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Multi-Year Plan to Prepare DOE-Managed Spent Fuel for Transportation

Josh Jarrell, Brett Carlsen, Gordon Petersen, Colleen Shelton-Davis, Phil Winston

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SUMMARY

The Department of Energy (DOE) Office of Nuclear Energy Nuclear Infrastructure Programs and Office of Spent Fuel and Waste Disposition co-sponsored this report to support the management of its non-commercial spent nuclear fuel. This report documents the objective, scope, system concept, and multi-year goals of preparing NE-managed spent fuel for transportation. Specifically, this plan lays out a timeline of activities that could be followed to ensure NE-managed spent fuel will be transportable without the need to further repackage the material. The focus of this project is to (1) confirm the DOE standardized canister design meets the DOE complex needs with a specific focus on Idaho National Laboratory (INL) fuels, (2) evaluate the current and proposed INL facilities needed to package spent fuel in DOE standardized canisters, (3) determine the appropriate storage configuration for spent fuel, and (4) develop a transportation license application to allow a transportation package to be certified with the standardized canister as approved content by the Nuclear Regulatory Commission (NRC). The key proposed actions, those specific to Advanced Test Reactor (ATR) spent fuel at INL, are identified below:

- Canister System Design
  - Re-evaluate the basis and need for advanced neutron absorber (ANA) for ATR fuel in the current context and, if deemed appropriate, re-establish dialog with industry partners that can supply the ANA poisons in the size and quantity necessary (FY-19).
  - Finalize internal configurations, including loading limits, basket designs, and any necessary criticality control measures for ATR fuel (FY-19).
  - Evaluate potential for removal of shield plug from canister design if all welding is performed remotely (FY-19).
  - Initiate partnerships with suppliers of spent fuel canisters that could fabricate the standardized canister (FY-20).
- Operational and Facility Evaluations
  - Review viability of other INL facilities for the loading and closure of standardized canisters (FY-19).
  - Evaluate drying technologies (e.g., forced gas dehydration, vacuum), including applicability to ATR fuels and deployment options at CPP-603 (FY-19).
  - Evaluate/confirm remote welding technologies applicability and compatibility in the hot cell at CPP-603, including remote Non-Destructive Examination (NDE) techniques (FY-19).
  - Demonstrate selected drying technology, welding technology, and NDE technology at CPP-603 (FY-20 and FY-21).
- Storage Configurations and Options

    - Evaluate/confirm CPP-666 and CPP-603 dry storage option for standardized canisters (FY-20).
    - Initiate partnerships with suppliers of storage systems or overpacks that may be able to accommodate the standardized canisters (FY-20).
- Transportation Certification and Options
    - Consult with industry to determine the most effective approach for obtaining NRC credit for moderator exclusion within the canisters. If appropriate, complete topical report to obtain NRC review and acceptance of the strategy related to moderator exclusion (FY-20 and FY-21).
    - Initiate partnerships with transport cask vendors to ensure DOE has the necessary information needed for vendors to amend transport licenses (FY-20).
    - Engage industry to certify one or more casks to transport standardized canisters for ATR fuel (FY-21 and beyond).

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ACRONYMS

ANA	advanced neutron absorber
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNF	aluminum-clad spent nuclear fuel
ATR	Advanced Test Reactor
CFR	Code of Federal Regulation
CPP	Chemical Processing Plant
DOE	Department of Energy
D&D	decontamination and decommissioning
FHC	Fuel Handling Cave
FSA	Fuel Storage Area
HFIR	High Flux Isotope Reactor
HLW	high level waste
EM	Office of Environmental Management
FWENC	Foster Wheeler Environmental Corporation
FWISF	Foster Wheeler Idaho Storage Facility
F&R	functions and requirements
HEU	highly-enriched uranium
ICP	Idaho Cleanup Project
IFSF	Irradiated Fuel Storage Facility
INL	Idaho National Laboratory
ISFF	Idaho Spent Fuel Facility
LA	license application
LEU	low-enriched uranium
LWBR	light-water breeder reactor
MCO	Multi-Canister Overpack
NDE	non-destructive examination
NE	Office of Nuclear Energy
NWTRB	Nuclear Waste Technical Review Board
NIP	Nuclear Infrastructure Programs
NRC	Nuclear Regulatory Commission
NSNFP	National Spent Nuclear Fuel Program
OCRWM	Office of Civilian Radioactive Waste Management
UNF	used nuclear fuel

ROM	rough order of magnitude
SFWD	Spent Fuel and Waste Disposition
SNF	spent nuclear fuel
TAD	Transportation, Aging, and Disposal
TMI	Three Mile Island
TRIGA	Training, Research, Isotope, General Atomics
V&V	validation and verification
YM	Yucca Mountain

Multi-Year Plan to Prepare DOE-Managed Spent Fuel for Transportation

1. INTRODUCTION AND BACKGROUND

This multi-year plan for preparing Department of Energy (DOE)-managed spent fuel for transportation provides necessary steps to ensure that containers and licensing are in place to allow road-ready packaging of spent fuel at Idaho National Laboratory (INL). It summarizes and references previous work related to the development of a multi-purpose canister termed the "DOE standardized canister." In addition, it describes the functions of the standardized canister and the underlying assumptions associated with its implementation.

1.1 Introduction

Spent fuel is currently stored across the national laboratory complex in a variety of environments, both wet and dry. In some cases, the current storage facilities are reaching capacity (e.g., dry storage at the INL Site) and/or are being used beyond their planned lifetimes. A canister type is being proposed, termed the DOE standardized canister, to allow a broad range of fuels to be loaded, stored, transported, and disposed of while avoiding the need to re-open the canister after initial loading. The concept of a multi- or triple-purpose (i.e., storage, transportation, and disposal) canister is consistent with the transportation, aging, and disposal (TAD) concept developed for commercial SNF, as well as the naval canister developed for the Naval Reactors Program. Fundamentally, the goal is to load and dry the fuel in a high-integrity welded canister that, with appropriate packaging and ancillary system components, is capable of long-term storage, eventual transportation, and final disposition. *Until disposal occurs, it is essential to manage SNF in a way that will facilitate its eventual disposal, and it is also important to improve understanding of processes related to packaging and storage of the SNF that could affect future transportation and disposal activities* [NWTRB 2017].

The reliance on the standardized canister as the basis for compliance with safety requirements minimizes the need for detailed fuel-specific condition, composition, mechanical, and chemical properties, etc., along with the costs and personnel exposure associated with characterization of the spent fuel. The goal of a robust, high-integrity canister is to ensure compliance with applicable requirements by relying on fuel-specific analyses and the associated data for defense in depth. This allows common safety analyses, operations equipment, and training, etc., to be applied to a broad range of DOE fuels to be packaged for storage, transportation, and disposal.

1.2 Background

While the standardized canister has been developed with broad, long-term goals and objectives, this project has been started to address more near-term needs. The focus of this work will be on (1) ensuring DOE-managed spent fuel at INL can be safely and efficiently stored until a transportation path forward is available without impacting current INL reactor missions and (2) ensuring it can be transported offsite without repackaging the fuel into a separate canister or package.

The focus of this effort will be on the Advanced Test Reactor (ATR) fuel at INL. The ATR generates approximately 100 spent fuel elements each year. The current ATR spent fuel storage options include the INL Site's wet storage facility, the Idaho Chemical Processing Plant (CPP)-666, and the dry storage facility at CPP-603. However, all spent fuel is scheduled to be removed from CPP-666 by the end of 2023. In addition, the CPP-603 dry storage has reached its initial capacity and is currently being re-configured to allow more fuel to be stored in the facility. However, there are a lack of viable alternatives for ATR spent fuel storage if CPP-603 storage becomes unavailable in the future. This lack of a contingency plan instigated a review of potential alternatives, culminating in a decision to evaluate the standardized canister as a potential option to alleviate storage capacity issues.

The standardized canister has been included in both a storage license (the Foster Wheeler Idaho Spent Fuel Facility[a] [FWISF 2001]) and a repository license application (the Yucca Mountain Repository [DOE 2008]). In addition, from 2006–2008, transportation configurations were analyzed and the Nuclear Regulatory Commission (NRC) was engaged to ensure a path forward for transportation of loaded standardized canisters [NRC 2007]. A significant amount of work and resources have been invested in the development of the standardized canister, storage configurations, transportation options, and disposal approaches.

The DOE Office of Environmental Management (EM) has recently initiated studies to understand and improve the technical basis for long-term dry storage of aluminum clad spent nuclear fuel (e.g., ATR, High Flux Isotope Reactor (HFIR)) [Connolly 2018]. While currently in the lab-scale R&D phase, the next step involves validation and verification (V&V) of the lab-scale results. One method to perform V&V is to load aluminum-clad spent fuel in an instrumented canister as a demonstration. The standardized canister design is the appropriate basis for the design of an instrumented canister. There is an opportunity to leverage the DOE-EM work to move a canister demonstration from planning to reality. Though this report is focused on the NE ATR fuel, the proposed activities are intended to complement (not duplicate) current DOE-EM work. In addition, most of the proposed work is applicable to other DOE-managed fuels.

2. OBJECTIVE

The objective of this report is to lay out a multi-year plan to maintain safe and efficient on-site storage for ATR fuel pending transportation off-site. Specifically, a multi-year plan involves finalizing the design of the standardized canister (Activity 1), confirming the ability to load ATR fuel at the INL Site (Activity 2), evaluating appropriate on-site storage options for the canister (Activity 3), and ensuring the canister is "road-ready" (Activity 4) to support future transportation of the spent fuel. In the context of this report, road-ready implies that a transportation package has been certified by the NRC with ATR fuel as an approved content of the standardized canister.

While the focus of this path forward is on the ATR fuel at the INL Site, the standardized canister has been designed with a range of baskets to be compatible with the diverse set of spent fuels within the DOE complex inventory. Therefore, the system developed could be applied to other fuels. The underlying reliance on canister integrity instead of spent fuel form integrity allows the storage configuration (Activity 3) and road-ready determinations (Activity 4) to be similar for all spent fuel forms.

3. CANISTER SYSTEM CONCEPTS AND REQUIREMENTS

This section describes the functions and requirements that a standardized canister system would satisfy. It includes a discussion of the canister concept, as well as the appropriate functions and requirements that would be relevant to the canister system and the larger spent fuel system. Finally, a list of assumptions is included.

3.1 Canister System Concept

In 1994, DOE-EM started the National Spent Nuclear Fuel Program (NSNFP) to manage the wide array of DOE SNF. The NSNFP was responsible for establishing consistency in technology development, integrating DOE complex-wide efforts, and developing a timely, cost-effective technical solution for DOE SNF management. This led to the introduction of the DOE standardized canister, which provided a solution to the lack of qualified information for a large percentage of DOE SNF by relying on the

[a] FWISF has previously been referred to as the Idaho Spent Fuel Facility (ISFF). Note that the license was transferred to the Department of Energy in 2009.

standardized canister as the basis for compliance with safety requirements to minimize the required fuel characterization activities.

The canister development program adopted the design and quality assurance (QA) principles of the American Society of Mechanical Engineers (ASME) code to support the bases for a low-failure-probability argument (i.e., ASME Section III Division 3). A finite-element model was developed to predict structural performance of the canister, and a testing program was developed to confirm canister performance and validate the model. To supplement the testing, the canisters were leak-tested in accordance with the American National Standards Institute (ANSI) N14.5, 1987, *American National Standard for Radioactive Materials-Leakage Tests on Packages for Shipment*.

A preliminary design specification mandated that an 18-inch or 24-inch diameter standardized canister should have either a 10-foot or 15-foot length. The canister shells were fabricated from welded or seamless ASME SA312, 316L stainless steel pipe. The top and bottom heads were dished and flanged [Morton 1999]. The heads were fabricated from ASME SA240, 316L stainless steel and were butt-welded to the shell. The canister design incorporated an energy absorbing skirt that deforms on impact during accidental drop events, providing a significant amount of protection to the actual containment boundary of the canister, including the welds. This deformed skirt could be removed (cut off) if necessary without disrupting the canister's containment, enhancing the canister's ability to still fit into other containers (e.g., a waste package) after a drop event. Also incorporated into the canister design was the option of a threaded plug in the top and bottom heads. These plugs could be used for a number of functions, including canister draining, inerting, leak testing, venting, monitoring, and remote inspection. Installation or removal of the plug(s) was to be performed while inside a hot cell or other approved area. Plugs were to be seal-welded using an appropriately qualified process prior to transport. An overview of the canister specifications for each size is found in Table 1. The preliminary design, along with key design features, are illustrated in Figure 1. The ATR fuel is expected to be loaded into 18-in. diameter canisters that are either 10 or 15 ft in length.

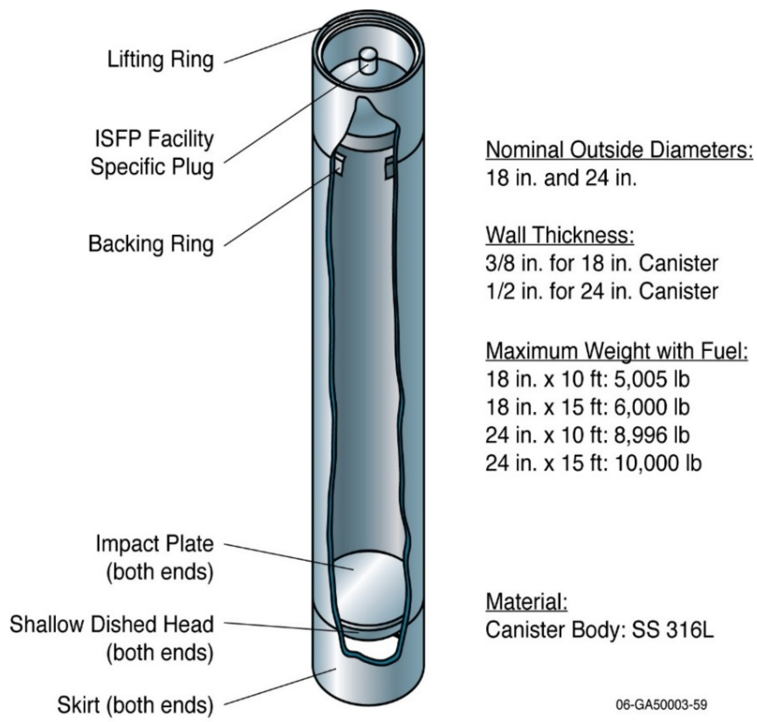


Figure 1. DOE standardized SNF canister arrangement.

Table 1. Standardized canister specification overview.

Canister Dimensions	Canister Weight	Intended Use
18-in. diameter 10-ft. total length	5,005-lb total weight	Shorter fuels that effectively utilize the length of a 10-ft canister[a]
18-in. diameter 15-ft. total length	6,000-lb total weight	Longer fuels and/or those that can be more efficiently stacked into the 15-ft canister[b]
24-in. diameter 10-ft. total length	8,996-lb total weight	LEU fuels, or small quantities of canistered HEU material
24-in. diameter 15-ft. total length	10,000-lb total weight	HEU High Flux Isotope Reactor (HFIR) outer assemblies and Shippingport Light-Water Breeder Reactor (LWBR) power-flattening blanket assemblies[c]

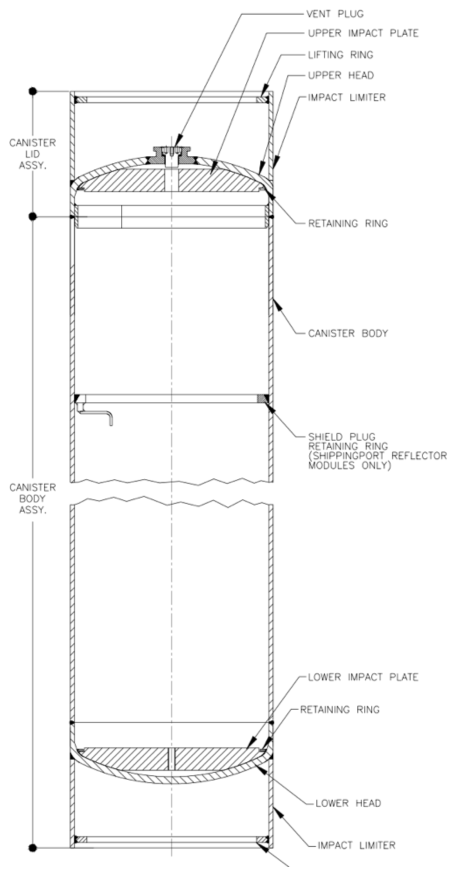
[a] For co-disposal, the shorter fuels are reserved for the shorter canisters to match (approximately) the number of 10-ft HLW canisters generated at both Savannah River and West Valley.

[b] Exceptions may occur as in the case of the much shorter Ft. St. Vrain fuels, where 3-high stacked blocks in short canisters vs. 5-high blocks in long canisters would cause an inordinate increase in the total number of SNF canisters generated.

[c] Both fuels contain significant quantities of fissile material, but because of their physical size, the 18-in. canister cannot be utilized. These fuel units also require additional poisoning internal to the fuel assemblies themselves in conjunction with their installation in the 24-in. diameter canister.

On May 19, 2000, DOE awarded a contract to Foster Wheeler Environmental Corporation (FWENC) to package fuel in 18-inch and 24-inch standardized canisters designed, licensed, fabricated, loaded, and sealed for storage in accordance with a 10 CFR Part 72 storage license. The NRC approved the FWENC license application on November 19, 2001 under SNM-2512 License Docket 72–75. The completed FWENC canister design differs from the original analyzed and tested standardized canister (as illustrated in Figure 2) by:

- Employing thicker heads on each end of the canister
- Using a retaining ring welded to hold internal impact plates
- Using an internal shield plug to allow work proximity for weld closure
- Eliminating the internal sleeve to reduce localized strains and galvanic corrosion
- Incorporating different fuel baskets
- Using a single larger vent plug on the top head only.



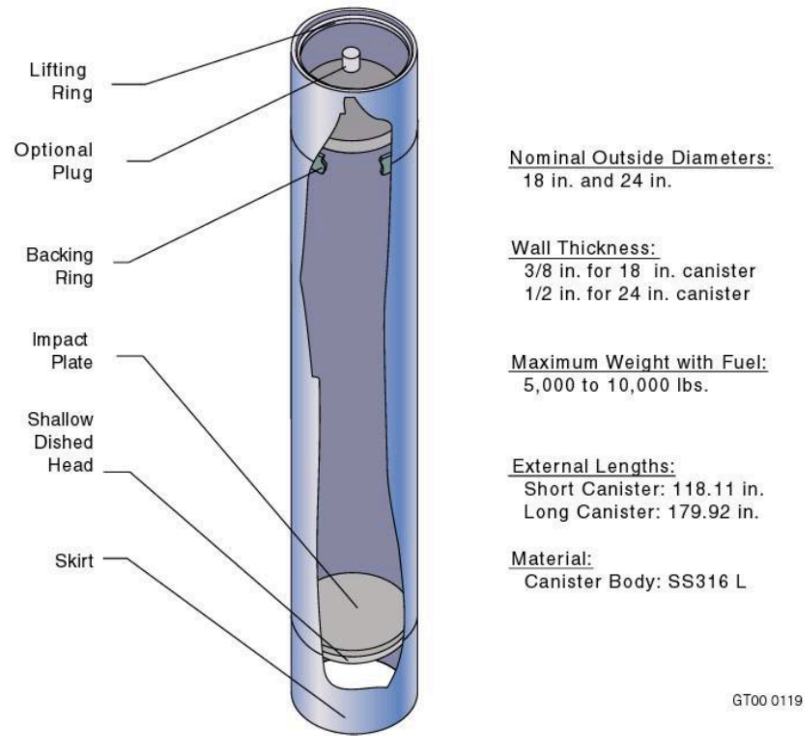


Figure 2. Foster Wheeler ISF Canister Design [Roberts 2003] (left) and DOE Standardized Canister [Larsen 2006] (right).

NSNFP analyzed these changes and determined they would not negatively impact the structural performance of the canister [DOE 2003a, DOE 2003b].

Loading spent nuclear fuel into DOE standardized canisters requires an approved configuration to ensure control of fissile mass, fuel geometry, and other criticality safety measures. These controls are implemented by a number of basket designs that accommodate various fuel geometries and properties [Taylor 2004]. SNF may be loaded into a basket that is pre-installed in the individual canisters; alternatively, baskets may be first loaded and then stacked within a canister.

3.2 General Functions and Requirements

Requirements for the canister design are driven by the need to achieve inclusion in a DOE-licensed storage facility, an NRC-certified transportation package, and an NRC-licensed disposal facility. Specific considerations include (1) demonstrating that a canister breach and radioactive release would be a low-probability event in a disposal environment, (2) ensuring criticality safety based on the canister boundary precluding intrusion of moderator (i.e., water) in a transportation package, and (3) selecting canister materials that avoid interactions that could result in unacceptable degradation in storage, transportation, or a disposal environment.

These functions and requirements (F&Rs) are only a partial list and will be updated as additional evaluations are performed.

R 1.0.0 Canister shall maintain control of SNF
Basis: Canister's primary function is to hold SNF in a safe, secure geometry in support of storage, transportation, and eventual disposition, so it must maintain control of SNF.

R 1.0.1 Canister shall decouple safety performance from form and conditions of contained fuel and act as primary barrier of SNF.
Basis: Only a small fraction of DOE SNF (<10%) have existing information and data adequate to support detailed structural, thermal, radiological release, and criticality analyses with the rigor.

R 1.0.2 Canister shall perform as required while subjected to the most severely anticipated environmental conditions and natural phenomenon postulated to occur for the entire service life of the canister.
Basis: Canister must prevent radionuclide release. Designing to the most extreme conditions is the only way to ensure that canister will maintain nuclide containment and prevent radioactive release.

R 1.1.0 SNF shall be loaded into canisters.
Basis: See R 1.0.0.

R 1.1.1 Prior to loading, all canister materials shall be suitably examined.
Basis: All material loaded into canister must meet requirements for storage, transportation, and disposal.

R 1.1.2 All final loading operations for canister shall be performed remotely.
Basis: Canister does not offer radiation protection. It is assumed to be contained in a hot cell or an overpack that provides shielding at all times. Canister must have shielding or be placed in a hot cell.

R 1.1.3 Canister shall be backfilled with an inert cover gas inside of the canister at a pressure of 13.8 to 27.6 kPa.
Basis: Canister internals must not have adverse chemical reactions. NRC-issued Bulletin 96-4 discusses how an inert cover gas introduced into the storage industry canisters or transportation casks could reduce the generation of hydrogen gas, which could combust during final seal welding. It can also significantly reduce SNF corrosion and provide more appropriate heat transfer conditions.

R 1.1.4 The final closure weld shall implement a welding procedure that can be qualified to yield leak-tight welds that have no detectable leak, tested using ANSI N14.5 at the time of closure. The results should be considered equal to or better than the required leak rate necessary to satisfy the applicable 10 CFR 71 and 72 requirements.
Basis: Canister must meet 10 CFR 71 and 10 CFR 72 requirements to transport SNF or to store SNF at a site.

R 1.2.0 Canister shall be designed to provide safe storage (in coordination with the storage facility design) of SNF at any location in the continental United States.

Basis: DOE SNF is located in many places across the United States. The location of an interim storage facility or a repository is not known. Canister must be able to provide safe storage in any environment.

R.1.2.1 The design lifetime of the canister shall be a minimum of 150 years from the time canister is loaded with SNF to the time the canister is loaded into a disposal overpack; that period could include multiple dry storage and transportation cycles. It is acceptable to use aging management protocols and/or engineered measures to ensure continued compliance with applicable requirements. Aging management protocols may extend lifetime if deemed necessary.
Basis: Canisters must maintain integrity until final disposition. With uncertainty related to repository availability, canisters must maintain integrity or be periodically checked for integrity for extended periods of time. It is recognized that projected canister performance is based on engineering judgment and is qualified by available data on material performance in potential service environments.

R 1.3.0 Loaded canister shall be handled using onsite cranes or canister transfer systems.
Basis: Canister must be moved around the facility to be tested, loaded, stored, and transported off-site.

R 1.3.1 The design of the standardized canister shall be robust enough to accommodate the grappling and handling equipment configurations at the interfacing facilities when loaded to the weight limits of the canister.
Basis: See R 1.3.0

R 1.4.0 Canister shall be transported to different sites.
Basis: Canister must be transported for final disposition. It is expected that interim storage or final disposition will not be on the same site for DOE SNF.

R 1.4.1 Canister incorporated into a transportation cask system shall adequately address hypothetical accident conditions of 10 CFR Part 71.73.
Basis: Canister and transportation cask system must meet standards set forth in 10 CFR 71.73 to remain leak tight in hypothetical accident conditions in order to apply for moderator exclusion.

R 1.5.0 Canister shall meet the material compatibility and criticality issues indicated in 10 CFR 63 (i.e., Yucca Mountain).
Basis: It is expected that once SNF is loaded into the canister, it will not need to be repackaged. Canister must meet disposition requirements to avoid repackaging. As noted in Section 3.3, it is assumed that any additional repository requirements will not be more stringent than those in 10 CFR 63.

R 2.0.0 Empty canister shall be transported both on and off sites containing DOE SNF.
Basis: Canister must be transported to sites containing DOE SNF in order to be loaded.

R 3.0.0 Empty canister shall be designed, fabricated, and examined per the requirements of the ASME B&PV Code, Section III, Division 3.
Basis: Canister must meet design requirements.

R 3.0.1 Besides the final closure weld, all canister welds necessary for structural integrity shall be volumetrically examined, using either radiography or ultrasonic methods, to assure weld integrity. The final closure weld requirements are identified in R 1.1.4.
Basis: Canister must provide welds that satisfy design and safety requirements of canister.

R 3.0.2 Canister shall physically maintain containment after a 9-meter (30-foot) drop.
Basis: Testing of canister must prove canister maintains containment after 9-meter drop to ensure a robust design. This test is the key argument for moderator exclusion. It also minimizes canister deformations and damage that could potentially occur during normal, everyday handling scenarios.

R 3.0.3 Canister shall avoid unwanted reactions with storage rack, transfer cask, transportation cask, storage cask, and waste package.
Basis: Canister must avoid criticality and enhanced age-related degradation due to material interactions.

R 4.0.0 A safety analysis shall be performed commensurate with the potential consequences of any activity being performed in conjunction with the canister.
Basis: Canister must be used for designated uses. If designated use expands or changes, a safety analysis must be performed to avoid compromising canister.

R 5.0.0 Canister shall be uniquely identifiable.
Basis: Canister must be properly labeled and accounted for at all times.

3.3 Assumptions

This path forward report and project is based on a number of assumptions, including the following:

- Funding will be sufficient to fully test and license the standardized canister for ATR SNF.
- Personnel and resources will be available as needed.
- Canister development, loading, and storage demonstration, as well as associated activities, will not unacceptably impact Fluor or Idaho Cleanup Project deliverables.
- DOE-licensed storage facilities will accommodate the standardized canister.
- Canister will rely on overpack or the storage facility for shielding (i.e., most shielding is not provided by the canister).
- Canister will be stored in a dry, road-ready storage configuration.
- Packaging/storage facility will ensure that the canister remains within the design basis (e.g., drop height, environmental conditions, movement of objects over canister, sharp objects in the pathway).
- The design of any internal components (such as baskets, spacers, sleeves, dividers, cans, etc.) necessary for the loading of the SNF and for the control of criticality must be constrained by the existing design and interior dimensions of the DOE SNF canisters.
- Canister shall be capable of accepting intact, failed, or damaged SNF, directly or canned.
- The loading of the SNF into a canister will not cause significant localized thermal gradients in the pressure boundary, nor will it result in significant bowing concerns for the canister
- The transportation certification will be determined by the NRC in accordance with 10 CFR Part 71.
- The transport system will provide shielding and containment during transportation.
- NRC will allow crediting canister for excluding moderator during transport accident conditions.
- The transport system will ensure that the canister remains within design basis (e.g., drop height, environmental conditions) for all credible events.

- Disposal requirements will not be significantly more stringent than for the Yucca Mountain Project.
- The NRC-approved license application from FWENC (SNM-2512 License Docket 72-75) will remain applicable.

4. POTENTIAL PATH FORWARD

This plan identifies four main activities. For each activity, a list of actions that could be completed is included.

4.1 Canister System Design

Activity 1 of this project will review and make needed standardized canister design modifications based on the current spent fuel environment. Example modifications include expansion of the types of fuels and evaluation of remote closure. As noted in Section 3, the design of the DOE standardized canister has been included in both storage and disposal license applications. Although much work has already been completed for the DOE standardized canister, the FWENC license, and the Yucca Mountain license application, there is still work to be done to ensure that the standardized canister will be ready for storage, transportation, and disposal. Though this report is focused on ATR fuel, there are many actions that could be taken that are independent of the fuel in the canister.

4.1.1 Potential Proposed Actions

The following major actions should be completed to finalize the design of the canister:

- Begin identification and development of monitoring, inspection, and aging-management capabilities to support extended storage of canisters for the time periods that may be necessary until an interim storage facility or disposal facility is available. This may require development of limited follow-on studies recommended by material interactions studies (e.g., free water vapor of hydrated corrosion products in a closed system, and rate of hydrogen production by corrosion of remaining aluminum cladding).
- Re-evaluate the basis and need for ANA in the current context and, if deemed appropriate, re-establish dialog with industry partners who can supply the ANA poisons in the size and quantity necessary.
- Finalize internal configurations, including loading limits, basket designs, and any necessary criticality control measures (e.g., further development of ANA, the addition of beads to intersperse additional poison and/or to displace the potential for moderator within the fuel).
- Develop guidance to qualify other fuels in the criticality groups for packaging and obtain acceptance.
- Develop technical basis for demonstrating canister will meet applicable performance requirements for transport following extended storage.
- Initiate partnerships with suppliers of spent fuel canisters that could fabricate the standardized canister.

There may be other activities involved in licensing and testing the DOE standardized canister as these actions are completed. In many cases, many smaller steps must be taken to accomplish one of these remaining actions.

4.2 Operational and Facility Evaluations

Activity 2 of this project will further evaluate the potential to load, dry, weld, and handle standardized canisters in current INL facilities. The most likely candidate facility is INTEC's CPP-603, Irradiated Fuel Storage Facility (IFSF), which is described in the following sections. It is recognized that packaging at

CPP-603 will require facility modifications and that the throughput will be significantly less than deployment at a new facility, such as that proposed in [FWISF 2001].

4.2.1 CPP-603 IFSF Description

INTEC's CPP-603 IFSF was originally constructed to dry store the Ft. St. Vrain High Temperature Gas Reactor core, which is composed of hexagonal graphite blocks approximately 33 inches high and 17 inches across the points. The currently operating areas are the Fuel Storage Area (FSA) and the Fuel Handling Cave (FHC), which are separated by a shield wall. The structure is an actively air-cooled array of 636 purpose-built canisters 11 feet long and 18 inches in diameter, suspended from a top end flange in a steel framework. This is topped by a steel deck plate that separates ventilation flow through the canisters below from the main crane-accessible workspace. Design air flow is 12,000 standard cubic feet per minute through the FHC and canister array, discharging through a dedicated stack. Due to the minimal decay heat of the stored fuel, the ventilation system has not been operated for at least 10 years, even though it was upgraded in 2003. Since the ventilation system is not operating, neither is the stack radiation release monitor. The facility stores approximately one-third of the Ft. St. Vrain core, as well as Peach Bottom graphite fuel. The remaining capacity is progressively being filled with aluminum plate type (e.g., ATR), as well as UZrHx TRIGA research reactor fuel. It has been designated as the destination for the next several decades of discharged ATR fuel, which will require reconfiguration of canisters to maximize capacity.

The FHC has one manual manipulator window work station at the floor level and one upper level control room window from which the electromechanical PaR 3000 manipulator, shuttle bin, and the CRN-GSF-101 crane can be operated. The FSA has one window from which the CRN-GSF-101 crane is controlled when it is placing canisters in the grid or retrieving them for repackaging. To maintain the crane, it must be moved to the Crane Maintenance Area adjacent to the FHC. Personnel access to the FHC is possible if all fuel has been removed. There is no personnel access into the FSA. Fuel is received and shipped out of the facility in casks that are brought into the FHC on an electric motor-driven cask Transfer Car. The Transfer Car has been demonstrated to have the dimensional clearance to receive casks of the Transnuclear TN-24/32/40 family. It is 12 ft wide by 35 ft long, constructed of 12-inch-thick steel deck plate, and weighs 153 tons. The rated capacity is 60 tons but has been reported to be designed for a maximum capacity of 278 tons [Wahnschaffe 2011]. Casks are hung vertically from an 8-ft, 7-inch diameter penetration in the steel deck using cask-specific inserts to mate to different support geometries. Overhead clearance in the FHC could accommodate handling of full-length commercial fuel assemblies [Bohachek 2013].

Casks are brought into the facility and removed from the transport vehicles using the east-west truck bay bridge crane CRN-SF-001 (originally a single 75-ton crane that was de-rated to 60 tons), which has recently been replaced by a pair of 75-ton units operating on individual bridges. This collective 150-ton capacity will be able to receive and transfer commercial-sized 100-ton casks when fitted with the appropriate rigging.

Plan and elevation views of IFSF are shown in Figure 3 and Figure 4.

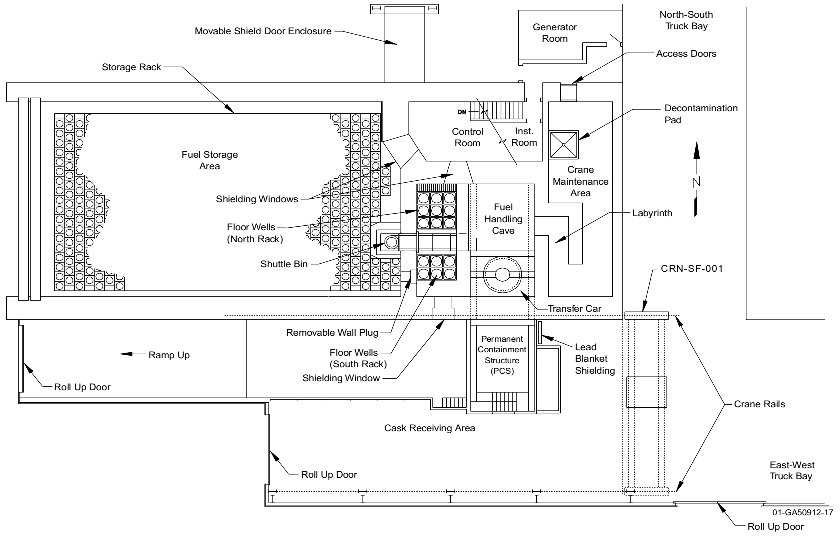


Figure 3. CPP-603 IFSF plan view.

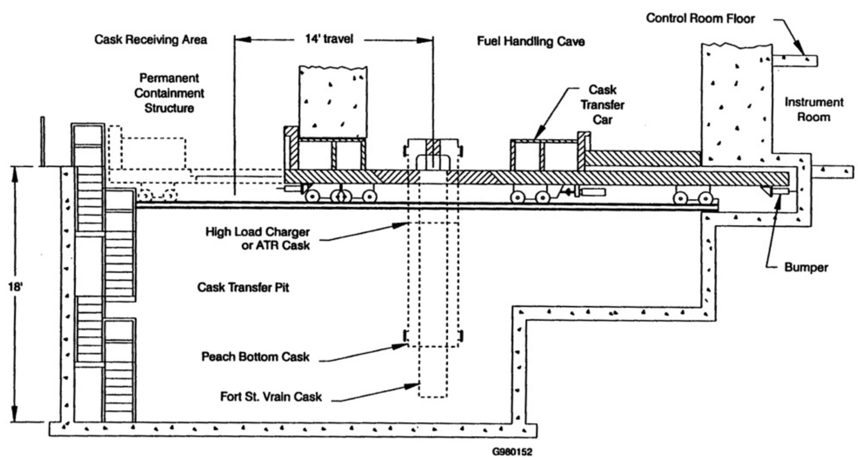


Figure 4. CPP-603 IFSF Transfer Car and FHC elevation view.

4.2.2 Transportation at CPP-603

With the truck bay crane upgrade, there is no apparent challenge to loading large-scale casks in CPP-603 [Bohachek 2013]. Assuming an inventory of dried, welded, inerted canisters can be accumulated in the FHC, transferring them to the transportation package will be limited only by potential crane and PaR manipulator down time, since the systems were put into service in 1975 and, unlike the crane in the truck bay, have not been upgraded. Although the rail spur that serves the truck bay was cut during decontamination and decommissioning (D&D) activities in the former wet storage basins of CPP-603, renovation of the rail represents an alternative to truck transport.

4.2.3 Drying and Welding at CPP-603

The shift from storage of graphite fuels and receipt of formerly wet-stored fuels mandated incorporation of a drying (fuel conditioning) station to dry the canisters prior to storage to meet criticality controls for free water. The drying station is a vessel mounted on the floor with band heaters and a vacuum lid placed in Cave Well 13 directly in front of the floor level manipulator workstation window.

Canisters are placed in the heated vessel and the vacuum lid is mounted to the canister. This system has a vacuum pump that can evacuate a canister down to 2 Torr. The heating operation is limited to a maximum of 100°C on the basis that, without a stack monitor in operation, the entire inventory of fuel radionuclides could be volatilized without detection if temperatures exceeding 100°C were achieved. Release of this inventory would invalidate the facility air permit. If it is assumed that the 18-inch diameter standardized canister is to be used for DOE fuels destined for the repository, the drying station in the FHC could be adapted to serve the purpose of evacuation and backfill prior to storage and eventual transportation.

Several considerations apply to this adaptation: first, the vacuum lid would require replacement, since it only fits IFSF top flange type canisters. Second, the 10-ft-long canister design would be readily accommodated, but the heated zone would need to be increased for any of the longer configurations. Third, the vacuum attachment point on the canister needs to specify a vent port as used on the Foster-Wheeler Idaho Storage Facility (FWISF) variation of the standardized canister. With a vent port available, the fuel would be loaded, the lid installed, and the canister dried. In that scenario, the lid weld would need to be made remotely in the FHC. Since the standardized canister is designed to be moved by the ring in the upper skirt, the weld would need to be made while the canister is in the drying station. Otherwise, the canister would need to be loaded and dried in an inert atmosphere cell so that when the drying lid was removed, it would not be filled by atmospheric air while being moved lidless to the welding station for the closure weld. A secondary means of lifting the canister shell would be required for that task as well. The existing drying station would need to be modified to incorporate inert gas backfilling capability. In the interest of developing an effective integrated system, an entire drying-welding module may need to be developed to replace the existing drying station.

Installation of the previously-developed module, illustrated in Figure 5 [Larsen 2006], would require significant modification of the FHC, since the cave floor is a relatively thin plate steel laid over the steel framework that allows air circulation to cool the canisters that hang in the space below the floor, which offers negligible shielding when fuel is in a canister in the cave.

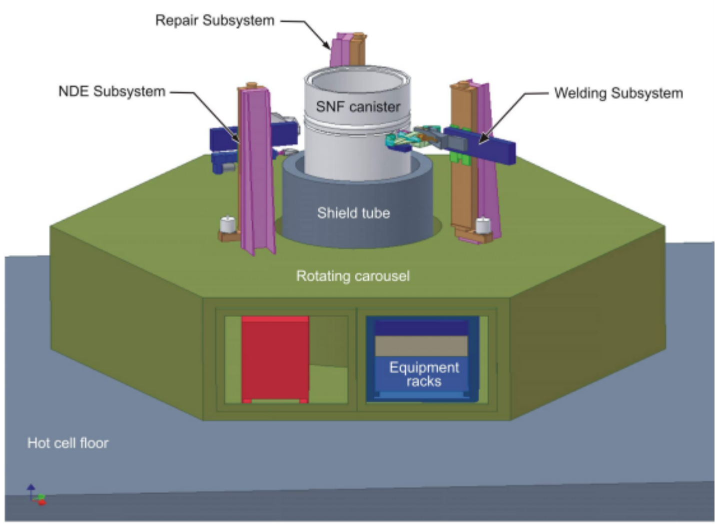


Figure 5. Canister weld and repair module as proposed by Larsen [Larsen 2006].

It would require removal of a floor section at the window to allow shielding to be installed around the canister welding volume. Laying sufficient shielding for personnel entry over the floor plate would be expected to exceed the support structure capacity. Despite being offered as a remote operation, the shielding included in this design would be complemented by the FWISF canister that incorporates a shield plug below the head weld, so that maintenance on the weld equipment could be done with reduced exposure. Installation of the shielded weld-dry repair module would require additional modification for weld leads, camera communications lines, and multiple control wires. Ultimately, the cost of decontamination and reconstruction may be significant.

4.2.4 Potential Proposed Actions

- Review viability of other INL facilities for the loading and closure of standardized canisters.
- Evaluate compatibility of the finalized canister design from Activity 1 with drying and welding capabilities at CPP-603.
  - Identify drying system modifications
  - Compare current drying systems with off-the-shelf options
  - Identify welding setup modifications
  - Compare welding technology option
  - Analyze remote maintenance options to determine shielding needs
  - Determine facility modifications and options to mitigate substantial modifications
  - Evaluate throughput rates of proposed options.
- Demonstrate selected drying technology, welding technology, and NDE technology at CPP-603.

4.3 Storage Configurations and Options

This activity is focused on ensuring identification and selection of a viable storage configuration at the INL site. A brief review of previously considered storage options is discussed, and proposed next steps are identified.

4.3.1 Foster Wheeler Interim Storage Facility

The Foster Wheeler Idaho Storage Facility (FWISF) design is a variation of the Ft. St. Vrain Independent Spent Fuel Storage Installation, as well as that used at the Hanford Site for storage of Multi-Canister Overpacks (MCO). It consists of a shielded below-grade vault that allows for placement of canisters using a shielded canister handling machine, which is effectively a bottom-loaded cask positioned by an overhead crane. Unlike the IFSF FSA, it is personnel-accessible so that the crane can be maintained while it is in the storage area, if needed. The FWISF conceptual configuration is shown in Figure 6.

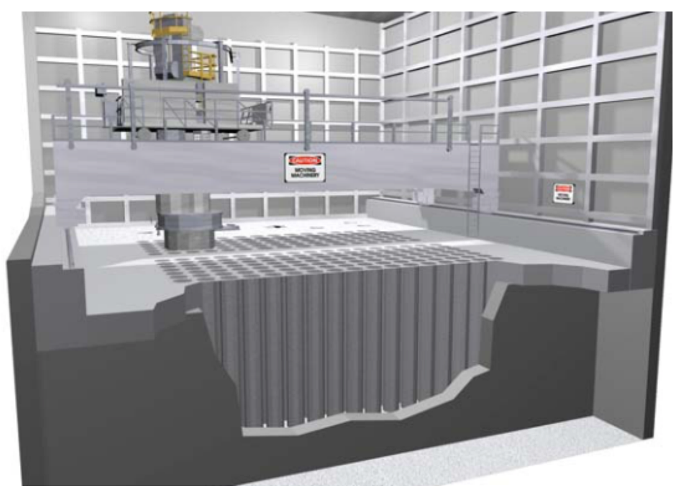


Figure 6. Foster Wheeler conceptual design [Roberts 2003].

Key design features in the license included fabrication of the canisters to ASME Section III, Division 3 code requirements, N-stamping for canister storage and transportation, packaging of fuel into standardized canisters, inclusion of a shield plug to reduce exposure during canister weld closure, canister emplacement in a vault with sealed storage tubes for redundant confinement, and the flexibility to receive and process all fuel types at the Idaho site. (N-stamps are certificates of authorization issued by ASME that signify the certificate holder has been through a rigorous survey to verify the adequacy and effective implementation of the quality assurance program. Certificate holders are allowed to certify and stamp newly constructed components, parts, and appurtenances used at a nuclear facility in accordance with Section III of the ASME BPVC). The initial contract for the design was narrowed to three types of fuel to support a fixed-price procurement and minimize risk in licensing. The fuels selected were:

- Cores 1 and 2 from Peach Bottom Unit 1 (18” diameter canister)
- Reflector modules and rods from Shippingport (24” diameter canister)
- Training, Research, Isotope, General Atomic (TRIGA) reactors (18” diameter canister).

Since these types of fuel are presumed to be categorically dry, a separate drying function was not incorporated into the design.

4.3.2 CPP-666

To comply with the 1995 Idaho Settlement Agreement, all wet-stored fuel is to be removed from CPP-666 by the end of 2023. Conversion of one or more of the CPP-666 pools for dry storage may be an acceptable option once all fuel has been removed from the pools. The facility contains six storage pools, two unloading pools, and a fuel cutting pool, all connected by a transfer channel. Storage Pools Two through Six are 31 feet wide by 46.5 feet long and 30 feet deep. Pool One is 41 feet deep and is adjacent to the unloading pools. The pool area is served by 10-ton CRN-FS-901, and the vehicle unloading area is served by the 130-ton CRN-FS-903. There is a rail provision built into the truck bay, but it is not connected to the rail spur used by CPP-603. The pool layout is shown in Figure 7 below.

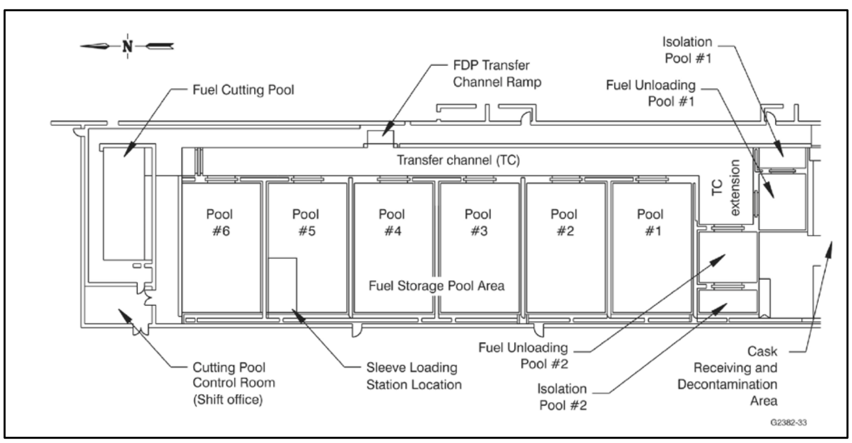


Figure 7. Plan view of CPP-666 Fuel Storage Area.

An alternative use of CPP-666 was proposed for the conversion of the CPP-666 storage pool to dry storage [Connolly 2017]. In this proposal, a sectional heavy steel deck plate that incorporates canister storage tubes would be placed over Pool One. A below-grade fuel canister loading, welding, and drying station would be installed in the adjacent unloading and isolation pool. The loading station would be served by a variation of the Canister Handling Machine to transfer loaded canisters into the storage positions. The shield plug canister proposed in the FWISF design would be compatible with this system. Due to its considerable depth, three 10-foot canisters, each containing two ATR-8 buckets, could be placed in each storage tube. With the new ATR-16 configuration, this could be greatly increased. The general configuration is shown in Figure 8 below. The modifications proposed here would have a negligible effect on waste treatment or fuel processing operations in the adjacent Fluorenol Dissolution Process cell, which is located on the other side of the building.

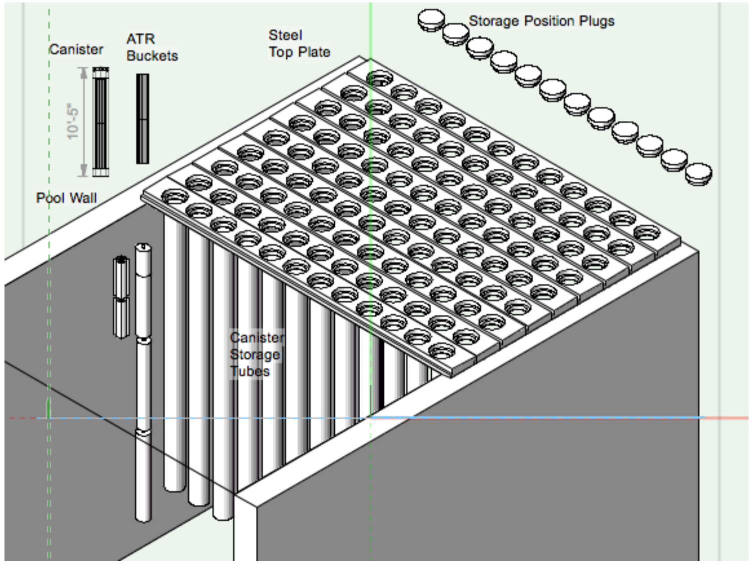


Figure 8. Conceptual dry storage conversion of CPP-666 Pool One [Connolly 2017].

The transfer cask is proposed to be supported by an air pallet, with supplemental position and lifting to be done by CRN-FS-901. An additional view of the proposed system is shown in Figure 9 below.

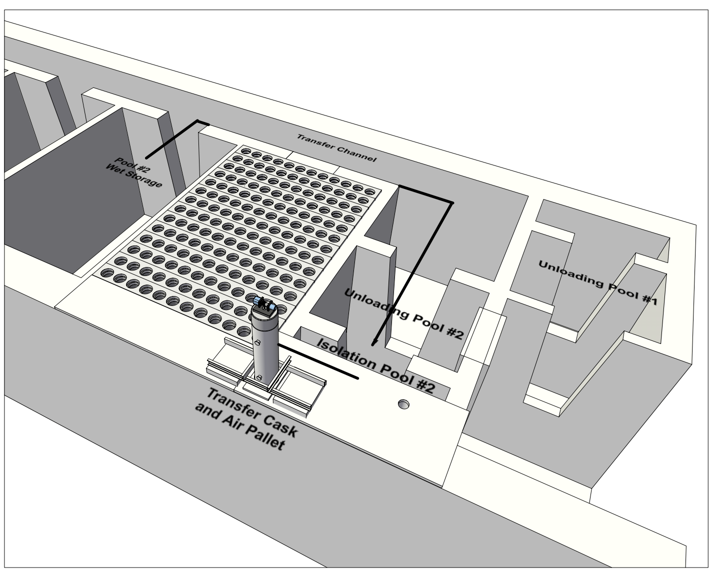


Figure 9. Transfer cask with air pallet and isolation pools [Connolly 2017].

If a part of wet handling functionality can be maintained, this facility could receive previously wet stored fuels for packaging into DOE Standardized Canisters. The availability of the pool would limit how much dry hot cell space would be needed for receipt of fuel from wet-loaded casks.

4.3.3 Cask-based dry storage

Another storage option that could be considered is a cask-based storage system that employs a large shielded cask or horizontal storage modules that would be placed on a storage pad, which is similar to commercial or naval dry storage systems. Currently, eight dry casks are stored at the CPP-2707 pad, as illustrated in Figure 10. Additional pad space is available for future casks.

Figure 10. Dry storage casks on the CPP-2707 pad at the INL Site. Note that TN-REG and TN-BRP casks are not pictured.

In addition, the Three Mile Island (TMI) fuel material is currently stored at CPP-1774 in an NRC-licensed horizontal storage module system that could be applicable for the storage of standardized canisters, as illustrated in Figure 11.

Figure 11. NRC-licensed TMI fuel dry storage in NUHOMS-12T horizontal storage modules at the INL Site.

4.3.4 Potential Proposed Actions

- Initiate partnerships with suppliers of storage systems or overpacks that may be able to accommodate the standardized canisters.
- Evaluate/confirm CPP-666 and CPP-603 dry storage option for standardized canisters, including packaging throughput capacities.
- Consider amending the FWENC storage license to reflect beneficial canister-design changes, packaging of ATR fuel, and optional storage configurations for the loaded standardized canisters.

4.4 Transportation Certification and Options

This activity will document the technical, regulatory, and other work needed to confirm transportability before loaded canisters are sealed. Because transport will be necessary to move DOE's SNFs from DOE sites for interim storage and/or for final disposition, assurance of transportability must be considered during the package design, loading, and operations that precede transport.

Transportation, under both normal and accident conditions, has the potential to pose the most significant challenges to the structural integrity of the canister, as well as to the contents. As a result, proper drying and aging management actions preclude unacceptable degradation and play a key role in ensuring transportability.

It is envisioned that standardized canisters will be certified for transport in one or more commercial casks. However, certifying a commercial cask to transport DOE SNFs using traditional methods will impose data requirements on the structural properties, physical condition, and chemical composition that cannot reasonably be satisfied with existing DOE SNF data. Hence, the strategy for demonstrating that transportation packages containing ATR fuel will comply with applicable transport requirements is outlined below:

- Reliance on the transport cask for shielding and to meet the 10 CFR Part 71-specified leak-tightness requirements, which imposes no additional requirements on a licensed transportation cask.
- Obtaining NRC concurrence that the additional leak-tight boundary provided by the canister provides sufficient assurance that intrusion of a moderator into the canister need not be considered under the transport accident conditions specified by 10 CFR Part 71, which requires only that the cask maintain the standardized canister within its design basis.
- Ensuring the canister performance, following an undefined period of storage, will continue to meet its performance objectives with respect to its safety function of maintaining a leak-tight boundary during specified conditions, which imposes no additional requirements on a licensed transportation cask.
- Ensuring canister loadings meet subcriticality requirements under all credible reconfigurations in the absence of moderator intrusion.[b]

In 2006 and 2007, a number of meetings were held with the NRC to review this strategy. Another purpose was to lay the foundation for a topical report to document this approach and to provide a referenceable basis for cask vendors to draw upon during the process of licensing a cask to transport one or more standardized canisters. A consensus was reached between the NSFNP and the NRC on a path forward for completing the topical report. However, funding for the NSNFP was shifted to support near-term repository licensing needs and later terminated following the suspension of the Yucca Mountain licensing process.

At that time, the DOE was breaking new ground with respect to establishing a basis for crediting moderator exclusion for compliance with subcriticality requirements during accident conditions of transport. In the intervening years, commercial vendors have moved forward with this concept and have licensed cask designs that have been credited for providing moderator exclusion in limited circumstances [NRC 2017].

4.4.1 Potential Proposed Actions

- Consult with industry to determine the most effective approach for obtaining NRC credit for moderator exclusion within the canisters and, if appropriate, complete topical report to obtain NRC review and acceptance of the strategy related to moderator exclusion.

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[b] This does not credit the fuel baskets or added poisons for transport. The neutron poisons were intended only as a measure to ensure post-closure criticality in a geologic repository. Crediting neutron poisons is not necessary if moderator is excluded.

- Develop guidance to qualify other fuels in the groups for packaging and obtain acceptance for different basket designs, if needed.
- Develop guidance to certify other fuels within a given criticality group as bounded by the analyses for the group's characteristic or representative fuel.
- Identify requirements for canister performance and for canister loading.
- Initiate partnerships with transport cask vendors to ensure DOE has the necessary information needed for vendors to amend transport licenses.
- Engage industry to certify one or more casks to transport standardized canisters with an initial focus on ATR fuel.

5. CONCLUSIONS AND RECOMMENDATIONS

This report documents the objective, scope, system concept, and multi-year goals of preparing NE-managed SNF for transportation. Specifically, this plan lays out a timeline of activities that could be followed to ensure NE-managed SNF will be transportable without the need to further repackage the material. The focus of this project is to (1) confirm the DOE standardized canister design meets the DOE complex needs with a specific focus on Idaho National Laboratory fuels, (2) evaluate the current and proposed facilities needed to package spent fuel in DOE standardized canisters, (3) determine the appropriate storage configuration for spent fuel, and (4) develop a transportation license application to allow a transportation package to be certified with the standardized canister as approved content by the NRC. The key proposed actions, those specific to ATR spent fuel at INL, for each major activity are identified below. A generic timeline is also included and illustrated in Figure 12.

- Canister System Design
  - Re-evaluate the basis and need for ANA for ATR fuel in the current context and, if deemed appropriate, re-establish dialog with industry partners that can supply the ANA poisons in the size and quantity necessary (FY-19 and FY-20).
  - Finalize internal configurations, including loading limits, basket designs, and any necessary criticality control measures for ATR fuel (FY-19 and FY-20).
  - Evaluate potential for removal of shield plug from canister design if all welding is performed remotely (FY-19 and FY-20).
  - Initiate partnerships with suppliers of spent fuel canisters that could fabricate the standardized canister (FY-20).
- Operational and Facility Evaluations
  - Review viability of other INL facilities for the loading and closure of standardized canisters (FY-19).
  - Evaluate drying technologies (i.e., forced gas dehydration, vacuum), including applicability to ATR fuels and deployment options at CPP-603 (FY-19 and FY-20).
  - Evaluate/confirm remote welding technologies applicability and compatibility in the hot cell at CPP-603, including remote NDE techniques (FY-19 and FY-20).
  - Demonstrate selected drying technology, welding technology, and NDE technology at CPP-603 (FY-20 and FY-21).
- Storage Configurations and Options
  - Evaluate/confirm CPP-666 and CPP-603 dry storage option for standardized canisters (FY-19 and FY-20).
  - Initiate partnerships with suppliers of storage systems or overpacks that may be able to accommodate the standardized canisters (FY-20 and FY-21).
- Transportation Certification and Options
  - Consult with industry to determine the most effective approach for obtaining NRC credit for moderator exclusion within the canisters and. If appropriate, complete topical report to obtain NRC review and acceptance of the strategy related to moderator exclusion (FY-20 and FY-21).
  - Initiate partnerships with transport cask vendors to ensure DOE has the necessary information needed for vendors to amend transport licenses (FY-20 and FY-21).
  - Engage industry to certify one or more casks to transport standardized canisters for ATR fuel (FY-21 and beyond).

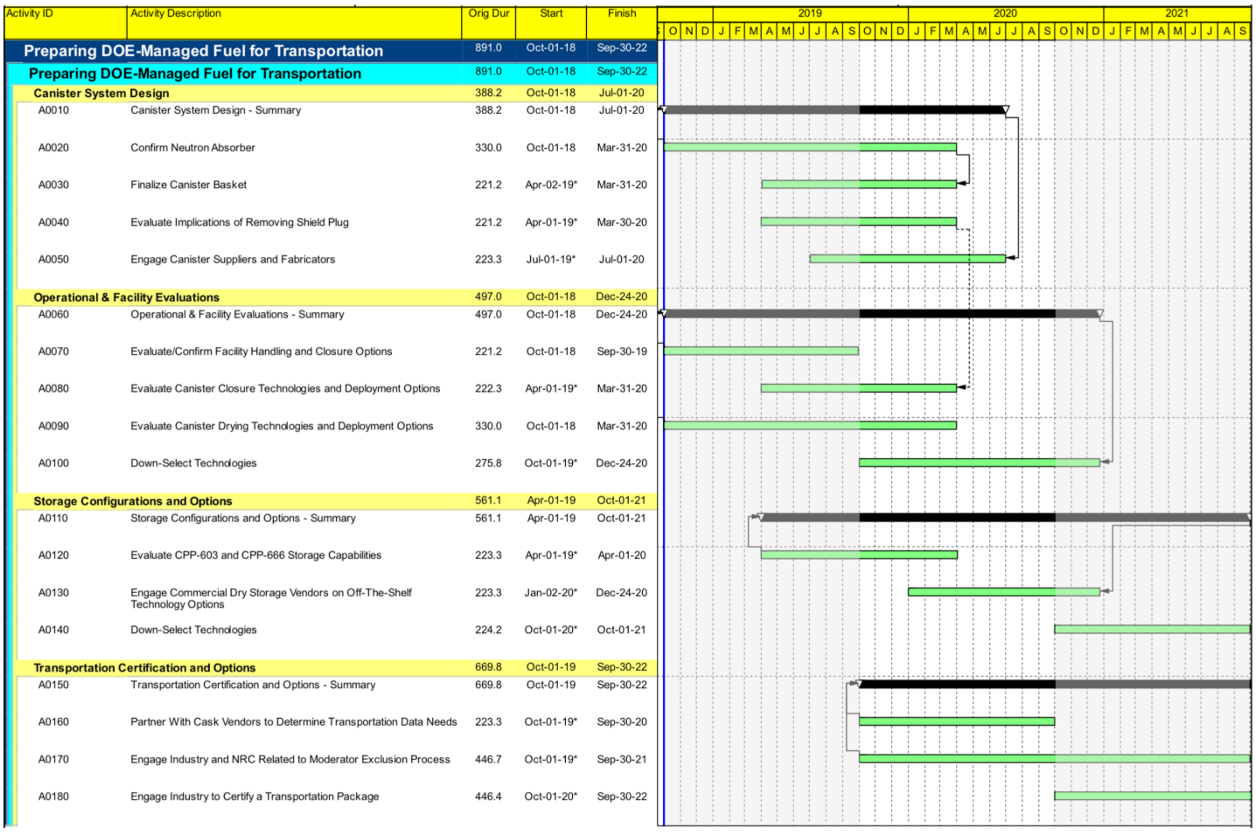

Figure 12. Proposed future schedule of actions and activities.

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