U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD

DEPARTMENT OF ENERGY-MANAGED SPENT NUCLEAR FUEL AT THE IDAHO NATIONAL LABORATORY

OVERVIEW[1]

The U.S. Department of Energy (DOE) manages approximately 2,500 metric tons of heavy metal (MTHM)[2] of spent nuclear fuel (SNF) that resulted mostly (85% by mass) from defense-related nuclear activities (primarily weapons plutonium production reactors and naval reactors). Nearly all the SNF is stored at four locations: the Hanford Site in Washington State, the Idaho National Laboratory (INL) in Idaho, the Savanah River Site in South Carolina, and the Fort St.Vrain Independent Spent Fuel Storage Installation in Colorado (see the Board's fact sheet on DOE-Managed Spent Nuclear Fuel).[3] Approximately 325 MTHM of SNF are stored at INL (Figure 1). The SNF inventory at INL comprises a broad range of fuels that were used during commercial, research, test, and naval reactor operations. The diversity of fuel types at INL leads to a wide variety of storage configurations. This diversity also dictates that a variety of treatment processes and packaging steps is and will continue to be needed to prepare the SNF for offsite transport and disposal.

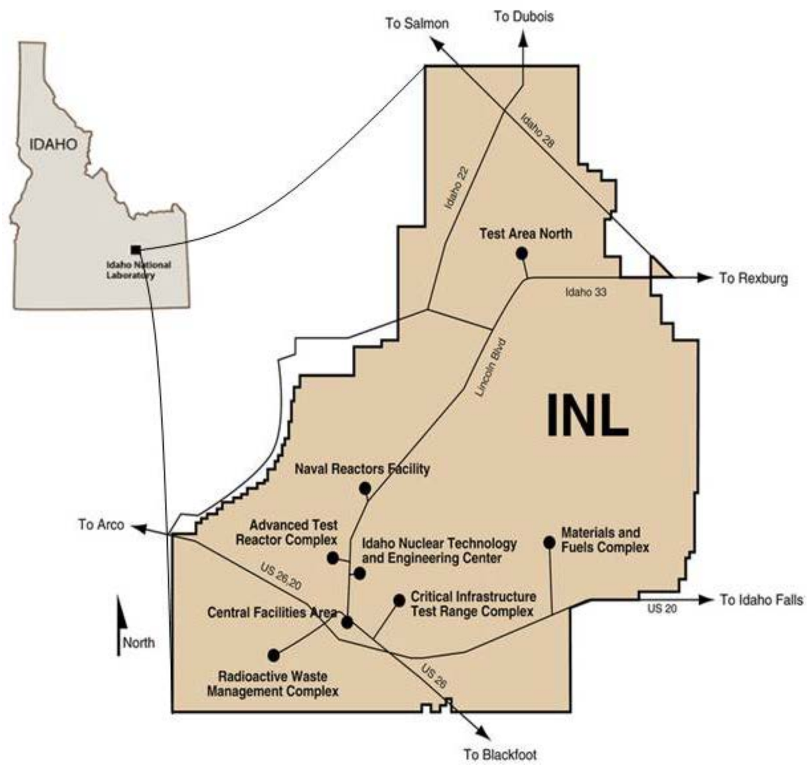

Figure 1. Idaho National Laboratory (adapted from INL 2017).

[1] Unless explicitly stated, this fact sheet does not present Board findings, conclusions, or recommendations and none should be inferred from its content.

[2] Metric ton of heavy metal is a commonly used measure of the mass of nuclear fuel. Heavy metal refers to elements with an atomic number greater than 89 (*e.g.*, thorium, uranium, and plutonium) in the fuel. The masses of other constituents of the fuel, such as cladding, alloy materials, and structural materials (and fission products in spent nuclear fuel), are not included in this measure. A metric ton is 1,000 kilograms, which is equal to about 2,200 pounds.

[3] Fact sheets providing summary information on DOE-managed SNF stored at the Hanford Site, Savannah River Site, and Fort St. Vrain can be found at the Board website: http://www.nwtrb.gov/our-work/fact-sheets. A more detailed description of DOE-managed SNF and SNF storage facilities is provided in the Board report, *Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel* (NWTRB 2017).

SPENT NUCLEAR FUEL AND STORAGE FACILITIES AT INL

Spent Nuclear Fuel. The SNF inventory at INL includes more than 250 types of SNF (Hill and Fillmore 2005). Table 1 lists the INL storage facilities, the type of storage (wet or dry), and summarizes the distinguishing characteristics of the majority of the stored SNF. Because of the large number of SNF types stored at some of the facilities, only the most prevalent types by mass are described in Table 1.

About seventy percent of the inventory by mass is SNF from commercial nuclear power reactors [including damaged fuel (core debris) from the Three Mile Island Unit 2 (TMI-2) reactor], about seventeen percent is a type of SNF called sodium-bonded SNF, and about nine percent is SNF from naval reactors. Many different SNF types make up the remaining four percent of the inventory. Within the inventory of commercial SNF at INL, TMI-2 core debris makes up the largest portion. A description of commercial SNF from pressurized water reactors and boiling water reactors can be found in the Board's fact sheet on Commercial Spent Nuclear Fuel. A description of SNF from the former gas-cooled commercial nuclear power reactor at Fort St. Vrain can be found in the Board's fact sheet on DOE-Managed Spent Nuclear Fuel at Fort St. Vrain. After commercial SNF, sodium-bonded SNF comprises the next largest inventory. TMI-2 core debris and sodium-bonded SNF are described in more detail below.

TMI-2 Core Debris. Core debris from the TMI-2 reactor accident includes approximately 82 MTHM of the "remains" of 177 pressurized water reactor fuel assemblies and other structural and control materials comprising the reactor core (NRC 1999). Figure 2 is a photograph of a piece of the core debris. At the TMI-2 site, DOE loaded the core debris into 344 stainless-steel canisters, called TMI-2 canisters, and shipped them to INL. When loaded, the average radioactivity of the material in each canister was approximately 20,000 curies and the average heat production was approximately 60 watts (INL 2012). At INL, DOE packaged the TMI-2 canisters into 29 carbon-steel dry storage canisters, which then were loaded into 29 concrete horizontal storage modules.

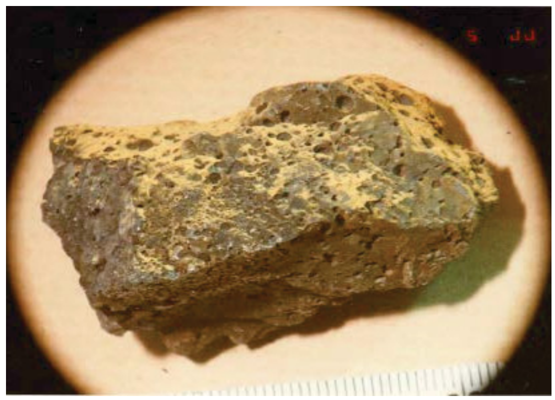

Figure 2. Three Mile Island Unit 2 Core Debris (Carmack and Braase 2015)

Sodium-bonded SNF. The sodium-bonded SNF at INL came from three reactors that are all decommissioned: the Fermi-1 breeder reactor in Michigan; the Experimental Breeder Reactor-II at INL; and the Fast Flux Test Facility at the Hanford Site in Washington State (DOE 2006). These reactors used molten sodium as a coolant and some of the fuel used in the reactors was fabricated with sodium between the fuel and the cladding. Fermi-1 and the Experimental Breeder Reactor-II used two types of fuel assemblies: driver fuel assemblies that generated power and the surrounding blanket fuel assemblies that captured neutrons to produce plutonium.

Sodium is highly chemically reactive, producing hydrogen gas and sodium hydroxide when in contact with water. Figure 3 depicts fuel cladding of sodium-bonded fuel that ruptured during a

Table 1. Spent Nuclear Fuel and Storage Facilities at the Idaho National Laboratory

Storage Facility*	Storage Type	Main Source of SNF	SNF Mass§ (MTHM)	SNF Characteristics (fuel type and cladding type)
INTEC CPP-1774	Dry	Core debris from Three Mile Island Unit 2 reactor accident	81.6	Uranium dioxide fuel with melted Zircaloy-4 cladding (core debris)
INTEC CPP-749	Dry	Shippingport Atomic Power Station; light water breeder reactor core	42.6	Thorium-uranium dioxide fuel with Zircaloy-4 cladding
	Dry	Fermi-1 fast breeder reactor blanket assemblies	34.2	Uranium-molybdenum alloy fuel with sodium bonding between the fuel and the stainless-steel cladding
	Dry	Peach Bottom Unit 1, Core 1	1.6	Thorium-uranium carbide fuel in a graphite matrix
INTEC CPP-2707	Dry	Commercial nuclear power reactors	64.7	Uranium dioxide fuel with Zircaloy or stainless-steel cladding
	Dry	14 fuel types from experiments at the Loss of Fluid Test facility	3.7	Various
INTEC CPP-666	Wet	Advanced Test Reactor fuel discharged after fiscal year 2005	1.6	Uranium aluminide fuel with aluminum cladding
	Dry	21 fuel types transferred from the CPP-666 pool, including all Advanced Test Reactor fuel discharged prior to fiscal year 2006	6.7	Various
MFC Radioactive Scrap and Waste Facility	Dry	Experimental Breeder Reactor-II blanket assemblies	19.2	Depleted uranium metal fuel with 1% plutonium and sodium bonding between the fuel and the stainless-steel cladding
	Dry	Experimental Breeder Reactor-II driver assemblies	2.3	High-enrichment uranium-molybdenum alloy fuel with sodium bonding between the fuel and the stainless-steel cladding
NRF Overpack Storage Building	Dry	Naval pressurized water reactors	~28.0‡	Metal fuel†
NRF Expended Core Facility	Wet	Naval pressurized water reactors	– ‡	Metal fuel†
INTEC CPP-603	Dry	Fort St. Vrain commercial nuclear power reactor	8.6	Thorium-uranium carbide fuel in a graphite matrix
	Dry	20 fuel types from domestic and foreign research reactors	3.3	Various
MFC Hot Fuel Examination Facility	Dry	Hanford Fast Flux Test Facility	<0.1	Uranium–plutonium alloy fuel with sodium bonding between the fuel and the stainless-steel cladding

Notes

*Abbreviations for storage facilities are as follows: INTEC is Idaho Nuclear Technology and Engineering Center; CPP is Chemical Processing Plant; MFC is Materials and Fuels Complex; and NRF is Naval Reactors Facility.

§ The listed INL inventory is from the Board's report (NWTRB 2017) and is as of January 2013, except for the naval SNF, which was 28 MTHM as of August 2014.

‡The quantities of naval SNF stored at NRF are estimates. A dash indicates a variable but small quantity.

†Details of the fuel and cladding design for naval SNF are not publicly available.

reaction of sodium with water vapor that leaked into the fuel. The storage locations and quantities of driver and blanket fuel assemblies stored at INL are provided in Table 1.

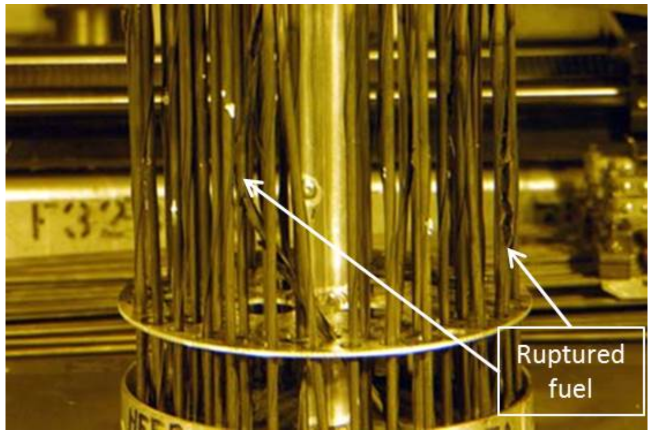

Figure 3. Sodium-bonded Fuel, including Fuel Ruptured by a Sodium-Water Reaction (DOE 2006).

From 1996 to 2017, DOE chemically treated about 4.5 MTHM of sodium-bonded SNF and treatment has continued since then. The chemical treatment process dissolves the fuel using molten salt. DOE's treatment process produces two high-level radioactive waste streams that are intended to be suitable for geologic disposal. One waste stream is metallic and the other will be converted to a ceramic waste form.

Additional details about sodium-bonded SNF and its treatment are provided in the Board's report, *Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel* (NWTRB 2017).

Spent Nuclear Fuel Storage Facilities. DOE stores SNF at INL in nine facilities at three locations on the INL site: the Idaho Nuclear Technology and Engineering Center, the Naval Reactors Facility, and the Materials and Fuels Complex (see Figure 1 and Table 1). The SNF storage facilities include a variety of storage configurations, including wet pool storage, indoor dry vaults, outdoor below-grade vaults, and SNF cask storage on concrete pads. Five of the nine storage facilities are more than 40 years old. Since the late 1990s, the U.S. Navy has built new dry-storage facilities at the Naval Reactors Facility to store naval SNF that has been removed from pool storage. Additional details about the storage facilities, stored SNF, and DOE efforts to manage the SNF while it awaits disposal are provided in the Board's report, *Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel* (NWTRB 2017).

PATH FORWARD FOR MANAGING AND DISPOSING OF INL SNF

The long-term management of SNF at INL is constrained to a large extent by a 1995 agreement between the State of Idaho, DOE, and the U.S. Navy. This "1995 Settlement Agreement" (Idaho *et al*. 1995) and two addenda, one signed in 2008 and another in 2019, specify, among other things, that "DOE shall complete the transfer of all spent fuel from wet storage facilities at Idaho National Engineering Laboratory by December 31, 2023," and that "DOE shall remove all SNF, including naval spent fuel and Three Mile Island spent fuel from Idaho by January 1, 2035". The Settlement Agreement does not permit more than 9 MTHM of naval SNF to be kept at INL after January 1, 2035.

The diversity of SNF types and characteristics (*e.g.*, size, shape, and composition) at INL has and will continue to require a diversity of treatment and packaging steps to prepare the SNF for offsite transport and disposal. In 1997, DOE began designing a multi-purpose container, known as the DOE Standard Canister. DOE planned to load SNF assemblies into DOE Standard Canisters for transportation offsite and disposal in a deep geologic repository (DOE 1999).

Consistent with the requirement for packaging its SNF at the INL site, DOE conducted early planning for a new facility at INL—the Idaho Spent Fuel Facility—with the capability to characterize, condition,[4] and package SNF in DOE Standard Canisters; to provide interim storage for packaged SNF; and enable shipment offsite by January 1, 2035 (DOE 2007). However, as of May 2020, DOE has not completed work to develop the Idaho Spent Fuel Facility or the DOE Standard Canister.

DOE recently started the process to define appropriate disposition paths for the entire inventory of DOE-managed SNF, including SNF stored at INL (Rovira 2020). DOE has initiated the development of roadmaps that identify reasonable disposition pathways based on the characteristics and potential challenges of the SNF. The potential pathways for the long-term management and disposition of DOE-managed SNF that DOE identified are: (i) direct disposal, (ii) existing processing, and (iii) alternate processing pathways (Rovira 2020).

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[4] DOE defines "conditioning" as any process that prepares or treats SNF or HLW for transportation or disposal in accordance with regulatory requirements.

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