USED FUEL TESTING TRANSPORTATION MODEL

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign
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SUMMARY

This report identifies shipping casks that might be used to ship pieces of used nuclear fuel rods, and the actions that would need to be taken, if any, to obtain U.S. Nuclear Regulatory (NRC) or other regulatory authority approval to use the shipping casks for this purpose.

This report identifies potential transportation options for the used nuclear fuel pieces and further investigates the best options for transportation that would be evaluated in greater detail as part of FY 2014 work scope. Specifically, Section 1 provides background on the Used Nuclear Fuel Disposition Campaign (UFDC) and the research this effort would support. Section 2 briefly describes the transportation options including candidate casks for UNF transport. Section 3 presents conclusions and recommendations for work scope in FY 2014.

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ACRONYMS

ANL	Argonne National Laboratory
CoC	certificate of compliance
DOE	U.S. Department of Energy
GWd/MTU	gigawatt-days per metric ton of uranium
INL	Idaho National Laboratory
LWT	legal weight truck
NAC	Nuclear Assurance Corporation
MWd/MTU	megawatt-days per metric ton of uranium
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
SET	separate effects testing
SST	small scale testing
TRU	transuranic
UFDC	Used Fuel Disposition Campaign
UNF	used nuclear fuel

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1. INTRODUCTION

The U.S. Department of Energy's (DOE's) Used Fuel Disposition Campaign (UFDC) Program plans to transport high burnup nuclear fuel (burnup exceeding 45 gigawatt-days per metric ton of uranium [GWd/MTU]) from domestic nuclear power plants to DOE national laboratory facilities, and between laboratory facilities for purposes of evaluation and testing. The evaluation and testing of high burnup used nuclear fuel (UNF) is integral to DOE initiatives to collect information that is useful in determining the integrity of fuel cladding for safe transportation of the fuel in the future, and for determining the effects of aging on the integrity of UNF subjected to extended storage and subsequent transportation.

This work also addresses a gap in the UFDC Experiments Control Account on research data for high burnup fuel samples. More research is needed because limited information is available on the properties of high burnup fuel, and because much of the fuel currently discharged from today's reactors exceeds this burnup threshold. As the burnup of fuel increases, a number of changes occur that may affect the performance of the fuel, cladding, and assembly hardware in storage and transportation. These changes include increased cladding corrosion layer thickness, increased cladding hydrogen content, increased cladding creep strains, increased fission gas release, and the formation of the high burnup structure at the surface of the fuel pellets. One of the focuses of the UFDC program will be to obtain the data on high burnup fuel and the newer cladding materials and how the storage and transportation systems perform to address the growing inventory of high burnup fuel. To meet its research objectives, this report identifies potential candidate casks for transportation of used nuclear fuel and identifies potential transportation issues for fuel sample transport between laboratories for separate effects testing.

The UFDC Program proposes to partner with the US commercial nuclear industry to identify and obtain UNF for testing. Individual fuel rods are needed for both separate effects (SET) and small scale testing (SST) whereas entire assemblies may be necessary for SST.. The UFDC Program also plans to partner with the owner(s) of suitable transportation casks to obtain, as needed, NRC certification of the casks, and to use the casks for shipping the selected high burnup nuclear fuel rods and/or assemblies to a national laboratory, and for shipping segments of high burnup fuel rods between laboratory facilities. Since the Idaho National Laboratory (INL) is the only national laboratory capable of receiving and handling an entire fuel assembly, for the purposes of this study it is assumed that all fuel, rods or assemblies, will initially be sent from the utility to INL.

The high burnup UNF rods or assemblies will be characterized by visual examination, reactor records, and other physical examinations at the utility (or utilities) site(s) before shipment. Following delivery to the INL hot cell facility, the UFDC Program researchers plan to further characterize the fuel and then segment a selection of high burnup fuel rods into 6- to 24-in.-long sections (assumed for the purposes of this study based on the sizes necessary for the currently planned SET) so that the nuclear fuel and cladding can be more easily examined and transported to other laboratories for independent and laboratory-specific SET. For this study, it is assumed that Pacific Northwest National Laboratory (PNNL), Oak Ridge National Laboratory (ORNL) , and Savannah River National Laboratory (SRNL) will be capable to receive segments of UNF with the fuel still in the cladding. The researchers also plan to ship sections of cladding with the nuclear fuel removed to Argonne National Laboratory (ANL) for SET.

While transportation of full-length fuel rods or assemblies will be limited to specific licensed casks, the transportation of the fuel segments will have options depending on the quantity and size of fuel to be shipped. The purpose of this study and the follow on work in FY14 is to identify these options with a primary goal of identifying low cost options to facilitate the greatest range of testing possible.

2. TRANSPORTATION OPTIONS FOR USED NUCLEAR FUEL

This section summarizes available casks, current contents authorized by the certificates of compliance (CoCs) for each, and the feasibility of obtaining regulatory approval for modifications to each of the CoCs to authorize transportation of high burnup used nuclear fuel in the respective casks. There may be other casks available that are not included in this list. Work scope for FY 2014 with objectives that contribute to implementing transportation of used fuel to support the UFDC Program.

2.1 Transportation Casks

Table 2.1 lists the transportation casks considered in this report. Included in the table are the identification numbers for each of the casks and, as applicable, the expiration dates of the CoCs. Table 2.1 also presents the estimated number of each of the listed casks that is available for use and briefly summarizes the authorized contents listed in the CoCs. (Note: Currently authorized contents for some of the listed casks do not include used nuclear fuel. In such cases, application to the regulatory authority would be required to obtain authorization to use any such cask to ship used nuclear fuel contents.)

Table 2.1. Transportation Casks Considered

Cask	Package ID Number	CoC Expiration Date	Packages Available	CoC Contents
BEA Research Reactor	USA/9341/B(U)F –96 (NRC 2011a)	1/22/15	1	19 irradiated TRIGA Fuel elements
NAC-LWT	USA/9225/B(U)F –96 (NRC 2013)	2/28/15	5	Up to 14 of 25 high burnup fuel rods can be classified as damaged
GE Model 2000	USA/9228/B(U)F (NRC 2011b)	5/31/16	1	Includes irradiated fuel rods which may be cut or segmented
ES-2100	DOE/NNSA/2000302/B(U)F (DOE 2002)	1/31/2008	125 at DOE Y-12 facility	Type B quantities of nuclear weapons radioactive material
T-3	USA/9132/B(M) F (DOE 2008)	12/31/2013 (termination of NRC CoC 1/10/07)	3	Various types of used nuclear fuel
10-160B	USA/9204/B(U)F –96 (DOE 2012)	10/31/15	2 Casks in service one owned by DOE (not verified)	200 thermal watts, TRU special form fissile material in secondary containers, RH-TRU
8-120B	USA/9168/B(U) (DOE 2013)	6/30/15	4	100 thermal watts waste material. Not approved for fissile material.
BUSS R-1	USA/9511/B(U) (NRC 1991)	3/31/2008	1 (not verified)	Cs/Sr Capsules

CoC = certificate of compliance
DOE = U.S. Department of Energy
ID = identification
NNSA = National Nuclear Security Administration
NRC = U.S. Nuclear Regulatory Commission
TRIGA = Training, Research ,Isotopes, General Atomics (research reactor)
TRU = transuranium

2.2 Activities Involved in the Transport of UNF Samples

Once a transportation cask is selected for transporting UNF samples between research facilities, the following activities would need to be conducted:

- Establishing agreements for use with the owner(s) of a cask(s)/package(s) that would be used to transport UNF between research facilities.
- As may be required, obtaining regulatory authority authorization for use of a selected transportation cask(s)/package(s) for the UNF contents of shipments that would be made.
- At the shipping and receiving facilities, preparing operations procedures for receiving, handling, loading, preparations for shipment, and shipment of UNF in a selected transportation cask(s)/package(s).
- At the shipping and receiving facilities, conducting training of operations personnel in cask/package handling, receiving, loading, shipment preparations, and shipping operations for UNF shipments.
- As may be required, retrieving records and other documentation regarding the selected transportation cask(s)/package(s) that would be necessary for its certification and use to transport UNF samples
- Identifying ancillary equipment and services that would be needed at shipping and receiving facilities for handling, loading, and testing shipping casks/packages
- Identifying shipment operations and support activities necessary for the movement of transport casks/packages containing UNF between research facilities, which would involve:
  - logistics management activities including obtaining state permits
  - in-transit security activities
  - transportation carrier services
  - delivery of ancillary equipment to shipping/receiving facilities
  - decontamination services
  - acquisition/construction of special components that may be needed to position UNF samples within transport packages.

2.3 Information about Transported UNF Packages

In order to collect the information that will be needed to provide information to fully describe the acquisition and use of each of the transport cask(s)/package(s) described above it will be necessary to collect the following information regarding each cask/package:

- design descriptions of the casks/packages
- COCs issued by regulatory authorities
- safety analyses for casks/packages that do not currently have UNF listed in authorized contents in the certificates of compliance

- as applicable, assessments of the scope of tasks that would need to be undertaken to obtain regulatory authorization for use of each candidate cask/package to transport the specified UNF (and fuel cladding) contents
- operating (including maintenance) procedures
- descriptions of ancillary equipment
- current condition, location, and ownership of the casks/packages
- costs and other commercial considerations for casks/packages owned by private parties
- requirements for return following use of casks/packages owned by other government agencies or other organizations within DOE.

It will also be necessary to collect information from operators of shipping and receiving facilities where UNF samples may be shipped/received including:

- assessments of the scope of facility modifications and special equipment (if any) that would be needed to be capable of receiving/shipping each of the candidate casks/packages with UNF contents
- assessments of the scope of operational readiness preparations that would be needed before the facility could receive/ship UNF using each of the candidate casks/packages
- assessments of the scope of operations that would be undertaken when receiving/shipping UNF using each of the candidate casks/packages

The information from the lists above and estimates for costs and duration for each direct and supporting activity must be collected before shipments could begin. Ultimately, the estimates of cost and schedule would be weighed against the value of distributing research on the performance of high burnup UNF among the laboratories. This decision process, which is not within the scope of this transportation study, would include the following considerations:

- Number of shipments and quantities and types of materials proposed to be shipped by origin/destination pair
- Years when shipment are expected to occur
- Transportation resources (casks and owner organizations) that should be considered as candidates for use in transporting UNF segments. Consideration will be given to acquiring a specially designed cask (or casks) for UNF shipments.

2.4 Specific Casks Considered

The transportation cask options are described in this section.

2.4.1 BEA Research Reactor Cask

One BEA Research Reactor legal-weight truck cask (USA/9341/B(U)F–96) is owned by the DOE, and operated from INL by the Battelle Energy Alliance (BEA). AREVA Federal Services

LLC (AFS) is the designer and licensee of the cask. The cask consists of a payload basket (of a design that is specific for the fuel being transported), a lead-shielded cask body, a separate, removable upper shield plug, a closure lid, twelve closure bolts, and upper and lower impact limiters containing polyurethane foam. Except for the closure bolts and impact limiter attachments, the cask is of welded construction, using Type 304 austenitic stainless steel (Figure 2-1). The cask is certified for the transportation of irradiated nuclear fuel elements from the Missouri University Research Reactor (MURR); Massachusetts Institute of Technology Nuclear Reactor (MITR); Advanced Test Reactor (ATR); and Training, Research, Isotopes, General Atomics (TRIGA) reactors. The cask may be loaded and unloaded under water in a pool or dry in a hot cell.

Figure 2.1. BEA Research Reactor Cask (printed with permission from AREVA Federal Services)

2.4.2 NAC LWT Shipping Cask

The NAC-LWT Cask (USA/9225/B(U)F–96) is a steel-encased, lead-shielded shipping cask having a forged stainless steel lid and 12 closure bolts, payload baskets that are tailored to the contents being shipped, water-ethylene-glycol neutron shield, and top- and bottom-end impact limiters (Figure 2-2). The cask is designed to transport one pressurized water reactor (PWR) assembly or two boiling water reactor (BWR) assemblies by truck. Five of the legal weight truck (LWT) casks are owned and offered for use by NAC International, which has its home office in Norcross, Georgia. The LWT cask is used to ship research reactor spent fuel, nuclear power plant spent fuel assemblies and fuel rods, and other irradiated materials. When used to ship fuel rods, the maximum burnup authorized in the cask's CoC is 80,000 MWd/MTU. For fuel assemblies, the maximum authorized burnup is 35,000 MWd/MTU. The cask can be loaded wet in a pool or dry in hot cell facilities or facilities with small pools and limited crane capacities.

Figure 2.2. NAC LWT Shipping Cask (printed with permission from NAC International)

2.4.3 Model 2000 Shipping Cask

The Model 2000 Shipping Cask (USA/9228/B(U)F-96) is owned by GE-Hitachi Nuclear Energy Americas, LLC, which has its offices in Wilmington, North Carolina. The cask's body (shielded containment vessel) is constructed of steel shells encasing lead radiation shielding. As is shown in Figure 2-3, for transport, the cask body is situated within a double-walled overpack with toroidal-shell impact limiters at each end. The Model 2000 Shipping Cask can be used to transport irradiated nuclear fuel, radioactive (contaminated and activated) nuclear reactor hardware, and radioactive waste. The cask is authorized for the shipment of light water reactor (LWR) fuel rod segments and fuel pellets having burnups up to 52,000 MWd/MTU.

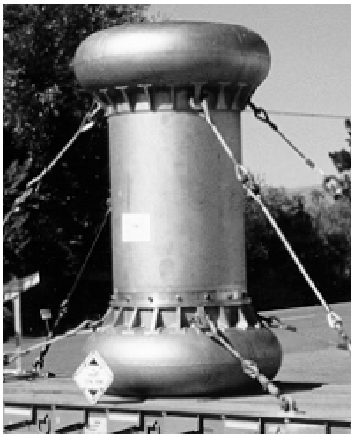

Figure 2.3. Model 2000 Shipping Cask

2.4.4 ES-2100 Shipping Container

An alternative to the large shipping casks could be DOE's National Nuclear Security Administration-(NNSA-) owned ES-2100 shipping containers. The ES-2100 package was previously authorized by the NNSA certification authority for shipments of Type-B quantities of nuclear weapons radioactive materials. NNSA's Y-12 organization is currently preparing a transportation safety analysis report (TSAR) for the ES-2100 package. The schedule date for submitting the TSAR to the NNSA certification authority is March 2014. The Y-12 organization's objective is to obtain a transportation CoC that will allow general use of the package for the shipment of radioactive materials. The ES-2100 package is a 23-in.-diameter, 36-in.-tall drum type package with a gross weight of 605 lb. (Figure 2-4). The package has a 8.3-in.-diameter, 20-in.-tall contents cavity. The maximum weight for package contents is 120 lb. It is reported that there are 125 ES-2100 packages that are currently not in use at the NNSA Y-12 site in Oak Ridge, Tennessee. Its viability as a package for shipping used fuel segments needs to be further evaluated considering contents and shielding requirements.

Figure 2.4. ES-2100 Shipping Container

2.4.5 T-3 Shipping Cask

The T-3 Shipping Cask (USA/9132/B(M)F) (Figure 2-5) is currently stored at the Fast Flux Test Facility near the Hanford Site in southeastern Washington state. Three T-3 Shipping Casks are available. The DOE CoC expires in December 2013. The authorized contents include UO_2 fuel rods and a maximum of 1400 thermal watts. The NRC CoC was terminated in January 2010.

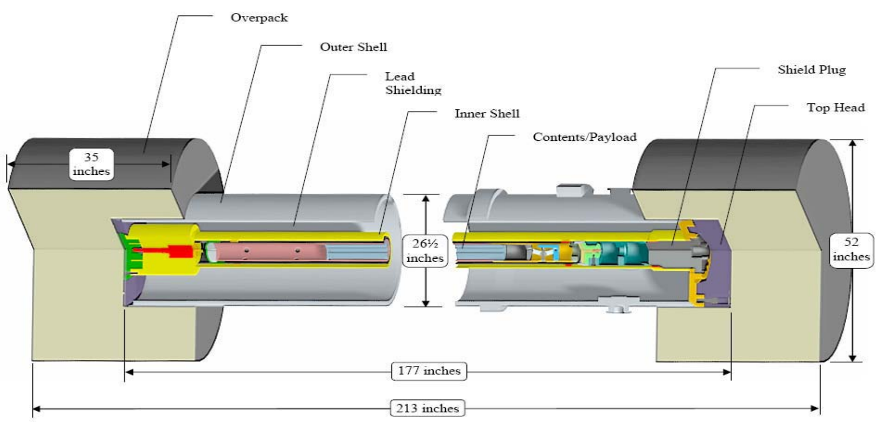

Figure 2.5. T-3 Shipping Cask

2.4.6 10-160B Shipping Cask

DOE owns one 10-160B Shipping Cask (USA/9204/B(U)F-96), which is a lead-shielded carbon steel shipping cask with a double lid bolted closure. The other 10-160B cask(s) are owned by Energy Solutions.

The primary lid is sealed with double silicone o-rings. The secondary lid is centered in the primary lid and is also sealed with double silicone o-rings. The cask is top loaded. It may be equipped with an optional vent plug and drain plug. The 10-160B cask has a redundant set of cask lift lugs, which can be used to meet NUREG 0612 lift requirements (George et al. 1980). The cask is shipped vertically and uses removable top and bottom polyurethane foam-filled impact limiters. Steel inserts (½ to 1 ½ in.) can be added to provide additional shielding as necessary. The authorized content is various kinds of radioactive materials, including miscellaneous radioactive solid waste materials, such as special form materials and powdered solids, in secondary containers. The authorized contents include a maximum of 200 thermal watts and not to exceed 3000 times A2 quantities. The CoC would need to be amended to accommodate shipment of UNF rod sections. The 10-160B is an overweight cask and would require permits in states along the routes (Figure 2-6).

Figure 2.6. 10-160B Shipping Cask

2.4.7 8-120B Shipping Cask

The 8-120B shipping cask (USA/9168/B(U)-96) is a lead-shielded carbon steel shipping cask with a double lid bolted enclosure. The primary lid is sealed with double silicone o-rings. The secondary lid is centered in the primary lid and is also sealed with double silicone o-rings. The cask is top loaded and is equipped with a vent plug and optional drain plug. The 8-120B cask is shipped vertically and uses removable top and bottom polyurethanefoam-filled impact limiters. The cask has a capacity to hold 8 55-gal. drums. The NRC CoC expires in August 2017. The authorized contents include radioactive waste material including by-product material and activated reactor components. Also, requirements include 2000 times a Type A quantity of material and a maximum of 100 thermal watts.

Figure 2.7. 8-120B Shipping Cask

2.4.8 Beneficial Uses Shipping System Cask

The major components of the Beneficial Uses Shipping System (BUSS) Cask include the cask body and lid, internal payload basket assembly, impact limiters, personnel barrier, and transport skid. The cask body is a cylindrical stainless steel forging with outer dimensions of 137.8 cm in diameter and 124.5 cm high. The cavity of the cask is 51.4 cm in diameter and 58.4 cm high. The cask provides approximately 40 cm (16 in.) of steel shielding for radioactive contents. On the outside surface of the cask body, 11, 10.2-cm high, integral, non-welded fins are situated symmetrically around the circumference of the cask for heat removal. The cask lid is a single 32.6-cm thick forging and is bolted to the cask body using 12 corrosion-resistant steel 1.5-inch diameter bolts through a 9.7-cm thick lid flange. The lid seal is provided by a combination elastomeric-metallic seal. The metallic seal is responsible for providing the necessary leak tightness, while the elastomeric seal, which is located outboard to the metallic seal, provides an annular test volume that enables leak testing of the metallic seal. Two covered ports on the side of the cask body, equipped with testable seals, are provided for filling the cask cavity with helium before transport, filling the cavity with water before unloading contents, and draining entrapped water after unloading or loading contents. A permanent repair plug was threaded and seal-welded into the cask body at the upper port to correct a fabrication machining error that damaged the sealing surface. This plug forms a new surface for the upper drain plug seal. A removable bore plug was also added to the upper port to reduce radiation streaming. One cask was fabricated and is being stored at a Hanford, Washington facility (Figure 2-8).

The BUSS Cask with impact limiters and transport skid weighs about 16 metric tons. The design of the BUSS Cask was developed by Sandia National Laboratories for DOE.

Figure 2.8. Beneficial Uses Shipping System Cask

The cask was approved for the transport of capsules of melt-cast cesium chloride or press-filled strontium fluoride qualified by testing or examination within the 12 months preceding shipment to verify compliance with the requirements of Special Form material specified in 10 CFR 71.75. A revised safety analysis report would need to be submitted to the responsible regulatory authority to obtain recertification of the BUSS Cask and to obtain approval to use the cask to transport samples of UNF

3. CONCLUSIONS AND RECOMMENDATIONS

For this report eight options that might allow the shipment of used fuel pieces between national laboratories were identified. More investigation is required to identify additional options, eliminate some of the candidates from the list, and further define gaps that need to be addressed for remaining candidates.

Additional work is needed to further evaluate the casks that have the most potential for transporting samples of high burnup UNF. Questions to be addressed by the FY 2014 evaluation of transportation issues concerning the available casks are listed below.

1. What actions would be needed, if any, to enhance the CoCs of existing candidate transportation casks so that these casks could be used to transport
   - high burnup fuel rod(s) or assembly(ies)
   - segments of high burnup fuel rods
   - segments of fuel cladding from high burnup fuel rods?
2. What actions and what level of effort, additional costs, and time would be required to obtain a specially designed cask(s) (or possibly resurrect a previously certified cask[s]) for UFDC Program shipments?
3. What are the expected costs of transporting fuel rod segments from INL to
   - PNNL
   - ORNL
   - SRNL
   - ANL (de-fueled cladding segments)

The transport costs will include:

- (As required) costs of preparation of safety analyses, submittal to NRC (or other certifying agency), and technical interactions with NRC (or other certifying agency) to obtain CoCs having authorized contents that include high burnup used nuclear fuel (assembly, rod segments, cladding segments)
- Expected costs of lease and use of transportation casks and associated ancillary equipment and transport vehicles
- Transportation hauling costs including in-transit security and satellite tracking costs (as applicable) and including anticipated demurrage and unloaded-return costs
- Origin and transited state inspection and state police escort charges. Also, state special permit charges (as applicable)
- Cask inspection and decontamination costs (as may be applicable)
- Transportation management costs including costs of obtaining permits and issuing notifications to states and communications with state officials?
- Preparing, loading, and unloading the fuel rod segments and de-fueled cladding segments for transportation between laboratory facilities.

The cost of supplying the fuel assemblies, preparing and loading them into the casks, preparing and drying the casks, and loading the casks onto the transport vehicles are not included.

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