program activities. The Plan, therefore, was revised to discuss principles and mechanisms by which participation in transportation activities will be supported. The Plan describes support available to potential host States and affected Indian Tribes under specific provisions of the NWPA, and plans to foster program participation by other States and Indian Tribes that may be affected by transportation through the use of contractual arrangements with national, regional, and transportation-related organizations.

POTENTIAL USE OF CONFLICT-RESOLUTION PROCEDURES

Many commenters suggested that OCRWM specify the manner in which it expects to manage conflicts. OCRWM plans to use all practical measures to resolve an issue through cooperative discussion and interaction. Forms of interaction, such as workshops, seminars, and issue study groups, are discussed in detail in the Plan. In recognition that an impass on certain issues could arise, the Plan reviews several mechanisms that may be appropriate to assist in issue resolution, including negotiation and mediation.

DISCUSSION OF SPECIFIC TRANSPORTATION ISSUES

While many comments focused on the framework for cooperation interactions in the development of the NWPA transportation system, numerous comments addressed specific transportation issues. OCRWM categorized such issues and associated issue-elements under 16 major headings in the *Draft Transportation Institutional Plan*:

- transportation of defense waste;
- prenotification;
- physical protection procedures;
- highway routing;
- rail routing;
- inspection and enforcement for highway and rail shipments;
- emergency response;
- liability coverage for transportation to NWPA facilities;
- cask design and testing;
- overweight truck shipments;
- rail service analysis;
- mixture of transportation modes;
- transportation infrastructure improvements;
- OCRWM training standards;
- transportation operational procedures; and
- State, tribal, and local regulation of transportation.

An Appendix to the revised Plan was then added with detailed discussion papers on each of the 16 issues. The discussion papers include an overview of the issues, identification of opportunities for public involvement in the evaluation of OCRWM policy options for addressing the issues, and provide a suggested time-frame for reaching policy decisions and conducting program activities. The tentative schedule for decisions accommodates OCRWM program requirements only; additional comments providing State, Indian Tribal, and other perspectives on timing are invited to enable a more definitive schedule.

CONCLUSION

The *Transportation Institutional Plan* establishes a foundation for OCRWM's projected interactions in establishing an NWPA transportation system. OCRWM hopes that continued cooperative effort in implementing provisions of the Plan and in addressing transportation concerns will facilitate the resolution of issues through a process that focuses on communication and constructive interaction rather than conflict.

— DOE —

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OCRWM Backgrounder

United States Department of Energy
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STUDIES OF ALTERNATIVE METHODS OF RADIOACTIVE WASTE DISPOSAL

INTRODUCTION

The Nuclear Waste Policy Act of 1982 (NWPA), signed into law by the President on January 7, 1983, establishes a national policy for the safe storage and permanent disposal of spent nuclear fuel and high-level radioactive waste (HLW).[1] The NWPA directs the U.S. Department of Energy (DOE) to develop and operate a system of waste disposal that emphasizes the use of deep-mined geologic repositories. Prior to the passage of the NWPA, DOE assessed the use of geologic repositories and other nuclear waste disposal alternatives in an Environmental Impact Statement (EIS) entitled the *Management of Commercially Generated Radioactive Waste* (DOE/EIS-0046F, October 1980). The EIS evaluated the following alternatives to deep-mined geologic repositories: subseabed disposal, emplacement in very deep holes, rock melt, island-based geologic, ice sheet, deep-well injection, and space disposal as well as the transmutation waste-form treatment, and indefinite surface storage. This backgrounder provides an overview of these nuclear waste disposal alternatives.

SUBSEABED DISPOSAL

The subseabed disposal concept involves the burial of solidified waste inside high-integrity canisters beneath the ocean floor. Since disposal would occur in the tectonically stable clay-rich sediments of the mid-plate regions, it is expected that the waste would remain isolated from the biosphere for extremely long periods of time and, therefore, not present a threat to plant and animal life. Movement of any waste isotopes escaping from the ocean sediments to the more biologically active near-surface water is expected to be a slow process, accompanied by dilution and dispersion. In addition, the great depth of the water constitutes a barrier to human intrusion.

Several potential problems remain, however. Most importantly, the feasibility of executing the concept has not been established. For example, it may be difficult to emplace the waste containers beneath the ocean floor to ensure containment until the waste decays to acceptable low levels. Additionally, the radionuclides may be altered by chemical reactions with the sediments. Even if subseabed disposal were to prove technically feasible, it may be difficult to develop an effective international, legal, and administrative structure to regulate and monitor a subseabed repository.

The Subseabed Disposal Program, a joint research effort between DOE, the Environmental Protection Agency, other Federal agencies, and international organizations (e.g., the Nuclear Energy Agency of the Organization for Economic Cooperation and Development) has been an ongoing program since 1974. However, recent and projected budget limitations on research and development expenditures have resulted in a reassessment of this program. As a result of this review, DOE did not request funds for the Subseabed Disposal Program in its fiscal year 1987 budget request to Congress. DOE's Office of Civilian Radioactive Waste Management (OCRWM) plans to conduct an orderly closing of the project while preserving the scientific information for future use.

DEEP HOLE DISPOSAL

The deep hole disposal concept involves the placement of waste canisters as far as 10,000 meters (approximately 6 miles) underground, a considerable distance from the accessible environment and below circulating ground water. At these depths, the nuclear waste may be

[1] Spent nuclear fuel refers to fuel that has been removed from a nuclear reactor core primarily because it can no longer sustain an efficient chain reaction. High-level radioactive waste, generated from the reprocessing of spent nuclear fuel to extract plutonium and the remaining usable uranium, results largely from defense nuclear activities.

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effectively contained while the waste decays to stable forms or levels that pose little threat to human health. To serve as a waste repository at these depths, the host rock must retain its character and structural stability under the heat and radiation conditions introduced by the waste.

The deep hole disposal concept was not defined as a proposed action in the EIS for the following reasons: (1) an incomplete understanding of the hydrologic characteristics of deep crystalline and sedimentary rock units, (2) the technical uncertainty associated with current drilling technologies that would have to be used to attain the extreme depths required to isolate nuclear waste from the biosphere, and (3) the lack of knowledge of in-situ rock mechanics properties under high pressure and temperature conditions.

ROCK MELT DISPOSAL

The rock melt disposal concept involves the emplacement of liquid or slurry waste into a deep underground hole or cavity. After the water in the waste has evaporated, the surrounding rock would melt from the heat generated by the decay of the radioactive waste. This process, in turn, would slowly dissolve the waste. The waste rock solution would slowly solidify, trapping the radioactive material in a relatively insoluble form deep below the surface of the Earth. The waste-rock-solidified conglomerate that would ultimately result is expected to be extremely leach resistant and, hence, could provide greater long-term containment of waste isotopes than could a mined geologic repository. Because less mining activity would be involved than for a mined geologic repository, the relative cost advantages of this concept could be substantial.

The rock melt disposal concept was not defined as a proposed action in the EIS largely because of the time required to monitor the process prior to full solidification of the nuclear waste. About 1,000 years would elapse before total solidification occurs. A lack of understanding of the heat transfer and phase-change phenomena in rock—information necessary to establish the stability of the molten rock matrix and to develop engineering methods for emplacement—would further complicate the monitoring task.

ISLAND GEOLOGIC DISPOSAL

The island geologic disposal concept involves the siting of deep-mined geologic repositories in islands. Preferred island locations are those in remote areas and devoid of known natural resources. Uninhabited islands that are hydrologically separated from large continental land masses offer potential advantages. Potentially adverse radiological health effects would be minimized. Further, any leakage of radioactivity into the island's ground water could be easily detected. Additionally, in the event of high-level radioactive waste leakage into the environment, the waste would be diluted by the surrounding seawater.

Drawbacks of the island geologic disposal concept include the risks associated with ocean transport of nuclear waste during adverse weather conditions. Additionally, many islands experience frequent and intense seismic and volcanic activity. Such activity could discharge the waste into either lava flows or into the atmosphere. Moreover, islands of volcanic origin have geologic foundations that are permeable and, hence, susceptible to interaction of fresh and marine water. The presence of water could contribute to the corrosion of waste canisters, leaching, and the eventual transport of radionuclides into the biosphere. Potential opposition from countries in the vicinity of a proposed island repository is an additional consideration.

ICE SHEET DISPOSAL

Without significant climatic changes, the Antarctic and Greenland ice caps could provide long-term isolation of nuclear waste from the biosphere. Three ice sheet disposal concepts have been considered: passive slow descent, anchor, and surface storage emplacement. Passive slow descent emplacement would allow for the waste canister to be placed in a shallow hole, eventually melting its way to the bottom of the ice sheet as heat is emitted from the radioactive decay process. Anchor emplacement parallels that of passive emplacement, but an anchor cable attached to the canister would limit the descent depth and enable retrieval of the waste canister. Surface storage emplacement requires the use of large storage units constructed above the snow surface and then filled with waste. The radioactive waste would act as a heat source causing the storage units to slowly melt their way to the bottom of the ice sheet.

An advantage of the ice sheet disposal concept is that the polar regions are uninhabited and desolate areas that would provide for the almost total isolation of the nuclear waste. The ice masses are thousands of meters thick, extend uniformly, and remain stable for long periods of time. At great depths (100 meters or more), ice behaves like a plastic and flows to seal fissures and to close cavities. Isolation of radioactive wastes would be ensured for long periods of time due to the very slow movement of ice.

Disadvantages of the ice sheet disposal concept include uncertainties surrounding both the disposal technologies and the impact of future climatic changes on the stability and size of the ice sheets. Another disadvantage is the expected high operational costs of ice sheet disposal because of the remoteness of the locations and the adversity of weather conditions. Ice sheet dynamics are not well known. Global climatic effects could accelerate the melting of large portions of ice masses from the heat generated from radioactive waste decay and thus open paths to the dispersion of waste. Finally, the Antarctic Treaty of 1959, of which the United States is a signatory, specifically prohibits the disposal of nuclear waste in the Antarctic.

DEEP-WELL INJECTION

The deep-well injection concept is the emplacement of liquid or slurried nuclear waste in deep geologic formations capped by an impermeable boundary layer. For acidic liquid waste, the method would involve the pressurized pumping of the waste to depths of 1,000 to 5,000 meters (3,300 to 16,000 feet) into a porous or hydrofractured geologic formation suitably isolated from the biosphere by relatively impermeable overlying strata. The waste would progressively disperse throughout the host rock. Deep-well injection is a working technology compared to technologies required to implement the rock melt and deep hole disposal concepts. Shale is considered a suitable geologic medium because of its ability to provide isolation of the waste from ground water and the environment.

The deep-well injection alternative requires either mechanical or chemical processing of spent fuel prior to its disposal, which is a possible drawback. Another possible limitation of the deep-well injection method concerns the mobility of a liquid waste form within a porous host rock formation. The combination of a liquid waste form and a porous rock body increases the chances that the waste could come into contact with the biosphere.

SPACE DISPOSAL

The National Aeronautics and Space Administration (NASA) and DOE have studied several space disposal concepts including the transport to and injection of nuclear waste into the sun or the emplacement of waste on the Earth's moon. These methods were found unsuitable for technical and space exploration reasons. Another concept involved sending reprocessed nuclear waste into a circular solar orbit about midway between Earth and the planet Venus. First, the space shuttle would carry the nuclear waste package to low Earth orbit. A transfer vehicle would then separate from the shuttle to place the waste package and another propulsion stage into an Earth-escape trajectory. The transfer vehicle would return to the shuttle while the remaining rocket stage would move the waste into solar orbit.

Disadvantages of the space disposal concept include the possibility of launch failure and the potential inability of the waste packaging system to contain the waste in the event of such a failure. Additionally, the costs of launching nuclear waste into space would be very high. Therefore, the space disposal concept would be restricted to providing for the extraterrestrial isolation of long-lived radionuclides such as Iodine^{129} and Technetium^{99}. In turn, this method would require the reprocessing of high-level radioactive waste into specially tailored waste forms. Waste remaining on earth would have to be disposed of in a mined geologic repository. The use of extraterrestrial disposal, in conjunction with terrestrial disposal, would require an expected additional cost without achieving a significant reduction in long-term risk over emplacement of waste only in a mined geologic repository. Consequently, in April 1982, NASA and DOE agreed to discontinue further study of the space disposal concept.

TRANSMUTATION

Transmutation is not a disposal method but a treatment method for high-level radioactive waste that would be used in conjunction with specific disposal alternatives, such as the deep-mined geologic disposal option. The transmutation concept involves the reprocessing of spent fuel to recover uranium and plutonium (or processing to obtain a liquid high-level waste stream when uranium and plutonium are not to be recycled). The remaining high-level waste stream is partitioned into an actinide[2] waste stream and a fission product stream. The fission product stream is concentrated, solidified, and sent to a mined geologic repository for disposal. The actinide waste stream is combined with uranium (or uranium and plutonium), fabricated into fuel rods, and reinserted into a reactor. In the reactor, about 5 to 7 percent of the recycled waste actinides are transmuted to stable or short-lived isotopes, which are separated out during the next recycle step for disposal in the repository. Numerous recycles would result in nearly complete transmutation of the waste actinides; however, additional waste streams are generated with every recycle. Transmutation provides no reduction in the quantities of long-lived fission product radionuclides, such as Technetium^{99} and Iodine^{129} in the fission product stream that is sent to geologic disposal.

[2]Actinides are a group of elements that include uranium and all man-made transuranic elements (e.g., Berkelium and Californium). Fission products are nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the fission fragments' radioactive decay.

SURFACE STORAGE

The surface storage alternative would allow for existing spent fuel to be left indefinitely where it is being stored. Any additional waste discharges from the operation of commercial nuclear powerplants would be stored indefinitely in water basin facilities at the reactors or at other sites. Reprocessing of wastes is assumed not to be undertaken. This alternative would allow for delays and contingencies that could not have been foreseen in the research, development, and planning stages for deep-mined geologic disposal.

Disadvantages associated with the surface storage alternative include the extensive maintenance and monitoring activities that necessarily accompany surface storage, as well as the potential health and safety and environmental risks attendant to storing nuclear waste in relatively accessible locations.

— DOE —

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OCRWM Backgrounder

United States Department of Energy
Office of Civilian Radioactive Waste Management
Washington, DC 20585

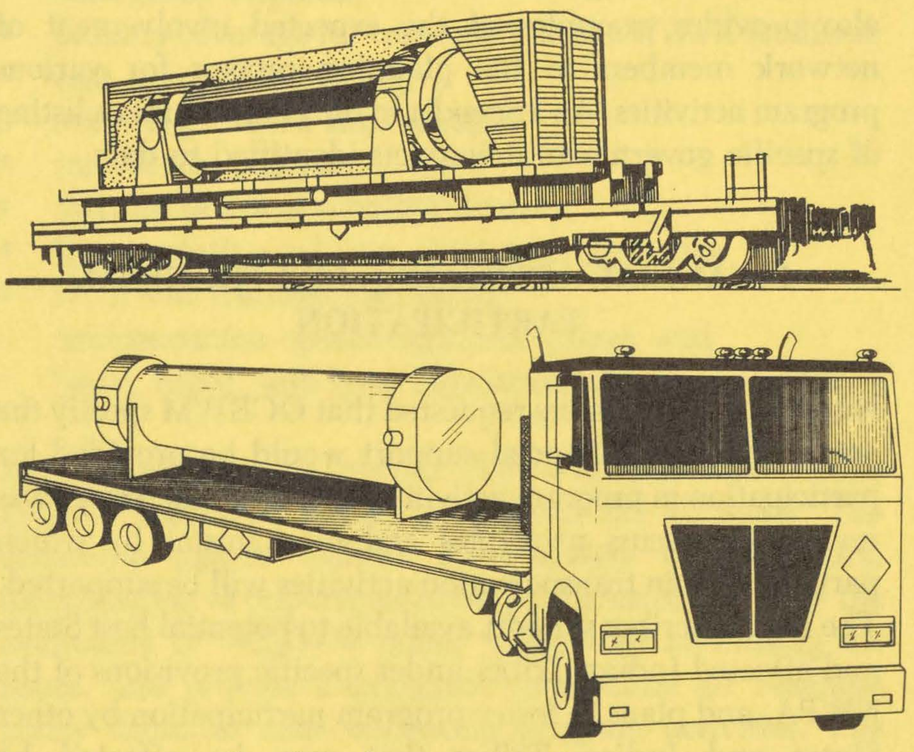
DOE/RW-0141

April 1987

PUBLIC PARTICIPATION IN THE DEVELOPMENT OF THE TRANSPORTATION INSTITUTIONAL PLAN

In cooperation with the public, the Office of Civilian Radioactive Waste Management (OCRWM) has developed the *Transportation Institutional Plan* (DOE/RW-0094, August 1986). This document lays the foundation for interaction among all interested parties in addressing and working to resolve issues related to the establishment and operation of a transportation system. This transportation system supports the requirements of the Nuclear Waste Policy Act of 1982 (NWPA) to develop a national capability for disposal of spent nuclear fuel.

The Plan is divided into three chapters. Chapter 1 provides background information, discusses the purposes of the Plan and planning principles, and describes the projected NWPA transportation system and plans for its integrated development. Chapter 2 describes the major participants with whom OCRWM expects to interact to build the transportation system. Chapter 3 suggests mechanisms for interaction that will foster wide participation in program planning and implementation, and provides a framework for managing and resolving transportation issues. Appendices to the Plan include discussion of specific transportation issues, detailed information on Federal roles in regulating transportation, and a directory of organizational contacts.



Representative rail and truck transport casks.

When developing the Plan, OCRWM made a special effort to address comments received on the *Draft Transportation Institutional Plan* (DOE/RW-0031, September 1985) and at the Transportation Institutional Workshop in Atlanta, Georgia, in November 1985. The most frequently received comments called for:

- development of a comprehensive transportation plan to provide integrated guidance on major elements of the NWPA transportation system;
- definition of the roles of various offices of the Department of Energy (DOE) in planning for NWPA transportation and Federal agency responsibilities for regulating nuclear waste transportation;
- clarification on planned interactions with interested parties;
- definition of the degree to which OCRWM will provide financial assistance to support participation in transportation planning activities;
- discussion of the potential use of conflict-resolution procedures; and
- detailed discussion of OCRWM's plans to address specific transportation issues, and the expected timing of related OCRWM policy decisions.

In response to such comments, the draft Plan was significantly revised and supplemented by a Comment/Response Document. The following discussion provides a synopsis of major comments and OCRWM's effort to effectively address such comments in the Plan.

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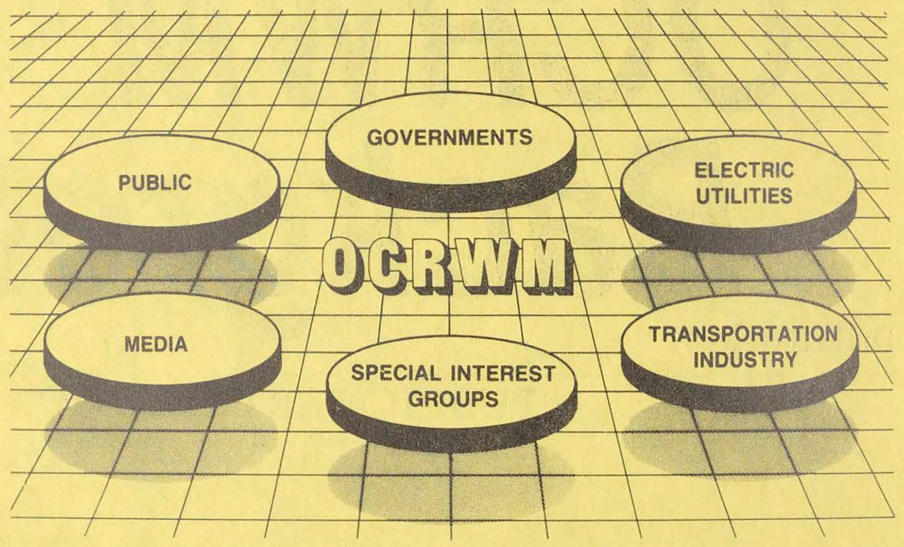
DEVELOPMENT OF COMPREHENSIVE TRANSPORTATION PLAN

The most frequent comment received by OCRWM was that the *Transportation Institutional Plan* should be combined with the *Transportation Business Plan* (DOE/RW-0046, January 1986) and an operations plan, yet to be developed, to provide integrated guidance on major elements of NWPA transportation planning. In response to such comments, OCRWM accelerated its schedule to produce a comprehensive transportation plan. As a first step, discussion papers on specific transportation issues that were originally intended to be published separately were incorporated into the *Transportation Institutional Plan* as an appendix, and an overview of OCRWM's preliminary plans for the technical development of the NWPA transportation system was provided.

A second major step toward integration of the transportation plan is expected in 1988 with the release in draft form of the first iteration of a comprehensive document containing three planning elements for: (1) institutional interactions and related planning principles; (2) business activities related to cask and equipment design and development, and the study of service and management options; and (3) operational procedures and activities. The operational element in the first version of the comprehensive plan will be a preliminary outline of operational activities and procedures. When the comprehensive plan is fully developed, the operational element will provide an overview of the basic procedures under which nuclear waste will be transported to NWPA facilities. The draft comprehensive plan will, of course, be issued for public review and comment.

FEDERAL AGENCIES INVOLVED IN TRANSPORTATION PLANNING AND REGULATION

Some commenters requested that OCRWM include in the *Transportation Institutional Plan* a discussion of various DOE offices now involved in planning for NWPA transportation, and a review of the roles of Federal agencies having responsibility for regulating nuclear waste transportation. A discussion was added to the Plan to define the roles of offices within OCRWM as well as the support that is provided by DOE Operations Offices and the repository program project offices. In addition, an appendix to the Plan provides a detailed summary of Federal agency roles in regulating nuclear waste transportation.



Six major groups will interact with OCRWM in the *Communications Network*.

INTERACTION WITH INTERESTED PARTIES

Many commenters suggested that the *Draft Transportation Institutional Plan's* discussion of planned interaction with interested parties was vague. The revised Plan therefore contains an expanded discussion of a network whose members OCRWM expects will actively participate in establishing a system for NWPA transportation. This network is comprised of six categories of participants: (1) Federal, State, Indian Tribal, and local governments; (2) the electric utilities; (3) the transportation industry; (4) special interest groups; (5) the media; and (6) the public at large. The Plan provides detailed information on methods OCRWM will use to facilitate interactions with members of the network, including information exchange; active participation in meetings, briefings and workshops; the potential use of issue-resolution mechanisms; and the support of program participation through various funding mechanisms. The Plan also provides examples of the expected involvement of network members in the planning process for various program activities. An appendix to the Plan includes a listing of specific governmental contacts identified to date.

FINANCIAL ASSISTANCE FOR PROGRAM PARTICIPATION

Numerous commenters requested that OCRWM specify the extent to which financial support would be provided for participation in program activities. The Plan, therefore, was revised to discuss principles and mechanisms by which participation in transportation activities will be supported. The Plan describes support available to potential host States and affected Indian Tribes under specific provisions of the NWPA, and plans to foster program participation by other States and Indian Tribes that may be affected by transportation through the use of contractual arrangements with national, regional, and transportation-related organizations.

POTENTIAL USE OF CONFLICT-RESOLUTION PROCEDURES

Many commenters suggested that OCRWM specify the manner in which it expects to manage conflicts. OCRWM plans to use all practical measures to resolve an issue through cooperative discussion and interaction. Forms of interaction, such as workshops, seminars, and issue study groups, are discussed in detail in the Plan. In recognition that an impass on certain issues could arise, the Plan reviews several mechanisms that may be appropriate to assist in issue resolution, including negotiation and mediation.

DISCUSSION OF SPECIFIC TRANSPORTATION ISSUES

While many comments focused on the framework for cooperation interactions in the development of the NWPA transportation system, numerous comments addressed specific transportation issues. OCRWM categorized such issues and associated issue-elements under 16 major headings in the *Draft Transportation Institutional Plan*:

- transportation of defense waste;
- prenotification;
- physical protection procedures;
- highway routing;
- rail routing;
- inspection and enforcement for highway and rail shipments;
- emergency response;
- liability coverage for transportation to NWPA facilities;
- cask design and testing;
- overweight truck shipments;
- rail service analysis;
- mixture of transportation modes;
- transportation infrastructure improvements;
- OCRWM training standards;
- transportation operational procedures; and
- State, tribal, and local regulation of transportation.

An Appendix to the revised Plan was then added with detailed discussion papers on each of the 16 issues. The discussion papers include an overview of the issues, identification of opportunities for public involvement in the evaluation of OCRWM policy options for addressing the issues, and provide a suggested time-frame for reaching policy decisions and conducting program activities. The tentative schedule for decisions accommodates OCRWM program requirements only; additional comments providing State, Indian Tribal, and other perspectives on timing are invited to enable a more definitive schedule.

CONCLUSION

The *Transportation Institutional Plan* establishes a foundation for OCRWM's projected interactions in establishing an NWPA transportation system. OCRWM hopes that continued cooperative effort in implementing provisions of the Plan and in addressing transportation concerns will facilitate the resolution of issues through a process that focuses on communication and constructive interaction rather than conflict.

— DOE —

DOE/RW-0167
OCRWM Backgrounder

NBMG

Radiation and High-Level Radioactive Waste

This Backgrounder presents information about the sources, effects, and relative risks of so-called "ionizing"[1] radiation, a topic gaining the attention of many citizens across the country as the Federal Government implements the provisions of the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 (Amendments Act). This legislation established a national policy for the management of spent nuclear fuel and high-level radioactive waste. DOE has been assigned the responsibility for developing and operating a system to store, transport and permanently dispose of such waste in a safe and environmentally acceptable manner and within a reasonable time frame.

Sources of Radiation

Radiation is a natural part of life, permeating the universe since time began. Life as we know it has evolved in the presence of radiation. Our society is already familiar with some forms of radiation as attested by our widespread use of microwave ovens, radio and television, medical and dental X-rays, as well as by the tans we acquire at the beach from exposure to radiation from the sun. Ionizing radiation stems from the activity of atoms, which are the basic building blocks of all matter. Many atoms are stable, which means that they retain their particular structures and characteristics forever. However, some atoms are unstable and change into another form. The unstable atom is said to be "radioactive," and the process by which it changes to become a new atom is known as "radioactive decay." During this process, the unstable atom releases excess energy in the form of either electromagnetic waves or fast-moving particles. It is this property that makes the radioactive atom both beneficial if properly managed and harmful if not safely managed.

We are constantly exposed to ionizing cosmic radiation from the sun and stars. Naturally occurring radioactive atoms found in the environment (such as radon, uranium, and potassium) have always been around us and are contained in the food we eat, the structures we live in and the air we breathe. Nearly two-thirds of all the radiation to which we are typically exposed each year come from natural sources. The levels of natural radiation vary greatly from location to location. For example, a person living in Denver, CO, receives more than twice as much cosmic radiation from outer space as a person living in Washington, DC, because of the higher elevation.

Manmade sources of ionizing radiation associated with medical and dental tests (such as X-rays) and radiotherapy for disease account for about one-third of the total radiation dosage absorbed annually by the average person in this country.

The remaining amount of ionizing radiation (representing less than 1 percent of the total) to which we are exposed emanates from industrial uses of radioactive materials, minute emissions from certain consumer products (such as smoke detectors), lingering traces of radiation from previously conducted aboveground nuclear weapons tests, nuclear powerplant operations and miscellaneous activities.

The Nature of Ionizing Radiation

The three main types of ionizing radiation from radioactive decay are alpha and beta particle radiation and gamma radiation. Alpha particles are positively charged particles emitted from naturally occurring radioactive elements (such as radon and uranium), as well as some manmade elements (such as plutonium, which is produced in a nuclear powerplant). Alpha particles have little penetrating power and can be stopped easily by a sheet of paper or layer of skin. Beta particles are fast-moving electrons ejected from the nuclei, or cores, of radioactive atoms. While beta particles can pass

[1] The energy released during radioactive decay is called "ionizing radiation" because it can ionize, or electrically charge, atoms, a process whereby stable atoms may be changed through alteration of their basic electrical charge.

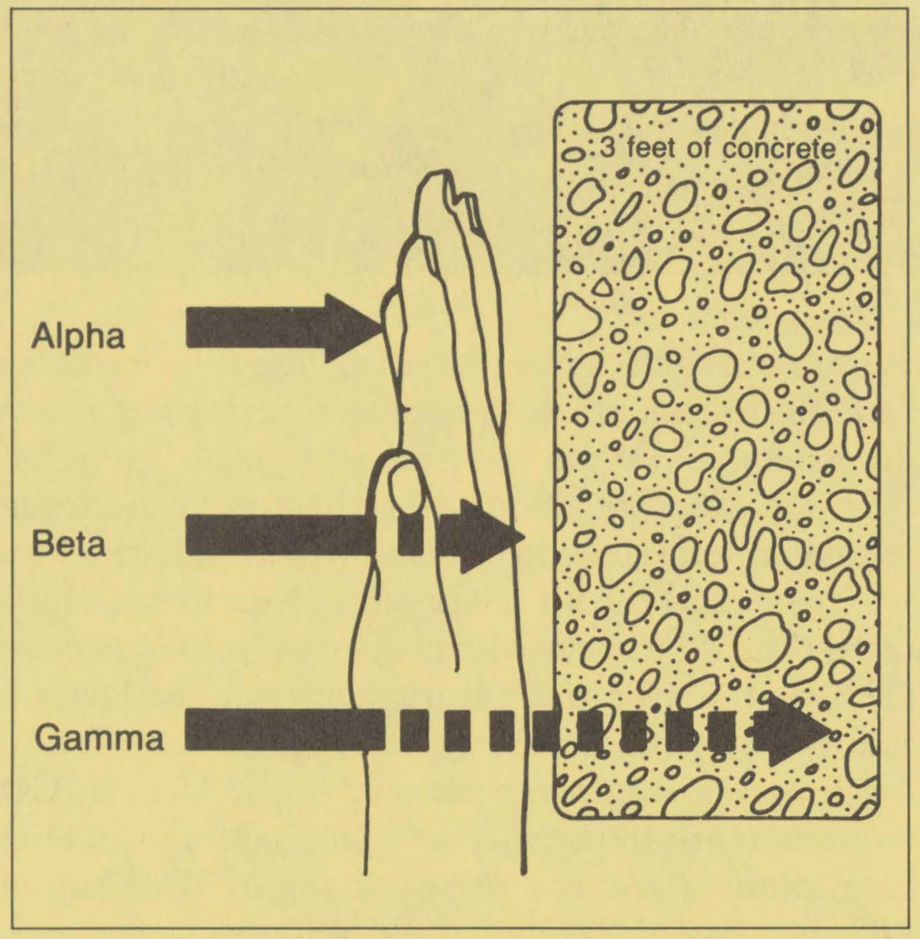


Figure 1 illustrates the penetrating properties of ionizing radiation.

through a sheet of paper, a thin sheet of aluminum foil can stop them. Gamma rays have great penetrating power, and they can pass through the human body. Gamma rays are used in cancer treatment to destroy the cells of a tumor without causing major damage to healthy cells nearby. Gamma rays require thick barriers of concrete, lead or steel to reduce their intensity.

Radioactivity essentially disappears over time as the radioactive atoms decay to nonradioactive elements. The time it takes the radioactive material to lose one-half of its radioactivity is called its "half-life." The half-lives of radioactive elements may vary from millionths of a second to billions of years.

Measuring Radiation

Radiation has been the subject of scientific inquiry for many decades. Scientists today know a great deal about what it is, where it comes from, how to detect and measure it and how it affects human beings.

Scientists and engineers use a variety of units to measure radiation. The unit commonly used to measure the radiation exposure that we receive is the "millirem" (mrem), which is one-thousandth of a "rem." This latter unit stands for "roentgen equivalent man," which is a unit devised by scientists to define the amount of damage to human tissue from a dose of ionizing radiation. Millirem dosages are usually related to time or events. To illustrate, most people in the United States receive a total dosage of less than 200 mrem per year from all sources of radiation. Naturally occurring radiation accounts for more than 130 mrem of that total, with medically related sources of radiation accounting for at least another 60 mrem. A dental X-ray gives a dose of a few mrem in a fraction of a second. A wide variety of other sources are responsible for the remaining radiation.

The Health Effects of Radiation

Ionizing radiation can cause changes in many things, including living human tissue. The biological effects of radiation depend on the amount of energy absorbed by living tissue, the types of cells exposed to radiation and the type of radiation striking the living tissue. If the radiation dosage was extremely small, or if it was received over a long period of time, there is no measurable biological damage. The human body can usually repair or replace cells that have been damaged or destroyed by the absorption of radiation energy.

However, exposure to sudden, very large doses of radiation can damage more cells than can be replaced quickly by the body, thereby causing radiation sickness, genetic defects, or even death. To illustrate, doses of more than 100,000 mrem can cause radiation sickness and bone-marrow disease. A sudden dose of more than 500,000 mrem can cause death.

Radiation Hazards and the Management of Radioactive Waste

The coalescence in the 1970s of two major national concerns—concern for the environment and concern for personal health and safety—has fostered an awareness of many of the hazards and uncertainties we face in our daily lives. For instance, risks that have been ascribed to the operation of commercial nuclear powerplants have led many citizens to examine and question the role of the nuclear power industry in helping to meet the Nation's future

energy needs. That concern has also found expression in the public debate over the management of high-level radioactive waste. Emerging from that debate was a bipartisan, national effort to address the problems of radioactive waste disposal. Enactment of the NWPA and the Amendments Act demonstrates the Nation's commitment to resolve those problems in a safe and environmentally acceptable manner.

Where do the high-level radioactive wastes that are to be managed and disposed of under the provisions of this legislation come from? Presently, they come from the production of electricity in commercial nuclear powerplants and the production of nuclear materials for national defense.

Nuclear fuel that is used in the production of electricity consists typically of ceramic uranium dioxide pellets that are inserted and sealed in hundreds of metal rods bundled together within a rigid metal structure called a "fuel assembly." These rods, which are composed of an alloy of the element zirconium, prevent radioactive fission products that are produced during the fission process from getting into the cooling water of the nuclear reactor. After about 3 years of use, the fuel is sufficiently depleted of fissionable elements that it is no longer useful as fuel; at which point, it becomes "spent" fuel and is removed (or discharged) from the reactor. Today, the spent fuel is stored temporarily in water pools adjacent to the power reactors. The water removes heat generated by the spent fuel and keeps the fuel cool. It also serves as an effective shield to protect workers and others at the reactor site from radiation.

High-level radioactive waste results from the chemical reprocessing of spent nuclear fuel discharged from a reactor for the purpose of recovering any usable fissile material. Although some countries use reprocessing as a means to extract uranium for subsequent use in new fuel assemblies, the United States uses reprocessing only in the production of nuclear materials for national defense. These materials are extracted from fuel used in DOE-owned reactors, not privately owned nuclear powerplants.

When can radiation be particularly hazardous? The answer to that question depends on the makeup, duration and intensity of radiation, as well as the form of exposure. For example, spent fuel assemblies just removed by remote control from the reactor core are thermally hot and highly radioactive. The spent fuel assemblies are handled with great care to protect workers and others from radioactive exposure. Without the stringent safety measures and levels of protection that exist at nuclear plant sites, an individual exposed for a couple of hours or less to the radiation emitted by a spent fuel assembly just removed from a reactor could die from radiation-induced damage to the body's organs.

Most of the heat and radiation from the spent fuel assemblies decays after about 10 years of storage, but spent fuel remains potentially dangerous for longer periods of time. Radioisotopes such as strontium-90 and plutonium-239 found in spent fuel could cause severe and possibly irreparable biological damage if inhaled or ingested.

The half-life and the specific activity of each radioactive component of spent nuclear fuel and high-level nuclear waste varies greatly.

Half-life is the amount of time required by a radioactive substance to lose 50 percent of its activity by decay. Specific activity is the level of emission of radiation. Some of the radioisotopes have a relatively short half-life and a high specific activity. In other words, radioactive substances with a short half-life decay quickly and emit more radiation initially. For example, the half-life of strontium-90 is 29 years, after which the radioactive emissions drop rapidly. On the other hand, plutonium-239 has a half-life of about 24,000 years, decaying slowly with low emissions over that period of time.

By the end of 1987, almost 15,700 metric tons uranium (MTU) of spent fuel were stored in water pools at over 100 commercial nuclear powerplants[2] in the United States, awaiting final disposal in geologic repositories. This inventory of spent fuel accounts for about 90 percent of the radioactivity[3] contained in all of the nuclear wastes produced in this country since the

[2] Nuclear energy accounts for about 18 percent of the electricity generated in the United States. Storage of the spent fuel in water pools is fully licensed by the U.S. Nuclear Regulatory Commission.

[3] As measured in curies, which are equivalent to the radioactivity of one gram of radium, or 37 billion disintegrations per second.

1940s. Based on recently published projections, the cumulative inventory of spent fuel in the year 2020 will reach 98,000 MTU. Spent fuel will continue to account for the preponderant share of radioactivity from all sources of nuclear waste. (See *Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics,* DOE/RW-0006, Rev. 3, September 1987.)

High-level waste from defense spent fuel reprocessing is distinguished from commercially generated spent fuel by its much greater volume, substantially lower radioactivity, lower heat output and variety of forms, ranging from liquids to solids. Also, its generation and storage are limited to a few sites that are operated and managed by the Federal Government.

Properly managed and disposed of, nuclear waste does not need to cause harm to either workers or the general public. In compliance with applicable regulations issued by several cognizant Federal agencies, safe methods for the transportation, storage and disposal of spent fuel and high-level radioactive waste are being developed by the U.S. Department of Energy, which is the designated Federal agency responsible for executing the provisions of the NWPA and the Amendments Act. Disposal of these wastes in a deep, underground, geologically stable repository has been selected as the method of permanent isolation. This decision was based on years of analysis of geologic and related data, as well as extensive evaluation of disposal alternatives, including, for example, ice sheet disposal and deep-well injection.

The repository will be designed to isolate nuclear waste from the environment for at least 10,000 years without imposing undue risk to public health and safety. The geologic repository is scheduled to commence operations around the turn of the century.

Conclusion

Life on earth has evolved in the presence of radiation. It is a natural phenomenon that has been harnessed recently by mankind to benefit society. Yet, radiation vexes society because of the potential health and safety problems it poses. In recognition of the possible radiation hazards associated with radioactive waste, Congress passed legislation which committed the Federal Government to a comprehensive program for the safe and permanent disposal of such waste.

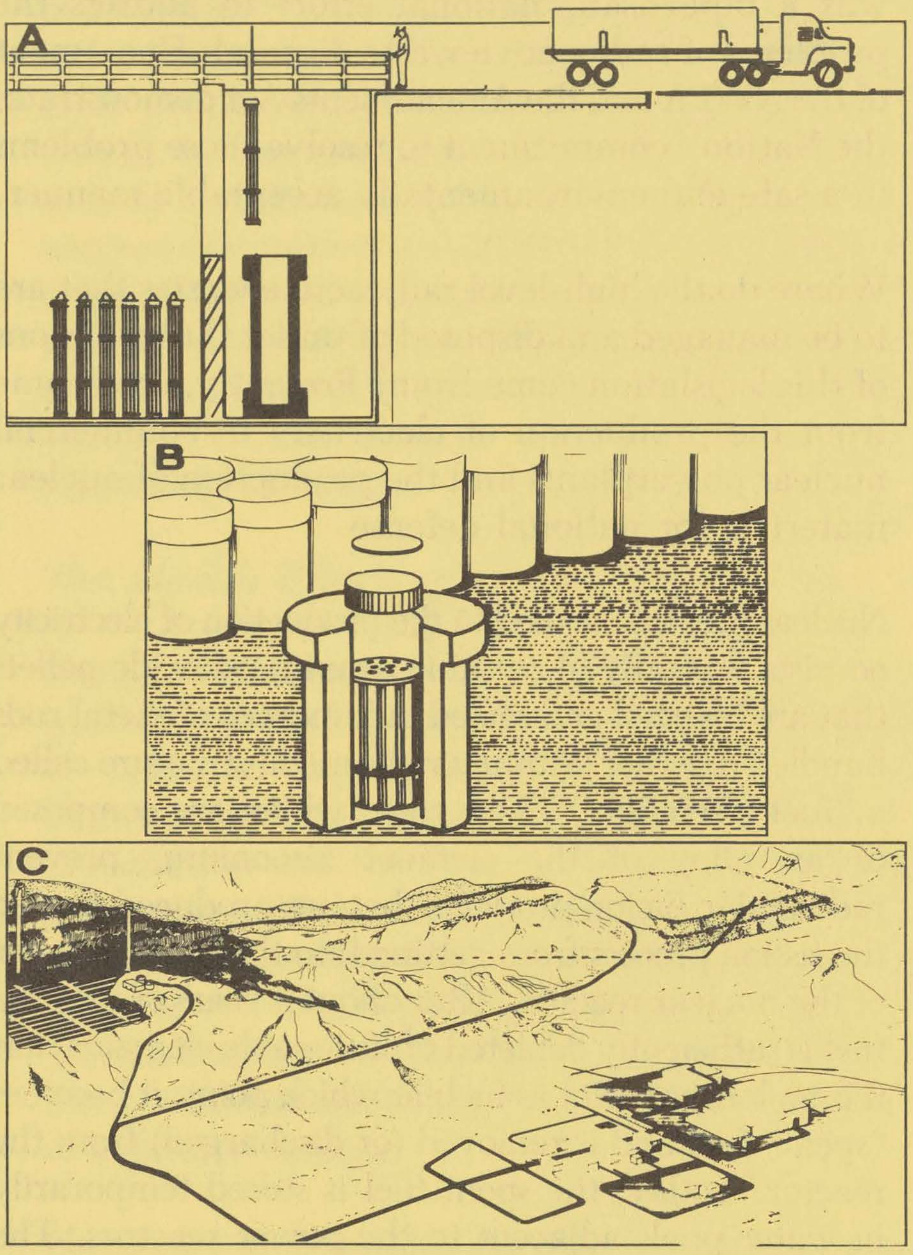


Figure 2 illustrates a proposed method of managing spent fuel leading toward ultimate disposal.

Panel A shows the spent fuel assembly being removed from the water pool at the reactor site for placement in a shipping cask.

Panel B shows the spent fuel to be disassembled, repackaged for compactness and placed in casks for storage.

Panel C illustrates a geologic repository where the canister containing the spent fuel will be placed for final disposal.

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DOE/RW-0168
OCRWM Backgrounder

Geographic Distribution of High-Level Radioactive Waste

The Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 (Amendments Act) authorize the U.S. Department of Energy (DOE) to develop a geologic repository for the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste. The repository is currently scheduled to begin accepting waste around the turn of the century.

Spent nuclear fuel is fuel that has been removed from a nuclear reactor because it can no longer economically sustain power production. High-level radioactive waste is generated from the reprocessing of spent nuclear fuel to extract plutonium and the remaining usable uranium. In the United States, reprocessing is only utilized in the production of nuclear materials

Table 1: Existing and Projected Inventories of Spent Nuclear Fuel by State: 1986 and 2000† (In hundreds of units)

State	Spent Nuclear Fuel 1986 (Metric Tons of Uranium)	Spent Nuclear Fuel 2000 (Metric Tons of Uranium)	Spent Nuclear Fuel 1986 (Cubic Meters)	Spent Nuclear Fuel 2000 (Cubic Meters)
Alabama	10	22	4	10
Arizona	0	8	0	4
Arkansas	3	7	1	3
California	4	17	1	7
Connecticut	7	16	3	7
Florida	8	18	3	7
Georgia	3	14	1	6
Illinois	22	55	9	23
Iowa	1	3	*	1
Kansas	*	3	*	1
Louisiana	*	6	*	3
Maine	3	5	1	2
Maryland	4	8	2	4
Massachusetts	3	6	1	2
Michigan	7	17	3	7
Minnesota	4	8	2	4
Mississippi	1	4	0	2
Missouri	*	3	*	1
Nebraska	2	6	1	3
New Hampshire	0	3	0	1
New Jersey	5	16	2	7
New York	10	26	5	9
North Carolina	5	18	2	7
Ohio	1	6	*	3
Oregon	2	4	1	2
Pennsylvania	10	33	5	13
South Carolina	9	25	3	10
Tennessee	2	11	1	5
Texas	0	9	0	4
Vermont	3	4	1	2
Virginia	6	15	3	6
Washington	*	5	*	2
Wisconsin	5	10	2	4
Total	140	411	57	172

† This excludes Idaho which will be receiving spent nuclear fuel generated at Ft. St. Vrain for storage in a DOE facility (see note on Figure 1).
** Less than 0.5*

Source: Pacific Northwest Laboratory, Reactor Specific Spent Fuel Discharge Projections, January 1988 (Preliminary Data).

Geographic Distribution of Nuclear Waste

Table 1 lists the 33 States where spent nuclear fuel was stored at reactor sites in 1986 or is projected to be generated by the year 2000. Table 2 shows the national inventory of high-level radioactive waste, which is and will continue to be, confined to four States (three of which account for defense-related high-level waste).

Table 2: Existing and Projected National Inventories of High-Level Radioactive Waste by Source and State: 1986 and 2000 (In thousands of units)

Source/State	*High-Level Radioactive Waste 1986 (cubic meters)*	*High-Level Radioactive Waste 2000 (cubic meters)*
Defense		
Idaho	10	16
South Carolina[1]	128	84
Washington	232	268
Commercial		
New York[2]	2	*
TOTAL	372	368

[1] *Decline in volume due to DOE's program to immobilize high-level waste for ultimate geologic disposal.*

[2] *High-level waste will be converted to a form suitable for geologic disposal.*

Source: Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics (DOE/RW-0006, Rev. 3), September 1987.

for national defense. High-level waste from defense spent fuel reprocessing is distinguished from commercially generated spent nuclear fuel by its much greater volume, substantially lower radioactivity, lower thermal output and variety of forms, ranging from liquids to solids.

The 1986 national inventory of spent nuclear fuel is expected to triple by the year 2000. This increase will occur because the inventory of spent nuclear fuel is growing rapidly as new commercial nuclear powerplants begin operation. This trend is significant because spent nuclear fuel is generated at widely dispersed reactor sites around the country, whereas the generation and storage of high-level radioactive waste is limited to a few sites that are owned and operated by the Federal Government.

The map in Figure 1 depicts the actual and anticipated geographic distribution of spent nuclear fuel and high-level radioactive waste.** Important inferences can be drawn from this map and the associated tables, such as:

- The national distribution of spent nuclear fuel will remain basically the same between 1986 and the year 2000, although the number of operating reactor sites is projected to increase significantly. High-level radioactive waste from defense-related activities, however, will continue to be located at only four sites.
- The preponderance of spent nuclear fuel is, and will continue to be, stored in the eastern half of the United States. In 1986, 26 states generated spent fuel. By the year 2000, the number of states generating spent fuel is expected to increase to 33.

** For detailed descriptions of this waste: See OCRWM *Backgrounder*, "Characteristics and Inventories of Nuclear Waste" DOE/RW-0140, April 1987, and DOE, *Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics* DOE/RW-0006, Rev. 3, September 1987.

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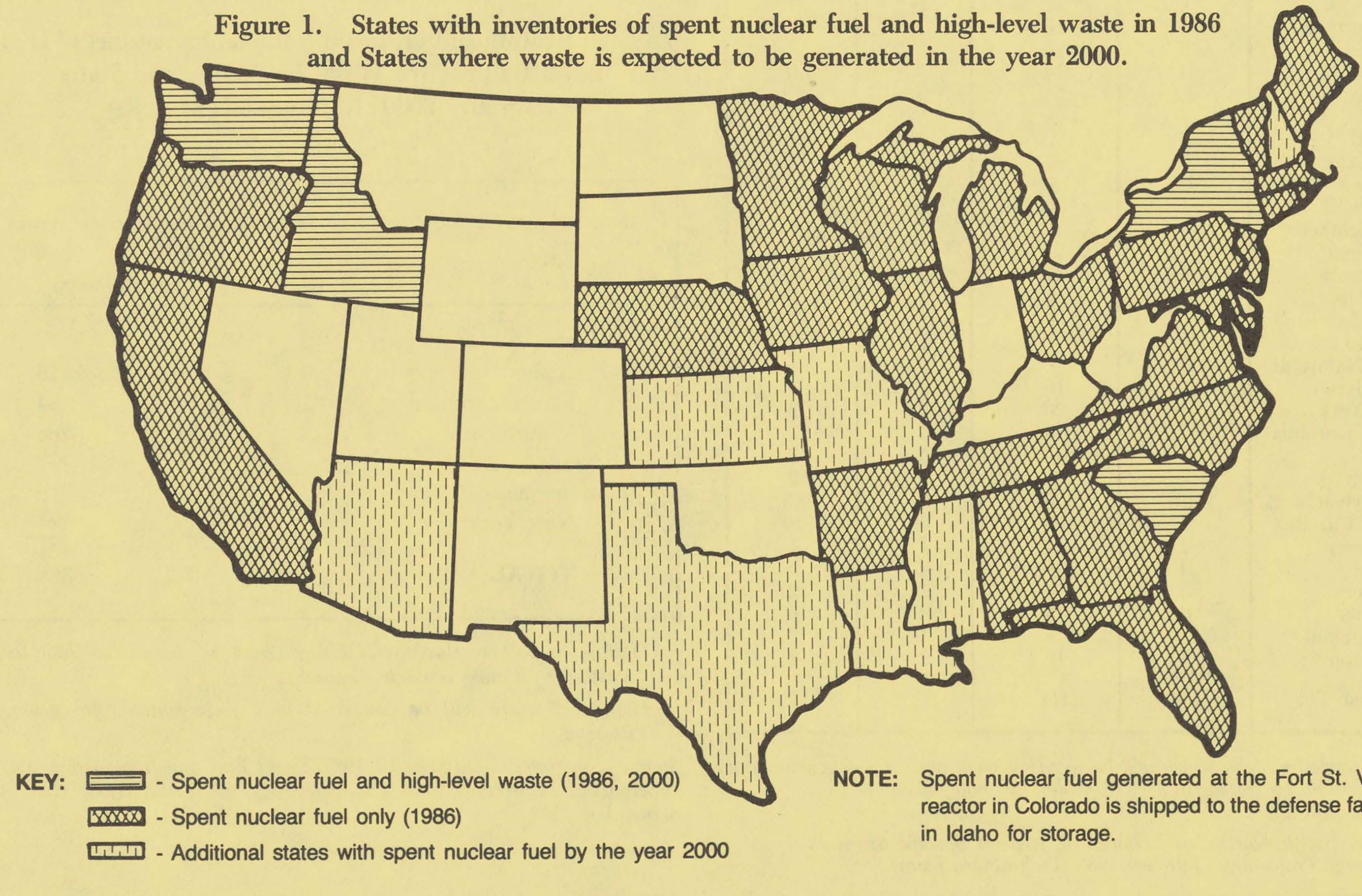
Figure 1. States with inventories of spent nuclear fuel and high-level waste in 1986 and States where waste is expected to be generated in the year 2000.



NOTE: Spent nuclear fuel generated at the Fort St. Vrain reactor in Colorado is shipped to the defense facility in Idaho for storage.

MB M.G.

The Multiple Barrier System of Geologic Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste

INTRODUCTION

Geologic disposal is the preferred method in the United States for disposing of spent nuclear fuel and high-level radioactive waste. This method was selected after evaluating a number of other methods (*Final Environmental Impact Statement-Management of Commercially Generated Radioactive Waste*, DOE/EIS-0046F, 1980) and is mandated by the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 (Amendments Act).

This legislation established a national policy for the management of spent nuclear fuel and high-level radioactive waste. It also assigned to the Department of Energy (DOE) the responsibility for developing and operating a system to store, transport and permanently dispose of such waste in a safe and environmentally acceptable manner and within a reasonable time frame.

High-level radioactive waste is potentially hazardous for thousands of years. To provide a high degree of assurance that the public will be adequately protected from exposure to these wastes over such a long time period, the disposal system includes a system of multiple barriers.

Spent Nuclear Fuel and High-Level Radioactive Waste

Virtually all of the radioactive waste to be accepted for disposal in a geologic repository is either used (spent) nuclear fuel, which is waste from commercial powerplants, or waste from the production of nuclear materials for national defense. Confidence is needed that the disposal system used will provide adequate long-term protection of the public. The U.S. Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) have specified performance requirements (40 CFR Part 191 and 10 CFR Part 60, respectively) for disposal of spent nuclear fuel and high-level radioactive waste that are intended to minimize risk to public health and safety.

EPA and NRC Performance Requirements

EPA standards are promulgated for the protection of the environment from releases of radionuclides from disposal facilities. These standards apply to doses that could be received by members of the public as the result of high-level waste disposal and to radioactive contamination of certain sources of ground water near the disposal facilities (40 CFR Part 191).

The EPA requires that the disposal system be designed to provide a reasonable expectation that the cumulative releases of radionuclides to the accessible environment for 10,000 years after disposal will have a chance of less than 1 in 10 of exceeding calculated quantities and less than 1 in 1,000 that the calculated quantities would be exceeded 10 times (40 CFR Part 191.13).

Multiple Independent Barrier - To protect the health and safety of the public over the long-term, multiple independent barriers, both natural and engineered, will be used. These barriers are designed to provide waste containment and isolation and are of three types: waste package, repository and natural system [also called geologic medium or host rock].

Engineered Barrier System - The manmade components of a disposal system are designed to prevent the release of radionuclides from the underground facility into the geohydrologic setting. It includes the radioactive waste form, radioactive waste canisters, materials placed over and around such canisters, any other components of the waste package and barriers used to seal penetrations in and to the underground facility.

From *Mission Plan for the Civilian Radioactive Waste Management Program*, Volume I, (DOE/RW-0005), June 1985.

The NRC, which is responsible for implementing and enforcing the EPA standards, has promulgated technical criteria for these purposes. The principle objective of the criteria is to provide reasonable assurance that high-level nuclear waste will be isolated by the geologic repositories for at least 10,000 years (10 CFR Part 60). For example, the waste package within the engineered barrier system is required to "provide substantially complete containment of the waste for 300 to 1,000 years."

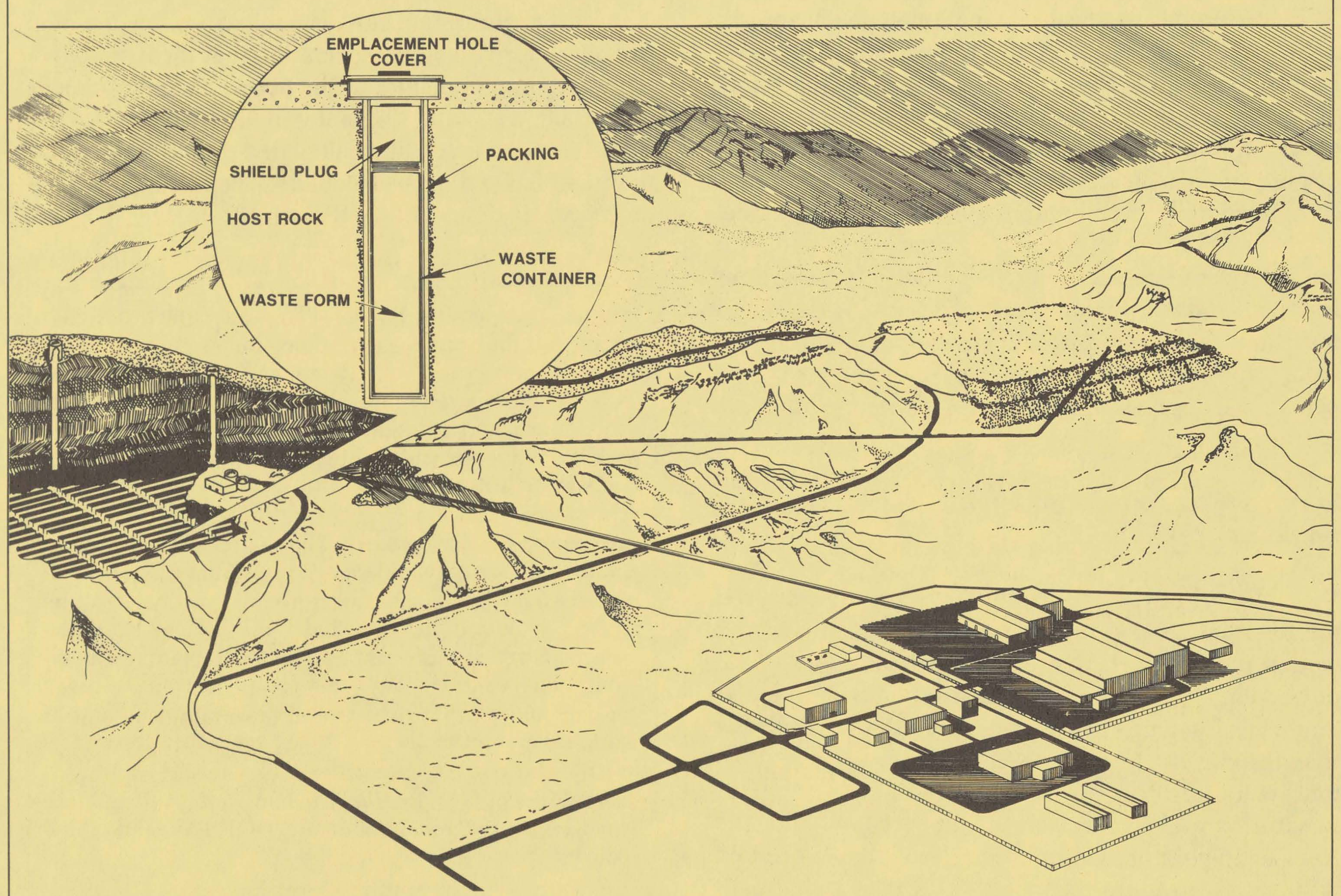
To assure compliance with EPA standards and NRC technical criteria, both agencies require the use of a multiple-barrier disposal system. The technology of the geologic repository will rely on a system of both engineered and natural barriers to contain the nuclear waste. This "multiple barrier" system consists of the waste package, the repository and the geologic medium (host rock).

COMPONENTS OF THE MULTIPLE BARRIER SYSTEM

The multiple barrier approach to nuclear waste containment and isolation can be characterized as "defense in depth." This term refers to manmade and natural barriers that would act together to provide redundant conservative performance to either prevent or retard the release of radioactivity to the accessible environment.

Waste Package

The waste package, itself, is the first barrier. That package consists of the waste form and any containers, shielding, seals, packing barriers and other absorbent materials that will separate the waste from the host rock. Both types of waste, the spent fuel and the defense waste, are in a solid, physical form that serves as a major impediment to the release of radioactivity. No liquids will be disposed of in the repository.



This conceptual view of a repository illustrates the "defense in depth" that is embodied in the multiple barrier system.

Spent fuel consists typically of pellets of irradiated ceramic uranium oxide that are sealed in metal tubes composed of a very strong corrosion and heat resistant alloy made of zirconium. This tubing—often called "cladding"—is designed to prevent radioactive fission products from escaping to other parts of the reactor system. Hundreds of the metal tubes are bundled together to form what is called a "fuel assembly." The spent fuel assembly constitutes a major barrier against potential radioactivity releases because essentially all waste products remain locked in the pellets and cladding.

Present plans call for high-level radioactive waste (HLW) generated in national defense activities to be fused with a protective material (borosilicate glass) under extremely high temperatures to create a monolithic waste form. Borosilicate glass was selected by DOE as the protective material to "immobilize" HLW because it is stable, possesses sufficient mechanical strength to resist the stresses of repository emplacement, withstands leaching under most anticipated repository conditions and is suitable for large-scale production operations which due to radioactivity must be operated remotely.

The mixture of high-level waste and molten borosilicate glass will be poured into stainless steel canisters. After cooling and solidification, the canister will be plugged, welded shut, leak tested, decontaminated, and transferred to a temporary storage vault. This type of canister is called a "pour canister."

An additional obstacle to the release of radioactivity is the waste package "disposal container," which serves as a high integrity physical partition between the capsule (e.g., HLW pour canister) holding the nuclear waste and the repository environment. The container is designed to delay exposing the encapsulated waste form to any underground water that may be present. Carbon steel, stainless steel and copper-based alloys are the candidate container materials for holding the spent nuclear fuel assemblies and HLW that would be emplaced in the repositories. Those materials were selected because they best resist corrosion when exposed to different geologic media. The geologic formation currently being investigated is tuff (solidified volcanic ash deposits).

Due to the unsaturated environment of the tuff formation under study for the repository, a packing material to limit ground water movement will not be employed in the reference design of the waste package. If the packing material were needed, it would: (1) provide sorption capacity for certain radionuclides contained in the waste form; (2) minimize chemical attack on the container; (3) decrease radionuclide solubility; and (4) serve as a plastic stress adjustment medium.

Repository

The repository portion of the multiple barrier system consists of engineered barriers which are not associated with the waste package. The backfilling of underground storage rooms, passageways and shafts is the principal repository barrier used to limit or control the movement of underground water. Backfill materials could also be used to: (1) enhance heat transfer from the waste to the surrounding rock; (2) mitigate localized stresses on the waste package; and (3) provide structural support to the host rock surrounding the repository. As presently planned, the backfill materials will be composed of the mined host rock, although the materials can be tailored to meet specific conditions by adding chemicals or other materials, such as clays.

Although not considered from a regulatory standpoint as part of the engineered barrier system, borehole and shaft seals will be utilized to prevent or substantially reduce water migration, as well as to thwart human intrusion once repository operations have ceased. The term "borehole" refers to a hole drilled into the earth, often for exploratory purposes. It is usually of a small diameter. The term "shaft" refers to a vertical excavation made for mining rock, raising rock, lowering men and materials or ventilating underground workings. Various candidate materials, including, for example, cement grouts, clays and polymers, are being tested to identify the required engineering properties for borehole and shaft seals.

Host Geologic Medium

The site of the geologic repository plays a crucial role in isolating the buried waste from the accessible environment. As such, it comprises the third and principal component of the multiple barrier system. The natural features of the site that affect long-term isolation are: (1) the suitability of the host rock for construction of the repository and containment of the waste; (2) the hydrologic and chemical characteristics of the site and its environment; and (3) the time required for radiation to flow from the repository to the accessible environment by credible paths such as by the ground water.

Desirable hydrologic features include low ground water flow rates, long pathways to be traversed by any migrating radionuclides and evidence of long-term stability. Favorable sorption properties of the host rock, coupled with its ability to rapidly dissipate heat and withstand natural and repository induced stress, help to diminish the potential for significant radionuclide migration. Tectonic conditions that show little likelihood of leading to radionuclide releases to the accessible environment constitute another host rock barrier. In addition, the site can be selected to reduce the possibility of human intrusion. These and other attributes of the natural barrier system boost the potential for long-term isolation of nuclear wastes within the repository after it has been sealed.

To summarize, the three elements that comprise the multiple barrier system, namely the waste package, the repository and the host rock, are designed to complement each other in order to provide a high degree of nuclear waste containment and isolation.

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DOE/RW-0167
OCRWM Backgrounder

Radiation and High-Level Radioactive Waste

This Backgrounder presents information about the sources, effects and relative risks of so-called "ionizing"[1] radiation, a topic gaining the attention of many citizens across the country as the Federal Government implements the provisions of the Nuclear Waste Policy Act of 1982 (NWPA) and the Nuclear Waste Policy Amendments Act of 1987 (Amendments Act). This legislation established a national policy for the management of spent nuclear fuel and high-level radioactive waste. DOE has been assigned the responsibility for developing and operating a system to store, transport and permanently dispose of such waste in a safe and environmentally acceptable manner and within a reasonable time frame.

Sources of Radiation

Radiation is a natural part of life, permeating the universe since time began. Life as we know it has evolved in the presence of radiation. Our society is already familiar with some forms of radiation as attested by our widespread use of microwave ovens, radio and television, medical and dental X-rays, as well as by the tans we acquire at the beach from exposure to radiation from the sun. Ionizing radiation stems from the activity of atoms, which are the basic building blocks of all matter. Many atoms are stable, which means that they retain their particular structures and characteristics forever. However, some atoms are unstable and change into another form. The unstable atom is said to be "radioactive," and the process by which it changes to become a new atom is known as "radioactive decay." During this process, the unstable atom releases excess energy in the form of either electromagnetic waves or fast-moving particles. It is this property that makes the radioactive atom both beneficial if properly managed and harmful if not safely managed.

We are constantly exposed to ionizing cosmic radiation from the sun and stars. Naturally occurring radioactive atoms found in the environment (such as radon, uranium and potassium) have always been around us and are contained the air we breathe, the structures we live in and the food we eat. Nearly two-thirds of all the radiation to which we are typically exposed each year comes from natural sources. The levels of natural radiation vary greatly from location to location. For example, a person living in Denver, CO, receives more than twice as much cosmic radiation from outer space as a person living in Washington, DC, because of the higher elevation.

Manmade sources of ionizing radiation associated with medical and dental tests (such as X-rays) and radiotherapy for disease account for about one-third of the total radiation dosage absorbed annually by the average person in this country.

The remaining amount of ionizing radiation (representing less than 1 percent of the total) to which we are exposed emanates from industrial uses of radioactive materials, minute emissions from certain consumer products (such as smoke detectors), lingering traces of radiation from previously conducted aboveground nuclear weapons tests, nuclear powerplant operations and miscellaneous activities.

The Nature of Ionizing Radiation

The three main types of ionizing radiation from radioactive decay are alpha and beta particle radiation and gamma radiation. Alpha particles are positively charged particles emitted from naturally occurring radioactive elements (such as radon and uranium), as well as some manmade elements (such as plutonium, which is produced in a nuclear powerplant). Alpha particles have little penetrating power and can be stopped easily by a sheet of paper or layer of skin. Beta particles are fast-moving electrons ejected from the nuclei, or cores, of radioactive atoms. While beta particles can pass through a sheet of paper, a thin sheet of aluminum foil can stop them. Gamma rays have great penetrating power, and they can pass through the human body. Gamma rays are used in cancer treatment to destroy the cells of a tumor without causing major damage to healthy cells nearby. Thick barriers of concrete, lead or steel provide shielding from gamma rays.

Radioactivity essentially disappears over time as the radioactive atoms decay to nonradioactive elements. The time it takes the radioactive material to lose one-half of its radioactivity is called its "half-life." The half-lives of

[1] The energy released during radioactive decay is called "ionizing radiation" because it can ionize, or electrically charge, atoms, a process whereby stable atoms may be changed through alteration of their basic electrical charge.

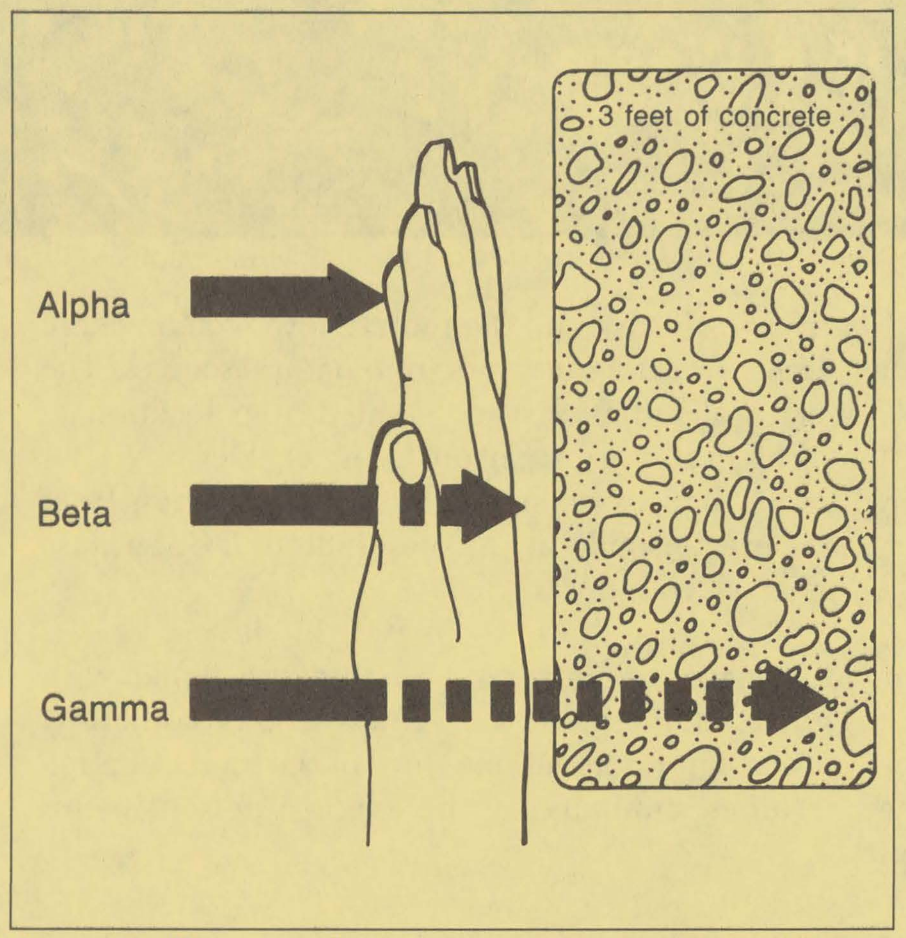

Figure 1 illustrates the penetrating properties of ionizing radiation.

radioactive elements may vary from millionths of a second to billions of years.

Measuring Radiation

Radiation has been the subject of scientific inquiry for many decades. Scientists today know a great deal about what it is, where it comes from, how to detect and measure it and how it affects human beings.

Scientists and engineers use a variety of units to measure radiation. The unit commonly used to measure the radiation exposure that we receive is the "millirem" (mrem), which is one-thousandth of a "rem." This latter unit stands for "roentgen equivalent man," which is a unit devised by scientists to define the amount of damage to human tissue from a dose of ionizing radiation. Millirem dosages are usually related to time or events. To illustrate, most people in the United States receive a total dosage of less than 200 mrem per year from all sources of radiation. Naturally occurring radiation accounts for more than 130 mrem of that total, with medically related sources of radiation accounting for at least another 60 mrem. A dental X-ray gives a dose of a few mrem in a fraction of a second. A wide variety of other sources are responsible for the remaining radiation.

The Health Effects of Radiation

Ionizing radiation can cause changes in many things, including living human tissue. The biological effects of exposure to radiation depend on the amount of energy absorbed by living tissue, the types of cells exposed and the type of radiation striking the living tissue.

There are two general categories of biological effects of exposure to radiation: somatic effects and genetic effects. Somatic effects are effects that occur in the exposed individuals and include slightly increased incidence of cancer, as well as early illness and death from very large, sudden doses of radiation. Genetic effects are effects which do not manifest themselves in the exposed individuals but rather in their offspring.

In general, early somatic effects are associated with accidental exposures involving doses greater than 100,000 mrem. Above this level the severity of the effect rapidly increases with the dose. For example, a dose in the range of 100,000 to 200,000 mrem will result in some signs of radiation illness but will rarely be fatal, whereas a dose in excess of 500,000 mrem is likely to be fatal.

In contrast to early somatic effects, the occurrence of cancers and genetic effects from exposure to radiation is a random process. An increase in the dose results in an increase in the probability of the occurrence of these effects rather than in their severity. For example, if a large population is exposed to an increased level of radiation, a small number of people may develop leukemia or may have children with genetic disease. However, it cannot be predicted in advance which specific individuals will be affected. For this reason, the number of cancers and genetic defects is estimated on the basis of the total dose received by the exposed population rather than on the basis of individual doses.

Because cancers and genetic defects occur naturally from many causes and because the increase in their incidence from exposure to radiation is small, the specific dependence between low-level radiation dose and probability of developing these effects can only be estimated from data at high levels of exposure. In setting radiation protection standards it is normally assumed that the probability of developing cancer and genetic defects is directly proportional to the dose received regardless of how small the dose is. It must be emphasized that this so called "linear, non-threshold" hypothesis is just an assumption and, in fact, below a certain dose level there may be no effects. However, most scientists consider this assumption to lead to overestimation rather than

underestimation of the biological effects of radiation and, thus, to be prudent for radiation protection purposes.

Radiation Hazards and the Management of Radioactive Waste

The coalescence in the 1970's of two major national concerns—concern for the environment and concern for personal health and safety—has fostered an awareness of many of the hazards and uncertainties we face in our daily lives. For instance, risks that have been ascribed to the operation of commercial nuclear powerplants have led many citizens to examine and question the role of the nuclear power industry in helping to meet the Nation's future energy needs. That concern has also found expression in the public debate over the management of high-level radioactive waste. Emerging from that debate was a bipartisan, national effort to address the problems of radioactive waste disposal. Enactment of the NWPA and the Amendments Act demonstrates the Nation's commitment to resolve those problems in a safe and environmentally acceptable manner.

Where do the high-level radioactive wastes that are to be managed and disposed of under the provisions of this legislation come from? Presently, they come from the production of electricity in commercial nuclear powerplants and the production of nuclear materials for national defense.

Nuclear fuel that is used in the production of electricity consists typically of ceramic uranium dioxide pellets that are inserted and sealed in hundreds of metal rods bundled together within a rigid metal structure called a "fuel assembly." These rods, which are composed of an alloy of the element zirconium, prevent radioactive fission products that are produced during the fission process from getting into the cooling water of the nuclear reactor. After about 3 years of use, the fuel is sufficiently depleted of fissionable elements that it is no longer useful as fuel; at which point, it becomes "spent" fuel and is removed (or discharged) from the reactor. Today, the spent fuel is stored temporarily in water pools adjacent to the power reactors. The water removes heat generated by the spent fuel and keeps the fuel cool. It also serves as an effective shield to protect workers and others at the reactor site from radiation.

High-level radioactive waste results from the chemical reprocessing of spent nuclear fuel discharged from a reactor for the purpose of recovering any usable fissile material. Although some countries use reprocessing as a means to extract uranium for subsequent use in new fuel assemblies, the United States uses reprocessing only in the production of nuclear materials for national defense. These materials are extracted from fuel used in DOE-owned reactors, not privately owned nuclear powerplants.

When can radiation be particularly hazardous? The answer to that question depends on the makeup, duration and intensity of radiation, as well as the form of exposure. For example, spent fuel assemblies just removed by remote control from the reactor core are thermally hot and highly radioactive. The spent fuel assemblies are handled with great care to protect workers and others from radioactive exposure. Without the stringent safety measures and levels of protection that exist at nuclear plant sites, an individual exposed for a couple of hours or less to the radiation emitted by a spent fuel assembly just removed from a reactor could die from radiation-induced damage to the body's organs.

Most of the heat and radiation from the spent fuel assemblies decays after about 10 years of storage, but spent fuel remains potentially dangerous for longer periods of time. Radioisotopes such as strontium-90 and plutonium-239 found in spent fuel could cause severe and possibly irreparable biological damage if inhaled or ingested.

The half-life and the specific activity of each radioactive component of spent nuclear fuel and high-level nuclear waste varies greatly. Half-life is the amount of time required by a radioactive substance to lose 50 percent of its activity by decay. Specific activity is the level of emission of radiation. Some of the radioisotopes have a relatively short half-life and a high specific activity. In other words, radioactive substances with a short half-life decay quickly and emit more radiation initially. For example, the half-life of strontium-90 is 29 years, after which the radioactive emissions drop rapidly. On the other hand, plutonium-239 has a half-life of about 24,000 years, decaying slowly with low emissions over that period of time.

By the end of 1987, almost 15,700 metric tons uranium (MTU) of spent fuel were stored in water pools at over 100 commercial nuclear powerplants[2] in the United States, awaiting final disposal in geologic repositories.

[2] Nuclear energy accounts for about 18 percent of the electricity generated in the United States. Storage of the spent fuel in water pools is fully licensed by the U.S. Nuclear Regulatory Commission.

This inventory of spent fuel accounts for about 90 percent of the radioactivity contained in all of the nuclear wastes produced in this country since the 1940's. Based on recently published projections, the cumulative inventory of spent fuel in the year 2020 will reach 98,000 MTU. Spent fuel will continue to account for the preponderant share of radioactivity from all sources of nuclear waste. (See *Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, DOE/RW-0006, Rev. 3, September 1987.)

High-level waste from defense spent fuel reprocessing is distinguished from commercially generated spent fuel by its much greater volume, substantially lower radioactivity, lower heat output and variety of forms, ranging from liquids to solids. Also, its generation and storage are limited to a few sites that are operated and managed by the Federal Government.

Properly managed and disposed of, nuclear waste does not need to cause harm to either workers or the general public. In compliance with applicable regulations issued by several cognizant Federal agencies, safe methods for the transportation, storage and disposal of spent fuel and high-level radioactive waste are being developed by the U.S. Department of Energy, which is the designated Federal agency responsible for executing the provisions of the NWPA and the Amendments Act. Disposal of these wastes in a deep, underground, geologically stable repository has been selected as the method of permanent isolation. This decision was based on years of analysis of geologic and related data, as well as extensive evaluation of disposal alternatives, including, for example, ice sheet disposal and deep-well injection.

The repository will be designed to isolate nuclear waste from the environment for at least 10,000 years without imposing undue risk to public health and safety. The geologic repository is scheduled to commence operations around the turn of the century.

Conclusion

Life on earth has evolved in the presence of radiation. It is a natural phenomenon that has been harnessed recently by mankind to benefit society. Yet, radiation vexes society because of the potential health and safety problems it poses. In recognition of the possible radiation hazards associated with radioactive waste, Congress passed legislation which committed the Federal Government to a comprehensive program for the safe and permanent disposal of such waste.

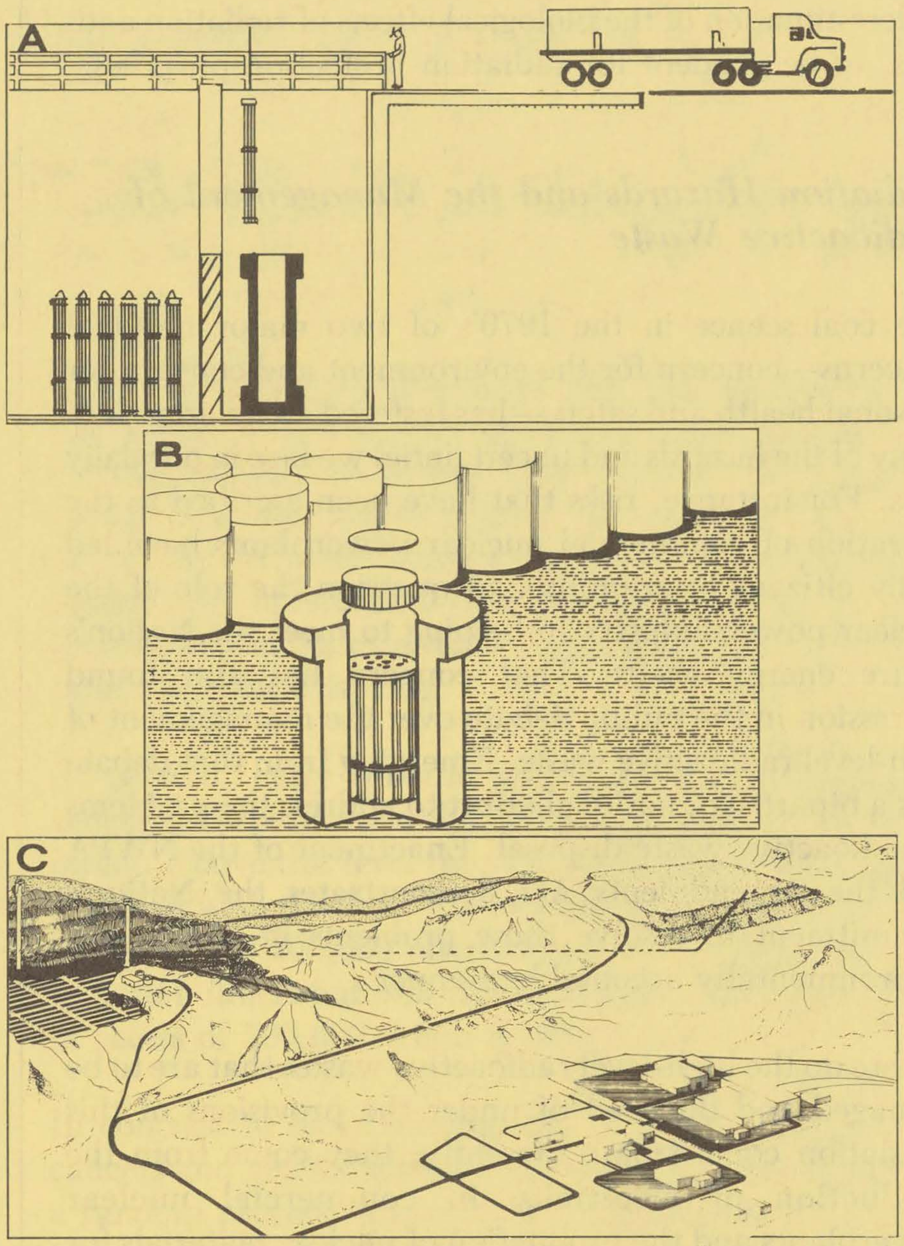

Figure 2 illustrates a proposed method of managing spent fuel leading toward ultimate disposal.

Panel A shows the spent fuel assembly being removed from the water pool at the reactor site for placement in a shipping cask.

Panel B shows the spent fuel to be disassembled, repackaged for compactness and placed in casks for storage.

Panel C illustrates a geologic repository where the canister containing the spent fuel will be placed for final disposal.

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DOE/RW-0240
OCRWM Backgrounder

Studies of Alternative Methods of Nuclear Waste Disposal

INTRODUCTION

The Nuclear Waste Policy Act of 1982 (NWPA) and its amendments establish a national policy for the safe storage and permanent disposal of spent nuclear fuel and high-level radioactive waste.[1] The amended NWPA directs the U.S. Department of Energy (DOE) to develop and operate a system of radioactive waste disposal that emphasizes the use of a deep-mined geologic repository. Before the passage of the NWPA, DOE assessed the use of a geologic repository and other nuclear waste disposal alternatives in an Environmental Impact Statement (EIS) entitled the *Management of Commercially Generated Radioactive Waste* (DOE/EIS-0046F, October 1980). The EIS evaluated the following alternatives to a deep-mined geologic repository: subseabed disposal, emplacement in very deep holes, disposal in melted rock, interment in island-based geologic repositories or in ice sheets, injection into deep wells, disposal in space and indefinite surface storage as well as the transmutation waste form treatment. This backgrounder provides an overview of these nuclear waste disposal alternatives.

SUBSEABED DISPOSAL

Subseabed disposal would involve the burial of solidified waste inside high-integrity canisters beneath the ocean floor. Since disposal would occur in the tectonically stable clay-rich sediments of the mid- plate regions, it is possible that the waste would remain isolated from the biosphere for extremely long periods of time and, therefore, not present a threat to plant and animal life. Movement of any waste isotopes escaping from the ocean sediments to the more biologically active near-surface water conceptually would be a slow process, accompanied by dilution and dispersion. In addition, the great depth of the water constitutes a barrier to human intrusion.

Several potential problems remain, however. Most importantly, the feasibility of executing the concept has not been established. For example, it may be difficult to emplace the waste containers beneath the ocean floor to ensure containment until the waste decays to acceptable low levels. Additionally, the radionuclides may be altered by chemical reactions with the sediments. Even if subseabed disposal were to prove technically feasible, it may be difficult to develop an effective international, legal and administrative structure to regulate and monitor a subseabed repository.

The Subseabed Disposal Program, a joint research effort between DOE, the Environmental Protection Agency, other Federal agencies and international organizations (e.g. the Nuclear Energy Agency of the Organization for Economic Cooperation and Development) has been an ongoing program since 1974. Under the amended NWPA, DOE is directed to report to Congress on subseabed disposal of spent nuclear fuel and high-level radioactive waste. The subseabed report shall include:

- an assessment of the current state of knowledge of subseabed disposal
- an estimate of the costs of subseabed disposal
- an analysis of institutional factors and international aspects associated with subseabed disposal

[1] Spent nuclear fuel refers to fuel that has been removed from a nuclear reactor core primarily because it can no longer sustain an efficient chain reaction. High-level radioactive waste, generated from the reprocessing of spent nuclear fuel to extract plutonium and the remaining usable uranium, results largely from defense nuclear activities.

- a full discussion of the environmental, public health and safety aspects of subseabed disposal
- recommendations on alternative ways to structure an effort in research, development and demonstration with respect to subseabed disposal
- the recommendations of DOE with respect to research, development and demonstration in subseabed disposal of spent nuclear fuel and high-level radioactive waste.

The NWPA, as amended, also established an Office of Subseabed Disposal Research within the Office of Energy Research of DOE, to carry out research, development and demonstration activities on all aspects of subseabed disposal. The Director of this Office may make grants to, or enter into contracts with, a university-based Subseabed Consortium. The Subseabed Consortium shall be established by DOE and involve leading oceanographic universities, national laboratories and other organizations, to investigate the technical and institutional feasibility of subseabed disposal. The Consortium will also identify and characterize potential subseabed disposal sites, and identify and assess the potential impacts of subseabed disposal on the human and marine environment.

DEEP-HOLE DISPOSAL

Deep-hole disposal involves the placement of waste canisters as far as 10,000 meters (approximately 6 miles) underground, a considerable distance from the accessible environment and below circulating ground water. At these depths, the nuclear waste may be effectively contained while the waste decays to stable forms or levels that pose little threat to human health. To serve as a waste repository at these depths, the host rock must retain its character and structural stability under the heat and radiation conditions introduced by the waste.

Deep-hole disposal was not defined as a proposed action in the EIS for the following reasons: (1) an incomplete understanding of the hydrologic characteristics of deep crystalline and sedimentary rock units, (2) the technical uncertainty associated with current drilling technologies that would have to be used to attain the extreme depths required to isolate nuclear waste from the biosphere, and (3) the lack of knowledge of *in situ* rock mechanics properties under high pressure and temperature conditions.

ROCK MELT DISPOSAL

Rock melt disposal involves the emplacement of liquid or slurry waste into a deep, underground hole or cavity. After the water in the waste has evaporated, the surrounding rock would melt from the heat generated by the decay of the radioactive waste. This process, in turn, would slowly dissolve the waste. The waste rock solution would slowly solidify, trapping the radioactive material in a relatively insoluble form deep below the surface of the Earth. The waste-rock-solidified conglomerate that would ultimately result is expected to be extremely leach resistant and, hence, could provide greater long-term containment of waste isotopes than could a mined geologic repository. Because less mining activity would be involved than for a mined geologic repository, the relative cost advantages of this concept could be substantial.

Rock melt disposal was not defined as a proposed action in the EIS largely because of the time required to monitor the process before full solidification of the nuclear waste. About 1,000 years would elapse before total solidification occurs. A lack of understanding of the heat transfer and phase-change phenomena in rock (information necessary to establish the stability of the molten rock matrix and to develop engineering methods for emplacement) would further complicate the monitoring task.

ISLAND GEOLOGIC DISPOSAL

Island geologic disposal involves the siting of deep-mined geologic repositories in islands. Preferred island locations are those in remote areas and devoid of known natural resources. Uninhabited islands that are hydrologically separated from large continental land masses offer potential advantages. Potentially adverse radiological health effects would be minimized. Further, any leakage of radioactivity into the island's ground water could be easily detected. Additionally, in the event of high-level radioactive waste leakage into the environment, the waste would be diluted by the surrounding seawater.

Drawbacks of island geologic disposal include the risks associated with ocean transport of nuclear waste during adverse weather conditions. Additionally, many islands experience frequent and intense seismic and volcanic activity. Such activity could discharge the waste into either lava flows or the atmosphere. Moreover, islands of volcanic origin have geologic foundations that are permeable and, hence, susceptible to interaction of fresh and marine water. The presence of water could contribute to the corrosion of waste canisters, leaching and the eventual transport of radionuclides into the biosphere. Potential opposition from countries in the vicinity of a proposed island repository is an additional consideration.

ICE SHEET DISPOSAL

Without significant climatic changes, the Antarctic and Greenland ice caps could provide long-term isolation of nuclear waste from the biosphere. Three types of ice sheet disposal have been considered: passive slow descent, anchor and surface storage emplacement. Passive slow descent emplacement would allow for the waste canister to be placed in a shallow hole, eventually melting its way to the bottom of the ice sheet as heat is emitted from the radioactive decay process. Anchor emplacement parallels that of passive emplacement, but an anchor cable attached to the canister would limit the descent depth and enable retrieval of the waste canister. Surface storage emplacement requires the use of large storage units constructed above the snow surface and then filled with waste. The radioactive waste would act as a heat source causing the storage units to slowly melt their way to the bottom of the ice sheet.

An advantage of the sheet disposal is that the polar regions are uninhabited and desolate areas that would provide for the almost total isolation of the nuclear waste. The ice masses are thousands of meters thick, extend uniformly and remain stable for long periods of time. At great depths (100 meters or more), ice behaves like a plastic and flows to seal fissures and to close cavities. Isolation of radioactive wastes would be ensured for long periods of time due to the very slow movement of ice.

Disadvantages of ice sheet disposal include uncertainties surrounding both the disposal technologies and the impact of future climatic changes on the stability and size of the ice sheets. Another disadvantage is the expected high operational costs of ice sheet disposal because of the remoteness of the locations and the adversity of weather conditions. Ice sheet dynamics are not well known. Global climatic effects could accelerate the melting of large portions of ice masses from the heat generated from radioactive waste decay and thus open paths to the dispersion of waste. Finally, the Antarctic Treaty of 1959, of which the United States is a signatory, specifically prohibits the disposal of nuclear waste in the Antarctic.

DEEP-WELL INJECTION

Deep-well injection is the emplacement of liquid or slurried nuclear waste in deep, geologic formations capped by an impermeable boundary layer. For acidic liquid waste, the method would involve the pressurized pumping of the waste to depths of 1,000 to 5,000 meters (3,000 to 16,000 feet) into a porous or hydrofractured geologic formation suitably isolated from the biosphere by relatively impermeable overlying strata. The waste would progressively disperse throughout the host rock. Deep-well injection is a working technology compared to technologies required to implement rock melt and deep hole disposal. Shale is considered a suitable geologic medium because of its ability to isolate the waste from ground water and the environment.

The deep-well injection alternative requires either mechanical or chemical processing of spent fuel before its disposal, which is a possible drawback. Another possible limitation of the deep-well injection method concerns the mobility of a liquid waste form within a porous host rock formation. The combination of a liquid waste form and a porous rock body increases the chances that the waste could come into contact with the biosphere.

SPACE DISPOSAL

The National Aeronautics and Space Administration (NASA) and DOE have studied several methods of space disposal including the transport to and injection of nuclear waste into the sun or the emplacement of waste on the Earth's moon. These methods were found unsuitable for technical and space exploration reasons. Another method involved sending reprocessed nuclear waste into a circular solar orbit about midway between Earth and the planet Venus. First, the space shuttle would carry the nuclear waste package to a low Earth orbit. A transfer vehicle would then separate from the shuttle to place the waste package and another propulsion stage into an Earth escape trajectory. The transfer vehicle would return to the shuttle while the remaining rocket stage would move the waste into solar orbit.

Disadvantages of space disposal include the possibility of launch failure and the potential inability of the waste packaging system to contain the waste in the event of such a failure. Additionally, the costs of launching nuclear waste into space would be very high. Therefore, space disposal would be restricted to providing for the extraterrestrial isolation of long-lived radionuclides such as Iodine^{129} and Technetium^{99}. In turn, this method would require the reprocessing of high-level radioactive waste into specially tailored waste forms. Waste remaining on Earth would have to be disposed of in a mined geologic repository. The use of extraterrestrial disposal, in conjunction with terrestrial disposal, would require an expected additional cost without achieving a significant reduction in long-term risk over emplacement of waste in a mined geologic repository only. Consequently, in April 1982, NASA and DOE agreed to discontinue further study of space disposal.

TRANSMUTATION

Transmutation is not a disposal method but a treatment method for high-level radioactive waste that would be used in conjunction with specific disposal alternatives, such as the deep-mined geologic disposal option. The transmutation concept involves the reprocessing of spent fuel to recover uranium and plutonium (or processing to obtain a liquid high-level waste stream when uranium and plutonium are not to be recycled). The remaining high-level waste stream is partitioned into an actinide[2] waste stream and a fission product stream. The fission product stream is concentrated, solidified and sent to a mined geologic repository for disposal. The actinide waste stream is combined with uranium (or uranium and plutonium), fabricated into fuel rods and reinserted into a reactor. In the reactor, about 5 to 7 percent of the recycled waste actinides are transmuted to stable or short-lived isotopes, which are separated out during the next recycle step for disposal in a repository. Numerous recycles would result in nearly complete transmutation of the waste actinides; however, additional waste streams are generated with every recycle. Transmutation provides no reduction in the quantities of long-lived fission product radionuclides, such as Technetium^{99} and Iodine^{129} in the fission product stream that is sent to geologic disposal.

SURFACE STORAGE

Surface storage would allow for existing spent fuel to be left indefinitely where it is being stored. Any additional waste discharges from the operation of commercial nuclear powerplants would be stored indefinitely in water basin facilities or in "dry casks" at the reactors or at other sites. Reprocessing of waste is assumed not to be undertaken. Surface storage would allow for delays and contingencies that could not have been foreseen in the research, development and planning stages for deep-mined geologic disposal.

Disadvantages associated with the surface storage alternative include the extensive maintenance and monitoring activities that necessarily accompany surface storage, as well as the potential health and safety and environmental risks attendant to storing nuclear waste in relatively accessible locations.

[2] Actinides are a group of elements that include uranium and all man-made transuranic elements (e.g. Berkelium and Californium). Fission products are nuclei (fission fragments) formed by the fission of heavy elements, plus the nuclides formed by the fission fragments' radioactive decay.

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Geographic Distribution of High-Level Nuclear Waste

The Nuclear Waste Policy Act of 1982 and its amendments authorize the U.S. Department of Energy (DOE) to develop a geologic repository for the safe, permanent disposal of spent nuclear fuel and high-level radioactive waste. The repository is currently scheduled to begin accepting waste soon after the turn of the century.

Spent nuclear fuel is fuel that has been removed from a nuclear reactor because it can no longer economically sustain power production. High-level radioactive waste is generated from defense activities, including the reprocessing of spent nuclear fuel to extract plutonium and the remaining usable uranium. In the United States, reprocessing is only utilized in the production of nuclear materials for national defense.

Table 1: Existing and Projected Inventories of Spent Nuclear Fuel by State: 1987 and 2000[1] (rounded to nearest unit)

State	Spent Nuclear Fuel 1987 (Metric Tons of Uranium)	2000 (Metric Tons of Uranium)	1987 (Cubic Meters)	2000 (Cubic Meters)
Alabama	992	2,019	390	807
Arizona	34	925	13	347
Arkansas	328	709	111	252
California	435	1,643	177	664
Connecticut	844	1,651	330	664
Florida	882	1,766	309	632
Georgia	386	1,369	130	524
Illinois	2,406	5,718	845	2,223
Indiana	49	49	70	70
Iowa	153	294	55	117
Kansas	48	305	18	113
Louisana	69	605	29	252
Maine	324	538	147	239
Maryland	436	859	186	369
Massachusetts	338	554	160	276
Michigan	712	1,743	258	688
Minnesota	385	805	146	346
Mississippi	101	398	44	182
Missouri	83	358	32	142
Nebraska	258	600	95	230
New Hampshire	0	224	0	83
New Jersey	537	1,493	200	560
New York	1,156	2,290	442	916
North Carolina	722	1,823	260	707
Ohio	94	645	34	254
Oregon	200	432	63	131
Pennsylvania	1,175	3,298	487	1,408
South Carolina	1,014	2,459	329	871
Tennessee	160	751	58	276
Texas	0	846	0	287
Vermont	271	433	113	184
Virginia	701	1,490	224	490
Washington	53	312	22	141
Wisconsin	557	979	180	341
Total	**15,903**	**40,293**	**5,957**	**15,786**

[1] *This excludes Idaho which will be receiving spent nuclear fuel generated at Ft. St. Vrain for storage in a DOE facility (see note on Figure 1).*

Source: U.S. Department of Energy, *Spent Fuel Storage Requirements 1988*, (DOE/RL-88-34), October, 1988.

Geographic Distribution of Nuclear Waste

Table 1 lists the 34 States where spent nuclear fuel was stored at reactor sites in 1987 or is projected to be generated by the year 2000. Table 2 shows that the national inventory of high-level radioactive waste is, and will continue to be, confined to four States (three of which account for defense-related high-level waste).

Table 2: Existing and Projected National Inventory of High-Level Radioactive Waste by Source and State: 1987 and 2000

Source/State	High-Level Radioactive Waste 1987 (*cubic meters*)	2000 (*cubic meters*)
Defense		
Idaho	12,000	15,000
South Carolina[2]	128,000	72,000
Washington	240,000	244,000
Commercial		
New York[3]	2,000	210
TOTAL	**382,000**	**331,000**

[2] *The decline in volume is the result of DOE's program to immobilize high-level waste for ultimate geologic disposal.*

[3] *High-level waste will be converted to a form suitable for geologic disposal.*

Source: U.S. Department of Energy, *Integrated Data Base for 1988: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics* (DOE/RW-0006, Rev. 4), September 1988.

High-level waste from defense spent fuel reprocessing is distinguished from commercially generated spent nuclear fuel by its much greater volume, lower thermal output and variety of forms, ranging from liquids to solids.

The 1987 national inventory of spent nuclear fuel is expected to increase two and a half times in weight by the year 2000. This increase will occur because the inventory of spent nuclear fuel is growing rapidly. Spent nuclear fuel is generated at widely dispersed reactor sites around the country, whereas the generation and storage of high-level radioactive waste is limited to a few sites that are operated and managed by the Federal Government.

The map in Figure 1 depicts the actual and anticipated geographic distribution of spent nuclear fuel and high-level radioactive waste.[4] Important inferences can be drawn from these maps and the associated tables:

- The national distribution of spent nuclear fuel will remain basically the same between 1987 and the year 2000, although the number of operating reactor sites is projected to increase. High-level radioactive waste, however, will continue to be located at only four sites.

- The preponderance of spent nuclear fuel is, and will continue to be, stored in the eastern half of the United States. In 1987, 32 States generated spent fuel. By the year 2000, the number of States generating spent fuel is expected to increase to 34.

[4] *For detailed descriptions of this waste, see: OCRWM Backgrounder, "Characteristics and Inventories of Nuclear Waste"* (DOE/RW-0140), April 1987, *and DOE, Integrated Data Base for 1988: Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics,* (DOE/RW-0006, Rev. 4), September 1988.

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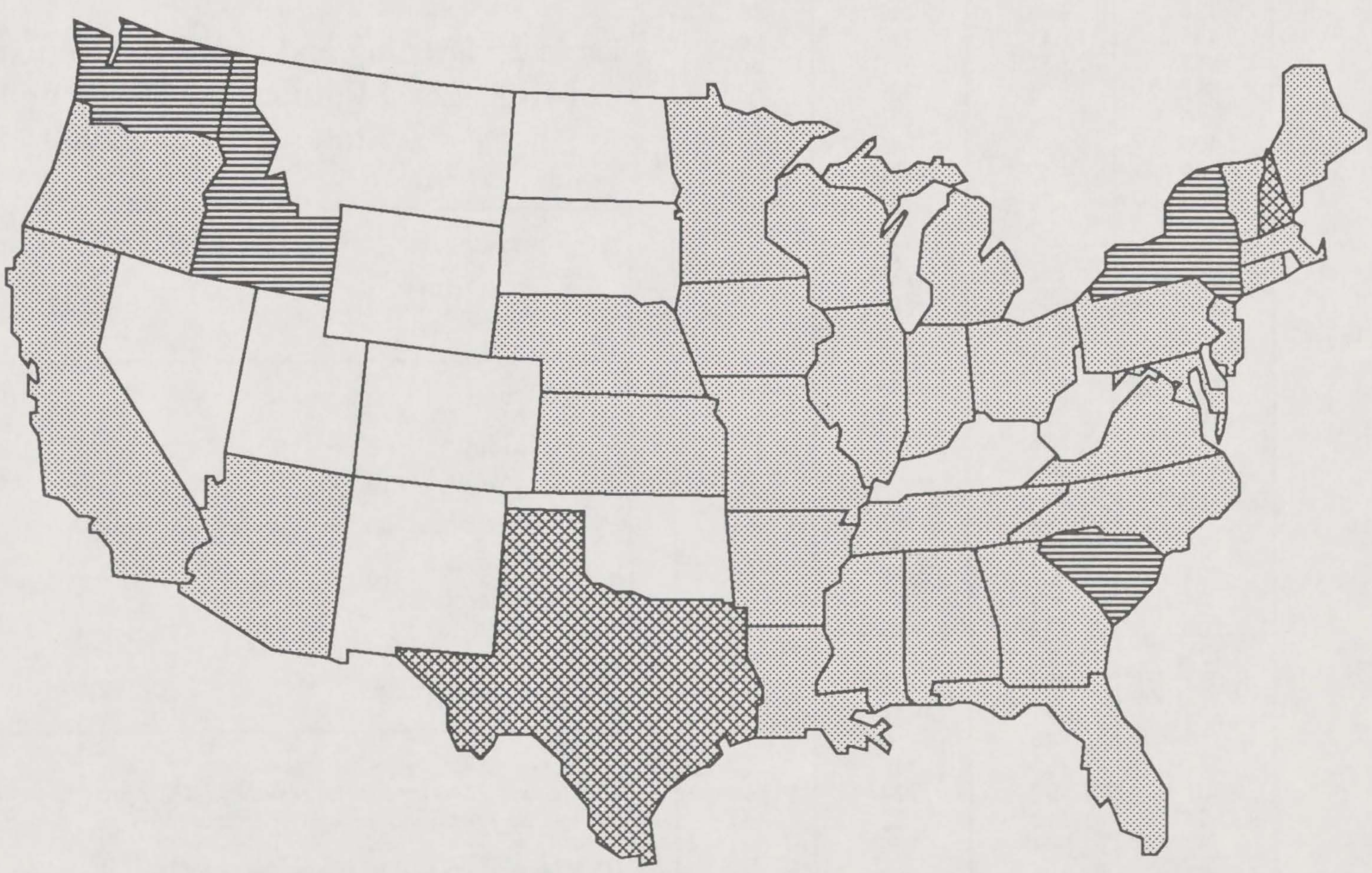
Figure 1. States with inventories of spent nuclear fuel and high-level waste in 1987 and States where waste is expected to be generated in the year 2000.



KEY:
- Spent nuclear fuel and high-level waste (1987, 2000)
- Spent nuclear fuel only (1987)
- Additional states with spent nuclear fuel by the year 2000

NOTE: Spent nuclear fuel generated at the Fort St. Vrain reactor in Colorado is shipped to the defense faclility in Idaho for storage.

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Federal Agencies Involved in the Implementation of the Nuclear Waste Policy Act of 1982

INTRODUCTION

The Nuclear Waste Policy Act of 1982 (NWPA) and its amendments established a national policy for the safe storage and permanent disposal of spent nuclear fuel and high-level radioactive waste. To assure successful implementation of NWPA provisions, Congress assigned key roles to several Federal agencies in their areas of expertise and statutory authority.

The U.S. Department of Energy (DOE) has primary responsibility for siting, constructing and operating the elements of the radioactive waste management system.

The U.S. Nuclear Regulatory Commission (NRC) has the primary regulatory responsibility for review of the nuclear safety aspects of certain DOE actions and for licensing the elements of the radioactive waste management system.

The Environmental Protection Agency (EPA) is responsible for developing generally applicable environmental standards for the management and disposal of spent nuclear fuel and high-level waste. EPA is also responsible for environmental review of various DOE actions in the siting of a geologic repository. The Council on Environmental Quality (CEQ) and the Department of the Interior (DOI) also have review responsibilities specified under the NWPA and its amendments.

Four other Federal agencies--whose roles are not directly specified in the NWPA or its amendments --have responsibilities by law for certain actions required to site, construct, license and operate the radioactive waste management system. They are the Departments of Agriculture (USDA), Defense (DOD), Justice (DOJ) and Transportation (DOT).

Of these agencies, DOT has a major role in regulating the transport of hazardous materials, including radioactive waste, to ensure that it is done safely.

This Backgrounder describes the regulatory responsibilities of the NRC and the EPA in siting and developing the Nation's geologic repository. It also outlines the responsibilities of DOT and the NRC in establishing a system for transporting spent nuclear fuel and high-level radioactive waste. In addition, it identifies the NRC's role in licensing a monitored retrievable storage (MRS) facility.

REPOSITORY SITING AND DEVELOPMENT ACTIVITIES

Nuclear Regulatory Commission

The NRC is the primary regulatory agency in the repository siting, construction, operation and decommissioning phases. At the beginning of the siting process, the NWPA required NRC concurrence on DOE's siting guidelines (10 CFR 960, *Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines*, DOE, December 1984) before their adoption.

The NWPA also requires that the NRC promulgate technical requirements and criteria to be used in licensing a repository (10 CFR 60). These regulations consist of procedural rules for the licensing of a geologic repository and technical criteria used in the evaluation of a license application submitted under the procedural rules. The procedural portion of 10 CFR 60 sets forth the basic steps of the licensing process for the repository, and also provides specific requirements for a site characterization program and the associated site characterization plan. The technical criteria of 10 CFR 60 stipulate a number of performance objectives. The NRC has issued (June 1986) a proposed rule to amend 10 CFR 60 to conform existing NRC regulations to the standards promulgated by the EPA in 40 CFR 191.

The most intensive level of NRC involvement occurs during the site characterization and license application phases of the repository program, where the NRC has considerable oversight authority. The NRC's activities during each phase are discussed in the following sections.

Site Characterization. Before the selection of a site for the first repository, the candidate site -- Yucca Mountain, Nevada -- will be studied extensively according to the requirements of the NWPA and its amendments. Before sinking exploratory shafts at the site, DOE was required to prepare a site characterization plan (SCP) that summarizes information collected to date about the geologic conditions at the site, describes conceptual designs for the repository and the waste package, and presents plans for obtaining the data necessary to demonstrate the suitability of the site for a repository. DOE issued a consultative draft of the SCP in January 1988.

Specifications for the content of the SCP are presented in Section 113(b)(1) of the NWPA and in Section 60.17 of 10 CFR 60. To facilitate compliance with these requirements, the NRC has developed regulatory guidance on the format and content of the SCP for a geologic repository (Regulatory Guide 4.17, Standard Format and Content of Site Characterization Plans for High-Level-Waste Geologic Repositories, Revision 1). The NRC also has the authority to require additional information in the SCP. Further, it must review the SCP and provide comments in the form of a Site Characterization Analysis, as required by 10 CFR 60. The NRC submitted comments on the consultative draft of the SCP to DOE staff in May 1988. Meetings were held with DOE to discuss NRC questions about the plan, and to discuss strategies for resolving any problems. The statutory SCP issued in December 1988 for public review and comment (*Site Characterization Plan for the Yucca Mountain Site, State of Nevada*, DOE/RW-0199, December 1988) represents a significant revision of the document. Interactions between the DOE and the NRC staff will continue throughout site characterization.

Before proceeding with site characterization, DOE will have in place a quality assurance (QA) program which is accepted by the NRC. The NRC requires demonstrable evidence that both the public's health and safety are adequately protected in the repository development, construction and operations phases. QA methods and procedures will be applied to all structures, systems and components important to public safety; barriers important to waste isolation; and engineering and technological data.

Under the amended NWPA, the NRC will also review and comment on the draft environmental impact statement (EIS) required by the National Environmental Policy Act (NEPA) and the NWPA, as amended. The NRC will also review and comment on the adequacy of site characterization studies for inclusion in the license application for the geologic repository [Sections 114(a)(1)(D) and (E) of the NWPA and Sections 160(h)(2)D) and (E) of the Amendments Act].

Licensing. After the President recommends to Congress a site for the geologic repository and the site designation becomes effective, the Secretary of Energy is required by the NWPA, as amended, to submit a license application to the NRC. If the NRC approves the application as required by 10 CFR 60.31, it will then issue DOE a construction authorization.

Between the time a license application is submitted and the construction authorization is granted (approximately 27 months are planned for NRC review and the required adjudicatory proceedings), the NRC is required by the NWPA to submit annual reports to Congress that describe the progress made in processing the license application [Section 114(c) of the NWPA]. Once the NRC grants authorization, construction can begin.

Environmental Protection Agency

The NWPA charges the EPA with responsibility for promulgating generally applicable standards for a geologic repository to protect the health and safety of the public from potential hazards during nuclear waste disposal. Under Section 121(a) of the NWPA, the EPA promulgated standards (40 CFR 191) on August 15, 1985, for protecting the public from the offsite release of radioactive materials. These standards set: (1) limits on the radiation dose equivalent to any member of the public as the result of preclosure operations; (2) a limit on the amount of radioactivity that may enter the environment for 10,000 years after disposal; (3) limits on the radiation dose that can be delivered to any member of the public for 1,000 years after disposal and; (4) requirements for the protection of certain sources of ground water for 1,000 years after disposal. Compliance with EPA standards will be enforced, as noted above, by the NRC.

As directed by the NWPA, the EPA has reviewed and commented on DOE's siting guidelines (10 CFR 960), as well as environmental assessments (EAs), for the geologic repository. The EPA must also review and comment on DOE's EIS. In this regard, DOE has requested that the EPA serve as a "cooperating agency" during development of the EIS. When the draft EIS is complete, the EPA will review and comment on the document, as required by Section 309 of the Clean Air Act* as amended.

NWPA TRANSPORTATION ACTIVITIES

DOT and the NRC are responsible, by law, for regulating safety in the development and operation of a radioactive waste management transportation system serving the repository and an MRS facility.

In June 1979, the NRC and DOT signed a Memorandum of Understanding that delineates the respective responsibilities of each agency under law for regulation of safety in the transportation of radioactive materials. Generally, DOT is responsible for regulating safety in transport of radioactive materials as specified in 49 CFR 171-179. The NRC is responsible for review and approval of package designs for the transportation of high-level radioactive waste as specified in 10 CFR 71.

Department of Transportation

DOT signed a Memorandum of Understanding with DOE in August 1985. The document outlined the agencies' responsibilities under the NWPA for the transportation of spent nuclear fuel and high-level radioactive waste. The memorandum stipulates that "management of the transportation of spent fuel and high-level radioactive wastes under the NWPA resides with DOE's Office of Civilian Radioactive Waste Management." However, this task will be performed in full compliance with the NWPA and all applicable DOT regulations. The memorandum also states that DOE and DOT will exchange information, consult with each other and provide appropriate support within the areas of their responsibilities. Both DOT and DOE will interact as well with public and intergovernmental agencies to identify transportation-related impacts and acceptable transportation routes.

Nuclear Regulatory Commission

In November 1983, DOE signed a procedural agreement with the NRC concerning the planning assumptions and procedures that each agency will observe for development of transportation packaging under provisions of the NWPA. Under this agreement, the NRC will be responsible for reviewing safety analyses (called "Safety Analyses Report Packages") on transportation casks for spent nuclear fuel and high-level radioactive waste. Under the legislation, DOE must use packaging that has been approved by the NRC in accordance with 10 CFR 71. The NRC will also be responsible for inspecting and certifying casks before use by DOE for transporting radioactive waste.

* The Clean Air Act (42 U.S.C. 7401 et seq.) includes the Clean Air Act of 1963, PL 88-206, and its amendments.

OTHER AGENCIES HAVING RESPONSIBILITIES UNDER THE NWPA

The DOI and CEQ also have responsibilities specified under the requirements of the NWPA. Both agencies were consulted during development of DOE's siting guidelines (10 CFR 960), and both are charged with review of DOE's EIS for a geologic repository.

FEDERAL AGENCIES

U.S. Department of Agriculture (USDA)
Washington, DC 20250

Council on Environmental Quality (CEQ)
Washington, DC 20006

U.S. Department of Defense (DOD)
Washington, DC 20330

U.S. Department of Energy (DOE)
Washington, DC 20585

Environmental Protection Agency (EPA)
Washington, DC 20460

U.S. Department of the Interior (DOI)
Washington, DC 20240

U.S. Department of Justice (DOJ)
Washington, DC 20530

Nuclear Regulatory Commission (NRC)
Washington, DC 20555

U.S. Department of Transportation (DOT)
Washington, DC 20590

MAJOR FEDERAL REGULATIONS REFERRED TO IN THIS BACKGROUNDER

10 CFR 60 *Disposal of High-Level Radioactive Wastes in Geologic Repositories*

10 CFR 71 *Packaging and Transportation of Radioactive Material*

10 CFR 960 *Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories; Final Siting Guidelines*

40 CFR 191 *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes*

49 CFR 171-179 *Hazardous Materials Regulations*

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DOE/RW-0255

OCRWM Backgrounder

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Cask Systems Development:
Titan Truck Cask

INTRODUCTION

The Nuclear Waste Policy Act of 1982, as amended, made the Office of Civilian Radioactive Waste Management (OCRWM) of the U.S. Department of Energy (DOE) responsible for managing the program for the permanent disposal of spent nuclear fuel from commercial power plants and high-level radioactive waste from national defense activities.

Transportation casks will contribute toward the safety of the nuclear waste transportation system. They will protect the public and transportation workers from potential exposure to radiation during normal transportation activities and if an accident occurs. This protection is provided through the use of rugged materials designed and constructed according to regulations established by the U.S. Nuclear Regulatory Commission (NRC).

The OCRWM Cask Systems Development Program is designing a variety of casks to safely transport radioactive waste from the generator sites to a geologic repository or a monitored retrievable storage facility. Five contracts have been awarded; three to develop rail/barge casks and two for legal-weight truck casks.

As of December 1989, all five cask contractors had submitted preliminary designs to the OCRWM. The designs have been reviewed by a Technical Review Group composed of national experts in cask development areas. This backgrounder describes the Westinghouse Titan spent fuel shipping cask for legal-weight truck shipments.

Contractor

Westinghouse Electric
Corporation
Pittsburgh, Pennsylvania

Type of Cask

27-ton legal-weight truck shipping cask

Size

Length—17′
Diameter—7′ **(with impact limiters)**
Weight—27 tons

Features

Cask body
Common pressurized-water reactor (PWR) or boiling-water reactor (BWR) use: Multilayered concentric shell accommodating removable fuel baskets

Payload
3 PWR or 7 BWR intact fuel assemblies

Structural material
Titanium alloy

Basket
Stainless steel

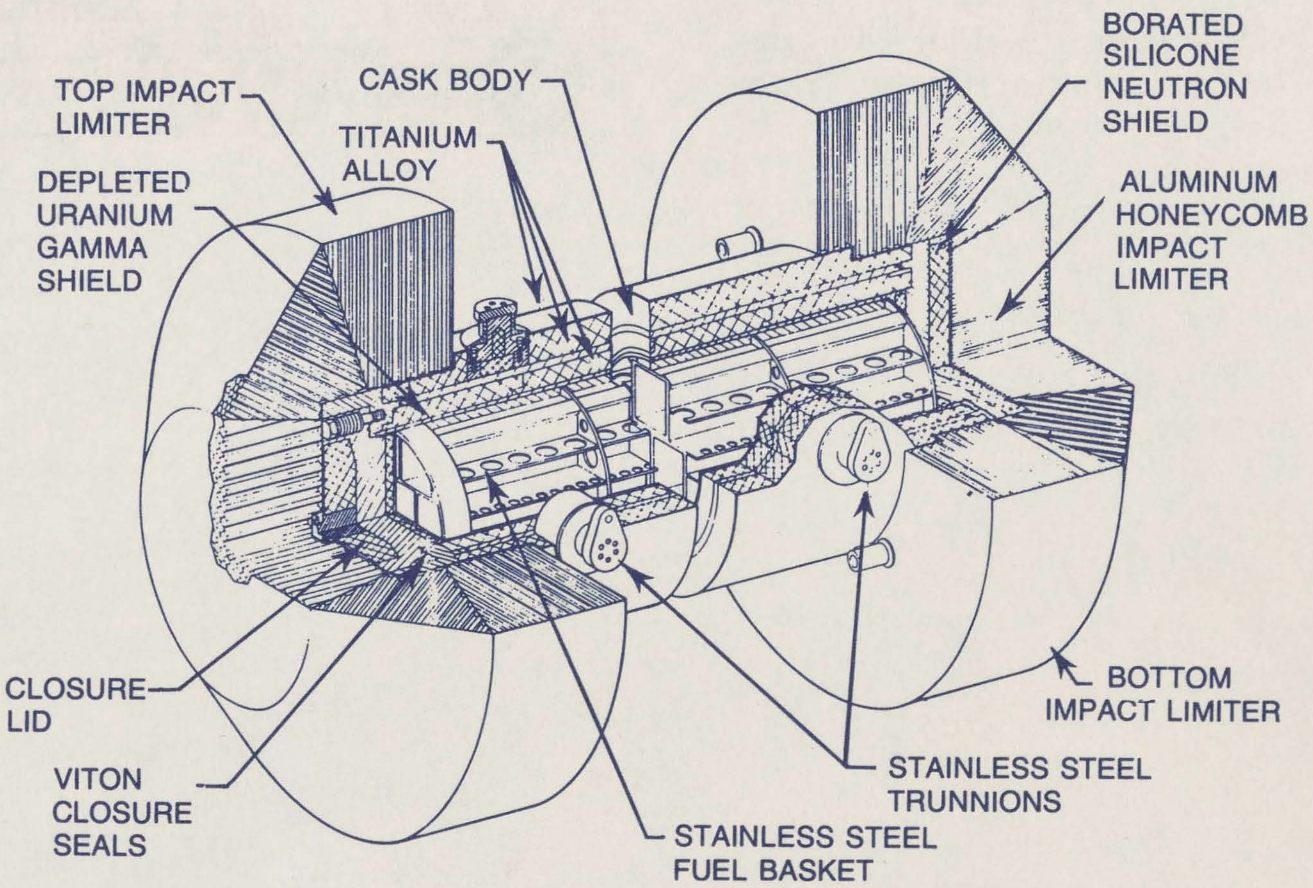
Gamma shielding
Depleted uranium

Neutron shielding
Borated silicone

Closure type
Bolted

Sealing type
Face seals

Impact limiters
Aluminum honeycomb with stainless steel shell



Westinghouse Titan 27-Ton Legal-Weight Truck Shipping Cask

The innovative cask design of the Westinghouse Titan uses high-strength-to-weight titanium alloy as the structural material for the cask body. Depleted uranium is the primary gamma shield material. Borated silicone is used for neutron shielding, and aluminum honeycomb for the impact limiters.

Casks must meet design performance standards, testing conditions, and certification requirements established by the NRC. Cask design certification applications must demonstrate to the NRC, through analysis and/or testing, that casks can withstand both normal transportation and accident conditions, as specified in Federal regulations.

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Interface Guidelines, Cask Size/Weight Limits

Diameter—6′

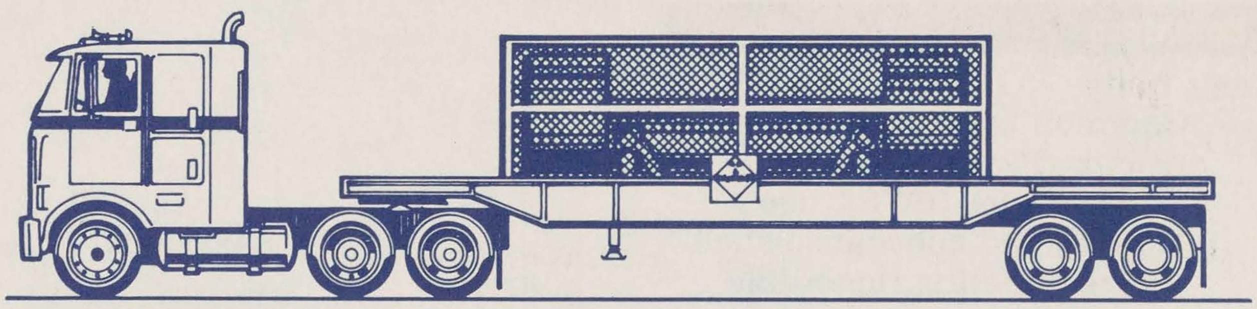
Height (Length)—Limited by headroom

Headroom—22′

Cask loading height—18′

Gross vehicle weight—40 tons (max.) including tractor, trailer, and loaded cask

Shipping Cask with Personnel Barrier on Truck Trailer



DOE/RW-0256
OCRWM Backgrounder

Cask Systems Development:
NuPac 140-B Rail/Barge Cask

INTRODUCTION

The Nuclear Waste Policy Act of 1982, as amended, made the Office of Civilian Radioactive Waste Management (OCRWM) of the U.S. Department of Energy (DOE) responsible for managing the program for the permanent disposal of spent nuclear fuel from commercial power plants and high-level radioactive waste from national defense activities.

Transportation casks will contribute toward the safety of the nuclear waste transportation system. They will protect the public and transportation workers from potential exposure to radiation during normal transportation activities and if an accident occurs. This protection is provided through the use of rugged materials designed and constructed according to regulations established by the U.S. Nuclear Regulatory Commission (NRC).

The OCRWM Cask Systems Development Program is designing a variety of casks to safely transport radioactive waste from the generator sites to a geologic repository or a monitored retrievable storage facility. Five contracts have been awarded; three to develop rail/barge casks and two for legal-weight truck casks.

As of December 1989, all five cask contractors had submitted preliminary designs to the OCRWM. The designs have been reviewed by a Technical Review Group composed of national experts in cask development areas. This backgrounder describes the Nuclear Packaging, Inc. NuPac 140-B spent fuel shipping cask for rail and barge shipments.

Contractor

Nuclear Packaging, Inc.
Federal Way, Washington

Type of Cask

100-ton rail/barge shipping cask

Size

Length—21′
Diameter—11′ (with impact limiters)
Weight—103.3 tons

Features

Cask body
Multilayered concentric shell

Payload
21 pressurized-water reactor or 52 boiling-water reactor intact fuel assemblies

Structural material
Stainless steel

Basket
Stainless steel

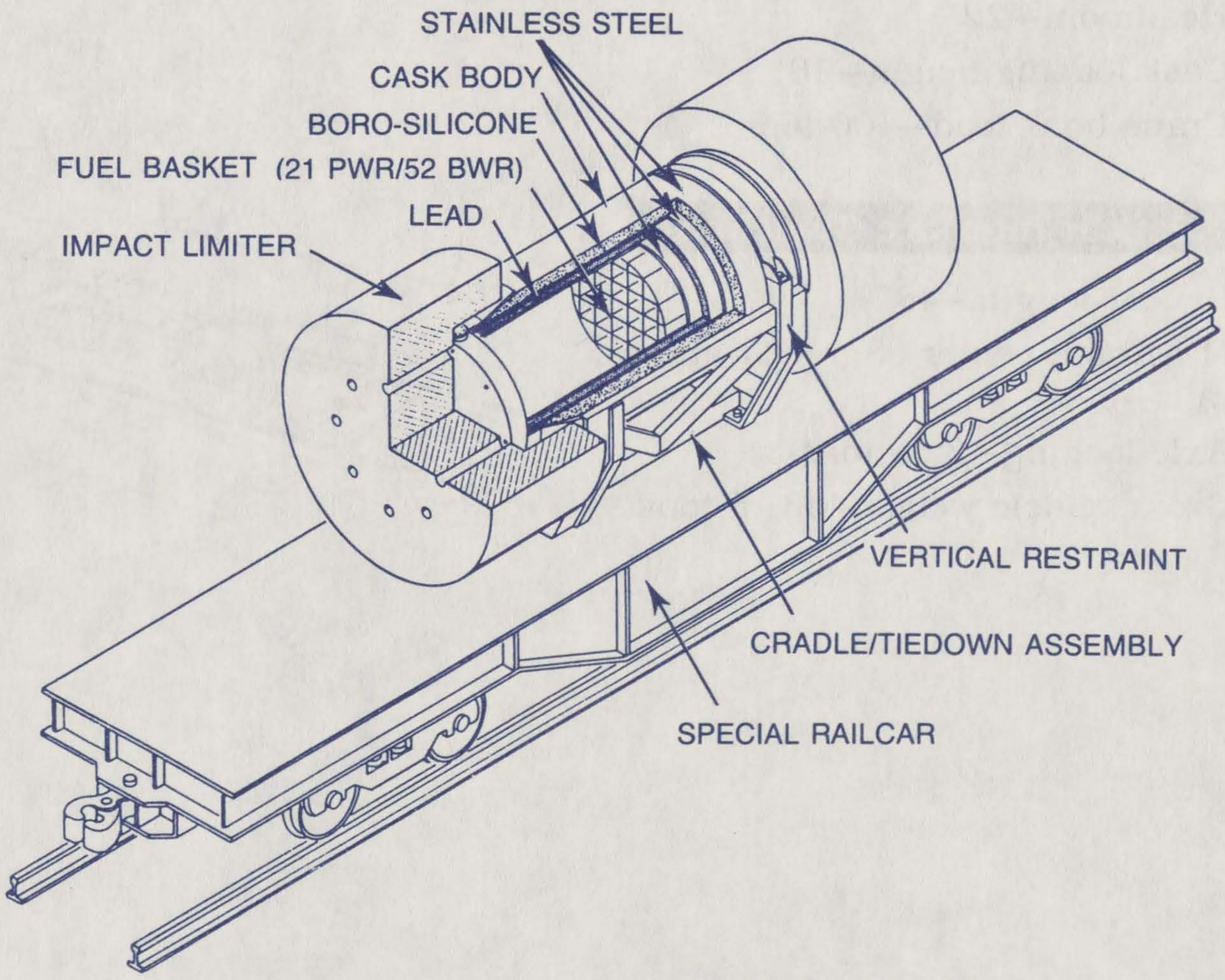
Gamma shielding
Lead

Neutron shielding
Borated silicone

Sealing type
Bore seal O-ring

Closure lid
Bolted

Impact limiters
Polyurethane with stainless steel shell



Nuclear Packaging, Inc. 140-B 100-Ton Rail/Barge Cask

Nuclear Packaging's 140-B, 100-ton rail/barge shipping cask uses a multilayered concentric shell for the cask body. Stainless steel inner and outer shells provide containment and structural integrity and enclose a lead gamma shield and borated silicone neutron shield. Copper fins are incorporated into the neutron shield to transfer heat from the cask. Smooth surfaces on all exposed areas minimize decontamination procedures after pool loading and "weeping" during shipment. The 140-B also features polyurethane impact limiters inside a stainless steel shell. The payload basket is constructed of light-weight jointed trusscore stainless steel panels clad with copper and a neutron-absorbing material.

Casks must meet design performance standards, testing conditions, and certification requirements established by the NRC. Cask design certification applications must demonstrate to the NRC, through analysis and/or testing, that casks can withstand both normal transportation and accident conditions, as specified in Federal regulations.

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Interface Guidelines, Cask Size/Weight Limits

Diameter—8′ 6″ (without impact limiters)

Height (Length)—Limited by headroom

Headroom—22′

Cask loading height—18′

Crane hook load—100 tons

Railcar Interface Guidelines

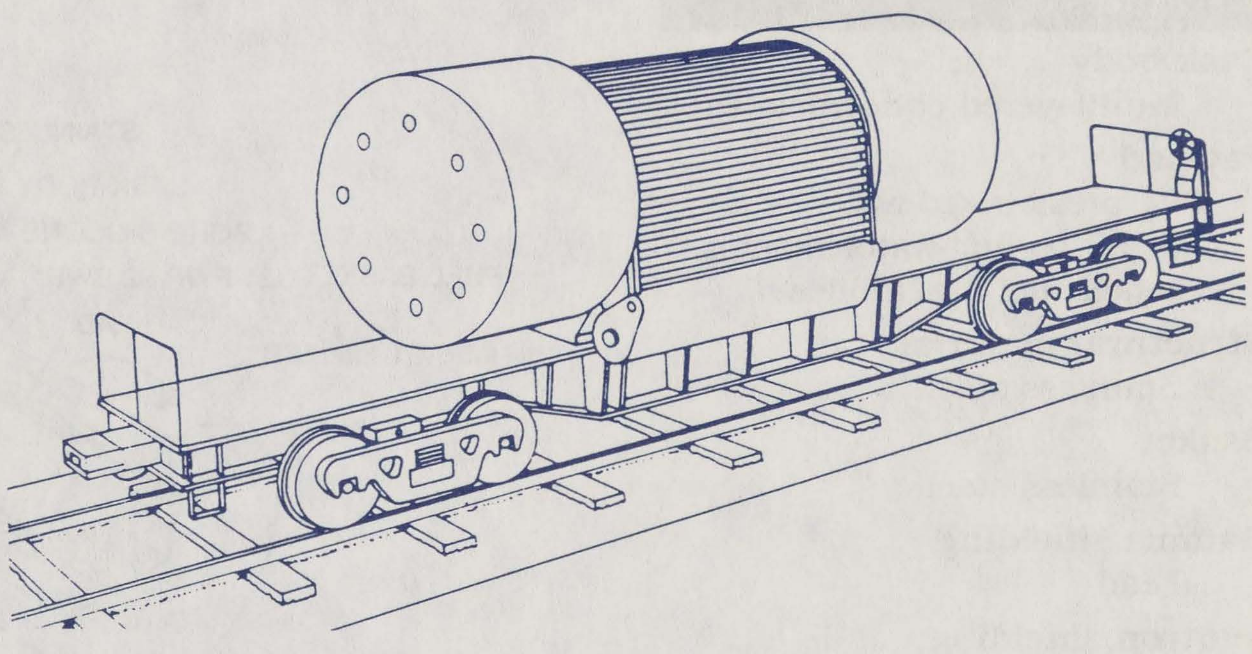
Railcar length—48′

Maximum center of gravity above rails—8′

Axle loading—32.8 tons

Gross vehicle weight—131.5 tons

Shipping Cask on Railcar



DOE/RW-0257

OCRWM Backgrounder

Cask Systems Development:
BR-100 Rail/Barge Cask

INTRODUCTION

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Transportation casks will contribute toward the safety of the nuclear waste transportation system. They will protect the public and transportation workers from potential exposure to radiation during normal transportation activities and if an accident occurs. This protection is provided through the use of rugged materials designed and constructed according to regulations established by the U.S. Nuclear Regulatory Commission (NRC).

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As of December 1989, all five cask contractors had submitted preliminary designs to the OCRWM. The designs have been reviewed by a Technical Review Group composed of national experts in cask development areas. This backgrounder describes the Babcock & Wilcox BR-100 cask for rail and barge shipments.

Contractor

Babcock & Wilcox
Lynchburg, Virginia

Type of Cask

100-ton rail/barge shipping cask

Size

Length—21′
Diameter—10.5′ (with impact limiters)
Weight—102 tons

Features

Cask body
Multilayered concentric shell

Payload
21 pressurized-water reactor (PWR) or 52 boiling-water reactor (BWR) intact fuel assemblies

Structural material
Stainless steel

Basket
Aluminum

Gamma shielding
Lead

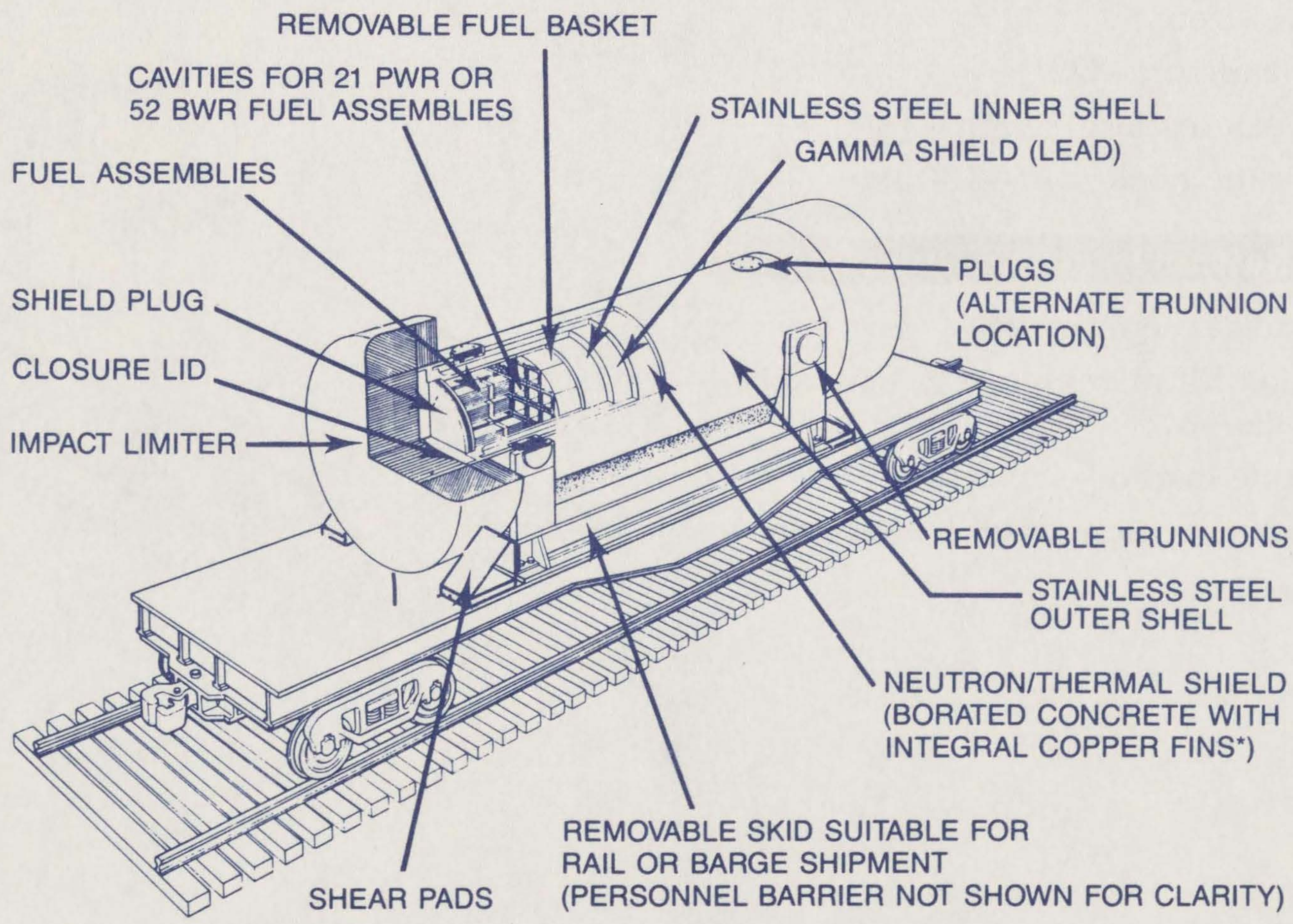
Neutron shielding
Borated concrete

Shield plug
Keyed in position

Sealing type
Face seals

Closure lid
Bolted

Impact limiters
Balsa and redwood enclosed in a high-strength plastic



*PATENTED BY ROBATEL SA

Babcock & Wilcox BR-100 100-Ton Rail/Barge Cask

The B&W BR-100 rail/barge shipping cask uses a multilayer concentric shell for the cask body. A lead gamma shield and borated concrete neutron shield, sandwiched between stainless steel inner and outer shells, provide heat dissipation, radioactive material containment, and radiation shielding. Smooth surfaces on all exposed areas minimize decontamination procedures after pool loading and "weeping" during shipment. The BR-100 also features impact limiters constructed of Kevlar® -enclosed balsa and redwood, and a two-piece closure system with a shield plug for radiation shielding and a separate closure lid for pressure containment.

Casks must meet design performance standards, testing conditions, and certification requirements established by the NRC. Cask design certification applications must demonstrate to the NRC, through analysis and/or testing, that casks can withstand both normal transportation and accident conditions, as specified in Federal regulations.

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To provide current background information on program facts, issues and initiatives. For further information write to: Information Services Division, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, Mail Stop RW-43, Washington, DC 20585.

Interface Guidelines, Cask Size/Weight Limits

Diameter—8′ 6″ (without impact limiters)

Height (Length)—Limited by headroom

Headroom—22′

Cask loading height—18′

Crane hook load—100 tons

Railcar Interface Guidelines

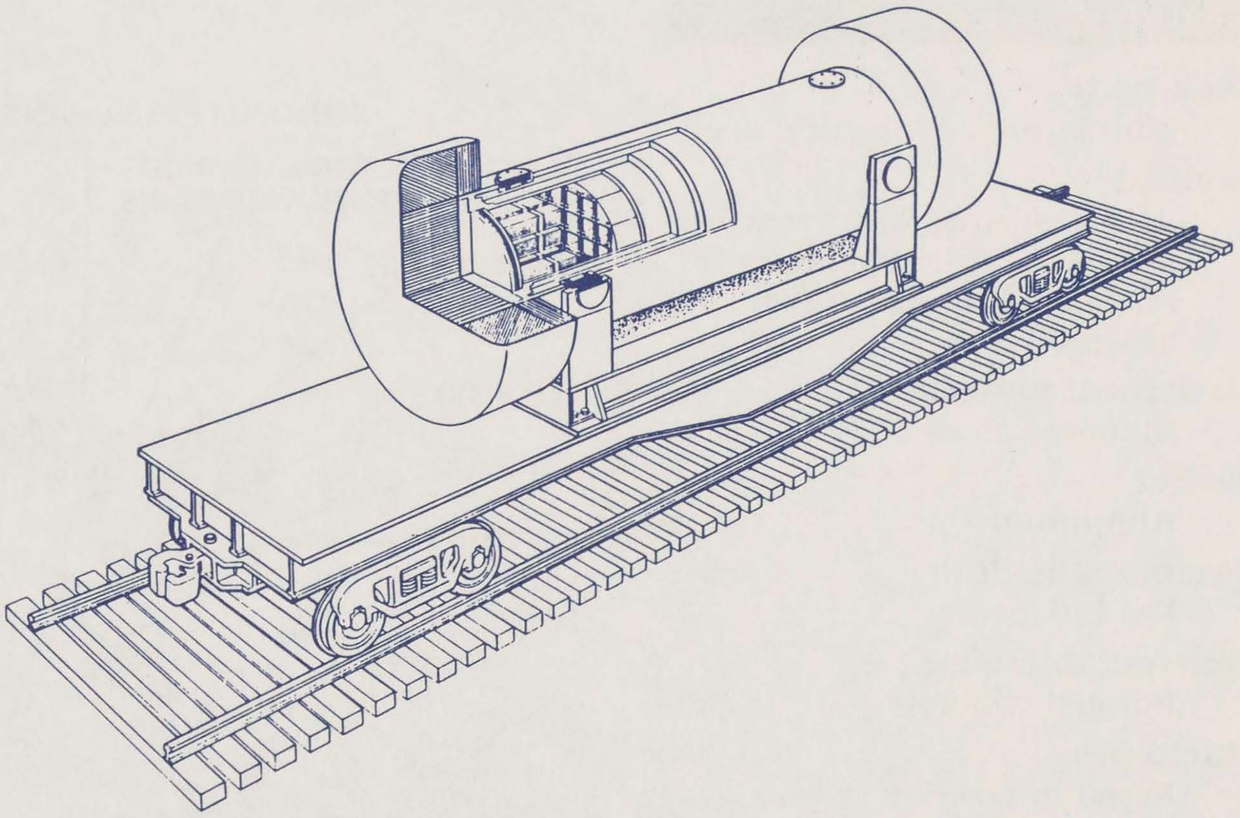
Railcar length—48′

Maximum center of gravity above rails—8′

Axle loading—32.8 tons

Gross vehicle weight—131.5 tons

Shipping Cask on Railcar



DOE/RW-0258
OCRWM Backgrounder

Cask Systems Development:
GA-4 & GA-9 Truck Cask

INTRODUCTION

The Nuclear Waste Policy Act of 1982, as amended, made the Office of Civilian Radioactive Waste Management (OCRWM) of the U.S. Department of Energy (DOE) responsible for managing the program for the permanent disposal of spent nuclear fuel from commercial power plants and high-level radioactive waste from national defense activities.

Transportation casks will contribute toward the safety of the nuclear waste transportation system. They will protect the public and transportation workers from potential exposure to radiation during normal transportation activities and if an accident occurs. This protection is provided through the use of rugged materials designed and constructed according to regulations established by the U.S. Nuclear Regulatory Commission (NRC).

The OCRWM Cask Systems Development Program is designing a variety of casks to safely transport radioactive waste from the generator sites to a geologic repository or a monitored retrievable storage facility. Five contracts have been awarded; three to develop rail/barge casks and two for legal-weight truck casks.

As of December 1989, all five cask contractors had submitted preliminary designs to the OCRWM. The designs have been reviewed by a Technical Review Group composed of national experts in cask development areas. This backgrounder describes the General Atomics GA-4 and GA-9 spent fuel shipping casks for legal-weight truck shipments.

Contractor

General Atomics Corporation
San Diego, California

Features

Square cask cavity
Two specialized designs: one exclusively for pressurized-water reactor (PWR) and another exclusively for boiling-water reactor (BWR) fuel.

Payload
4 PWR (GA-4) or 9 BWR (GA-9) intact fuel assemblies

Structural material
Stainless steel

Basket
Stainless steel

Gamma shielding
Depleted uranium

Neutron shielding
Borated polyethylene

Closure type
Bolted

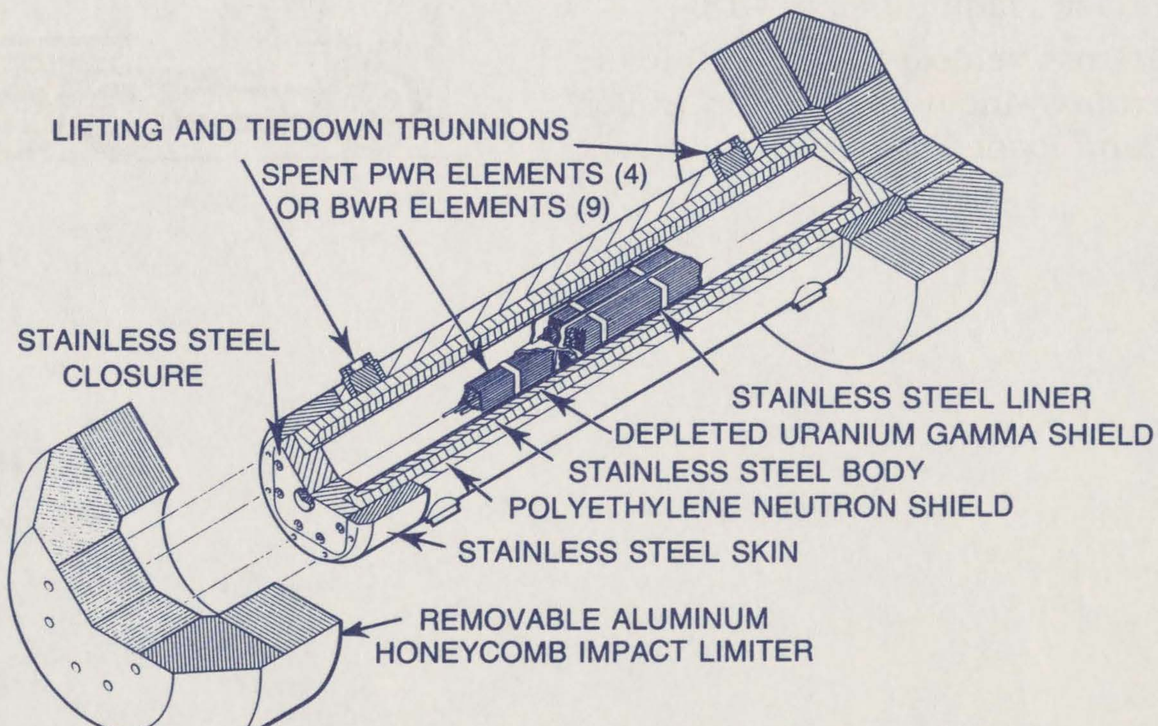
Impact limiters
Aluminum honeycomb with stainless steel shell

Type of Cask

27-ton legal-weight truck shipping casks

Size

Length—19.5′ (GA-4) and 20.3′ (GA-9)
Diameter—7.5′ and 7.5′ **(with impact limiters)**
Weight—26.3 and 26.45 tons



GA-4/GA-9 LEGAL-WEIGHT TRUCK SHIPPING CASK

General Atomics Corporation GA-4 and GA-9 27-Ton Legal-Weight Truck Shipping Casks

General Atomics Corporation's GA-4 and GA-9 are two specialized shipping cask designs: one for pressurized-water reactor fuel assemblies and the other for boiling-water reactor fuel assemblies. The casks' stainless steel structural material has distinctive shaped cross-sections that minimize weight and maximize payload. Neutron shielding is provided by borated polyethylene and the gamma shielding is constructed of depleted uranium. The removable impact limiters are made from aluminum honeycomb with a stainless steel shell.

Casks must meet design performance standards, testing conditions, and certification requirements established by the NRC. Cask design certification applications must demonstrate to the NRC, through analysis and/or testing, that casks can withstand both normal transportation and accident conditions, as specified in Federal regulations.

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Interface Guidelines, Cask Size/Weight Limits

Diameter—6′

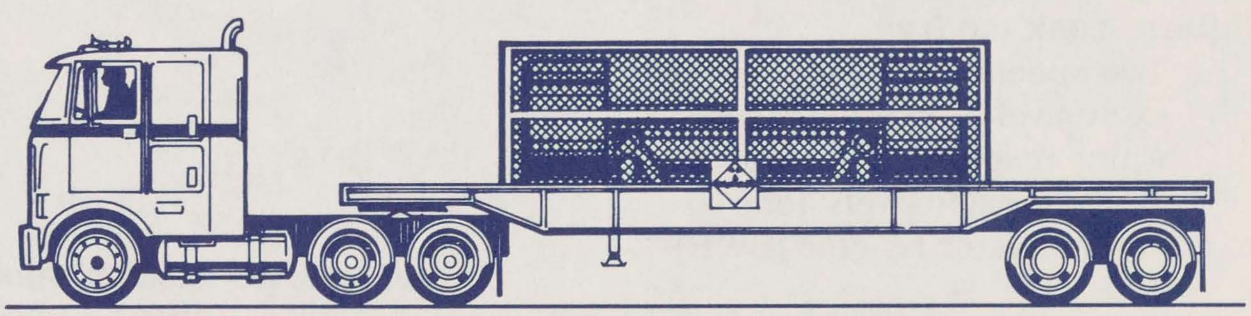
Height (Length)—Limited by headroom

Headroom—22′

Cask loading height—18′

Gross vehicle weight—40 tons (max.) including tractor, trailer, and loaded cask

Shipping Cask with Personnel Barrier on Truck Trailer



DOE/RW-0259
OCRWM Backgrounder

Cask Systems Development:
NAC-CTC Rail/Barge Cask

INTRODUCTION

The Nuclear Waste Policy Act of 1982, as amended, made the Office of Civilian Radioactive Waste Management (OCRWM) of the U.S. Department of Energy (DOE) responsible for managing the program for the permanent disposal of spent nuclear fuel from commercial power plants and high-level radioactive waste from national defense activities.

Transportation casks will contribute toward the safety of the nuclear waste transportation system. They will protect the public and transportation workers from potential exposure to radiation during normal transportation activities and if an accident occurs. This protection is provided through the use of rugged materials designed and constructed according to regulations established by the U.S. Nuclear Regulatory Commission (NRC).

The OCRWM Cask Systems Development Program is designing a variety of casks to safely transport radioactive waste from the generator sites to a geologic repository or a monitored retrievable storage facility. Five contracts have been awarded; three to develop rail/barge casks and two for legal-weight truck casks.

As of December 1989, all five cask contractors had submitted preliminary designs to the OCRWM. The designs have been reviewed by a Technical Review Group composed of national experts in cask development areas. This backgrounder describes the Nuclear Assurance Corporation NAC-CTC spent fuel shipping cask for rail and barge shipments.

Contractor

Nuclear Assurance Corporation
Norcross, Georgia

Type of Cask

100-ton rail/barge shipping cask

Size

Length—22′
Diameter—10′ (with impact limiters)
Weight—107 tons

Features

Cask body
Multilayered concentric shell

Payload
26 pressurized-water reactor or 52 boiling-water reactor intact fuel assemblies

Structural material
High-strength ferritic steel inner and outer shells
Stainless steel outer skin

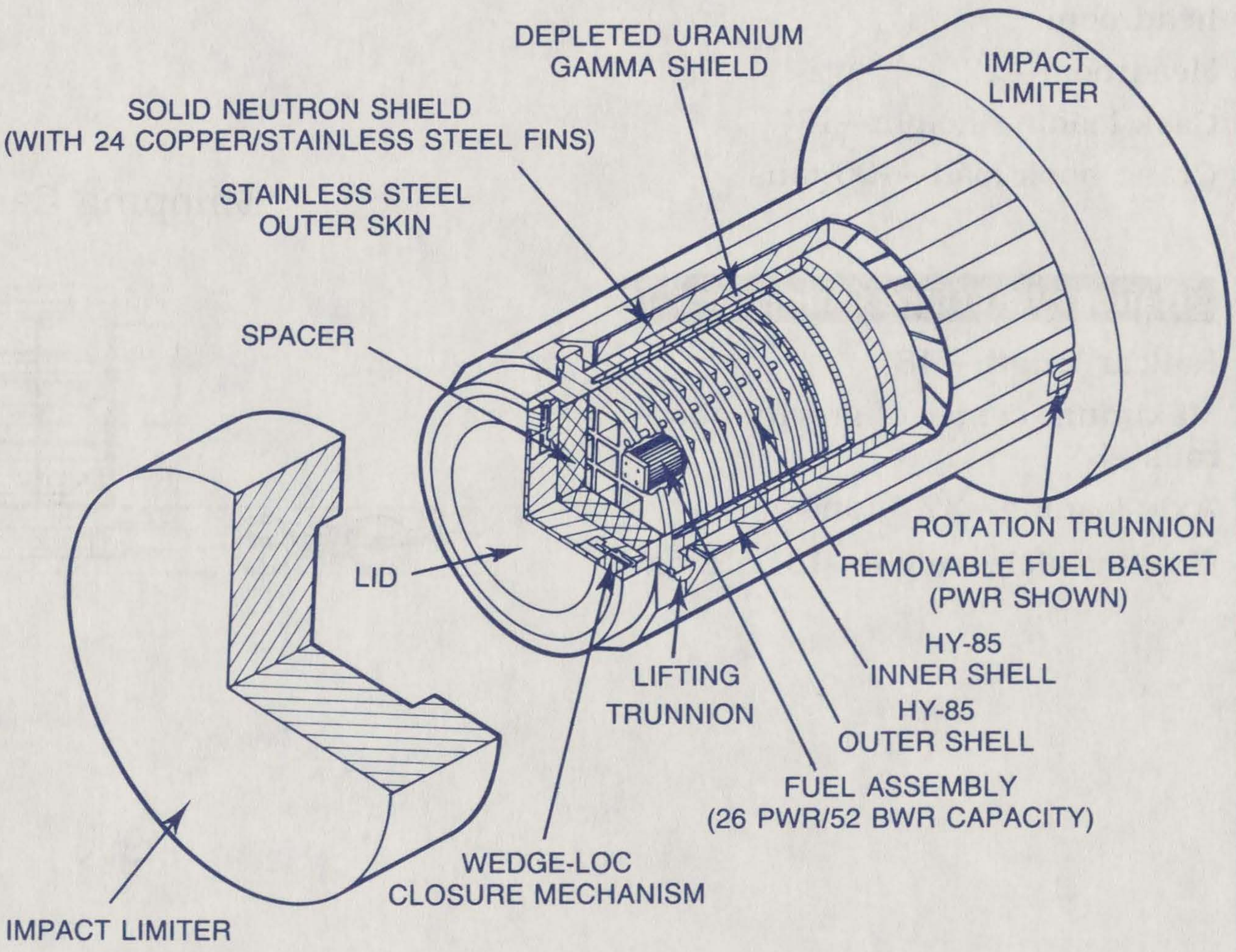
Basket
Aluminum

Gamma shielding
Depleted uranium

Neutron shielding
NS4FR

Lid
WEDGE-LOC closure system

Impact limiters
Aluminum honeycomb with stainless steel shell



Nuclear Assurance Corporation NAC-CTC 100-Ton Rail/Barge Combined Transport Cask

Nuclear Assurance Corporation's NAC-CTC 100-ton rail/barge shipping cask body consists of two concentric high-strength ferritic steel shells. The cask utilizes a layer of depleted uranium as the gamma shield which is sandwiched between ferritic steel shells. A synthetic polymer, NS4FR, is used for neutron radiation shielding. The fuel basket is constructed of aluminum because of its high thermal conductivity and low weight. A patented WEDGE-LOC lid closure system provides a positive verification of wedge engagement/disengagement and significantly reduces occupational radiation exposure. The impact limiters are constructed of aluminum honeycomb material.

Casks must meet design performance standards, testing conditions, and certification requirements established by the NRC. Cask design certification applications must demonstrate to the NRC, through analysis and/or testing, that casks can withstand both normal transportation and accident conditions, as specified in Federal regulations.

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Interface Guidelines, Cask Size/Weight Limits

Diameter—8′6″ (without impact limiters)

Height (Length)—Limited by headroom

Headroom—22′

Cask loading height—18′

Crane hook load—100 tons

Railcar Interface Guidelines

Railcar length—48′

Maximum center of gravity above rails—8′

Axle loading—32.8 tons

Gross vehicle weight--131.5 tons

Shipping Cask on Railcar