Date: January 21, 2009
To: Special Committee on Nuclear Energy Analysis, President Pro Tem, Speaker
Through: Ezra Hausman, Synapse Energy Economics
From: Bruce Lacy
Subject: Spent Nuclear Fuel

This memorandum addresses four general issues related to Spent Nuclear Fuel ("SNF"). These are:
1. Requirements for establishing an "offsite" SNF facility,
2. Experience to-date with "offsite" SNF storage facilities,
3. General issues involved in transportation of SNF between sites, and
4. Flood plains and siting SNF storage facilities

Summary
The US Nuclear Regulatory Commission ("NRC") regulates all aspects of the storage and disposal of SNF, including issuing licenses for Independent Spent Fuel Storage Installations ("ISFSI", is-fi-see) and certifications for storage canisters. A total of 55 licenses have been issued for ISFSI's in 33 states including the Vermont Yankee site. Commercial sources report that over 1,000 canisters of SNF are currently stored at these ISFSI's. All but one of the privately-owned ISFSI's are co-located with operating or decommissioned commercial nuclear power plants.

The most recently issued license for a co-located facility is at the Diablo Canyon site in California and took approximately two years from time of application until the license was received. The only example of a privately owned ISFSI not co-located on a plant site is the Private Fuel Storage ("PFS") initiative in Utah which took approximately nine years from time of application until the license was received. At this time no spent fuel has yet been moved to the PFS site.

Transportation of SNF has been occurring routinely since the beginning of commercial nuclear power with over 30,000 shipments made to-date. All these shipments have been made in containers specifically designed for shipping small amounts of SNF, primarily between existing reactor sites and fuel manufacturer research facilities. Shipments of SNF in larger containers used in ISFSI's for dry storage have not taken place, primarily because of delays in establishment of the permanent repository at the Yucca Mountain site. Loading and unloading SNF from canisters requires handling capabilities that are currently found primarily in the spent fuel pools at reactor sites.

NRC siting requirements for ISFSI's include flood considerations. Multiple types of flooding are considered, including rainfall and drainage, dam failures and ice flooding. Canisters and their storage casks/bunkers are also evaluated by the NRC for inundation, even for sites where inundation is not likely. The design of the sealed canisters must be shown to prevent any release of radioactive material and the weight of the canisters and storage casks/bunkers on the above ground concrete storage pads must show they will not be swept away. At 254 feet above mean sea level, the surface of the Vermont Yankee ISFSI pad is above both the 100 and 500 year flood levels established in the FEMA flood study for the area and above the Probable Maximum Flood ("PMF") approved by the NRC in the licensing of the site for the original reactor facility.

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Detailed Discussion

The memorandum focuses on the federal US Nuclear Regulatory Commission ("NRC") requirements and industry experience. Depending upon the level of interest in further details on any of these topics, additional legal and technical analysis may be appropriate, particularly with regard to Vermont laws and regulations.

A general understanding of the nature of commercial spend nuclear fuel ("SNF") is useful in understanding the basis for its proper treatment and regulation. A brief discussion is provided in Appendix A.

Several topics commonly brought into commercial SNF discussions are not included in this memorandum. These include recycling of commercial SNF, the prospective permanent repository at Yucca Mountain, US Navy reactor and SNF storage and disposal, plutonium and nuclear weapons proliferation, the nuclear waste disposal issues associated with the US nuclear weapons program, and management of SNF in other countries

1. Requirements for establishing an "offsite" spent fuel storage facility

The public health and safety aspects of SNF storage are regulated by the NRC. A total of 55 licenses for ISFSI's in 33 states have been issued under the authority of the NRC.

Two forms of ISFSI licensing are available; the General License and the Site Specific License, the latter sometimes referred to as an "offsite" facility. Figure 1 shows the locations of these ISFSI's. Commercial sources report that over 1,000 canisters of commercial SNF are currently in storage in these ISFSI's.

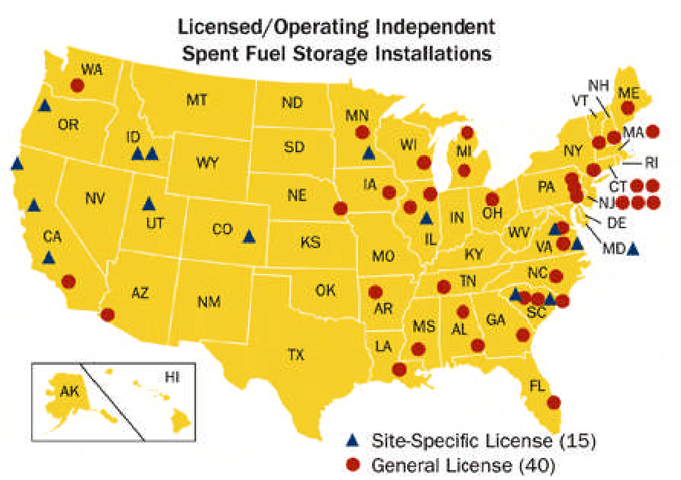


Figure 1

The most commonly used form of site license is the General License authorized by 10CFR72. There are currently 40 ISFSI's licensed under the General License process, including the ISFSI at Vermont Yankee. The General License authorizes any existing holder of a nuclear power plant operating license to develop an ISFSI at their facility using NRC certified storage technology. Only SNF from the associated operating plant may be stored in the General Licensed ISFSI. The General License requires the site licensee to use only storage technologies certified by the NRC and to verify that the site complies with all the requirements established by the NRC for the particular storage technology selected. Site licensees will notify the NRC of their intentions to use the General License, identify the selected technology, formally verify and document the suitability of the technology for the site and undergo an inspection by the NRC of the documents and site before being allowed to move any SNF into canisters and onto the ISFSI.

Vendors design their storage technologies for a wide range of site characteristics that will allow their use at most if not all nuclear plant sites even though many sites will have less stringent site characteristics. An example of this is inundation and resistance of the storage casks or bunkers to moving water. Site conditions may vary considerably depending upon their proximity to lakes, rivers or oceans. The NRC Certificate of Compliance for the Hi-Storm 100 Cask System used at Vermont Yankee requires that the analyzed flood conditions not exceed 15 feet per second water velocity and height of 125 feet of water (full submergence of the loaded cask). The ISFSI pad at Vermont Yankee, being above the PMF for the site, meets these requirements.

The General License is valid only during the period of time that there is an active operating license for the adjacent nuclear power plant. When an operating license is terminated as part of the power plant decommissioning process, the General License must be replace by a Site Specific License if SNF will continue to be stored in the ISFSI.

The Site Specific License authorized by 10CFR72 is less commonly used. There are currently 15 ISFSI's with Site Specific Licenses as discussed below. The Site Specific License is a standalone license, not relying on the nearby presence of a nuclear power plant, and therefore goes through a standalone process to establish the qualification of the site and related SNF storage activities. SNF stored at the Site Specific Licenses site is not restricted to fuel associated with the neighboring operating plant. Any stored SNF must be in containers certified by the NRC and the technology selected must be part of the application. Site Specific Licenses are valid for 20 years with the option of renewal. Site Specific Licenses are typically used when the General License is not feasible for specific reasons or is no longer available as an option. The 15 Site Specific Licenses fall into four main categories:

A. Decommissioned sites where SNF is stored subsequent to operation of the site. The five sites in this category include four former reactors sites, Humboldt Bay and Rancho Seco in California, Trojan in Oregon, and Ft. St. Vrain in Colorado, and the reprocessing plant built by GE in Morris, IL. While growth in this category appears inevitable with its association with plant decommissioning, growth will generally be slow and well into the future as operating plant licenses are extended.

B. Sites where the associated plant owners have decided for various reasons to do the extra work associated with obtaining a Site Specific License. The reasoning for pursuing a Site Specific License instead of a General License is specific to each applicant and site. The motivation for each of the seven sites where this track has been pursued could be investigated and the reasoning explained.

C. Two sites where the US government is storing commercial SNF. Both of these are in Idaho with one of the sites being the location of the damaged fuel from the TMI-2 reactor.

D. The one PFS site where a group of utilities have formed a private joint venture to establish an ISFSI for interim storage of SNF away from their operating reactor sites. The site they have licensed is on tribal land in Utah.

The major requirements in 10CRF72 for a Site Specific License are as follows:
Subpart B – License Application, Form and Contents
Subpart C – Issuance and Conditions of License
Subpart D – Records, Reports, Inspections and Enforcement
Subpart E – Siting Evaluation Factors
Subpart F – General Design Criteria
Subpart G – Quality Assurance
Subpart H – Physical Protection
Subpart I – Training and Certification of Personnel

In addition to extensive technical and other information, each application will include an Environmental Report. The NRC will notice the application and provide opportunity for input by the public and interested parties. The process includes the opportunity for hearings and adjudication by an appointed Atomic Safety and Licensing Board and the NRC Commissioners. Decisions of the NRC may be appealed into the federal court system. The review process used by the NRC staff is detailed in the Standard Review Plan for Spent Fuel Dry Storage Facilities (NUREG-1567)

The application for a Site Specific License will identify the type of storage technology that is intended to be used at the site. Applicants can and have changed technology selections over time as improvements in new technology become available.

The experience with Site Specific Licenses has varied depending upon the circumstances surrounding each proposed site.

Storage of SNF must be in containers certified by the NRC. Requirements for certification are in 10CRF72 Part L – Approval of Spent Fuel Storage Casks. The review process used by the NRC staff is detailed in Standard Review Plan for Dry Cask Storage Systems (NUREG-1536). Currently, four companies provide multiple options for approved storage containers. There has been a steady progression of improvements in containers with the first certificate of compliance for a design issued in 1990 and the most recent issued in 2003. Further upgrades in container designs are pending review and approval by the NRC.

The typical design for SNF dry storage uses a robust steel storage canister and heavy steel/concrete storage cask or bunker. The storage casks or bunkers are located above ground on a prepared concrete slab or pad. The fuel assemblies are secured in racks inside the canister which is sealed shut after being loaded. The canister is then placed in a storage cask or bunker. A typical bunker is approximately the size of a single car garage. Figures 2 and 3 provide examples of typical designs. Typical storage canisters in use today, when loaded with SNF, weigh approximately 40 to 50 tons.

The concrete and steel storage casks or bunkers in which the canisters are stored weigh up to 160 tons.

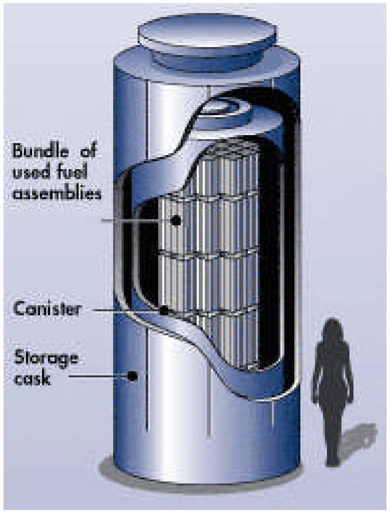


Figure 2
Typical Vertical Storage

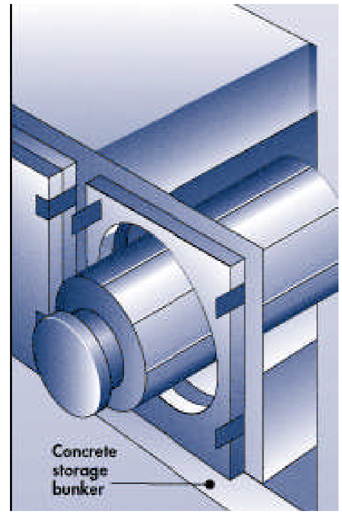


Figure 3
Typical Horizontal Storage

The loading of the canister is accomplished under water in a specifically designed area of the existing spent fuel pool. After the fuel assemblies are loaded into the canister, the canister is removed from the spent fuel pool, the water drained out, lids are welded on, the inside air replace with an inert gas, and the canister then transported inside a transfer cask to be put into the storage cask or bunker in the ISFSI. Fuel is typically allowed to cool approximately five years before being put in a canister. The natural decay of the SNF over five years significantly reduces the heat produced by the fuel bundles thereby allowing the use of natural cooling. This also reduces the level of radiation and the need for protection during transfer to the ISFSI or to another site such as a permanent repository or regional interim storage facility. As indicated earlier, over 1,000 canisters of SNF are currently stored in ISFSI's in the United States.

<u>2. Experience to-date with "offsite" SNF storage facilities,</u>

As indicated above, there are four main groups of applicants who have sought and obtained Site Specific or "offsite" Licenses. The experience of the four groups will be summarized with two cases discussed in greater detail.

A. Decommissioned Sites – Obtaining a Site Specific License has been relatively straightforward. This appears to be influenced by two primary factors. On a technical level, each decommissioned site has already been through an extensive licensing review with the consequence that typically little new significant information needs to be examined. On a political level, the intensity of intervener and local public involvement varies, but has generally been tempered for some by the view that the Site Specific License is part of a larger issue, e.g. the shutdown of the associated power plant.

B. Operating Sites – Obtaining a Site Specific License has again been relatively straightforward although PG&E's application at Diablo Canyon in California will be discussed in further detail. Technically, the proximity to the nuclear plant with its extensive operating licensing process results in little additional technical information. Politically, again the level of intervener and local public involvement varies, but in this case the outcome may be of greater consequence than whether or not the ISFSI itself is licensed. Preventing the ISFSI from being licensed may have consequences in terms of limiting the operating life of the adjacent nuclear plant by limiting storage space for SNF. However, there have been no unsuccessful applications for Site Specific Licenses, although given the greater effort and opportunity for intervener and public involvement, there may have been a deterrent effect on those who may have been contemplating a General vs. Site Specific License application.

The Site Specific License application by PG&E is informative as to the time sequences and types of additional procedural activity that may accompany an application for a Site Specific License. The application was submitted on December 21, 2001 and approved by the NRC on March 22, 2004. Subsequently a petition for review was filed by several parties with the US Court of Appeals, 9th Circuit, asking that the NRC be required to explicitly consider terrorist acts in its Environmental Assessment (“EA”). The Court held on June 2, 2006 that the NRC could not categorically refuse to consider the consequences of a terrorist attack. On February 26, 2007, the NRC Commission directed the NRC staff to prepare a revised EA addressing the likelihood and potential consequences of a terrorist attack on the ISFSI. In May 2007 the NRC staff issued a supplement to the EA and a draft Finding of No Significant Impact (FONSI). The FONSI addressed both the likelihood and consequences of different types of terrorist attacks. The document has been noticed for public review and a thirty day comment period was provided. There does not appear to have been any further action by any party and the original license stands.

C. Government Sites – The two sites, both in Idaho located on land controlled by the Idaho National Energy and Environmental Laboratory, are unique given the government ownership interests involved. The history of these applications can be further explored if desired but are not considered particularly instructive for most Site Specific License efforts.

D. The PFS Site – The PFS initiative is the most ambitious and “pure” example of an “offsite” ISFSI licensing effort. It is a private initiative and not affiliated in any way with an adjacent operating or decommissioned nuclear plant. The site is located on land controlled by Native Americans. The Indian Reservation and the site are adjacent to federally controlled land used for military purposes.

The PFS group formed in 1994 and submitted their application in June 1997. The application has been subjected to substantial intervention and court challenges from local, regional and national groups. The Site Specific License was issued on February 22, 2006.

The PFS effort provides an excellent example of the scope and depth of technical and procedural issues that are tested in the licensing process. Whether or not the Utah site is actually used for SNF storage is now increasingly a business decision of the PFS owners although there will continue to be opportunities for interveners to participate as additional steps may be taken. Additional review of the PFS experience could be instructive.

3. General issues involved in transportation of SNF between sites

The public health and safety aspects of SNF storage are regulated by the NRC. These regulations are found primarily in 10CFR Part 71 and 72. The review process used by the NRC staff is detailed in the Standard Review Plan for Transportation Packages for Spent Nuclear Fuel (NUREG-1617).

> Over the last 30 years, thousands of shipments of commercially generated spent nuclear fuel have been made throughout the United States without causing any radiological releases to the environment or harm to the public. Most of these shipments occur between different reactors owned by the same utility to share storage space for spent fuel, or they may be shipped to a research facility to perform tests on the spent fuel itself.
>
> (www.nrc.gov/waste/spent-fuel-transp, December 23, 2008)

These shipments, primarily by truck, have all taken place in small casks designed for shipment of a few assemblies or a few rods. These shipping casks, while suitable for shipping, are not intended for interim dry storage of SNF. The shipping casks are designed to maximize the efficiency with which SNF assemblies can be loaded and unloaded in reactor spent fuel pools.

Shipments of canisters with larger numbers of assemblies, such as those used for dry storage at civilian nuclear power plants, (figures 2 and 3) have not taken place. This is due in large part to the lack of a place to ship them, not due to a lack of technical shipping capability. The major dry storage vendors have NRC-approved designs for shipping their canisters, packaged inside transportation casks for the duration of the shipping, but these transportation casks have not been built due to lack of need at this time. As storage canister designs improve, corresponding transportation cask designs are also upgraded. Several upgraded designs are currently being reviewed by the NRC. While transportation casks with canisters are generally capable of being moved by heavy haul trailer, the preferred mode of transportation from a reactor site to a centralized interim or permanent storage facility will likely be by rail. Rail offers many advantages, including the fact that the transport cask and canister are in a weight range more suitable for railroads than for trucks and public highways and roadways, particularly given the distance that may need to be covered.

Variations of the shipping casks, called transfer casks, have been manufactured and are used routinely for transfer activities between spent fuel pools and ISFSI's located at the same reactor site. The more than 1,000 canisters in use have all been transferred with a small number of transfer casks used over and over again.

All transportation activities are regulated by the NRC. All transportation is in NRC approved transportation casks.

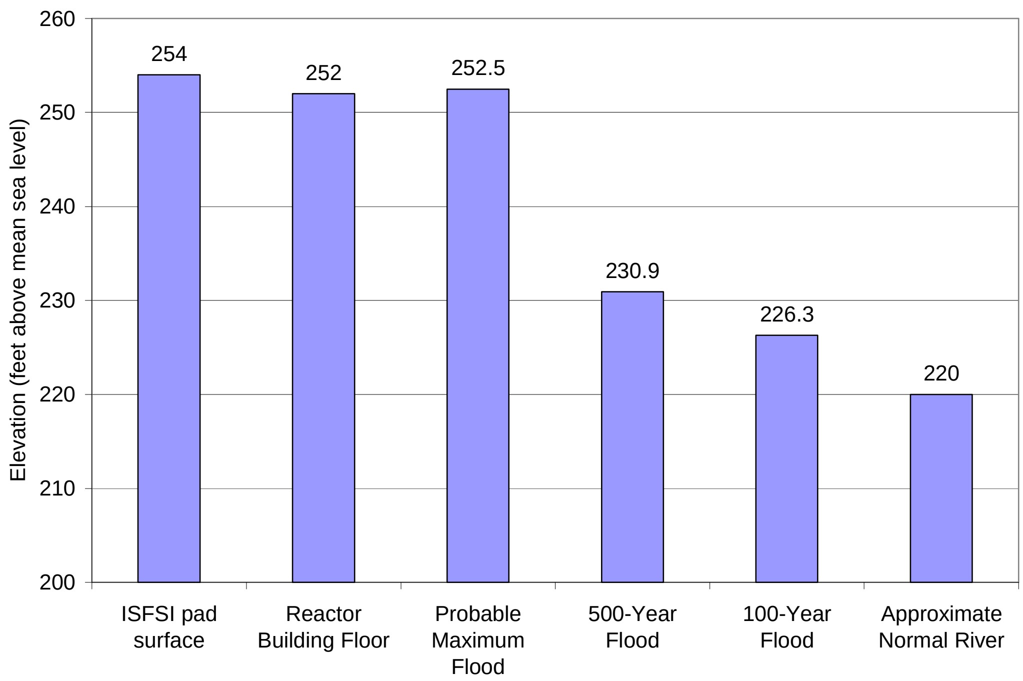
A separate issue involves the type of canister that the US DOE will accept at the prospective permanent repository at Yucca Mountain. The DOE has not indicated that it will accept the existing dry storage canisters. This raises the question of whether some form of fuel transfer/repackaging may be required in the future and where such transfer/repackaging may need to take place.

4. Flood plains and siting SNF storage facilities

All thermal power plants, most commonly coal and nuclear, are sited adjacent to some form water to condense steam that goes through a plant's turbine. The potential for flooding is considered as part of the licensing process. Multiple types of flooding are considered, including rainfall and drainage, dam failures and ice flooding. For nuclear plants with dry cask fuel storage, inundation of the spent fuel storage canisters is also evaluated. The NRC (and the plant owner) will strive for a siting selection that will minimize the risk of flooding. Each site has its own specific flood profile with 1% annual (100 year) and 0.2% annual (500 year) flood profiles along with a "worst case", "design basis" or "probable maximum flood", or PMF. The determination of each of these is unique to each site. The PMF is calculated by combining multiple worst case and low-probability inputs, to intentionally exceed any historical or reasonably conceivable flood situation.

Although as noted above the storage canisters at Vermont Yankee are built to withstand severe flooding and inundation conditions, it is reasonable to expect that The ISFSI at the plant site will never be flooded. This is supported by the data in Figure 4, showing the key site and flood elevations at the Vermont Yankee site.

Figure 4
Vermont Yankee key elevations



The ISFSI and reactor building elevations are from site elevation drawings based on independent surveys using regional US Geologic Survey ("USGS") benchmarks. Flood elevations are based on the 1983 FEMA Flood Survey, the most current available. The PMF has been accepted by the NRC as part of the initial licensing of Vermont Yankee. All elevations are based on USGS mean sea level.

It is possible that over very long time periods, or as a result of changes in regional hydrology, the chances of flooding at the Vermont Yankee ISFSI may change. An example of this is the 0.2% (500 year flood) at the Vermont Yankee site which has declined from 231.9 ft to 230.9 since the plant started up in 1972. The change is a result of the FEMA flood study done in 1983 that updated regional flooding analyses. Even if a flood covering the ISFSI were to occur, however, a flooding event should not result in any radiological consequences given the design characteristics of the canisters and storage casks as described above. The canisters and storage casks/bunkers are extremely heavy, much too heavy to float, and would be highly resistant to any kind of movement off of their concrete pad. If the canisters and casks/bunkers were inundated, there should be no release of any radioactive material nor should any water that comes into contact with the canister acquire any radioactive contamination. Each canister is sealed shut with a lid welded into place to prevent any water from making contact with the fuel assemblies inside. Specific quality assurance requirements for the welding are specified as part of the overall canister design approved by the NRC. The outside of each canister is free of radioactive contamination as a result of decontamination procedures undertaken as it is removed from the spent fuel pool when the fuel assemblies were loaded, so no contamination could be washed away from the outside. Finally, water is a good conductor of heat, so any disruption of the natural air cooling that is used in the storage cask/bunkers design would be compensated for by the water itself.

Appendix A

Background on Spent Nuclear Fuel ("SNF")

SNF is the nuclear fuel after its energy production capability has been substantively used up in a nuclear reactor and is removed from the reactor. Sometimes SNF is referred to as used nuclear fuel or nuclear waste.

Nuclear fuel for a commercial reactor is composed of solid ceramic pellets of uranium oxide, each pellet approximately 0.5" in diameter by approximately 0.5" long. These pellets are stacked inside stainless steel tubes or "rods", each approximately 12 feet long. To facilitate handling of the rods, they are grouped into bundles or assemblies, each approximately 13 feet long (length of the rods plus top and bottom end pieces) which can be handled as a unit. Boiling Water Reactor fuel assemblies, such as are used at Vermont Yankee, contain between 80 and 100 rods and are approximately 6" by 6" square and 13 feet long, while Pressurized Water Reactor assemblies contain approximately twice as many rods and are correspondingly bulkier but of similar length.

Reactors are designed for a specific number of fuel assemblies to be held vertically in place in a fixed grid pattern. Larger reactors have grids designed for larger numbers of assemblies. Fuel designs, the concentration of uranium in the pellets and the number of rods in an assembly, have evolved over time based on experience to allow increases in the production of heat from the reactor core and consequently greater electrical output. Given the fixed nature of the fuel support grids in the reactors, there is no change for a specific reactor in the basic height, width and length of fuel assemblies and the number of them in the reactor.

SNF when removed from the reactor is both physically hot and radioactively hazardous. It needs to be cooled and personnel shielded from the gamma (high energy x-ray) radiation. The heat and gamma radiation is due principally to the radioactive decay of the fission products that are created by the splitting of uranium and plutonium atoms in the fuel pellets. As the fission products decay over time, they will become stable, non-radioactive elements. Each fission product has its own decay time frame or "half life", ranging from fractions of a second to up to around 30 years. The fission products are encapsulated in the solid ceramic pellets of uranium oxide. SNF has cooled sufficiently after five years to allow it to be moved from wet storage in a fuel pool to dry storage in a canister.

The SNF also contains other heavy elements created from Uranium by capture of neutrons instead of by fissioning. These elements include Plutonium, of which one isotopic form contributes to the fissioning process and generation of energy along with the fissionable isotopic form of Uranium. These non-fission results of the nuclear reactor are relatively stable with long half lives and very little gamma ray hazard associated with them. The principle hazard associated with these relatively stable elements is ingesting them, e.g. eating or breathing. Like the fission products, these elements are encapsulated in the solid ceramic pellets of uranium oxide.