TWO APPROACHES TO THE GEOLOGIC DISPOSAL OF LONG-LIVED NUCLEAR WASTE: YUCCA MOUNTAIN, NEVADA AND THE WASTE ISOLATION PILOT PLANT, CARLSBAD, NEW MEXICO

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ABSTRACT

A key component of the US energy program is to provide for the safe and permanent isolation of spent nuclear fuel and long-lived radioactive waste produced through programs related to national defense and the generation of electric power by nuclear utilities. To meet this challenge, the US Department of Energy (DOE) has developed a multi-faceted approach to the geologic disposal of long-lived nuclear wastes. Two sites are being developed or studied as current or potential deep geologic repositories for long-lived radioactive wastes, the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico and Yucca Mountain, Nevada.

INTRODUCTION

Commercial electric power generation, nuclear weapons production, the operation of naval reactors, decontamination and decommissioning operations, and research and development activities produce spent nuclear fuel, high-level radioactive waste and transuranic (TRU) wastes. By definition, TRU waste contains alpha-emitting radionuclides with atomic numbers greater than that of uranium (92) and has a half-life greater than 20 years in concentrations greater than 100 nanocuries per gram of waste. These long-lived radioactive materials have been accumulating since the mid-1940s at various sites now managed by the DOE and since 1957 at commercial reactors and storage facilities across the country. The responsible management and disposal of these materials is a critical part of the DOE mission to meet statutory obligations.

REGULATORY FRAMEWORK AND PROGRAM HISTORIES

The U. S. has been evaluating methods for the safe storage and disposal of radioactive waste for more than 40 years. Many academic groups, technical organizations, and government agencies have participated in these studies. In the 1950s, at the request of the US Atomic Energy Commission, the National Academy of Sciences evaluated options for geologic disposal of radioactive waste and concluded that salt deposits were one promising disposal option. Studies continued to analyze nuclear waste management options throughout the 1960s and 1970s culminating in an Interagency Review Group composed of representatives from 14 federal government entities, which, in 1979, recommended disposal in mined geologic repositories as the preferred long-term environmental solution for the management of nuclear waste to the President. This opinion was reflected in the DOE National Security and Military Applications of Nuclear Energy Authorization Act of 1980, which authorized DOE to construct WIPP and to seek endorsement from the state of New Mexico to operate a geologic repository for waste generated for defense purposes (weapons development waste). A similar conclusion was also expressed in the Nuclear Waste Policy Act of 1982 (NWPA), which established the responsibility and policy for the disposal of spent nuclear fuel and high-level radioactive waste.

In 1981 construction of the surface facilities began at WIPP, and by 1983 the first exploratory underground rooms, 655 meters below the land surface, were completed to facilitate site characterization. During the 1980s, underground, surface, and laboratory testing to determine the suitability of WIPP for the disposal of defense related long-lived radioactive waste was conducted, and in 1988 the first disposal rooms were constructed. In 1992 the President signed the WIPP Land Withdrawal Act[1] (LWA) into law, designating the Environmental Protection Agency (EPA) as the primary regulator, and establishing an array of regulatory conditions and standards for WIPP covering everything from the types and amounts of waste to be disposed of to the transportation safety measures required. By 1996, the EPA had established radiation protection standards for the WIPP and developed criteria to determine if the site's expected performance would meet these containment standards. In late 1996, the DOE submitted its WIPP Compliance Certification Application[2] to the EPA, representing the results of decades of research, review, and public comment. On May 18, 1998, the EPA certified[3] that the repository system would meet the containment standards, and on March 26, 1999, the first shipment of TRU waste arrived for disposal at the WIPP site.

Congress established the framework for addressing the issues of spent nuclear fuel and high-level nuclear waste disposal in the 1982 NWPA and related statutes, and designated the roles and responsibilities of various federal government agencies and the owners and generators of the waste. Congress amended the NWPA in 1987 and directed DOE to investigate Yucca Mountain, Nevada, exclusively, to determine whether it is a suitable site for a geological repository for the nation's most hazardous radioactive wastes. The DOE has studied Yucca Mountain for more than 20 years to characterize the site and assess the future performance of a potential repository. The EPA has established the radiation protection standard the repository will have to meet and the Nuclear Regulatory Commission (NRC) is designated as the regulatory body that will evaluate the license application.

PRESENT STATUS

WIPP Repository

Currently, DOE is operating the WIPP repository, located approximately 48 kilometers east of Carlsbad New Mexico, for the deep geologic disposal of defense-related transuranic waste. Geologically, the WIPP is located in the Delaware Basin and consists of a labyrinth of rooms and tunnels excavated in a bedded salt formation of Permian age some 655 meters below the land surface. The allowed 176,000 cubic meters of waste will be mostly packaged in 55-gallon (208 liter) drums and standard waste boxes (each having a capacity of about 1.88 cubic meters), surrounded by a magnesium oxide (MgO) backfill. The repository safety strategy relies on the physical properties of the salt beds to provide permanent isolation of the emplaced waste. Specifically, due to the low values of viscosity characteristic of salt, the weight of the superincumbent strata will eventually cause the bedded salt of the repository to flow into the unoccupied space surrounding the waste drums and boxes emplaced in the storage rooms, effectively entombing the waste. The MgO backfill provides an additional chemical barrier surrounding the emplaced waste to ensure minimal migration of radionuclides released due to rupturing of the waste packages as the slowly-flowing salt eventually fills the storage rooms.

The WIPP repository will eventually consist of eight panels, each of which will contain seven waste disposal rooms. Presently, only two disposal panels and the experimental areas, known as Q-Room, have been mined at WIPP (Fig.1). Panel 1, which was completed in 1988, was not used for waste disposal until March 1999. Since 1988, the original shape of the walls and floors has been maintained by grinding off the salt that, due to the plastic nature of the salt formation, continually creeps or closes in on open areas. In addition, roof bolts were installed in Panel 1 to reinforce the ceiling. However, due to the salt creep and the economics of trying to keep the rooms open, three rooms in Panel 1 were determined to be unusable and will not be filled with waste. The remaining rooms in Panel 1 have been almost completely filled with waste and closure of Panel 1 is expected to begin in late 2002.

Panel 2 mining was completed in July 2000. Panels will be closed as they are filled, and waste disposal will continue in the next panel. Because of the tendency of salt to fill excavated voids, mining of panels and storage rooms will be performed on a staggered schedule dictated by the rate at which waste is received at WIPP. When a panel is half filled with waste, mining will begin on the next panel. Each panel is expected to take approximately five years to mine, fill and close.

Two types of TRU wastes are disposed of in WIPP: mixed wastes that contain radionuclides along with hazardous substances including PCB's, solvents, lead, etc., and non-mixed waste that contain only radioactive substances. Most of the TRU waste to be disposed of at WIPP is contaminated sludge and refuse including rags, tools, protective clothing, and equipment. The bulk of these items are from activities associated with the production of nuclear weapons, including plutonium fabrication and reprocessing, research and development, decontamination and decommissioning, and environmental restoration programs at various sites. Most (97%) of this waste is classified as contact-handled waste (CH) with only 3% of the waste having radioactivity high enough (an external surface dose rate that exceeds 200 mrem per hour) to require remote handling (RH). Presently WIPP is only certified to receive CH TRU waste for disposal.

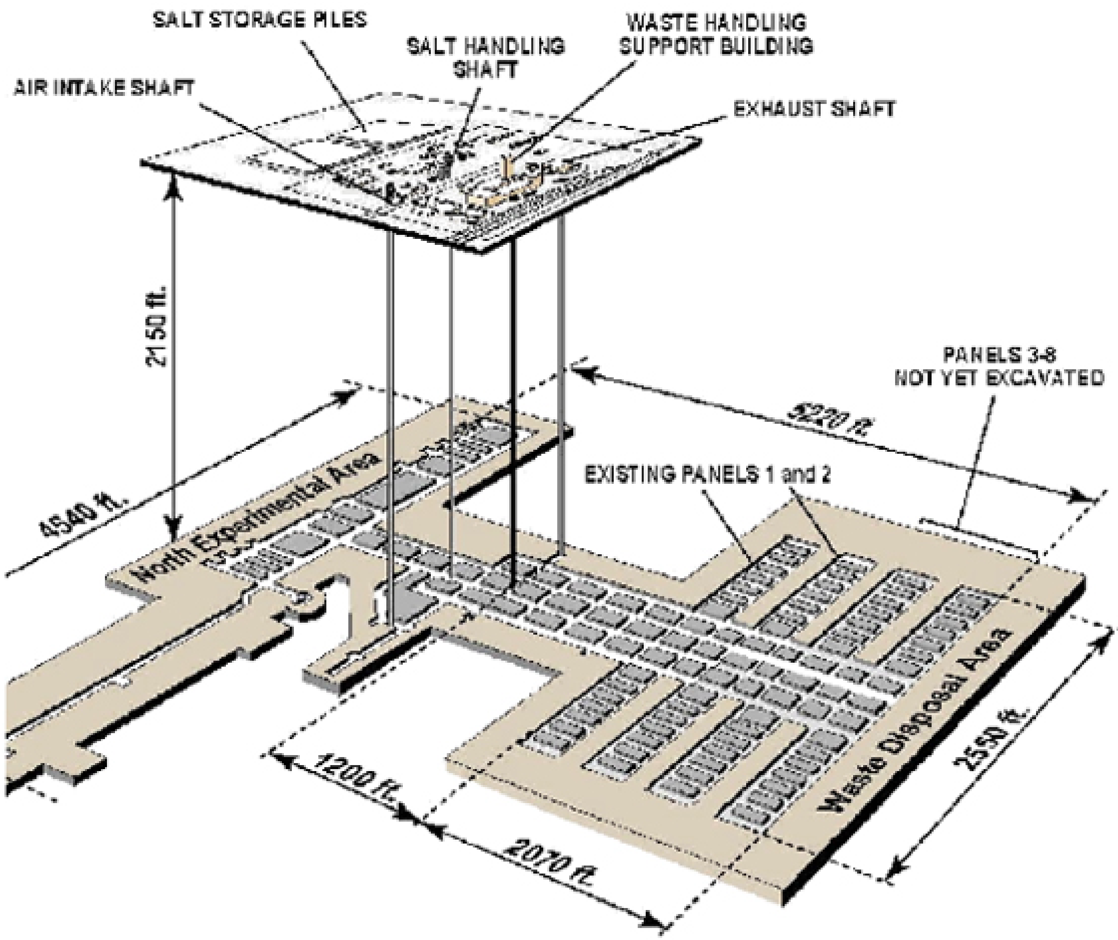

Fig. 1. WIPP Repository Layout

During WIPP's operational phase, expected to last 35 to 40 years, shipments will originate from 6 major sites and more than 12 small quantity sites in 16 states (see Fig.2). Before shipments from a site can begin, the DOE's Carlsbad Field Office and the EPA must certify each site's ability to characterize, prepare, and package the waste for transportation and storage purposes. The LWA required DOE to obtain NRC approval and licensing for all shipping containers carrying waste to WIPP. DOE designed and tested a unique design called the Transuranic Packaging Transporter - Model II (TRUPACT-II), and NRC has issued several revisions to this license over the years. These unique shipping containers make the transportation of waste one of the most noticeable activities of the disposal phase. For the transportation of contact-handled TRU waste, each shipment consists of a truck and trailer with up to three TRUPACT-II containers.

DOE has also licensed a shipping container for transportation of remote-handled TRU waste called the RH-72B. This container (certified by NRC in 1999) was designed to shield 1000 rems/hour canisters down to an external dose rate less than 200 mrems/hour. Shipments of RH TRU waste are planned to begin in 2003.

Yucca Mountain Repository Study

For more than 20 years, the DOE has studied the suitability of Yucca Mountain as the nation's first potential repository for the disposal of spent nuclear fuel and high-level nuclear waste. The spent fuel originates mainly from more than 100 commercial reactors, with an additional component from the DOE and Naval reactors programs (Fig. 3). The high-level radioactive wastes are vitrified products from US defense programs. The NWPA currently limits the amount of spent nuclear fuel and high-level radioactive waste that can be emplaced in the repository to 70,000 metric tons of heavy metal (MTHM) equivalent. However, the repository design will be capable of expanding the capacity to 118,000 metric tons should repository requirements and legal constraints change. The materials that may be disposed of at Yucca Mountain include about 63,000 MTHM of commercial spent nuclear fuel, about 2,333 MTHM of DOE and Naval reactor spent nuclear fuel, and about 4,667 MTHM of DOE high-level radioactive waste. All the waste forms transported to and received at the repository would be solid materials. No liquid waste forms would be accepted for disposal. DOE plans to dispose of the waste in robust bimetallic canisters composed of stainless steel and a corrosion-resistant nickel-based alloy. The waste will be emplaced in tunnels excavated an average of 300 meters below the ridge crest of Yucca Mountain, within layers of unsaturated welded tuff ca. 300 meters above the water table (Fig. 4).

The Yucca Mountain site is located in southern Nevada approximately 160 kilometers northwest of Las Vegas. Yucca Mountain consists of an uplifted ridge of alternating layers of welded and non-welded silicic volcanic tuffs of Miocene age. The degree of welding of the various tuff units determines the manner in which water can move through each particular unit. Generally speaking, fracture flow dominates in the welded units, while matrix flow is characteristic of the non-welded units.

Fig. 2. Waste Locations and Transportation Routes

Fig. 3. Origins of High-Level Waste Forms

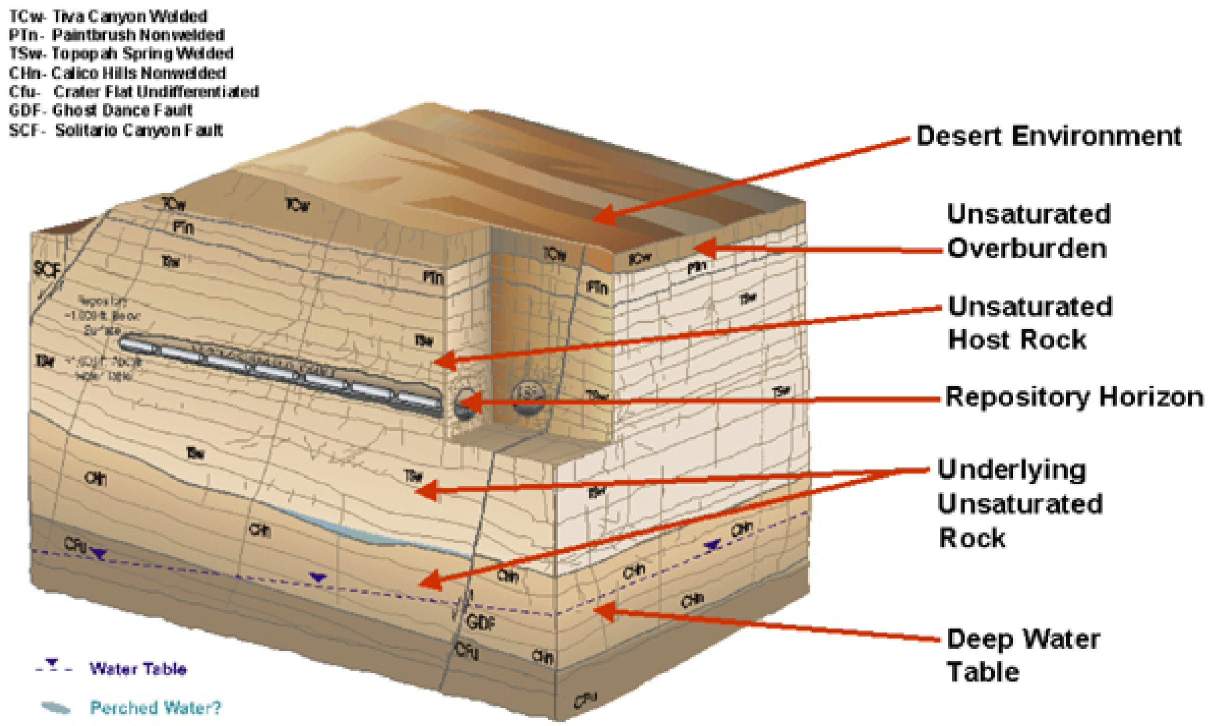

Fig. 4. Natural System of Yucca Mountain

Characterization of Yucca Mountain as a potential repository for high-level waste presented several unique technical challenges not encountered during the characterization of the WIPP site. Specifically, there were few studies or sources of information concerning intermittent fracture flow in deeply buried, variably welded, unsaturated volcanic media which could be utilized to aid the characterization effort. In addition, radioactive decay associated with high-level waste produces large amounts of heat that can affect flow and transport in the host media in various ways. Investigation of such complex thermal, hydrological, chemical, and mechanical coupled processes is without precedent in the available literature. Consequently, major programs have been conducted to address these important issues.

Of prime importance in the evaluation of site suitability is the question of the environmental conditions that are expected to prevail in the repository horizon. Since the presence of sufficient amounts of water is required for waste package degradation and subsequent transport of radionuclides, hydrogeologic conditions that restrict the quantity of available water are most conducive for safe repository operations. Generally speaking, the low surface precipitation and modest infiltration produce a subsequently small percolation flux at depth, estimated at between 5-10 mm/year[4]. This low percolation flux is expected to produce minimal seepage into the waste emplacement drifts. Seepage is defined as flow of liquid water into an underground opening and the seepage threshold is the critical percolation flux below which seepage into the openings is unlikely to occur. For unsaturated conditions, the quantity of water available as seepage flux is expected to be even less than the percolation flux because the drift opening acts as a capillary barrier. Only where flux from a large area becomes concentrated through favorable geometry inherent to the fracture network would seepage thresholds be exceeded[5]. The combination of limited water and waste packages specifically designed to resist corrosion and degradation will ensure that potential release of radionuclides is minimal during the 10,000 year regulatory period and beyond.

The effects of heat produced by the decay of radioactive waste have been investigated through a series of experiments that addressed the relevant phenomena on scales ranging from core samples to full-scale waste emplacement drifts. Testing and analysis of thermally-driven coupled-processes indicates that thermal-hydrologic, thermal-chemical, and thermal-mechanical effects on the repository environment are relatively minor and do not adversely affect repository performance. Furthermore, the effects of future climate, principally changes in mean annual precipitation and mean annual temperature, have been evaluated with respect to their impact on resultant infiltration and percolation flux. Even under the most conservative scenarios, i.e., ones that produce the greatest percolation flux, repository performance would still ensure a high degree of safety for the general public[6].

Numerous studies of the hydrologic, geologic, and geochemical processes operating at Yucca Mountain have been conducted to evaluate the suitability of the site. These studies indicate that the combined attributes of the natural system plus various engineering design enhancements (e.g., waste package and repository design) would successfully provide a suitable environment for the safe emplacement and isolation of high-level waste.

On January 10th, 2002, the Secretary of Energy notified the Governor of Nevada that he intends to recommend the Yucca Mountain site to the President of the United States for development of a geologic repository for spent nuclear fuel and high-level nuclear waste. DOE is currently preparing the required documentation to support the national decision regarding future development of the site as the nation's first high-level nuclear waste repository. If the President recommends the site, and the site is designated, the DOE will proceed with the NRC license application process. The earliest date a potential repository at Yucca Mountain would be constructed and ready to receive waste is 2010.

SUMMARY

The US Department of Energy has been tasked by the US Congress to manage the disposal of long-lived nuclear waste through the construction and operation of geologic repositories. After decades of research, review, and public comment, WIPP was certified and began disposing of the nation's defense-related transuranic wastes in March of 1999 in a deep geologic repository in southeastern New Mexico. Site characterization, repository design, and safety assessments of the proposed repository location for spent nuclear fuel and high-level nuclear waste at Yucca Mountain Nevada are nearing completion. In January, 2002, the Secretary of Energy notified the Governor of Nevada that he intended to recommend Yucca Mountain to the President for development of a geologic repository for high-level nuclear waste. Future developments concerning the potential construction and operation of the nation's geologic repository for long-lived

nuclear waste materials await the action of President, the Governor and/or Legislature of Nevada, and the Congress.

REFERENCES

1. U.S. Congress, "*Waste Isolation Pilot Plant Land Withdrawal Act,*" Public Law 102-579, 1992 and amended 1996.

2. U.S. Department of Energy, "*Compliance Certification Application,"* DOE/CAO 1996-2184, U.S. Department of Energy, Carlsbad Area Office, 1996.

3. U.S. Environmental Protection Agency, "*WIPP Docket No. A-93-02*," 1998.

4. U.S. Department of Energy, "*Yucca Mountain Science and Engineering Report,*" DOE/RW-0539 (May 2001).

5. Bechtel SAIC Company, "*FY01 Supplemental Science and Performance Analyses, Vol. 1: Scientific Bases and Analyses,"* TDR-MGR-MD-000007, REV 00, URN-0887 (June 2001).

6. Bechtel SAIC Company*, "FY01 Supplemental Science and Performance Analyses, Vol. 2: Performance Analyses,"* TDR-MGR-PA-000001, REV 00, URN-0902 (July 2001).