PNL-SA--19567

DE91 013223

THE U.S. PROGRAM FOR MANAGEMENT OF SPENT NUCLEAR FUEL

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April 1991

Prepared for Use at the
Advisory Group Meeting on
Strategies, Options, and Trends
in Spent Fuel Management
International Atomic Energy Agency
Vienna, Austria
April 15-18, 1991

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Introduction

The basic policy for management of spent nuclear fuel (SNF) and high-level waste (HLW) in the United States is storage, followed by disposal in a geologic repository. In 1980, following preparation of an environmental impact statement on commercial radioactive waste, the Department of Energy (DOE) made a formal record of decision to adopt geologic disposal as the method for disposal of SNF and HLW. Subsequently, Congress passed two acts of legislation which established the basic direction followed since that time. These were: The Nuclear Waste Policy Act of 1982 (NWPA-1982) and The Nuclear Waste Policy Amendments Act of 1987 (NWPAA-1987). These acts assign the responsibility for management of SNF and HLW to DOE, with the costs of these activities to be borne by the owners/generators of the waste.

The funds to pay for the storage and disposal activities are obtained by assessing a fee against the electricity produced and sold by the nuclear plants (10 CFR 961). This fee is presently in the amount of 1 mill (1/1000 of a dollar) per kilowatt-hour of electricity sold, based on the anticipated total system lifecycle costs (DOE 1987) for managing the wastes. Congress has the option to increase the fee should future analyses show that additional funding will be necessary to complete the program.

The possibility of reprocessing of SNF to recover the residual fuel values (uranium and plutonium) for recycle back into the fuel feed stream was ended in the U.S. in 1977 by an executive order issued by President Jimmy Carter. While President Reagan rescinded the prohibition against commercial reprocessing in the early 1980s, all initiatives were left to the private sector, which has been unwilling to accept the financial risks associated with the construction and operation of a reprocessing facility.

Without reprocessing, inventories of SNF have continued to build in the storage pools at reactor sites, forcing many utilities to take actions to increase the storage capacities of their sites. The most prevalent action taken by the utilities has been to re-rack their storage pools with higher capacity storage racks. A few utilities have tried fuel assembly consolidation as a means of increasing the capacity of their pools, and a few more have installed dry storage devices of various types on their sites to permit storage outside of their reactor pools.

The projected total annual discharge of SNF from the operating reactors in the U.S. ranges from about 1700 metric tons of initial uranium per year (MTU/yr) to about 2400 MTU/yr, and averages about 1850 MTU/yr (DOE 1990). The cumulative out-of-pool SNF storage requirements are illustrated as a function of time in Figure 1. Also shown are the number of reactor sites that will be needing out-of-

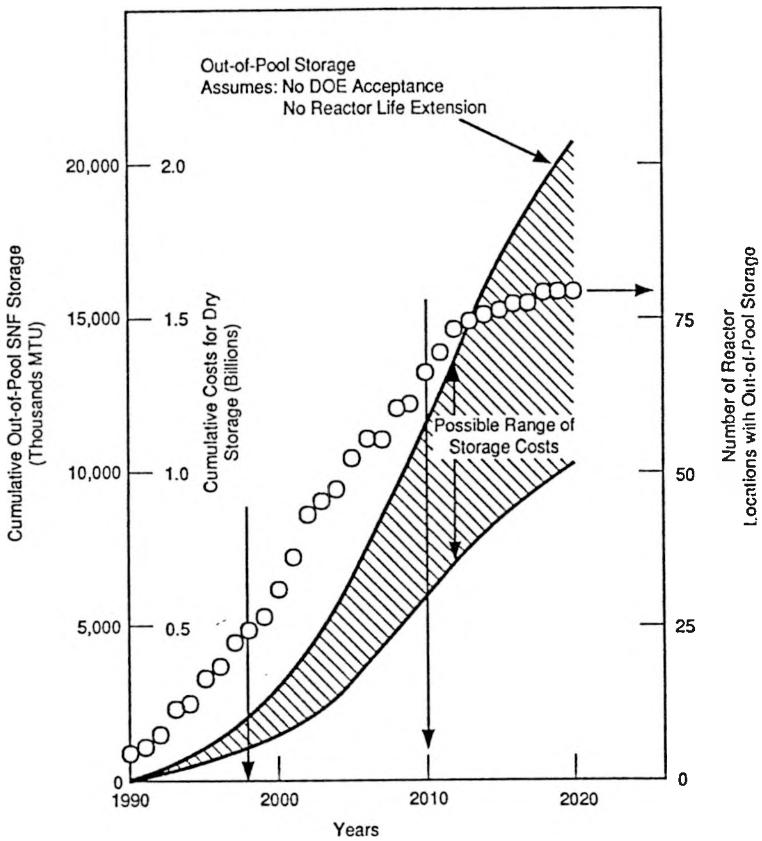

FIGURE 1 Projected SNF Out-of-Pool Inventory and Costs

pool storage, and the ranges of projected cumulative storage costs, assuming all reactors cease operations at the end of their original license term (nominally 40 years), and that DOE has not accepted any SNF from the reactors. These totals will be even larger if, as seems likely, some utilities extend their operating licenses beyond the initial 40-year period, which is now possible under a recent NRC ruling (10 CFR 50.51). The cost of dry storage in the various concepts under consideration in the U.S. range from about $50 per initial kilogram of uranium (kgU) to over $100/kgU (DOE 1989), depending upon the concept selected and the eventual total installed site capacity.

Options for SNF Management

As discussed above, the options for SNF management in the U.S. are presently limited by law to storage, with eventual geologic disposal. Current schedules call for a repository to begin operation in 2010, assuming the candidate site at Yucca Mountain, Nevada is found to be suitable and the various institutional difficulties presently delaying the repository program can be successfully overcome. However, should the Yucca Mountain site be found to be unsuitable, it is likely that repository operations will be delayed for a number of years while another site is located and qualified. As a result, at least until 2010, storage is the only SNF management option in the U.S. During this extended storage period, the SNF will remain readily retrievable and available should reprocessing again become viable.

Current Status of SNF Storage

Nearly all of the SNF stored in the U.S. is contained in the water-filled pools associated with the nuclear reactors that generated the SNF. The early reactors were built with limited pool storage space, planning on the reprocessing plants to accept the fuel before storage volume became a problem. Many of these reactors are now beginning to run out of storage capacity in their pools. Some of the reactors built after the reprocessing option was terminated were designed with the capacity to store a life-time accumulation of SNF in their pools. However, by 1998, the year that DOE has committed to begin acceptance of SNF from the utilities, nearly one-third of the U.S. reactors will need some amount of out-of-pool storage capacity (DOE 1990), and as illustrated in Figure 1, the number of sites and the amount of SNF requiring out-of-pool storage increases every year thereafter.

Licensing of facilities for the storage and for the disposal of SNF in the U.S. is under the jurisdiction of the Nuclear Regulatory Commission (NRC), and is governed by the regulations contained in Title 10, Code of Federal Regulations, Parts 50, 72, and 60 (10 CFR 50, 10 CFR 72, 10 CFR 60), for reactor operations, independent spent fuel storage installations (ISFSI) and monitored retrievable storage (MRS) installations, and geologic repository operations, respectively.

A variety of SNF storage concepts have been developed and implemented in the U.S. The first concept to be employed was the large water-filled pool, located separately from any reactors. Such facility is in service at Morris, Illinois, and is the first such facility licensed under 10 CFR 72. The next concept to be employed was the dry metal storage cask, providing additional out-of-pool storage capacity at reactor sites. One utility has already established an ISFSI on his reactor site containing metal storage casks, using three different cask designs. To facilitate the addition of dry storage capacity at the reactor sites, the NRC has issued a general license under 10 CFR 72, Subpart K, applicable to all operating reactor sites licensed under 10 CFR 50, which permits the licensee to store his SNF on his site in casks previously certified for storage service without having to go through a full-scale licensing action. There are presently four cask designs (CASTOR V/21, MC-10, NAC S/T, and NAC-C28 S/T) certified for storage service in the U.S. under this general license. Two other metal cask designs (CASTOR X, NAC-STC) are undergoing NRC review for certification. A typical metal storage cask (NAC-S/T) is illustrated in Figure 2.

For storage concepts other than these four metal casks, the licensee must work through the complete licensing process for an ISFSI as defined in 10 CFR 72. The horizontal concrete storage module (NUHOMS), illustrated in Figure 3, has been licensed and is in service at two reactor sites, with two other sites in the licensing stage. The Topical Report for the natural circulation vault, illustrated in Figure 4, has been approved by NRC and a license application has been filed for an installation employing this concept at Ft. St. Vrain in Colorado. The ventilated concrete cask concept,

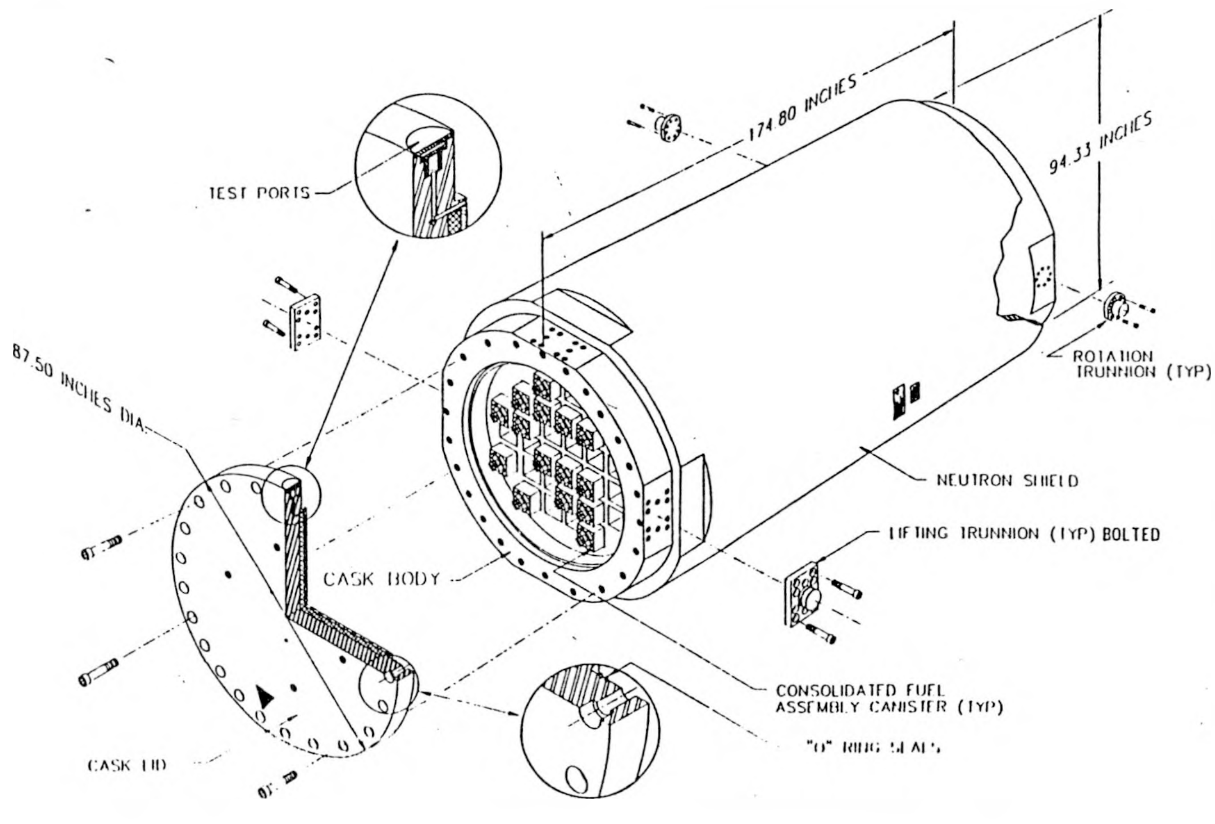

FIGURE 2. Typical Metal Storage Cask (NAC-S/T)

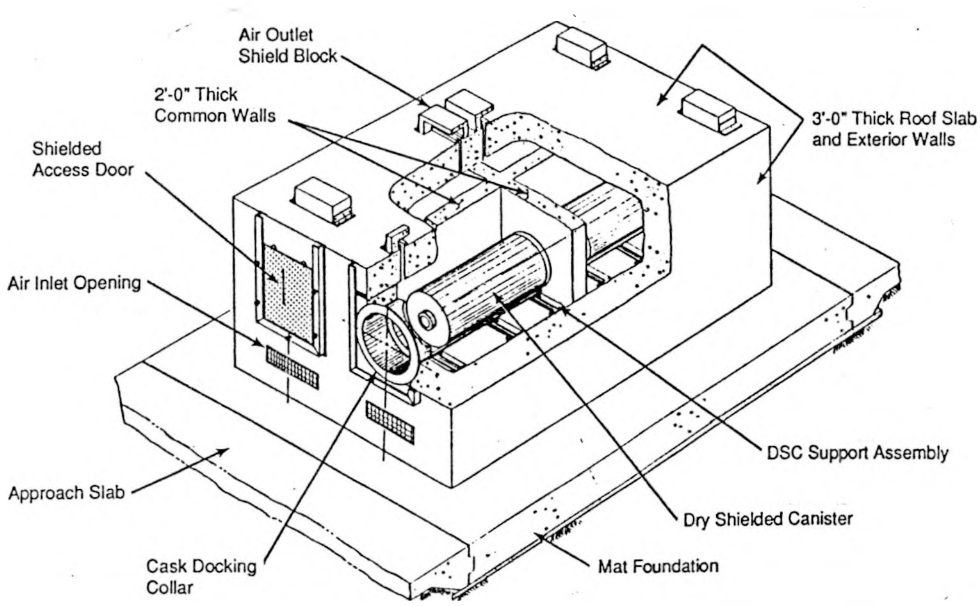

FIGURE 3. Horizontal Concrete Storage Module (NUHOMS 24P)

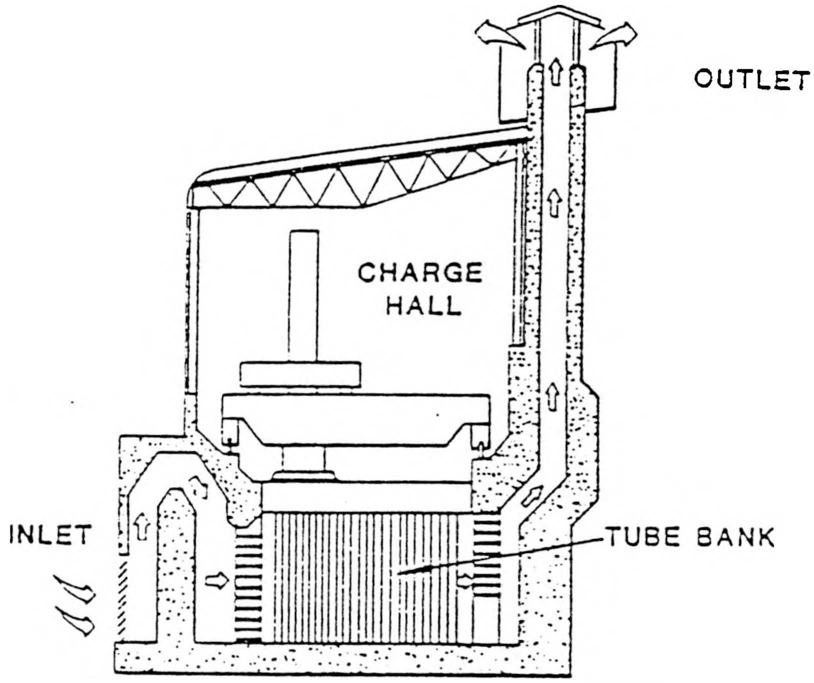

FIGURE 4. Natural Circulation Vault (MVDS)

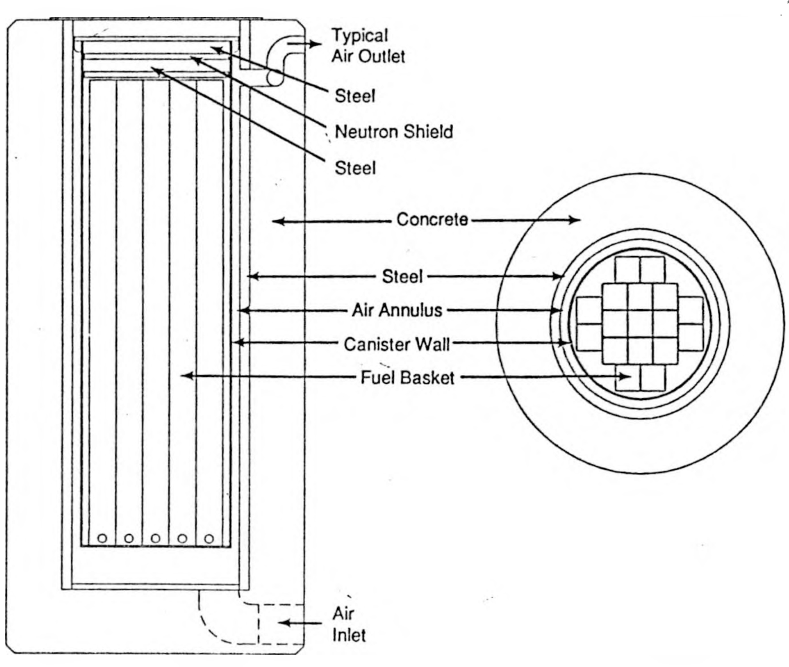

FIGURE 5. Ventilated Concrete Storage Cask (PSN-17)

illustrated in Figure 5, has been tested at the Idaho National Engineering Laboratory (INEL), and the Topical Report is under review by the NRC, with approval expected. Several utilities have expressed an interest in the ventilated concrete cask concept.

For the at-reactor installations, system economics tend to favor the concepts that permit small incremental additions to the total storage capacity (DOE 1989), because of the uncertainties about just how much SNF a given site might have to store before the DOE begins accepting SNF into the federal waste management system. Thus, the metal and concrete casks and the horizontal concrete modules tend to be preferred over a water pool or a vault because the initial capital investments are smaller. However, if the amount of SNF to be stored can be clearly defined, and that quantity is fairly large, the economics of the pool and the vault become more acceptable.

The storage concept to be used at DOE's MRS facility has not yet been determined. An earlier concept evaluation (DOE 1984) had selected the concrete cask as the preferred choice. A review of that selection (Fletcher 1989) reached the same conclusion. However, DOE has chosen to keep its options open and will make its final selection of the storage concept during the current conceptual design effort for the MRS facility.

Storage of High Burnup Fuel

As the technology of light-water reactors has improved over the years, the ability of the fuel to survive for longer periods of irradiation has also improved. Most fuel from the earlier operating periods was irradiated to levels of 25,000 to 30,000 megawatt-days per metric ton (MWD/MTU), and much of the federal waste management system has so far been designed to accommodate fuel with burnup in that range and which had been cooled for 10 years following final discharge. Much of the fuel being discharged currently and expected to be discharged in the future will have been irradiated to levels of 40,000 to 50,000 MWD/MTU, and the cooling times may be as little as 5 years. A consequence of higher burnup and shorter cooling is a larger inventory of fission products and transuranic elements in the fuel, with the accompanying higher levels of radioactivity (more intense gamma-ray and neutron emissions). Thus, both the shielding capability and the heat removal capacity of the storage devices must by increased, to provide the same level of radiation protection to the public and thermal protection to the fuel as was previously provided.

Several alternative approaches can be considered for dealing with this problem. One obvious solution is to increase the cask shielding. If the same outside dimension is maintained, increasing the shielding reduces the number of assemblies that can be placed in the cask, which reduces both the size of the radiation source and the heat source in the cask. However, reducing the cask capacity increases the unit cost of storage because the cost of the cask is not very sensitive to the inside dimensions of the cask.

Another approach, zoned loadings, allows storage of the higher burnup fuel in the casks designed for the lower burnup fuel. It has been demonstrated by experiment and by calculation (see Table 1) that the chief contributor to the radiation dose rate on the exterior of a cask is the fuel immediately adjacent to the cask wall, i.e., those fuel assemblies in the outermost positions in the cask basket. Thus, the higher burnup fuel could be stored in the inner locations in the cask basket, surrounded by fuel at least as old and cold as the cask design point fuel. In this way, the higher burnup fuel is shielded by the older, colder fuel that surrounds it. Obviously, this approach will only work if there is enough of the old, cold fuel in the inventory to fill the outer rings of the casks. Fortunately, system analyses which examined the expected burnups and cooling times of SNF when it enters the federal waste management system have shown that, except for fuel from reactors which have terminated operations, most of the SNF will be cooled sufficiently to permit this zoned loading approach to be viable.

TABLE 1. Cask Surface Radiation Dose Rate Calculations for Zoned Loadings

Cask Contents and Configuration	Surface Dose Rate (mR/hr)				
	Neutron	Secd. γ	Pri. γ	Total[a]	% Change
35/10 Cask Design					
24 assemblies of 35,000/10 fuel	1.5	0.7	46.7	48.8	---
20 ea. 35/10, central 4 empty	1.5	0.7	46.6	48.7	- 0.2
20 ea. 35/10, central 4 ea. 60/14	1.8	1.0	46.7	49.5	+ 1.4
20 ea. 35/10, central 4 ea. 60/5	2.0	1.1	46.6	49.8	+ 2.0
12 ea. 35/10, central 12 ea. 60/14	3.2	1.8	47.0	52.0	+ 6.6
12 ea. 35/10, central 12 ea. 60/5	4.1	2.4	49.8	56.3	+ 15.4
24 assemblies of 60/14 fuel	8.7	3.1	66.1	77.9	+ 59.6
8 outer empty, central 16 ea. 60/14	6.2	3.2	40.0	49.4	+ 1.2
45/14 Cask Design					
24 assemblies of 45,000/14 fuel	1.9	1.1	39.8	42.8	---
20 ea. 45/14, central 4 empty	1.8	1.0	39.8	42.7	- 0.2
20 ea. 45/14, central 4 ea. 60/14	2.1	1.3	39.9	43.3	+ 1.2
20 ea. 45/14, central 4 ea. 60/5	2.2	1.5	39.8	43.5	+ 1.2
12 ea. 45/14, central 12 ea. 60/14	3.0	2.0	40.3	45.3	+ 5.8
12 ea. 45/14, central 12 ea. 60/5	3.7	2.6	42.9	49.0	+ 14.5
24 assemblies of 60/14 fuel	6.6	3.7	58.2	68.5	+ 60.0
8 outer empty, central 16 ea. 60/14	4.7	3.0	35.5	43.1	+ 0.7
55/20 Cask Design					
24 assemblies of 55,000/20 fuel	3.0	2.0	32.2	37.1	---
20 ea. 55/20, central 4 ea. 60/14	3.1	2.1	32.1	37.3	+ 0.5
12 ea. 55/20, central 12 ea. 60/14	3.5	2.5	31.6	37.6	+ 1.3

REFERENCES

10 CFR 50	Title 10, Code of Federal Regulations, Part 50, Domestic Licensing of Production and Utilization Facilities.
10 CFR 50.51	Title 10, Code of Federal Regulations, Part 50.51, Duration of License, Renewal.
10 CFR 60	Title 10, Code of Federal Regulations, Part 60, Disposal of High-Level Radioactive Wastes in Geologic Repositories.
10 CFR 72	Title 10, Code of Federal Regulations, Part 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.
10 CFR 961	Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste. Title 10, Code of Federal Regulations, Part 961. April 1983.
DOE 1980	Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste. DOE/EIS-0046F. U.S. Department of Energy, Washington, D.C. October 1980.
DOE 1984	Selection of Concepts for Monitored Retrievable Storage of Spent Nuclear Fuel and High-Level Radioactive Waste. DOE/RL-84-2. U.S. Department of Energy, Richland Operations Office, Richland, Washington. April 1984.
DOE 1987	Analysis of the Total System Life Cycle Cost for the Civilian Radioactive Waste Management Program, Volumes 1 and 2. DOE/RW-0047, U.S. Department of Energy, Washington, D.C. June 1987.
DOE 1989	Final Version Dry Cask Storage Study. DOE/RW-0220, U.S. Department of Energy, Washington, D.C. February 1989.
DOE 1990	Spent Fuel Storage Requirements 1990 - 2040. DOE/RL-90-44, U.S. Department of Energy, Richland, Washington. November 1990.
Fletcher 1989	Fletcher, J. F. and R. I. Smith. Re-evaluation of Monitored Retrievable Storage Concepts. PNL-5176 Addendum 1. Pacific Northwest Laboratory, Richland, Washington. April 1989.
NWPA-1982	Nuclear Waste Policy Act of 1982. Public Law No. 97-425, Congress of the United States of America, Washington, D.C. January 1982.
NWPAA-1987	Nuclear Waste Policy Amendments Act of 1987. Public Law 100-203, Congress of the United States of America, Washington, D.C.