71-9270

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January 31, 2002

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Attn: Document Control Desk

Subject: Submittal of Supplemental Information for UMS® Universal Transport Cask Application Docket No. 71-9270 (TAC No. L22452)

References:
1. Submittal of the NAC Responses to the NRC Request for Additional Information, not including Chapter 2 Structural Evaluation, Revision UMST-01A, NAC International, March 14, 2001
2. Submittal of the NAC Responses to the NRC Request for Additional Information (RAI) on the UMS® Universal Transport Cask Application, Chapter 2 Structural Evaluation, Revision UMST-01B, NAC International, March 30, 2001
3. Request for Additional Information related to the NAC-UMS® Transportation Package Certificate of Compliance Amendment Request, U.S. Nuclear Regulatory Commission, June 14, 2001
4. Submittal of the NAC International Responses to the NRC Request for Additional Information on the UMS® Universal Transport Cask Application, Revision UMST-01D, NAC International, November 16, 2001

In accordance with various discussions with Steve Baggett (NRC), NAC International (NAC) herewith submits ten copies of supplemental information to Reference 4.

This submittal includes Safety Analysis Report (SAR) changed pages, which are designated as Revision UMST-02A of the UMS® Universal Transport Cask SAR. Changes are editorial in manner throughout and a list of these changes is attached. Note: The enclosed SAR changed pages are to be inserted as replacement or new additional pages, as applicable, into the existing SAR binders. The List of Effective Pages provided in this submittal can be used to ensure that the correct page revisions are incorporated in the SAR binders.

The changed pages have been prepared in accordance with the following conventions:

- Revision indicators (shading and revision bars) are used to highlight changes. Shading indicates a revision from SAR Revision 0, while a revision bar indicates a change in the SAR from a previous revision, other than Revision 0.

- The changed pages for this submittal are designated as Revision UMST-02A to provide a unique identification of the pages and changes.

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- All of the pages in the List of Effective Pages are designated Revision UMST-02A and no revision bars are used on those pages.

This submittal includes two new drawings:

412-501, Revision 2 Spent Fuel Can Assembly, Maine Yankee (MY), NAC-UMS®
412-502, Revision 2 Fuel Can Details, Maine Yankee (MY), NAC-UMS®

These drawings of the Maine Yankee Fuel Can details were inadvertently omitted in the previous submittal. However, the appropriate analyses were included in the previous submittal.

This submittal also includes a NAC Proprietary Information Calculation Package, EA790-2801, Revision 3, "Structural Analysis of PWR and BWR Fuel Assemblies in a Top End-Drop Accident." Three copies of the calculation package are provided in appropriately marked separate packaging. The required Proprietary Information Affidavit has been executed and is attached.

If you have any comments or questions, please contact me on my direct line at 678-328-1321.

Sincerely,

W. J. Lee for T.C.T.

Thomas C. Thompson
Director, Licensing
Engineering & Design Services

Enclosures: 10 copies of UMST-02A changed SAR pages
3 copies of Calculation Package, EA790-2801, Revision 3

Attachments: List of UMST-02A changes
Proprietary Information Affidavit

cc: Paul Plante (MY)
Tom Williamson (MY)

ED20020055

NAC's Responses to the NRC's UMS® Transport RAI-2 Acceptance Review Concerns

1/24/02 Concerns

1. In Chapter 3, Thermal: Pages 3.4-57 through 3.4-70 were deleted from the submittal and the List of Effective Pages and were thus intended to be removed from the binder. In the future, more specific and clearer instructions will be provided.

   Also, note that pages 3.5-29 through 3.5-31 have likewise been deleted from the submittal and should be removed from the binder.

2. Table 3.4-17 versus Tables 1.2-6 and 1.2-7: Tables 1.2-6 and 1.2-7 are for the generic UMS® contents—i.e., the fuel assemblies with burnup <45 GWD/MTU. Only the Maine Yankee site-specific fuel is evaluated for burnup up to 50 GWD/MTU.

   In the clad temperature analysis, the extension of fuel burnup to 50 GWD/MTU (for Maine Yankee) is included in the generic calculation of allowable clad temperatures. This was done in order not to repeat the clad temperature analysis in Section 3.6 for the Maine Yankee site-specific fuel

3. Table 5.4-21 versus Table 1.2-6: Table 5.4-21 is correct. Table 1.2-6 will be revised to be consistent with Table 5.4-21.

4. Review Chapters 3 and 5 to ensure that the text references to figures and tables are correct: Chapters 3 and 5 have been reviewed in detail for Section, Figure and Table references, with the following being noted:

   Chapter 3

   - Table 3.4-4 on page 3.4-49 – Title is not consistent with the List of Tables. The List of Tables, Table 3.4-4 on page 3-viii, will be corrected to match the Table title in the text.

   - Text, page 3.6-8 – First paragraph refers to Canister Gas: Air in Table 3.4-1. The "Canister Gas: Air" reference will be deleted since Table 3.4-1 was revised per discussion with the NRC to show helium only.

   Chapter 5

   - Text, page 5.2-7 – The first reference to Table 5.2-20 will be changed to Table 5.2-19.

   - Text, page 5.4-5 – Fourth paragraph reference to Table 3.4-8 will be changed to Table 3.4-16

5. Chris Brown's concerns about the adequacy of NAC's response to RAI 1-2 on high burnup fuel material properties: No response required from NAC at this time.

1/25/02 Concerns

1. List of Drawings: The List of Drawings in the submittal was inadvertently printed from an earlier version. The correct List of Drawings will be provided, including two additional drawings to address the Maine Yankee fuel can that were not originally on the list.

2. Section 2.10.3.11: Section 2.10.3 was revised significantly and compressed upon completion of the scale model side drop test at Sandia in March 2001. Consequently, Section 2.10.3.11 was deleted and should not be referenced in the SAR. Chapter 2 was reviewed for references to Section 2.10.3.11 and no references were found. (Note: Sections 2.10.3.8, 2.10.3.9 and 2.10.3.10 were also deleted.)

3. Review Chapters 2 and 7 to ensure that the text references to figures and tables are correct: Chapters 2 and 7 have been reviewed in detail for Section, Figure and Table references, with the following being noted:

   Chapter 2

   - Text, page 2.3-13 – Second paragraph – A sentence will be added to reference Table 2.3.5-3.
   - Text, page 2.3-22 – Second paragraph will be revised to be consistent with the remainder of the section.
   - Text, page 2.5-50 – First paragraph reference to Figure 2.5.2-1 will be changed to Figure 2.5.2.1-2.
   - Text, page 2.6-1 – Fourth paragraph reference to PWR and BWR cask pressures from Section 3.4.4 will be changed to 6.91 psig and 3.65 psig, respectively.
   - Text, page 2.6-24 – Third paragraph reference to Table 2.6.7.5-3 will be changed to Table 2.6.7.5-6.
   - Text, page 2.6-25 – First paragraph reference to Table 2.6.7.5-3 will be changed to Table 2.6.7.5-6.
   - Text, page 2.6-25 – Fourth paragraph reference to Table 2.6.7.1-16 will be changed to Table 2.6.7.1-15.
   - Text, page 2.6-38 – First paragraph reference to Table 2.6.7.5-3 will be changed to Table 2.6.7.5-6.
   - Text, page 2.6-38 – Third paragraph reference to minimum margins of safety will be changed to +0.08 and +0.33 to agree with Tables 2.6.7.2-5 and 2.6.7.2-6, respectively.
   - Text, page 2.6-95 – Line 12 reference to Table 4.2-1 will be corrected.
   - Text, page 2.6-116 – Fourth paragraph reference to Table 1.2-3 will be changed to Table 1.2-2.
   - Text, page 2.6-116 – Fifth paragraph reference to Tables 2.1.2-2 and 2.1.2-3 will be changed to Tables 2.1.2-3 and 2.1.2-4.

- Text, page 2.6-244 – First paragraph reference overall lengths of two BWR canisters will be changed to 185.6 and 190.4 to agree with Table 1.2-2.
- Text, page 2.6-244 – First paragraph reference to Table 1.2-3 will be changed to Table 1.2-2.
- Text, page 2.6-244 – First paragraph reference to longest canister length of 191.95 in. will be changed to 191.80 to agree with Table 1.2-2.
- Text, page 2.6-244 – Second paragraph reference to ISG-4 will be changed to ISG-15 (as ISG-4 was superseded by ISG-15 in January 2001).
- Table 2.6.14.9-1, page 2.6-288 -- The minimum margin of safety for the bottom corner drop + pressure + thermal (cold), 45° basket will be changed from +1.54 to +1.57 to agree with Table 2.6.14.9-4.
- Text, page 2.6-355 – First paragraph reference to Section 2.6.15.6.3 will be changed to Section 2.6.15.6.2.
- Pages 2.6-383 through 2.6-402 are duplicate pages and should be removed from the binder.
- Text, page 2.7-3 – Third full paragraph reference to Section 2.1.2.3 will be changed to Section 2.1.2.4.
- Text, page 2.7-22 – Second paragraph will be deleted.
- Text, page 2.7-139 – First paragraph reference to ISG-4 will be changed to ISG-15 (as ISG-4 was superseded by ISG-15 in January 2001).
- Text, page 2.10.3-2 – Second paragraph reference to Section 2.10.3.9 will be changed to Section 2.10.3.7.
- Text, page 2.10.3-24 – Last line on page reference to Section 2.10.3.9 will be changed to Section 2.10.3.7.
- Text, page 2.10.3-25 – Third line reference to Section 2.10.3.9 will be changed to Section 2.10.3.7.
- Text, page 2.10.4-1 – Third paragraph reference to Table 2.6.7.5-1 will be changed to Table 2.10.4.1-1.
- Text, page 2.10.4-7 – Last paragraph reference to Table 2.6.7.5-1 will be changed to Table 2.10.4.1-1.
- Text, page 2.11.1-2 – Third paragraph, the first reference to Figure 2.11.1.1-1 will be changed to Table 2.11.1.1-1.

Chapter 7

- Text, page 7-1 – The last paragraph will be deleted.
- Text, page 7.1-4 – The reference to Section 7.5 in the third bullet will be changed to the UMS® Storage System FSAR.
- Text, page 7.3-4 – The references to Table 7-2 in Steps 31 and 33 will be changed to Table 7-1.

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AFFIDAVIT PURSUANT TO 10 CFR 2.790

Willington J. Lee (Affiant), Vice President & Chief Engineer of NAC International, 655 Engineering Drive, Norcross, Georgia 30092, being duly sworn, deposes and says that:

1. Affiant has reviewed the information described in Item 2 and is personally familiar with the trade secrets and privileged information contained therein, and is authorized to request its withholding.

2. The information sought to be withheld is the following NAC International calculation package in support of the NAC-UMS® Universal Transport Cask submittal, which is being transmitted with NAC Letter No. ED20020055:

   - Calculation Package, EA790-2801, Revision 3, "Structural Analysis of PWR and BWR Fuel Assemblies in a Top End-Drop Accident."

   NAC International is the owner of this information; the information is considered proprietary to NAC International.

3. NAC International makes this application for withholding of proprietary information based upon the exemption from disclosure set forth in: the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4) and the Trade Secrets Act, 18 USC Sec. 1905, and NRC Regulations 10 CFR Part 9.17(a)(4), 2.790(a)(4), and 2.790(b)(1) for "trade secrets and commercial financial information obtained from a person, and privileged or confidential" (Exemption 4). The information for which exemption from disclosure is here sought is all "confidential commercial information," and some portions may also qualify under the narrower definition of "trade secret," within the meaning assigned to those terms for purposes of FOIA Exemption 4.

4. Examples of categories of information that fit into the definition of proprietary information are:

   a. Information which discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by NAC's competitors without license from NAC International constitutes a competitive economic advantage over other companies.

   b. Information which, if used by a competitor, would reduce their expenditure of resources or improve their competitive position in the design, manufacture, shipment, installation, assurance of quality or licensing of a similar product.

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(continued)

c. Information which reveals cost or price information, production capacities, budget levels or commercial strategies of NAC International, its customers, or its suppliers.

d. Information which reveals aspects of past, present or future NAC International customer-funded development plans and programs of potential commercial value to NAC International.

e. Information that discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in Items 4a, 4b, and 4d.

5. The information sought to be withheld is being transmitted to the United States Nuclear Regulatory Commission (NRC) in confidence.

6. The information sought to be withheld, including that compiled from many sources, is of a sort customarily held in confidence by NAC International, and is, in fact, so held. This information has, to the best of my knowledge and belief, consistently been held in confidence by NAC International. No public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in Items 7 and 8 following.

7. Initial approval of proprietary treatment of a document is made by the Project Manager and/or the Director of Licensing, the persons most likely to know the value and sensitivity of the information in relation to industry knowledge. Access to proprietary documents within NAC International is limited via "controlled distribution" to individuals on a "need to know" basis. The procedure for external release of NAC proprietary documents typically requires the approval of the Project Manager based on a review of the documents for technical content, competitive effect and accuracy of the proprietary designation. Disclosures of proprietary documents outside of NAC International are limited to regulatory agencies, customers and potential customers and their agents, suppliers, licensees and contractors with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

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(continued)

8. NAC International has invested a significant amount of time and money in the research, development, engineering and analytical costs to develop the information that is sought to be withheld as proprietary. This information is considered to be proprietary because it contains detailed descriptions of analytical approaches, methodologies, technical data and evaluation results not available elsewhere. The precise value of the expertise required to develop the proprietary information is difficult to quantify, but it is clearly substantial.

9. Public disclosure of the information that is sought to be withheld is likely to cause substantial harm to the competitive position of NAC International, as the owner of the information, and reduce or eliminate the availability of profit-making opportunities. The proprietary information is part of NAC International's comprehensive spent fuel storage and transport technology base, and its commercial value extends beyond the original development cost to include the development of the expertise to determine and apply the appropriate evaluation process. The value of this proprietary information and the competitive advantage that it provides to NAC International would be lost if the information were disclosed to the public. Making such information available to other parties, including competitors, without their having to make similar investments of time, labor and money would provide competitors with an unfair advantage and deprive NAC International of the opportunity to seek an adequate return on its large investment.

STATE OF GEORGIA, COUNTY OF GWINNETT

Mr. Willington J. Lee, being duly sworn, deposes and says:

That he has read the foregoing affidavit and the matters stated therein are true and correct to the best of his knowledge, information and belief.

Executed at Norcross, Georgia, this 31st day of January 2002.

Willington J. Lee

Willington J. Lee
Vice President & Chief Engineer
NAC International

Subscribed and sworn before me this 31st day of January, 2002

Katherine M DeLoughy

MY COMMISSION EXPIRES MAY 15, 2005

EA790-SAR-001

DOCKET NO. 71-9270

UMS®

UNIVERSAL MPC SYSTEM®

SAFETY ANALYSIS REPORT

for the

UMS® Universal Transport Cask

JANUARY 2002 UMST-02A

VOLUME 1 OF 2

NAC INTERNATIONAL

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1.0 GENERAL INFORMATION

NAC International (NAC) has designed a canister-based system for the storage and transportation of spent nuclear fuel. The system is designated the Universal MPC System®. Its design is based on the dual-licensed, patented, and proven technology of the NAC Storable Transport Cask (NAC-STC, Docket No. 71-9235) and its basket and other licensed NAC cask designs. The transportation component of the UMS®, designated the Universal Transportation System, consists of a Universal Transport Cask loaded with a Transportable Storage Canister containing either spent fuel or Greater Than Class C (GTCC) waste. This Safety Analysis Report (SAR) demonstrates the ability of the Universal Transport Cask to satisfy the requirements of the U.S. Nuclear Regulatory Commission (NRC) for the transport of spent fuel as defined in the 10 CFR 71 [1]. In addition to these requirements, the cask also satisfies the requirements of IAEA Safety Series No. 6 [2] for the international transport of radioactive material.

The value of the transport index for nuclear criticality control for the cask containing Pressurized Water Reactor (PWR) or Boiling Water Reactor (BWR) spent fuel is determined to be zero (0) in accordance with 10 CFR 71.59. Therefore, an infinite number of packages with optimum internal and external moderation remain subcritical. The transport index based on dose rate evaluations at 1 meter from the external surface of the package is determined to be eighteen (18) in accordance with 10 CFR 71.4 (Transport Index).

This Safety Analysis Report is formatted in accordance with U.S. NRC Regulatory Guide 7.9 [3] and NUREG-1617 [6]. This chapter presents a general introduction to the Universal Transport Cask and a detailed description of its design features. The terminology used throughout this report is summarized in Table 1-1.

Table 1-1 Terminology

Universal Transport Cask	The packaging, consisting of a Universal Transport Cask body with a closure lid and energy-absorbing impact limiters. The Universal Transport Cask is used to transport a Transportable Storage Canister containing spent fuel or GTCC waste. The cask body provides the primary containment boundary during transport.
Packaging	The assembly of components necessary to ensure compliance with the packaging requirements of 10 CFR 71. Within this report, the packaging is denoted as the Universal Transport Cask.
Package	The packaging with its radioactive contents (spent fuel or GTCC waste), as presented for exclusive transport use (10 CFR 71.4). Within this report, the package is denoted as the Universal Transport Cask, the transport cask, or, simply, the cask.
Contents	Twenty-four PWR fuel assemblies, fifty-six BWR fuel assemblies or Greater Than Class C (GTCC) waste. The fuel assemblies may be configured as site specific fuel. The fuel assemblies or waste is contained in a Transportable Storage Canister.
Standard fuel	Irradiated fuel assemblies having the same configuration as when originally fabricated consisting generally of the end fittings, fuel rods, guide tubes, and integral hardware. For BWR fuel, the channel is considered to be integral hardware. The design basis fuel characteristics and analysis are based on Zircaloy clad fuel rods in a standard fuel configuration.
Intact fuel assembly	Irradiated fuel that does not show evidence of greater than pinhole leaks or hairline cracks in the fuel rod cladding.
Intact fuel rod	A fuel rod without known or suspected cladding defects greater than a pinhole leak or a hairline crack.

Table 1.-1 Terminology (continued)

Site specific fuel	Spent fuel configurations that are unique to a site or reactor due to the addition of other components or reconfiguration of the fuel assembly at the site. It includes fuel assemblies which hold nonfuel-bearing components, such as control components or instrument and plug thimbles, or which are reconfigured as required by expediency in reactor operations, research and development or testing. Reconfiguration may consist of individual fuel rod removal, fuel rod replacement of similar or dissimilar material or enrichment, or the installation, removal or replacement of burnable poison rods. Site specific fuel includes irradiated fuel assemblies designed with variable enrichments or axial blankets and fuel that is consolidated.
Consolidated fuel	A nonstandard fuel configuration in which the individual fuel rods from one or more fuel assemblies are placed in a single container or a lattice structure that is similar to a fuel assembly.
Greater than Class C waste	Activated and surface contaminated metal, usually stainless steel, whose disposal is controlled by 10 CFR 61 due to the presence of very long-lived isotopes, including ^{59}Ni, ^{94}Nb and ^{14}C.
Containment system	The components of the packaging that retain the radioactive material and gases during transport.

Table 1.-1 Terminology (continued)

Cask cavity	The volume of space within the containment boundary.
Cask body	
- multiwall body	Consists of concentric layers of the inner shell, gamma shielding, outer shell, and neutron shielding material.
- neutron shield	Consists of a stainless steel outer shell, and end plates; copper stainless steel (Cu/SS) fins; and solid NS-4-FR neutron shielding material.
Cask lid	A 6.5 in.-thick steel disk used to close the Universal Transport Cask. The lid is attached to the top forging by 48 bolts.
Top forging	The component that forms the top of the Universal Transport Cask cavity and to which the cask lid is bolted.
Cask bottom	
- Bottom forging	The cup-shaped component that forms the bottom of the Universal Transport Cask cavity.
- Bottom plate	The plate welded to the outer shell to form the bottom of the cask. The bottom plate encloses the neutron shielding material in the bottom of the cask.
Drain port	Penetration through the bottom forging and the bottom ring that may be used to drain the cask cavity if necessary.
Vent port	Penetration used to access the cask cavity to backfill and leak-test the cask cavity prior to transport. The vent port is recessed in the cask lid.
Seal test port	The port used to test the containment seal. The test port is closed by a threaded plug fitted with an o-ring. The seal test port is recessed in the cask lid.
Port coverplates	The sealed covers that protect the quick disconnect located in the ports.

Table 1-1 Terminology (continued)

Quick disconnect	The valved nipple used to operate the ports.
Lifting trunnions	Four high-strength stainless steel components located at the top forging that are used in pairs for lifting and handling the Universal Transport Cask. The two primary lifting trunnions are welded to the top forging and the two secondary lifting trunnions are bolted to the top forging.
Rotation pocket	Two stainless steel blocks, each provided with a deep machined groove to accept the rear cask support. These pockets are welded onto the outer shell near the bottom of the cask.
NS-4-FR	A solid, synthetic polymer; a borated hydrogenous material with neutron absorption capabilities similar to those of borated water. Developed by BISCO Products, Inc. and previously supplied by Genden Engineering Services & Construction Company, NS-4-FR is now supplied by the Japan Atomic Power Company and its product licensees. Genden Engineering Services & Construction Company is a former subsidiary of Japan Atomic Power.
Transport impact limiters (upper and lower)	Impact limiters designed for use during transport of the Universal Transport Cask. They protect the cask by limiting impact loads during the 1-ft free drop (normal conditions of transport) and the 30-ft free drop (hypothetical accident conditions).
Transportable Storage Canister	The stainless steel cylindrical shell, bottom end plate, shield lid, and structural lid that contains the fuel or GTCC waste basket structure and the contents.
Shield lid	A 7 in.-thick stainless steel disk that is the inner component of a double-welded closure system for the Transportable Storage Canister. The shield lid provides a containment/confinement boundary (for storage only) and shielding for the contents.
Structural lid	A 3 in.-thick stainless steel disk that is the outer component of a double-welded closure system for the Transportable Storage Canister. Positioned on top of the shield lid and welded to the canister, the structural lid provides a confinement boundary (for storage) shielding for the contents, and canister lifting/handling capability.

Table 1.1-1 Terminology (continued)

Basket	The structure located within the Transportable Storage Canister that provides structural support, criticality control, and primary heat transfer paths for the fuel assemblies or GTCC waste.
- support disk	A circular steel plate with 24 (PWR basket) or 56 (BWR basket) square holes machined in a symmetrical pattern. The support disk is the primary lateral load-bearing component of the basket. Each square hole in the support disk is a location for a fuel tube. For GTCC waste, the support disk design is modified to accommodate the GTCC basket configuration.
- heat transfer disk	A circular aluminum plate with 24 (PWR basket) or 56 (BWR basket) square holes machined in a symmetrical pattern. The heat transfer disks are the primary heat transfer component in the PWR and BWR fuel baskets.
- fuel tube	A stainless steel tube with a square cross-section that encases BORAL neutron poison material on its exterior surfaces. One fuel tube is inserted through each square hole in the support disks and heat transfer disks of the PWR and BWR baskets. Fuel assemblies are loaded into the fuel tube.
- tie rod	Aligns, retains and supports the support disks and the heat transfer disks in the PWR and BWR fuel basket. The tie rods extend from the top weldment to the bottom weldment of the fuel basket.
-spacer	Installed on the tie rod between the support disks (BWR only) or between the support disks and upper and lower weldments (BWR and PWR) to properly position the disks and provide axial support for the support disks.
- split spacer	Installed on the tie rod between the support and heat transfer disks to properly position the disks and provide axial support for the support disks and heat transfer disks in the PWR and BWR baskets.

Table 1 -1 Terminology (continued)

Canister spacer	Stainless steel or aluminum components that position the canister in the Universal Transport Cask cavity during transport. Spacers are used for canisters containing fuel of Classes 1, 2, 4, or 5.
Transfer cask	A shielded lifting device used for handling of the Transportable Storage Canister during loading of spent fuel or GTCC waste, canister closure operations, and transfer of the canister into or out of the Universal Transport Cask, or into or out of the vertical concrete cask during storage operations. The Transfer Cask is described in the Safety Analysis Report for the onsite storage (10 CFR 72) components of the UMS®, Docket No. 72-1015.
Vertical concrete cask	The cask used to store the Transportable Storage Canister containing spent fuel or GTCC waste. The Vertical Concrete Cask is described in the Safety Analysis Report for the on-site storage (10 CFR 72) components of the UMS®, Docket No. 72-1015.
Maine Yankee Fuel Can	A specially designed stainless steel screened can sized to hold an intact fuel assembly, consolidated fuel or damaged fuel. The can screens permit draining and drying, while precluding the release of gross particulates into the canister cavity. The Maine Yankee Fuel Can may only be loaded into a Class 1 Canister.
High Burnup Fuel	A Maine Yankee fuel assembly having a burnup between 45,000 and 50,000 MWD/MTU, which must be preferentially loaded in periphery positions in the basket. An intact high burnup fuel assembly in which no more than 1% of the fuel rods in the assembly have a peak cladding oxide thickness greater than 80 microns, and in which no more than 3% of the fuel rods in the assembly have a peak oxide layer thickness greater than 70 microns, as determined by measurement and statistical analysis, may be stored as intact fuel. High burnup fuel not meeting these criteria is classified as damaged fuel.

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Radioactive material shipments in the Universal Transport Cask shall be subject to the following limits:

1. The maximum contents weight for the Universal Transport Cask shall not exceed 77,500 lb.

2. The design basis fuel characteristics shall be in accordance Tables 1.2-4 and 1.2-5.

3. The total decay heat of the cavity contents shall not exceed 20 kW for PWR fuel and 16 kW for BWR fuel.

4. The total weight of the PWR fuel assemblies, including standard inserts such as burnable poison rods or guide tube thimble plugs, shall not exceed 38,500 lb.

5. The total weight of the BWR fuel assemblies shall not exceed 39,000 lb.

6. Radiation levels shall not exceed the requirements of 10 CFR 71.47, 10 CFR 71.51, and IAEA Safety Series No. 6, paragraph 469.

7. Surface contamination levels shall not exceed the requirements of 10 CFR 71.87(i)(1) and IAEA Safety Series No. 6, paragraph 408.

8. Cask general spent fuel contents shall be in accordance with the limiting values shown below, and must be loaded in accordance with Tables 1.2-6 (PWR) and 1.2-7 (BWR).

Parameter	PWR Cask	BWR Cask
Number of assemblies	24	56
Max. UO_2 weight (MTU)	11.53	11.08
Max initial enrichment (wt % ^{235}U)	4.2	4.0
Min. initial enrichment (wt % ^{235}U)	1.9	1.9
Max. Burnup (MWD/MTU)	45,000	50,000
Min. cooling time (years)	5	6

9. Cask site-specific contents may include Maine Yankee fuel with maximum burnup up to 50,000 MWD/MTU and GTCC waste as described in Section 1.3.1.1 based on the site-specific fuel characteristics and preferential loading pattern.

Figure 1.2-1 Operational Schematic for the Universal Transport Cask

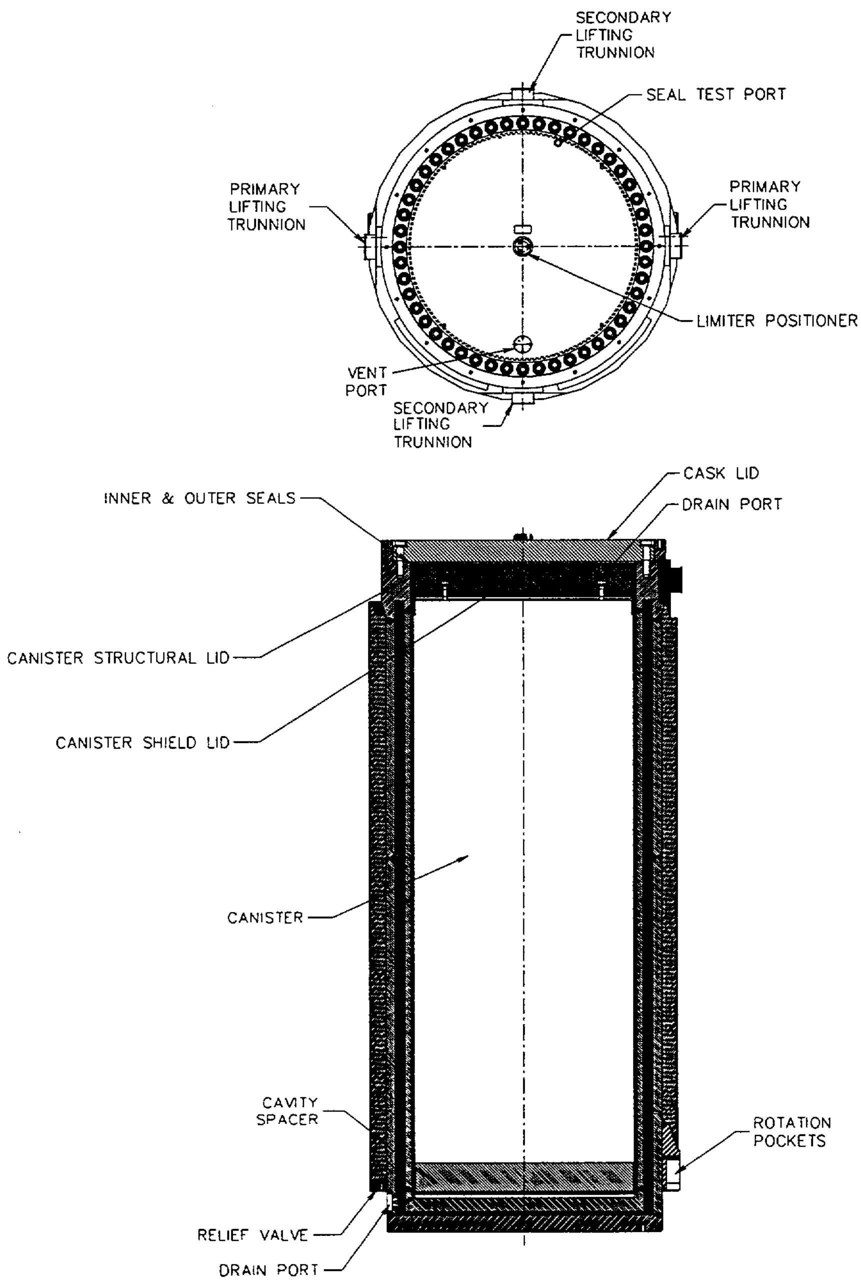


Table 1.2-3 Basket Assembly Design Parameters

Basket Parameter	Value
Basket Assembly Length (in.)	
Class 1 (PWR)	162.8
Class 2 (PWR)	171.9
Class 3 (PWR)	179.5
Class 4 (BWR)	173.3
Class 5 (BWR)	178.1
Basket Assembly Diameter (in.)	65.5
No. of support disks	
Class 1 (PWR)	30
Class 2 (PWR)	32
Class 3 (PWR)	34
Class 4 (BWR)	40
Class 5 (BWR)	41
No. of heat transfer disks	
Class 1 (PWR)	29
Class 2 (PWR)	31
Class 3 (PWR)	33
Class 4 (BWR)	17
Class 5 (BWR)	17
No. of fuel tubes	
Classes 1 - 3 (PWR)	24 (BORAL on all four sides)
Classes 4 - 5 (BWR)	56 (42 with BORAL on two sides; 11 with BORAL on one side; and 3 with no BORAL)
No. of tie rods	
Classes 1 - 3 (PWR)	8
Classes 4 - 5 (BWR)	6

Table 1.2-4 PWR Fuel Assembly Characteristics

Canister Class[1]	Vendor[2]	Array	Max. Length (in)	Max. Width (in)	Max. Assembly Weight (lb)	Max. MTU	No of Fuel Rods	Max. Pitch (in)	Min. Rod Dia. (in)	Min. Clad Thick (in)	Max. Pellet Dia.(in)	Max. Active Length (in)	Min. Guide Tube Thick (in)
1	CE	14x14	157.3	8.11	1292	0.404	176	0.590	0.438	0.024	0.380	137.0	0.040
1	Ex/ANF	14x14	160.2	7.76	1271	0.369	179	0.556	0.424	0.030	0.351	142.0	0.034
1	WE	14x14	159.8	7.76	1177	0.362	179	0.556	0.400	0.024	0.345	144.0	0.034
1	WE	14x14	159.8	7.76	1302	0.415	179	0.556	0.422	0.022	0.368	145.2	0.034
1	WE, Ex/ANF	15x15	159.8	8.43	1472	0.465	204	0.563	0.422	0.024	0.366	144.0	0.015
1	Ex/ANF	17x17	159.8	8.43	1348	0.413	264	0.496	0.360	0.025	0.303	144.0	0.016
1	WE	17x17	159.8	8.43	1482	0.468	264	0.496	0.374	0.022	0.323	144.0	0.016
1	WE	17x17	160.1	8.43	1373	0.429	264	0.496	0.360	0.022	0.309	144.0	0.016
2	B&W	15x15	165.7	8.54	1515	0.481	208	0.568	0.430	0.026	0.369	144.0	0.016
2	B&W	17x17	165.8	8.54	1505	0.466	264	0.502	0.379	0.024	0.324	143.0	0.017
3	CE	16x16	178.3	8.10	1430	0.442	236	0.506	0.382	0.023	0.3255	150.0	0.035
1	Ex/ANF[3]	14x14	160.2	7.76	1215	0.375	179	0.556	0.417	0.030	0.351	144.0	0.036
1	CE[3]	15x15	147.5	8.20	1360	0.432	216	0.550	0.418	0.026	0.358	132.0	---
1	Ex/ANF[3]	15x15	148.9	8.25	1339	0.431	216	0.550	0.417	0.030	0.358	131.8	---
1	CE[3]	16x16	158.2	8.10	1300	0.403	236	0.506	0.382	0.023	0.3255	136.7	0.035

1. Minimum and maximum initial enrichments are 1.9 wt % ^{235}U and 4.2 wt % ^{235}U, respectively. All fuel rods are Zircaloy clad.
2. Vendor ID indicates the source of assembly base parameters. Loading of assemblies meeting dimensional limits is not restricted to the vendor(s) listed.
3. 14x14, 15x15 and 16x16 fuel manufactured for Prairie Island, Palisades and St. Lucie 2 cores, respectively. These are not generic fuel assemblies provided to multiple reactors.

Table 1.2-5 BWR Fuel Assembly Characteristics

Canister Class[1,5]	Vendor[4]	Array	Max. Length (in)	Max. Assembly Width (in)[6]	Max. Assembly Weight (lb)[7]	Max. MTU	No of Fuel Rods	Max. Pitch (in)	Min. Rod Dia. (in)	Min. Clad Thick (in)	Max. Pellet Dia.(in)	Max. Active Length (in)[2]
4	Ex/ANF	7 X 7	171.3	5.51	620	0.196	48	0.738	0.570	0.036	0.490	144.0
4	Ex/ANF	8 X 8	171.3	5.51	563	0.177	63	0.641	0.484	0.036	0.405	145.2
4	Ex/ANF	9 X 9	171.3	5.51	557	0.173	79	0.572	0.424	0.030	0.357	145.2
4	GE	7 X 7	171.1	5.51	681	0.199	49	0.738	0.570	0.036	0.488	144.0
4	GE	7 X 7	171.2	5.51	681	0.198	49	0.738	0.563	0.032	0.487	144.0
4	GE	8 X 8	171.1	5.51	639	0.173	60	0.640	0.484	0.032	0.410	145.2
4	GE	8 X 8	171.1	5.51	681	0.179	62	0.640	0.483	0.032	0.410	145.2
4	GE	8 X 8	171.1	5.51	681	0.186	63	0.640	0.493	0.034	0.416	144.0
5	Ex/ANF	8 X 8	176.1	5.51	588	0.180	62	0.641	0.484	0.036	0.405	150.0
5	Ex/ANF	9 X 9	176.1	5.51	576	0.167	74[3]	0.572	0.424	0.030	0.357	150.0
5[6]	Ex/ANF	9 X 9	176.1	5.51	576	0.178	79[3]	0.572	0.424	0.030	0.357	150.0
5	GE	7 X 7	175.9	5.51	683	0.198	49	0.738	0.563	0.032	0.487	144.0
5	GE	8 X 8	176.1	5.51	665	0.179	60	0.640	0.484	0.032	0.410	150.0
5	GE	8 X 8	175.9	5.51	681	0.185	62	0.640	0.483	0.032	0.410	150.0
5	GE	8 X 8	175.9	5.51	681	0.188	63	0.640	0.493	0.034	0.416	146.0
5	GE	9 X 9	176.1	5.51	646	0.186	74[3]	0.566	0.441	0.028	0.376	150.0
5	GE	9 X 9	176.1	5.51	646	0.198	79[3]	0.566	0.441	0.028	0.376	150.0

1. Maximum Peak Planar Average Enrichment 4.0 wt % ^{235}U. Minimum enrichment is 1.9 wt % ^{235}U. All fuel rods are Zircaloy clad.
2. 150 inch active fuel length assemblies contain 6" natural uranium blankets on top and bottom.
3. Shortened active fuel length in some rods.
4. Vendor ID indicates the source of assembly base parameters. Loading of assemblies meeting dimensional limits is not restricted to the vendor(s) listed.
5. UMS Class 4 accommodates BWR reactor class 2-3 fuel. UMS Class 5 accommodates BWR reactor class 4-6 fuel.
6. Assembly width including channel. Unchanneled or channeled assemblies may be loaded based on a maximum channel thickness of 120 mil.
7. Exxon/ANF assembly weights are listed without channel.

Table 1.2-6 Loading Table for PWR Fuel

Enrichment	Burnup ≤ 30 GWD/MTU Minimum Cool Time [years]					30 < Burnup ≤ 35 GWD/MTU Minimum Cool Time [years]					35 < Burnup ≤ 40 GWD/MTU Minimum Cool Time [years]				
wt % ^{235}U (E)	CE14x14	14x14	15x15	16x16	17x17	CE14x14	14x14	15x15	16x16	17x17	CE14x14	14x14	15x15	16x16	17x17
1.9 ≤ E < 2.1	6	8	8	7	8	8	10	11	9	10	11	15	15	13	15
2.1 ≤ E < 2.3	6	7	8	6	7	7	10	10	8	10	10	13	14	12	13
2.3 ≤ E < 2.5	6	7	7	6	7	7	9	10	8	9	9	12	13	11	12
2.5 ≤ E < 2.7	6	7	7	6	7	7	9	9	7	8	9	12	12	10	11
2.7 ≤ E < 2.9	6	7	7	6	7	6	8	9	7	8	8	11	11	9	11
2.9 ≤ E < 3.1	5	7	7	6	6	6	8	8	7	8	8	10	10	9	10
3.1 ≤ E < 3.3	5	6	7	6	6	6	8	8	7	7	7	10	10	9	10
3.3 ≤ E < 3.5	5	6	6	6	6	6	7	8	6	7	7	9	10	8	9
3.5 ≤ E < 3.7	5	6	6	6	6	6	7	7	6	7	7	9	10	8	9
3.7 ≤ E ≤ 4.2	5	6	6	6	6	6	7	7	6	7	7	8	10	8	9

Enrichment	40 < Burnup ≤ 45 GWD/MTU Minimum Cool Time [years]				
wt % ^{235}U (E)	CE14x14	14x14	15x15	16x16	17x17
1.9 ≤ E < 2.1	18	20	21	20	20
2.1 ≤ E < 2.3	15	19	19	18	19
2.3 ≤ E < 2.5	14	17	19	17	17
2.5 ≤ E < 2.7	12	16	18	15	17
2.7 ≤ E < 2.9	11	15	18	14	17
2.9 ≤ E < 3.1	10	14	18	13	15
3.1 ≤ E < 3.3	10	13	17	13	15
3.3 ≤ E < 3.5	9	12	17	13	15
3.5 ≤ E < 3.7	8	11	17	12	15
3.7 ≤ E ≤ 4.2	8	11	15	12	14

1.3.1 Site Specific Contents

This section describes fuel assembly characteristics and configurations, or waste configurations, which are unique to specific reactor sites. These site specific content configurations result from conditions that occurred during reactor operations, participation in research and development programs, testing programs intended to improve reactor operations, from decommissioning activities, and from the placement of control components or other items within the fuel assembly.

Site specific fuel assembly configurations are either shown to be bounded by the analysis of the standard design basis fuel assembly configuration of the same type (PWR or BWR), or are shown to be acceptable contents by specific evaluation of the configuration.

Site specific Greater Than Class C (GTCC) waste configurations are shown to be acceptable by specific evaluation.

In general, the evaluations of site specific contents are presented in the Appendix section of the appropriate SAR Chapter. This enables the site specific fuel assembly configuration evaluations, which encompasses a wide range of configurations, to be separated from the evaluations performed for the standard fuel assembly configurations.

1.3.1.1 Maine Yankee Site Specific Contents

This section describes Transportable Storage Canister spent fuel contents which differ from the standard design basis 14x14 fuel assembly by virtue of reconfiguration of individual fuel assemblies during the course of reactor operations. It also describes the GTCC waste placed in the GTCC waste canister and basket, Drawings 790-612 and 790-611, respectively. The design basis fuel assembly (Westinghouse 17x17 as described in Section 1.2.3 and Table 1.2-4) bounds most of the Maine Yankee site specific fuel configurations. However, as appropriate to the configuration, additional analysis is provided in the Appendix to the appropriate Chapter.

1.3.1.1.1 Maine Yankee Site Specific Spent Fuel Configurations

The standard Maine Yankee reactor fuel assembly is the Combustion Engineering (CE) 14x14. The principal characteristics of this fuel are shown in Table 1.2-4. Fuel of the same design has also been supplied by Westinghouse and by Exxon. The evaluation of this standard fuel is bounded by the evaluation of the Westinghouse 17x17 spent fuel assembly, which is the design basis PWR fuel assembly for the NAC-UMS® Universal Transport Cask.

In the course of reactor operations, certain of the 14x14 fuel assemblies were modified to change the standard configuration. The principal modifications are of three general types:

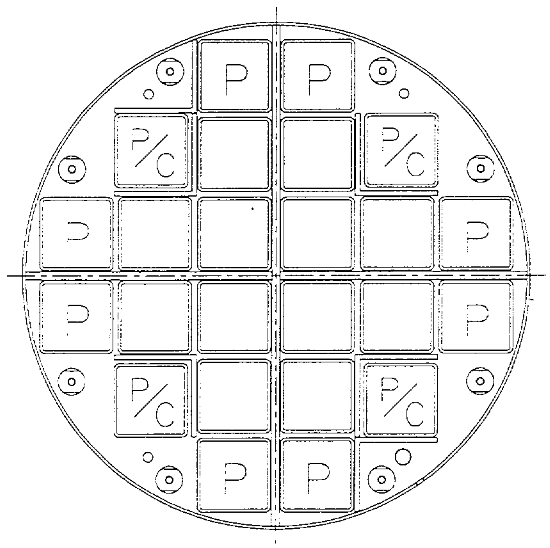
- The removal of fuel rods without replacement;
- The replacement of removed fuel rods or burnable poison rods with rods of another material, such as stainless steel, or with fuel rods of a different enrichment; and,
- The insertion of control elements, or instrument or plug thimbles, in guide tube positions.

In addition to the modified fuel assemblies, there are fuel assemblies that were designed with variable enrichment and axial blankets. These fuel assemblies are not modified, but differ from the cask design basis fuel assemblies.

As part of a research and development program, Maine Yankee removed the fuel rods from several fuel assemblies and installed those fuel rods in two lattice structures that are similar to a 17x17 fuel assembly. This fuel is referred to as consolidated fuel. The lattice structures are constructed of stainless steel 17x17 grids that are equally spaced on 4 stainless steel support rods. Stainless steel end plates are attached to the ends of the support rods to hold the spent fuel rods within the grids. The upper end plate conforms to the fuel assembly upper end fitting design so that the consolidated fuel rod holder can be lifted with the fuel assembly grapple. One consolidated fuel lattice has 283 fuel rods with 2 empty fuel rod positions. The second lattice has 172 fuel rods with the remaining fuel rod positions either unused or holding stainless steel dummy rods.

A fuel assembly with removed fuel rods, poison rods or a consolidated fuel lattice shall be loaded in one of the four corner positions of the PWR fuel basket. Additionally, only one consolidated fuel lattice may be loaded in any single basket. These corner positions, designated "P/C" in the following figure, are separated from the other fuel positions by slightly larger flux traps, which results in these positions having less reactive interaction with the remaining fuel positions. The corner positions are also peripheral positions designated by the letter "P."

Preferential Loading Diagram for Maine Yankee Site Specific Spent Fuel



The canister loading procedures will indicate that the loading of a fuel assembly with removed fuel or poison rods, or a consolidated fuel lattice, is administratively controlled to ensure the correct loading in one of the corner positions and that only one consolidated fuel lattice is loaded in any single canister.

The configurations of the Maine Yankee site specific fuel assemblies that have been evaluated and found to be acceptable contents include:

- Fuel assemblies with up to 176 fuel rods removed from the assembly lattice.
- Fuel assemblies with fuel rods replaced with either stainless steel rods, solid Zircaloy rods or fuel rods enriched to 1.95 wt %.
- Fuel assemblies with burnable poison rods replaced with hollow Zircaloy tubes.
- Fuel assemblies that are variably enriched.
- Fuel assemblies with annular axial blankets.
- Fuel assemblies with a control element inserted.
- Fuel assemblies with an instrument thimble inserted in the center guide tube.
- Fuel assemblies with up to two fuel rods inserted in any or all of the guide tubes.
- Consolidated fuel lattices.
- High burnup fuel assemblies.
- Fuel assemblies with start-up sources and other non-fuel items inserted in the guide tubes.
- Damaged fuel.

A fuel assembly, with a Control Element Assembly (CEA), CEA flow plug, or thimble plug inserted, will be loaded in a Class 2 canister and basket for storage and transport due to the increased length of the assembly with the control element installed; however, such an assembly is not restricted to any specific location within the basket.

A fuel assembly having fuel rods replaced by solid stainless steel or Zircaloy rods may be loaded in any location in the basket.

Intact fuel assemblies may have non-fuel items inserted in the guide tubes. The non-fuel items are irradiated and unirradiated start-up sources, CEA fingertips and a segment of an in-core instrument (ICI) thimble. Start-up sources are inserted in a center guide tube position. The remaining items must be installed in corner guide tube positions. These guide tubes are closed on the bottom end by the assembly end plate and are closed on the top end by a CEA flow plug. Only one start-up source may be loaded in any fuel assembly; however, a fuel assembly with a start-up source may also hold all of the remaining non-fuel items. Any fuel assembly with a start-up source must be loaded in one of the corner fuel positions of the basket.

The structural evaluation of the Maine Yankee site specific fuel configurations is provided in Section 2.11.1. The thermal, containment, shielding and criticality evaluations are provided in Sections 3.6.1, 4.5.1.1, 5.5.1.1 and 6.6.1.1, respectively. As shown in those evaluations, the design basis spent fuel assembly analyses generally bound the loading of the Maine Yankee spent fuel. Where the design basis analysis is not bounding, preferential loading is required.

Table 1.3.1-1 shows the currently known population of Maine Yankee fuel assemblies. This table also shows the proposed loading scheme for those fuel assemblies in the Transportable Storage Canister.

Table 1.3.1-1 Maine Yankee Spent Fuel Population

Spent Fuel Configuration	**Number of Assemblies**	**Canister Loading Position**	**Canister Class**
Standard	1,434	Any	1
Inserted Control Component	168	Any	2
Inserted Instrument Thimble	138	Any	1
Consolidated Fuel	2	P/C[1]	1
Fuel Rod Replaced by Rod Enriched to 1.95 wt %	3	Any	1
Fuel Rod Replaced by Stainless Steel Rod or Zircaloy Rod	18	Any	1
Fuel Rods Removed	10	P/C	1
Variable Enrichment	72	Any	1
Axial Blanket	68	Any	1
Burnable Poison Rod Replaced by Hollow Zircaloy Rod	80	P/C	1 or 2
Burnup between 45,000 and 50,000 MWD/MTU	90	Any	1
Maine Yankee Fuel Can	As Required	P/C	1
Inserted Start-up Source	5	P/C	1
Inserted CEA Fingertips or ICI String Segment	1	Any	2

1. Only one consolidated fuel lattice may be loaded in any Transportable Storage Canister.

1.3.1.1.2 Maine Yankee Greater Than Class C Waste

The disposal of Greater Than Class C (GTCC) waste is controlled by 10 CFR 61 [7]. GTCC is defined in 10 CFR 61.55(a)(3) and (4) by the concentration of long-lived radionuclides, i.e., ^{14}C, ^{59}Ni, and ^{94}Nb, and/or short-lived radionuclides, i.e., ^{3}H, ^{60}Co, and ^{63}Ni.

GTCC waste consists of radiation activated and surface contaminated steel. Stainless steel core baffle structure, which is located adjacent to the reactor vessel in a high neutron flux field, is the major component of GTCC waste. The core baffle structure is cut underwater into pieces that are loaded into a GTCC basket. The GTCC basket is installed in a GTCC canister that has the same external dimensions as a Class 1 fuel canister.

The principal isotopic constituents of typical GTCC waste are presented in Table 1.3.1-2. The radionuclide composition of the waste was determined based on radiochemical assay of samples and dose rate measurements of the waste containers. The isotopes that primarily contribute to the radiological source term are ^{54}Mn, ^{55}Fe, ^{60}Co, and ^{63}Ni. The source terms applied in the evaluation of the GTCC waste are presented in Table 5.5.1.2-1. There is no combustible gas generation from the GTCC waste and there are no chemical or galvanic corrosion reactions with the stainless steel canister.

The design of the GTCC canister and basket is shown in Drawings 790-612 and 790-611, respectively. This basket is designed to fit the Class 1 Transportable Storage Canister. The structural evaluation of the basket for Maine Yankee waste is shown in Section 2.11.2. The thermal evaluation is shown in Section 3.6.1. The containment and shielding evaluations are shown in Sections 4.5.1.1 and 5.5.1.2, respectively. Since the GTCC waste does not contain any significant fissionable material, no criticality analysis is required.

The calculated weight of the loaded and sealed GTCC waste canister is:

	Pounds
GTCC waste canister (with both lids):	18,140
Weight of GTCC basket:	32,320
Weight of GTCC waste	20,000
Total	70,460

This weight is less than the weight of the Class 1 Transportable Storage Canister containing spent fuel.

The GTCC waste canister is essentially identical to the UMS® Class 1 Transportable Storage Canister, except for the placement of lifting lugs and the placement of a keyway within the canister. Consequently, the interior and exterior dimensions and the materials of fabrication of the GTCC waste canister and lids are the same as those for the Class 1 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 stainless steel plate. The cylinder is centered in the GTCC waste canister by 14 Type 304 stainless steel support plates along its length. The support plates are 1-inch thick and 65.3 inches in diameter. The interior diameter of the basket cavity is 48.8 inches and its interior length is 157 inches. A 3-inch thick stainless steel separator fixture divides the cylinder into two vertically stacked compartments, each 77 inches deep. The separator fixture restricts the diameter of the upper compartment to 47.8-inches.

Since the GTCC waste canister has the same external dimensions as the UMS® Class 1 Transportable Storage Canister, one 16.75-inch canister spacer is required during transport of the GTCC waste canister. Transport spacers are described in Section 1.2.1.2.9.

Table 1.3.1-2 Isotopic Constituents of the Design Basis GTCC Waste

Radionuclide	**Curie Inventory (Ci)/Canister**
^{3}H	3.00E+02
^{14}C	1.50E+02
^{54}Mn	3.50E+02
^{55}Fe	2.00E+05
^{58}Co	1.00E+01
^{60}Co	2.90E+05
^{59}Ni	8.20E+02
^{63}Ni	9.00E+04
^{94}Nb	1.00E+01
^{99}Tc	1.00E+01
Total	5.82E+05

1.3.4 License Drawings

This section contains the License Drawings pertinent to the Universal Transport Cask. The dimensions indicated on the drawings are generally limited to one significant digit past the decimal point. Note that analysis of systems or components may present dimensions with additional significant digits based on more detailed engineering drawings.

Drawing No.	Rev. No.	Title
790-209	1	Impact Limiter Assembly-Upper, Cask, NAC-UMS®
790-210	1	Impact Limiter Assembly-Lower, Cask, NAC-UMS®
790-500	2	Assembly, Universal Transport Cask, Overpack, NAC-UMS®
790-501	3	Canister/Basket Assembly Table, NAC-UMS®
790-502	4	Cask Body, Transport Cask, NAC-UMS®
790-503	1	Lid Assembly, NAC-UMS® Cask
790-504	1	Port Coverplate Assembly, NAC-UMS®
790-505	1	Lifting Trunnion, NAC-UMS®
790-508	2	Misc. Details, Transport Cask, NAC-UMS®
790-509	2	Nameplates - NAC-UMS®
790-516	1	Package Assembly, Universal Transport Cask (UTC), NAC-UMS®
790-519	0	Package Assembly, Transport, Universal Transport Cask (UTC), NAC-UMS®
790-520	2	Spacers, Universal Transport Cask, NAC-UMS®
790-570	3	Fuel Basket Assembly, 56 Element BWR, NAC-UMS®
790-571	2	Bottom Weldment, Fuel Basket, 56 Element BWR, NAC-UMS®

Licensed Drawings (Continued)

Drawing No.	Rev. No.	Title
790-572	4	Top Weldment, Fuel Basket, 56 Element BWR, NAC-UMS®
790-573	7	Support Disk and Misc. Basket Details, 56 Element BWR, NAC-UMS®
790-574	3	Heat Transfer Disk Fuel Basket, 56 Element BWR, NAC-UMS®
790-575	7	BWR Fuel Tube, NAC-UMS®
790-581	5	PWR Fuel Tube, NAC-UMS®
790-582	6	Shell Weldment, Canister, NAC-UMS®
790-583	4	Assembly, Drain Tube, Canister, NAC-UMS®
790-584	9	Details, Canister, NAC-UMS®
790-585	7	Transportable Storage Canister (TSC), NAC-UMS®
790-591	2	Bottom Weldment, Fuel Basket, 24 Element PWR, NAC-UMS®
790-592	4	Top Weldment, Fuel Basket, 24 Element PWR, NAC-UMS®
790-593	4	Support Disk and Misc. Basket Details, 24 Element PWR, NAC-UMS®
790-594	2	Heat Transfer Disk, Fuel Basket, 24 Element PWR, NAC-UMS®
790-595	4	Fuel Basket Assembly, 24 Element PWR, NAC-UMS®
790-605	8	BWR Fuel Tube, Over-Sized Fuel, NAC-UMS®
790-611	0	GTCC Waste Basket, Maine Yankee, NAC-UMS®
790-612	1	GTCC Waste Canister, Maine Yankee, NAC-UMS®
412-501	2	Spent Fuel Can Assembly, Maine Yankee (MY), NAC-UMS®
412-502	2	Fuel Can Details, Maine Yankee (MY), NAC-UMS®

FIGURE WITHHELD UNDER 10 CFR 2.390

QTY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
1	2	TOP ASSEMBLY			412-502-98	
1	1	SPENT FUEL CAN WELDMENT			412-502-99	

NAC INTERNATIONAL

SPENT FUEL CAN ASSEMBLY
MAINE YANKEE (MY)
NAC-UMS®

PROJECT 412 DRAWING 501 REV 2

SCALE FULL EST. WT. 133# SH 1 OF 1

NEXT ASSEMBLY: N/A DRAWING TYPE: LICENSE

FIGURE WITHHELD UNDER 10 CFR 2.390

INTERNATIONAL

FUEL CAN DETAILS
MAINE YANKEE (MY)
NAC–UMS®

QUANTITY				
DIMENSIONING AND TOLERANCING SHALL BE PER ANSI Y14.5–82 UNSPECIFIED DIMENSIONS AND TOLERANCES SHOWN BELOW. DIMENSIONS ARE IN INCHES. FRACTIONAL TOLERANCE: ±1/8				
SYM. GEOMETRY	.XXX	TOL.	.XX	TOL.
	UNDER 3		UNDER 6	±.04
FLATNESS	3–12		6–18	±.06
STRAIGHTNESS	OVER 12		OVER 18	±.09
	.X	±.1	ANGLES ±.5°	
ANGULARITY	ALL UNSPECIFIED TOOL RADII: .01 – .03			
PERPENDICULARITY	BREAK ALL SHARP CORNERS .01 – .03			
PARALLELISM	ALL UNSPECIFIED MACHINED SURFACES SHALL BE 125 OR BETTER			
CONCENTRICITY	NEXT ASSEMBLY: 412–501			
TRUE POSITION	DRAWING TYPE: LICENSE			

GROUP	NAME	DATE
PREPARER	[illegible]	5-25-00
CHECKER	R. [illegible]	5-25-00
PROJECT MANAGER	[illegible]	5-25-00
DIRECTOR DESIGN AND ANALYSIS	[illegible]	5/26/00
DIRECTOR LICENSING	[illegible]	5/26/00
VICE PRESIDENT, QUALITY	[illegible]	[illegible]

PROJECT 412		DRAWING 502	REV 2
SCALE FULL	EST.WT. NOTED	SH 1 OF 4	4:02PM 5-25-2000

FIGURE WITHHELD UNDER 10 CFR 2.390

NAC INTERNATIONAL

FUEL CAN DETAILS
MAINE YANKEE (MY)
NAC-UMS®

PROJECT 412		DRAWING 502	REV 2
SCALE FULL	EST.WT. NOTED	SH 2 OF 4	3-25-2000

FIGURE WITHHELD UNDER 10 CFR 2.390

NAC INTERNATIONAL			
FUEL CAN DETAILS MAINE YANKEE (MY) NAC–UMS®			
PROJECT 412		DRAWING 502	REV 2
SCALE FULL	EST.WT. NOTED	SH 3 OF 4	4:07PM 3-25-2009

FIGURE WITHHELD UNDER 10 CFR 2.390

NAC INTERNATIONAL

FUEL CAN DETAILS
MAINE YANKEE (MY)
NAC–UMS®

PROJECT 412		DRAWING 502	REV 2
SCALE FULL	EST.WT. NOTED	SH 4 OF 4	

2.3.5 Bolting Materials

The bolting materials for the Universal Transport Cask are selected to provide high strength, good resistance to corrosion and coefficients of thermal expansion similar to those of the components being joined.

The cask lid bolts are made of SB-637, Grade N07718 nickel alloy bolting material. The mechanical properties of this material are presented in Table 2.3.5-1. The mechanical properties for the port coverplate bolts, which are fabricated of SA-193, Grade B6 stainless steel, are presented in Table 2.3.5-2. The mechanical properties for the retaining rods, which are made of SA-193, Grade B8S austenitic stainless steel, are presented in Table 2.3.5-3.

Table 2.3.5-1 Mechanical Properties of SB-637, Grade N07718 Nickel Alloy Steel Bolting Material

Property	**Value**							
Temperature (°F)	**-40**	**-20**	**70**	**200**	**300**	**400**	**500**	**750**
Ultimate Strength Stress, S_u *	No Value Given	185.0	185.0	177.6	173.5	170.6	168.7	165.0
Yield Stress, S_y (ksi) *	No Value Given	150.0	150.0	144.0	140.7	138.3	136.8	133.8
Maximum Allowable Stress, S (ksi) [21]	No Value Given	37.0	37.0	36.0	35.2	34.6	34.2	33.5
Design Stress Intensity, S_m (ksi) [21]	No Value Given	50.0	50.0	48.0	46.9	46.1	45.6	44.6
Modulus of Elasticity, E (ksi) [21]	29.6E+03	29.5E+03	29.0E+03	28.3E+03	27.8E+03	27.6E+03	27.1E+03	26.1E+03
Alternating Stress @ 10 cycles (ksi) [17]	13.3	13.7	13.1	12.7	12.5	12.4	12.2	11.7
Coefficient of Thermal Expansion, α (in/in/°F) [21]	No Value Given		7.05E-06	7.22E-06	7.33E-06	7.45E-06	7.57E-06	7.82E-06
Poisson's Ratio [21]	← 0.31 →							
Density [21]	← 503 lbm/ft³ (0.291 lbm/in³) →							

Note: Reference [17] Appendix I.

* Calculated based on Design Stress Intensity:

$$\left(\frac{S_{m-temp}}{S_{m\,70^\circ}}\right) S_{u70} = S_{u-temp}$$

Table 2.3.7-2 Mechanical Properties of NS-4-FR

Property	**Value**			
Temperature (°F)	**86**	**158**	**212**	**302**
Compressive Modulus, E_c (ksi) [26]	561	561	561	561
Coefficient of Thermal Expansion, α (in/in/°F) [26]	2.22E-05	4.72E-05	5.88E-05	5.741E-05
Density, (lbm/in^3) [26]	0.0607	0.0607	0.0607	0.0607

2.3.8 Impact Limiter Materials

The transport impact limiters for the Universal Transport Cask are fabricated from redwood and balsa wood that is encased in stainless steel shells. The impact limiters absorb the kinetic energy of the loaded cask in a drop impact by crushing the redwood and balsa wood. The energy dissipated, or absorbed by crushing the wood, for a given increment of time, is equal to the integral of the area (i.e., area of impact limiter engaged in crushing) times the crush strength of the wood. The area under the force-deflection curve is equal to the amount of energy absorbed by crushing of the redwood, balsa wood, and the impact limiter shell.

The static and dynamic crush properties have been determined by performing tests on redwood and balsa wood used in the impact limiters. The results of these tests are discussed in Section 2.6.7.5.3. These properties have been used in LS-DYNA, which is an explicit finite element program capable of performing three-dimensional nonlinear analysis of structures containing nonlinear material behavior such as plastic deformation of steel or crushing of wood.

The component stresses on the effective thickness weld group are:

$$S_{AC} = \frac{M_y c_x}{I_y} = \frac{(5{,}167{,}500)(12.07)}{(8886)} = 6{,}887 \text{ psi} \quad \text{(bending stress at points A \& C)}$$

$$S_{BC} = \frac{M_x c_y}{I_x} = \frac{(1{,}404{,}000)(8.375)}{6570} = 1{,}790 \text{ psi} \quad \text{(bending stress at points B \& C)}$$

$$S_s = \frac{F_R}{A_W} = \frac{1{,}373{,}000}{168} = 8{,}030 \text{ psi} \qquad \text{(resultant direct shear stress)}$$

$$(S_{ST})_A = \frac{M_Z}{2bht_A} = \frac{2{,}412{,}000}{(2)(19.94)(13.875)(1.0)} = 4385 \text{ psi (torsional shear stress at point A)}$$

$$(S_{ST})_B = \frac{M_Z}{2bht_B} = \frac{2{,}412{,}000}{(2)(19.94)(13.875)(2.875)} = 1517 \text{ psi (torsional shear stress at point B)}$$

The Von Mises equivalent stresses at Points A, B, and C are:

$$S_{EA} = \left[S_{AC}^2 + 3(S_S{}^2 + (S_{ST}^2)_A)\right]^{0.5} = 17{,}279 \text{ psi}$$

$$S_{EB} = \left[S_{BC}^2 + 3(S_S{}^2 + (S_{ST}^2)_B)\right]^{0.5} = 14{,}267 \text{ psi}$$

$$S_{EC} = \left[(S_{AC} + S_{BC})^2 + 3S_S^2\right]^{0.5} = 16{,}393 \text{ psi}.$$

The minimum margin of safety at the weld/cask interface is based on the yield strength of cask material A-240, Type 304 stainless steel outer shell with S_y = 25 ksi and is:

$$MS = \frac{25{,}000}{17{,}279} - 1 = +0.45.$$

The positive margins of safety show that the rotation pockets satisfy the requirements of 10 CFR 71.45 (b).

2.5.2.3 Front Support

The longitudinal force toward the top end of the cask is resisted by a shear ring welded to the cask top forging. The shear ring bears on the shipping frame along two 46-degree arcs (Figure 2.5.2.1-2).

The load on the shear ring is $R_{jx} = 2{,}600{,}000$ lb.

Assuming that the neoprene cradle cushion compresses to 0.25 in. thick, the effective width of the ring in direct bearing against the side of the support frame is 1.65 in. The bearing pressure is

$$A_{brg} = (2)(92/360)(\pi)(42.88)(1.65) = 113.6 \text{ in}^2$$
$$S_{brg} = 2{,}600{,}000/113.6 = 22{,}887 \text{ psi.}$$

The allowable bearing stress on the surface of SA-336 Type 304 stainless steel is

$$(S_{brg})_{Allow} = 25{,}000 \text{ psi at a temperature of } 200°\text{F.}$$

The margin of safety for bearing is $MS = \frac{23{,}750}{22{,}887} 4 - 1 = +0.09.$

The shear stress across the weld is

$$S_s = R_{jx}/A_w = 2{,}600{,}000/185 = 14{,}054 \text{ psi}$$

where $A_w = \pi(0.5)(85.26 + 82.61)(92/360)(1.375)(2) = 185 \text{ in}^2.$

The margin of safety for shear is $MS = \frac{(0.6)(23{,}750)}{14{,}054} 5 - 1 = +0.07.$

2.6 Normal Conditions of Transport

This section presents the evaluation of the Universal Transport Cask for structural integrity for the normal conditions of transport.

10 CFR 71.71 requires that the Universal Transport Cask be structurally adequate for the following normal conditions of transport: (1) heat, (2) cold, (3) reduced external pressure, (4) increased external pressure, (5) vibration, (6) water spray, (7) free drop, (8) corner-drop, (9) compression, and (10) penetration. In the free-drop analyses, the cask impact orientation evaluated is the orientation that inflicts the maximum damage to the cask. The regulation requires that the cask be evaluated for the normal conditions of transport at the most unfavorable ambient temperature in the range from -40°F to +100°F.

The results of these evaluations demonstrate that the cask satisfies the requirements of 10 CFR 71.71 for normal conditions of transport.

2.6.1 Heat

The Universal Transport Cask is analyzed for structural adequacy in accordance with the requirements of 10 CFR 71.71(c)(1), "Heat (normal condition of transport)." The cask is loaded, ready for shipment, and supported in the horizontal position with an ambient temperature environment of 100°F, an internal pressure of 150 psig (from Section 3.4.4, the calculated pressures are 6.91 psig and 3.65 psig for casks containing PWR and BWR fuel, respectively), maximum decay heat load, maximum solar insolation, and still air.

The stress analysis of the cask is performed by using a three-dimensional finite element model and the ANSYS computer program [32]. The model considers thermal heat, internal pressure, bolt preload, gravity, and combined loading conditions. The finite element model is described in Appendix 2.10.2. The temperature-dependent material properties considered in the analysis are documented in Section 3.2.

The following categories of load on the cask are considered for the heat condition:

1. Closure lid bolt preload—The required total bolt preload on the lid bolts is 5.4×10^6 lb (111,680 lb/bolt for 48 bolts). Bolt preload is applied to the model by imposing initial strains to the bolt shafts.

2. Internal pressure—For analysis purposes, an internal pressure of 150 psig is applied on the interior surfaces of the cask cavity in the outward normal direction. On the basis of the calculated maximum normal operating cavity pressures for PWR and BWR casks (7.3 and 5.0 psig, respectively) use of 150 psig is conservative. The pressure loading region includes the mating surfaces of the lid and upper body forging outward to the lid seal centerline.

3. Thermal—The heat transfer analyses performed for maximum normal operating conditions determine the cask temperature distribution for the heat condition. For the heat condition, the cask is considered to be in the horizontal position subjected to an ambient temperature of 100°F, with maximum decay heat load and maximum solar insolation, in still air. The cask temperature distribution obtained for this heat condition is used as input to the ANSYS analysis to determine the stresses in the cask. The ANSYS analysis determines the stresses resulting from thermal expansion of the cask from its initial 70°F condition to its normal transport temperature condition. These stresses include the effects of the differential thermal growth within the components, which result from the temperature difference across the cask walls. The cask temperature distribution is also used in the ANSYS structural analysis to determine the values of the temperature-dependent material properties.

4. Gravity—The mechanical loads consist of gravity acting on the cask structure and its contents. The cask is assumed to be loaded and resting in the horizontal position on the front and rear cask supports. Mechanical loads resulting from a 1-g application of the cask structure and contents are imposed on the model. The weight of the cavity contents is imposed on the model as a contents pressure on the contact surface of the cask cavity.

5. Fabrication and Installation—The effects of stresses resulting from the processes used in fabrication and installation are negligible.

The ratio of the normal transport vibration acceleration to the resultant acceleration for the combined longitudinal and vertical shock is used to ratio the stresses. The alternating shear stresses are S_{max} = (2.0/10.2)(28,546) = 5,597 psi and S_{min} = -(2.0/10.2)(28,546) = -5,597 psi. The margin of safety for the rotation pocket as a rear tiedown device for normal transport is:

$$MS = (S_a/S_{alt}) - 1 = (23{,}700/5{,}597) - 1 = +3.2$$

Therefore, the Universal Transport Cask satisfies the requirements for normal vibration incident to transportation as required by 10 CFR 71.71(c)(5).

2.6.6 Water Spray

Water causes negligible corrosion of the stainless shell of the Universal Transport Cask, and the cask contents are protected in the sealed cavity. A water spray as specified in 10 CFR 71.71(c)(6) has no adverse impact on the package. The cask surface temperature specified during the water spray is between 100°F and -20°F. Consequently, the induced thermal stress in the cask components is less than the thermal stresses that occur during the extreme temperature conditions for normal transport. Therefore, the requirements of 10 CFR 71.71(c)(6) are satisfied.

2.6.7 Free Drop (1-Foot): Cask Body Analysis

The free drop scenario outlined by 10 CFR 71.71(c)(7) requires the Universal Transport Cask to be structurally adequate for a 1-ft drop (normal conditions of transport) onto a flat, essentially unyielding horizontal surface in the orientation that inflicts the maximum damage to the cask. In the following subsections, the cask body, impact limiters, closure lid and bolts, neutron shield shell, and upper ring components are evaluated for the end, side, and corner-drop orientations.

Evaluation of each drop orientation is accomplished by using finite element analysis techniques. A complete description of the 3D model used to analyze the cask body is presented in Appendix 2.10.2. Appendix 2.10.2 also describes the loadings applied to the finite element model, the thermal conditions considered, and the locations of the sections on the cask body that are evaluated. The results of each drop orientation listed above are presented in this section. The impact limiters and the impact limiter attachments are evaluated in Section 2.6.7.5 for all loading conditions and orientations.

The analysis is performed using a 20g acceleration for the end and side drops. Using a 20g acceleration provides a bounding analysis, as it exceeds the calculated g-loads for the end and side drop events shown in Table 2.6.7.5-6.

For normal conditions, the one-ft drop is not a sufficient height to rotate the cask to an oblique orientation following a drop. Therefore, oblique drop orientations are not considered a credible event, and are not included in these analyses.

Only the analyses for enveloping structural conditions, representing the more restrictive of either the PWR or BWR fuel payload configuration are presented. Where necessary, a composite payload of the PWR configuration decay heat load and the BWR configuration weight is used for the cask body analysis. This composite configuration imposes larger impact loads on the cask components and raises the component temperatures, thereby lowering the material strength, resulting in a more restrictive loading configuration than either the PWR or BWR payload configurations would impose.

2.6.7.1 One-Foot End Drop

In accordance with the requirements of 10 CFR 71.71, the Universal Transport Cask is structurally evaluated for the normal condition of transport 1-ft end-drop. In this event, the cask (equipped with an impact limiter over each end) falls a distance of 1 ft onto a flat, unyielding, horizontal surface. The cask strikes the surface in a vertical position; consequently, an end impact on the bottom end or top end of the cask occurs. The analysis is performed using a 20g acceleration, which provides a bounding analysis as it exceeds the calculated g-loads for the end drop event shown in Table 2.6.7.5-6.

Stress results for the 1-ft top-and bottom-end-drop combined loading are documented in Tables 2.6.7.1-1 through 2.6.7.1-16. These tables document the primary membrane (P_m), primary membrane plus primary bending (P_m + P_b), primary membrane plus primary bending plus secondary peak stress (P + Q), and critical (P_m, P_m + P_b, and P + Q) stresses in accordance with the criteria presented in Regulatory Guide 7.6.

As shown in Tables 2.6.7.1-1 through 2.6.7.1-8, the margins of safety for the primary stress intensity category are positive for all of the 1-ft top-end-drop conditions. The most critically stressed component in the system is the top forging for the top-end-drop. The minimum margin of safety for P_m stress intensity for the top-end-drop condition is found to be 1.66 as documented in Table 2.6.7.1-5. The minimum margin of safety for P_m + P_b stress intensity for the top-end-drop condition is found to be 1.17, as documented in Table 2.6.7.1-6. The minimum margin of safety for the P + Q stresses (2.43) occurs in the inner shell, as documented in Table 2.6.7.1-8.

As shown in Tables 2.6.7.1-9 through 2.6.7.1-16, the margins of safety for the primary stress intensity category are positive for all of the 1-ft bottom-end-drop conditions. The most critically stressed components in the system are the cask body ligaments for the bottom-end-drop. The minimum margin of safety for P_m stress intensity for the bottom end-drop condition is found to be 0.74, as documented in Table 2.6.7.1-13. The minimum margin of safety for P_m + P_b stress intensity for the bottom-end-drop condition is found to be 1.29, as documented in Table 2.6.7.1-14. The minimum margin of safety for the P + Q stresses (2.49) occurs in the inner shell as documented in Table 2.6.7.1-15.

Because the margins of safety are all positive, the Universal Transport Cask satisfies the requirements of 10 CFR 71.71(c)(7) for the 1-ft end-drop (normal transport) condition.

Table 2.6.7.1-1 P_m Stresses—1-Foot Top End-Drop, Bolt Preload, Internal Pressure

		Cylindrical Stress Components (ksi)							Allowable Stress	
Section	Angle	S_X	S_Y	S_Z	S_{XY}	S_{YZ}	S_{XZ}	SI (ksi)	(ksi)	MS
1	70	0.3	0.3	0	0	0	0.1	0.4	20	44.31
2	180	0.3	0.3	0	0	0	0.1	0.4	20	48.47
3	180	0.2	0.4	0.2	0	0	0.2	0.4	20	48.37
4	180	0.3	0.2	0.3	0	0	0.3	0.6	20	35.02
5	180	-0.1	-0.1	-0.2	0	0	0	0.1	20	157.23
6	80	-0.1	-0.1	-0.1	0	0	0.1	0.2	20	92.5
7	0	-0.1	0.1	0.5	0	0	0.1	0.7	20	28.2
8	180	1.1	0	-0.2	-0.1	0	0.4	1.5	20	12.06
9	105	-0.7	-0.6	-0.2	-0.1	0.1	0.4	0.9	20	21.26
10	135	0.8	-0.5	-1.6	-0.1	0	0.6	2.7	19.1	6.1
11	135	0.2	-1.1	-2.8	-0.1	0.1	0.6	3.3	19.1	4.85
12	80	0.2	0.1	0.8	-0.1	0	0	0.8	19.1	24.3
13	80	0.7	0.4	1.4	-0.1	-0.1	0.1	1	19.1	17.24
14	135	-0.2	-0.1	0.5	0	0	-0.2	0.8	19.7	24.06
15	80	0.6	0.1	0.5	-0.1	-0.1	0.1	0.6	19.7	33.05
16	0	0	1	0.1	-0.1	0	0	1	19.7	18.04
17	0	0	1.3	-0.1	-0.1	0	0	1.5	19.7	12.58
18	0	-0.1	1.6	-0.3	-0.2	0	0	1.9	19.7	9.33
19	0	-0.1	2	-0.5	-0.2	0	0	2.5	19.7	6.79
20	0	-0.1	2.8	-0.8	-0.3	0	0	3.7	19.7	4.39
21	0	-0.1	4.1	-1.2	-0.4	0	0	5.3	19.7	2.72
22	0	-0.2	5.6	-1.8	-0.6	0	0.1	7.4	19.7	1.66
23	105	-0.1	0.2	-0.6	0	0.2	0.2	1	19.1	18.69
24	120	-0.1	1.5	-0.7	0	0.1	0	2.2	19.1	7.59
25	0	-0.1	1.1	-0.9	-0.1	0	0	2	19.1	8.44
26	0	-0.2	0.9	-1.2	-0.1	0	0	2.1	19.1	8.06
27	0	-0.2	0.7	-1.5	0	0	0	2.2	19.1	7.82
28	0	-0.2	0	-1.7	0.1	0	0	1.7	19.1	10.23
29	10	-0.2	-1.2	-1.9	0	0	0	1.7	19.1	10.2
30	20	-0.2	-2.8	-1.9	0	-0.1	0	2.6	19.1	6.41
31	90	-0.4	-3	-1.7	0.1	-0.5	0.1	2.8	19.1	5.87
32	0	-0.3	4.3	-2	-0.5	0	-0.3	6.4	20	2.1
33	0	1.1	2.9	-1.9	-0.2	0	-0.6	5	20	3.02
34	0	3.4	3.3	-3.1	-0.1	0.1	1.2	7	20	1.87
35	180	-0.6	1.5	-2.1	0.3	-0.2	0.2	3.8	20	4.31
36	0	1.5	1	-3.2	0	0.3	0.1	4.8	20	3.18
37	0	-0.3	-0.2	-1.2	0	0.2	0.6	1.4	20	12.85
38	0	-0.3	-0.2	-1.1	0	0.2	0.5	1.3	20	14.86
39	0	-0.1	-0.5	-3.1	0	0.1	0.2	3	20	5.7
40	0	-2	-2	-6.2	0	-0.1	-1.2	4.8	20	3.15
41	135	-0.2	-0.2	-0.6	0	0	0.2	0.5	20	40.25

Table 2.6.7.1-15 Critical $P_m + P_b + Q$ Stress Summary (ksi)—1-Foot Bottom End-Drop, Bolt Preload, Internal Pressure, Thermal Hot

Component	Section	Angle	SI (ksi)	Allowable Stress (ksi)	Margin of Safety
1	4	0	13.8	60	3.34
2	9	0	17.2	60	2.49
3	10	180	8.8	57.4	5.51
4	15	0	8.9	59.1	5.67
5	16	0	6.9	59.1	7.51
6	22	0	3.4	59.1	16.42
7	23	0	9.2	57.4	5.27
8	27	0	15.2	57.4	2.78
9	31	0	7.4	57.4	6.72
10	35	0	9.9	60	5.08
11	40	60	11.2	60	4.37
12	41	180	4.8	60	11.57

Table 2.6.7.1-16 Critical $P_m + P_b + Q$ Stress Summary (ksi)—1-Foot Bottom End-Drop, Bolt Preload, Internal Pressure, Thermal Cold

Component	Section	Angle	SI (ksi)	Allowable Stress (ksi)	Margin of Safety
1	4	180	5.8	60	9.36
2	8	180	10.2	60	4.91
3	10	180	11.2	57.4	4.12
4	15	180	9.6	59.1	5.17
5	16	20	6.1	59.1	8.64
6	22	0	1.8	59.1	32.29
7	23	180	5.1	57.4	10.3
8	27	0	3.1	57.4	17.63
9	31	0	3.5	57.4	15.57
10	35	0	8.1	60	6.45
11	40	10	8.4	60	6.14
12	41	180	4.2	60	13.45

2.6.7.2 One-Foot Side Drop

In the 1-ft side-drop event, the cask (equipped with an impact limiter over each end) falls a distance of 1 foot onto a flat, unyielding, horizontal surface. The cask strikes the surface in a horizontal position, thereby resulting in a side impact on the cask. The types of loading involved in a side-drop event are closure lid bolt preload, internal pressure load, thermal load, and inertial body load. The analysis is performed using a 20g acceleration load, which provides a bounding analysis, since it exceeds the calculated g-loads for the one-foot side drop event shown in Table 2.6.7.5-6.

The same conditions evaluated for the end-drop are also used in the side drop evaluation. Stress results for the combined 1-ft side-impact loading condition are documented in Tables 2.6.7.2-1 through 2.6.7.2-8.

As shown in Tables 2.6.7.2-5 and 2.6.7.2-6, the margins of safety for the primary stress intensity category are positive for the 1-ft side-drop condition. The most critically stressed component in the system is the cask body ligament region. The minimum margin of safety is found to be +0.08 for primary membrane stress intensity, as documented in Table 2.6.7.2-5. The minimum margin of safety is found to be +0.33 for primary membrane plus bending stress intensity, as documented in Table 2.6.7.2-6.

As seen from the tables, the minimum margin of safety for primary plus secondary stress intensity for the 1-ft side-drop is 1.18 (Table 2.6.7.2-8).

Because the margins of safety are all positive, the Universal Transport Cask satisfies the requirements of 10 CFR 71.71(c)(7) for the 1-ft side-drop (normal transport) condition.

where

$\alpha_{NS\text{-}4\text{-}FR}$ = 4.72×10^{-5} in/in/°F, coefficient of thermal expansion at 158°F

α_{304SS} = 8.79×10^{-6} in/in/°F, coefficient of thermal expansion at 200°F

L = Length of the section

ΔT = 150 - 75 = 75°F, average temperature differential

Considering differential thermal expansion and 3% initial compression of the HT800 expansion foam on the inside surface of the neutron shield shell, a compressive load develops. The total compression is

$$\text{Compression} = 3\%\ (0.125) + 0.033 = 0.037 \text{ in}$$

The equivalent compression of the foam is

$$\%\ \text{Compression} = \frac{0.037}{0.125} \times 100 = 29.6\%\ .$$

Interpolating the manufacturer design information presented in Reference [60], the equivalent pressure load developed on the neutron shield shell is 12.1 psi.

2. Potential pressure developed from extended service of the NS-4-FR neutron shield at high temperatures is defined as 3 psi for this evaluation.

Service Level C

1. Service Level B loads plus dynamic induced load from a postulated one foot side impact (20 *g*).

   Considering the mass of the neutron shield shell and NS-4-FR, the effective pressure load becomes

$$P = MA = (0.346)(20) = 6.9 \text{ psi}$$

where, from the dimensions provided in Fig. 2.6.7.7-1

M= [(4.5)(0.0607) + (0.25)(0.291)] x 1 = .346 lb, the mass of a 1 in^2 unit area,

A= 20 g, the acceleration during a side drop.

Service Level D

1. Service Level B loads plus dynamic induced load from a postulated 30-foot side impact (60 g). Considering the mass of the neutron shield shell and the NS-4-FR, the effective pressure load becomes

$$P = (0.346)(60) = 20.8 \text{ psi.}$$

The following evaluation is presented for two different load orientations of the fin welds. Case 1 represents the loads induced as a result of loading applied to the neutron shield and Case 2 represents loading applied to the radial heat transfer fin.

Case 1—Neutron Shield Shell Loading

Implementing the design criteria for noncontainment support structures presented in NF-3250, normal operation load service level stress in the weld region connecting the neutron shield shell to the radial heat transfer fin is evaluated using a conservative simplification of the plate and shell structure to that of a uniformly loaded beam having unit depth.

The maximum tension stress from Service Level B is:

$$S = \frac{6m}{t^2} \; 17{,}867 \text{ psi}$$

Table 2.6.11.2-1 Stress Analysis Results for Uniform Pressure Loading of Inner Shell Due to Lead Pouring (Continued)

X (ft)	Hoop stress, σ_2 (psi)	Radial Deflection, y (in.)
9.90	-247.1	-0.00031
10.05	-247.1	-0.00031
10.20	-247.1	-0.00031
10.35	-247.1	-0.00031
10.50	-247.1	-0.00031
10.65	-247.1	-0.00031
10.80	-247.1	-0.00031
10.95	-246.9	-0.00031
11.10	-246.9	-0.00031
11.25	-246.9	-0.00031
11.40	-246.9	-0.00031
11.55	-246.9	-0.00031
11.70	-246.7	-0.00031
11.85	-246.7	-0.00031
12.00	-246.7	-0.00031
12.15	-246.7	-0.00031
12.30	-246.9	-0.00031
12.45	-247.1	-0.00031
12.60	-247.6	-0.00031
12.75	-248.2	-0.00031
12.90	-249.1	-0.00032
13.05	-250.4	-0.00032
13.20	-251.7	-0.00032
13.35	-253.2	-0.00032
13.50	-254.5	-0.00032
13.65	-255.3	-0.00032
13.80	-255.1	-0.00032
13.95	-253.2	-0.00032
14.10	-248.6	-0.00031
14.25	-240.7	-0.0003
14.40	-227.9	-0.00029
14.55	-209.9	-0.00027
14.70	-185.9	-0.00024
14.85	-156.5	-0.0002
15.00	-123.5	-0.00016

2.6.12 PWR Transportable Storage Canister Analysis - Normal Conditions of Transport

In this section, the Transportable Storage Canister assembly containing PWR fuel is evaluated for the normal conditions of transport. The principal components of the canister assembly are the canister, the fuel basket assembly, the shield lid, and the structural lid. The canister and the canister shell, bottom plate, and lids are shown in Figures 2.6.12-1 and 2.6.12-2.

Spacers are used to properly locate the canisters containing Class 1 and 2 PWR fuel in the cask cavity. The analysis of the spacers is presented in Section 2.6.16. The geometries and materials of construction of the canister, baskets, and spacers are described in Section 1.2.1.2.

2.6.12.1 Analysis Description

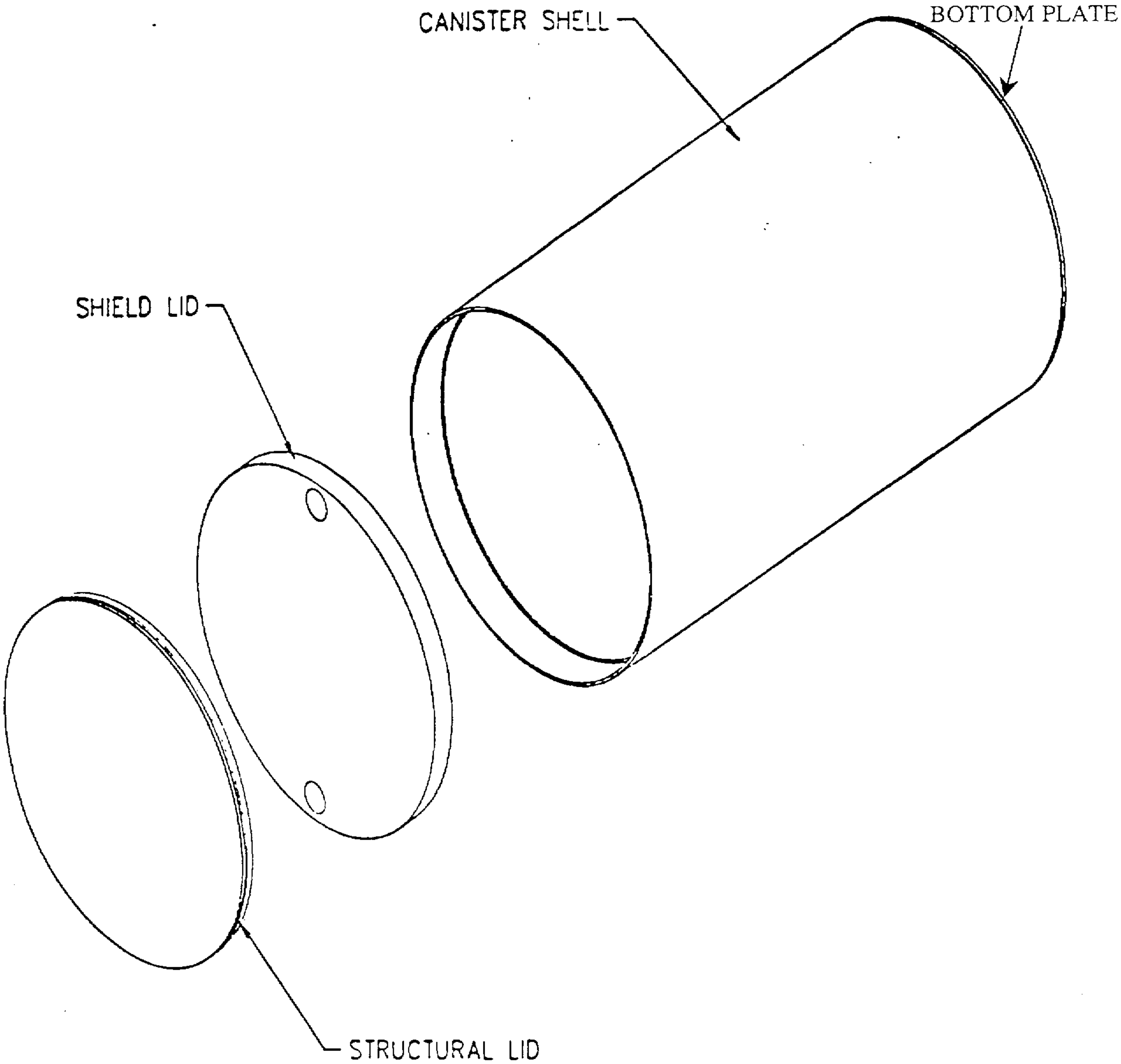
The Transportable Storage Canister contains and confines the spent fuel in the fuel basket. The canister is the defined confinement boundary for its contents during transport and storage operations, but the canister is not considered to provide containment during transport operation; the Universal Transport Cask provides the containment boundary for transport. The canister in the transfer cask serves as the handling component for its basket and contents during loading, closure, and transfer from the pool to storage or to the transport vehicle.

Three canisters of varying lengths are designed to accommodate the three classes of PWR fuel. The design parameters of the canisters are provided in Table 1.2-2. For this analysis, the canister is modeled with the heaviest fuel (Class 2).

The structural design criteria for the canister is from the ASME Code Section III, Subsection NB. Consistent with this criterion, the structural components of the canister are shown to satisfy the allowable stress limits presented in Tables 2.1.2-3 and 2.1.2-4 as applicable. The allowable stresses used in this analysis are based on a temperature of 380°F for all locations in the canister, unless otherwise indicated. These allowables are conservative for all sections in the canister with the exception of Sections 5 and 6 (see Figure 2.6.12.3-1 for section locations).

For the canister structural lid weld (Section 13, Figure 2.6.12.3-1), base metal properties are used to define the allowable stress limits since the weld filler rod tensile properties are greater than the base metal. Also, the allowable stress is multiplied by a stress reduction factor of 0.8 per ISG-4 [49].

Figure 2.6.14-2 BWR Transportable Storage Canister Shell and Lids



2.6.14.1 Analysis Description

Two canisters of different lengths are designed to accommodate the two classes of BWR fuel. The overall lengths of the two BWR canisters are 185.6 in and 190.4 in. Other design parameters of the canisters are provided in Table 1.2-2. For this analysis, the largest load per disk configuration (BWR Class 4) is modeled with the longest canister of 191.80 inches.

As is the case for the PWR canister, the structural design criteria for the BWR canister is the ASME Code, Section III, Subsection NB. Consistent with this criterion, the structural components of the canister are shown to satisfy the allowable stress limits presented in Tables 2.1.2-3 and 2.1.2-4 as applicable. The allowable stresses used in this analysis are based on a maximum material temperature of 380°F for all locations in the canister, unless otherwise indicated. These allowables are conservative for all sections because the maximum temperature in the canister shell central region is determined to be 363°F in the thermal analysis presented in Section 3.4.2. For the canister structural lid weld (Section 13, Figure 2.6.12.3-1), base metal properties are used to define the allowable stress limits since the weld filler rod tensile properties are greater than the base metal. Also, the allowable stress is multiplied by a stress reduction factor of 0.8 per ISG-15 [49].

The ANSYS finite element computer program is used to analyze the canister for the 1-ft free-drop condition in the top and bottom end, side, and top and bottom corner-impact orientations. In addition, the effects of normal operating internal pressure and thermal stresses resulting from exposure of the cask to the hot (100°F ambient and solar insolance) and cold (-40°F ambient) normal conditions are evaluated. The worst-case stresses from these analyses are presented in Section 2.6.14.4.

2.6.14.2 Finite Element Model Description - BWR Canister

To evaluate the BWR Transportable Storage Canister for normal conditions of transport, ANSYS is used to construct and analyze a finite element model of the canister and its contents. The contents modeled consist of the fuel basket support disks and weldments. The fuel assemblies, fuel tubes, tie-rods, and related hardware are not explicitly modeled but are accounted for by applying pressure loads to the support disk slots as appropriate.

2.6.14.9 Stress Evaluation of BWR Canister for Combined Thermal and 1-Foot Corner-Drop Load Conditions

The thermal stress loads described in Section 2.6.14.3 are applied in conjunction with the primary loads in Section 2.6.14.8 to produce a combined thermal stress plus corner impact loading. The stress evaluation is performed according to the ASME Code, Section III, Subsection NB. On the basis of results in Section 2.6.14.8, the most critical sections are listed in Table 2.6.14.9-1. The stresses reported in this table correspond to the nodal stress at the surface. The minimum margin of safety is +1.57 when 3 S_m is used as the stress criterion. Tables 2.6.14.9-2 through 2.6.14.9-5 present the results for top and bottom corner-drop with thermal results for the loading conditions that result in the minimum margins of safety. The margins of safety are calculated as:

MS = (allowable stress/SI) -1.

Table 2.6.14.9-1 BWR Canister Critical Sections for the Combined 1-Foot Corner-Drop and Thermal Load Condition

Condition	**Stress**	**Critical Section**	**Table No.**	**Minimum Margin of Safety**
Top Corner-Drop + Thermal (cold)	$P_m + P_b + Q$	2	2.6.14.9-2	+ 2.02
Top Corner-Drop + Thermal (hot)	$P_m + P_b + Q$	2	2.6.14.9-3	+ 2.05
Bottom Corner-Drop + Pressure + Thermal (cold), 45° Basket	$P_m + P_b + Q$	9	2.6.14.9-4	+ 1.57
Bottom Corner-Drop + Thermal (hot)	$P_m + P_b + Q$	11	2.6.14.9-5	+1.62

2.6.15.7 Stress Evaluation of BWR Support Disk for Combined Thermal and 1-Foot Side-Drop Load Conditions

The loading for the 1-ft side-drop is combined with the thermal loading for Thermal Case 2 to produce the largest stress intensities. The allowable stress intensity, 3 $S_{m,}$ is evaluated at Thermal Case 3 (see Section 2.6.15.6.2). The corner-drop condition is bounded by the side and end-drops.

The 20 cross sections with the smallest margins of safety are presented in Tables 2.6.15.7-1 through 2.6.15.7-5. The margins of safety are calculated as

MS = (stress allowable/stress intensity) - 1.

The tables are identified here.

Table Number	Basket Orientation (Deg)	Thermal Case	Stress Evaluation	Minimum Margin of Safety
2.6.13.7-1	0	2	$P_m + P_b + Q$	+ 1.44
2.6.13.7-2	31.82	2	$P_m + P_b + Q$	+ 0.78
2.6.13.7-3	49.46	2	$P_m + P_b + Q$	+ 0.59
2.6.13.7-4	77.92	2	$P_m + P_b + Q$	+ 1.40
2.6.13.7-5	90	2	$P_m + P_b + Q$	+ 2.08

Table 2.6.15.7-1 $P_m + P_b + Q$ Stresses for Support Disk - 1-Foot Side-Drop, 0° Orientation, Thermal Case 2

Section	Sx	Sy	Sxy	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
14	25.5	18.4	14.5	36.9	90.0	1.44
13	24.3	17.6	-14.0	35.3	90.0	1.55
234	6.5	-14.4	5.1	23.3	90.0	2.86
232	-.2	-23.1	-.2	23.1	90.0	2.89
298	-.1	-23.1	.0	23.1	90.0	2.90
300	8.8	-11.9	-4.1	22.3	90.0	3.04
290	-.1	-21.0	.1	21.0	90.0	3.28
224	-.1	-20.6	-.2	20.6	90.0	3.37
281	-.1	-19.8	.1	19.8	90.0	3.55
145	-11.9	-14.9	6.0	19.6	90.0	3.60
111	-11.9	-14.9	6.0	19.6	90.0	3.60
215	-.1	-19.3	-.3	19.3	90.0	3.65
18	-9.3	-15.0	6.2	19.0	90.0	3.74
266	-9.3	-15.0	6.2	19.0	90.0	3.74
230	-4.1	-17.4	4.7	18.9	90.0	3.76
194	-4.1	-17.4	4.7	18.9	90.0	3.76
270	.0	-18.5	-.4	18.5	90.0	3.87
134	-15.2	-9.7	5.3	18.4	90.0	3.89
165	-15.2	-9.7	5.3	18.4	90.0	3.89
146	-12.9	-12.7	5.4	18.2	90.0	3.93

strength of lead. Therefore, the effects of stresses resulting from the processes used in fabrication of the cask are considered to be negligible. Further discussion of fabrication stresses in provided in Section 2.6.11.

The following sections contain the evaluation of the cask for impact orientations in which the cask strikes the impact surface on its end (top and bottom), side, corner (top and bottom), and end oblique (top and bottom). The impact conditions in accordance with Regulatory Guide 7.8 and the categories of load to be considered for the hypothetical accident conditions are similar to those for the 1-foot free drops, under normal conditions of transport, discussed in Appendix 2.10.2. Therefore, the discussions in the following sections refer to Appendix 2.10.2 wherever applicable.

Three categories of load—closure lid bolt preload, internal pressure, and inertial body loads—are considered on the cask. The inertia loads imposed upon the cask by the impact limiter result from the mass of the entire assembly being acted upon by a design deceleration value of 60 *g* for the 30-ft end-drop case. The closure lid bolt preload, internal pressure load, and contents loads considered for the 30-ft end-drop condition are similar to those considered for 1-ft end-drop condition in Section 2.6.7.1, with the exception that thermal stresses are not considered for accident conditions. The material properties of the components are considered to be temperature dependent.

The allowable stress limit criteria is discussed in Section 2.1.2.4. These criteria are used to determine the allowable stresses for each cask component, conservatively using the maximum operating temperature within a given component to determine the allowable stress throughout that component (refer to Table 2.10.2.2-1). For cask body analyses presented in this section, the maximum heat conditions (thermal condition 1) is 100°F ambient temperature, maximum decay heat load, and maximum solar insolation.

2.7.1.1 30-Foot End Drop

In accordance with the requirements of 10 CFR 71.73(c)(1), the Universal Transport Cask is structurally evaluated for the 30-foot end-drop condition. In this hypothetical accident, the cask, with its payload, spacer (if appropriate), and the impact limiters, falls 30 feet onto a flat, unyielding, horizontal surface. The cask strikes the surface in a vertical position; consequently, an end impact on the bottom or top end of the cask occurs. The types of loading involved in an end-drop accident are closure lid bolt preload, internal pressure, thermal, and inertial body load. Appendix 2.10.2 describes the application of each loading condition.

Figures 2.10.2.2-1 through 2.10.2.2-4 depict the sections used in the post-processing of the cask body results. Tables 2.7.1.1-1 through 2.7.1.1-4 present the results for the top-end drop. Tables 2.7.1.1-3 and 2.7.1.1-4 provide a summary of P_m and $P_m + P_b$ stresses for the top-end drop. Tables 2.7.1.1-5 through 2.7.1.1-8 tabulate the results for the bottom-end drop. Tables 2.7.1.1-7 and 2.7.1.1-8 provide a summary of P_m and $P_m + P_b$ stresses for the bottom end drop. For the top end, combined impact loading case, the calculated minimum margin of safety is 1.74 in the top forging (Table 2.7.1.1-3). The calculated minimum margin of safety is 0.87 (Table 2.7.1.1-4) for primary membrane plus bending. For the bottom end combined impact loading case, the minimum margin of safety is 0.53 (Table 2.7.1.1-7) in the ligaments. The minimum margin of safety for primary membrane plus bending stress intensity is 0.95 (Table 2.7.1.1-8) in the bottom forging.

Table 2.7.1.3-7 Critical P_m Stress Summary—30-Foot Bottom Corner-Drop, Thermal Condition 1

Component	Section	Angle	SI (ksi)	Allowable Stress (ksi)	Margin of Safety
1	3	0	15.9	48	2.03
2	9	70	12.0	48	3.01
3	11	0	25.8	45.9	0.78
4	15	0	18.2	47.3	1.6
5	16	50	18.5	47.3	1.56
6	22	70	7.4	47.3	5.38
7	23	20	15.8	45.9	1.9
8	24	60	10.9	45.9	3.2
9	31	40	9.9	45.9	3.64
10	36	180	8.2	48	4.82
11	40	80	3.6	48	12.49
12	41	0	12.5	48	2.85

Table 2.7.1.3-8 Critical $P_m + P_b$ Stress Summary—30-Foot Bottom Corner-Drop, Thermal Condition 1

Component	Section	Angle	SI (ksi)	Allowable Stress (ksi)	Margin of Safety
1	3	0	20.2	72	2.57
2	8	0	25.7	65	1.53
3	11	0	32.6	68.8	1.11
4	14	0	36.7	70.9	0.94
5	16	40	21.9	70.9	2.23
6	22	40	10.6	70.9	5.67
7	23	0	22.2	68.8	2.1
8	24	20	13.9	68.8	3.95
9	31	40	15.2	68.8	3.54
10	34	60	11.6	62.7	4.39
11	40	40	6.8	63	8.31
12	41	0	22.7	72	2.17

2.7.1.4 30-Foot Oblique Drop

In accordance with the requirements of 10 CFR 71.73, (c) (1) the Universal Transport Cask is structurally evaluated for the hypothetical accident 30-foot oblique drop condition. In this event, the cask, with its payload, spacer (if appropriate), and impact limiters, falls 30 feet onto a flat, unyielding, horizontal surface. The cask strikes the surface obliquely on its top or bottom corner. An oblique orientation angle of 75° from vertical is evaluated for the oblique drops.

The results of the stress evaluation are provided in Tables 2.7.1.4-1 through 2.7.1.4-4 for the top oblique and 2.7.1.4-5 through 2.7.1.4-8 for the bottom oblique drop orientations. For the top oblique combined impact loading case, the minimum margin of safety for membrane stress intensity is 0.59 (Table 2.7.1.4-3) in the bottom portion of the outer shell. The minimum margin of safety for membrane plus bending stress intensity is 0.11 (Table 2.7.1.4-4) in the bottom forging.

For the bottom oblique, combined impact loading case, the minimum margin of safety for membrane stress intensity is 0.79 (Table 2.7.1.4-7) in the top portion of the inner shell. The minimum margin of safety for membrane plus bending stress intensity is 0.34 (Table 2.7.1.4-8) in the bottom section of the outer shell.

2.7.9.1 Analysis Description

The structural design criteria for the canister are contained the ASME Code, Section III, Subsection NB. Consistent with these criteria, the structural components of the canister (shell, bottom plate, and structural lid) are shown to satisfy the allowable stress intensity limits presented in Table 2.1.2-3. For the canister structural lid weld (Section 13, Figure 2.6.12.3-1), base metal properties are used to define the allowable stress limits since the weld filler rod tensile properties are greater than the base metal. Also, the allowable stress is multiplied by a stress reduction factor of 0.8 per ISG-15 [49].

The ANSYS finite element program is used to evaluate the canister for the 30-ft drop conditions in the top and bottom-end, top and bottom-corner, and side-impact orientations. The ANSYS finite element model is the same as that used for the evaluation of the 1-ft drop impacts evaluated for normal conditions of transport. The model is described in Section 2.6.14.2.

2.7.9.2 Analysis Results - BWR Canister

The detailed results of the analysis for the 30-ft side, top and bottom corner, and top and bottom-end drops are presented in Tables 2.7.9.2-1 through 2.7.9.2-10. Only the load cases that result in the worst case margins are presented for each of the drop orientations considered. For the side drop, the worst case configuration is without pressure and the basket oriented at 0°. For the bottom-drop, the worst case occurs with internal pressure. For the top-end drop, the most severe condition occurs without pressure. For the bottom-corner drops, the worst case stresses occur without pressure and the basket oriented at 0°. For the top-corner drops, the worst case occurs with pressure for primary membrane and without pressure for membrane plus bending.

A drop accident stress evaluation is performed for the 30-ft side-drop, top and bottom-end drops, and for the top and bottom-corner drop conditions by applying a 60 *g* deceleration load. The loads developed in the basket are transferred through the canister wall into the inner shell (for the side-drop and oblique drops), and any axial component is transferred into the ends of the cask cavity. The axial loads are maximized for the end-drops and corner-drop conditions. The lateral loads are maximized in the side-drop since an enveloping acceleration is employed in the analysis. Regardless of the angle of the drop, the canister wall is uniformly supported along its length by the transport cask inner shell, and the load path is not affected by drop orientations close to the side-drop orientation. The oblique orientation will not provide enveloping loading above the side-drop conditions. Therefore, oblique orientations other than the corner drops are not considered.

The section stresses presented in the tables are identified by a section number. The minimum margin of safety at each section is presented by denoting the circumferential angle where the minimum margin of safety occurs. A cross-section of the canister showing the section numbers is presented in Figure 2.7.9.2-1. Stresses are evaluated at 9° increments around the circumference for each of the locations shown in Figure 2.7.9.2-1. The canister minimum margins of safety for the governing drop conditions are summarized in Table 2.7.9.2-11.

The methodology used to evaluate the stresses for the side drop is identical to that used for the normal conditions 1-ft side drop for the BWR canister (Section 2.6.14.6). Sections 9, 10, and 11 at the 0° circumferential position (see Figure 2.6.12.3-1) are not included in the evaluation. These regions are characterized as a bearing stress since they result from the canister shell bearing against cask inner shell. An evaluation of these bearing stresses is not required for accident conditions. Results for Sections 9, 10, and 11 at angular locations other than 0° are included in the evaluation.

Design changes were made to the BWR basket after the initial analyses were performed. The effects of the design changes on the BWR canister are discussed in Section 2.6.14.2. The same procedure used to scale the BWR canister stress intensities in Section 2.6.14.2 is used for the accident conditions in the following evaluation.

The allowable stresses presented in the tables are for Type 304L stainless steel. The shield lid is constructed of Type 304 stainless steel, which possesses higher allowable stresses, resulting in a conservative evaluation. These allowables are evaluated at 380°F, unless otherwise indicated. Review of the thermal analyses shows that the maximum temperature of the canister is 363°F (Section 3.4), so the presented margins of safety are conservative.

2.10.3 Confirmatory Testing Program – UMS® Impact Limiters and Attachments

This section provides a description of the scale model test program, which was carried out as confirmatory support of the analysis and licensing effort for the design qualification of the NAC-UMS® Transport Cask impact limiters and attachments. More specifically, the purpose of the UMS® Scale Model Test Program was to confirm (1) the capability of the impact limiters to restrict the deceleration of the cask to the design limits used in the structural evaluation of the transport cask; and (2) the impact limiters remain attached to the cask body.

The test results confirm the impact limiter analysis and provide physical evidence that the UMS® impact limiters will function as designed to limit the deceleration applied to the cask and its contents and to remain attached to the transport cask during an accident condition impact.

The scale model test program for the NAC-UMS® impact limiters included: (1) 30-foot drops of a quarter-scale model of the UMS® cask in the top end, side, and top corner impact orientations and (2) a static compression test for the top end drop cask orientation. The total weight of the quarter-scale model and impact limiters (4,060 pounds) corresponded to the full-scale 260,000 pounds design limit of the NAC-UMS® Transport Cask.

This section presents the scale model impact limiter and attachment drawings, the test descriptions, test results, and conclusions that demonstrate the design qualification of the impact limiters and their attachments.

2.10.3.1 Confirmatory Testing Program Results Summary

Three 30-foot drop tests were performed for the UMS® transport cask scale model test program. The top end drop and top corner drop test were performed at the drop test facility at the Oak Ridge National Laboratory (ORNL) in April 1999. The side drop test was performed at Sandia National Laboratory (SNL) using a different quarter-scale model in March 2001.

Since the purpose of the UMS® Drop Test Program was to confirm the design of the UMS® transport cask impact limiters and attachments, the design of the scale model package focused on the limiters and their attachments to the cask body. The scale model body was designed to accurately represent the interface between the cask body and the impact limiters and the weight, CG and mass moment of inertia of the cask body and its contents. The use of a scale model is appropriate to perform these tests and the scale selected for the tests was a quarter-scale model.

Using a smaller scale model would present fabrication difficulties, while use of a larger scale model would increase the drop pad requirement (mass and geometric size). The drop pads at ORNL and SNL meet the requirement of the IAEA to simulate an unyielding surface for the UMS® quarter-scale model. The test data consisted of measurements of the deformations of the impact limiters, the package accelerations, and inspection of the retaining rods. Impact limiter measurements were performed before and after each test to determine the crush depth of the impact limiters. The measured crush depths are used to demonstrate that the impact limiter design calculations are bounding. The accelerations are recorded by accelerometers attached to the model body. The accelerometers are positioned and oriented so that a single accelerometer records the vertical acceleration of the model. The acceleration data obtained from the accelerometers contained contributions to the acceleration signal that were extraneous based on the frequencies of the contributions. For this reason, the acceleration data was further processed to extract accelerations, which were compared to the accelerations calculated by the LS-DYNA finite element analysis program. Additional test documentation included high-speed photography that confirmed the orientation of the cask at impact and still photographs of the scale model, impact limiters, and the impact limiter retaining rods. Post-test inspection of the retaining rods and the impact limiters confirmed that the impact limiters have a significant margin of safety for remaining attached to the cask body during and after a 30-foot drop test impact.

The LS-DYNA analyses for the quarter-scale model are presented in Section 2.10.3.7.

The quarter-scale model 30-foot drop test acceleration values and the LS-DYNA predicted (calculated) values are summarized in the following table:

UMS Cask model Drop Orientation	Quarter-Scale Drop Test Results (g)		LS-DYNA Prediction (g)		Design Basis Acceleration (g)
	Top Accelerometer	Bottom Accelerometer	Top Accelerometer	Bottom Accelerometer	
Top Corner	121	N/A	143	N/A	240
Top End	207	N/A	226	N/A	240
Side	190	198	220	213	240

The drop test measured crush depths and the LS-DYNA predicted (calculated) values are summarized in the following table:

Where:

$\lambda = \pi$

L = 44.6 inches

Using the cross-section of both pipes, the moment of inertia is:

$$I_{20} = \frac{\pi}{64}(D_0^4 - D_i^4) = \frac{\pi}{64}(20^4 - 17^4) = 3{,}754 \text{ in}^4, \text{for the 20-inch pipe, and}$$

$$I_{14} = \frac{\pi}{64}(D_0^4 - D_i^4) = \frac{\pi}{64}(14^4 - 12.5^4) = 687 \text{ in}^4 \text{ for the 14-inch pipe}$$

The total moment of inertia is 4,441 in^4.

E = 28.3E+06 psi

ρ' = effective mass per unit length of beam

= 2,812/44.6/386.4 = .163 lb-sec^2 / in^2

Substituting,

fb = 694 Hz

In accordance with Blevins, the shear and bending mode frequencies are combined as:

1/fc = 1/fs + 1/ fb

or

fc = 330 Hz

The filter frequency is conservatively selected to be 450 Hz for the side drop.

2.10.3.4.3 Results/Evaluation for the 30-Foot Side Drop

The 30-foot side drop was the only test performed at SNL using the quarter-scale model for the transport cask. Prior to lifting the scale model package to the 30-foot drop height, the torque for the retaining rods and nuts were inspected to ensure that the torque specifications were met.

High-speed cameras were positioned at two locations with respect to the model. Cameras were positioned to view the model from the end and cameras were positioned to obtain a side view of the model impacting the pad. The lateral view confirmed that the axis of the cask model was effectively horizontal at the time of impact. There appeared to be no rocking of the cask during the drop and the model rebound was less than six inches after the initial 30-foot drop impact.

2.10.3.4.4 Impact limiter Deformation and Attachment Data

After the side drop test, it was observed that the impact limiters remained attached to the cask body model (see Figure 2.10.3-5). The impact limiters were removed and it was observed that twelve attachment rods remained intact for the top impact limiter and nine attachment rods remained intact for the bottom impact limiter. These results indicate that both impact limiters remained attached to the cask body during and after the side drop test. Upon inspection of the rods, it was determined that the rods, which failed outside the crushed region, exhibited a tensile failure at the location where the attachment rod abruptly changed diameter (threaded undercut). The design of the square cut out in the attachment rod has been reversed to allow the thread run out to terminate at the location of the previous square cut out.

Measurements of the deformed model impact limiter dimensions were obtained after the side drop test to determine the crush depth that occurred. These dimensions are tabulated below, along with the crush depth calculated by LS-DYNA for the quarter-scale model (The description of the LS-DYNA analyses supporting these values is presented in Section 2.10.3.7).

	Model Drop Test Crush Depth (inch)			**LS-DYNA Crush Depth Prediction (inch)**		
Location	**Original Thickness**	**Final Thickness**	**Measured Crush**	**Original Thickness**	**Final Thickness**	**Total Crush**
Side Drop–under the trunnion	3.50	0.63	2.87	3.47	1.11	2.36
Side Drop–bottom impact limiter	5.13	2.38	2.75	5.13	2.42	2.71

2.10.3.4.5 Accelerometer Data from the 30-Foot Side Drop Test

The unfiltered accelerometer traces were electronically stored to permit filtering after the tests. Three acceleration traces were obtained near the bottom of the model and three acceleration traces were obtained near the top of the model. The acceleration time histories, both the filtered and the unfiltered data with maximum accelerations, are shown in Figure 2.10.3-6 for the top end and Figure 2.10.3-7 for the bottom end locations on the cask model. Figure 2.10.3-8 shows the acceleration trace containing the maximum acceleration for the top end along with the acceleration time history computed by LS-DYNA (as described in Section 2.10.3.7). A similar set of curves is shown in Figure 2.10.3-9 for the bottom end of the cask that compares the maximum acceleration obtained from testing to the acceleration time history obtained from the LS-DYNA analysis in Section 2.10.3.7. The peak accelerations for the quarter-scale model are shown below.

UMS® Cask Model Drop Orientation	Model Acceleration Results (g)		LS-DYNA Acceleration Prediction (g)		Design Basis Acceleration (g)
	Top Accelerometer	Bottom Accelerometer	Top Accelerometer	Bottom Accelerometer	
Side	190	198	193	210	240

2.10.3.4.6 Energy Absorption Capacity of the Impact Limiter in the 30-Foot Side Drop

The capacity to absorb energy is the function of the impact limiter. For a side impact, the energy absorption of the impact limiter can be obtained from the 30-foot side drop test results. Similarly, the results of the static test for the end drop orientation can be used to determine the energy absorption for the end orientation. The side drop acceleration time history can be integrated twice to obtain the displacement, which can be plotted versus the force (the product of the acceleration time history and the model weight, i.e., the acceleration time history in units of g). This force versus displacement time history is shown in Figure 2.10.3-10. The area under this curve corresponds to 1.46E6 inch-pounds, which is within 1% of the total energy (TE) of the side drop test (1.47E6 inch-pounds). The total energy is obtained by multiplying the model weight of 4,060 pounds times the total distance traversed, which is 360 inches plus the average of the crush depths (2.87 + 2.75)/2. From the side drop test results, the upper impact limiter has a 0.5-inch depth of uncrushed wood remaining at the trunnion cutout and the lower impact limiter has a 2.25-inch depth of uncrushed wood remaining at the maximum crush location. Thus, the upper limiter is most limiting. Since the upper impact limiter can crush until the trunnion comes into contact with the impact plane, there is an additional 0.5-inch crush depth available. Using 750,000 pounds (which represents the total force from the top and bottom impact limiter) from the force-displacement time history curve, this potential additional 0.5-inch crush distance corresponds to 0.5×(750,000) or 375,000 inch-pounds of additional energy, which could be absorbed. Thus, for a side impact, the UMS® impact limiters have an additional energy absorption capacity of approximately 25% (375,000/1.46E6).

2.10.3.4.7 Summary of the Side Drop Test

The comparison of the maximum test accelerations to those computed by LS-DYNA is considered to be acceptable. The LS-DYNA results shows that the predicted accelerations are approximately 10% above the test values. Additionally, the design acceleration corresponding to the quarter-scale model is 240g. This indicates that, not only is there a 10% margin between LS-DYNA and the design basis acceleration, but there is considered to be additional margin between the predicted values and the test data. With respect to maximum crush depth, LS-DYNA was shown to provide a conservative prediction. Using the dynamic force-deflection curve, the UMS® impact limiter design is shown to have an additional 25% energy absorption capacity required to decelerate the transport cask. The side drop test performed at Sandia National Laboratory confirms that the UMS® impact limiters are adequate to limit the cask component accelerations well within the design basis accelerations.

2.10.3.5 Evaluation of the 30-Foot Oblique Drop

In Section 2.6.7.5.5, a parametric study was performed to show that for the NAC-STC cask, the side drop produces the maximum lateral accelerations. This is due to the low length to radius of gyration ratio for the STC cask. The following table compares the L/r of the UMS® and the NAC-STC casks:

Cask	L/r
UMS®	1.48
NAC-STC	1.50

Based on this comparison, it is concluded that the side drop provides bounding accelerations over shallow oblique drops. Consequently, a separate oblique drop test is not required.

2.10.3.6 Scale Model Drawings

The drawings for the ORNL and SNL quarter-scale models are included in this section for reference.

2.10.3.6.1 ORNL Drop Test Model

The detailed dimensions, welding and materials are shown on the drawings of the model body and impact limiters used in the ORNL drop tests.

2.10.4 Dynamic Load Factor (DLF) Evaluation for PWR and BWR Support Disks

Design basis accelerations of 20g and 60g are used in the PWR and BWR support disk evaluations for normal conditions (Sections 2.6.13 and 2.6.15) and accident conditions (Sections 2.7.8 and 2.7.10), respectively. This section is to demonstrate that, with the consideration of the Dynamic Load Factors (DLF), the maximum acceleration occurring at the support disks is bounded by the design basis accelerations. The 1-foot end drop and 1-foot side drop conditions are evaluated in Sections 2.10.4.1 and 2.10.4.2, respectively. Both the PWR and BWR support disks are considered.

2.10.4.1 1-Foot End Drop Analysis

Two ANSYS finite element models, constructed using SHELL63 elements, are used for the end drop analysis as shown in Figures 2.10.4.1-1 and 2.10.4.1-2 for PWR and BWR support disks, respectively. The model represents a single support disk restrained at the tie-rod locations in the Z-direction (perpendicular to the plane of the disk).

The maximum acceleration (g_{max}) at the cask surface determined by the impact limiter analysis is 17.1g for the 1-foot end drop (Table 2.10.4.1-1). The corresponding acceleration time histories are shown in Figure 2.10.4.1-3.

The steps used to determine the DLF, and the response acceleration of the support disk for the 1-foot drop condition, are:

1. The acceleration time history for the 1-foot end drop condition obtained from impact limiter analysis (Figure 2.10.4.1-3) is transformed into a frequency response spectrum as shown in Figure 2.10.4.1-4, using the response spectrum generator in ANSYS. The zero-period acceleration (>1000 Hz) is noted as 17.33g.

2. A modal analysis is performed for the PWR and BWR support disks using the ANSYS models shown in Figures 2.10.4.1-1 and 2.10.4.1-2. The modal frequencies and the corresponding modal participation factors (MPF) are determined by the analysis. Note that the MPFs for modes above 1000 Hz are negligible and hence not included.

3. Based on the frequency response spectrum obtained in Step 2, the response acceleration (g_{SRSS}) is calculated using the square-root-of-the-sum-of-the-squares (SRSS) method in conjunction with the absolute sum of the modal response for closely spaced modes (see NRC Regulatory Guide 1.92 [59]). As shown in Tables 2.10.4.1-1 and 2.10.4.1-2, the response acceleration is calculated to be 13.45g and 13.53g for PWR and BWR support disks, respectively. Only the out-of-plane vibrational modes are considered.

The DLF is determined by dividing the response acceleration (g_{SRSS}) by the maximum acceleration (g_{max}) from the impact limiter analysis results (i.e., DLF = (g_{SRSS}) / (g_{max})). Consequently, the DLF for the PWR support disks is calculated to be 0.79 (13.45/17.1). The DLF for the BWR support disks is calculated to be 0.79 (13.53/17.1).

As shown in Tables 2.10.4.1-1 and 2.10.4.1-2, the maximum response acceleration for both the PWR and BWR support disks for 1-foot end drop condition is less than 20g and, hence, are bounded by the design basis accelerations of 20g for normal conditions of transport. Similar results are expected for the accident conditions and, therefore, no further evaluation is performed.

2.10.4.2 Side Drop Analysis

The ANSYS PWR and BWR disk models used in the side drop analysis are shown in Figures 2.10.4.2-1 and 2.10.4.2-2, respectively. The models are the same as those for the end drop analyses except that different boundary conditions are applied, as shown. For each model, the support at location "A" allows movement in the "x" direction, but constrains movement in the "y" and "z" directions. Similarly, the support at location "B" allows movement in the "y" direction, but constrains movement in the "x" and "z" directions.

Figure 2.10.4.2-3 shows the LS-DYNA finite element model for the side drop analysis. This model represents a half-symmetry section (1.5 inch in longitudinal direction) of the cask body (outer shell, lead shell, inner shell), canister and a support disk.

Symmetry boundary conditions are applied at the plane of symmetry. Inertia load is applied in the negative "y" direction. The cask body is very heavy compared with the mass of the support disk and fuel. Hence, a model of cask body with an axial length equivalent to 3 times the disk thickness is sufficient to represent the physical interaction between the cask shells and the support disk. An effective density is used for the support disk to account for the self-weight of the disk and the weight of the fuel assembly.

The mass of the support disk is negligible compared with the mass of the cask shells. Therefore, there is no disk-to-cask interaction. The influence of the disk natural frequencies on the self-excitation of cask body is negligible. Since the main interaction is from cask-to-disk, the support disk is simply modeled as a rigid material. The BWR support disk configuration is used for the disk in the model. The density of the disk is adjusted to account for the actual weight for PWR and BWR configurations. The structural behavior of the cask shells is elastic-plastic. The model has four contact interfaces:

1. between the support disk and canister.
2. between the canister and inner shell.
3. between the inner shell and lead shell.
4. between the lead shell and outer shell.

The maximum acceleration (g_{max}) at the cask surface determined by the impact limiter analysis is 16.4g for the 1-foot side drop (Table 2.10.4.1-1). The corresponding acceleration time histories are shown in Figure 2.10.4.2-4.

The steps used to determine the DLF, and the response acceleration of the support disk, are:

1. The acceleration time history for side drop condition obtained from the impact limiter analysis is used as a dynamic load input to the LS-DYNA model. The response acceleration time history corresponding to the support disk is determined by this analysis.

2. The response acceleration time history is filtered at 1000 Hz (because MPFs above this frequency are negligible) using the LS-DYNA post-processor to remove the high frequency components of the response. See Figures 2.10.4.2-5 and 2.10.4.2-6 for the unfiltered and filtered acceleration time histories for PWR and BWR, respectively.

3. The filtered acceleration time history obtained above is transformed into a frequency response spectrum using the response spectrum generator in ANSYS. The zero-period accelerations (>1000 Hz) are noted as 10.38g for PWR (Figure 2.10.4.2-7) and as 11.66g for BWR (Figures 2.10.4.2-8), respectively.

4. A modal analysis is performed for the PWR and BWR support disks using the ANSYS models (Figures 2.10.4.2-1 and 2.10.4.2-2). The modal frequencies and the corresponding modal participation factors (MPF) are determined by the analysis. Note that the MPFs for modes above 1000 Hz are negligible and hence not included.

5. Based on the frequency response spectrum obtained in step-4, the response acceleration (g_{SRSS}) is calculated using the square-root-of-the-sum-of-the-squares (SRSS) method in conjunction with the absolute sum of the modal response for closely spaced modes (see NRC Regulatory Guide 1.92). As shown in Tables 2.10.4.2-1 and 2.10.4.2-2, the acceleration response (g_{SRSS}) is calculated to be 14.99g and 15.72g for PWR and BWR support disks, respectively. Only the in-plane vibrational modes are considered.

The DLF is determined by dividing the response acceleration (g_{SRSS}) by the maximum acceleration (g_{max}) from the impact limiter analysis results (i.e. DLF = (g_{SRSS}) / (g_{max})). The DLF for the PWR and BWR support disks is calculated to be 0.91 (14.99/16.4) and 0.96 (15.72/16.4), respectively.

As shown in Tables 2.10.4.2-1 and 2.10.4.2-2, the maximum response acceleration for both the PWR and BWR support disks for 1-foot side drop condition are less than 20g and, hence, are bounded by the design basis accelerations of 20g for normal conditions of transport. Similar results are expected for the accident conditions and, therefore, no further evaluation is performed.

2.11.1.1 Maine Yankee Site Specific Spent Fuel

The standard spent fuel assembly for the Maine Yankee site is the Combustion Engineering (CE) 14x14 fuel assembly. Fuel of the same design has also been supplied by Westinghouse and by Exxon. The standard 14x14 fuel assemblies are included in the population of the design basis PWR fuel assemblies for the UMS® Transport System (see Table 1.2.5). The structural evaluation for the UMS® transport system loaded with the standard Maine Yankee fuels is bounded by the structural evaluations in Sections 2.6 and 2.7 for the normal conditions of transport and hypothetical accident conditions, respectively. The Maine Yankee site specific fuel is described in Section 1.3.1.

The weight of a standard 14x14 fuel assembly with the control element assembly inserted is 1,360 lbs. This weight is bounded by the weight of the design basis PWR fuel assembly (37,608/24 = 1,567 lbs) used in the PWR support disk analysis presented in Section 2.6.13. The fuel configurations with removed fuel rods, with fuel rods replaced by solid stainless steel or Zircaloy rods, or with poison rods replaced by hollow Zircaloy rods, all weigh less than the standard 14x14 fuel assembly. The configuration with instrument thimbles installed in the center guide tube position weighs less than the standard assembly with the control element assembly installed. Consequently, this configuration is also bounded by the weight of the design basis fuel assembly. Since the weight of any of these fuel assembly configurations is bounded by the design basis fuel assembly weight, no additional analysis of these configurations is required.

A structural evaluation is required for the support disk for the configuration holding consolidated fuel. There are two consolidated fuel lattices, each constructed of 17x17 Zircaloy fuel grids and stainless steel end fittings which are connected by 4 stainless steel support rods. One of the consolidated fuel lattices has 283 fuel rods with 2 empty positions. The other has 172 fuel rods with the remaining positions either empty or holding stainless steel rods. The calculated weight for the heaviest of the two consolidated fuel lattices is 2,100 lbs.

A parametric study is performed to show that the PWR support disk holding a Maine Yankee consolidated fuel lattice is bounded by the UMS® PWR support disk stress evaluation presented in Section 2.6.13. Note that only one consolidated fuel lattice will be loaded in any single Transportable Storage Canister and that the loading position of the consolidated fuel assembly is restricted to a basket corner position (see Section 1.3.1.1).

However, Maine Yankee fuel cans holding other intact or damaged fuel can be loaded in the other three corner positions of the basket (Maine Yankee fuel cans may be loaded only in the four corner positions of the basket. See Figure 2.11.1.1-1 for corner positions). Therefore, the bounding case for Maine Yankee is the basket configuration with twenty (20) Maine Yankee fuel assemblies, three (3) fuel cans containing spent fuel, and one (1) fuel can containing consolidated fuel.

The two-dimensional ANSYS model used in the support disk evaluation (see Figure 2.6.13-2) in Section 2.6.13 is employed for the parametric study. The boundary condition of the model is modified by restraining the outer surface of the canister shell. The load from a PWR fuel assembly is modeled as a pressure load at the inner surface of each support disk slot opening. The design basis fuel pressure loading is 12.26 psi (see Section 2.6.13.2). Based on the same design parameters (slot size = 9.272 in., disk thickness = 0.5 inch, and the number of disks = 30), the pressure load corresponding to a Maine Yankee standard CE 14x14 fuel assembly is 10.3 psi. The pressure load is 11.3 psi for a Maine Yankee fuel can holding an intact or damaged fuel assembly. For a Maine Yankee fuel can holding consolidated fuel, the pressure load is 17.0 psi.

This study considers both the 1-foot (20g) and the 30-foot (60g) side drop conditions for four different drop orientations: 0°, 18.22°, 26.28°, and 45°, as shown in Table 2.11.1.1-1. A total of five cases are considered in the study. Inertial loads are applied to the support disk in all cases. The base case considers that all 24 fuel positions hold design basis PWR fuel assemblies. The other four cases (Cases 1 through 4) represent four possible load combinations for the placement of four Maine Yankee fuel cans in the corner positions, one of which holds consolidated fuel. The remaining twenty (20) basket positions hold Maine Yankee standard 14×14 fuel assemblies. The basket loading positions are shown in Figure 2.11.1.1-1. The load combinations evaluated in the four Maine Yankee fuel can loading cases are:

Case	**Basket Position 1**	**Basket Position 2**	**Basket Position 3**	**Basket Position 4**
1	Consolidated	Damaged	Damaged	Damaged
2	Damaged	Consolidated	Damaged	Damaged
3	Damaged	Damaged	Damaged	Consolidated
4	Damaged	Damaged	Consolidated	Damaged

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UMS®

UNIVERSAL MPC SYSTEM®

SAFETY ANALYSIS REPORT

for the

UMS® Universal Transport Cask

JANUARY 2002 UMST-02A

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NAC INTERNATIONAL

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Chapter 6

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Chapter 7

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8. Damaged Fuel Assemblies

Damaged fuel assemblies are standard fuel assemblies with fuel rods that have known or suspected cladding defects greater than hairline cracks or pinhole leaks. Each damaged fuel assembly will be placed in a Maine Yankee fuel can. The primary function of the fuel can is to confine fuel material within the can and to facilitate handling and retrievability. The Maine Yankee fuel can is shown in Drawings 412-501 and 412-502. The placement of the loaded fuel cans is restricted by operating procedures and/or Technical Specifications to loading into the four fuel tube positions at the periphery of the fuel basket as shown in Figure 3.6.1.1-4. The heat load for each damaged fuel assembly is limited to the design basis heat load of 0.833 kW (20 kW/24).

A steady-state thermal analysis is performed using the three-dimensional cask model described in Section 3.4.1.1.1 simulating 100% failure of the damaged fuel rods held in the Maine Yankee fuel can. The canister is assumed to contain twenty (20) design basis PWR fuel assemblies and damaged fuel assemblies in fuel cans in each of the four corner positions.

A debris compaction length of 104 inches is considered in the analysis based on the volume of fuel rods and a 50% compaction of the debris. Additionally, this 104-inch debris region is assumed to be located at the center of the active fuel region of the design basis PWR fuel assemblies, as shown in Figure 3.6.1.1-4. The entire heat load for a single fuel assembly (i.e., 0.833 kW) is considered to be concentrated in the debris region. The effective thermal conductivities for the design basis PWR fuel assembly (Section 3.4.1.1.2) are used for the debris region. This is conservative, since the debris (100% failed rods) is expected to have a higher density (better conduction) and more surface area (better radiation) than an intact fuel assembly. In addition, the thermal conductivity of helium is used for the remainder of the active fuel length. Boundary conditions corresponding to normal transport are used at the outer surface of the cask (see Section 3.4.1.1.1). The results of the steady-state thermal analysis for 100% fuel rod, fuel cladding and guide tube failure are:

Description	Maximum Temperature (°F)			
	Fuel Cladding	Damaged Fuel	Support Disk	Heat Transfer Disk
Configuration with damaged fuel loaded in four basket corner locations	682	633	618	614
Design basis PWR fuel	673	N/A	608	605
Allowable	716	N/A	650	700

As shown in the previous table, the maximum temperatures for the fuel cladding, damaged fuel assembly, support disks, and heat transfer disks for the configuration with damaged fuel loaded in four (4) basket corner locations are within the allowable temperature range. Additionally, the maximum temperature of the support disk remains bounded by that used in the structural analyses of the fuel basket.

Damaged high burnup fuel must be loaded into damaged fuel cans. These fuel assemblies have more than 1% of rods with oxide layers greater than 80 microns or more than 3% of rods with oxide layers greater than 70 microns and burnup greater than 45,000 MWD/MTU. The cask pressure for this condition is used as input to the containment analysis. Consistent with the containment analysis, a basket release fraction of 20% is applied. This release fraction accounts for up to 12 high burnup assemblies, including up to four classified as damaged. Applying this release fraction to the pressure evaluation in Section 3.4.4.1 yields a normal conditions cask pressure of 15.61 psig, calculated using B&W 17x17 Mark C fuel assembly parameters.

$$r = \frac{\overline{S}}{S(\overline{B})} = \frac{\frac{a}{H}\int B^b dz}{a\overline{B}^b}$$

where H is the height of the fuel region. With the burnup profile normalized to unity, this becomes

$$r = \frac{1}{H}\int B^b dz \, .$$

The integral is evaluated numerically by using the trapezoid rule, and the resulting scale factors are shown in Table 5.2-19 for PWR and BWR neutron source rates. The scale factor is unity for photon sources because photon source rates vary linearly with burnup.

The fuel neutron and fuel gamma source rate profile for the design basis PWR fuel assembly is tabulated in Table 5.2-20 and shown graphically in Figure 5.2-3. Corresponding BWR profiles are given in Table 5.2-21 and Figure 5.2-4.

Figure 5.2-1 Enveloping Axial Burnup Profile for PWR Design Basis Fuel

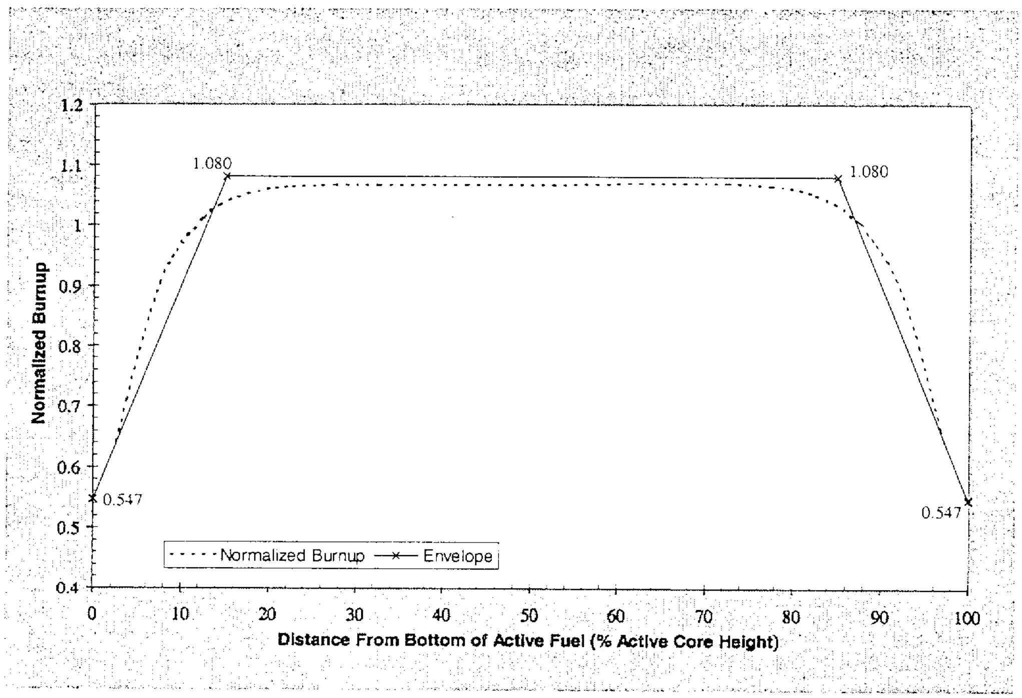
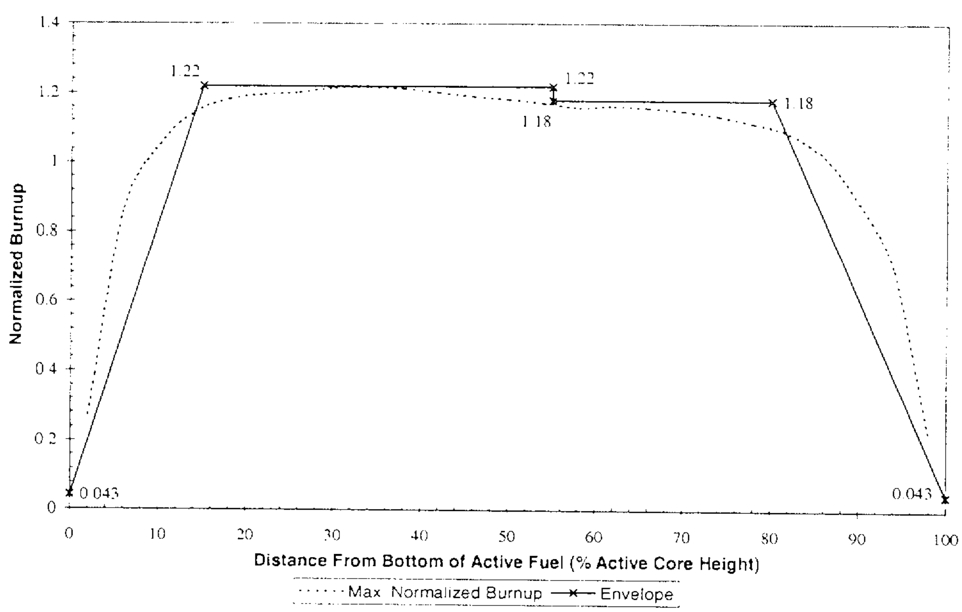


Figure 5.2-2 Enveloping Axial Burnup Profile for BWR Design Basis Fuel



5.4.3.1 Methodology

The loading table analysis extends the applicability of the initial 10-year cooled 45,000 MWD/MTU PWR and 40,000 MWD/MTU BWR shielding design basis evaluation by providing minimum cool times for 30,000 MWD/MTU to 45,000 MWD/MTU burned fuel assemblies in increments of 5,000 MWD/MTU. In addition to the burnup range the loading table evaluation also includes minimum initial enrichment limits ranging from 1.9 to 3.7 wt % ^{235}U in 0.2 wt % ^{235}U increments. Changes in the initial enrichment can have a substantial impact on the actinide neutron source of the spent nuclear fuel and, thereby, modifies the minimum cool times required to meet the decay heat and dose rate limits imposed on the transport cask.

The fuel types analyzed in the loading table analysis include the candidate design basis fuel assemblies listed in Section 5.1.1. Note that the analysis of BWR fuel types considers only the longer BWR-4/6 type fuel, which bound the shorter BWR-2/3 type fuels.

A complete set of source spectra and decay heat values for this set of limiting assemblies is then computed using the SAS2H [4] code at various initial enrichment, burnup, and cool times representative of the fuel intended for shipment in the UMS Transport Cask.

Next, the cool time required for each fuel type, initial enrichment, and burnup combination to meet limiting values of decay heat and dose rate is determined. The decay heat limits are set based on the cool-time dependent decay heat limits established in Section 3.4.6, as shown in Table 3.4-16. The dose rate limits are established based on a one-dimensional analysis of the Transport Cask containing the design basis PWR and BWR fuels under both normal and accident conditions.

With the limiting cool times identified for each fuel combination, the results are further summarized by identifying the most limiting fuel type within each array size classification. This array size classification is intended to simplify the application of the loading tables in determining the suitability of a particular fuel for shipment without need for a detailed analysis.

The SCALE computer code system is used to evaluate radiation source terms and to perform one dimensional shielding calculations. Source terms are evaluated using the SAS2H code, which provides a simplified interface to the ORIGEN-S code, including burnup-dependent cross-section processing. Source spectra at additional cool times are evaluated by direct application of the ORIGEN-S code. The SAS1 code sequence is used to determine one-dimensional dose rates and the dose rate response functions. The SAS1 driver provides an interface to the XSDRNPM one-dimensional transport code. All SCALE analyses are conducted using the SCALE 27N18G group library.

The key analytical assumption made in this analysis is the validity of extending one-dimensional dose rate comparisons to conclusions about the dose rate field in the vicinity of the cask. This assumption is supported by the following:

1. The geometry of the cask system is essentially the same regardless of the fuel type loaded. This is particularly true when the dissipating effects on dose rate of the cask shielding materials are considered. Possible concerns about an unfavorable geometry (e.g., a fuel assembly end fitting adjacent to an area of minimal shielding) occurring for a particular fuel assembly have been considered both implicitly in the design of the system and directly in the three dimensional shielding analyses conducted for the design basis fuels.

2. The one-dimensional radial dose rates used for the comparison are themselves accurate predictions of actual dose rates. The ratio of the length of the cask to its diameter ensures that the buckling approximation implicit in a one-dimensional calculation is valid. This assumption is further justified based on the results of a three-dimensional verification study.

Furthermore, the one-dimensional dose rate comparisons are made on the basis of fuel region sources alone. This analysis is intended to consider the impact of the relationship between initial enrichment and burnup on actinide production in the active fuel region. The three-dimensional shielding calculations performed for the Transport Cask incorporate the maximum plenum and end-fitting hardware descriptions of all assemblies intended for shipment in the UMS system.

Hence, the non-fuel source regions have already been considered to the maximum extent, and it is only necessary to demonstrate that the fuel region sources are bounded by the design basis.

This argument is also applied to the suitability of considering dose rates computed only for the radial case. Since no aspect of the cask shield construction changes with varying fuel type, it is

7.0 OPERATING PROCEDURES

The Universal Transport Cask is designed to transport spent nuclear fuel and Greater Than Class C (GTCC) waste. The cask is dry loaded in the spent fuel building or at the onsite Independent Spent Fuel Storage Installation (ISFSI). This chapter outlines the procedures for dry loading or unloading at either location, conducting the receiving inspection, preparing the cask prior to loading or unloading, and preparing the cask for transport following loading or unloading. These procedures are based on the assumption that an empty cask is hauled onsite by a railcar or heavy haul trailer. Table 7-1 summarizes the major torque values to be used in the procedures.

The operating procedures outlined in this chapter represent the minimum generic requirements to ensure safe and reliable operation of the cask. The cask user is responsible for developing, preparing, and approving site-specific procedures in accordance with these procedures, the package certificate of compliance, and the user's quality assurance program. Following the user-approved operating procedures will assure that cask handling and shipping activities are performed in accordance with the Certificate of Compliance, safety analysis report, and applicable U.S. Nuclear Regulatory Commission and U.S. Department of Transportation regulations governing the packaging and transport of radioactive materials.

The generic procedures primarily address the loading and unloading of a Universal Transport Cask with a Transportable Storage Canister that has already been loaded with spent fuel or GTCC waste (Sections 7.1.3 and 7.3.3). These procedures describe the use of the transfer cask, which is primarily a lifting device, but also provides biological shielding when it contains a loaded canister. The transfer cask is used for the vertical transfer of the canister between workstations and the storage or transport casks. The transfer cask is more fully described in the Safety Analysis Report (SAR) for the UMS® Universal Storage System, Docket No. 72-1015.

Table 7-1 Torque Values

Component*	Number Used	Fastener	Torque Value
Cask lid bolt	48	2 - 8 UN - Socket Head Bolt	3,900 ± 100 ft-lb
Vent/drain port coverplate bolt	8	1/2 - 13 UNC - Socket Head Cap Screw	300 ± 50 in-lb
Lid o-ring test port plug	1	Parker #16 P5N	30 ± 5 in-lb
Vent/Drain o-ring test port plug	2	Cajon #SS-2-PST	125 ± 5 in-lb
Impact limiter retaining rods	32	ASTM A193 GRB8S Aust. Stainless Steel	75 ± 5 ft-lb [5]
Impact limiter nut	32	1-1/4 - 7 UNC Heavy Hex Nut	35 ± 2 ft-lb
Impact limiter jam nut	32	1-1/4- 7 UNC Hex Jam Nut	75 ± 5 ft-lb
Adapter plate bolts	4	1-1/4- 7 UNC - Socket Head Cap Screw	250 ± 30 ft-lb [5]
Secondary trunnion bolts	24	1-1/8 - 12 UNF Socket Head Cap Screw	500 ± 50 ft-lb
Personnel barrier (Tie Down Bolts)	6	3/8 - 16 UNC Hex Head Bolt	35 ± 2 ft-lb
Impact limiter positioner (upper and lower)	6	3/4 - 10 UNC Socket Head Cap Screw	50 ± 5 in-lb

* Torque values for components not shown in this table are provided on the appropriate license drawings in Section 1.3.4.

Note: Threaded fasteners shall be lightly lubricated with Nuclear Grade NEOLUBE® or equivalent.

2. Detorque and remove the vent coverplate bolts.
3. Remove the vent port coverplate from the lid.

   Note: The drain port coverplate need not be removed for dry loading or unloading.
4. Visually inspect the port coverplate o-rings for damage or defects and replace if necessary. Store the coverplate so that the o-rings and o-ring grooves are protected from incidental damage.
5. Detorque the cask lid bolts using the reverse torquing sequence.
6. Remove the bolts and store them in a temporary storage area.
7. Clean and visually inspect bolts for damage. Replace any damaged bolts.
8. Install the two cask lid alignment pins.
9. Install lifting hoist rings in the lid-lifting holes.
10. Attach the lid-lifting device to the lid and an overhead crane.

    Caution: Ensure that the o-rings and o-ring grooves in the lid are protected from any incidental damage to the seal area in its temporary storage position.
11. Remove the lid and store in a temporary storage area.
12. Decontaminate the lid and visually inspect the lid o-rings for damage and wear and replace as necessary.

    Note: Visually Inspecting and cleaning of bolts can be performed in parallel to other operations performed in this procedure.

13. Clean and visually inspect the threaded connections in the top forging.
14. Remove the two cask lid alignment pins.
15. Visually examine the internal cavity to ensure that no damage has occurred during transit and that no foreign materials are present.
16. Record all inspection results.
17. Install the cask adapter ring to protect the cask sealing surfaces.
18. If a canister spacer is to be installed:
    a) Attach the spacer lift fixture to the spacer.
    b) Using an appropriate crane, lower the spacer into the cask cavity and remove the lift fixture.
19. Install the transfer cask adapter plate guide pins.
20. Install the adapter plate on top of the cask.
21. Remove the adapter plate guide pins.
22. Install the transfer cask on the adapter plate.

7.1.3 Loading Transportable Storage Canister into Universal Transport Cask

A transfer cask is used to load the Transportable Storage Canister into the Universal Transport Cask at the spent fuel building or at the ISFSI loading area. The assumptions underlying this procedure are :

- The canister is already loaded with fuel or GTCC waste.
- The canister is seal welded, vacuum dried, and helium backfilled.
- The canister is located in a transfer cask. (The procedures for closing the canister following fuel loading, and for draining, sealing, drying, inerting, and leak testing the canister and installing hoist rings are provided in Section 7.5 of the UMS® Storage System FSAR.)
- All of the required steps of Section 7.1.2 are complete, including adapter plate and bottom spacer installation (if necessary).
-
- The Universal Transport Cask is positioned in the designated area in the spent fuel building or at the ISFSI with the cask lid off.

The movement and operation of the transfer cask with a loaded canister prior to inserting the canister into the Universal Transport Cask are part of in-plant operations and preparation for storage. Steps for these operations are therefore not included in the following procedures.

1. Verify that the retaining ring is installed on the transfer cask.
2. Lift the transfer cask and lower it on top of the adapter plate on the transport cask and engage the hydraulic cylinders with the doors.
3. Engage the transportable storage canister lifting sling's master ring with the crane hook and engage the individual sling hooks with their respective hoist rings located on the structural lid of the transportable storage canister.
4. Raise the canister enough to remove the load on the Transfer Cask doors and then open the doors.

   CAUTION: While lowering the canister in Step 5, be careful to avoid contact with the interior cavity wall of the Universal Transport Cask.

8. Remove the threaded plugs and attach the lifting eyes in the cask lid.
9. Attach the lid-lifting device to the cask lid and to the overhead crane.
10. Remove the cask lid and place the lid in a designated area.
11. Ensure that the O-ring grooves in the lid are protected so that they will not be damaged during handling.
12. Decontaminate the lid as necessary.
13. Remove the two alignment pins.
14. Install the cask adapter ring to protect the sealing surfaces of the cask.
15. Install the adapter plate guide pins.
16. Install the transfer cask adapter plate to protect the sealing surfaces of the transport cask and to provide a seating surface for the Transfer Cask.
17. Install the four adapter plate bolts.
18. Install the transfer cask alignment pins in the adapter plate.

7.3.3 Unloading Transportable Storage Canister from Universal Transport Cask

A transfer cask is used to unload the Transportable Storage Canister. The transfer cask could be used to transfer the loaded canister to the spent fuel building for subsequent storage in the spent fuel pool or to transfer it to another storage or disposal overpack. Prior to beginning operation of the transfer cask doors and the hydraulic system should be checked. The transfer cask retaining ring should be installed.

1. Remove threaded plugs from structural lid.
2. Install the swivel hoist rings in the canister structural lid.
   CAUTION: The structural lid may be thermally hot.
3. Install the transport cask adapter ring to protect the sealing surfaces of the transport cask.
4. Install the transfer cask adapter plate on the transport cask.
5. Attach the canister lifting sling to the hoist rings in the structural lid. Position the sling so that the free end of the sling can be engaged by the cask-handling crane hook.
6. Attach the transfer cask lifting yoke to the cask-handling crane hook.
7. Engage the yoke to the lifting trunnions of the transfer cask.
8. Lift the transfer cask and move it above the Universal Transport Cask.
9. Lower the transfer cask to engage the alignment pins of the transfer cask adapter plate.
10. Once the transfer cask is fully seated, remove the transfer cask lifting yoke and store it in the designated location.

11. Install the transfer cask bottom door hydraulic operating system.
12. Open the transfer cask bottom doors.
13. Lower the cask-handling crane hook through the transfer cask and engage the canister lifting sling.

    CAUTION: When raising the canister in Step 14, be careful to minimize any contact between the canister and the cavity wall of the Universal Transport Cask and between the canister and the cavity wall of the transfer cask.
14. Raise the canister into the transfer cask just far enough to allow the transfer cask bottom doors to close.
15. Close the transfer cask bottom doors and install the door locking pins.
16. Carefully lower the canister until it rests on the transfer cask bottom doors.
17. Disengage the canister lifting sling from the crane hook.
18. Retrieve the transfer cask lifting yoke and engage it with the transfer cask trunnions.
19. Lift the transfer cask from the transport cask and move it to the designated location.
20. Attach the adapter plate lifting fixture.
21. Remove the four bolts securing the adapter plate to the Universal Transport Cask.
22. Using the auxiliary crane, lift the adapter plate from the top of the cask and move the adapter plate to the designated storage location.
23. Remove cask adapter ring.
24. Install the vent port coverplate over the vent port in the cask lid.
25. Install/torque the coverplate bolts to the values specified in Table 7-1.
26. Install the cask lid alignment pins.
27. With the lid-lifting device, install the cask lid by using the alignment pins to assist in proper seating.
28. Remove the lid-lifting device, lid lift hoist rings, and the lid alignment pins.
29. Install the lid bolts and torque them to the value specified in Table 7-1.
30. Using a pressure test fixture, pressurize the o-ring annulus of the cask lid to 15 psig and hold for 10 minutes. There should be no loss of pressure during the test period.
31. Install the plug in the Seal Test port, verifying that the test plug o-ring is in place, and torque the plug to the value specified in Table 7-1.
32. Using a pressure test fixture, pressurize the vent coverplate o-ring annulus to 15 psig and hold for 10 minutes. There should be no loss of pressure during the test period.
33. Install the plug in the seal test port, verifying that the test plug o-ring is in place, and torque the plug to the value specified in Table 7-1.
34. Repeat Steps 32 and 33 for the drain port, if the drain port was used.