SPENT NUCLEAR FUEL

Produced for the Leadership in Nuclear Energy (LINE) Commission and residents of the State of Idaho by the Energy Policy Institute with contributions and review by Idaho National Laboratory, Fluor Idaho, and Boise State University.

Summary

This report on spent nuclear fuel is part of a series of technical reports that was completed on nuclear waste and spent fuel. Special emphasis is on the relevance of the topics for Idaho.

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1. Definition: What is spent nuclear fuel?

Spent Nuclear Fuel (SNF) is fuel removed from a nuclear reactor after irradiation and not likely to be reprocessed or reused.[1] SNF is radioactive, meaning that heat and radiation are released as it decays and that it must be stored appropriately to protect the public and environment. The composition of SNF includes fission products, uranium, and other actinides.[2]

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[1] Irradiation is a process in which an object, in this case the fuel, is exposed to radiation.

[2] Fissile elements are mainly uranium-235 (^{235}U) and plutonium (Pu). When fissile atoms split, energy is released. The resulting fission products are responsible for most of the radioactivity in the waste.

Fission products cesium-137 (^{137}Cs) and strontium-90 (^{90}Sr) are responsible for much of the radiation during the first, few hundred years. The half-life, or time it takes for the radioactivity of ^{137}Cs to decay to half its original value, is thirty years. Similarly, the half-life of ^{90}Sr is twenty-nine years.

Different reactors may use different fuel composition, and different cladding materials, in their operations.[3] The cladding's primary purpose is to confine the fuel and its fission products and gases. The Department of Energy (DOE) SNF cladding materials include aluminum, stainless steel, zircaloy, and several other materials.

DOE SNF also includes fuels with a sodium bond between the fuel and the cladding to help improve heat transfer. Sodium is an integral part of this fuel; therefore, it is considered part of the SNF along with the cladding.

2. Source: Where did spent nuclear fuel that is in Idaho come from?

The Spent Nuclear Fuel at Idaho National Laboratory (INL) comes primarily from nuclear engineering research, naval vessels such as submarines, US commercial power plants, and test reactors worldwide. From the early 1950s through the early 1990s, the Idaho Nuclear Technology and Engineering Center (INTEC), located at INL, reprocessed SNF to recover fissile elements such as ^{235}U and ^{239}Pu for reuse. With the termination of spent fuel reprocessing at INTEC, spent fuel is now being stored until it can be packaged and shipped off site for final disposition.

Since 1951, used fuel from INL experimental testing has been stored at INL.[4] Other SNF from government-owned research and testing in Idaho and beyond, as well as SNF from government-supported commercial activities, are also stored at the INL. The sodium-bonded SNF at INL is primarily from three reactors: Experimental Breeder Reactor II (EBR-II), Enrico Fermi Atomic Power Plant (Fermi-1), and the Fast Flux Test Facility (FFTF).[5] Aluminum-clad SNF originates from research test reactors that have aluminum-based alloys as the fuel cladding material.[6]

[3] Cladding material is the outer layer of fuel rods, which separates the coolant and the nuclear fuel.

[4] INL was established in 1949 by the US Atomic Energy Commission. The main goal of the Lab was to advance nuclear technology by research and development. Nuclear reactors were constructed and tested at INL beginning in 1951 with the Experimental Breeder Reactor I. Since the inception of reactor testing, there have been fifty-two reactors constructed at INL. Only two of these reactors are currently operational, the Advanced Test Reactor (ATR) and the recently re-activated Transient Reactor Test Facility (TREAT).

[5] The EBR-II was a research test reactor in Idaho from 1964 to 1994, operated and maintained by Argonne National Laboratory (ANL).

Fermi-1 was a 60 MW_e nuclear power plant in Newport, Michigan that was operated by Detroit Edison (DTE) Energy, a gas and electric utility company. Fermi-1 became a commercial plant on August 7th, 1966, and was permanently shut down in 1972.

The FFTF was a research test reactor owned by DOE located at the Hanford site in Richland, Washington. The construction of the reactor was finished in 1978 and it operated for a decade from 1982 to 1992.

[6] In the late 1950s aluminum was tested as a cladding material in research reactors because of its thermal and neutronic properties and has since been used in numerous research and test reactors.

3. Quantity: How much spent nuclear fuel is stored in Idaho?

As of December 2017, there is approximately 263 metric tons of heavy metal (MTHM)[7] of SNF stored at INL (not including Naval Reactors Facility SNF), which accounts for 13% (by mass) of the total SNF stored at DOE-managed locations around the country. 70% of INL's total SNF originated from commercial applications. The remaining 30% is from DOE and Naval SNF. The SNF is stored at INL's INTEC, Materials and Fuels Complex (MFC), and Naval Reactors Facility (NRF).

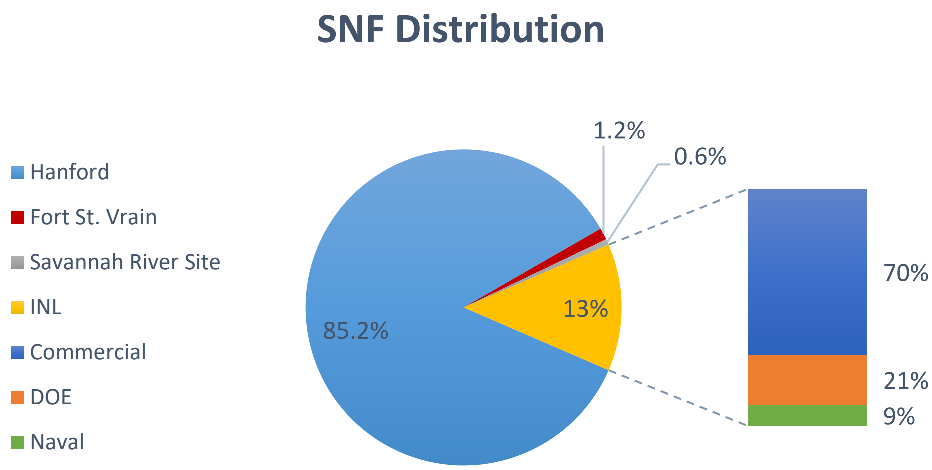

Fig 1. Total DOE SNF distribution *(Left)*. SNF waste profile at INL *(Right)*. *Source: [20].*

4. Storage: How is spent nuclear fuel stored?

SNF is maintained in either wet or dry storage. Wet storage refers to underwater storage in a pool. The water facilitates the cooling of decay heat and provides radiation shielding.

Dry fuel storage is considered safer than wet storage, once decay heat levels have decreased sufficiently to permit this. This safer state is due to reduced corrosion rates of the fuel cladding. In addition, the fuel in dry storage is better positioned for placing into containers for transport from the State of Idaho to a long-term storage repository.

INL SNF in wet storage is either at the NRF[8] or at the INTEC facility[9]. Of the 263 MTHM of SNF at the INL, ~3 MTHM, or approximately 1%, is in wet storage at the INTEC CPP-666 facility. An example of a storage pool is shown in Figure 2.

[7] Metric Tons of Heavy Metal (MTHM) defines the total of fissionable elements in the SNF such as Uranium, Plutonium, and Thorium.

[8] Based on the 1995 Settlement Agreement, a small variable quantity is stored in pools at the NRF.

[9] Fuel discharged from the ATR is temporarily held in the ATR canal for re-insertion into the reactor and/or cooling prior to transfer to INTEC for storage.

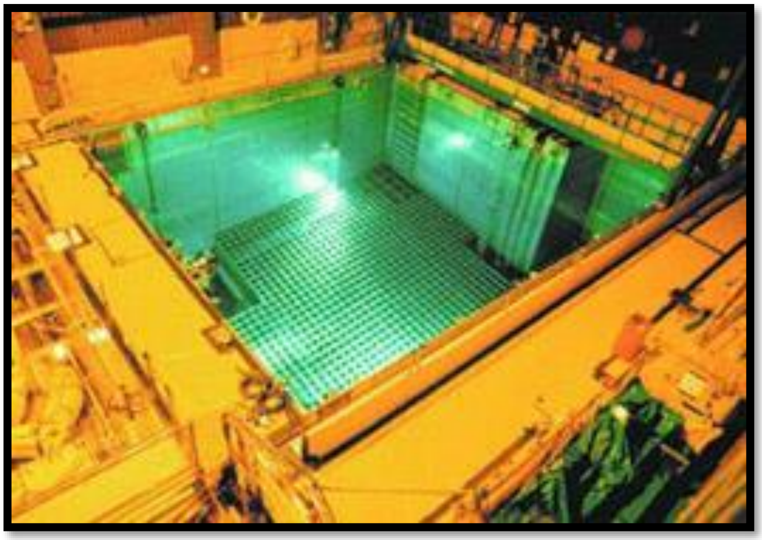

Fig 2. SNF wet storage. *Source: [17].*

Dry SNF storage refers to SNF that is stored below ground in a dry vault, above ground within a cask, or in a shielded cell. The cask consists of a bolted or welded-closed steel cylinder surrounded by an inert gas that helps prevent corrosion. Examples of dry cask storage are shown in Figure 3. INL SNF in dry storage constitutes the bulk of SNF storage, at approximately 248 MTHM at INTEC and 29.6 MTHM at the MFC.

The 1995 Idaho Settlement Agreement between the DOE, Navy, and State of Idaho requires the transfer of all the fuel in wet storage to dry storage at INTEC by December 31st, 2023. The Idaho Cleanup Project (ICP) managed by Fluor Idaho has just completed removal of all Navy fuel from the basin at INTEC and is currently working on the removal of the Advanced Test Reactor and Experimental Breeder Reactor fuels from wet storage to dry storage. ICP is now also receiving spent fuel from the Advanced Test Reactor canal directly into dry storage. All the INTEC SNF will be removed from wet storage once these fuel transfers are complete. ICP is on schedule to meet the Idaho Settlement Agreement deadline of December 31st, 2023.

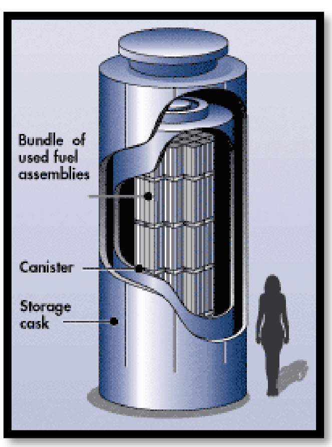

Fig 3 and 4. Example of dry cask storage. *Source: [18] (Left); [22] (Right).*

5. Risks: What key risks are associated with spent nuclear fuel?

Storage facilities and equipment are designed to ensure adequate shielding and confinement of radioactive materials. Although radiation levels and the associated risk decay with time, these facilities must, nonetheless, be maintained and repaired/replaced as they age to ensure that they continue to perform their safety function. For example, the CPP-666 basin has a full stainless-steel liner to prevent pool water from reaching the concrete basin structure, thus precluding any leaching. Monitored collection sumps between the liner and the concrete basin will detect any leakage through the liner. The sump levels and water pool level are recorded twice a day. The sumps are also alarmed. Such precautions are intended to prevent the possibility of the SNF basin water leaking to the environment.

Additional concerns about wet storage relate to the reactive nature of sodium-bonded SNF. Elemental sodium is known to react with water and produce a potentially explosive gas (hydrogen). Therefore, sodium-bonded SNF must be processed or otherwise treated to remove the sodium prior to disposal.

The types of corrosion that are of concern during wet storage are pitting, crevice, galvanic and intergranular corrosion, which can lead to degradation of the SNF cladding and potential handling issues in the future. Distinct from general corrosion, localized corrosion is less predictable and more complex. Importantly, clad types, such as stainless steel and zircaloy, are less susceptible to localized corrosion than aluminum-based SNF.

Awareness of the potential for contamination and corrosion have prompted the move from wet storage to dry storage at INL. According to DOE, INL is on track to have all SNF in wet storage transferred to dry storage by 2023.

6. Transport: What needs to occur in order for spent nuclear waste to be transported out of Idaho?

Spent fuel and/or high-level waste (HLW) resulting from reprocessing must be packaged consistent with applicable transport regulations. SNF is not governed as waste per 40 CFR 261.4(a)(4) which specifically excluded SNF from the definition of waste due to the inherent aspects required to handle, treat/package, transport and store SNF. The packaging requirements depend on the specific properties of the SNF or HLW form, the transportation vendor and cask selected, and the acceptance requirements of the destination facility.

Sodium-bonded SNF is handled differently than other SNF types because this SNF is not suitable to transport out of the State of Idaho in its current form. Therefore, the INL is presently processing sodium-bonded fuel at its Material Fuels Complex using an electrometallurgical process. The process stabilizes the sodium, separates the uranium producing a non-fuel uranium product, and will produce a ceramic type high-level waste that is expected to be suitable for transport and disposal in a geologic repository.

7. Destination: Where can spent nuclear fuel be sent for permanent disposal?

In 1987, the US Congress directed DOE to study Yucca Mountain in Nye County, Nevada, as the final permanent disposal site for high-level waste and spent nuclear fuels. The Yucca Mountain project was defunded under the Obama Administration in 2011, causing the Department of Energy and Nuclear Regulatory Commission to suspend efforts to license the site. A Blue-Ribbon Panel subsequently conducted a review and made recommendations to address the path forward for SNF.

Recent efforts by Congress to resume the Yucca Mountain project could result in the packaging and shipping to Yucca Mountain for permanent disposal of the SNF and high-level waste which results from processing of SNF in Idaho. In the absence of an acceptable disposition path, the spent fuel and associated high-level waste will continue to be stored at the INL until a repository is identified, licensed, and accepting waste.

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