SPENT FUEL STORAGE IN THE DOE COMPLEX: A DISCUSSION OF THE CURRENT STATUS AND UNRESOLVED ISSUES

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ABSTRACT

Spent fuel interim storage has drawn increased attention in the last ten years because of delays in the development of a geologic repository. Spent fuel storage concepts fall into two classes, wet storage and dry storage. The majority of DOE-stored spent fuel is currently stored in conventional water-cooled fuel storage pools. This capacity, however, is being exhausted. A variety of concepts, such as high-density packing (reracking), double tiering, and rod consolidation, are either in use or under development to increase the interim storage capacity. In addition dry storage options are also being evaluated. This paper examines the current status of spent fuel storage in the DOE complex and discusses unresolved issues pertaining to the future storage of DOE spent fuel.

INTRODUCTION

The delays in the development of a geologic repository for the disposal of high-level radioactive waste and spent fuel generated in the U.S. have focused increasing attention on the interim storage of spent fuel until such a facility is developed. Many storage concepts have been developed and implemented both by commercial generators and the U.S. Department of Energy (DOE). This paper discusses spent fuel that has been generated or stored at DOE facilities and is not scheduled for reprocessing. High-level radioactive waste and commercial spent fuel are excluded from the discussion presented in this paper. Similarly, production fuels and naval reactors fuels are excluded from this discussion. Specifically, this paper presents a discussion of the following issues:

- Historical spent fuel storage practices in the U.S.
- Spent fuel management at the DOE sites
- Data sources for current national spent fuel inventories
- Summary of unresolved spent fuel storage issues in the DOE complex.

HISTORICAL SPENT FUEL STORAGE PRACTICES IN THE U.S.

The management practices related to the storage of spent fuel are broadly classified into two categories, wet storage and dry storage. Wet storage in water pools is still the predominant storage method, and the majority of the spent fuel assemblies are currently held in at-reactor or fuel reprocessing facilities, usually as bare fuel elements. Away-from-reactor facilities are presently under development in the U.S. (1). Research for both commercial and DOE spent fuel has focused on dry storage because of the expanding need for outside-of-reactor-facility and away-from-reactor storage. Dry storage concepts also require much less maintenance and are chemically more inert than wet storage environments. Dry storage concepts include underground natural-convection cooled dry wells, natural-convection cooled dry-cask storage, aboveground forced-convection and natural-convection cooled vaults, and fuel storage pools with argon as the cooling medium (1). In recent years there has also been an interest in casks that serve a dual purpose as an interim storage vessel and shipping container.

Dry storage methods are currently the topic for many demonstration programs across the spent fuel management system. Dry storage is currently being evaluated for two potential applications: as an interim option to wet storage and as a method of final spent fuel disposal. Four dry storage concepts are being studied in detail. These are vaults, silos or concrete canisters, storage casks, and dry wells. Dry storage facilities will require simpler operations than those for wet storage facilities. Some of the operations may be more reliable and economical than those for wet storage facilities and may not be as demanding in terms of future decommissioning requirements. Another potential advantage of dry storage is the possibility of long-term storage with little or no corrosion and relatively low doses of radiation to operating personnel and the environment.

SPENT FUEL MANAGEMENT AT THE DOE SITES

The DOE sites that have generated or stored the majority of spent fuel currently under title to DOE are:

- Brookhaven National Laboratory (BNL)
- Hanford Reservation (including Pacific Northwest Laboratory)
- Idaho National Engineering Laboratory (INEL)
- Oak Ridge National Laboratory (ORNL)
- Savannah River Site (SRS)
- West Valley Demonstration Project (WVDP).

In addition, small quantities of DOE-titled spent fuel have been generated and stored at the Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL).

Brookhaven National Laboratory

The High-Flux Beam Reactor (HFBR) is currently operated at BNL. Spent fuel and damaged fuel elements from the HFBR are stored in a water-filled canal system that allows for radioactive decay of fission products and removes heat generated from the spent fuel. Normally, the canal is covered with fiberglass sections that serve the dual purpose of reducing evaporation of water from the canal and slowing down the growth of algae by reducing the light in the canal.

The present capacity for canal storage at Brookhaven is limited to 980 fuel elements, of which 769 were already in existing storage as of early 1992. Thus, current available capacity is approximately 211 elements, and this is estimated to be filled in 2.6 to 3.3 years, depending on the operating level of the reactor. Therefore, BNL is evaluating options of fabricating additional storage racks, as well as expanding short-term storage capacity by installing existing standby storage racks. These options would extend the time projected to reach full storage capacity from 3.7 years to 5.6 years. BNL does not have the option of transporting spent fuel to another site because it does not possess a cask approved by the DOE and the U.S. Nuclear Regulatory Commission (NRC) for shipping spent fuel.

Hanford Reservation

Hanford has four categories of spent fuel storage. These are the Defense Reactor Fuel Storage (DRFS) (which includes the PUREX Plant), the Fast Flux Test Facility Fuel Storage (FFTF), the PWR Core II Fuel Storage (PWR), and the Miscellaneous Fuel (MF) storage at the 200 Area Low-Level Burial Grounds and at the 324 Building in the 300 Area. Miscellaneous fuel is a compilation of research and development fuel residue (irradiated fuel pieces and experimental fuel assemblies).

The DRFS basins are enclosed water-filled storage pools constructed of reinforced concrete walls and floors. They house N Reactor and Single Pass Reactor (SPR) fuels. One basin received an epoxy coating before housing N Reactor fuel. N Reactor fuel is also stored in the PUREX plant storage basin. The PUREX plant, which is a chemical processing facility that recovers plutonium from irradiated nuclear fuel, is currently in standby status. The PUREX plant storage basin is an unlined concrete basin that is open to a canyon. Fuel is stored in buckets with a grid of drain holes in the bottom.

The FFTF is the only operating reactor at Hanford. FFTF irradiated fuel is stored in the FFTF Reactor vessel, the Interim Decay Storage (IDS) vessel, and in the Fuel Storage Facility. The fuel is stored in a liquid sodium environment. FFTF fuel is stored in the active core region, as well as the in-vessel storage area of the reactor vessel. Currently, there are 81 fuel assemblies in the active core and 51 fuel assemblies in the in-vessel storage area (2). The IDS vessel, located inside the FFTF containment structure, maintains sodium at a purity level that allows fuel transfer back into the reactor or allows the fuel to remain in place for further cooling and decay. Currently, the IDS vessel has 72 fuel assemblies or pin containers. The Fuel Storage Facility currently houses 133 fuel assemblies or pin containers also in a liquid sodium environment.

PWR Fuel Storage is a water-filled pool that houses PWR CORE II fuel assemblies. Miscellaneous fuel is stored at the 200 Area Low-Level Burial Grounds and at the 324 and 327 Buildings in the 300 Area is in the form of small fuel fragments and pellets. The small fuel fragments and pellets are placed in a sealed container, which is then placed in a storage-disposal package. Thirty-five of the containers are uncovered while forty others are in waste trenches that have been backfilled with a layer of soil. Irradiated fuel is no longer being covered with soil in order to improve retrieval. The miscellaneous fuel in the 324 Building is stored in remotely operated shielded cells (2). Approximately 2.2 metric tons of irradiated miscellaneous fuel is stored in the Waste Technology Engineering Laboratory. Less than 0.4 metric tons is stored in shielded storage containers in the Burial Grounds (2).

Spent fuel storage at the Hanford Reservation is problematic because facilities to be used for interim storage of spent fuel must be upgraded to meet DOE and regulatory compliance standards. DOE has determined that alternatives for interim storage of irradiated fuel at Hanford should be considered and that a new Environmental Impact Statement (EIS) be prepared to provide input on the environmental impacts of all viable alternatives. Three alternatives for the storage of spent fuel have been proposed (3).

- Continued storage of the fuel in the existing storage facilities ("no action" alternative).
- Storage of fuel in existing storage facilities after these facilities have been modified to comply with minimum requirements for interim storage of irradiated fuel.
- Provide a new alternative storage capability at the site, a system that would comply with current standards for interim storage of irradiated fuel. If this alternative is used, the Hanford Defense Reactor fuel may have to be converted to a more stable form for interim storage.

A decision on which of these alternatives is most appropriate for spent fuel management has not been made. Storage capacity at the three FFTF storage locations may not be sufficient to support FFTF activities prior to the implementation of the EIS Interim Storage of Hanford Irradiated Fuel record of decision. If necessary, an option is to expand storage capacity by employing interim aboveground dry storage in casks. Any sodium contamination would be removed from the irradiated fuel prior to emplacement in dry storage. This option, however, would require an Environmental Assessment/EIS for implementation.

Pacific Northwest Laboratories (PNL)

In addition to the spent fuel inventory at the Hanford production facilities, a relatively small inventory of spent fuel is managed by PNL. These fuels were provided by commercial reactors and have been used for research, mostly involving fuel characterization at the Materials Characterization Center.

The majority of the spent fuel at PNL is dry-stored in vertical storage racks in a hot cell. Seven fuel bundles are stored in this facility. Four of these bundles are intact while the other three were partially disassembled. Spent fuel research projects at PNL have now ended, and PNL does not anticipate receiving any additional spent fuel shipments from commercial facilities. PNL currently plans to decontaminate and decommission the cell where these spent fuel bundles are stored. This decontamination and decommissioning effort will include packing the fuel bundles in casks and relocating them to another storage facility, presumably at Hanford. PNL hopes to complete this decontamination and decommissioning by 1994 (4).

The remainder of the spent fuel inventory at PNL consists of small bits and pieces of spent fuel rods that were received from commercial reactors for various research projects at

PNL. Most of these research materials are stored in stainless steel canisters (4).

Idaho National Engineering Laboratory

Spent fuels from INEL reactors have been and are managed on site. In addition, INEL has received spent fuel from 33 different university, commercial and industrial reactors, DOE-owned and operated reactors, and U.S.-fabricated fuels from other reactors (5). Spent fuel is currently stored at the Power Burst Facility (PBF), Test Reactor Area (TRA), Test Area North (TAN), Idaho Chemical Processing Plant (ICPP), Argonne National Laboratory–West, and Naval Reactors Facility (NRF) in various dry and wet storage facilities. The bulk of the spent fuel resides at the ICPP.

Most of the irradiated fuels at ICPP are stored in two water-filled basins. One of these, ICPP-603 has three storage pools. It is not in compliance with current DOE orders. Plans are in place to remove all of it's fuel to other locations and deactivate the basin. The second, ICPP 666, has six pools. It meets current requirements and will continue as a storage facility. Options for increasing its capacity through reracking are being evaluated. In addition, ICPP has two facilities for dry storage of irradiated fuel. One of the dry storage areas consists of caisson-type dry wells bored in the soil (6). The other facility, a canyon vault or cell type, is enclosed within an air-cooled concrete structure (6).

Spent fuel is also stored in the TAN Hot Shop pool. It does not meet current requirements. Plans are being developed to remove its contents and place them in dry storage casks. The majority of this spent fuel is from the TMI-2 core debris. TMI-2 fuel consists of defueling debris from the recovery of the TMI-2 reactor. The material is contained in 343 stainless steel canisters. The total payload weight of all canisters is approximately 154,768 kilograms (kg) (341,200 pounds); gross weight is approximately 342,082 kg (754,150 pounds) (5). The pool also houses Loss of Fluid Test (LOFT) fuel bundles and commercial utility fuel bundles (8). LOFT Facility fuel modules are 13 PWR-like LOFT reactor fuel assemblies. There are 12 intact assemblies and 1 destructively tested and examined assembly (containerized). The walls and floor of the storage pool are constructed of steel-reinforced concrete which has been sealed with paint. Commercial fuel assemblies are located in four dry storage casks located at TAN. These casks are being used to demonstrate long term storage of spent fuel in dry storage casks.

Highly enriched Advanced Test Reactor (ATR) fuel elements are located in the Advanced Test Reactor canal at the TRA. During each shutdown cycle at the ATR, a portion of the 40 fuel elements are removed for the new core loading. These elements are then placed in the ATR canal until either the fuel is recycled back into the reactor during the next or future core loading or it is sent to the ICPP. Also located at the TRA are 99 highly enriched CFRMC fuel elements, 10 plates, 1 can of 29 pellets, 6 capsules from fuel element inserts, 1 assembly from the CFRMC core containing 217 kg of depleted uranium, and uranium metal from the CFRMC core.

The following are specific storage issues requiring resolution at INEL (5):

- There is no clear ownership of spent fuel at the INEL; although DOE will eventually take ownership of these fuels, multiple responsibility will adversely impact the storage of spent fuel until DOE takes title.
- More than 80 percent of INEL spent fuel (stored by volume) is currently in a form that appears to be unacceptable to the projected or proposed requirements for the MRS or the repository; a prominent example is the TMI-2 core debris.
- Spent fuel storage facilities at the INEL are inadequate; e.g., current storage configuration is not adequate for long-term custodial care, and second generation storage modifications may be required.
- The storage of spent fuels owned by DOE are not specifically addressed in most DOE Orders, EPA, or NRC regulations.

Los Alamos National Laboratory

A research reactor is currently operated by the Isotope and Nuclear Chemistry Division which uses fuel containing 232 grams of ^{235}U per fuel element. At the current rate of operation, the reactor requires refueling approximately every ten weeks and discharges about eight spent fuel elements per year. Historically, spent fuels from the research reactors operated at LANL have been shipped to the ICPP at INEL for reprocessing and have not been stored on site. However, since 1985, a small inventory of spent fuel has been stored at LANL, first because LANL did not have a DOT-certified spent fuel shipping cask and more recently because the State of Idaho has imposed a moratorium on receiving radioactive wastes and spent fuel from out of state (9). Interim storage presents a severe problem for the reactor division because LANL had not anticipated having to provide long-term storage of the spent fuel and does not have adequate facilities or capacity for spent fuel storage. LANL is investigating the possibility of shipping its spent fuel to the SRS. If off-site shipping of spent fuel cannot be resumed, LANL may be forced to limit the use of the research reactor (9).

Spent fuel is being stored at LANL in two ways. Most of the spent fuel is placed in wet storage in the reactor tank, which can accommodate up to 50 fuel elements. The remaining spent fuel is temporarily placed in dry storage at the Chemistry and Metallurgical Research Building, where spent fuels have not been stored before. Temporary dry storage was provided in anticipation of shipping the spent fuel to INEL (9).

Oak Ridge National Laboratory

Spent fuel at ORNL is currently stored at the High Flux Isotope Reactor (HFIR), the Bulk Shielding Reactor (BSR), the Molten Salt Reactor Experiment vessel, and in dry wells at Buildings 3019 and 4501. Spent fuels from the HFIR and the BSR are stored on site in at-reactor pools (10). Spent fuel from the Molten Salt Reactor Experiment remained within the Molten Salt Reactor Experiment vessel when the experiment was concluded in 1969. Some samples or specimens of fuels received by ORNL for research projects from commercial reactors and other DOE facilities are also stored on site in Buildings 3019 and 4501.

HFIR assemblies are stored on racks that accommodate four spent fuel assemblies each. The twelve storage positions in the west clean pool are currently filled with old (circa 1985) fuel assemblies. The east pool currently contains 20 storage locations, 18 of which are presently filled. Future plans for the spent fuel array configuration for the east pool involve adding storage racks as needed until a maximum of 48 storage positions are filled. ORNL staff project that this capacity will be filled by January 1995, assuming present rates of fuel use and assuming all storage positions are useable (11,12). The BSR pool currently contains 73 spent fuel elements. Most of the elements are contained in three fuel storage racks. Five of the elements have been stored in the BSR pool since 1965-1966 (13). Spent fuel samples from other DOE facilities and commercial reactors are dry-stored in aluminum or stainless steel canisters that are emplaced in dry wells in specially designed facilities in Buildings 3019 and 4501 (14,15).

Spent fuel storage issues at ORNL relate to the fact that fuels are no longer reprocessed at SRS. In addition, ORNL's lack of a certified spent fuel shipping cask prevents the transportation of these fuels from ORNL to SRS. This requires that the spent fuel be stored on-site in the spent fuel pools. Storage capacity in the pool at ORNL has been expanded but will be filled by January 1995 at the current rate of spent core discharge from the HFIR. If fuel cannot be shipped off site by then, the reactor most likely will have to be shut down. Spent fuel elements from both the BSR and the HFIR have been stored in the pool since 1985 and are showing signs of corrosion. Corrosion of the fuel makes the handling of fuel elements difficult and further complicates the problems of long-term underwater storage (11).

Sandia National Laboratories

Five research reactors have been operated at SNL since 1961. Four of these reactors are still in operation. Each of the SNL reactors is designed so that the uranium fuel source essentially lasts the designed life of the reactor. Consequently, none of the reactors require periodic refueling or discharge spent fuel. Very little spent fuel is stored at SNL. Spent fuel is only removed from the reactor core when a reactor is decommissioned, and there are no current plans to decommission any of the operating reactors. The lone decommissioned reactor has its fuel wet-stored on site. Available storage capacity is adequate for SNL's current requirements.

Savannah River Site

The Receiving Basin for Offsite Fuels (RBOF) facility at SRS provides for the storage of a variety of irradiated fuels in a system of water-filled basins. Storage of intact fuel assemblies and bundled fuel elements and assemblies is maintained in 55 rows. A total of 1003 bundles of fuel were in storage as of June 1991 (16). In addition to the RBOF facility, there are two other facilities at SRS where spent fuels are stored. These storage facilities are associated with two reprocessing facilities known as F-Canyon and H-Canyon. Irradiated fuel and targets from the different SRS reactors are stored underwater in basins at each of the reprocessing "canyons." (17).

The primary storage issue at SRS relates to recent decisions to terminate reprocessing. If the SRS reprocessing facilities are indeed shut down, a major issue that is likely to arise is providing interim storage for these fuels. Since original storage capacities built at the site did not include the possibility of a complete shutdown of reprocessing operations, current on-site storage capabilities are limited.

West Valley Demonstration Project

The WVDP facility is located in western New York state, about 40 miles south of Buffalo. DOE owns 125 commercial fuel assemblies stored there in a fuel storage pool. The site was the first and only operational commercial nuclear fuel reprocessing facility in the nation. Reprocessing was discontinued at West Valley in 1972 (18). The fuel storage pool has concrete walls, painted with "carboline," but is unlined and has no leak detection system. Fuel is stored in cylindrical, aluminum storage canisters. Each canister can accommodate one PWR assembly or two BWR assemblies stacked on end.

The spent fuel inventory at West Valley consists of 85 BWR fuel assemblies and 40 PWR fuel assemblies. Fuel is in pellet form, clad in zircaloy tubes, which are arranged in rectangular assemblies. Visual inspection of the fuel assemblies in 1989 showed two BWR and five PWR assemblies that had rods with minor cladding breaches in the outer rods. The assemblies also showed varying amounts of crud on the outer surfaces.

Spent fuel at the WVDP facility was intended for shipment to the INEL as part of a cask demonstration project. However, in 1991, the Secretary of Energy notified the Idaho Congressional delegation that the fuel would not be shipped to Idaho but would be stored at West Valley until shipments can begin to a federal MRS facility or geologic repository. Options for continued interim storage or shipment to another facility are currently being evaluated.

DATA SOURCES FOR CURRENT NATIONAL SPENT FUEL INVENTORIES

The primary data bases that compile information on spent fuel inventories are the Characteristics Data Base (19) and the Integrated Data Base (IDB) (20). A second compilation of spent fuel inventories is a survey conducted by DOE-HQ, EM-331 (21). There are discrepancies between the inventory reported in the IDB and that reported in the other data bases. These discrepancies will require a thorough review by DOE and storage-site personnel before the correct inventory lists can be finalized. According to the data in the IDB, more than 98 percent of the nonproduction spent fuel currently stored at DOE facilities is at two facilities, INEL and SRS (20).

SUMMARY OF UNRESOLVED SPENT FUEL STORAGE ISSUES IN THE DOE COMPLEX

Since a permanent geologic repository or MRS facility does not yet exist, the DOE sites are forced to provide on-site, long-term storage of spent fuels in facilities designed for short-term storage only. Furthermore, once a federal repository opens, the disposal of commercially owned spent fuel from the nuclear power industry and government-owned high-level waste from defense weapons production will have priority over DOE-owned spent fuel. Interim storage facilities at most DOE sites are inadequate and are already approaching full storage capacity. In addition, reprocessing of spent fuel has been or is being halted at DOE facilities such as the SRS, thereby requiring DOE to provide interim storage for spent fuels.

The most straightforward interim storage option is to increase the capacity of existing pool storage systems to their structural or economic limit. The second storage option of dry modular storage systems is rapidly evolving as a practical option for interim storage of spent fuel, especially after the existing storage pool capacity is exhausted at a site. Dry storage is attractive because it is modular, passive, and can be implemented on a relatively short lead time once it has been licensed. The final option for interim storage is the development of systems for the consolidation of spent fuel as a means of increasing the capacity of both pool and modular storage configurations. The process consists of dismantling the fuel assemblies, consolidating the fuel rods in a canister for storage, and compacting the scrap hardware in separate containers for storage.

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