71-9225

NAC INTERNATIONAL

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May 3, 2007

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

Attn: Document Control Desk

Subject: Responses to Request for Additional Information (RAI) on the Amendment Application for CoC No. 9225 for the NAC-LWT Cask to Incorporate Various Changes to the Authorized Contents and the Operating Procedures (TAC L24043)

Docket No. 71-9225

Reference:
1. Model No. NAC-LWT Package, Certificate of Compliance (CoC) No. 9225, Revision 43, U.S. Nuclear Regulatory Commission (NRC), December 15, 2006
2. Safety Analysis Report (SAR) for the NAC Legal Weight Truck Cask, Revision 37, NAC International, June, 2005
3. Submittal of a Request for an Amendment of Certificate of Compliance (CoC) No. 9225 for the NAC-LWT Cask to Incorporate Various Changes to the Authorized Contents and the Operating Procedures, NAC International, November 17, 2006
4. Submittal of Proposed Certificate of Compliance (CoC) Changes and a Supplement to the November 17, 2006 Request for an Amendment of CoC No. 9225 for the NAC-LWT Cask, NAC International, March 2, 2007
5. NAC-LWT Review Telephone Call and Request for Additional Information (TAC L24043), NRC, April 30, 2007

NAC International (NAC) herewith provides responses to the RAI (Reference 5) on NAC's application for an amendment to Reference 1 to incorporate various changes to the NAC-LWT contents and the operating procedures as described in References 3 and 4.

This submittal has been prepared in accordance with NRC/NAC discussions and includes six copies of this transmittal letter, six copies of the RAI questions with the NAC responses presented in the standard NAC RAI response format, and six copies of the Revision LWT-07C changed SAR pages for Reference 2. The changed NAC-LWT SAR pages incorporate the requested information. Attachment 1 to this letter contains a detailed list of SAR changes for the Revision LWT-07C changed pages.

Consistent with NAC administrative practice, this proposed revision is numbered to uniquely identify the applicable changed pages. Revision bars mark the SAR text changes (on Revision LWT-07C pages) that are proposed. Upon final approval, the changed pages will be reformatted, assigned the next appropriate revision number, and incorporated into the NAC-LWT SAR. A List of Effective Pages is included for clarity.

NMSS01

NAC INTERNATIONAL

Timely approval of this amendment request as supplemented by the requested information will support the shipment of the proposed modified contents in the NAC-LWT cask. To support anticipated spent fuel shipping schedules, equipment preparation and project planning, NAC respectfully requests continued review and subsequent approval of this amendment request by June 5, 2007.

If you have any comments or questions, please contact me on my direct line at 678-328-1274.

Sincerely,

Anthony L. Patko

Anthony L. Patko
Director, Licensing
Engineering

Attachment 1 – List of SAR Changes for the NAC-LWT Cask Transport Amendment, Revision LWT-07C in Response to the NRC Letter Dated 4/30/07

Enclosures

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Attachment 1

List of SAR Changes for the

NAC-LWT Cask Transport Amendment

Revision LWT-07C

in Response to the NRC Letter Dated 4/30/07

NAC International

May 2007

List of Changes in NAC-LWT SAR, Revision LWT-07C

Chapter/Page/ Figure/Table	Response to RAI Number	Description of Change
Chapter 1		
Page 1-1	6-1	Section 1.0, last paragraph, last sentence – changed "the mass limits of 10 CFR 71.53" to "the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c)"
Page 1-2	6-1	Next to last paragraph, 2nd sentence – changed "the mass limits of 10 CFR 71.53" to "the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c)"
Page 1-4, Table 1-1	1-3	Added new definitions for Intact LWR Fuel (Assembly or Rod) and Damaged LWR Fuel (Assembly or Rod)
Page 1-5	6-1	Irradiated Hardware definition, 1st sentence – changed "the mass limits of 10 CFR 71.53" to "the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c)"
Page 1.1-2	6-1	1st bullet – revised throughout
Page 1.2-6	6-1	2nd bullet – revised throughout
Page 1.2-7	6-1	Item 17, 1st sentence – changed "the mass limits of 10 CFR 71.53" to "the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c)"
Page 1.2-16	6-1	Section 1.2.3.10, 1st paragraph, last sentence – changed "the mass limits of 10 CFR 71.53" to "the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c)"
Page 1.2-45	1-5 & 6-1	Revised the value for Hardware Material as well as footnote 3. Footnote 4 – changed "the mass limits of 10 CFR 71.53" to "the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c)"
Chapter 3		
Page 3.5-3	Editorial & 3-1	Section 3.5.1.2, 1st paragraph, 1st sentence – changed "analysis of NAC-LWT cask" to "analysis of the NAC-LWT cask"; 2nd sentence – added "Section 3.4.1.7" and changed "for NAC-LWT cask" to "for the NAC-LWT cask" 2nd paragraph – added new text to justify the selection of the Condition 2 model (air in cavity) for the thermal transient.

NAC INTERNATIONAL

RESPONSE TO THE

UNITED STATES
NUCLEAR REGULATORY COMMISSION

REQUEST FOR ADDITIONAL INFORMATION

APRIL 30, 2007

LEGAL WEIGHT TRUCK CASK (NAC-LWT)

TRIGA FUEL AMENDMENT

(TAC. NO. L24043, DOCKET NO. 71-9225)

MAY 2007

TABLE OF CONTENTS

NAC-LWT TRIGA FUEL RAI RESPONSES

CHAPTER 1 GENERAL INFORMATION

1-1 Table 1.2-12. Verify that the maximum content length allowed for the solid irradiated hardware is 171.5 inches as listed.

Drawing 315-40-03 shows the cask cavity length of 180.9 inches, measuring from the crown of the slightly bulged bottom forging to the top surface of the lower flange of the upper forging. As depicted in Drawings 315-40-04 and 315-40-145, subtraction of the lid insert and spacer depths of 3.3 inches and 6.5 inches, respectively, from the cavity length, will result in a net cavity length of 171.1 inches. This discrepancy needs to be clarified.

Complete and accurate information must be provided in the application in accordance with the 71.7(a) requirements.

NAC International Response

The Table 1.2-12 dimension for the irradiated hardware of 171.5 inches is the result of subtracting the 3.3-inch lid lower section and the 6.6-inch spacer from the 181.3-inch distance to the bottom of the NAC-LWT cavity indicated in Drawing 315-40-03. The 181.3-inch length represents the distance to the lowest point on the NAC-LWT bottom forging. The distance to the top of the crowned bottom forging is 180.9 inches. Therefore, the maximum cavity length dimension of 171.5 inches available for the placement of irradiated hardware is correct and a revision to Table 1.2-12 is not required.

CHAPTER 1 GENERAL INFORMATION

1-2 ANSTO Fuel Basket Weldment. Revise Drawings 315-40-140, -141, and -142, as appropriate, to add chamfer preparation details for the top, support, and bottom plates of the basket modules, respectively.

The application recognizes the bottom plate edge details for bearing load transfer by stating, "The base plate of the base module is either supported by ... or supported by the chamfered plate periphery interfacing with the transition of the cask inner shell and the bottom forging." Chamfer details such as those for the DIDO basket modules should be added to the drawings.

Complete and accurate information must be provided in the application in accordance with the 71.7(a) requirements.

NAC International Response

The original design intent of the ANSTO basket was to support the baskets and contents by interfacing with the base of the cask cavity through base plates of the baskets. However, as documented in an NAC letter from Anthony L. Patko, Director, Licensing, to the U.S. Nuclear Regulatory Commission dated November 9, 2006, the SAR was revised to define the base plate of the base ANSTO basket module as the load-bearing surface interfacing with the cask inner shell and the bottom forging. The acceptability of the alternative load-bearing arrangement (i.e., without the installation and use of the drain alignment ring [Item 13, Drawing 315-40-02]) was authorized by the NRC in a letter from Robert A. Nelson, Chief, Licensing Branch, Division of Spent Fuel Storage and Transportation to Anthony L. Patko, NAC, dated November 15, 2006 (TAC No. L24041).

In the above-referenced NRC letter, NAC was authorized to use the NAC-LWT package in the alternative shipping arrangement. The authorization is scheduled to expire on November 15, 2007.

NAC confirms that the NAC Engineering/Design Drawings used for the fabrication of the ANSTO basket modules include a similar requirement to chamfer the base plate of each

NAC International Response to RAI 1-2 (cont'd)

module by 45° × .06 and a 3° taper on the base plates. Therefore, the reference to the "... chamfered plate periphery interfacing with the transition of the cask inner shell ..." is a correct and valid statement. As part of the effort to reduce unnecessary fabrication detail from the NAC Licensing Drawings, this detail was not included in NAC Drawings 315-40-140, -141, and -142.

In order to make permanent corrections to the basket and NAC-LWT cask cavity fit-up issue identified in the NAC request and the NRC authorization, NAC is currently redesigning the drain alignment ring (Item 13, Drawing 315-40-02) to ensure proper fit-up with all module basket assemblies requiring its use during basket module dry transfer loading and unloading operations.

As part of the planned submittal correcting these fit-up issues, NAC will revise Drawings 315-40-140, -141, and -142 to incorporate the plate basket module base plate chamfer detail prior to the next use of the affected baskets.

CHAPTER 1 GENERAL INFORMATION

1-3 In Table 1-1, the definition of damaged fuel is incomplete. The definition of damaged fuel should be changed to "damaged fuel rods." The definition does not entail hardware damage. Under this definition, assemblies with severe hardware damage could be considered undamaged.

Complete and accurate information must be provided in the application in accordance with the 71.7(a) requirements.

NAC International Response

The definitions in Table 1-1 are revised to clearly indicate the definition of intact and damaged LWR fuel (assembly or rod). As such, the damaged fuel definition is revised to include structural and handling limitations, and an "Intact LWR Fuel" definition is added.

CHAPTER 1 GENERAL INFORMATION

1-4 In Section 1.2.3, changes are indicated by change bars that are not in agreement with the request in the reference letter. Changes to this section and Tables 1.2-1 and 1.2-2 need to be clearly stated.

Complete and accurate information must be provided in the application in accordance with the 71.7(a) requirements.

NAC International Response

The changes to Section 1.2.3 (pages 1.2-5 through 1.2-11) in LWT amendment LWT-06G are as follows:

Chapter/Page	Description of Change
Chapter 1	
Pages 1.2-5 & 1.2-6	Section 1.2.3, 1st paragraph – changed the contents information from a paragraph format to a bulleted list format. Revised the bulleted list to include irradiated hardware and damaged fuel (in lieu of failed fuel).
Pages 1.2-6 & 1.2-7	Itemized list of limits – Item 2 – changed "Tables 1.2-1 through 1.2-11" to "Tables 1.2-1 through 1.2-12"; Item 4 – changed "0.693 kW for TPBARs" to "0.693 kW for 300 TPBARS"; added "and 1.26 kW for solid, nonfissile, irradiated hardware"; Item 7 – changed "failed" to "damaged"; Item 8 – added as new item; subsequently changed the numbering of the following items.
Page 1.2-7	Added new Item 17. Section 1.2.3.1, 2nd paragraph – revised 3rd sentence throughout & added new 4th sentence.
Page 1.2-8	Section 1.2.3.1.1.1, 1st paragraph – revised throughout; 2nd paragraph – deleted 2nd sentence; new 2nd sentence – added "approximately" in 2 places; deleted following paragraphs.
Page 1.2-9	Section 1.2.3.1.1.3 – revised Item 2 throughout; added new Item 3.
Page 1.2-10	3rd paragraph – combined & revised 1st & 2nd sentences; revised new 2nd sentence. 4th paragraph – revised throughout; made a separate 5th paragraph (no text revision).
Page 1.2-11	Section 1.2.3.2 – the indicated change is actually in Table 1.2-4, which is referenced in the last paragraph of this section.

NAC International Response to RAI 1-4 (cont'd)

Note that as a result of preparing our responses to this RAI, additional changes have been made to some of the pages listed in the preceding table. The new changes are listed in Attachment 1 to NAC letter ED20070024 dated May 3, 2007.

Tables 1.2-1 and 1.2-2 were completely revised and reformatted to present the information type and characteristics for TRIGA fuel elements as listed in the NAC-LWT CoC, No. 9225, Revision 43, Condition 5.(b)(1)(vi). The tables were further refined to present the TRIGA fuel characteristics acceptable for loading in the poisoned TRIGA basket (Table 1.2-1) and the TRIGA fuel characteristics acceptable for loading in the nonpoisoned TRIGA basket (Table 1.2-2). It was believed that this presentation format for TRIGA fuel element characteristics would then allow the revised Tables to be directly incorporated into the revision of the CoC.

Therefore, a comparison of new Table 1.2-1 and new Table 1.2-2 to the current TRIGA fuel characteristics table in the CoC identifies the following items have been revised, added or corrected:

- Maximum Element Weight, lbs., was increased from 6.4 pounds for the TRIGA LEU (aluminum) to a value of 13.2 pounds. Therefore, all TRIGA fuel elements are now listed with a maximum element weight of 13.2 pounds.
- Maximum Element Length, in., was increased to 47.74 inches from the previous values of 45 (stainless steel) and 28.4 (aluminum) inches.
- Minimum Cladding Thickness, in., for TRIGA elements acceptable for loading in poisoned baskets was unchanged at 0.02 in. for stainless steel and 0.03 in. for aluminum clad elements. For TRIGA elements acceptable for loading in the nonpoisoned baskets, the minimum element cladding thickness was reduced to 0.01 in. for all cladding material types.
- Active Fuel Length, in., presented in Table 1.2-1 for fuel elements acceptable for loading in the poisoned basket was unchanged. Table 1.2-2 references Note 5 and refers the user to Chapter 6, Section 6.4.5.6 for evaluating acceptable active fuel length.
- Element (or Maximum Element) Diameter, in., was unchanged for the TRIGA characteristics acceptable for loading in the poisoned basket in Table 1.2-1. Table 1.2-2 increased the acceptable diameter to 1.5 in. maximum for all TRIGA fuel types for loading in the nonpoisoned TRIGA basket.

NAC International Response to RAI 1-4 (cont'd)

- Fuel Diameter, in., Table 1.2-1 values for TRIGA fuel elements acceptable for loading in the poisoned basket were unchanged. Table 1.2-2 identified Note 5 referring users to Chapter 6, Section 6.4.5.6 for evaluations on acceptable fuel characteristics.
- Maximum Initial U Content/Element, kilograms, is unchanged in either Table 1.2-1 or 1.2-2 from the allowed U content in the CoC.
- Maximum Initial ^{235}U Mass, grams – no changes in the data presented.
- Maximum Initial ^{235}U Enrichment, weight percent – no changes in the data presented.
- Zirconium Mass, grams, Table 1.2-1 incorporated a reference to new Note 5, but the zirconium weights were unchanged from those presented in the CoC table. Table 1.2-2 refers to Note 5 and directs users to Chapter 6, Section 6.4.5.6 for evaluation of critical fuel characteristics.
- Hydrogen to Zirconium Mass, max., the values in Table 1.2-1 were unchanged from 1.6, 1.7 and 1.0 for the three fuel types listed in the CoC. A new Note 5 was added. Table 1.2-2 refers the user to Chapter 6, Section 6.4.5.6 for evaluation of critical fuel characteristics acceptable for loading in the nonpoisoned TRIGA fuel basket.
- Maximum Average Burnup, MWd/MTU, no changes were made to the values listed in the CoC table.
- Minimum Cooling Time, no changes were made to the value of 90 days or a maximum decay heat per element of 7.5 watts in the CoC table.

No additional changes were incorporated in Tables 1.2-1 or 1.2-2 as a result of this response to the RAI.

CHAPTER 1 GENERAL INFORMATION

1-5 Table 1.2-12 indicates that the irradiated hardware is just stainless or carbon steel. Table 1.1 allows any structural material such as inconel, Zircalloy, besides stainless, and carbon steels. Tables 1.1 and 1.2-12 need to be consistent.

Complete and accurate information must be provided in the application in accordance with the 71.7(a) requirements.

NAC International Response

Table 1.2-12 was revised to generically reference fuel assembly structural and reactor internal components consistent with the definition section text (Table 1.1). Irradiated materials are bounded by the previously licensed payloads provided that the gamma source listed in Table 1.2-12 is not exceeded regardless of irradiated and/or contaminated material type. Footnote 3 to Table 1.2-12 is revised to account for the generic material statement.

CHAPTER 3 THERMAL SAFETY

3-1 Justify the assumption of modeling air as the gas in the cask cavity (Section 3.5.1.2 & 3.4.1.7.2) for the HAC fire, when helium has been added to the cask during loading operations (Section 7.1.1, Step 32). Air has a conductivity of approximately 5 times less than helium and would tend to insulate the fuel from the fire temperatures, thus resulting in a non-conservative fuel cladding temperature identified in Table 3.5.1. Correct the affected SAR sections and tables.

10 CFR Part 71.107 Package Design Control requires that the applicant shall...assure that...the package design...are correctly translated into...procedures and instructions.

NAC International Response

NAC has revised Chapter 3, Section 3.5.1.2 of the NAC-LWT SAR to include a presentation justifying the selection of the Condition 2 model (air in cavity) for the thermal transient.

The selection of Condition 2 with air is conservative, as at the initiation of the thermal transient, the clad temperature is 225°F higher than the Condition 1 (helium in cavity) model steady-state condition results. The new evaluation concludes that the final transient temperature for the helium case is bounded by the air case (Condition 2) due to the higher starting steady-state temperature. In addition, the conservative modeling of air in the cavity with its lower thermal conductivity retards the heat removal from the fuel in the post-fire section of the transient.

The revised presentation in Section 3.5.1.2 concludes that Condition 2 (air in the cavity) is conservative for evaluation of fire transient fuel clad temperatures.

CHAPTER 6 CRITICALITY SAFETY

6-1 Revise Section 1.1 of the application, as well as any similar statements, to reflect that the regulations regarding fissile exemptions have moved to 10 CFR 71.15. Additionally, specify which exemption under §71.15 applies to the requested contents.

Section 1.1 of the application, as well as several similar statements throughout the application, references §71.53 to limit fissile material associated with irradiated and contaminated hardware. As of October 1, 2004, §71.53 was revised and moved to §71.15 in the regulations. Additionally, the regulations regarding exemption from classification as fissile material were revised, and now include six paragraphs ((a)-(f)) of potential exemptions. The application should state which of these exemptions the irradiated and contaminated hardware will meet for shipment in the NAC-LWT.

This information is needed to ensure that the package meets the requirements of §71.15 for contents consisting of irradiated and contaminated hardware.

<u>NAC International Response</u>

References to 10 CFR 71.53 are replaced by references to 10 CFR 71.15, paragraphs (a), (b) and (c).

May 2007

Revision LWT-07C

NAC-LWT

Legal Weight Truck Cask System

SAFETY ANALYSIS REPORT

Docket No. 71-9225

NAC INTERNATIONAL

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List of Effective Pages

LIST OF EFFECTIVE PAGES

Chapter 1

LIST OF EFFECTIVE PAGES (Continued)

Chapter 2

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

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LIST OF EFFECTIVE PAGES (Continued)

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LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

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LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

Chapter 5

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

5.3-181 .... Revision LWT-06A
5.3-182 .... Revision LWT-06A
5.3-183 .... Revision LWT-06A
5.3-184 .... Revision LWT-06A
5.3-185 .... Revision LWT-06A
5.3-186 .... Revision LWT-06A
5.3-187 .... Revision LWT-06A
5.3-188 .... Revision LWT-06A
5.3-189 .... Revision LWT-06A
5.3-190 .... Revision LWT-06A
5.3-191 .... Revision LWT-06A
5.3-192 .... Revision LWT-06A
5.3-193 .... Revision LWT-06A
5.3-194 .... Revision LWT-06A
5.3-195 .... Revision LWT-06A
5.3-196 .... Revision LWT-06A
5.3-197 .... Revision LWT-06A
5.3-198 .... Revision LWT-06A
5.3-199 .... Revision LWT-06A
5.3-200 .... Revision LWT-06A
5.3-201 .... Revision LWT-06A
5.3-202 .... Revision LWT-06A
5.3-203 .... Revision LWT-06A
5.3-204 .... Revision LWT-06A
5.3-205 .... Revision LWT-06A
5.3-206 .... Revision LWT-06A
5.3-207 .... Revision LWT-06A
5.3-208 .... Revision LWT-06A
5.3-209 .... Revision LWT-06A
5.3-210 .... Revision LWT-06A
5.3-211 .... Revision LWT-06A
5.3-212 .... Revision LWT-06A
5.3-213 .... Revision LWT-06A
5.3-214 .... Revision LWT-06A
5.3-215 .... Revision LWT-06A
5.3-216 .... Revision LWT-06A
5.3-217 .... Revision LWT-06A
5.3-218 .... Revision LWT-06A
5.3-219 .... Revision LWT-06A
5.3-220 .... Revision LWT-06A
5.3-221 .... Revision LWT-06A
5.3-222 .... Revision LWT-06A
5.3-223 .... Revision LWT-06A
5.3-224 .... Revision LWT-06A
5.3-225 .... Revision LWT-06A
5.3-226 .... Revision LWT-06A
5.3-227 .... Revision LWT-06A
5.3-228 .... Revision LWT-06A
5.3-229 .... Revision LWT-06A
5.3-230 .... Revision LWT-06A
5.3-231 .... Revision LWT-06A
5.3-232 .... Revision LWT-06A
5.3-233 .... Revision LWT-06A
5.3-234 .... Revision LWT-06A
5.3-235 .... Revision LWT-06A
5.3-236 .... Revision LWT-06A
5.3-237 .... Revision LWT-06A
5.3-238 .... Revision LWT-06A
5.3-239 .... Revision LWT-06A
5.3-240 .... Revision LWT-06A
5.3-241 .... Revision LWT-06A
5.3-242 .... Revision LWT-06A
5.3-243 .... Revision LWT-06A
5.3-244 .... Revision LWT-06A
5.3-245 .... Revision LWT-06A
5.3-246 .... Revision LWT-06A
5.3-247 .... Revision LWT-06A
5.3-248 .... Revision LWT-06A
5.3-249 .... Revision LWT-06A
5.3-250 .... Revision LWT-06A

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

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LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

LIST OF EFFECTIVE PAGES (Continued)

Chapter 8

Chapter 9

Master Table of Contents

MASTER TABLE OF CONTENTS

MASTER TABLE OF CONTENTS (continued)

MASTER TABLE OF CONTENTS (continued)

MASTER TABLE OF CONTENTS (continued)

MASTER TABLE OF CONTENTS (continued)

MASTER TABLE OF CONTENTS (continued)

MASTER TABLE OF CONTENTS (continued)

MASTER TABLE OF CONTENTS (continued)

Chapter 1

1.0 GENERAL INFORMATION

This chapter of the NAC International, Legal Weight Truck spent fuel shipping cask (NAC-LWT) Safety Analysis Report (SAR) presents a general introduction to, and description of, the NAC-LWT cask. Terminology used throughout this report is presented in Table 1-1.

Shipment of the NAC-LWT cask by truck, ISO container, and/or by railcar, as a Type B(U)F-96 package, as defined in 10 CFR 71.4, is authorized for the following contents:

- PWR and BWR fuel assemblies[1];
- MTR fuel assemblies and plates;
- DIDO fuel assemblies, metallic fuel rods;
- 25 high burnup PWR and BWR fuel rods (including up to 14 fuel rods classified as damaged);
- TRIGA fuel elements and TRIGA fuel cluster rods;
- General Atomics (GA) High-Temperature Gas-Cooled Reactor (HTGR) and Reduced-Enrichment Research and Test Reactor (RERTR) Irradiated Fuel Materials (IFM);
- up to 700 PULSTAR fuel elements;
- spiral fuel assemblies; and
- MOATA plate bundles.

The authorized contents previously listed include both irradiated and unirradiated forms of the materials.

Irradiated hardware is also authorized to be shipped in the NAC-LWT cask by truck, ISO container, and/or by railcar, as a Type B(U)F-96 package, as defined in 10 CFR 71.4. Irradiated hardware is defined as solid, irradiated and contaminated fuel assembly structural or reactor internal component hardware, which may include fissile material, provided the quantity of fissile material does not exceed a Type A quantity and does not exceed the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c).

[1] NAC-LWT casks containing PWR and BWR fuel assemblies are to be transported on a open trailer with a personnel barrier.

Shipment of the NAC-LWT cask by truck, ISO container, and/or by railcar, as a Type B(M)-96 package, as defined in 10 CFR 71.4, is also authorized for the following contents:

- up to 300 Tritium Producing Burnable Absorber Rods (TPBARs), of which two can be prefailed

In accordance with 10 CFR 71.59, the NAC-LWT cask is assigned a Criticality Safety Index (CSI) for criticality control of the approved contents as follows:

- 100 for PWR fuel assemblies;
- 33.4 for package with any number of canned PULSTAR fuel;
- 12.5 for DIDO fuel assemblies and TRIGA payloads in a nonpoisoned basket and no canisters, or a canister loaded withup to two equivalent TRIGA elements;
- 5.0 for BWR fuel assemblies; and
- 0.0 for metallic fuel rods, up to 25 PWR fuel rods, uncanned intact PULSTAR fuel assemblies and elements, 42 spiral fuel assemblies, MOATA plate bundles, TPBARS, up to 25 high burnup PWR and BWR rods, MTR fuel assemblies, TRIGA fuel elements, TRIGA elements loaded into a poisoned basket, TRIGA fuel cluster rods, TRIGA payloads with screened cans containing up to four TRIGA elements in a nonpoisoned basket, and GA IFM.

TPBARs do not contain fissile material and criticality assessments are not required. Solid, irradiated and contaminated hardware contents could include fissile material not exceeding a Type A quantity and the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c). A CSI of 0 is assigned for these contents for documentation purposes.

The estimated Transport Index (TI) for shielding for the prior listed contents is shown in Table 5.1-1. The actual TI for individual shipments will be determined in accordance with 10 CFR 71.4 by the licensee.

Table 1-1 Terminology and Notation

Cask Model	NAC-LWT
Package	The Packaging with its radioactive contents (payload), as presented for transportation (10 CFR 71.4). Within this report, the Package is denoted as the NAC-LWT cask or simply as the cask.
Packaging	The assembly of components necessary to ensure compliance with packaging requirements (10 CFR 71.4). Within this report, the Packaging is denoted as the NAC-LWT cask.
NAC-LWT Cask	This packaging consists of a spent-fuel shipping cask body and closure lid with energy absorbing impact limiters.
Contents (Payload)	• 1 PWR assembly • up to 2 BWR assemblies • up to 25 PWR or BWR rods (including high burnup fuel rods and up to 14 fuel rods classified as damaged) • up to 42 MTR fuel elements (including plates) • up to 42 DIDO fuel assemblies • up to 15 sound (cladding intact) metallic fuel rods • up to 9 damaged metallic fuel rods or 3 severely damaged metallic fuel rods in filters • up to 140 intact or damaged TRIGA fuel elements/debris • up to 560 intact or damaged TRIGA fuel cluster rods • 2 GA IFM packages • up to 300 TPBARs (including up to 2 damaged TPBARs) • up to 700 intact or damaged PULSTAR fuel elements in either assembly or element form, including fuel debris • up to 42 intact spiral fuel assemblies (also referred to as Mark III spiral fuel). Spiral fuel assemblies may be cropped. • up to 42 intact MOATA plate bundles • any combination of individual ANSTO basket modules containing either spiral fuel assemblies or MOATA plate bundles up to a total of 42 assemblies/bundles • irradiated hardware
Impact Limiters	Aluminum honeycomb energy absorbers located at the ends of the cask.

Table 1-1 Terminology and Notation (cont'd)

Intact LWR Fuel (Assembly or Rod)	Spent nuclear fuel that that is not Damaged LWR Fuel, as defined herein. To be classified as intact, fuel must meet the criteria for both intact cladding and structural integrity. An intact fuel assembly can be handled using normal handling methods, and any missing fuel rods have been replaced by solid filler rods that displace a volume equal to, or greater than, that of the original fuel rod.
Damaged LWR Fuel (Assembly or Rod)	Spent nuclear fuel that includes any of the following conditions that result in either compromise of cladding confinement integrity or reconfiguration of fuel assembly geometry. 1. The fuel contains known or suspected cladding defects greater than a pinhole leak or a hairline crack that have the potential for release of significant amounts of fuel particles. 2. The fuel assembly: a. is damaged in such a manner as to impair its structural integrity; b. has missing or displaced structural components such as grid spacers; c. is missing fuel pins that have not been replaced by filler rods that displace a volume equal to, or greater than, that of the original fuel rod; d. cannot be handled using normal handling methods. 3. The fuel is no longer in the form of an intact fuel assembly and consists of, or contains, debris such as loose pellets, rod segments, etc.
Damaged Fuel (TRIGA)	TRIGA fuel (elements and cluster rods) having cladding failures greater than hairline cracks or pinhole leaks.
Fuel Debris (TRIGA)	TRIGA damaged fuel that does not maintain its structural integrity, including fuel particles, fuel debris, and broken fuel rods.
TPBAR	Tritium Producing Burnable Absorber Rod
Irradiated Fuel Material (IFM)	High-Temperature Gas-Cooled Reactor (HTGR/IFM) and Reduced-Enrichment Research and Test Reactor (RERTR/IFM) type TRIGA fuel entities produced by General Atomics.

PULSTAR Fuel Element	PULSTAR fuel rod. May be contained in either assembly, rod holder or can form for shipment. PULSTAR fuel elements may be intact or damaged.
Damaged PULSTAR Fuel Element	PULSTAR fuel rods having cladding failures greater than hairline cracks or pinhole leaks. The damaged fuel definition for PULSTAR fuel elements includes fuel debris. Damaged PULSTAR fuel elements may also be referred to as failed and must be transported in either of two types of PULSTAR cans.
Irradiated Hardware	Solid, irradiated and contaminated fuel assembly structural or reactor internal component hardware, which may include fissile material, provided the quantity of fissile material does not exceed a Type A quantity and does not exceed the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c). Authorized quantity of irradiated hardware and components is limited to 4,000 lbs (including spacers, dunnage and containers) and a gamma source term as defined in Table 1.2-12.

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1.1 Introduction

The NAC-LWT spent-fuel shipping cask has been developed by NAC International (NAC) as a safe means of transporting radioactive materials authorized as approved contents. The cask design is optimized for legal weight over the road transport, with a gross weight of less than 80,000 pounds. The cask provides maximum safety during the loading, transport, and unloading operations required for spent-fuel shipment. The NAC-LWT cask assembly is composed of a package that provides a containment barrier, preventing the release of radioactive material. The actual containment boundary provided by the package consists of a 4.0-inch thick bottom plate, a 0.75-inch thick, 13.375-inch inner diameter shell, an upper ring forging, and an 11.3-inch thick closure lid. The cask lid closure is accomplished using twelve, 1-inch diameter bolts. The cask has an outer shell, 1.20 inches thick, to protect the containment shell and also to enclose the 5.75-inch thick lead gamma shield. Neutron shielding is provided by a 5.0-inch thick neutron shield tank with a 0.24-inch (6mm) thick outer wall, containing a water/ethylene glycol mixture and 1.0 weight percent (wt %) boron (58 wt % ethylene glycol; 39 wt % demineralized water; 3 wt % potassium tetraborate [$K_2B_4O_7$]). The neutron shield tank system includes an expansion tank to permit the expansion and contraction of the shield tank liquid without compromising the shielding or overstressing the shield tank structure. Aluminum honeycomb impact limiters are attached to each end of the cask to absorb kinetic energy developed during a cask drop, and limit the consequences of normal operations and hypothetical accident events.

The NAC-LWT is a legal weight truck cask designed to transport the following contents:

- 1 PWR assembly;
- up to 2 BWR assemblies;
- up to 15 sound metallic fuel rods;
- up to 42 MTR fuel elements;
- up to 42 DIDO fuel assemblies;
- up to 25 high burnup PWR fuel rods (including up to 14 rods classified as damaged);
- up to 25 high burnup BWR fuel rods (including up to 14 rods classified as damaged);
- up to 9 damaged metallic fuel rods;
- up to 3 severely damaged metallic fuel rods in filters;
- up to 140 TRIGA intact or damaged fuel elements/fuel debris ("TRIGA" is a Trademark of General Atomics);
- up to 560 TRIGA fuel cluster rods;
- 2 GA IFM packages;
- up to 300 TPBARs (of which two can be prefailed);
- up to 700 PULSTAR fuel elements (intact or damaged);
- up to 42 spiral fuel assemblies;
- up to 42 MOATA plate bundles; or

- up to 4,000 lbs of solid, irradiated and contaminated hardware, which may include fissile material less than a Type A quantity and meeting the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c). Total allowed mass includes the weight of spacers, shoring and dunnage.

High burnup PWR or BWR fuel rods may be placed in a fuel rod insert (also referred to as a rod holder) or in a fuel assembly lattice. The lattice may be irradiated or unirradiated. Up to 14 of the high burnup fuel rods may be classified as damaged. Damaged fuel rods must be placed in a rod holder. Damaged fuel rods or rod sections may be encapsulated to facilitate handling prior to placement in the rod holder.

PULSTAR fuel elements may be configured as intact fuel assemblies, may be placed into a fuel rod insert, i.e., a 4×4 rod holder (intact elements only), or may be loaded into one of two can designs, designated as the PULSTAR screened fuel can or the PULSTAR failed fuel can. Damaged PULSTAR fuel elements and nonfuel components of PULSTAR fuel assemblies must be loaded into cans. PULSTAR fuel cans may only be loaded into the top or base module of the 28 MTR basket assembly. Intact PULSTAR fuel assemblies and intact PULSTAR fuel elements in a TRIGA fuel rod insert may be loaded in any basket module.

Irradiated hardware may be loaded directly into the NAC-LWT cavity or preloaded into a canister or cage. Stainless steel dunnage may be used to limit the movement of the irradiated hardware within the cask cavity. The maximum gamma source term of the irradiated hardware shall be limited to that defined for the authorized PWR content condition as described in Chapter 5.

The NAC-LWT cask provides a testable containment for the fuel during both normal operations and hypothetical accident conditions, satisfying the requirements of 10 CFR 71.51. Any number of NAC-LWT casks may be shipped at one time, each on its own vehicle.

NAC-LWT casks may be shipped in a closed International Shipping Organization (ISO) container when containing all fuel contents other than PWR and BWR fuel assemblies. NAC-LWT casks containing PWR and BWR fuel assemblies are to be transported on an open trailer with a personnel barrier.

The terminology of MTR, DIDO and TRIGA fuel elements will be used independent of whether the element contains low, medium or high enriched uranium (i.e., LEU, MEU or HEU), except when required for analysis or loading purposes.

The closure lid of the cask, and the two valve port covers (alternate and Alternate B designs) are one-piece fixtures to speed handling and maintain personnel dose rates as low as reasonably achievable (ALARA). The closure lid has built-in alignment grooves to facilitate installation. The alternate and Alternate B port cover designs provide clearance for valves underneath the port cover. Interior O-rings located on the vent and drain valve port cover body are a component of the cask containment boundary. TPBARs must be shipped with the cask configured with the Alternate B drain and vent port covers employing metallic seals, TPBAR basket, consolidation canister, TPBAR spacer, standard drain tube, and neutron shield fluid. An alternative drain tube, including a drain tube alignment ring, is installed and utilized when loading and transporting segmented (not full length) fuel baskets and canisters. The impact limiters and the personnel barrier are designed to be removed and installed without the aid of supplemental lifting gear or fixtures. Metallic fuel rods, MTR fuel elements, DIDO fuel assemblies, TRIGA fuel elements/debris, standard PWR fuel rods, high burnup PWR and BWR fuel rods, GA IFM packages, TPBARs, PULSTAR fuel elements, spiral fuel assemblies, and MOATA plate bundles may be shipped in an International Shipping Organization (ISO) container. All operational features are readily apparent from an inspection of the drawings provided in Section 1.4. Operational procedures are delineated in Chapter 7.

1.2.3 Contents of Packaging

The NAC-LWT cask is analyzed as presented in this SAR for the transport of the following contents:

- 1 PWR assembly;
- up to 2 BWR assemblies;
- up to 25 PWR or BWR rods (including high burnup fuel rods and up to 14 fuel rods classified as damaged);
- up to 42 MTR fuel elements (including plates);
- up to 42 DIDO fuel assemblies;
- up to 15 sound (cladding intact) metallic fuel rods;
- up to 9 damaged metallic fuel rods or 3 severely damaged metallic fuel rods in filters;
- up to 140 intact or damaged TRIGA fuel elements/debris;
- up to 560 intact or damaged TRIGA fuel cluster rods;
- 2 GA IFM packages;
- up to 300 TPBARs (of which 2 can be prefailed);
- up to 700 intact or damaged PULSTAR fuel elements in either assembly or element form, including fuel debris;
- up to 42 spiral fuel assemblies;

- up to 42 MOATA plate bundles; or any combination of individual ANSTO basket modules containing either spiral fuel assemblies or MOATA plate bundles up to a total of 42 assemblies/bundles;
- up to 4,000 lbs of solid, irradiated and contaminated hardware, which may include fissile material less than a Type A quantity and meeting the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c). Total allowed mass includes the weight of spacers, shoring and dunnage.

Shipments in this package shall not exceed the following limits:

1. The maximum contents weight shall not exceed 4,000 pounds.
2. The limits specified in Tables 1.2-1 through 1.2-12 for the fuel and other radioactive contents shall not be exceeded.
3. Any number of casks may be shipped at one time, one cask per tractor/trailer vehicle.
4. The decay heat shall not exceed 2.5 kW for PWR fuel assemblies, 2.2 kW for BWR fuel assemblies, 1.41 kW for 25 PWR rods, 2.3 kW for 25 high burnup PWR fuel rods, 2.1 kW for 25 high burnup BWR fuel rods, 1.26 kW for MTR fuel, 1.05 kW for DIDO fuel assemblies, 1.05 kW for TRIGA fuel elements or fuel cluster rods, 13.05 W for GA IFM packages, 0.693 kW for 300 TPBARs, 0.84 kW for the PULSTAR fuel contents, 0.756 kW for spiral fuel assemblies (0.126 kW per basket), 0.126 kW for MOATA plate bundles (21 W per basket), and 1.26 kW for solid, nonfissile, irradiated hardware.
5. Radiation levels shall meet the requirements delineated in 10 CFR 71.47 or 49 CFR 173.441. The neutron shield tank may be drained for shipment of metallic fuel rods.
6. Surface contamination levels shall meet the requirements of 10 CFR 71.87(i) or 49 CFR 173.443.
7. TRIGA damaged fuel and fuel debris (up to two equivalent elements) will be shipped in a sealed or screened failed fuel can.
8. TRIGA damaged fuel elements will be transported in a sealed failed fuel can (maximum of two) or in a screened can (maximum of four).
9. MTR fuel elements may consist of any combination of intact or damaged highly enriched uranium (HEU), medium enriched uranium (MEU) or low enriched uranium (LEU) fuel elements that are enveloped by the parameters listed in Table 1.2-4, as supported by information presented in Table 5.1-2, Table 6.2.3-1, Table 6.2.3-2, and Table 6.2.3-3.
10. High burnup PWR fuel rods will be shipped in either sealed, free flow or screened cans.
11. High burnup BWR fuel rods will be shipped in either sealed, free flow or screened cans.

12. Up to 25 high burnup PWR or BWR fuel rods in a fuel assembly lattice or rod holder. Up to 14 of the fuel rods in a rod holder may be classified as damaged. Damaged fuel rods or rod sections may be placed into fuel rod capsules prior to placing them in the fuel rod holder. Typical failed fuel rod capsule configuration is shown in Figure 1.2-11.
13. TPBARs will be shipped in an open top consolidation canister.
14. Intact PULSTAR fuel elements may be loaded into a fuel rod insert or the PULSTAR screened or failed fuel cans.
15. Damaged PULSTAR fuel elements and nonfuel components of PULSTAR fuel assemblies shall be loaded into either a PULSTAR failed fuel or screened fuel can, and placed into the top or base module of the 28 MTR fuel basket. Damaged fuel, including fuel debris, may be placed in an encapsulating rod prior to loading in a PULSTAR can.
16. Any combination of spiral fuel assemblies or MOATA plate bundles, each loaded into separate ANSTO basket modules containing up to a total of 42 assemblies/bundles.
17. Solid, irradiated and contaminated hardware containing less than a Type A quantity of fissile material and meeting the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c), loaded directly into the cask or contained in a secondary container or basket. The irradiated hardware spacer will be installed to limit the axial movement of the hardware above the lead shielded region of the cask body. As needed, additional secondary containers, dunnage and shoring may be used to limit the movement of the contents during normal and accident conditions of transport.

1.2.3.1 TRIGA Fuel and Basket Description

Two basic types of TRIGA fuel are to be transported in the NAC-LWT cask: TRIGA fuel elements and smaller fuel rods from TRIGA fuel cluster assemblies. TRIGA fuel elements are approximately 1-1/2 inches in diameter and are described in Section 1.2.3.1.1.1. TRIGA fuel cluster rods are smaller, approximately 1/2-inch in diameter and are described in Section 1.2.3.1.1.2.

Up to 140 TRIGA fuel elements in the form of: a) standard fuel elements – either aluminum clad or stainless steel clad; b) instrumented fuel elements – similar to standard fuel elements (aluminum clad or stainless steel clad), but containing thermocouple instrumentation; and c) fuel follower control rod elements (aluminum or stainless steel clad) – poison rods with a fuel follower in a single tube may be shipped in the NAC-LWT cask. Up to 560 TRIGA fuel cluster rods may also be shipped. Up to the equivalent of two damaged fuel elements and debris may be loaded and shipped in either a sealed or screened failed fuel can. Up to four fuel elements having cladding damage may be loaded in a screened fuel can. The transport baskets and failed fuel cans are described in Section 1.2.3.1.2.

1.2.3.1.1 TRIGA Fuel

1.2.3.1.1.1 TRIGA Fuel Elements

The characteristics of the design basis TRIGA fuel element are presented in Table 1.2-1 for the poisoned baskets and in Tables 1.2-2 and 1.2-4 for the nonpoisoned basket.

The fuel material in a TRIGA fuel element is a solid, homogeneous mixture of uranium-zirconium hydride alloy, i.e., a metal alloy fuel. Both the aluminum-clad and the stainless steel-clad TRIGA fuel elements are approximately 1.5-inch diameter rods by approximately 30 inches long. The fuel follower control rod elements range in length from 45 inches to 66.5 inches. Instrumented fuel elements are identical to standard fuel elements with the exception of thermocouples and wires and lead-out tubing. The lead-out tubing needs to be detached prior to shipment in order for the instrumented fuel elements to fit into the standard element height envelope. The aluminum-clad TRIGA fuel element and instrumented fuel element, the stainless steel-clad TRIGA fuel element and instrumented fuel element, and the standard fuel follower control rod element are shown in Figures 1.2-1 through 1.2-5, respectively.

1.2.3.1.1.2 TRIGA Fuel Cluster Rods

The design basis TRIGA cluster rod characteristics are shown in Table 1.2-3.

The fuel material in TRIGA fuel cluster rods is a solid, homogeneous mixture of uranium-zirconium-erbium hydride alloy, i.e., a metal alloy fuel. Erbium is a burnable neutron poison that is used in the fuel to enhance the flux profile along the length of the fuel rod, and is conservatively ignored in the nuclear evaluations. The rods have an external diameter of approximately 0.55 inch and are approximately 31 inches long. The rod cladding is Incoloy 800 material and is 0.015 inch thick, minimum. Instrumented rods are identical to the standard rods, with the exception of thermocouples and wires. A diagram of the TRIGA fuel cluster rods, and the individual fuel pin (cluster rod) making up the cluster, is shown in Table 1.2-6.

The active fuel region of a TRIGA fuel cluster rod is a maximum of 0.53 inch in diameter, 22.5 inches in length, and has an initial uranium enrichment of up to 93.3 percent. A compression spring is utilized to fill the space in the plenum region of the rod, and top and bottom plugs are used to seal the fuel within the rod. The design-basis TRIGA fuel cluster rod characteristics are summarized in Tables 1.2-3, 1.2-4, 5.1-1, 5.1-2, 6.2.6-1, and 6.2.6-2.

debris; b) facilitate retrieval of the contents from the transportation cask; and c) confine damaged fuel and/or debris within a known volume to facilitate criticality control, maintain dose limits, and control thermal loads within the cask. PULSTAR fuel pellets, pieces, and debris may be placed in an encapsulating rod for handling purposes prior to placement into either a sealed or screened can. The encapsulating rod is not required and has no safety significance. In addition to fuel elements, the cans may contain fuel assembly hardware up to the total content weight limit specified in Figure 1.2-9. For operational/retrievability purposes, stainless steel rod inserts may be used to position the PULSTAR fuel elements within the fuel rod insert. Total content weight shall not exceed the total weight limit specified in Table 1.2-9. The fuel rod insert is composed of a 4×4 grid of 0.75-inch OD × 0.065-inch wall stainless steel tubes. The tubes provide structural support for individual intact PULSTAR fuel elements during transport in the NAC-LWT.

Spacers may be used to axially position PULSTAR fuel contents near the top of the module for ease of loading and unloading operations. The spacers are provided for ease of operations and do not provide a safety function.

1.2.3.9 ANSTO Basket and Payload Description

Two basic fuel types are to be transported in the ANSTO baskets within the NAC-LWT cask: spiral fuel assemblies and MOATA plate bundles. Spiral fuel assemblies are composed of cylindrical aluminum inner and outer shells connected by curved metallic fuel plates. Further detail on the spiral fuel assemblies is provided in Section 1.2.3.9.1. MOATA plate bundles are comprised of up to 14 MTR fuel plates. Further detail on the plate bundles is provided in Section 1.2.3.9.2. Spiral fuel assemblies and MOATA plate bundles shall be intact. Note that spiral assemblies may be cropped by removing nonfuel-bearing hardware to fit within the basket tubes. Cropped spiral fuel assemblies are classified as intact fuel.

Up to 42 spiral fuel assemblies or 42 MOATA plate bundles may be loaded. A full cask load contains 6 baskets of up to 7 fuel assemblies or plate bundles per basket. The mixed loading of ANSTO basket modules containing either spiral fuel assemblies or MOATA plate bundles is authorized.

1.2.3.9.1 Spiral Fuel Assemblies

The design basis characteristics of spiral fuel assemblies are presented in Table 1.2-10. The fuel material in spiral fuel assembly plates is a solid, homogeneous mixture of uranium-aluminum alloy, i.e., a metal alloy fuel. The fuel meat of each plate is clad in aluminum. A set of 10 curved fuel plates is located between an inner and outer cylindrical aluminum shell. Fuel elements are cropped to fit axially within the basket envelope. Fuel material is not cut during the

cropping operation. The fuel plates are located in a spiral pattern, maintaining a constant pitch between fuel plate centers. A sketch of the assembly cross-section is provided in Figure 1.2-14.

1.2.3.9.2 MOATA Plate Bundles

The design basis characteristics of MOATA plate bundles are presented in Table 1.2-11. The fuel material in the plate bundle is a solid, homogeneous mixture of uranium-aluminum alloy, i.e., a metal alloy fuel. Each plate is clad in aluminum. A plate bundle is comprised of up to 14 fuel plates. Two thick (0.635 cm) aluminum nonfuel side plates support the fuel plate stack from two sides, making a possible total of 16 plates per bundle. At each axial end, the plates in the stack are connected by a pin. Spacing between plates is maintained by disk spacers placed onto the top and bottom pins between each fuel plate and the aluminum side plates. A sketch of a typical MOATA plate bundle is provided in Figure 1.2-15.

1.2.3.10 Solid, Irradiated and Contaminated Hardware

The design basis characteristics of the solid, irradiated and contaminated hardware are provided in Table 1.2-12. As described in the content definition, the solid, irradiated and contaminated hardware may contain small quantities of fissile materials. Fissile materials in the irradiated hardware contents are acceptable if the quantity of fissile material does not exceed a Type A quantity and does not exceed the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c).

The irradiated hardware may be directly loaded into the NAC-LWT cask cavity, or may be contained in a secondary container or basket. As needed, appropriate component spacers, dunnage and shoring may be used to limit the movement of the contents during normal and accident conditions of transport.

To ensure that the movement of the irradiated hardware contents above the lead shielded length of the NAC-LWT cask body (i.e., the approximately upper 6.25 inches of the cavity length) is precluded, an Irradiated Hardware Lid Spacer as shown on Drawing No. 315-40-145 shall be installed for all irradiated hardware content configurations. The total installed height of the spacer is 6.5 inches. Therefore, the available cavity length for the irradiated hardware is approximately 171 inches. The NAC-LWT cask shall be assembled for transport as shown on NAC Drawing No. 315-40-01 with the irradiated hardware spacer installed on the lid.

A comparative shielding evaluation for a conservatively selected irradiated hardware transport configuration (i.e., a single line source with no self-shielding) or consideration of the additional shielding provided by additional spacers, dunnage, inserts or secondary containers is presented in Chapter 5. The evaluations show that the regulatory dose rate requirements per 10 CFR 71.47 for normal conditions of transport, or 10 CFR 71.51(b) under hypothetical accident conditions, are not exceeded.

Table 1.2-12 Solid, Irradiated Hardware Characteristics[4]

Parameter	Value
Maximum Content Weight	4,000 pounds [1]
Maximum Content Length	171.5 inches [2]
Hardware Material	Solid, irradiated and contaminated fuel assembly structural or reactor internal component hardware [3]
Maximum Cask Heat Load	1.0 KW
Maximum Activity per Cask, Ci	6.0 x 10E+6
Maximum Source Term, gamma/sec	6.0 x 10E+15
Maximum Source Term, MeV/sec	1.0 x 10E+15

1 Maximum content weight includes any spacers, containers or dunnage loaded in the cavity with the irradiated hardware.

2 Length of cavity is limited to 171.5 inches by the installation and use of an irradiated hardware spacer bolted to the underside of the closure lid.

3 For dissimilar materials, appropriate secondary containers will be used to prevent any contact and cross-contamination between the activated hardware and the stainless steel internals of the cask cavity.

4 The irradiated hardware contents may contain fissile material, provided the quantity of fissile material does not exceed a Type A quantity and does not exceed the exemptions of 10 CFR 71.15, paragraphs (a), (b) and (c).

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Chapter 3

ANSYS 5.5 version and computational solvers account for the differences in calculated results. The transient temperature analysis results are presented in Figures 3.5-12, 3.5-13, and 3.5-14.

Exactly the same model described above was rerun using ANSYS 5.5 for the alternate port cover to determine the bolt head and thread temperatures and the temperatures at both O-ring locations. The output is post-processed to determine the maximum average temperatures at specific locations of interest. The temperatures calculated are presented in Table 3.5-1.

3.5.1.2 Two-Dimensional Planar Thermal Model

Thermal analysis of the NAC-LWT cask loaded with PWR and BWR high burnup fuel rods is performed using a two-dimensional planar thermal model. The thermal model is identical to the model utilized to perform the steady-state analysis (Condition 2, Section 3.4.1.7) for the NAC-LWT cask loaded with PWR and BWR high burnup fuel rods. The detailed model description is contained in Section 3.4.1.7.2.

The Condition 2 model was selected since it initiates the thermal transient with clad temperatures 225°F higher (from Table 3.4-10, 896°F-671°F) than the Condition 1 model steady-state condition. This increase in the initial condition temperature for the cask cavity air-filled condition overcompensates for the higher conductivity of helium as the cavity gas. The effect of the higher helium conductivity heat input during the period of fire exposure is significantly less due to the influence of the parallel heat transfer paths by conduction through the metal contents and by radiation across the gas-filled space. This influence is seen in the transient maximum temperature difference from the higher steady-state temperature of 896°F to the maximum transient temperature of 1014°F (a change of 118°F), which is significantly bounded by the steady-state temperature condition difference of 225°F, as stated previously. In addition to the conservative modeling introduced by the initial steady-state temperature, during the cooldown portion of the transient, the use of air thermal conductivity in the cavity retards the heat removal from the fuel (as compared to helium conductivity). This also results in a maximum transient temperature higher than when modeling helium as the cavity gas.

A thermal transient analysis for the design basis fuel is performed using the two-dimensional planar thermal model (see Figure 3.4-12). To impose the fire accident condition on this model, a temperature time history was applied to the outer surface of the model, which corresponds to the inner surface of the inner shell. This temperature time history at the inner shell inner surface near the axial midplane is obtained from the fire accident analysis (heat load of 2.5 kW and a peaking factor of 1.2, as described in Section 3.5.2) using the axisymmetric two-dimensional model described in Section 3.5.1.1.

Using a two-dimensional planar model of the cross-section, a 50.5-hour transient analysis is performed with a heat load of 2.1 kW with a peaking factor of 1.22. This represents the bounding heat load for the high burnup PWR and BWR fuel rods.

3.5.2 Package Conditions and Environment

The fire accident is preceded by the cask drop and cask puncture portions of the hypothetical accident. The only damage that occurs as a result of the drop and puncture accident events that are of importance to the cask thermal performance is the damage to the NAC-LWT cask neutron shield. As a result of these events, it is assumed that the integrity of the neutron shield has been damaged to such an extent that the entire contents of the neutron shield are no longer present.

The fuel heat load of 2.5 kW is applied using a nonuniform heat flux with a peaking factor of 1.2. Solar insolation is applied to the outer surfaces of the cask, including the area covered by the impact limiters, during the post-fire conditions, and neglected during the fire condition. The value of solar insolation, based on a 24-hour average to curved surfaces, is:

$$Q_{sun}=1475/(24\times 144) = 0.4268 \text{ BTU/hr-in}^2$$

Convection and radiation heat transfer at the outer surfaces of the cask were considered in the analysis. During the pre-fire (normal) and post-fire periods, the ambient temperature assumed is 100°F, and the cask outer surface emissivity is 0.36. During the fire, the ambient temperature is 1475°F, and the cask surface emissivity is 0.9. The convection coefficient applied is 0.02446 Btu/hr-in^2-°F.

Using a decay heat of 2.5 kW, the conditions for the hypothetical fire accident are:

Analysis condition	Loads and boundary conditions
Initial steady-state (pre-fire)	• Solar Insolation • Combined convection (using the film coefficent for the cask surface, $0.00125\Delta T^{0.33}$ Btu/hr-in^2-°F) and radiation heat transfer (as defined in Section 3.2.3) between the cask exterior (ε=0.36) and the ambient (100°F) • The surface of the cask in contact with the impact limiter is adiabatic

Analysis condition	Loads and boundary conditions
Fire transient (during fire)	• Ambient temperature 1475°F with no solar insolation • Combined convective (additional coefficient of 0.02446 Btu/hr-in^2-°F) and radiative heat transfer using a film coefficient (as defined in Section 3.2.3) between the cask exterior (ε=0.9), including the area normally covered by impact limiters, and the fire • Neutron shield fluid lost
Cool down (post-fire)	• Ambient temperature 100°F with solar insolation • Combined convection (using the film coefficent for the cask surface, $0.00125\Delta T^{0.33}$ Btu/hr-in^2-°F) and radiation heat transfer (as defined in Section 3.2.3) between the cask exterior (ε=0.36), including the area covered by the impact limiters, and ambient • Neutron shield fluid lost

3.5.3 Package Temperatures

The temperatures of the cask body resulting from the fire are determined using ANSYS. The heat load used in the transient thermal analysis corresponds to the PWR fuel, since its heat load envelopes all other fuel types that can be transported in the NAC-LWT cask.

The maximum temperatures of the basket and fuel for the different fuel types are determined using the results of the fire transient analysis of the cask body and the maximum temperature differences between the basket and fuel and the inner shell of the cask body as computed in the steady state thermal evaluations.

3.5.3.1 Evaluation for PWR Fuel Contents

The maximum temperatures of the cask body and principal components are evaluated using the ANSYS model described in Section 3.5.1.1. A radial temperature profile is obtained during the postulated 30-minute fire and for a cooldown period of 50 hours. The maximum cask component temperatures for the hypothetical accident are presented in Table 3.5-1.

Maximum time dependent temperatures of different cask components, before, during and after the fire, are shown in Figures 3.5-4 and 3.5-5. The temperatures of the components show a sharp increase during the fire and a sharp decrease that begins right after the fire. After the 50 hour cooling period, the temperatures of the components do not return to the normal conditions of transport values. This is attributed to the loss of the liquid neutron shield during the accident, which results in the loss of the (liquid) convection heat transfer across the tank.

As noted previously, the fuel and the fuel basket were not directly modeled in the ANSYS analysis. To determine the maximum temperature of the components inside the basket, the following method is applied:

$$T_{max} = Tis_{max} + \Delta T_{comp}$$

where:

Tis_{max} is the maximum temperature of the inner shell, obtained in the ANSYS transient thermal analysis.

ΔT_{comp} is the difference in maximum temperatures from Table 3.4-2 between the inner shell and the fuel basket outer wall or the fuel rod cladding during normal transport.

The maximum temperatures of fuel cladding and basket wall are:

Component	ΔT_{comp} (°F) [1]	Tis_{max} (°F) [2]	T_{max} (°F)
Fuel basket outer wall	2 (276-274)	505	507
Fuel cladding	198 (472-274)	505	703

[1] Temperatures from Table 3.4-2.
[2] Temperatures obtained in the ANSYS evaluation.

As a result, the maximum average cavity gas temperature can be taken as the average of the maximum basket wall and maximum fuel cladding temperatures. This produces an average cavity gas temperature of 605°F.

As shown in Table 3.5-1, all of the cask component temperatures are within the allowable temperature limit during the fire accident event.

3.5.3.2 Evaluation of MTR Fuel Contents

The temperatures in the MTR fuel basket and MTR fuel plates produced during the fire accident were determined using the two ANSYS finite element models of the NAC-LWT cask for MTR fuel element discussed in Section 3.4.1.3.2. The gas in the NAC-LWT cask cavity is considered to be air. Other conditions applied to the model are the same as those described in Sections 3.5.1 and 3.5.2 for the axisymmetric fire transient model with respect to the liquid neutron shield and outer surface boundary conditions. The accident thermal models for MTR fuel are shown in Figures 3.5-6 and 3.5-7, for the design basis decay heat loading and the variable decay heat loading, respectively.

The transient calculation is performed to determine the maximum temperatures in the MTR fuel elements only for the variable decay heat loading because this is the worst-case condition. The cask

model is used to determine the temperature history of the cask components, including the basket. The fuel element model is used to determine the temperature rise between the basket and the hottest point in the fuel element. The capacitance of the fuel element is negligible compared to the very large capacitance of the cask assembly. Therefore, a constant ΔT between basket and fuel is used. The temperature history for the MTR fuel variable heat load fire accident analysis is shown Figure 3.5-8. The temperature profile within the cask model at the time of the maximum fuel temperature is shown in Figure 3.5-9. The bounding case is an element with 10 fuel plates, a decay heat of 120W and with worst-case dimensions. The maximum temperatures of the components are presented in Table 3.5-2.

These results demonstrate that the maximum MTR fuel plate temperature for the variable decay heat loading is 473°F. The MIL-HDBK-5F Specification for 6061-T6 aluminum alloy indicates that the material retains more than 35% of its room temperature yield and ultimate strengths during transient exposure to temperatures as high as 500°F. Therefore, the reduction in strength for the fuel cladding as a result of the fire transient is minor when compared to the values presented in Section 3.4.1.3.3 for aluminum at 400°F. Since the fuel cladding temperatures are maintained significantly below 500°F, it is concluded that the structural integrity of the fuel cladding is maintained. Furthermore, the aluminum cladding of the MTR fuel elements is heated to a temperature of approximately 900°F during the fabrication process and it is clear that the cladding integrity is maintained during that process.

3.5.3.3 Evaluation of TRIGA Fuel Contents

The accident condition temperatures are obtained by applying the temperature differential calculated for the MTR fuel configuration to the TRIGA fuel configuration. To determine the TRIGA accident condition maximum cladding temperature, the temperature difference between the maximum basket temperatures for the normal and accident component temperatures calculated for MTR fuel in Section 3.5.3.2, is added to the maximum cladding temperature calculated for TRIGA fuel in Section 3.4.1.5.

The maximum basket temperature for the MTR fuel design basis heat load fire accident analysis is 374°F, as reported in Table 3.5-2. This temperature is 107°F higher than the normal condition maximum temperature (267°F) reported in Table 3.4-6. The corresponding maximum TRIGA fuel cladding temperature for the fire accident condition is reported in Table 3.5-3 to be 433°F. The MIL-HDBK-5F Specification for 6061-T6 aluminum alloy indicates that the material retains more than 35% of its room temperature yield and ultimate strengths during transient exposure to temperatures as high as 500°F. Therefore, the reduction in strength for the aluminum-clad TRIGA fuel cladding as a result of the fire transient is minor when compared to the values presented in Section 3.4.1.3.3 for aluminum at 400°F. Since the fuel cladding temperatures are maintained significantly below 500°F, it is concluded that the structural integrity of the aluminum-clad TRIGA

fuel is maintained. The allowable temperature for stainless steel-clad TRIGA fuel is significantly higher.

The TRIGA fuel generates small amounts of fission gases during reactor operations, but it contains no initial charge of helium gas. Consequently, the internal pressure developed in the accident condition is less for TRIGA fuel than for the design basis PWR fuel.

3.5.3.4 Evaluation of TRIGA Fuel Cluster Rod Contents

The temperatures in the TRIGA fuel cluster rod basket and cladding produced during the fire accident were determined using the ANSYS finite element model of the NAC-LWT for the TRIGA fuel discussed in Section 3.4.1.6 for Condition 2 (air in the cavity and without the ISO container). The gas in the NAC-LWT cask cavity is considered to be air. Other conditions applied to the model are the same as those described in Sections 3.5.1 and 3.5.2 for the axisymmetric fire transient model with respect to the liquid neutron shield and outer boundary conditions.

The temperatures in the basket are bounded by the maximum temperatures of the fuel region. The temperature time history for the fuel region is shown in Figure 3.5-10. The maximum temperature of the clad was determined to be 394°F. This value is below the 800°F limit for the clad or the 400°F limit for the aluminum specified in Section 3.4.1.6. Therefore, the components are determined to be acceptable for the fire accident condition.

3.5.3.5 Evaluation for PWR and BWR High Burnup Fuel Rod Contents in a Rod Holder

The maximum temperatures of the principal components are evaluated using the ANSYS model described in Section 3.5.1.2. The maximum cask component temperatures for the hypothetical accident are identical to those presented in Table 3.5-1 since the bounding temperature history from the analysis of NAC-LWT PWR contents is used as a boundary condition for the analysis for PWR and BWR high burnup fuel rod contents.

Maximum time dependent temperatures of different components, before, during and after the fire, are shown in Figure 3.5-11. For the maximum time dependent temperatures of cask components see Figures 3.5-4 and 3.5-5.

As a result, the maximum average cavity gas temperature for fire accident is calculated as the average of the air contained inside the basket. This produces an average cavity gas temperature of 695°F.

Table 3.5-4 shows the can weldment and fuel rod cladding temperatures during the fire accident event.