SAND2010-6561P

NPP Container Concept Evaluation

Task 1 & 2 Report

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Sandia National Laboratories

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Executive Summary

This report documents an evaluation by Sandia National Laboratories (Sandia) of technical and marketplace issues related to the Nuclear Protection Products AS (NPP) container concept, which are the subject of Tasks 1 and 2 of Intra-Lockheed Martin Work Transfer Agreement IWTA-RFL1006. Initiated on September 8, 2010, this report was prepared for discussion among Sandia, NPP, and LMC during the PATRAM meeting October 3-8, 2010 to refine the remaining work scope under the IWTA.

Section 1 provides an introduction and background information for the project. Section 2 introduces definitions, requirements, and references to describe the U.S. Nuclear Regulatory Commission (NRC) certification process for Type B packaging of commercial products for the transportation of radioactive material, and identifies the 76 active packagings having NRC certification that are discussed in more detail in the remainder of the document. Section 3 discusses systems available for storage and transport of commercial spent nuclear fuel and the packagings certified for transport of these materials. Section 4 lists the key requirements associated with certification of spent nuclear fuel transport packaging. Section 5 provides a summary description of the designs for storage of commercial spent nuclear fuel. Sections 6, 7, and 8 describe the remaining packagings certified for transport of materials other than spent nuclear fuel. Section 9 provides a brief description of the NPP container concept and a discussion of possible applications. Finally, Section 10 provides references for information discussed in the text.

The NPP container concept is for a cylindrical package consisting of a lead gamma shield sandwiched between layers of high density polyethylene (HDPE) of specific characteristics, and manufactured under an NPP patent. Possible advantages of this container concept are the longevity of the HPDE and that it is not subject to corrosion as are metals, smaller container dimensions and weight, and lower production costs.

The NPP container, utilizing both HDPE and lead, might be considered for applications requiring both neutron and gamma shielding, although there is considerable competition from material suppliers and packaging vendors. From the review of the 76 active NRC Certificate of Compliance (CoCs), possible applications are for transport and storage of spent nuclear fuel and some kinds of nuclear waste, and other radioactive materials used for medical, industrial, or research applications. In addition to providing adequate shielding for neutron and gamma radiation, certification requirements address goals for material containment under normal and accident conditions, prevention of nuclear criticality, and heat dissipation. The NPP container concept would need considerable development and testing to demonstrate compliance with these rigorous requirements.

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1. Introduction

On August 17, 2010, Sandia National Laboratories (Sandia), Lockheed Martin Corporation (LMC), and Nuclear Protection Products AS (NPP) concurred on the "Proposed Scope of Work for Evaluation of NPP Container Concept" document, which described three tasks planned for Sandia to provide an evaluation of NPP's container concept with respect to the nuclear packaging market and planning for further development and qualification of the NPP concept for selected applications. Under an Intra-Lockheed Martin Work Transfer Agreement (IWTA) initiated July 15, 2010, funding was provided and authorization to proceed received September 8, 2010. The purpose of this report is to document Sandia's evaluation of technical and marketplace issues related to the NPP container concept, which are the subject of Tasks 1 and 2 of IWTA-RFL1006. The intention is for Sandia and NPP to discuss a final draft of this report during PATRAM 2010, the 16th International Symposium on the Packaging and Transport of Radioactive Materials, in London, England October 3-8, 2010. Discussion of the draft report is expected to refine the scope of Task 3 and define plans for the effective use of remaining funding under the IWTA.

Sandia initially discussed the NPP container concept with Jørgen Bertheau, former NPP president during his visit to Sandia on April 24, 2009. Following approval of IWTA-RFL1006, telecons between Sandia and NPP were held on September 2 and 14, 2010. Lars Lund-Roland, NPP President, Per Varskog, and Jan Erik Hager participated from NPP; Joe Schelling, Carlos Lopez, and David Miller participated from Sandia. The purpose of these discussions was to introduce each other, discuss the planned work, and enhance Sandia's technical understanding of NPP's container concept, status, and business plan. These discussions were productive in giving Sandia staff a much better comprehension of the maturity of the design, interests and understanding of NPP personnel in the area of radioactive material packaging, and technical considerations associated with the NPP concept. Following each of these telecons, NPP provided additional technical information which will further Sandia's understanding.

Task 1, as described in the work scope document, involved summarizing characteristics of commercially available containers used for storage and transportation of spent nuclear fuel and medical isotopes. Clarification of this scope with NPP personnel during initial conversations was to focus on spent nuclear fuel from both power reactors and research and test reactors, which are regulated in the U.S. under Title 10 of the Code of Federal Regulations Part 71, "Packaging and Transportation of Radioactive Material," (10CFR71) with particular reference to Type B packaging, which is used for materials having higher radioactivity contents and therefore subject to more stringent safety and certification requirements than required for other radioactive material packaging. Task 2 was focused more on identifying alternative uses of the NPP container concept for other than spent nuclear fuel, such as gamma sources, medical isotopes, and other high value nuclear material.

Section 2 introduces definitions, requirements, and references to describe the U.S. Nuclear Regulatory Commission (NRC) certification process for Type B packaging of commercial products for the transportation of radioactive material, and identifies the 76 active packagings having NRC certification that are discussed in more detail in the remainder of the document. Section 3 discusses systems available for storage and transport of commercial spent nuclear fuel and the packagings certified for transport of these materials. Section 4 lists the key requirements associated with certification of spent nuclear fuel transport packaging. Section 5 provides a summary description of the designs for storage of commercial spent nuclear fuel. Sections 6, 7, and 8 describe the remaining packagings certified for transport of materials other than spent

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nuclear fuel. Section 9 provides a brief description of the NPP container concept and a discussion of possible applications. Finally, Section 10 provides references for information discussed in the text.

2. NRC Certified Commercial Type B Packaging

As defined in 10CFR71, the term '*Type B package means a Type B packaging together with its radioactive contents*,' and the term '*packaging*' is defined as *'the assembly of components necessary to ensure compliance with the packaging requirements of this part* {Part 71}*. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The vehicle, tie-down system, and auxiliary equipment may be designated as part of the packaging*.' Testing used to demonstrate compliance are specified in §71.71 "Normal Conditions of Transport," §71.73, "Hypothetical Accident Conditions," and §71.61 "Special Requirements for Type B Packages Containing More Than 10^5 A_2." (The determination of A_2 activity limits is described in Appendix A to Part 71, "Determination of A_1 and A_2.") A_2 is the maximum activity of radioactive material, other than special form material, low specific activity material, or surface contaminated object material permitted in a Type A package.

General standards for all packages are specified in §71.43, lifting and tie-down standards in §71.45, and external radiation standards in §71.47. Additional general requirements for fissile material packages are specified in §71.55 and §71.59. Section 4 provides more detail and the regulatory text for these requirements.

NUREG-0383, "Directory of Certificates of Compliance for Radioactive Materials Packages," "Certificates of Compliance," Vol. 2, Rev. 27, January 2009, is the most recent publication of Certificates of Compliance (CoCs) for packaging approved for transportation by the U.S. Nuclear Regulatory Commission (NRC) under 10CFR71. Current CoCs are also available online at the RAMPAC (Radioactive Material Packaging) website provided by the U.S. Department of Energy's (DOE) Office of Environmental Management, http://rampac.energy.gov. RAMPAC includes CoCs issued by the NRC, as well as those issued by DOE (which certifies packaging under similar requirements as authorized under 49CFR173.7(d)), and the U.S. Department of Transportation (DOT) and International Atomic Energy Agency (IAEA).

Appendix H, "Dry Spent Fuel Storage Designs: NRC-Approved for Use by General Licensees," of the most recent release of the annual NRC publication, NUREG-1350, "2010-2011 Information Digest," lists the vendor and model identification of approved spent nuclear fuel storage casks. Appendix I, "Dry Spent Fuel Storage Locations," lists the storage cask models used by U.S. nuclear utilities. Spent Fuel Storage Casks are certified under 10CFR72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-related Greater Than Class C Waste," with particularl attention to §72.236.

Additional information on casks and modules used for the storage and transportation of commercially generated spent nuclear fuel in the U.S. is available in "Shipping and Storage Cask Data for Commercial Spent Nuclear Fuel," prepared by the JAI Corporation.

The Electric Power Research Institute (EPRI) has also issued an "Industry Spent Fuel Storage Handbook," containing a great deal of information on various aspects of spent fuel storage, and which is available online at http://my.epri.com/portal/server.pt?Abstract_id=000000000001021048.

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The Institute of Nuclear Materials Management (INMM) provides a brief "Packaging and Transportation Overview" on their website at: www.inmm.org/about/tech_div/P&TTutorial.ppt. INMM has also published a Monograph on Spent Fuel Storage Technologies, which can be ordered through their website at: http://www.inmm.org/Spent_Fuel_Monograph/1699.htm.

A search of the RAMPAC website on September 8, 2010 identified 80 10 CFR 71 CoCs, of which 76 are still active. The distribution of the different package types is shown in Table 1.

Table 1. Number of Active Certified Type B Packages by Package Type

Package Type*	Number	Contents
AF	10	Used primarily for unirradiated fuel
AF-85	5	Unirradiated fuel, U wastes
AF-96	6	Unirradiated fuel
B(U)	4	Sealed sources; reactor waste
B(U)-85	3	Sealed sources
B(U)-96	16	Primarily sealed sources and devices
B(M)F-96	1	Transuranic (TRU) waste
B(U)F	2	Unirradiated fuel
B(U)F-85	9	Primarily fresh and irradiated spent fuel
B(U)F-96	20	Irradiated and unirradiated fuels, wastes

**An 'F' in the package type designator indicates it is approved for use with fissile material. Other designators in the package type are described in 10CFR71.*

Most (53/76 or 70% of the total) are used for fissile material (as indicated by the 'F' in the package type designation); roughly half of these (23/76 61% of the total) are limited primarily to unirradiated fuel and the rest (30/76 or 39% of the total) for irradiated spent fuel and other high activity waste. The remainder (23/76 or 30% of the total) are for sealed sources and non-fissile higher activity wastes. Of the 76 packages having NRC certificates, 33 also appear on the RAMPAC list of DOT-IAEA certificates.

The 21 AF packages primarily used for unirradiated fuel and uranium wastes are typically constructed of steel with various insulating or cushioning materials, such as wood, polyurethane, or vermiculite. Some include Gd_2O_3 or borated aluminum for neutron absorption. One, used for packaging PuBe sources, uses HDPE for shielding.

The 23 B packages, which are not authorized for fissile material, are also typically constructed from steel, often with Pb (lead) or DU (depleted uranium) for gamma shielding for a range of sealed sources, including Co-60, Sc-46, Se-75, Mo-99, Ir-192, Cs-137, and Yb-169. Some of these packages are also used for various waste materials.

The 32 B()F packages for fissile material are certified for transporting used spent nuclear fuel, TRU waste, unirradiated fuel and other enriched materials. Gamma and neutron shielding is needed for most of these materials as is ensuring criticality safety. Borated aluminum and borated cementitious materials, and various forms of hydrogenated materials are used for neutron shielding and poisoning (internal package neutron absorption), and Pb or DU typically used for gamma shielding.

For purposes of the following discussion, the 76 transport certificates have been grouped into the following categories:

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Category	# of CoCs	Discussion*
Commercial Spent Nuclear Fuel (SNF)	12	Section 3
Other Fissile Material (Fresh Unirradiated Fuel and Materials)	24	Section 6
Other (e.g., Research & Test Reactors) SNF	8	Section 7
Non-Fuel Type B	32	Section 8

**Section 4 discusses certification requirements and Section 5 spent fuel storage.*

3. Commercial Spent Nuclear Fuel Shipping and Storage Packaging

"Shipping and Storage Cask Data," JAI Corporation, March 2005, provides a compilation of information on casks and modules used for the storage and/or transport of commercially generated spent fuel in the U.S. based on publicly available information.

For multiple assembly canisters used in canister-based storage systems, Table 1 of the JAI report lists four suppliers: BNFL Fuel Solutions, Holtec International, NAC International, and Transnuclear Inc. Of these, all but Transnuclear are shown in JAI Table 2 as suppliers of storage casks used in canister-based systems for SNF. Shipping casks for these systems are shown in JAI Table 4 as supplied by all four suppliers.

JAI Table 3 lists GNS, Hitachi Zosen, Westinghouse, Mitsubishi, NAC International, OCL Corp., U.S. DOE, and Transnuclear as suppliers of storage casks and dual purpose casks for uncanistered SNF. JAI Table 5 shows for shipping casks for uncanistered SNF GNS, BNFL, General Atomics, Transnuclear Inc., Nuclear Packaging, NAC International, and Nuclear Fuel Transport. In all, thirteen suppliers are identified for different components of these systems. This information is summarized in Table 2 below.

Loaded weight ranges from 22,000-109,000 lbs (11-55 tons) for canister-based systems, 80-125 tons for uncanistered SNF storage and dual purpose casks; shipping casks for canistered systems range from 127-139 tons loaded and for uncanistered 23-119 tons loaded.

For transportation, twelve CoCs certifying packages for transportation of commercial spent nuclear fuel are shown in Table 3. Following the table are descriptions of these systems taken directly from the CoCs.

Table 2. Summary of JAI Information on Commercial SNF Shipping and Storage Cask Suppliers

	Canistered SNF			Uncanistered SNF	
	Multiple Assembly canisters	Storage	Shipping	Storage	Shipping
Supplier	Table 1	Table 2	Table 4	Table 3	Table 5
BNFL Fuel Solutions	Yes	Yes	Yes		Yes
Holtec International	Yes	Yes	Yes		
NAC International	Yes	Yes	Yes	Yes	Yes
Transnuclear Inc.	Yes		Yes	Yes	Yes
GNS				Yes	Yes*
Hitachi Zosen				Yes	
Westinghouse				Yes	
Mitsubishi				Yes	
OCL Corp.				Yes	
U.S. DOE				Yes	
General Atomics					Yes
Nuclear Packaging					Yes*
Nuclear Fuel Transport					Yes*

* Although listed in JAI Table 5, NRC CoC's are not available for these suppliers (The GNS cask is not yet licensed, the NP cask was designed and used for DOE shipments of TMI-2 fuel debris; and the NFT casks are only used in Japan.)

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Table 3. NRC Certified Packagings for Transportation of Commercial SNF

Package Identification Number	Model No.	Certificate Owner	Structure Material	Gamma Shield	Neutron Shield	Impact Limiter	Internal Neutron Absorber
USA/9225/B(U)F-96	NAC-LWT	NAC Int'l, Inc.	Steel	Pb	Ethylene Glycol, Water, 1 wt% B	Al honeycomb	n/a
USA/9226/B(U)F-85	GA-4	General Atomics	Steel	DU	proprietary hydrogeneous material	Al honeycomb	B_4C
USA/9235/B(U)F-96	NAC-STC	NAC Int'l, Inc.	Steel	Pb	NS4FR	redwood, balsa	n/a
USA/9253/B(U)F-96	TN-FSV	U.S. DOE (Ft. St. Vrain and Peach Bottom 1 HTGR fuel)	Steel	Pb	n/a	redwood, balsa	borated Al
USA/9255/B(U)F-85	NUHOMS MP187 Multi-Purpose Cask	Transnuclear, Inc.	Steel	Pb	cementitious	steel	borated plates
USA/9261/B(U)F-96	HI-STAR 100 System	Holtec Int'l	Steel	Steel	n/a	Al honeycomb	n/a
USA/9270/B(U)F-96	UMS Universal Transport Cask Package	NAC Int'l, Inc.	Steel	Pb	NS4FR	redwood, balsa, steel	n/a
USA/9276/B(U)F-85	FuelSolutions TS125 Transportation Package	EnergySolutions (BNFL Fuel Solutions)	Steel	Pb	'hydrogeneous material'	Al honeycomb	Borated steel
USA/9293/B(U)F-85	TN-68 Transport Package	Transnuclear, Inc.	Steel	Steel	borated polyester resin	redwood, balsa, steel	Borated Al or B_4C /Al
USA/9302/B(U)F-85	NUHOMS® - MP197	Transnuclear, Inc.	Steel	Pb	'neutron shield'	redwood, balsa, steel	borated Al
USA/9325/B(U)F-96	HI-STAR 180	Holtec Int'l	Steel	n/a	n/a	Al honeycomb, steel	Al and B_4C matrix
USA/9336/B(U)F-96	HI-STAR 60	Holtec Int'l	Steel	Steel	n/a	Al honeycomb, steel	n/a

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NAC-LWT

The LWT is a steel-encased, lead-shielded shipping cask. The cask is designed to transport various radioactive contents as listed in 5.(b)(1). The overall dimensions of the package, with impact limiters, are 232 inches long by 65 inches in diameter. The cask body is approximately 200 inches in length and 44 inches in diameter. The cask cavity is 178 inches long and 13.4 inches in diameter. The volume of the cavity is approximately 14.5 cubic feet.

The cask body consists of a 0.75-inch-thick stainless steel inner shell, a 5.75-inch-thick lead gamma shield, a 1.2-inch-thick stainless steel outer shell, and a neutron shield tank. The inner and outer shells are welded to a 4-inch-thick stainless steel bottom end forging. The cask bottom consists of a 3-inch-thick, 20.75-inch-diameter lead disk enclosed by a 3.5-inch-thick stainless steel plate and bottom end forging. The cask lid is 11.3-inch-thick stainless steel stepped design, secured to a 14.25-inch-thick ring forging with twelve 1-inch diameter bolts. The cask seal is a metallic O-ring. A second teflon O-ring and a test port are provided to leak test the seal. Other penetrations in the cask cavity include the fill and drain ports, which are sealed with port covers and O-rings.

The neutron shield tank consists of a 0.24-inch-thick stainless steel shell with 0.50-inch-thick end plates. The neutron shield region is 164 inches long and 5 inches thick. The neutron shield tank contains an ethylene glycol/water solution that is 1% boron by weight.

The cask is equipped with aluminum honeycomb impact limiters. The top impact limiter has an outside diameter of 65.25 inches and a maximum thickness of 27.8 inches. The bottom impact limiter has an outside diameter of 60.25 inches and maximum thickness of 28.3 inches. Both impact limiters extend 12 inches along the side of the cask body.

The maximum weight of the package is 52,000 pounds and the maximum weight of the contents and basket is 4,000 pounds.

GA-4

The GA-4 Legal Weight Truck Spent Fuel Shipping Cask consists of the packaging (cask and impact limiters) and the radioactive contents. The packaging is designed to transport up to four intact pressurized-water reactor (PWR) irradiated spent fuel assemblies as authorized contents. The packaging includes the cask assembly and two impact limiters, each of which is attached to the cask with eight bolts. The overall dimensions of the packaging are approximately 90 inches in diameter and 234 inches long.

The containment system includes the cask body (cask body wall, flange, and bottom plate); cask closure; closure bolts; gas sample valve body; drain valve; and primary O-ring seals for the closure, gas sample valve, and drain valve.

Cask Assembly

The cask assembly includes the cask, the closure, and the closure bolts. Fuel spacers are also provided when shipping specified short fuel assemblies to limit the movement of the fuel. The cask is constructed of stainless steel, depleted uranium, and a hydrogenous neutron shield. The cask external dimensions are approximately 188 inches long and 40 inches in diameter. A fixed fuel support structure divides the cask cavity into four spent fuel compartments, each approximately 8.8 inches square and 167 inches long. The closure is recessed into the cask body and is attached to the cask flange with 12 1-inch diameter bolts.

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The closure is approximately 26 inches square, 11 inches thick, and weighs about 1510 lbs.

The cask has two ports allowing access to the cask cavity. The closure lid has an Integral half-inch diameter port (hereafter referred to as the gas sample valve) for gas sampling, venting, pressurizing, vacuum drying, leakage testing, or inerting. A 1-inch diameter port in the bottom plate allows draining, leakage testing, or filling the cavity with water. A separate drain valve opens and closes the port The primary seals for the gas sample valve and drain valve are recessed from the outside cask surface as protection from punctures The gas sample valve and the drain valve also have covers to protect them during transport.

Cask

The cask includes the containment (flange, cask body, bottom plate and drain valve seals), the cavity liner and fuel support structure; the impact limiter support structure; the trunnions and redundant lift sockets; the depleted uranium gamma shield; and the neutron shield and its outer shell. The cask body is square, with rounded corners and a transition to a round outer shell for the neutron shield. The cask has approximately a 1.5 inch thick stainless steel body wall, 2.6 inch-thick depleted uranium shield (reduced at the corners), and 0.4 inch thick· stainless steel fuel cavity liner.

The cruciform fuel support structure consists of stainless steel panels with boron-carbide (B_4C) pellets for criticality control. A continuous series of holes in each panel, at right angle with the fuel support structure-axis, provides cavities for the B_4C pellets. The fuel support structure is welded to the cavity liner and is approximately 18 inches square by 166 inches long and weighs about 750 lbs.

The flange connects the cask body wall and fuel cavity liner at the top of the cask and the bottom plate connects them at the bottom. The gamma shield is made up of five rings, which are assembled with zero axial tolerance clearance within the depleted uranium cavity, to minimize gaps. The impact limiter support structure is a slightly tapered 0.4 inch thick shell on each end of the cask. The shell mates with the impact limiter's cavity and is connected to the cask body by 36 ribs.

The neutron shield is located between the cask body and the outer shell. The neutron shield design maintains continuous shielding immediately adjacent to the cask body under normal conditions of transport. The details of the design are proprietary. The design, in conjunction with the operating procedures, ensures the availability of the neutron shield to perform its function under normal conditions of transport.

Two lifting and tie-down trunnions are located about 34 inches from the top of the cask body, and another pair is located about the same distance from the bottom. The trunnion outside diameter is 10 inches, increasing to 11.5 inches at the cask interface. Two redundant lift sockets are located about 26 inches from the top of the cask body and are flush with the outer skin.

Materials

All major cask components are stainless steel, except the neutron shield, the depleted uranium gamma shield, and the B_4C pellets contained in the fuel support structure. All O-ring seals are fabricated of ethylene propylene.

Impact Limiters

The impact limiters are fabricated of aluminum honeycomb, completely enclosed by an all welded austenitic stainless steel skin. Each of the two identical Impact limiters is attached to the cask with eight bolts. Each Impact limiter weighs approximately 2,000 lbs.

NAC-STC

A steel, lead, and polymer (NS4FR) shielded shipping cask for (a) directly loaded irradiated PWR fuel assemblies, (6) intact, damaged and/or the fuel debris of Yankee Class or Connecticut Yankee irradiated PWR fuel assemblies in a canister, and (c) non-fissile, solid radioactive materials (referred to hereafter as Greater Than Class C (GTCC) as defined in 10 CFR Part 61) waste in a canister. The cask body is a right circular cylinder with an impact limiter at each end. The package has approximate dimensions as follows:

Cavity diameter	71 inches
Cavity length	165 inches
Cask body outer diameter	87 inches
Neutron shield outer diameter	99 inches
Lead shield thickness	3.7 inches
Neutron shield thickness	5.5 inches
Impact limiter diameter	124 inches
Package length:	
without impact limiters	193 inches
with impact limiters	257 inches

The maximum gross weight of the package is about 260,000 Ibs.

The cask body is made of two concentric stainless steel shells. The inner shell is 1.5 inches thick and has an inside diameter of 71 inches. The outer shell is 2.65 inches thick and has an outside diameter of 86.7 inches. The annulus between the inner and outer shells is filled with lead.

The inner and outer shells are welded to steel forgings at the top and bottom ends of the cask. The bottom end of the cask consists of two stainless steel circular plates which are welded to the bottom end forging. The inner bottom plate is 6.2 inches thick and the outer bottom plate is 5.45 inches thick. The space between the two bottom plates is filled with a 2-inch thick disk of a synthetic polymer (NS4FR) neutron shielding material.

The cask is closed by two steel lids which are bolted to the upper end forging. The inner lid (containment boundary) is 9 inches thick and is made of Type 304 stainless steel. The outer lid is 5.25 inches thick and is made of SA-705 Type 630, H1150 or 17-4PH stainless steel. The inner lid is fastened by 42, 1-1/2-inch diameter bolts and the outer lid is fastened by 36, 1-inch diameter bolts. The inner lid is sealed by two O-ring seals. The outer lid is equipped with a single O-ring seal. The inner lid is fitted with a vent and drain port which are sealed by O-rings and cover plates. The containment system seals may be metallic or Viton. Viton seals are used only for directly-loaded fuel that is to be shipped without long-term interim storage.

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The cask body is surrounded by a 1/4-inch thick jacket shell constructed of 24 stainless steel plates. The jacket shell is 99 inches in diameter and is supported by 24 longitudinal stainless steel fins which are connected to the outer shell of the cask body. Copper plates are bonded to the fins. The space between the fins is filled with NS4FR shielding material.

Four lifting trunnions are welded to the top end forging. The package is shipped in a horizontal orientation and is supported by a cradle under the top forging and by two trunnion sockets located near the bottom end of the cask.

The package is equipped at each end with an impact limiter made of redwood and balsa. Two impact limiter designs consisting of a combination of redwood and balsa wood encased in Type 304 stainless steel are provided to limit the g-loads acting on the cask during an accident. The predominantly balsawood impact limiter is designed for use with all the proposed contents. The predominately redwood impact limiters may only be used with directly loaded fuel or the Yankee-MPC configuration.

The contents are transported either directly loaded (uncanistered) into a stainless steel fuel basket or within a stainless steel transportable storage canister (TSC).

The directly loaded fuel basket within the cask cavity can accommodate up to 26 PWR fuel assemblies. The fuel assemblies are positioned within square sleeves made of stainless steel. Boral or TalBor sheets are encased outside the walls of the sleeves. The sleeves are laterally supported by 31 ½-inch thick, 71-inch diameter stainless steel disks. The basket also has 20 heat transfer disks made of Type 6061-T651 aluminum alloy. The support disks and heat transfer disks are connected by six, 1-5/8-inch diameter by 161-inch long threaded rods made of Type 17-4 PH stainless steel.

The TSC shell, bottom plate, and welded shield and structural lids are fabricated from stainless steel. The bottom is a 1-inch thick steel plate for the Yankee-MPC and 1.75-inch thick steel plate for the CY-MPC. The shell is constructed of 5/8-inch thick rolled steel plate and is 70 inches in diameter. The shield lid is a 5-inch thick steel plate and contains drain and fill penetrations for the canister. The structural lid is a 3-inch thick steel plate. The canister contains a stainless steel fuel basket that can accommodate up to 36 intact Yankee Class fuel assemblies and Reconfigured Fuel Assemblies (RFAs), or up to 26 intact Connecticut Yankee fuel assemblies with RFAs, with a maximum weight limit of 35,100 Ibs. Alternatively, a stainless steel GTCC waste basket is used for up to 24 containers of waste.

One TSC fuel basket configuration can store up to 36 intact Yankee Class fuel assemblies or up to 36 RFAs within square sleeves made of stainless steel. Boral sheets are encased outside the walls of the sleeves. The sleeves are laterally supported by 22 ½-inch thick, 59-inch diameter stainless steel disks, which are spaced about 4 inches apart. The support disks are retained by split spacers on eight 1.125-inch diameter stainless steel tie rods. The basket also has 14 heat transfer disks made of Type 6061-T651 aluminum alloy.

The second fuel basket is designed to store up to 26 Connecticut Yankee Zirc-clad assemblies enriched to 3.93 wt. percent, stainless steel clad assemblies enriched up to 4.03 wt. Percent, RFAs, or damaged fuel in CY-MPC damaged fuel cans (DFCs). Zirc-clad fuel enriched to between 3.93 and 4.61 wt. percent, such as Westinghouse Vantage 5H fuel, must be stored in the24-assembly basket. Assemblies approved for transport in the 26-assembly configuration may also be shipped in the 24-assembly configuration. The construction of the two basket configurations is identical except that two fuel loading positions of the 26-assembly basket are blocked to form the 24-assembly basket.

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RFAs can accommodate up to 64 Yankee Class fuel rods or up to 100 Connecticut Yankee fuel rods, as intact or damaged fuel or fuel debris, in an 8x8 or 10x10 array of stainless steel tubes, respectively. Intact and damaged Yankee Class or Connecticut Yankee fuel rods, as well as fuel debris, are held in the fuel tubes. The RFAs have the same external dimensions as a standard intact Yankee Class or Connecticut Yankee fuel assembly.

The TSC GTCC basket positions up to 24 Yankee Class or Connecticut Yankee waste containers within square stainless steel sleeves. The Yankee Class basket is supported laterally by eight 1-inch thick, 69-inch diameter stainless steel disks. The Yankee Class basket sleeves are supported full-length by 2.5-inch thick stainless steel support walls. The support disks are welded into position at the support walls. The Connecticut Yankee GTCC basket is a right-circular cylinder formed by a series of 1.75-inch thick Type 304 stainless steel plates, laterally supported by 12 equally spaced welded 1.25-inch thick Type 304 stainless steel outer ribs. The GTCC waste containers accommodate radiation activated and surface contaminated steel, cutting debris (dross) or filter media, and have the same external dimensions of Yankee Class or Connecticut Yankee fuel assemblies.

The Yankee Class TSC is axially positioned in the cask cavity by two aluminum honeycomb spacers. The spacers, which are enclosed in a Type 6061-T651 aluminum alloy shell, position the canister within the cask during normal conditions of transport. The bottom spacer is 14-inches high and 70-inches in diameter, and the top spacer is 28-inches high and also 70-inches in diameter.

The Connecticut Yankee TSC is axially positioned in the cask cavity by one stainless steel spacer located in the bottom of the cask cavity.

TN-FSV

A steel and lead shielded shipping cask for irradiated, nuclear fuel. The cask has three shipping configurations: Configuration 1 for shipping irradiated Fort St. Vrain high temperature gas-cooled reactor (HTGR) fuel elements; Configuration 2 for shipping irradiated fuel parts and intact irradiated Peach, Bottom Unit 1 fuel elements within a secondary containment vessel; and Configuration 3 for shipping irradiated Pressurized Water Reactor (PWR) fuel rods within a shielded basket. The cask is a right circular cylinder, with a balsa and redwood impact limiter at each end. The package has approximate dimensions and weights as follows:

Cavity diameter	18 inches
Cavity length	199 inches
Cask body outer diameter	31 inches
Lead shield thickness	3.44 inches
Package overall outer diameter, including impact limiters	78 inches
Package overall length, including impact limiters	247 inches
Packaging weight (Configuration 1)	42,000 pounds
Gross package weight, including contents (Configurations 1 and 2)	47,000 pounds

The cask body is made of two concentric shells of Type 304 stainless steel, welded to a bottom plate and a top closure flange. The inner shell has an ID of 18 inches and is 1.12 inches

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thick. The outer shell has an OD of approximately 30 inches and is 1.5 inches thick. The annular space between the inner and outer shells is filled with lead. The bottom plate is 5.5-inch thick Type 304 stainless steel. The closure lid is 2.5-inch thick Type 304 stainless steel, and is fully recessed into the cask top flange. The lid is fastened to the cask body by 12, 1-inch diameter closure bolts. The lid is sealed with double O-ring seals with a leak test port. A vent port and drain port are sealed with single O-rings and cover plates.

Configuration 1 uses silicone O-ring seals and Configurations 2 and 3 use butyl O-ring seals. The cask body is covered with a stainless steel thermal shield composed of 0.25-inch thick stainless steel plate over a wire wrap. The impact limiters are constructed of balsa and redwood encased in stainless steel shells.

The cask has two lifting sockets bolted to the cask top flange. Two rear trunnions are provided for cask tie-down.

<u>For Configuration 1:</u>

Irradiated hexagonal HTGR fuel elements are shipped in Configuration 1. The fuel elements are stacked in a carbon steel fuel storage container, which has an OD of approximately 17.6 inches and an overall length of 195 inches. The fuel storage container has a 0.5-inch thick shell, a 2.0-inch thick bottom plate, and a 1.5" thick lid. The lid accommodates a removable depleted uranium plug.

<u>For Configuration 2:</u>

Irradiated fuel parts and intact Peach Bottom Unit 1 fuel elements are shipped in Configuration 2. Canisters, containing either fuel parts or a single intact Peach Bottom fuel element, are loaded into a separate, secondary containment vessel, the Oak Ridge Container. The Oak Ridge Container is composed of a right circular cylindrical vessel and a basket assembly. The stainless steel vessel has a 10-gage (0.135-inch) wall thickness, an overall length of approximately 198 inches, and an outside diameter of approximately 20 inches at the lid end. The lid is approximately 7 inches thick and is closed by 12, 1/2-inch diameter bolts and two butyl O-ring seals. There is a single penetration through the lid which is closed by a bolted port cover and two butyl O-ring seals. The basket is composed of a series of discs, tie rods, and support tubes, with five fuel compartment tubes arranged in a star-like configuration. The basket incorporates fixed borated aluminum neutron poison plates. Flux trap spacers are positioned axially between stacked fuel parts canisters, and the canisters and spacers are positioned within a stainless steel sleeve that forms the fuel compartment. Canisters containing fuel parts (called Oak Ridge Canisters) and canisters containing intact Peach Bottom fuel elements may be shipped together.

<u>For Configuration 3:</u>

Irradiated PWR fuel rods are shipped in Configuration 3. The fuel rods are loaded into a PWR fuel rod shielded basket. The basket has an overall length of 166 inches and an overall diameter of 17.5 inches, and fits closely within the TN-FSV cask cavity. The basket consists of a bottom end spacer, a cylindrical body with an inner diameter of 4 inches and an outer diameter of 10-1/2 inches with lateral support discs, and an 11-inch thick top lid. The basket is constructed of stainless steel. Up to 7 PWR fuel rods are loaded into individual stainless steel tubes within the basket.

NUHOMS MP187 MULTI-PURPOSE CASK

The NUHOMS MP187 Multi-Purpose Cask consists of an outer cask, into which one of the four different dry shielded canisters (DSC) is paired. During shipment energy-absorbing impact limiters are utilized and additional package protection.

Cask

The purpose of the cask is to provide containment and shielding of the radioactive materials contained within the DSC during shipment. The cask is constructed of stainless steel and lead with a neutron shield of cementitious material. The inside cavity of the cask is a nominal 68 inches in diameter and 187 inches long. The bottom access closure is approximately 5 inches thick and 17 inches in diameter, secured by 12 1-inch diameter bolts. The top closure is approximately 6.5 inches thick and is secured by 36 2-inch diameter bolts. Both closures are sealed by redundant O-rings.

Containment is provided by a stainless steel closure lid bolted to the stainless steel cask. The containment system of the NUHOMS® MP187 transportation cask consists of (a) the inner shell, (b) the bottom end closure plate, (c) the top closure plate, (d) the top closure inner O-ring seal, (e) the ram closure plate, (f) the ram closure inner O-ring seal, (g) the vent port screw, (h) the vent port O-ring seal, (i) the drain port screw, and (j) the drain port O-ring seal. No credit is given to the DSC as a containment boundary.

Shielding is provided by 4 inches of stainless steel, 4 inches of lead, and approximately 4.3 inches of neutron shielding. The overall length of the cask is approximately 200 inches; the outer diameter is approximately 93 inches. The maximum gross weight of the package, with impact limiters, is approximately 282,000 lbs. The total length of the package with the impact limiters attached is approximately 308 inches. Four removable trunnions (two upper and two lower) are provided for handling and lifting.

Dry Shielded Canisters (DSCs)

The purpose of the DSC, which is placed within the transport cask, is to permit the transfer of spent fuel assemblies, into or out of a storage module, a dry transfer facility, or a pool as a unit. The DSC also provides additional axial biological shielding during handling and transport. The DSC consists of a stainless steel shell and a basket assembly. The approximately 5/8-inch thick shell has an outside diameter of about 67 inches and an external length of about 186 inches. The DSC basket assembly provides criticality control and contains a storage position for each fuel assembly. The basket is composed of circular spacer discs machined from thick carbon steel plates. Axial support for the DSC basket is provided by four high strength steel support rod assemblies. Carbon steel components of each DSC basket assembly are electrolytically coated with a thin layer of nickel to inhibit corrosion.

On the bottom of each DSC is a grapple ring, which is used to transfer a DSC horizontally from the cask into and out of dry storage modules. Because of the nature of the fuel that is to be transported, four different types of DSC are designed for the package. Variations in the DSC configurations are summarized below:

Fuel-Only Dry Shielded Canisters (FO-DSC)

The FO-DSC has a cavity length of approximately 167 inches and has solid carbon steel shield plugs at each end. The FO-DSC is designed to contain up to 24 intact Babcock and Wilcox (B&W) pressurized water reactor (PWR) spent fuel assemblies. The FO-DSC basket assembly consists of 24 guide sleeve assemblies with integral borated neutron absorbing plate, 26, spacer discs, and 4 support rod assemblies.

Fuel/Control Components Dry Shielded Canisters (FC-DSC)

The FC-DSC has an internal cavity length of approximately 173 inches to accommodate fuel with the B&W control components installed. To obtain the increased cavity length, the shield plugs are fabricated from a composite of lead and steel. The FC basket is similar to the FO-DSC except that the support rod assemblies and guide sleeves are approximately 6-inches longer. The FC-DSC is also designed to contain up to 24 intact B&W PWR spent fuel assemblies with control components.

Failed Fuel Dry Shielded Canister (FF-DSC)

The FF-DSC has an internal cavity length of approximately 173 inches to accommodate 13 damaged B&W PWR spent fuel assemblies. Because the cladding has been locally degraded, individual (screened) fuel cans are provided to confine any gross loose material, maintain the geometry for criticality control, and facilitate loading and unloading operations. The FF-DSC is similar to FC-DSC in most respects with the exception of the basket assembly. The FF-DSC basket may be fabricated from austenitic stainless steel.

24PT1 Dry Shielded Canister (24PT1-DSC)

The 24PT1-DSC has an internal cavity length of approximately 167 inches with a solid carbon steel shield plug at each end. The 24PT1-DSC will accommodate 22 to 24 Westinghouse (WE) 14x14 PWR spent fuel assemblies, including control components. Control components authorized that are integral to WE 14x14 fuel assemblies include rod cluster control assemblies, thimble plug assemblies, and neutron source assemblies only. Fuel assemblies may be damaged or intact as described in 5.b(2)(a). The 24 PT1-DSC basket assembly consists of 24 guide sleeve assemblies with integral borated neutron absorbing plates, 26 spacer discs, and 4 support rod assemblies. Up to four screened individual failed fuel cans are provided for storage of damaged fuel within the guide sleeve assemblies. These failed fuel cans are similar in configuration to the FF-DSC failed fuel cans.

Impact Limiters

The impact limiter shells are fabricated from stainless steel. Within that shell are closed-cell polyurethane foam and aluminum honeycomb material. The impact limiter is attached to the cask by carbon steel bolts. Each impact limiter is bolted to the cask body through the neutron shield top and bottom support rings. The weight of each impact limiter is approximately 15,800 lbs.

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HI-STAR 100 SYSTEM

The HI-STAR 100 System is a canister system comprising a Multi-Purpose Canister (MPC) inside of an overpack designed for both storage and transportation (with impact limiters) of irradiated nuclear fuel. The HI-STAR 100 System consists of four interchangeable MPCs that house the spent nuclear fuel and an overpack that provides the containment boundary, helium retention boundary, gamma and neutron radiation shielding, and heat rejection capability. The outer diameter of the overpack of the HI-STAR 100 is approximately 96 inches without impact limiters and approximately 128 inches with impact limiters. Maximum gross weight for transportation (including overpack, MPC, fuel, and impact limiters) is 282,000 pounds. Specific tolerances germane to the safety analyses are called out in the drawings listed below. The HI-STAR 100 System includes the HI-STAR 100 Version HB (also referred to as the HISTAR HB).

Multi-Purpose Canister

There are seven Multi-Purpose Canister (MPC) models designated as the MPC-24, MPC-24E, MPC-24EF, MPC-32, MPC-68, MPC-68F, and the MPC-HB. All MPCs are designed to have identical exterior dimensions, except 1) MPC-24E/EFs custom-designed for the Trojan plant, which are approximately nine inches shorter than the generic Holtec MPC design; and 2) MPC-HBs custom-designed for the Humboldt Bay plant, which are approximately 6.3 feet shorter than the generic Holtec MPC designs. The two digits after the MPC designate the number of reactor fuel assemblies for which the respective MPCs are designed. The MPC-24 series is designed to contain up to 24 Pressurized Water Reactor (PWR) fuel assemblies; the MPC-32 is designed to contain up to 32 intact PWR assemblies; and the MPC-68 and MPC-68F are designed to contain up to 68 Boiling Water Reactor (BWR) fuel assemblies. The MPC-HB is designed to contain up to 80 Humboldt Bay BWR fuel assemblies.

The HI-STAR 100 MPC is a welded cylindrical structure with flat ends. Each MPC is an assembly consisting of a honeycombed fuel basket. baseplate, canister shell, lid, and closure ring. The outer diameter and cylindrical height of each generic MPC is fixed. The outer diameter of the Trojan MPCs is the same as the generic MPC, but the height is approximately nine inches shorter than the generic MPC design. A steel spacer is used with the Trojan plant MPCs to ensure the MPC-overpack interface is bounded by the generic design The outer diameter of the Humboldt Bay MPCs is the same as the generic MPC, but the height is approximately 6.3 feet shorter than the generic MPC design. The Humboldt Bay MPCs are transported in a shorter version of the HI-STAR overpack, designated as the HI-STAR HB. The fuel basket designs vary based on the MPC model.

Overpack

The HI-STAR 100 overpack is a multi-layer steel cylinder with a welded baseplate and bolted lid (closure plate). The inner shell of the overpack forms an internal cylindrical cavity for housing the MPC. The outer surface of the overpack inner shell is buttressed with intermediate steel shells for radiation shielding. The overpack closure plate incorporates a dual O-ring design to ensure its containment function. The containment system consists of the overpack inner shell, bottom plate, top flange, top closure plate, top closure inner O-ring seal, vent port plug and seal, and drain port plug and seal.

Impact Limiters

The HI-STAR 100 overpack is fitted with two impact limiters fabricated of aluminum honeycomb completely enclosed by an all-welded austenitic stainless steel skin. The two impact limiters are attached to the overpack with 20 and 16 bolts at the top and bottom, respectively.

UMS UNIVERSAL TRANSPORT CASK PACKAGE

The UMS is a canister-based system for the storage and transportation of spent nuclear fuel. The transportation component of the UMS system, designated the Universal Transport System, consists of a Universal Transport cask body with a closure lid and energy-absorbing impact limiters loaded with a Transportable Storage Canister (TSC) containing either spent Pressurized Water Reactor (PWR) or Boiling Water Reactor (BWR) nuclear fuel or Maine Yankee site specific contents including Greater than Class C (GTCC) waste.

The NAC-UMS is designed to transport up to 24 intact PWR spent fuel assemblies, 56 intact BWR spent fuel assemblies, GTCC waste, or site specific spent nuclear fuel with associated component hardware. Based on the length of the fuel assemblies, PWR fuels are grouped into three classes (Classes 1 through 3), and BWR fuels are grouped into two classes (Classes 4 and 5). Class 1 and 2 PWR fuel assemblies include non-fuel-bearing inserts (components which include thimble plugs and burnable poison rods installed in the guide tubes). Class 4 and 5 BWR fuel assemblies include the zirconium alloy channels. The loading of site specific fuels that include control component hardware may require the use of a TSC that is longer than if the hardware were excluded. The spent fuel is loaded into a TSC which contains a stainless steel grid work referred to as a basket.

The cask body of the UMS is a right-circular cylinder of multi-wall construction which consists of 304 stainless steel inner and outer shells separated by lead gamma radiation shielding which is poured in place. The inner and outer shells are welded to a 304 stainless steel top forging which mates to the cask lid. The inner shell is also welded to a 304 stainless steel bottom forging and the outer shell is welded to the bottom plate. The cask bottom consists of the bottom forging and bottom plate with neutron shield material sandwiched between them. Layers of 4.5 inches thick 304 stainless steel ring and two 0.75 inch stainless steel disks are located at the bottom lead annulus between the bottom forging and the outer shell.

Neutron shield material is also placed in an annulus that surrounds the cask outer shell along the length of the cask cavity and is enclosed by a stainless steel shell with top and bottom plates, The neutron shield material is a solid synthetic polymer (NS-4-FR). Twenty-four bonded copper and Type 304 stainless steel fins are located in the radial neutron shield to enhance the heat rejection capability of the cask and to support the neutron shield shell and end plates.

The containment boundary of the UMS consists of the inner shell; bottom forging; top forging; case lid and lid inner O-ring; vent port cover plate and vent port cover plate inner O-ring; and drain port cover plate and drain port cover plate inner O-ring.

There are five TSCs of different lengths, each to accommodate a different class of PWR or BWR fuel assembly. Each TSC has an outside diameter of about 67 inches and the lengths vary from about 175 to 192 inches long. The TSC assembly consists of a right circular cylindrical shell with 3 welded bottom plate, a fuel basket, a shield lid, two penetration port covers, and a structural lid. The TSC contains the basket and fuel assemblies or GTCC waste. Spacers are placed below each Class 1, 2, 4 or 5 canisters to locate and support the canister in the cask cavity.

The spacers are free standing structures that are confined in place by the bottom of the canister and the cask bottom inner surface. The spacer(s) ensure that the canister lid is laterally supported by the cask top forging when the cask is horizontal and minimizes axial movement of the canister. Each Class 1 PWR canister is positioned by a stainless steel spacer that is 16.75 inches in length. Each Class 2 PWR canister is positioned by a stainless steel spacer that is 7.65 inches in length. No spacers are used with the Class 3 PWR canister. The Class 4 BWR canister is located by four 1.5 inch aluminum spacers and the Class 5 BWR canister is located with a 1.5 inch aluminum spacer.

The spent fuel basket design uses a series of high strength stainless steel PWR or carbon steel BWR support disks to support the fuel assemblies in stainless steel tubes. The PWR fuel tubes contain neutron absorber on all four sides of the tubes. Three types of fuel tubes are designed to contain the BWR fuel: (1) tubes containing neutron absorber on two sides of the tubes; (2) tubes containing neutron absorber on one side; and (3) tubes containing no neutron absorber. Aluminum heat transfer disks are provided in both the PWR and BWR fuel baskets to enhance thermal performance of the basket. The heat transfer disks are supported by stainless steel tie rods and split spacers that maintain the basket assembly configuration.

The GTCC waste canister is essentially identical to the Class 1 TSC, except for the placement of lifting lugs and the placement of a key way within the canister. The GTCC basket is constructed of Type 304 stainless steel and consists primarily of a cylinder with a 3-inch thick wall closed at the bottom end with a 3-inch thick plate. The cylinder is centered in the GTCC waste canister by 14 Type 304 stainless steel support plates along its length. A 3-inch thick 304 stainless steel separator fixture divides the cylinder into two vertically stacked components, each 77 inches deep with a diameter of 47.8 inches.

The package has impact limiters at each end of the cask body. The impact limiters consist of a combination of redwood and balsa wood encased in Type 304 stainless steel. The impact limiters limit the g-Ioads acting on the cask during a transport drop load condition due to crushing of the redwood and balsa wood. The upper and lower impact limiters are bolted to the cask body by 16 equally spaced attachment rods with nuts.

The approximate dimensions and weights of the package are as follows:

Overall length (with impact limiters, in)	273.3
Overall length (without impact limiters, in)	209.3
Impact Limiter Outside diameter (in)	124.0
Outside diameter (without impact limiters, in)	92.9
Cavity diameter (in)	67.6
Cavity length (in)	192.5
Cask lid thickness (in)	6.5
Bottom thickness (in)	10.3
Inner shell thickness (in)	2.0
Outer shell thickness (in)	2.75
Gamma shield thickness (in)	2.75
Radial neutron shield thickness (in)	4.50

Transportable Storage Canister

Shell thickness (in)	0.625
Shell bottom (in)	1.75
Shield lid thickness (in)	7
Structural lid thickness (in)	3
Outer diameter (in)	67
Internal cavity diameter (in)	65.8
Internal fuel cavity length (in), depending on class	163-180
Overall length (in), depending on class	175-192

Fuel Basket

Basket assembly length (in), depending on class	162-180
Basket assembly diameter (in)	65.5
Number of support disks, depending on class	30-41

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Number of heat transfer disks, depending on class	17-33

Total weight (pounds) including cask, basket, impact limiters, fuel, canister with lids, cask Id and spacers for each fuel class is approximately:

Class 1 (PWR)	251.000
Class 2 (PWR)	252,000
Class 3 (PWR)	249,000
Class 4 (BWR)	256,000
Class 5 (BWR)	255,000

FUELSOLUTIONS TS125 TRANSPORTATION PACKAGE

The FuelSolutions™ TS125 Transportation Package consists of a TS125 Transportation Cask and impact limiters, together with a FuelSolutions™ W21 or W74 canister and its payload. The FuelSolutions™ canister and its payload are contained inside the TS125 Transportation Cask cavity. The TS125 Transportation Cask cavity is sized to accommodate one FuelSolutions™ long canister, or alternatively, one FuelSolutions™ short canister with a cask cavity spacer. The approximate dimensions and weights of the package are as follows:

Package Length:	342.4 inches
Package Outside Diameter:	143.5 inches
Cask Length (w/o impact limiters):	210.4 inches
Cask Outside Diameter (w/o impact limiters):	94.2 inches
Cask Cavity Length:	193.0 inches
Cask Cavity Diameter (section at rails):	66.88 inches
Canister Outside Diameter:	66.0 inches
Maximum Long Canister Length:	192.25 inches
Maximum Short Canister Length:	182.25 inches
Cask Cavity Spacer Length:	10.0 inches
Max. Package Weight:	285,000 pounds
Max. Cask Payload Weight (incl. canister and cavity spacer):	85,000.0 pounds

The TS125 Transportation Cask body is an assembly composed of stainless steel components of an inner shell, an outer shell, a top ring forging, a closure lid with a seal test port and a cavity vent port, a bottom plate forging, and a cavity drain port. The inner and outer shells are welded to the bottom plate forging and the top ring forging. The cask body also includes an annular lead gamma shield; an annular neutron shield with cask tie-down rings, support angles, and jacket; a bottom end neutron shield with a support ring and jacket; a longitudinal shear block; and lifting trunnion mounting bosses. The inner and outer shells form the annular cavity for the lead gamma shield. The outer shell and the neutron shield jacket form the annular cavity for the solid neutron shield. The neutron shield support angles facilitate heat rejection through the solid neutron shielding material to the outer surface of the cask body. The cask closure lid includes a thick recessed plate with two concentric "Helicoflex" silver-jacketed metallic o-ring seals, the cavity vent port, and the seal test port. The closure lid is secured to the cask body during transport with 60-2 inch diameter closure bolts. The vent and drain ports are closed by a plug assembly to maintain containment integrity during transportation.

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The Transportation Cask's containment boundary consists of the inner cylindrical shell, the bottom plate forging (which forms the bottom closure of the cask), the top ring forging and sealing surfaces, the closure lid and sealing surfaces, the welds associated with the above components, the closure bolts, the innermost closure lid o-ring seal, the cavity vent port seal gland and o-ring seal, and the cavity drain port seal gland and o-ring seal. The package is designed to be "leaktight" as defined by ANSI N14.5 (leakage rate less than or equal to 1 x 10^{-7} ref-cm^3/s. The structural components of the Transportation Cask are made of high-strength austenitic stainless steel. The gamma shielding is made of lead and is completely enclosed within the annular region between the inner and outer steel shells. The neutron shielding is solid hydrogenous material that is completely enclosed within the annular region between the cask outer shell and neutron shield jacket with tie-down rings at each end.

The FuelSolutions™ TS125 Transportation Cask has identical energy-absorbing impact limiters at both ends. Each impact limiter assembly consists of crushable aluminum honeycomb energy-absorbing core segments that are encased in a sealed stainless steel shell. In addition to confining the aluminum honeycomb core segments in the event of a free drop, the impact limiter shell protects the aluminum honeycomb material from the weather. Both the top and bottom impact limiters are attached to the transportation cask body tie-down rings with 12, one inch diameter bolts. A tamper-indicating device is provided which connects each impact limiter to the transportation cask to assure that the package has not been opened by unauthorized personnel during transport.

A FuelSolutions™ canister consists of a steel shell assembly and an internal basket assembly. The shell assembly maintains a helium atmosphere for transport conditions. Credit is not taken for containment provided by the canister shell for transport conditions. The shell assembly also provides radiological shielding in both the radial and axial directions. The internal basket assembly provides geometric spacing, structural support, and criticality control for the spent nuclear fuel (SNF) assemblies for transport conditions.

There are two classes of W21 canisters (W21T and W21M), differing primarily in materials of construction. Each W21 canister class includes four different canister types, as follows. The W21T canister class includes a long canister with lead shield plugs (W21T-LL), a long canister with carbon steel shield plugs (W21T-LS), a short canister with lead shield plugs (W21T-SL), and a short canister with carbon steel shield plugs (W21T-SS). The W21M canister class includes a long canister with depleted uranium shield plugs (W21M-LD), a long canister with carbon steel shield plugs (W21M-LS), a short canister with depleted uranium shield plugs (W21M-SD), and a short canister with carbon steel shield plugs (W21M-SS). There are also two classes of W74 canisters (W74T and W74M), differing primarily in materials of construction. Both the W74T and W74M canister classes include only a long canister with carbon steel shield plugs.

A FuelSolutions™ canister shell assembly consists of a steel cylindrical shell, bottom end closure, bottom shield plug, bottom shell extension, bottom outer plate, top shield plug, top inner closure plate, and top outer closure plate. The closure plates at the top and bottom are welded to the cylindrical shell. All structural components of the canister shell assembly are constructed of austenitic stainless steel, with the exception of the shield plugs. The shield plug materials may be composed of lead, depleted uranium or carbon steel, depending upon the specific canister variant. To prevent any corrosion, galvanic, or chemical reactions between the shield plug materials and the cask environment or contents, the shield materials are isolated from the environment and cask interior. The lower shield plugs are encased within stainless steel. The upper shield plugs that are made of lead or depleted uranium are encased in stainless steel. The carbon steel upper shield plug is electroless nickel-plated.

A FuelSolutions™ W21 canister basket assembly consists of 21 guide tubes that are positioned and supported by a series of circular spacer plates, which are in turn positioned and supported by support rod assemblies. The W21 guide tubes include neutron absorber sheets on all four sides.

The W74 canister includes two stackable basket assemblies with a capacity to accommodate up to 64 Big Rock Point fuel assemblies. Each basket includes 37 cell locations, with the center five cell locations mechanically blocked to prevent fuel loading in these locations. The W74 basket assembly consists of a series of circular spacer plates that are positioned and supported by four support tubes that run through the spacer plates and support sleeves between the spacer plates. Each basket cell location, with the exception of the four support tubes and the five blocked-out center cells, contain a guide tube assembly. The W74 guide tube assemblies include borated stainless steel neutron absorber sheets on either one side or two opposite sides. The guide tubes are arranged in the basket to position at least one poison sheet between adjacent fuel assemblies, with the exception of intact fuel assemblies placed in the support tubes.

In the W74 basket, damaged fuel is placed in damaged fuel cans that are accommodated in the support tube cell locations. The W74 damaged fuel cans are similar to the W74 guide tubes, but include a screened bottom end, a screened removal lid, and borated stainless steel neutron absorber sheets on all four sides.

TN-68 TRANSPORT PACKAGE

The-TN-68 is predominantly a steel package that is used to transport up to 68 intact BWR fuel assemblies with or without channels. The overall dimensions of the package are 271 inches long and 144 inches in diameter with the impact limiters installed.

The package generally consists of four components, the fuel basket assembly, a containment vessel within a forged steel cask body, a radial neutron shield, and impact limiters.

The basket assembly locates and supports the fuel assemblies, transfers heat to the cask body wall and provides neutron absorption to satisfy sub-criticality requirements. The basket structure consists of an assembly of stainless steel cells, joined by fusion welding of 1.75 inch wide stainless steel plates. Above and below the plates are slotted borated aluminum (or boron carbide/aluminum) metal matrix composite neutron poison plates which form an egg-crate structure. This construction forms a honey-comb like structure of cell liners which provides compartments for 68 fuel assemblies. The nominal dimensions of each cell is 6.0 inches x 6.0 inches.

A thick-walled (6.0 inch), forged steel cask body for gamma shielding surrounds the containment vessel inner shell and bottom closure. The thickness of the bottom of the cask body is 8.25 inches. A 4.5 inch thick steel gamma shield is also welded to the inside of the containment lid.

The containment boundary consists of the inner shell and bottom plate, shell flange, lid outer plates, lid bolts, penetration cover plate and bolts and the inner metallic O-rings of the lid seal and the two lid penetrations (vent and drain). The containment vessel length is approximately 189 inches with a wall thickness of 1.5 inches. The cylindrical cask cavity has a nominal diameter of 69.5 inches and a length of 178 inches. The containment lid is 5 inches thick and is fastened to the cask body with 48 bolts. Double metallic O-ring seals are provided for lid closure. To preclude air in-leakage, the cask cavity is pressurized with helium to above atmospheric pressure. There are two penetrations through the containment vessel which are located in the lid. These penetrations are for draining and venting. Double metallic seals are also used on these two lid penetrations. The OP port provides access to the interspace lid seals for leak testing purposes. The OP transport cover is not part of the containment boundary.

Neutron shielding is provided by a borated polyester resin compound surrounding the gamma-shield. The resin compound is cast into long, slender aluminum containers. The total thickness of the resin and aluminum is approximately 6 inches. The array of resin-filled containers is enclosed within a smooth 0.75 inch outer steel shell constructed of two half cylinders.

The package has impact limiters at each end of the cask body. The impact limiters consist of balsa wood and redwood blocks, encased in sealed stainless steel shells that maintain the wood in a dry atmosphere and provide wood confinement when crushed during a free drop. The impact limiters have internal radial gussets for added strength and confinement. The impact limiters are attaching to each other using 13 tie rods and to the cask by eight bolts attaching to brackets welded to the outer shell in eight locations (four bolting locations per impact limiter).

The approximate dimensions and weights of the package are as follows:

Overall length (with impact limiters, in)	271
Overall length (without impact limiters, in)	197
Impact Limiter Outside diameter, (in)	144
Outside diameter (without impact limiters, in)	98
Cavity diameter (in)	69.5
Cavity length (in)	178
Containment shell thickness (in)	1.5
Containment vessel length (in)	184
Body wall thickness (in).	7.5
Containment, lid thickness (in)	5
Overall lid thickness (in)	9.5
Bottom thickness (in)	9.75
Resin and aluminum box thickness (in)	6
Outer shell thickness (in)	0.75
Overall basket length (in)	164
Maximum weight of package (pounds)	272,000
Maximum weight of BWR fuel contents (pounds)	47,900
Maximum weight of impact limiters and attachments (pounds)	32,000

NUHOMS®-MP197

The NUHOMS®-MP197 package consists of an outer cask, into which a NUHOMS®-61 BT transportable dry shielded canister (DSC) is placed. During shipment, energy-absorbing impact limiters are utilized for additional package protection. Additionally, a personnel barrier is mounted to the transportation frame to prevent access to the cask body.

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Cask

The NUHOMS®-MP197 transport cask is fabricated primarily of stainless steel. Non-stainless steel members include the cask lead shielding between the containment boundary inner shell and the structural shell, the o-ring seals, the neutron shield, and carbon steel closure bolts. The body of the cask consists of a 1.25 inch thick, 68 inch inside diameter, stainless steel inner (containment) shell and a 2.5 inch thick, 82 inch outside diameter stainless steel structural shell, without impact limiters, which sandwich the 3.25 inch thick cast lead shielding. The overall external dimensions of the cask are 208 inches long and 91.5 inches in outer diameter. The weight of cask body is 148,840 pounds, including about 10,000 pounds of neutron shield and 60,000 pounds of cast lead.

The containment system of the NUHOMS®-MP197 transportation cask consists of the inner shell, a 6.50 inch thick bottom plate, 2.5 inch thick RAM access closure with a diameter of approximately 24 inches, a top closure flange, a 4.5 inch thick top closure lid with closure bolts, drain port closures and bolts, and double o-ring seals for each penetration. The containment vessel prevents leakage of radioactive material from the cask cavity. The cask cavity is pressurized to above atmospheric pressure with an inert gas (helium). Helium assists in the heat removal. Shielding is provided by about 4 inches of stainless steel, 3.25 inches of lead, and about 4.5 inches of neutron shielding. Four removable trunnions are provided for handling and lifting of the cask.

Dry Shielded Canister (DSC)

The purpose of the DSC, which is placed within the transport cask, is to permit the transfer of spent fuel assemblies, into or out of a storage module, a dry transfer facility, or a pool as a unit. The DSC also provides additional axial biological shielding during handling and transport. The DSC consists of a stainless steel shell and a basket assembly. The shell has an outside diameter of about 67 inches and an external length of about 200 inches. The DSC basket assembly provides criticality control and contains a storage position for each fuel assembly. No credit is given to the DSC as a containment boundary. The basket is designed to accommodate 61 intact BWR fuel assemblies with or without fuel channels. The basket structure consists of a welded assembly of stainless steel tubes (fuel compartments) separated by poison plates and surrounded by larger stainless steel boxes and support rails.

The poison plates are constructed from borated aluminum, and provide a heat conduction path from the fuel assemblies to the canister wall, as well as the necessary criticality control.

Impact Limiters

The impact limiter shells are fabricated from stainless steel. Within that shell is a laminate of balsa wood and redwood. Each impact limiter is attached to the cask top (front) and bottom (rear) by 12 bolts. The impact limiters are provided with seven fusible plugs that are designed to melt during a fire accident, thereby relieving excessive internal pressure. Each impact limiter has two hoist rings for handling. The hoist rings are threaded into the impact limiter shell. During transportation, the impact limiter hoist rings are removed. An aluminum thermal shield is added to the bottom impact limiter to reduce the impact limiter wood temperature. The weight of the impact limiters, the thermal shield, and attachment bolts, is approximately 28,000 lbs.

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HI-STAR 180

The HI-STAR 180 package is designed for transportation of undamaged irradiated Uranium Oxide (UO_2) and Mixed Oxide (MOX) fuel assemblies. The fuel basket provides criticality control and the packaging body provides the containment boundary, helium retention boundary, moderator exclusion barrier, gamma and neutron radiation shielding, and heat rejection capability. The outer diameter of the HI-STAR 180 packaging is approximately 2700 mm without impact limiters and approximately 3250 mm with impact limiters. The maximum gross weight of the loaded HI-STAR 180 package is 140 Metric Tons.

<u>Fuel Basket</u>

Metamic-HT, a metal matrix composite of aluminum and boron carbide, is the principal constituent material of the fuel basket, both as structural material and neutron absorber material. Two interchangeable fuel basket models, designated F-32 and F-37, contain either 32 or 37 Pressurized Water Reactor (PWR) fuel assemblies respectively, in regionalized and uniform loading patterns. The fuel basket features a honeycomb structure and flux traps between some but not all cells.

<u>Packaging Body</u>

The cylindrical steel shell containment system is welded to a bottom steel baseplate and a top steel forging machined to receive two independent steel closure lids, with each lid being individually designated as a containment boundary component. The outer surface of the cask inner shell is buttressed with a monolithic shield cylinder for gamma and neutron shielding. Each closure lid features a dual metallic self-energizing seal system designed to ensure its containment and moderator exclusion functions. For this package, the inner closure lid inner seal and the inner closure lid vent/drain port cover inner seals are the containment boundary components on the inner lid; the outer closure lid inner seal and the outer closure lid access port plug seal are the containment boundary components on the outer lid.

<u>Impact Limiters</u>

The HI-STAR 180 cask is fitted with two impact limiters fabricated of aluminum honeycomb crush material completely enclosed by an all-welded austenitic stainless steel skin. The two impact limiters are attached to the cask with 16 bolts.

HI-STAR 60

The HI-STAR 60 packaging is designed for transportation of irradiated nuclear fuel assemblies. The fuel basket provides criticality control and the cask provides the containment boundary, helium retention boundary, gamma and neutron radiation shielding, and heat rejection capability. The outer diameter of the HI-STAR 60 package is approximately 1924 mm without impact limiters and approximately 2864 mm with impact limiters. The maximum gross weight of the loaded HI-STAR 60 package, as presented for transportation, is 74.4 Metric Tons.

<u>Fuel Basket</u>

The fuel basket, designated F-12 for the transport of 12 Pressurized Water Reactor (PWR) fuel assemblies, is a fully welded, stainless steel, honeycomb structure and features flux traps between some but not all cells.

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Fuel Impact Attenuators

Fuel Impact Attenuators are spacers designed to limit internal gaps between the fuel assembly end-fittings and the internal surfaces of the package. Fuel Impact attenuators also mitigate the G loads on the fuel assemblies due to secondary internal impact.

Cask

The HI-STAR 60 cask is a multi-layer steel cylinder with a welded base-plate and bolted lid (closure plate). The inner shell of the cask forms an internal cylindrical cavity for housing the basket. The outer surface of the cask inner shell is buttressed with intermediate steel shells for radiation shielding. The cask closure plate incorporates a dual O-ring design to ensure its containment function. The containment system consists of the cask inner shell, bottom plate, top flange, top closure plate, top closure inner O-ring seal, vent port plug and seal, and drain port plug and seal.

Impact Limiters

The HI-STAR 60 cask is fitted with two impact limiters fabricated of aluminum honeycomb crush material completely enclosed by an all-welded austenitic stainless steel skin. The two impact limiters are attached to the cask with 8 bolts at the top and bottom, respectively.

Fastener Strain Limiters

Fastener strain limiters are collapsible devices designed to limit the axial stress imparted to the impact limiter attachment bolts.

4. Certification Requirements for Spent Nuclear Fuel Transport Packagings

As described above, regulations for radioactive material transport packaging are given in 10 CFR71. General standards for all packages are specified in §71.43, lifting and tie-down standards in §71.45, and external radiation standards in §71.47. Additional requirements for Type B packages are specified in §71.51. Additional general requirements for fissile material packages are specified in §71.55 and §71.59. A technical reference book on packaging design, manufacture and testing is the Radioactive Materials Packaging Handbook published by Oak Ridge National Laboratory in 1978, and available from the DOE Office of Scientific and Technical Information (OSTI) and the U.S. Department of Commerce National Technical Information Service (NTIS).

Both Type A and Type B packages are subjected to testing defined for normal conditions of transport under §71.71, including, in sequence, the following tests:

- Water spray (5 cm/hr for 1 hr)
- Free drop (1.2 m for packages < 5000 kg)
- Stacking (5 x the package weight for 24 hours for packages < 5000 kg)
- Penetration (6 kg steel cylinder 3.2 cm in diameter from 1 m)

Type B packages are subject to additional tests specified in §71.73 for hypothetical accident conditions, again conducted in sequence and in the most damaging configuration, which include the following:

- Impact (9m drop onto an unyielding target, and 1 m drop onto 15 cm steel par on an unyielding target)
- Fire (fully engulfing 30 min fire with an 800ºC minimum average temperature)
- Water immersion (15 m, and 0.9 m if fissile, and 200 m for larger quantities of radioactive material)

General: The general standards from §71.43 include:

Minimum Dimension	(a)	The smallest overall dimension of a package may not be less than 10 cm (4 in).
Tamper Indication	(b)	The outside of a package must incorporate a feature, such as a seal, that is not readily breakable and that, while intact, would be evidence that the package has not been opened by unauthorized persons.
Pressure Seal	(c)	Each package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package.
Material Properties	(d)	A package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents, including possible reaction resulting from inleakage of water, to the maximum credible extent. Account must be taken of the behavior of materials under irradiation.
Unauthorized operation	(e)	A package valve or other device, the failure of which would allow radioactive contents to escape, must be protected against unauthorized operation and, except for a pressure relief device, must be provided with an enclosure to retain any leakage.
Normal Transport	(f)	A package must be designed, constructed, and prepared for shipment so that under the tests specified in §71.71 ("Normal conditions of transport") there would be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging.
Surface Temperature	(g)	A package must be designed, constructed, and prepared for transport so that in still air at 38 °C (100 °F) and in the shade, no accessible surface of a package would have a temperature exceeding 50 °C (122 °F) in a nonexclusive use shipment, or 85 °C (185 °F) in an exclusive use shipment.
Venting	(h)	A package may not incorporate a feature intended to allow continuous venting during transport.

Lifting and Tie-Down: Lifting and tie-down standards in §71.45 include:

(a)	Lifting	Any lifting attachment that is a structural part of a package must be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner, and it must be designed so that failure of any lifting device under excessive load would not impair the ability of the package

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		to meet other requirements of this subpart. Any other structural part of the package that could be used to lift the package must be capable of being rendered inoperable for lifting the package during transport, or must be designed with strength equivalent to that required for lifting attachments.
(b)	Tie-down devices:	(1) If there is a system of tie-down devices that is a structural part of the package, the system must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of 2 times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package with its contents, and a horizontal component in the transverse direction of 5 times the weight of the package with its contents.
		(2) Any other structural part of the package that could be used to tie down the package must be capable of being rendered inoperable for tying down the package during transport, or must be designed with strength equivalent to that required for tie-down devices.
		(3) Each tie-down device that is a structural part of a package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this part.

<u>External Radiation:</u> External radiation standards in §71.47 include:

(a) Except as provided in paragraph (b) of this section, each package of radioactive materials offered for transportation must be designed and prepared for shipment so that under conditions normally incident to transportation the radiation level does not exceed 2 mSv/h (200 mrem/h) at any point on the external surface of the package, and the transport index does not exceed 10.

(b) A package that exceeds the radiation level limits specified in paragraph (a) of this section must be transported by exclusive use shipment only, and the radiation levels for such shipment must not exceed the following during transportation:

(1) 2 mSv/h (200 mrem/h) on the external surface of the package, unless the following conditions are met, in which case the limit is 10 mSv/h (1000 mrem/h):

(i) The shipment is made in a closed transport vehicle;

(ii) The package is secured within the vehicle so that its position remains fixed during transportation; and

(iii) There are no loading or unloading operations between the beginning and end of the transportation;

(2) 2 mSv/h (200 mrem/h) at any point on the outer surface of the vehicle, including the top and underside of the vehicle; or in the case of a flat-bed style vehicle, at any point on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load or enclosure, if used, and on the lower external surface of the vehicle; and

(3) 0.1 mSv/h (10 mrem/h) at any point 2 meters (80 in) from the outer lateral surfaces of the vehicle (excluding the top and underside of the vehicle); or in the case of a flat-

bed style vehicle, at any point 2 meters (6.6 feet) from the vertical planes projected by the outer edges of the vehicle (excluding the top and underside of the vehicle); and

(4) 0.02 mSv/h (2 mrem/h) in any normally occupied space, except that this provision does not apply to private carriers, if exposed personnel under their control wear radiation dosimetry devices in conformance with 10 CFR 20.1502.

(c) For shipments made under the provisions of paragraph (b) of this section, the shipper shall provide specific written instructions to the carrier for maintenance of the exclusive use shipment controls. The instructions must be included with the shipping paper information.

(d) The written instructions required for exclusive use shipments must be sufficient so that, when followed, they will cause the carrier to avoid actions that will unnecessarily delay delivery or unnecessarily result in increased radiation levels or radiation exposures to transport workers or members of the general public.

Additional Type B Requirements: The additional requirements for Type B packages specified in §71.51 include:

(a) A Type B package, in addition to satisfying the requirements of §§71.41 through 71.47, must be designed, constructed, and prepared for shipment so that under the tests specified in:

(1) Section 71.71 ("Normal conditions of transport"), there would be no loss or dispersal of radioactive contents—as demonstrated to a sensitivity of $10^{-6}A_2$ per hour, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging; and

(2) Section 71.73 ("Hypothetical accident conditions"), there would be no escape of krypton-85 exceeding 10 A_2 in 1 week, no escape of other radioactive material exceeding a total amount A_2 in 1 week, and no external radiation dose rate exceeding 10 mSv/h (1 rem/h) at 1 m (40 in) from the external surface of the package.

(b) Where mixtures of different radionuclides are present, the provisions of appendix A, paragraph IV of this part shall apply, except that for Krypton-85, an effective A_2 value equal to 10 A_2 may be used.

(c) Compliance with the permitted activity release limits of paragraph (a) of this section may not depend on filters or on a mechanical cooling system.

(d) For packages which contain radioactive contents with activity greater than 105 A_2, the requirements of §71.61 must be met.

Normal Transport: The general standards from §71.43(f) point to §71.71 "Normal conditions of transport."

(a) *Evaluation.* Evaluation of each package design under normal conditions of transport must include a determination of the effect on that design of the conditions and tests specified in this section. Separate specimens may be used for the free drop test, the compression test, and the penetration test, if each specimen is subjected to the water spray test before being subjected to any of the other tests.

(b) *Initial conditions.* With respect to the initial conditions for the tests in this section, the demonstration of compliance with the requirements of this part must be based on the ambient temperature preceding and following the tests remaining constant at that value between −29 °C (−20 °F) and +38 °C (+100 °F) which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system must be considered to be the maximum normal operating pressure, unless a lower internal pressure consistent with the ambient temperature considered to precede and follow the tests is more unfavorable.

(c) *Conditions and tests —*

(1) *Heat.* An ambient temperature of 38 °C (100 °F) in still air, and insolation according to the following table:

Insolation Data

Form and location of surface	Total insolation for a 12-hour period ($g\ cal/cm^2$)
Flat surfaces transported horizontally:	
Base	None
Other surfaces	800
Flat surfaces not transported horizontally	200
Curved surfaces	400

(2) *Cold.* An ambient temperature of −40 °C (−40 °F) in still air and shade.

(3) *Reduced external pressure.* An external pressure of 25 kPa (3.5 lbf/in^2) absolute.

(4) *Increased external pressure.* An external pressure of 140 kPa (20 lbf/in^2) absolute.

(5) *Vibration.* Vibration normally incident to transport.

(6) *Water spray.* A water spray that simulates exposure to rainfall of approximately 5 cm/h (2 in/h) for at least 1 hour.

(7) *Free drop.* Between 1.5 and 2.5 hours after the conclusion of the water spray test, a free drop through the distance specified below onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.

Criteria for Free Drop Test (Weight/Distance)

Package weight		Free drop distance	
Kilograms	**(Pounds)**	**Meters**	**(Feet)**
Less than 5,000	(Less than 11,000)	1.2	(4)
5,000 to 10,000	(11,000 to 22,000)	0.9	(3)
10,000 to 15,000	(22,000 to 33,100)	0.6	(2)
More than 15,000	(More than 33,100)	0.3	(1)

(8) *Corner drop.* A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1 ft) onto a flat, essentially unyielding, horizontal surface. This test applies only to fiberboard, wood, or fissile material rectangular packages not exceeding 50 kg (110 lbs) and fiberboard, wood, or fissile material cylindrical packages not exceeding 100 kg (220 lbs).

(9) *Compression.* For packages weighing up to 5000 kg (11,000 lbs), the package must be subjected, for a period of 24 hours, to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The compressive load must be the greater of the following:

(i) The equivalent of 5 times the weight of the package; or

(ii) The equivalent of 13 kPa (2 lbf/in^2) multiplied by the vertically projected area of the package.

(10)Penetration. Impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25 in) diameter and 6 kg (13 lbs) mass, dropped from a height of 1 m (40 in) onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface.

Additional general requirements for fissile material packages are specified in §71.55 and §71.59. §71.55 contains the following:

(a) A package used for the shipment of fissile material must be designed and constructed in accordance with §§71.41 through 71.47. When required by the total amount of radioactive material, a package used for the shipment of fissile material must also be designed and constructed in accordance with §71.51.

(b) Except as provided in paragraph (c) or (g) of this section, a package used for the shipment of fissile material must be so designed and constructed and its contents so limited that it would be subcritical if water were to leak into the containment system, or liquid contents were to leak out of the containment system so that, under the following conditions, maximum reactivity of the fissile material would be attained:

(1) The most reactive credible configuration consistent with the chemical and physical form of the material;

(2) Moderation by water to the most reactive credible extent; and

(3) Close full reflection of the containment system by water on all sides, or such greater reflection of the containment system as may additionally be provided by the surrounding material of the packaging.

(c) The Commission may approve exceptions to the requirements of paragraph (b) of this section if the package incorporates special design features that ensure that no single packaging error would permit leakage, and if appropriate measures are taken before each shipment to ensure that the containment system does not leak.

(d) A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in §71.71 ("Normal conditions of transport")—

(1) The contents would be subcritical;

(2) The geometric form of the package contents would not be substantially altered;

(3) There would be no leakage of water into the containment system unless, in the evaluation of undamaged packages under §71.59(a)(1), it has been assumed that moderation is present to such an extent as to cause maximum reactivity consistent with the chemical and physical form of the material; and

(4) There will be no substantial reduction in the effectiveness of the packaging, including:

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(i) No more than 5 percent reduction in the total effective volume of the packaging on which nuclear safety is assessed;

(ii) No more than 5 percent reduction in the effective spacing between the fissile contents and the outer surface of the packaging; and

(iii) No occurrence of an aperture in the outer surface of the packaging large enough to permit the entry of a 10 cm (4 in) cube.

(e) A package used for the shipment of fissile material must be so designed and constructed and its contents so limited that under the tests specified in §71.73 ("Hypothetical accident conditions"), the package would be subcritical. For this determination, it must be assumed that:

(1) The fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents;

(2) Water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents; and

(3) There is full reflection by water on all sides, as close as is consistent with the damaged condition of the package.

(f) For fissile material package designs to be transported by air:

(1) The package must be designed and constructed, and its contents limited so that it would be subcritical, assuming reflection by 20 cm (7.9 in) of water but no water inleakage, when subjected to sequential application of:

(i) The free drop test in §71.73(c)(1);

(ii) The crush test in §71.73(c)(2);

(iii) A puncture test, for packages of 250 kg or more, consisting of a free drop of the specimen through a distance of 3 m (120 in) in a position for which maximum damage is expected at the conclusion of the test sequence, onto the upper end of a solid, vertical, cylindrical, mild steel probe mounted on an essentially unyielding, horizontal surface. The probe must be 20 cm (7.9 in) in diameter, with the striking end forming the frustum of a right circular cone with the dimensions of 30 cm height, 2.5 cm top diameter, and a top edge rounded to a radius of not more than 6 mm (0.25 in). For packages less than 250 kg, the puncture test must be the same, except that a 250 kg probe must be dropped onto the specimen which must be placed on the surface; and

(iv) The thermal test in §71.73(c)(4), except that the duration of the test must be 60 minutes.

(2) The package must be designed and constructed, and its contents limited, so that it would be subcritical, assuming reflection by 20 cm (7.9 in) of water but no water inleakage, when subjected to an impact on an unyielding surface at a velocity of 90 m/s normal to the surface, at such orientation so as to result in maximum damage. A separate, undamaged specimen can be used for this evaluation.

(3) Allowance may not be made for the special design features in paragraph (c) of this section, unless water leakage into or out of void spaces is prevented following

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application of the tests in paragraphs (f)(1) and (f)(2) of this section, and subsequent application of the immersion test in §71.73(c)(5).

(g) Packages containing uranium hexafluoride only are excepted from the requirements of paragraph (b) of this section provided that:

(1) Following the tests specified in §71.73 ("Hypothetical accident conditions"), there is no physical contact between the valve body

and any other component of the packaging, other than at its original point of attachment, and the valve remains leak tight;

(2) There is an adequate quality control in the manufacture, maintenance, and repair of packagings;

(3) Each package is tested to demonstrate closure before each shipment; and

(4) The uranium is enriched to not more than 5 weight percent uranium-235.

Fissile Material Arrays: § 71.59 establishes standards for arrays of fissile material packages.

(a) A fissile material package must be controlled by either the shipper or the carrier during transport to assure that an array of such packages remains subcritical. To enable this control, the designer of a fissile material package shall derive a number "N" based on all the following conditions being satisfied, assuming packages are stacked together in any arrangement and with close full reflection on all sides of the stack by water:

(1) Five times "N" undamaged packages with nothing between the packages would be subcritical;

(2) Two times "N" damaged packages, if each package were subjected to the tests specified in §71.73 ("Hypothetical accident conditions") would be subcritical with optimum interspersed hydrogenous moderation; and

(3) The value of "N" cannot be less than 0.5.

(b) The CSI must be determined by dividing the number 50 by the value of "N" derived using the procedures specified in paragraph (a) of this section. The value of the CSI may be zero provided that an unlimited number of packages are subcritical, such that the value of "N" is effectively equal to infinity under the procedures specified in paragraph (a) of this section. Any CSI greater than zero must be rounded up to the first decimal place.

(c) For a fissile material package which is assigned a CSI value—

(1) Less than or equal to 50, that package may be shipped by a carrier in a nonexclusive use conveyance, provided the sum of the CSIs is limited to less than or equal to 50.

(2) Less than or equal to 50, that package may be shipped by a carrier in an exclusive use conveyance, provided the sum of the CSIs is limited to less than or equal to 100.

(3) Greater than 50, that package must be shipped by a carrier in an exclusive use conveyance, provided the sum of the CSIs is limited to less than or equal to 100.

Hypothetical Accident Conditions: § 71.73 Hypothetical accident conditions include:

(a) *Test procedures.* Evaluation for hypothetical accident conditions is to be based on sequential application of the tests specified in this section, in the order indicated, to determine their

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cumulative effect on a package or array of packages. An undamaged specimen may be used for the water immersion tests specified in paragraph (c)(6) of this section.

(b) *Test conditions.* With respect to the initial conditions for the tests, except for the water immersion tests, to demonstrate compliance with the requirements of this part during testing, the ambient air temperature before and after the tests must remain constant at that value between −29 °C (−20 °F) and +38 °C (+100 °F) which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system must be the maximum normal operating pressure, unless a lower internal pressure, consistent with the ambient temperature assumed to precede and follow the tests, is more unfavorable.

(c) *Tests.* Tests for hypothetical accident conditions must be conducted as follows:

(1) *Free drop.* A free drop of the specimen through a distance of 9 m (30 ft) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.

(2) *Crush.* Subjection of the specimen to a dynamic crush test by positioning the specimen on a flat, essentially unyielding horizontal surface so as to suffer maximum damage by the drop of a 500-kg (1100-lb) mass from 9 m (30 ft) onto the specimen. The mass must consist of a solid mild steel plate 1 m (40 in) by 1 m (40 in) and must fall in a horizontal attitude. The crush test is required only when the specimen has a mass not greater than 500 kg (1100 lb), an overall density not greater than 1000 kg/m^3 (62.4 lb/ft^3) based on external dimension, and radioactive contents greater than 1000 A_2 not as special form radioactive material. For packages containing fissile material, the radioactive contents greater than 1000 A_2 criterion does not apply.

(3) *Puncture.* A free drop of the specimen through a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 15 cm (6 in) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (0.25 in), and of a length as to cause maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar must be vertical.

(4) *Thermal.* Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent, and in sufficiently quiescent ambient conditions, to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 800 °C (1475 °F) for a period of 30 minutes, or any other thermal test that provides the equivalent total heat input to the package and which provides a time averaged environmental temperature of 800 °C. The fuel source must extend horizontally at least 1 m (40 in), but may not extend more than 3 m (10 ft), beyond any external surface of the specimen, and the specimen must be positioned 1 m (40 in) above the surface of the fuel source. For purposes of calculation, the surface absorptivity coefficient must be either that value which the package may be expected to possess if exposed to the fire specified or 0.8, whichever is greater; and the convective coefficient must be that value which may be demonstrated to exist if the package were exposed to the fire specified. Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction, must be allowed to proceed until it terminates naturally.

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(5) *Immersion—fissile material.* For fissile material subject to §71.55, in those cases where water inleakage has not been assumed for criticality analysis, immersion under a head of water of at least 0.9 m (3 ft) in the attitude for which maximum leakage is expected.

(6) *Immersion—all packages.* A separate, undamaged specimen must be subjected to water pressure equivalent to immersion under a head of water of at least 15 m (50 ft). For test purposes, an external pressure of water of 150 kPa (21.7 lbf/in^2) gauge is considered to meet these conditions.

5. Dry Spent Nuclear Fuel Storage Designs

For storage systems, Table 4 from NUREG-1350, Vol. 22, Appendix H, lists the Dry Spent Fuel Storage Designs approved by the NRC for use with a general license. The NRC website at http://www.nrc.gov/waste/spent-fuel-storage/designs.html also provides references to related documents. Detailed information for these systems can be found in "Shipping and Storage Cask Data for Commercial Spent Nuclear Fuel," JAI-582, JAI Corporation, March 2005, which is available for purchase at http://www.jaicorp.com/JAI%20publications.htm, and in the Electric Power Research Institute (EPRI) "Industry Spent Fuel Storage Handbook," which is available online at http://my.epri.com/portal/server.pt?Abstract_id=000000000001021048.

Table 4. Approved NRC Dry Spent Fuel Storage Designs

Vendor	Docket#	Storage Design Model
General Nuclear Systems, Inc.	72-1000	CASTOR V/21
NAC International, Inc.	72-1002	NAC S/T
	72-1003	NAC-C28 S/T
	72-1015	NAC-UMS
	72-1025	NAC-MPC
	72-1031	Magnastor
Holtec International	72-1008	HI-STAR 100
	72-1014	HI-STORM 100
BNG Fuel Solutions Corporation	72-1007	VSC-24
	72-1026	Fuel Solutions™ (WSNF-220, -221, -223)
		W-150 Storage Cask
		W-100 Transfer Cask
		W-21 Canisters
		W-74, W-74 Canisters
Transnuclear, Inc.	72-1005	TN-24
	72-1027	TN-68
	72-1021	TN-32, 32A, 32B
	72-1004	Standardized NUHOMS®-24P, 24PHB, -24PTH, -32PT, -32PTH1, -52B, -61BT, -61BTH
	72-1029	Standardized Advanced NUHOMS®-24PT1, -24PT4
	72-1030	NUHOMS® HD-32PTH

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Of the more than 50 licensed Independent Spent Fuel Storage Installations (ISFSIs) in the U.S., the information in NUREG-1350, Appendix I, shows that the primary vendors are Transnuclear, Holtec International, NAC, and BNG Fuel Solutions.

Spent Fuel Storage Casks are certified under 10CFR72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-related Greater Than Class C Waste." In particular, §72.236, "Specific requirements for spent fuel storage cask approval and fabrication." The requirements of §72.236 are given below.

The certificate holder and applicant for a CoC shall ensure that the requirements of this section are met.

(a) Specifications must be provided for the spent fuel to be stored in the spent fuel storage cask, such as, but not limited to, type of spent fuel (*i.e.,* BWR, PWR, both), maximum allowable enrichment of the fuel prior to any irradiation, burn-up (*i.e.,* megawatt-days/MTU), minimum acceptable cooling time of the spent fuel prior to storage in the spent fuel storage cask, maximum heat designed to be dissipated, maximum spent fuel loading limit, condition of the spent fuel (*i.e.,* intact assembly or consolidated fuel rods), the inerting atmosphere requirements.

(b) Design bases and design criteria must be provided for structures, systems, and components important to safety.

(c) The spent fuel storage cask must be designed and fabricated so that the spent fuel is maintained in a subcritical condition under credible conditions.

(d) Radiation shielding and confinement features must be provided sufficient to meet the requirements in §§72.104 and 72.106.

(e) The spent fuel storage cask must be designed to provide redundant sealing of confinement systems.

(f) The spent fuel storage cask must be designed to provide adequate heat removal capacity without active cooling systems.

(g) The spent fuel storage cask must be designed to store the spent fuel safely for a minimum of 20 years and permit maintenance as required.

(h) The spent fuel storage cask must be compatible with wet or dry spent fuel loading and unloading facilities.

(i) The spent fuel storage cask must be designed to facilitate decontamination to the extent practicable.

(j) The spent fuel storage cask must be inspected to ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce its confinement effectiveness.

(k) The spent fuel storage cask must be conspicuously and durably marked with—

(1) A model number;

(2) A unique identification number; and

(3) An empty weight.

(l) The spent fuel storage cask and its systems important to safety must be evaluated, by appropriate tests or by other means acceptable to the NRC, to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

(m) To the extent practicable in the design of spent fuel storage casks, consideration should be given to compatibility with removal of the stored spent fuel from a reactor site, transportation, and ultimate disposition by the Department of Energy.

(n) Safeguards Information shall be protected against unauthorized disclosure in accordance with the requirements of §73.21 and the requirements of §73.22 or §73.23 of this chapter, as applicable.

6. Other Fissile Material Packagings (Fresh Unirradiated Nuclear Fuel and Material)

There are 24 CoCs certifying packagings for fresh unirradiated nuclear fuel and similar materials, summarized in Table 5.

7. Other (e.g., Research & Test Reactor) Spent Nuclear Fuel Packagings

Six NRC CoCs are currently active for fresh, unirradiated research and test reactor fuel Type B packagings, and two CoCs are active for irradiated research and test reactor fuel Type B packaging, and are summarized in Table 6.

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Table 5. Other NRC Certified Fissile Material Packagings

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/0361/B(U)F-96	PAT-1 (Pu oxide; air transport)	U.S. Nuclear Regulatory Commission	PuO_2 and daughter products	Stainless steel vessel (6.75" OD x 8.5" L) surrounded by stainless and redwood overpack (24.5" OD x 42.5" L); loaded weight ~41.7 lbs.
USA/5086/B(U)F	UNC-2600	BWXT, Nuclear Products Division	Unirradiated uranium-zirconium fuel elements	Inner steel box (2-5/8" x 7" x 96") supported in a steel drum (22.5" ID x 102.5")
USA/9196/B(U)F-96	UX-30	EnergySolutions (Duratek, Inc.)	Overpack for transport of 30" enriched UF_6 cylinders	Stainless steel shells filed w/6" foam; 43.5" dia x 96"; maximum gross weight 8270 lbs.
USA/9203/AF	DHTF	Framatome ANP, Inc. (Framatome Cogema Fuels)	Dry UO_2 pellets or scrap.	Stainless steel vessel (9.5" x 9.5" x 17.5") supported in a steel drum (~22.5" dia x 34" h); gross weight 490 lbs.
USA/9217/AF	ANF-250	Framatome ANP Richland, Inc. (Siemens Power Corp.)	Dry UO_2 powder or pellets	Steel inner vessel (11.5" ID x 57") supported in a steel drum (22.5" ID x 68 3/8") w/vermiculite. Max gross weight 616 lbs.

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Table 5. Other NRC Certified Fissile Material Packagings

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9239/AF	MCC-3, MCC-4, AND MCC-5	Westinghouse Electric Co., LLC	Unirradiated UO_2 fuel assemblies	Steel outer container; internal cradle assembly w/ Gd_2O_3 neutron absorber plates. Dimensions: 44.5"ODx194.5" (max. wt. 7544 lbs); 44.5"ODx226" (max. wt. 10533 lbs), and 44.5xODx226" (max. wt. 10533 lbs)
USA/9248/AF	SP-1, SP-2, AND SP-3	Framatome ANP, Inc.	Unirradiated UO_2 fuel rods and assemblies	Rectangular metal inner container 11.5"x18"x179.5") in wooden outer container (30"x20"x207") with cushioning foam; max. wt. 2800 lbs.
USA/9250/B(U)F-85	5X22	BWX Technologies	Unirradiated uranium	Outer steel drum 22.5" dia. x 34.75" h; inner vessel capped stainless steel pipe 5" IDx22"h.; max. wt. 300 lbs.
USA/9251/AF	BW-2901	AREVA NP, Inc.	Low-enriched UO_2 powder and pellets	Inner steel container (11.15"x11.15"x29.5") w/borated Al plates, insulation, outer container drum (22.5" dia. x 34.25" or 35.25" h); max wt. 660 lbs.

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Table 5. Other NRC Certified Fissile Material Packagings

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9252/AF	51032-2	Framatome ANP, Inc. (B&W Fuel Co.)	Unirradiated fuel assemblies	Steel shipping container, 43" dia x 216"; max wt. 7500 lbs.
USA/9274/AF	ABB-2901	Westinghouse Electric Company, LLC	Low-enriched UO_2 pellets	Inner steel container (10.75"x10.75"x30"), insulation, outer container drum (22.5" ID x 36"); max. wt. 660 lbs.
USA/9284/B(U)F-85	ESP-30X PROTECTIVE SHIPPING PACKAGE FOR 30-INCH UF6 CYLINDERS	Columbiana Hi-Tech, LLC (Eco-Pak Specialty Packaging)	Overpack for transport of 30" enriched UF_6 cylinders	Steel outer cylinder (43" ID x 96"), insulating foam, inner shell (30 7/8" ID x 82 5/8"); max wt. 9365 lbs.
USA/9288/B(U)F-96	CHT-OP-TU	Columbiana Hi-Tech, LLC	UO2 pellets, powder, and uranium-bearing materials.	Stainless steel outer container (45"x45"x62"), foam filled, 4 sleeves for stainless steel oxide vessels.
USA/9289/B(U)F-85	WE-1	Framatome ANP, Inc. (Framatome Cogema Fuels)	Fresh fuel assemblies	Cylindrical steel outer container (44" dia x 216")and rectangular steel inner container (16.5" w x 165" l); max. wt. 9090 lbs.
USA/9291/B(U)F-96	LIQUI-RAD (LR) TRANSPORT UNIT PACKAGE	Columbiana Hi-Tech, LLC	Type B quantities of fissile uranyl nitrate solutions	Cylindrical package in rectangular frame (56"x56"x73") w/ foam insulation

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Table 5. Other NRC Certified Fissile Material Packagings

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9292/AF-85	PATRIOT (SERIAL NO. 001 THRU 039, INCLUSIVE)	Westinghouse Electric Company, LLC	Unirradiated fuel assemblies	Metal inner container (11.25"x18 1/8" x 182"); cushioning; wood outer container (30.25"x31.25"x207.75"); max. wt. 2988 lbs or 2964 lbs.
USA/9294/AF-96	NPC	Global Nuclear Fuel – Americas, LLC	Type A quantities of low enriched UO_2 powder, pellets, and U-compounds	Cubic stainless steel and foam outer package (45" x 45" x 44"); inner stainless steel w/ Cd and polyethylene (8.515" ID x 32"); max. wt. 2870 lbs.
USA/9297/AF-96	TRAVELLER STD AND TRAVELLER XL	Westinghouse Electric Company	Unirradiated uranium fuel assemblies or rods.	Horizontal tube outerpack w/foam and sheet metal impact limiters, Al clamshell structure w/neutron absorber plates, and stainless steel fuel assembly/rod container.
USA/9301/AF-85	TNF-XI	Transnuclear Inc. (Packaging Technology, Inc.)	Unirradiated enriched forms of uranium oxides.	Outer stainless steel container (44"x44"x37"); foam insulation; 4 inner wells for 3 pails having borated steel rings, and neutron poisoning BORA resin.

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Table 5. Other NRC Certified Fissile Material Packagings

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9309/B(U)F-96	RAJ-II	Global Nuclear Fuel – Americas, LLC	BWR fuel assemblies or rods meeting ASTM C996-96 standard.	Outer stainless steel box (29.21”x28.35”x199.53”); Al silicate and polyethylene foam; inner double-walled stainless steel structure.
USA/9315/B(U)F-96	ES-3100	U.S. Department of Energy (BWXT Y-12, LLC)	Highly-enriched uranium materials; cement based-borated neutron absorber.	Cylinder (19” dia x 43”) outer drum and inner vessel (5” dia x 32”); surrouned by borated cementitious neutron absorber Concrete/vermiculite insulation/impact limiting; max wt. 420 lbs.
USA/9319/B(U)F-96	MAP-12 AND MAP-13	AREVA NP, Inc.	Unirradiated uranium fuel assemblies.	Stainless steel strong-back base w/neutron moderator and absorber; stainless steel cover, rigid polyurethane foam, and outer stainless steel shell; polyurethane/steel impact limiters. Overall dimensions 208”x45”x31” or 221”x45”x31” (max wt. 8630 lbs)

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Table 5. Other NRC Certified Fissile Material Packagings

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9328/AF-96	TN-55	AREVA Federal Services, LLC (Packaging Technology, Inc.)	Unirradiated uranium oxide powder	55-gal. Drum (51 5/8" dia x 32") w/steel and fiberglass overpack; polyurethane foam; max wt. 1010 lbs.
USA/9342/AF-96	VERSA-PAC IN TWO CONFIGURATIONS, I.E., VP-55 AND VP-110	Century Industries	Uranium materials	55-gal (23 1/16" OD x 34 ¾") or 110-gal (30 7/16" OD x 42 ¾") carbon steel container w/ceramic fiber insulation. Max. Weight 640 lbs (55-gal) or 965 lbs (110-gal)

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Table 6. NRC Certified Packagings for Research and Test Reactor Fuel

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/5797/B(U)F	INNER HFIR UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER, AND OUTER HFIR UNIRRADIATED FUEL ELEMENT SHIPPING CONTAINER	U.S. Department of Energy	U-235 enriched U_3O_8-Al cermet w/ aluminum clad HFIR fuel	Carbon steel shell filled with stacked fir plywood rings. Inner Fuel Element packaging: 25" o.d. x 45" h, 660 lbs. Outer Fuel Element packaging: 31.3" o.d. x 45.75" h, 1050 lbs.
USA/9034/AF	TRIGA-I	General Atomics	TRIGA fuel elements containing uranium-zirconium-hydride or erbium-uranium-zirconium-hydride, clad with stainless steel, aluminum or incoloy.	Steel drum outer packaging 22.5" dia. x 39.25" h.; Inner vessel 5" Schedule 40 carbon steel pipe, ~31" h, ¼" wall, 5" inside dia. Inner vessel has a threaded pipe cap and welded ¼" thick flat disc bottom. Inner vessel supported in the outer packaging by eight 3/8" braced support rods. Void space filled with vermiculite having 4.5 lbs/ft^3 minimum density. Maximum weight including contents ~235 lbs.
USA/9037/AF	TRIGA-II	General Atomics	Special function TRIGA fuel elements containing uranium-zirconium-hydride or erbium-uranium-zirconium-hydride, clad with stainless steel, aluminum or incoloy.	Steel drum outer packaging 22.5" dia. x 57.5" h.; Inner vessel 5" Schedule 40 carbon steel pipe, ~50" h, ¼" wall, 5" inside dia. Inner vessel has a threaded pipe cap and welded ¼" thick flat disc bottom. Inner vessel supported in the outer packaging by eight 3/8" braced support rods. Void space filled with vermiculite having 4.5 lbs/ft^3 minimum density. Maximum weight including contents ~330 lbs.

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Table 6. NRC Certified Packagings for Research and Test Reactor Fuel

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9099/B(U)F-85	ATR	U.S. Department of Energy	Unirradiated Advanced Test Reactor (ATR) fuel elements, each element contains 19 formed fuel plates clad in aluminum 6061.	Right parallelepiped inner container, ~69.7” x 23 13/16” of ¾” plywood covered w/16-gauge steel. Top and bottom lined w/HDPE foam and 0.02” Cd plate. Wood spacers w/sponge rubber and 0.02” Cd plate to separate 4 fuel assemblies. Continuous hinge closure w/ 2 wire sealed hinge pins. Inner container enclosed in overpack container, 73 15/16” x 31 ¾” x 11 3/16”, 1” plywood, steel framing members and covered w/18-gauge steel; aluminum honeycomb impact limiters on both ends. Overpack closure w/4 hinge pins secured w/ 1/16” cotter pins. Package weight ~853 lbs.
USA/9228/B(U)F-96	2000	GE-Hitachi Nuclear Energy Americas, LLC (General Electric Co.)	Irradiated HFIR fuel assembly, TSR fuel elements, irradiated fuel rods, byproduct, source or SNM	Stainless steel encased lead shielded shipping cask, w/ overpack and impact limiters; Overall dimensions ~131”h x 72” dia; weight ~33,550 lbs.
USA/9246/AF	ST	National Institute of Standards and Technology	Unirradiated NBSR fuel element of enriched uranium and aluminum.	Closed steel pipe 5.5” o.d., ~71” long, closed bottom end and flanged top end. Top end closed by cover plate ¼” thick x 6.5” dia. and a gasket, secured to pipe flange w/8 cap screws. Fuel assembly positioned with a wooden nozzle support and a top support. Weight including fuel element ~75 lbs.

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Table 6. NRC Certified Packagings for Research and Test Reactor Fuel

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9330/AF-96	ATR FFSC	U.S. Department of Energy	Unirradiated Mark VII Advanced Test Reactor fuel composed of uranium aluminide (UAL), and contained in aluminum-clad fuel plates.	Insulated stainless steel package for transport of unirradiated research reactor fuel consisting of a body, lid, and inner packaging internals. Body composed of two thin-walled stainless steel shells. Outer shell is a square tube of 8” cross section, 72” long, and 3/16” thickness. Inner shell a round tube, 6” dia. and 0.120” thick. Inner tube wrapped with ceramic fiber insulation overlaid with a stainless steel sheet. Shells are welded on the bottom to a 0.88” thick stainless steel base plate, and on the top to a 1.5” thick stainless steel flange. Closure with circular stainless steel plates with fiber insulation using four rotated bayonets secured with two spring pins. Package internals include either a Fuel Handling Enclosure for intact fuel elements or a Loose Plate Basket Assembly for loose fuel plates.

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Table 6. NRC Certified Packagings for Research and Test Reactor Fuel

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9341/B(U)F-96	BEA Research Reactor (BRR) Package	AREVA Federal Services LLC	1. Irradiated MURR fuel element, max. burnup 180 MWD or U-235 depletion of 30.9%; min. cooling 180 days; 2. Irradiated MITR-II fuel element, max burnup 225 MWD or U-235 depletion of 59.3%; min. cooling 930 days; 3. Irradiated ATR fuel element, max. burnup 480 MWD or U-235 depletion of 58.6%; min. cooling 1,670 days; 4. Irradiated TRIGA fuel elements of five specific fuel types (GA 101, GA 103, GA109, GA 117, and GA 203).	ASTM Type 304 stainless steel structural material; lead-shielded cask body, payload basket, upper shield plug, closure lid, upper and lower impact limiters. Cylindrical cask 77.1” l x 38” dia. Thick lead shielding between two circular structures, in lower end structure, and in shield plug. Payload cavity 54” l x 16” dia. Loaded package prepared for transport is 119.5” l x 78” dia (over impact limiters), weight 32,000 lb.

8. Non-Fuel Type B Packagings

Sealed sources, radiography exposure devices, and other radioactive materials, such as the medical isotope Mo-99 fall under 21 CoCs; all but one of these are designated Type B(U); one is a Type AF for transporting PuBe neutron sources. In general, these packages are generally constructed of stainless steel with DU or lead shielding and using rigid polyurethane foam for structural support. Table 7 provides some summary detail on these packagings. These CoCs are held by the following organizations:

- AREVA Federal Services LLC
- Industrial Nuclear Co.
- MDS Nordion
- Neutron Products, Inc.
- QSA Global, Inc. (and AEA Technology QSA, Inc.)
- Source Production & Equipment Co. (SPEC)
- EnergySolutions Spent Fuel Division
- U.S. Department of Energy

An additional 11 CoCs are used for a variety of other waste materials. Table 8 summarizes details on these waste packagings.

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Table 7. NRC Certified Packagings for Sealed Sources, Radiological Exposure Devices, and Medical Isotopes

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/6613/B(U)-96	MODEL NO. 702	QSA Global, Inc.	Cs-137, Ir-192, Se-75, Yb-169 sealed sources	9” x 21” x 20” cask w/DU shielding mounted on steel skid; max. weight 410 lbs.
USA/9027/B(U)-96	741-OP	QSA Global, Inc.	Co-60 or Ir-192 sealed sources	Gamma ray projected within carbon steel container. Projector has steel shell, polyurethane foam, and DU shielding.
USA/9036/B(U)-96	C-1	Source Production & Equipment Co.	Ir-192, Se-75, Yb-169 sealed sources	Inner steel box w/DU shielding and 12-gal foam filled drum overpack. Max weight 100 lbs.
USA/9056/B(U)	SPEC 2-T	Source Production & Equipment Co.	Ir-192 sealed sources	Steel encased, DU shielded gamma ray projector; 13 3/8” l x 4 11/16” h x 4 3/8” w; max weight 56 lbs.
USA/9148/B(U)-85	770	AEA Technology QSA, Inc.	Ir-192, Co-60, Sc-46, Cs-137 sealed sources	Steel encased, DU shielded w/ polyurethane foam source changer; 23” l x 24” w x 19.75” h; gross weight 970 lbs.
USA/9157/B(U)-96	IR-100	Industrial Nuclear Co.	Ir-192 sealed sources	Stainless steel exposure device housing w/ DU shielding and rigid polyurethane foam; 8.87” l x 4.5” w x 8.5” h.
USA/9185/B(U)-96	OP-100	Industrial Nuclear Co.	Ir-192 sealed sources	Source changer or exposure device positioned in a 10 gal. Steel drum. Devices are ~8.87” l x 4.5” w x 8.5” h w/ DU shielding in stainless housing filled w/rigid foam; max weight 53 or 77 lbs.
USA/9187/B(U)-96	865	QSA Global, Inc.	Ir-192 sealed sources	Steel encased, DU shielded radiographic exposure device; 5” dia. x 12.25” l; gross weight ~59 lbs.
USA/9215/B(U)	NPI-20WC-6 MKII	Neutron Products, Inc.	Co-60 sealed sources	Steel encased, lead shielded cask in a wood overpack with outer steel shell. Overpack 49” dia x 59” h; max. weight 6000 lbs.
USA/9263/B(U)-96	SPEC-150	Source Production & Equipment Co.	Ir-192 sealed sources	Ti encased, DU shielded radiographic exposure device; 5.4”w x 5.6”h x 14.5” long box; max weight 53 lbs.
USA/9269/B(U)-96	650L	QSA Global, Inc.	Ir-192, Se-75 sealed sources	Stainless steel, DU shielded source changer; 10” l x 113.25” h x 8.25” wide box; max weight 90 lbs.

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Table 7. NRC Certified Packagings for Sealed Sources, Radiological Exposure Devices, and Medical Isotopes

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9282/B(U)-96	SPEC-300	Source Production & Equipment Co.	Co-60 sealed sources	DU shielded radiography device in stainless steel and polyurethane foam; max weight 780 lbs.
USA/9283/B(U)-96	OPL-660 AND OP-660	QSA Global, Inc.	Ir-192 sealed sources	Radiography camera w/DU shielding in steel/wood/foam protective container.
USA/9287/B(U)-85	STERIGENICS EAGLE	AREVA Federal Services LLC (Packaging Technology, Inc.)	Co-60 sealed sources	Stainless steel, lead shielded shipping cask w/removable impact limiters, inner supporting basket. Lead shielding thickness: 10 3/8" side, 14 3/8" top, 11 7/8" bottom. Outer dimensions 49 7/8" h x 37 11/16" dia.; max total weight 20,000 lbs.
USA/9290/B(U)-96	MODEL NO. F-430/GC-40 TRANSPORT PACKAGE	MDS Nordion	Cs-137 sealed source	Cylindrical stainless steel transport package for irradiator device; max weight 7000 lbs.; nested stainless steel shells w/rigid polyurethane foam; lead shielded irradiator device.
USA/9296/B(U)-96	880 SERIES PACKAGES	QSA Global, Inc.	Ir-192, Se-75 sealed sources	Exposure device/transport package.13 5/16" h x 5" dia stainless steel cylinder w/DU shielding.
USA/9299/B(U)-85	F-423	MDS Nordion	Co-60 sealed sources	Double-walled stainless steel overpack w/polyurethane foam for shipping lead shielded gamma irradiator devices.
USA/9310/B(U)-96	MODEL NO. F-431 TRANSPORT PACKAGE	MDS Nordion	Cs-137 sealed sources (special form and non-special form)	Overpack (stainless steel and rigid foam), lead shielded irradiator device containing source material. 50.5" h x 42" dia. on steel skid; max weight 5000 lbs.
USA/9314/B(U)-96	976 SERIES	QSA Global, Inc.	Ir-192, Se-75, Yb-169 sealed sources	Six versions, all wi/ 20 gal stainless drum outer container and cork inserts to support inner shield containers made of steel/stainless steel w/DU shielding.
USA/9320/B(U)-96	MIDUS	EnergySolutions Spent Fuel Division	Mo-99 liquid solution	Inner shielded cask w/impact and thermal overpack. Inner cask DU sandwiched between stainless steel; overpack of stainless steel shells filled with polyurethane foam. Overall 551mm h x 520 mm dia.; 330 kg max weight.
USA/9329/AF-96	S300	U.S. Department of Energy	PuBe sealed sources	55-gal. Steel drum (35" h x 23" dia.); package weight 480 lbs; internal polyethylene liner, stainless steel pipe w/ HDPE shielding insert.

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Table 8. NRC Certified Packagings for Waste Materials

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9168/B(U)	CNS 8-120B	EnergySolutions (Chem-Nuclear Systems, Inc.)	Byproduct material and activated reactor components	Carbon steel, lead shielded 74" OD x 88" h cask; thermal barrier; steel/rigid polyurethane foam impact limiters
USA/9184/B(U)	PAS-1	AREVA Federal Services LLC (Nuclear Packaging, Inc.)	Containerized liquid or gas samples; byproduct and activation materials	Primary stainless steel containment vessel (20.5"ODx23.4"OH) inside a secondary vessel and lead radiation shield (32.5"ODx39"OH); foam-filled steel encased overpack.
USA/9204/B(U)F-96	10-160B	EnergySolutions (Chem-Nuclear Systems, Inc.)	Byproduct, source, and SNM; activated reactor components	Cylindrical carbon steel and lead shielded cask (78.5" OD x 88"h); stainless steel thermal shield; impact limiters
USA/9212/B(M)F-96	RH-TRU 72-B	U.S. Department of Energy (Westinghouse TRU Solutions, LLC)	Byproduct, source, and SNM	Stainless steel, lead-shielded cask (41 5/8" OD x 141 ¾" H) for TRU waste; inner stainless steel vessel; foam-filled impact limiters.
USA/9218/B(U)F-96	TRUPACT-II	U.S. Department of Energy (Westinghouse TRU Solutions, LLC)	TRU and tritium-contaminated materials and wastes	Stainless steel and polyurethane foam insulated shipping container (~94" dia x 122" h) for contact-handled TRU; max. weight 19,250 lbs.

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Table 8. NRC Certified Packagings for Waste Materials

Package Identification Number	Model No.	Certificate Owner	Content	Summary Description
USA/9233/B(U)-96	TN-RAM	Transnuclear, Inc.	Dry irradiated and contaminated non-fuel-bearing solid materials.	Steel encased, lead shielded, w/wood impact limiters. Cask: 51"OD x 129" L; Overall (w/limiters) 92" OD x 178" L. Gross weight ~80,000 lbs.
USA/9279/B(U)F-96	HALFPACT WASTE SHIPPING CONTAINER	U.S. Department of Energy (Westinghouse TRU Solutions, LLC)	Byproduct, source, and SNM	Stainless steel and polyurethane foam insulated shipping container (~74" dia x 69" h) for contact-handled TRU; max. weight 18,100 lbs.
USA/9280/AF-85	UBE-1	BWX Technologies, Inc.	U and U-Be mixtures	55-gal. Steel drum; gross weight ~600 lbs.
USA/9281/AF-85	UBE-2	BWX Technologies, Inc.	U and U-Be mixtures	70-gal. Steel drum; gross weight ~1000 lbs.
USA/9285/AF-85	SRP-1	Global Nuclear Fuels – Americas, LLC (GE)	U-contaminated solid residues	55-gal. Steel drum; maximum weight ~825 lbs.
USA/9305/B(U)F-96	TRUPACT-III PACKAGE	AREVA Federal Services LLC	TRU contaminated materials and wastes	Rectangular box 98.4" w x 104.3" h x 168.8" l.; stainless steel, polyurethane foam, balsa wood; maximum package weight: 55, 116 lbs.

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9. Discussion of NPP Container Concept

The NPP container concept is for a cylindrical package consisting of a lead gamma shield sandwiched between layers of high density polyethylene (HDPE) of specific characteristics, and manufactured under an NPP patent. Silica (SiO_2) has been suggested as a possible backfill material supporting the radioactive material content, and an outer fireproof coating has been proposed for thermal protection. Possible advantages of this container concept are the longevity of the HPDE and that it is not subject to corrosion as are metals, smaller container dimensions and weight, and lower production costs. A heat flux calculation was performed in 2006 for a model package having an inner HDPE thickness of 2.0 cm, a lead thickness of 2.0 cm, and outer HDPE thickness of 1.0 cm, heated at 1000W. A finite element code was used to model steady-state heat transfer for thermal conduction and radiation, and gave an outer surface temperature of 46ºC, and an inner HDPE surface temperature of 60ºC. Results of an experiment exposing the material to nuclear radiation are available but have not yet been reviewed. How well the package would perform under the testing requirements for obtaining NRC certification is unknown.

HDPE, sometimes including boron, is available commercially for neutron shielding (see for example http://johncaunt.com/pages/shielding/neutron_shield.html). Other companies supplying similar products include Shielding Solutions, Shieldwerx, MarShield, Quadrant EPP, and San Diego Plastics. Lead has long been used for gamma shielding, and is also available commercially from a number of sources. The NPP container, utilizing both HDPE and lead, might therefore be considered for applications requiring both neutron and gamma shielding. From the review of the 76 active NRC CoCs, possible applications are for transport and storage of spent nuclear fuel and some kinds of nuclear waste, and other radioactive materials used for medical, industrial, or research applications. In addition to providing adequate shielding for neutron and gamma radiation, certification requirements address goals for material containment under normal and accident conditions, prevention of nuclear criticality, and heat dissipation. The NPP container concept would need considerable development and testing to demonstrate compliance with these rigorous requirements.

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10. References

1. "Proposed Scope of Work for Evaluation of NPP Container Concept," prepared by Lockheed Martin and Sandia National Laboratories, August 17, 2010.
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