November 2017

Revision 17D

NAC-STC

NAC Storage Transport Cask

SAFETY ANALYSIS REPORT

STC High Burnup Fuel Shield Ring Configuration

Non-Proprietary Version

Docket No. 71-9235

NAC INTERNATIONAL

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Enclosure 1

Additional Information and Supporting Documents for

NAC-STC SAR, Revision 17D

November 2017

List of Calculations and Supporting Documents

1. **Calculation 423-3000, Revision 5 and data flash drive (1)**
2. **Calculation 423-5003, Revision 1 and data flash drive (1)**
3. **Calculation 423-5004, Revision 4 and data flash drive (1)**
4. **Calculation 30067-2010, Revision 0**

Calculations Withheld in Their Entirety per 10 CFR 2.390

Enclosure 2

List of Changes

NAC-STC SAR, Revision 17D

November 2017

List of Changes, NAC-STC SAR, Revision 17D

Chapter 1

- Page 1-v, modified List of Drawings as needed to reflect drawing revisions and additions.
- Page 1-vi thru 1-viii, text flow changes.
- Page 1-12, added "Shield Ring Assembly" to the end of Table 1.1, "Terminology."
- Page 1.2-1, revised text in Section 1.2.1.1.

Chapter 2

- Page 2-iii, updated the table of contents to reflect the addition of Section 2.6.7.8.
- Page 2-xvii, updated the list of figures to reflect the addition of Figure 2.6.7.8-1.
- Page 2.1.1-5, added the last paragraph on the page.
- Page 2.2-4, added a note to Table 2.2-1, as indicated by double asterisks (**).
- Pages 2.6.7.8-1 thru 2.6.7.8-4, added Section 2.6.7.8.
- Page 2.13.1-2, Added note number 4 to Table 2.13.2-1 in Section 2.13 for the STC-HBU configuration.

Chapter 3

- Page 3.3-2, modified the middle of the fourth paragraph of Section 3.3.2.
- Page 3.4-7, added the last paragraph of Section 3.4.1.1.1.
- Pages 3.4-8 thru 3.4-16, text flow changes.
- Page 3.8.3-2, modified the last paragraph on the page of Section 3.8.3.2.
- Page 3.8.4-4, added the last paragraph of Section 3.8.4.1.1.1.
- Page 3.8.4-5, text flow changes.
- Page 3.8.5-1, added text to the end of the second paragraph of Section 3.8.5.
- Page 3.8.5-2, modified Table 3.8-6 by adding text to the second note, as indicated by 2 asterisks (**), and added the third note, as indicated by three asterisks (***).

Chapter 4

- No changes.

Chapter 5

- Pages 5-iii, 5-x thru 5-xii and 5-xviii thru 5-xx, modified table of contents, list of figures, and list of tables to reflect changes in this submittal and editorial changes.
- Page 5-2, modified the first paragraph on the page.
- Page 5.8-1, modified Section 5.8 throughout the page.
- Page 5.8.1-1, modified the first paragraph of Section 5.8.1.1.
- Pages 5.8.1-4 thru 5.8.1-5, updated Figures 5.8.1-1 and 5.8.1-2.
- Page 5.8.1-6, modified Table 5.8.1-1.
- Pages 5.8.1-7 thru 5.8.1-9, replaced Tables 5.8.1-2 thru 5.8.1-4.
- Page 5.8.2-2, added the second paragraph on the page.

- Page 5.8.2-3, modified the bullets near the end of Section 5.8.2.2; editorial change to correct the section number 5.8.2.3, as it had been incorrectly numbered in Revision 18.
- Page 5.8.2-4, text flow changes.
- Page 5.8.2-8, added Table 5.8.2-2.
- Page 5.8.4-3, replaced Figure 5.8.4-1.
- Page 5.8.5-1, modified the third paragraph of Section 5.8.5.
- Pages 5.8.5-2 thru 5.8.5-3, replaced Tables 5.8.5-1 thru 5.8.5-7.
- Pages 5.8.6-1 thru 5.8.6-5, modified Section 5.8.6 throughout.
- Pages 5.8.7-1 thru 5.8.7-10, modified Section 5.8.7 throughout.
- Pages 5.8.8-1 thru 5.8.8-6, modified Section 5.8.8 throughout.
- Page 5.8.9-1, modified the end of the paragraph of Section 5.8.9.
- Pages 5.9-1 thru 5.9-5, added new Section 5.9.

Note

See the table at the end of this enclosure for a list of those figures and tables that have changed in number and title. The table maps the previous table numbers and titles to their corresponding new numbers and titles.

Chapter 6

- No changes.

Chapter 7

- Page 7-i thru 7-ii, updated table of contents and list of figures where indicated.
- Page 7-3, added the last two rows and note "3" to Table 7-1.
- Page 7.1-1, added new Steps 8 and 9 to Section 7.1.1 and renumbered Step 10.
- Pages 7.1-2 thru 7.1-13, text flow changes.
- Page 7.1-14, added new Step 38 to Section 7.1.3.1, and renumbered Steps 39 and 40.
- Pages 7.1-15 thru 7.1-18, text flow changes.
- Pages 7.2-1 thru 7.2-2, added new Steps 3 and 4 to Section 7.2.1 and renumbered Steps 5 thru 15.
- Pages 7.2-3 thru 7.2-6, text flow changes
- Pages 7.3-1 thru 7.3-2, added new Steps 7, 8 and 9 to Section 7.3.1 and renumbered Steps 10 and 11.
- Pages 7.3-3 thru 7.3-8, text flow changes
- Pages 7.3-9 thru 7.3-10, added new Steps 3 and 4 to Section 7.3.4 and renumbered Steps 5 thru 12.
- Page 7.3-11, text flow changes

Chapter 8

- No changes.

Chapter 9

- Page 9-13, added new reference to the bottom of the page.

[redacted]

Enclosure 3

List of Drawing Changes

NAC-STC SAR, Revision 17D

November 2017

List of Drawing Changes, NAC-STC SAR, Revision 18

Drawing 423-802, Sheet 1 of 7, Revision 24

Sheet 1:

1. Changed note 1: "deleted" to delta note 1: "Item 15 (Insulation Cover) and Item 16 (Insulation) are optional".
2. Added Delta note 1 to B.O.M. Items 15 and 16.

Drawing 423-802, Sheets 1, 3 and 5 of 7, Revision 23

Revision 23 is currently under NRC Review.

Drawing 423-880, Revision 3P

[redacted]

Drawing 423-900, Revision 9

1. B.O.M., added Item 13, Qty "A/R" for Assy 99 and 97, Name "Shield Ring Assembly", Drawing "423-927-99".
2. B.O.M., added Delta note 7 symbol to item 13.
3. Added Delta note 7 as follows "SHIELD RING ASSEMBLY IS OPTIONAL"

Drawing 423-927, Revision 0P

1. Initial Issuance

Drawing 423-927, Revision 0NP

1. Initial Issuance

Enclosure 4

Proposed Changes for Certificate of Compliance Revision 18

NAC-STC SAR, Revision 17D

November 2017

CoC Sections (revised)

Page 5 of 22
5.(a)(3) Drawings

(i) The cask is constructed and assembled in accordance with the following Nuclear Assurance Corporation (now NAC International) Drawing Nos.:

423-800, sheets 1-3, Rev. 18P & 18NP	423-811, sheets 1-2, Rev. 12
423-802, sheets 1-7, Rev. 24	423-812, Rev. 6
423-803, sheets 1-2, Rev. 14	423-900, Rev. 9
423-804, sheets 1-3, Rev. 11	423-209, Rev. 0
423-805, sheets 1-2, Rev. 7	423-210, Rev. 0
423-806, sheets 1-2, Rev. 12	423-901, sheets 1-2, Rev. 3
423-807, sheets 1-3, Rev. 4	423-927, Rev. 0P & 0NP

(ii) For the directly loaded configuration, the basket is constructed and assembled in accordance with the following Nuclear Assurance Corporation (now NAC International) Drawing Nos.:

423-870, Rev. 6	423-874, Rev. 2
423-871, Rev. 5	423-875, sheets 1-2, Rev. 11
423-872, Rev. 6	423-878, sheets 1-2, Rev. 4
423-873, Rev. 2	423-880, Rev. 3P & 1NP

Page 14 of 22
Table 10 – Yankee Class Fuel Assembly Characteristics

Page 15 of 22
Table 11 – Connecticut Yankee Fuel Assembly Characteristics

Page 16 of 22
Table 12 – LACBWR Fuel Assembly Characteristics

Page 21 of 22
12. For shipment of high burn up fuel assemblies, as described in content 5.(b)(1)(i)(2) and 5.(b)(1)(i)(4) and limited in 5.(b)(2)(i)(2) and 5.(b)(2)(i)(4) respectively, the maximum time duration from the time the package breaks the surface of the spent fuel pool until the package is placed in the horizontal orientation is limited to 72 hours. If this time limit cannot be met, the package may be re-flooded. HBU fuel assemblies subjected to a package re-flood are not authorized for shipment. High burnup fuel shipments are limited to a total duration of 6 months from the time package loading is complete until the package arrives at its final destination. These time limits also apply to packages containing commingled loadings of high burnup fuel and low burnup fuel as described in 5.(b)(2)(i).

CoC Sections (new)

Page 10 of 22

5.(b)(1)(i) Contents – Type and Form of Material – Irradiated PWR fuel assemblies (Continued)

(3) Undamaged 17x17 Advanced Fuel Assembly PWR low burnup (i.e., assembly average burnup less than or equal to 45 GWd/MTU) fuel assemblies that meet the fuel assembly criteria for Framatome-Cogema 17x17 fuel listed in Table 1 for content 5.(b)(1)(i)(1). The maximum heat load per assembly is 850 watts and the maximum burnup may not exceed 45 GWd/MTU. The minimum fuel assembly cool time is determined from Table 6. The use of the optional shield ring assembly, as configured in NAC International Drawing No. 423-927, is required.

(4) Undamaged 17x17 Advanced Fuel Assembly PWR high burnup (i.e., assembly average burnup exceeding 45 GWd/MTU) fuel assemblies that meet the fuel assembly criteria for Framatome-Cogema 17x17 fuel listed in Table 1 for content 5.(b)(1)(i)(1). The maximum assembly decay heat may not exceed 1.71 kW, and the maximum burnup may not exceed 55 GWd/MTU, provided the loading pattern meets the requirements of Configuration A, B or C as shown in NAC International Drawing No. 423-800. Only Zirc-4 and M5® Zirconium alloy cladding may be loaded per shipment, with a maximum of 4 Zirc-4 fuel assemblies may be loaded per shipment. Gadolinium based integral fuel burnable absorber rods (IFBAs) are permitted, but boron-based IFBAs are not. The minimum fuel assembly cool time is determined from Tables 7 through 9, depending on loading configuration. The fuel assemblies shall not have been previously stored in an independent spent fuel storage installation licensed under 10 CFR Part 72.

Table 6 – Fuel Cool Time Table
Minimum fuel Cool Time in Years

Enr.	Burnup [GWd/MTU]													
[wt. %]	B≤10	10<B≤15	15<B≤20	20<B≤25	25<B≤30	30<B≤32.5	32.5<B≤35	35<B≤37.5	37.5<B≤40	40<B≤41	41<B≤42	42<B≤43	43<B≤44	44<B≤45
1.7 ≤ E < 1.9	4.0	4.0	4.0	4.5	5.9	7.2	9.8	-	-	-	-	-	-	-
1.9 ≤ E < 2.1	4.0	4.0	4.0	4.4	5.5	6.4	8.3	11.4	15.3	-	-	-	-	-
2.1 ≤ E < 2.3	4.0	4.0	4.0	4.3	5.2	5.9	7.2	9.7	13.2	-	-	-	-	-
2.3 ≤ E < 2.5	4.0	4.0	4.0	4.2	4.9	5.6	6.6	8.4	11.4	12.8	14.3	15.9	17.6	19.2
2.5 ≤ E < 2.7	4.0	4.0	4.0	4.1	4.8	5.3	6.0	7.4	9.8	11.1	12.5	13.9	15.5	17.1
2.7 ≤ E < 2.9	4.0	4.0	4.0	4.0	4.7	5.0	5.7	6.7	8.5	9.6	10.8	12.1	13.6	15.1
2.9 ≤ E < 3.1	4.0	4.0	4.0	4.0	4.6	5.0	5.6	6.2	7.6	8.4	9.4	10.6	11.9	13.3
3.1 ≤ E < 3.3	4.0	4.0	4.0	4.0	4.6	5.0	5.5	6.0	6.9	7.6	8.3	9.2	10.4	11.7
3.3 ≤ E < 3.5	4.0	4.0	4.0	4.0	4.6	4.9	5.4	6.0	6.7	7.0	7.5	8.2	9.1	10.2
3.5 ≤ E < 3.7	4.0	4.0	4.0	4.0	4.5	4.9	5.4	5.9	6.6	6.9	7.2	7.6	8.2	9.0
3.7 ≤ E < 3.9	4.0	4.0	4.0	4.0	4.5	4.9	5.3	5.9	6.5	6.8	7.1	7.5	7.9	8.4
3.9 ≤ E < 4.1	4.0	4.0	4.0	4.0	4.5	4.8	5.3	5.8	6.5	6.8	7.0	7.4	7.8	8.3
4.1 ≤ E < 4.3	4.0	4.0	4.0	4.0	4.5	4.8	5.3	5.8	6.4	6.7	7.0	7.4	7.7	8.1
4.3 ≤ E < 4.5	4.0	4.0	4.0	4.0	4.4	4.8	5.2	5.8	6.4	6.6	6.9	7.3	7.7	8.1

Table 7 – Fuel Cool Time Table
(Configuration A 17x17 PWR HBU)
Minimum Fuel Cool Time Table

Enr.	Burnup [GWd/MTU]									
[wt. %]	45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55
2.9 ≤ E < 3.1	4.0	4.0	4.5	5.0	5.7	6.3	6.9	7.6	8.4	-
3.1 ≤ E < 3.3	4.0	4.0	4.0	4.3	4.8	5.4	6.0	6.7	7.4	8.1
3.3 ≤ E < 3.5	4.0	4.0	4.0	4.1	4.2	4.7	5.2	5.8	6.4	7.1
3.5 ≤ E < 3.7	4.0	4.0	4.0	4.0	4.1	4.2	4.5	5.0	5.6	6.2
3.7 ≤ E < 3.9	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.8	5.4
3.9 ≤ E < 4.1	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.5	4.7
4.1 ≤ E < 4.3	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5
4.3 ≤ E < 4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.4	4.5

Table 8 – Fuel Cool Time Table
(Configuration B 17x17 PWR HBU)
Minimum Fuel Cool Time Table

Enr.	Burnup [GWd/MTU]									
[wt. %]	45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55
2.9 ≤ E < 3.1	4.4	4.9	5.5	6.1	6.8	7.6	8.3	9.1	10.0	-
3.1 ≤ E < 3.3	4.4	4.5	4.7	5.3	5.9	6.6	7.3	8.0	8.8	9.7
3.3 ≤ E < 3.5	4.3	4.4	4.5	4.7	5.1	5.7	6.3	7.0	7.8	8.6
3.5 ≤ E < 3.7	4.2	4.4	4.5	4.6	4.7	4.9	5.5	6.1	6.8	7.5
3.7 ≤ E < 3.9	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.3	5.9	6.6
3.9 ≤ E < 4.1	4.1	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.7
4.1 ≤ E < 4.3	4.1	4.2	4.3	4.4	4.5	4.7	4.8	5.0	5.1	5.3
4.3 ≤ E < 4.5	4.0	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.2

Table 9 – Fuel Cool Time Table
(Configuration C 17x17 PWR HBU)
Minimum Fuel Cool Time Table

Enr.	Burnup [GWd/MTU]									
[wt. %]	45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55
2.9 ≤ E < 3.1	7.4	8.2	9.1	10.0	11.0	12.0	13.1	14.3	15.5	-
3.1 ≤ E < 3.3	6.4	7.1	7.9	8.8	9.7	10.7	11.6	12.7	13.9	15.1
3.3 ≤ E < 3.5	5.5	6.2	6.9	7.7	8.5	9.4	10.4	11.3	12.4	13.5
3.5 ≤ E < 3.7	5.4	5.6	6.0	6.7	7.5	8.3	9.2	10.1	11.0	12.0
3.7 ≤ E < 3.9	5.3	5.5	5.7	5.9	6.6	7.3	8.1	8.9	9.8	10.8
3.9 ≤ E < 4.1	5.2	5.4	5.6	5.8	6.0	6.4	7.1	7.9	8.7	9.6
4.1 ≤ E < 4.3	5.2	5.4	5.6	5.7	5.9	6.1	6.4	7.0	7.7	8.5
4.3 ≤ E < 4.5	5.1	5.3	5.5	5.7	5.9	6.0	6.3	6.6	6.8	7.6

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5.(b)(2)(i) Maximum quantity of material per package

(3) Low burnup assemblies, as described in 5.(b)(1)(i)(3), shall have a maximum decay heat not to exceed 22.1 kW per package.

(4) For high burnup fuel assemblies, as described in 5.(b)(1)(i)(4), the number and the positioning of the fuel assemblies and shielded thermal shunts shall meet the requirements as shown in Configuration A, B or C of NAC International Drawing No. 423-800 and shall have a maximum decay heat not to exceed 24 kW per package. A maximum of four Zirc-4 fuel assemblies may be loaded per shipment.

Low burnup fuel assemblies described in Item 5.(b)(1)(i)(1) may be comingled with high burnup fuel assemblies described in 5.(b)(1)(i)(4), however, the requirements for contents described in Item 5.(b)(1)(i)(4) regarding assembly and thermal shunt numbers and positions apply to package containing the comingled loads.

Low burnup fuel assemblies described in Item 5.(b)(1)(i)(3) may be comingled with high burnup fuel assemblies described in 5.(b)(1)(i)(4), however, the requirements for contents described in Item 5.(b)(1)(i)(4) regarding assembly and thermal shunt numbers and positions apply to package containing the comingled loads. The use of the optional shield ring assembly, as configured in NAC International Drawing No. 423-927, is required.

Enclosure 5

SAR Changed Pages and LOEP

NAC-STC SAR, Revision 17D

November 2017

November 2017

Revision 17D

NAC-STC

NAC Storage Transport Cask

SAFETY ANALYSIS REPORT

Non-Proprietary Version
Volume 1 of 2

Docket No. 71-9235

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List of Effective Pages

Chapter 1

Chapter 2

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Chapter 3

Chapter 4

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Chapter 5

Chapter 6

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Chapter 7

Chapter 8

Chapter 9

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List of Drawings

Drawing Number	Revision No.	Title
423-800, sheets 1-3	Rev 18P(1)	Cask Assembly – NAC-STC Cask
423-800, sheets 1-3	Rev 18NP(1)	Cask Assembly – NAC-STC Cask
423-802, sheets 1-7	Rev 24	Cask Body – NAC-STC Cask
423-803, sheets 1-2	Rev 14	Lid Assembly – Inner, NAC-STC Cask
423-804, sheets 1-3	Rev 11	Details - Inner Lid, NAC-STC Cask
423-805, sheets 1-2	Rev 7	Lid Assembly – Outer, NAC-STC Cask
423-806, sheets 1-2	Rev 12	Port Coverplate Assy – Inner Lid, NAC-STC Cask
423-807, sheets 1-3	Rev 4	Assembly, Port Cover, NAC-STC Cask
423-209	Rev 0	Impact Limiter Assy – Upper, NAC-STC Cask
423-210	Rev 0	Impact Limiter Assy – Lower, NAC-STC Cask
423-257	Rev 2	Balsa Impact Limiter, Upper, NAC-STC Cask
423-258	Rev 2	Balsa Impact Limiter, Lower, NAC-STC Cask
423-811, sheets 1-2	Rev 12	Details – NAC-STC Cask
423-812	Rev 6	Nameplates – NAC-STC Cask
423-843	Rev 6	Transport Assembly, Balsa Impact Limiters, NAC-STC
423-859	Rev 0	Attachment Hardware, Balsa Limiters, NAC-STC
423-870	Rev 6	Fuel Basket Assembly, PWR, 26 Element, NAC-STC Cask
423-871	Rev 5	Bottom Weldment, Fuel Basket, PWR, 26 Element, NAC-STC Cask
423-872	Rev 6	Top Weldment, Fuel Basket, PWR, 26 Element, NAC-STC Cask
423-873	Rev 2	Support Disk and Misc. Basket Details, PWR, 26 Element, NAC-STC Cask
423-874	Rev 2	Heat Transfer Disk, Fuel Basket, PWR, 26 Element, NAC-STC Cask
423-875, sheets 1-2	Rev 11	Tube, NAC-STC Cask
423-878, sheets 1-2	Rev 4	Alternate Tube Assembly, NAC-STC Cask
423-880	Rev 3P(1)	Shielded Thermal Shunt Assembly, NAC-STC Cask
423-880	Rev 1NP(1)	Shielded Thermal Shunt Assembly, NAC-STC Cask
423-900	Rev 9	Package Assembly Transportation, NAC-STC Cask
423-901, sheets 1-2	Rev 3	Transportation Package Concept, NAC-STC Cask
423-927	Rev 0P(1)	Shield Ring Assembly, NAC-STC Cask
423-927	Rev 0NP(1)	Shield Ring Assembly, NAC-STC Cask

(1) Proprietary and Non-proprietary drawing versions are only included in their respective SAR versions.

List of Drawings (continued)

Drawing Number	Revision No.	Title
455-800, sheets 1-2	Rev 2	Assembly, Transport Cask, MPC-Yankee
455-801, sheets 1-2	Rev 4	Assembly, Transport Cask, NAC-MPC
455-820, sheets 1-2	Rev 3	Spacers, Transport Cask, MPC-Yankee
455-870	Rev 5	Canister Shell, MPC-Yankee
455-871, sheets 1-2	Rev 8	Details, Canister, MPC-Yankee
455-871, sheets 1-3	Rev 7P2	Details, Canister, MPC-Yankee
455-872, sheets 1-2	Rev 12	Assembly, Transportable Storage Canister (TSC), MPC-Yankee
455-872, sheets 1-2	Rev 11P1	Assembly, Transportable Storage Canister (TSC), MPC-Yankee
455-873	Rev 4	Assembly, Drain Tube, Canister, MPC-Yankee
455-881, sheets 1-3	Rev 8	PWR Fuel Tube, MPC-Yankee
455-887, sheets 1-3	Rev 4	Basket Assembly, 24 GTCC Container, MPC-Yankee
455-888, sheets 1-2	Rev 8	Assembly, Transportable Storage Canister (TSC), 24 GTCC Container, MPC-Yankee
455-891, sheets 1-2	Rev 1	Bottom Weldment, Fuel Basket, MPC-Yankee
455-891, sheets 1-3	Rev 2P0	Bottom Weldment, Fuel Basket, MPC-Yankee
455-892, sheets 1-2	Rev 3	Top Weldment, Fuel Basket, MPC-Yankee
455-892, sheets 1-3	Rev 3P0	Top Weldment, Fuel Basket, MPC-Yankee
455-893	Rev 3	Support Disk and Misc. Basket Details, MPC-Yankee
455-894	Rev 2	Heat Transfer Disk, Fuel Basket, MPC-Yankee
455-895, sheets 1-2	Rev 5	Fuel Basket Assembly, MPC-Yankee
455-895, sheets 1-2	Rev 5P0	Fuel Basket Assembly, MPC-Yankee
455-919	Rev 2	Retainer, United Nuclear Test Assy, MPC-Yankee
414-801, sheets 1-2	Rev 2	Cask Assembly, NAC-STC, CY-MPC
414-820	Rev 0	Canister Spacer CY-MPC
414-870	Rev 3	Canister Shell, CY-MPC
414-871, sheets 1-2	Rev 6	Details, Canister CY-MPC
414-872, sheets 1-3	Rev 6	Assembly, Transportable Storage Canister (TSC), CY-MPC
414-873	Rev 2	Drain Tube Assembly, CY-MPC
414-874	Rev 0	Shim, Canister, CY-MPC
414-875	Rev 0	Spacer Shim, Canister, CY-MPC
414-881, sheets 1-2	Rev 4	Fuel Tube, Transportable Storage Canister (TSC), CY-MPC

List of Drawings (Continued)

Drawing Number	Revision No.	Title
414-882, sheets 1-2	Rev 4	Oversize Fuel Tube, Transportable Storage Canister (TSC), CY-MPC
414-887, sheets 1-4	Rev 4	Basket Assembly, GTCC, CY-MPC
414-888, sheets 1-2	Rev 4	Canister Shell, GTCC, CY-MPC
414-889, sheets 1-3	Rev 7	Assembly, Transportable Storage Canister (TSC), GTCC, CY-MPC
414-891	Rev 3	Bottom Weldment, Fuel Basket CY-MPC
414-892, sheets 1-3	Rev 3	Top Weldment Fuel Basket CY-MPC
414-893, sheets 1-2	Rev 2	Support Disk and Misc. Basket Details CY-MPC
414-894	Rev 0	Heat Transfer Disk, Fuel Basket CY-MPC
414-895, sheets 1-2	Rev 4	Fuel Basket Assembly CY-MPC
Yankee-Class Reconfigured Fuel Assembly		
YR-00-060	Rev D3	Yankee-Class Reconfigured Fuel Assembly
YR-00-061	Rev D4	Yankee-Class Reconfigured Fuel Assembly Shell Weldment
YR-00-062, Sheet 1	Rev D4	Yankee-Class Reconfigured Fuel Assembly Top End Fitting Assembly
YR-00-062, Sheet 2	Rev D2	Yankee-Class Reconfigured Fuel Assembly Top End Plate
YR-00-062, Sheet 3	Rev D1	Yankee-Class Reconfigured Fuel Assembly Top End Template
YR-00-063	Rev D4	Yankee-Class Reconfigured Fuel Assembly Bottom End Fitting Assy.
YR-00-064	RevD4	Yankee-Class Reconfigured Fuel Assembly Nozzle Bolt and Alignment Pin
YR-00-065	Rev D2	Yankee-Class Reconfigured Fuel Assembly Fuel Basket Assembly
YR-00-066, Sheet 1	Rev D5	Yankee-Class Reconfigured Fuel Assembly Fuel Tube Assembly
YR-00-066, Sheet 2	Rev D3	Yankee-Class Reconfigured Fuel Assembly Fuel Tube Assembly
Yankee Rowe Damaged Fuel Can		
455-901	Rev 0P0	Can Assembly, Damaged Fuel, MPC-Yankee
455-902, sheets 1-5	Rev 0P4	Can Details, Damaged Fuel, MPC-Yankee
Connecticut Yankee Damaged Fuel Can		
414-901	Rev 1	Assembly, Damaged Fuel Can, CY-MPC
414-902, sheets 1-3	Rev 3	Details, Damaged Fuel Can, CY-MPC

List of Drawings (Continued)

Drawing Number	Revision No.	Title
Connecticut Yankee Reconfigured Fuel Assembly		
414-903, sheets 1-2	Rev 1	Reconfigured Fuel Assembly, CY- MPC
414-904, sheets 1-3	Rev 0	Details, Reconfigured Fuel Assembly, CY- MPC
STC-LACBWR System Components		
630045-800, sheets 1-2	0	Assembly, Transport Cask, MPC-LACBWR
630045-820	0	Spacer, Transport Cask, MPC-LACBWR
630045-870	2	Shell Weldment, Canister (TSC), MPC-LACBWR
630045-871, sheets 1-4	2	Details TSC, MPC-LACBWR
630045-872, sheets 1-2	1	Assembly, Transportable Storage Canister (TSC), MPC-LACBWR
630045-873	1	Assembly, Drain Tube TSC, MPC-LACBWR
630045-877	1	Bottom Weldment, Fuel Basket, MPC-LACBWR
630045-878	1	Top Weldment, Fuel Basket, MPC-LACBWR
630045-881, sheets 1-2	1	Fuel Tube Assembly, MPC-LACBWR
630045-893	1	Support Disk, Fuel Basket, MPC-LACBWR
630045-894	1	Heat Transfer Disk, Fuel Basket, MPC-LACBWR
630045-895, sheets 1-3	1	Fuel Basket Assembly, 68 Element BWR, MPC-LACBWR
630045-901	0	Assembly, Damaged Fuel Can (DFC), MPC-LACBWR
630045-902, sheets 1-2	1	Details, Damaged Fuel Can (DFC), MPC-LACBWR

Table 1-1 Terminology (continued)

Directly Loaded Undamaged Fuel Assembly	A spent nuclear fuel assembly that can meet all fuel-specific and system-related functions. Directly loaded undamaged assembly is spent nuclear fuel that does not contain assembly structural defects that adversely affect radiological and/or criticality safety. As such, the assembly may contain rods with minor defects up to hairline cracks or pinholes, but cannot contain grossly breached fuel rods.
MPC-WVDP HLW Contents	Up to five (5) welded HLW canisters filled with vitrified, solidified high-level waste, or up to two (2) melter-evacuated canisters that are partially filled with glass, and one (1) HLW debris canister.
HLW Debris Canister	An HLW canister containing borosilicate glass and radioactive waste material within the glass matrix. The canister also contains refractory material (Alfibond 2800) and may contain alumina from melter inserts. The source of the refractory material are melter inserts. Alfibond 2800 is a non-organic insulator composed (99+%) of alumina (Al2O3) and silica (SiO2). No organic material is present in the insulator.
Personnel Barrier	An expanded metal screen with appropriate support structure that is installed between the impact limiters and covers the cask during transport. The expanded metal screen, and its support structure, are aluminum. The personnel barrier precludes incidental contact with the cask surface, which may be at elevated temperature compared to the rail car.
Lattice	A fuel assembly structure that is used to hold up to 204 Intact Fuel Rods or Damaged Fuel Rods from other fuel assemblies. A Lattice is sometimes called a fuel skeleton, cage or structural cage. It is built from the same components as a standard fuel assembly, but some of those components may be modified slightly, such as relaxed grids, to accommodate the distortion that may be present in a Damaged Fuel Rod. The outside dimensions are identical to a standard fuel assembly.

Table 1-1 Terminology (continued)

Failed Rod Storage Canister	A handling container for moving up to 60 individual intact or damaged fuel rods in stainless steel tubes into a CY-MPC Damaged Fuel Can. The steel tubes are held in place by regularly spaced plates welded in an open stainless steel frame. The failed rod storage canister, which is closed at the top end by a bolted closure and at the bottom by a welded plate to capture the fuel rods in the tubes, must be loaded in a CY-MPC Damaged Fuel Can.
Redwood Impact Limiter	A device constructed primarily of redwood with limited use of balsa wood. This device is designed to dissipate energy during normal and accident conditions impact events for packages weighing up to 250,000 lb. The redwood impact limiter is 124 inches in diameter with redwood providing primary protection during end and side impact events and balsa wood for corner impact events.
Structural Damage	Damage to the fuel assembly that does not prevent handling the fuel assembly by normal means. Structural damage is defined as partially torn, abraded, dented or bent grid straps, end fittings or guide tubes. The damaged grid straps or end fittings must continue to provide support to the fuel rods, as designed, and may not be completely torn or missing. Guide tubes cannot be ruptured and must be continuous between the upper and lower end fittings. Fuel assemblies with structural damage are considered to be intact fuel assemblies provided that they do not have failed or damaged fuel rods.
Shield Ring Assembly	An optional stainless steel ring assembly installed on the upper cask body, adjacent to the neutron shield, that provides additional radiation shielding in the upper region of the cask which does not include lead shielding within the cask body.

1.2 Package Description

This section presents a basic description of the NAC-STC and the contents that may be transported. An operational schematic of the cask is presented in Figure 1.2-1. Detailed dimensional drawings are provided in Section 1.3.2. The design characteristics of the NAC-STC are summarized in Table 1.2-1.

1.2.1 Packaging

1.2.1.1 Gross Weight

The maximum gross transport weight of the NAC-STC spent-fuel shipping cask, excluding the optional shield ring assembly, is calculated to be 249,700 pounds for directly loaded fuel with the standard (redwood) impact limiters and is 254,589 pounds for CY-MPC canistered GTCC waste with the lightweight (balsa) impact limiters. A shipper may use the optional shield ring assembly provided the total cask weight for directly loaded fuel is less than the maximum analyzed cask weight as summarized in this section. When the NAC-STC is loaded on its railcar, the gross weight of the railcar (including cask, impact limiters, supports, and personnel barrier) will satisfy the requirements of the Association of American Railroads. The calculated component weights, detailed in Tables 2.2-1 through 2.2-5, are summarized as seen on the following page:

MPC Component	Directly Loaded Fuel Weight (pounds)	Yankee-MPC Canistered Fuel Weight (pounds)	Yankee-MPC Canistered GTCC Waste Weight (pounds)	CY-MPC Canistered Fuel Weight (pounds)	CY-MPC Canistered GTCC Waste Weight (pounds)	MPC-WVDP HLW Overpack Weight (pounds)
Cask Body	175,970	175,970	175,970	175,970	175,970	175,970
Basket	16,820	--	--			
Fuel, GTCC Waste or HLW	39,000	30,600	12,340	35,100	20,230	27,500
Canister	--	14,600	14,600	16,666	16,666	9,500
Canister Basket	--	9,530	26,471	14,055	28,926	5,000
Spacers	--	860	860	1,374	1,374	3,800
Total (calculated)	**231,790**	**231,560**	**230,241**	**243,165**	**243,166**	**221,770**
With Standard (Redwood) Impact Limiters	249,520	249,290	247,971	--	--	--
With Lightweight (Balsa) Impact Limiters	243,213	242,983	241,664	254,588	254,589	236,000
Analysis Weight	**250,000**	**250,000**	**250,000**	**260,000**	**260,000**	**260,000**

The weight of the CY-MPC fuel basket is that of the 26-assembly basket. The weight of the 24-assembly basket is 13,451 pounds.

R-236067

REV	CHANGE
0	INITIAL ISSUE

PROPRIETARY INFORMATION REMOVED

99 SHIELD RING ASSEMBLY

97 ASSY	98 ASSY	99 ASSY	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		8	13	THREAD INSERT	ST. STL.	COML		
		A/R	12	PLUG	ST. STL.	COML		PROPRIETARY INFORMATION REMOVED
		A/R	11	LOCKING WIRE	ST. STL.	COML		PROPRIETARY INFORMATION REMOVED
		8	10	TREADED INSERT	ST. STL.	COML		PROPRIETARY INFORMATION REMOVED
		8	9	FLAT WASHER	ST. STL.	COML		PROPRIETARY INFORMATION REMOVED
		8	8	HEX BOLT	410 ST. STL.	ASME SA193, Gr. B6		PROPRIETARY INFORMATION REMOVED
		8	7	SOCKET HEAD SCREW	410 ST. STL.	ASME SA193, Gr. B6		PROPRIETARY INFORMATION REMOVED
		1	6	SIDE SECTOR, LH	304 ST. STL.	ASME SA240/SA182		PLATE/FORGING
		1	5	SIDE SECTOR, RH	304 ST. STL.	ASME SA240/SA182		PLATE/FORGING
		1	4	BOTTOM SECTOR	17-4PH ST. STL.			FORGING/PLATE
	2		3	LIFT LUG	304 ST. STL.	ASME SA240/SA276		PLATE/BAR
	1		2	TOP SECTOR	304 ST. STL.	ASME SA240/SA182		PLATE/FORGING
		1	1	TOP SECTOR WELDMENT			423-927-98	

QUANTITY

PROPRIETARY INFORMATION REMOVED

NOTES:

UNLESS OTHERWISE STATED
DIMENSIONING AND TOLERANCING SHALL BE PER ASME Y14.5M-94
ALL THREAD DEPTH CALLOUTS ARE TO BE CONSIDERED AS A MIN. DEPTH OF PERFECT TREADS
ALL DIMENSIONS ARE IN INCHES
MACHINED SURFACES SHALL BE ▽ OR BETTER
NEXT ASSEMBLY: 423-900
DRAWING TYPE: LICENSE

GROUP	NAME	DATE
PREPARER	V. Shtylman	10-12-17
CHECKER		10-13-17
PROJECT MANAGER		10/13/17
ENGINEERING		10/13/17
LICENSING		10/17/17
QUALITY		10/18/17

NAC INTERNATIONAL

SHIELD RING ASSEMBLY, NAC-STC CASK

PROJECT 423 | DRAWING 927 | REV 0NP
SCALE N. T. S. | WEIGHT N/A | SH 1 OF 1 | 8/29/2017

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waste. The Yankee-MPC canister has a capacity of up to 36 Yankee Class spent fuel elements, or 32 Yankee Class fuel elements and four damaged fuel cans in the four basket corners, or up to 24 loading positions for GTCC waste. Similarly, the CY-MPC canister serves as the enclosure for the Connecticut Yankee spent fuel, damaged fuel cans and GTCC waste. The CY-MPC canister has a capacity of up to 26 Connecticut Yankee spent fuel assemblies or up to 24 containers of GTCC waste. The canister consists of a cylindrical shell with a welded bottom plate, a fuel or GTCC basket, a shield lid and a structural lid. The canister provides leak tight containment of the spent fuel or waste that it holds. This leak tight level of containment is maintained in all of the design basis normal conditions of transport and hypothetical accident conditions. Consequently, it qualifies as the separate inner container required by 10 CFR 71.63(b) for failed or damaged fuel that may be in the canister. The canister is evaluated for normal conditions of transport in Sections 2.6.13 and for hypothetical accident conditions in Section 2.7.11 in the transport configuration.

For the NAC-STC cask configuration with red wood impact limiters, an optional shield ring assembly may be bolted to the top forging of the cask to enhance shielding performance. See Section 2.6.7.8 for the evaluation of the bolted connection for the shield ring.

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TSC in the cask, with the noted number of design basis fuel assemblies in the basket. "Under-the-hook loaded with fuel" describes the loaded NAC-STC without the outer lid in place, and with the yoke. "Loaded with fuel/ready for transport" describes the loaded NAC-STC with helium in the cavity and the upper and lower impact limiters installed on the cask. The axial locations of the centers of gravity are measured from the bottom outer surface of the cask body. The centers of gravity are on the axial centerline of the cask because it is essentially symmetric about that axis. The design weight of the NAC-STC "loaded with fuel/ready for transport" in the STC-LACBWR configuration is 250,000 pounds. This design weight is used in all normal transport, hypothetical accident, and lifting/handling analyses.

The calculated weights of the major components of the HBU fuel in a directly loaded configuration of the NAC-STC are tabulated in Table 2.13.2-1. The table also presents a summary of the weights and center of gravity locations of the NAC-STC for the three HBU fuel cask configurations most likely to occur – empty, under the hook loaded with fuel, and loaded with fuel/ready for transport. The term "loaded with fuel" refers to the loaded HBU fuel contents with thermal shunts. The heaviest fuel configuration with 20 fuel assemblies and 6 thermal shunts is shown in the table. "Under-the-hook loaded with fuel" describes the loaded NAC-STC with the yoke. "Loaded with fuel/ready for transport" describes the loaded NAC-STC with helium in the cavity and the upper and lower impact limiters installed on the cask. The axial locations of the centers of gravity are measured from the bottom outer surface of the cask body. The centers of gravity are on the axial centerline of the cask because it is essentially symmetric about that axis. The weight of the NAC-STC "loaded with fuel/ready for transport" in the STC-HBU configuration using the balsa impact limiters and redwood impact limiters is 242,320 pounds and 248,620 pounds, respectively. This is less than the design weight of 260,000 pounds and 250,000 pounds for the balsa wood and redwood impact limiters respectively. The STC-HBU cask body structural evaluation is based on the bounding 26 assembly directly loaded fuel configuration, which is associated with the use of the redwood impact limiters for transport.

Table 2.2-1 NAC-STC Calculated Weights and Centers of Gravity for Directly Loaded Fuel

Component	**Calculated Weight (lbs)**	**Center of Gravity* (in)**	**Calculated Weight (lbs)**	**Center of Gravity* (in)**
Impact Limiter Configuration	**Redwood**		**Balsa**	
Body Assembly	157,160		157,160	
Outer Lid	8,120		8,120	
Inner Lid	10,690		10,690	
TOTAL	175,970	96.8	175,970	96.8
Fuel (26 PWR Assemblies @ 1,500 lbs)	39,000		39,000	
Fuel Basket	16,820		16,820	
Water In Cavity	16,430		16,430	
Yoke	2,150		2,150	
Transport Impact Limiters				
Top	8,865	203.6	5,787	203.6
Bottom	8,865	-10.5	5,636	-10.5
TOTAL WEIGHT**				
Empty	192,790	96.8	192,790	96.8
Under-the-Hook Loaded with Fuel	242,250	96.0	242,250	96.0
Loaded with Fuel/Ready for Transport	249,520	96.0	243,213	96.0
Design - Loaded with Fuel/ Ready for Transport	250,000	96.0	250,000	96.0

* Measured from bottom outer surface of cask body.

** For the cask configuration with redwood impact limiters, the optional shield ring (920 lbs.) is permitted by limiting the fuel weight to 38,500 lbs. Therefore, the design transport weight of 250,000 lbs. remains bounding.

2.6.7.8 Bolted Connection for the Shield Ring

An optional shield ring assembly may be bolted to the top forging of the NAC STC cask configuration using red wood impact limiters. The structural evaluation of the bolted connection of the shield ring assembly to the cask is described in this section. The bolts and related components are qualified to the criteria in ASME B&PV Code, Section III, Subsection NF for Normal Conditions of Transport. Classic hand calculations are used for the evaluation of the connection. An operating temperature of 250°F is considered for the evaluation.

The shield ring consists of four sectors: bottom sector, top sector and two side sectors. The bottom sector of the shield ring assembly is an SA-705, Type 630, 17-4PH stainless steel forging. The top sector and side sectors are fabricated from SA-240, Type 304 stainless steel. The bolt material is SA-193, Grade B6, Type 410 stainless steel for all bolts.

The bolted connections securing the shield ring assembly are evaluated for two bounding load conditions for the 1-Foot Free Drop. The 20g bounds the deceleration values as presented in Section 2.6.7.4, Table 2.6.7.4.1-3.

A. 20g End Drop
B. 20g Side Drop

The inertia of the shield ring sub-components (bottom sector, top sector, and two side sectors) load the bolts as a result of the 20g decelerations.

In an end drop, the transport cask body remains vertical. The shield ring assembly is restrained by eight 1-8 UNC bolts, each installed radially through the top and bottom sector sub-components, and into the cask top forging. The end drop loads the eight bolts in shear. The side sector sub-components are attached only to the top and bottom sector sub-components, not directly to the cask top forging. For this reason, the mass of the side sectors is included with the mass of the top or bottom sector when evaluating the shear of the eight bolts. The bolts are evaluated assuming the bolt shear planes are located in the threaded portion of the bolt. The side sector sub-components are each restrained by four ½-13 UNC bolts, each installed radially through a side sector and into the top and bottom sectors. The end drop loads the four bolts (per side sector) in shear. The bolts are evaluated assuming the bolt shear planes are located in the threaded portion of the bolt.

The minimum Factors of Safety for shear and bearing stresses for the bolts connecting the shield ring to cask top forging are calculated to be 2.53 and 4.5, respectively, for the end drop condition.

In a side drop, the transport cask body is horizontal. The cask body may be at any angular orientation about its own axis. Therefore, the side impact may be at any radial orientation of the bolt pattern of the eight bolts securing the shield ring assembly to the cask body. The three orientations described below (see Figure 2.6.7.8-1) bounds the resulting tensile and shear forces on the bolts:

- Orientation #1: The drop aligns exactly with one of the eight 1-8 UNC bolts.
- Orientation #2: The drop aligns exactly midway between two of the eight 1-8 UNC bolts
- Orientation #3: The drop aligns exactly with two of the four ½-13 UNC bolts securing a side sector plate

For Orientation #1, the evaluation results for the single bolt on drop centerline are summarized in the following table.

Evaluation for the 1-8 UNC at Drop Centerline	**Factor of Safety**
Bolt Tensile Stress	1.13
Bolt External Thread Shear Stress	2.42
Cask Top Forging Internal Thread Shear Stress	2.56
Bearing Stress on shield ring top or bottom sector, under bolt head	1.83
Shear Stress in shield ring top or bottom sector, due to bolt head	1.74

For Orientation #1, the interaction ratio for the combined tensile and shear stress for the 1-8 UNC bolts located 45° away from the drop centerline is calculated to be 0.39 (< 1).

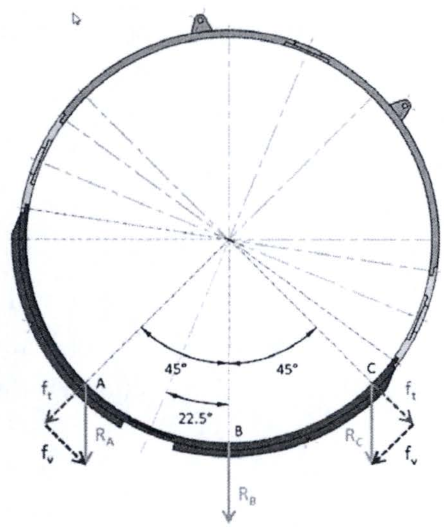
For Orientation #2, the interaction ratio for the combined tensile and shear stress for the 1-8 UNC bolts located 22.5° and 67.5° away from the drop centerline is calculated to be 0.56 (< 1) and 0.32 (< 1) respectively.

For Orientation #3, the evaluation results for the ½-13 UNC bolt connecting the side sector to the top and bottom sectors are summarized in the following table.

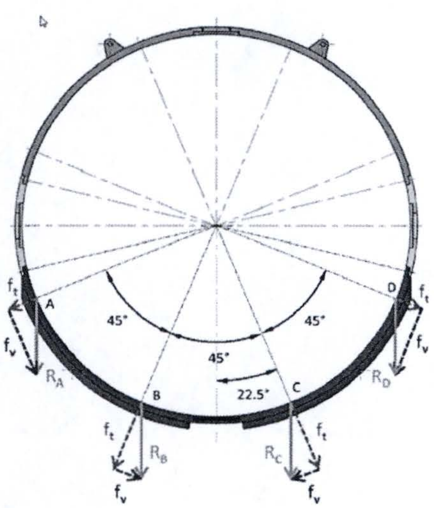
Evaluation for the ½-13 UNC Bolt	Factor of Safety
Bolt Tensile Stress	1.03
Bolt External Thread Shear Stress	2.39
Shield Ring Top and Bottom Sector Internal Thread Shear Stress	2.61
Bearing Stress on shield ring side sector, under bolt head	1.43
Shear Stress in shield ring side sector, due to bolt head	4.30

Therefore, the bolted connections of the NAC-STC shield ring assembly meet the structural criteria of the ASME Boiler & Pressure Vessel Code, Section III, Subsection NF for a Class 1 support for normal condition of transport. More detailed evaluation is documented in Appendix D of NAC Calculation No. 30067-2010 (as listed in Section 9.0 References).

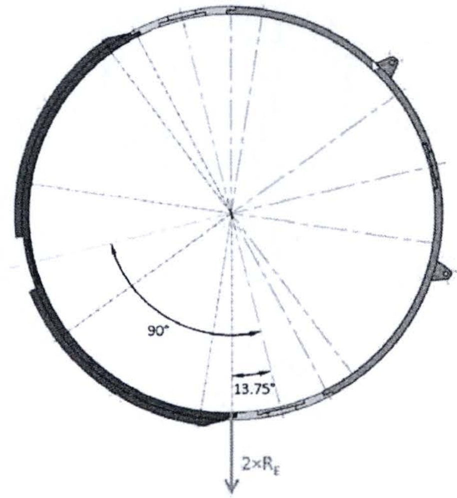
Figure 2.6.7.8-1 Orientations for Shield Ring Bolt Evaluation for Side Drop Conditions



Orientation #1



Orientation #2



Orientation #3

November 2017

Revision 17D

NAC-STC

NAC Storage Transport Cask

SAFETY ANALYSIS REPORT

Non-Proprietary Version
Volume 2 of 2

Docket No. 71-9235

NAC INTERNATIONAL

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2.13.2 Weights and Centers of Gravity – STC-HBU Assembly

This section provides the weights and centers of gravity for the STC-HBU configuration of the NAC-STC with the balsa wood impact limiter design. The balsa wood impact limiter design is shown in Drawings 423-257 and 423-258, and the redwood impact limiter is shown in drawings 423-209 and 423-210. Either impact limiter design can be used for the STC-HBU configuration of the NAC-STC (see Section 2.1.1).

The calculated weights of the major components of the STC-HBU configuration are tabulated in Table 2.13.2-1. The table also presents a summary of the weights and center of gravity locations of the NAC-STC for the three STC-HBU configurations. The table presents a summary of the weights and center of gravity locations of the NAC-STC for the three STC -HBU configurations most likely to occur – empty, under the hook loaded with STC-HBU contents, and loaded with STC-HBU contents/ready for transport. The term "loaded with contents" refers to the loaded STC-HBU, the cask, with STC-HBU contents. "Under-the-hook loaded with fuel" describes the loaded NAC-STC with the yoke. "Loaded with fuel/ready for transport" describes the loaded NAC-STC with inert backfill gas in the cavity and the upper and lower impact limiters installed on the cask. The axial locations of the centers of gravity are measured from the bottom outer surface of the cask body. The centers of gravity are on the axial centerline of the cask because it is essentially symmetric about that axis. The weight of the NAC-STC "loaded with fuel/ready for transport" in the STC-HBU configuration using the balsa impact limiters and redwood impact limiters is 242,320 pounds and 248,620 pounds, respectively. This is less than the design weight of 260,000 pounds for the balsa wood and 250,000 pounds for the redwood impact limiters. The STC-HBU cask body structural evaluation is based on the directly loaded fuel configuration, which is associated with the use of the redwood impact limiters for transport.

Table 2.13.2-1 NAC-STC Calculated Weights and Center of Gravity Summary for HBU Fuel

Description	Weight (lb.)	C.G. (in.)[3]
NAC-STC Cask Body Assembly[1]	157,160	N/A
Outer Lid[1]	8,120	N/A
Inner Lid[1]	10,690	N/A
Total Weight of NAC-STC Cask & Lids[1]	**175,970**	**96.8**
Maximum STC-HBU (fuel and shunts)	38,100	N/A
Fuel Basket	16,820	95.9
Total Weight of Contents (STC-HBU)	54,920	96.4
Yoke[1]	2,150	N/A
Impact Limiter Configuration	**Balsa[2]**	
NAC-STC Balsa Impact Limiters		
Top Impact Limiter[2]	5,790	203.6
Bottom Impact Limiter[2]	5,640	-10.5
Total Weight of STC-HBU Transport Cask	**Balsa[2]**	
Under the Hook, Loaded with Contents	233,040	N/A
Loaded with Content, Ready for Transport	242,320	96.8
Impact Limiter Configuration	**Redwood[2]**	
NAC-STC Redwood Impact Limiters		
Top Impact Limiter[2]	8,865	203.6
Bottom Impact Limiter[2]	8,865	-10.5
Total Weight of STC-HBU Transport Cask	**Redwood[2, 4]**	
Under the Hook, Loaded with Contents	233,040	N/A
Loaded with Content, Ready for Transport	248,620	96.7

1. There are no changes to the cask body assembly for the MPC-STC-HBU contents (see Table 2.2-1 for cask body weights)
2. Balsa impact limiters or Redwood impact limiters can be used for the transport of the STC-HBU (Section 2.1.1).
3. Measured from bottom outer surface of cask body.
4. The weight of the optional shield ring is 920 lb. Therefore, the weight of the cask configuration with the shield ring remains bounded by the design transport weight of 250,000 lb.

3.3 Technical Specifications for Components

The heat rejection capability of the NAC-STC is the result of passive heat transfer within the cask and from the cask surface. Heat is transferred from the fuel assemblies to the fuel basket tubes, and through the tubes and steel support disks and aluminum heat transfer disks to the fuel basket surface, by conduction, convection and radiation. The steel support disks are considered to be the structural member, and the aluminum heat transfer disks are supported by the steel structure and were added to enhance the heat rejection capacity of the basket. Heat is transferred from the basket surface to the cavity wall, or from the basket surface to the canister wall, and then to the cavity wall, primarily by conduction and radiation. Heat is then transferred by conduction through the cask wall to the inside of the neutron shield. For the gap considered to be present between the lead and the outer shell or inner shell, radiation is also considered to be active. There are 24 explosively bonded copper/stainless steel heat transfer fins. The stainless steel portion of the fin is primarily a structural member supporting the neutron shield. The copper is explosively bonded to the steel to aid in heat transfer through the neutron shield. The solid neutron shield region that covers the majority of the length of the cask transfers the heat by conduction to the shield tank surface. Because of the presence of the impact limiters, no heat is transferred to the environment through the ends of the cask. From the radial surfaces, heat is rejected to the environment by radiation and convection. The NAC-STC heat rejection components are analyzed for normal transport conditions in Section 3.4 and for hypothetical accident conditions in Section 3.5.

3.3.1 Radiation Protection Components

Radiation protection is provided by the NAC-STC gamma and neutron shielding. The primary gamma radiation shielding components are the materials used in fabricating the multiwall body, the end forgings of the cask body, the inner lid and the outer lid. The multiwall body consists of the cast lead enclosed between the inner and outer stainless steel shells. The lead is cast in place between the cylindrical cask body shells. Neutron shielding is provided by a radial solid neutron shield and 2-inch thick disks in the bottom of the cask and the inner lid. The neutron shields are borated to suppress secondary gamma generation. The capture of neutrons by many materials produces a secondary gamma ray that must also be shielded; however, when ^{10}B absorbs a neutron, an alpha particle is emitted that is stopped locally. Thus, the secondary gamma dose rate is minimized. The radiation protection components are analyzed for normal transport conditions in Section 3.4 and for hypothetical accident event conditions in Section 3.5.

3.3.2 Safe Operating Ranges

There are four major components that must be maintained within their safe operating temperature ranges: the O-rings in the inner lid and inner lid port coverplate, the lead gamma shield, the NS-4-FR solid neutron shield, and the aluminum heat transfer disks.

The safe operating ranges for the lead gamma shield, solid neutron shield, aluminum heat transfer disks and O-rings are:

Component	Safe Operating Range
Lead gamma shield	-40°F to +600°F
Radial NS-4-FR neutron shield	-40°F to +300°F
Aluminum heat transfer disks	-40°F to +600°F
PTFE O-rings	-40°F to +735°F
Metallic O-rings	-40°F to +500°F
Viton O-rings	-40°F to +400°F

The safe operating range of the O-rings is obtained from the technical information presented in Section 4.5, and ensures that the contents are contained within the cask and are not released to the atmosphere due to thermal failure of the O-rings. As shown in the Viton O-ring technical information, a temperature of +400°F for continuous service is acceptable in the accident condition. The analyses of Sections 3.4 and 3.5 show that the temperatures of the O-rings are maintained within the safe operating range during normal transport and hypothetical accident conditions.

The safe operating range of the lead gamma shield is based on preventing the lead from reaching its melting point of 620°F (Baumeister). The cask design includes Fiberfrax 972-H Ceramic Fiber Paper to provide insulation at the corners of the lead at each end of the cask during the 10 CFR 71 hypothetical fire accident. The Fiberfrax is optional for the directly loaded NAC-STC since the fire accident analysis shows that the lead temperature is maintained in its safe operating range even without the presence of the Fiberfrax. A 0.125-inch layer of the material is located around the top and bottom corners of the lead gamma shield above and below the coverage provided by the radial neutron shield.

The maximum operating temperature limit of the NS-4-FR solid neutron shield material to ensure sufficient neutron shielding capacity was determined by the product developer to be

No heat transfer occurs between the ends of the cask and the environment due to the presence of the impact limiters. The impact limiters essentially insulate the ends of the cask from the temperatures in the environment, due to both the low thermal conductivity and the thickness of the wood in the limiter.

An optional shield ring may be bolted to the top forging of the cask to enhance radiation shielding. The shield ring is made from the same material (stainless steel) as the top forging and is machined to match the actual diameter of the cask top forging, which ensures that the shield ring is in contact with the cask top forging. Adding the shield ring is thermally equivalent to increasing the diameter of the top forging, with a slightly larger surface area for transferring heat to the ambient by convection and radiation. Therefore, the optional shield ring has an insignificant effect on the thermal performance of the cask.

3.4.1.1.2 180 Degree Section Three-Dimensional Cask Model for the Directly Loaded NAC-STC

To simulate the cask basket resting on the inner shell during transportation, a half symmetry finite element model is constructed. This model, shown in Figures 3.4-6 through 3.4-8, consisted of a 180-degree section of the cross-section with a length of 4.86 inches and containing an aluminum heat transfer disk and a steel disk. The cross-section of the basket, the multiwall body and shields in this 180-degree section, is identical to the cross-section of the quarter symmetry model described in Section 3.4.1.1.1. Whereas the three-dimensional quarter symmetry model simulated the axial heat transfer, the three-dimensional 180-degree section model ignores axial heat transfer and defines the top and bottom axial surfaces as adiabatic.

The orientation of the basket in the cask shown in Figure 3.4-8 corresponds to the orientation of the basket during transport.

To simulate contact of the basket with the inner shell, the basket model is shifted towards one side of the cavity (see Figure 3.4-8). The length of contact was centered about the plane of symmetry and extended for an angle of 45 degrees. The gap varied from zero (contact) to a maximum value of 0.13 inches at the top. In addition, the fuel assemblies are treated as resting on the fuel tubes. Material properties used in the quarter symmetry model in Section 3.4.1.1.1 are incorporated into this model.

The volumetric heat generation rate corresponded to 0.935 kilowatts per fuel assembly, which includes a peaking factor of 1.1 applied to the design value of 0.85 kilowatts per assembly. The solar insolance shown in Table 3.1-1 is applied to the surface of the model and the ambient temperature is taken to be 100°F.

The steady-state analysis of the 180-degree section model using the transport conditions provided the maximum temperatures for the following components:

aluminum heat transfer disks	inner shell	radial neutron shield
steel support disks	lead shield	maximum surface temperature
fuel tubes	outer shell	

3.4.1.1.3 Directly Loaded Fuel Assembly Model

3.4.1.1.3.1 Fuel Assembly Description

The detailed analysis of the fuel assembly is used to determine the effective conductivity of a homogenized model of a fuel assembly as well as to determine the maximum fuel rod cladding temperature.

A quarter symmetry model of the fuel assembly is constructed using ANSYS 4.4, which is shown in Figures 3.4-9 and 3.4-10. The dimensions for the rods are for the directly loaded design basis fuel (Table 5.1-2). The material properties for the fuel and cladding are listed in Tables 3.2-9 and 3.2-10. In this model, the fuel rod is treated as being homogenized. The properties for the air and helium are shown in Tables 3.2-5 and 3.2-6. The material properties account for the conductivity through the cavity gas (either air or helium). The rod to rod radiation is governed by the expression in Section 3.2.2 and modeled via radiation links (STIF31). This element, which is modeled from pin surface to pin surface, requires emissivity and a form factor. The emissivity is taken from experimental data for Zircaloy tubes. Form factor determination is accomplished via a utility (AUX12) in ANSYS, which performs a radiation view factor (form factor) calculation. The results from AUX12 are used in the steady state analysis of the model of the fuel assembly.

To simulate the fuel load, uniform volumetric heat generation is applied to the elements representing the fuel and the total heat load of the model corresponds to 0.85 kilowatts per assembly.

3.4.1.1.3.2 Determination of Effective Fuel Conductivity

A two step procedure is used to determine the effective conductivity for the fuel.

Using the fuel assembly model, a uniform temperature is applied to the exterior of the model (see Figure 3.4-9) in conjunction with the volumetric heat generation. From this analysis, the maximum temperature located at the center of the fuel assembly is determined. This is at the corner of the model, which represents the center of the entire fuel assembly.

A Sandia National Laboratory Report (SAND90-2406) defines an expression to determine the maximum temperature of a square cross-section of an isotropic homogeneous fuel with a uniform volumetric heat generation. At the boundary of this square cross-section, the temperature is constrained to be uniform. The expression for the maximum temperature is given by

$$T_c = T_e + 0.29468 \frac{Qa^2}{K_{eff}}$$

where:

T_c	=	the temperature at the center of the fuel (°F)
T_e	=	the temperature applied at the exterior of the fuel (°F)
Q	=	volumetric heat generation rate (Btu/hr-in^3)
A	=	half length of the square cross-section of the fuel (inch)
K_{eff}	=	effective thermal conductivity for the isotropic homogeneous fuel material (Btu/hr-in-°F)

Using the maximum temperature, located at the center of the fuel, from the detailed fuel assembly model, the above expression is used to determine the K_{eff} for an isotropic homogeneous representation of the fuel assembly. The conductivities calculated were 0.05 BTU/hr-in-°F for helium and 0.03 BTU/hr-in-°F in air at a temperature of 600°F. The constant values are used in both the quarter model (Section 3.4.1.1.1) and the 180-degree section model (Section 3.4.1.1.2) for the fuel assembly.

Two analyses and K_{eff} determinations are performed; a K_{eff} corresponding to air in the cavity in which the fuel assembly model used air and a K_{eff} for helium in the cavity in which the fuel assembly model used helium as the cavity gas.

3.4.1.1.3.3 Determination of Maximum Fuel Clad Temperature

Two models are needed to determine the cask maximum fuel rod cladding temperature. The two models are:

1. 180-degree section model of the cask body - ANSYS, 3-D Model (Section 3.4.1.1.2)
2. Detailed two-dimensional model of the fuel assembly.

The three-dimensional ANSYS model from Section 3.4.1.1.2 is used to determine the maximum fuel tube temperature, which is applied to the exterior of the fuel assembly model. Since the cavity gas can be air or helium, two separate analyses are performed. For the case of the air in the cavity, the maximum fuel tube temperature from the transport condition using air in the cavity is used as the exterior boundary condition for the fuel assembly model. The fuel assembly model used the same material properties as the three-dimensional model with air in the cavity. For the helium in the cavity, the analyses are repeated but using the properties for helium in the cavity for both models.

3.4.1.2 Analytical Models for the Yankee-MPC

The thermal analysis for the canistered Yankee Class design basis fuel uses three finite element ANSYS models. A three-dimensional model ("three-dimensional canister model") is employed to evaluate the cask in a horizontal position with the canister basket in contact with the canister which is, in turn, in contact with the cask inner shell. The model is comprised of the fuel assemblies, including damaged fuel, fuel tubes, stainless steel support disks, aluminum heat transfer disks, the canister shell, lids and bottom plate, the aluminum honeycomb spacers at the top and bottom of the canister, the NAC-STC inner shell, lead, outer shell, neutron shield and neutron shield shell. The fuel regions and the fuel tubes with BORAL neutron absorber sheets in the three-dimensional model are modeled using effective conductivities. (BORAL is used in the thermal analysis since BORAL has a lower effective conductivity than TalBor and, therefore, bounds TalBor.) The effective conductivity of the fuel is determined by a second model ("fuel model"), which is a detailed two-dimensional thermal model of the fuel assembly. The model includes the fuel pellets, cladding and gas (considered to be helium) occupying the gap between the fuel pellets and cladding. A third model ("fuel tube model") is used to determine the effective conductivities of the tube wall and BORAL neutron absorber sheet. These models are described in Sections 3.4.1.2.1 through 3.4.1.2.3.

The thermal analysis for the damaged fuel is performed using the three-dimensional model described in Section 3.4.1.2.1 with modifications to the fuel distribution in the fuel assemblies at the four corners as described in Section 3.4.2.3. The Reconfigured Fuel Assembly analysis uses the two-dimensional reconfigured fuel model. The model is described in Section 3.4.1.2.4. A classical thermal analysis is performed for the Greater Than Class C waste canister using a thermal resistor model, as described in Section 3.4.1.2.5.

3.4.1.2.1 Three-Dimensional Cask and Canister Model for the Yankee-MPC Configuration

The 3-D Yankee-MPC canister model is a half symmetry finite element model constructed using ANSYS Version 5.2. The model considers the fuel assemblies, fuel tubes, stainless steel support disks, aluminum heat transfer disks, the canister shell, lids and bottom plate, the aluminum honeycomb spacers at the top and bottom of the canister, the NAC-STC inner shell, lead, outer shell, neutron shield and neutron shield shell. The model is shown in Figure 3.4-20. The top and bottom portions of the NAC-STC (lid, top forging, bottom plate and bottom forging) are not included in the model because these components are enclosed by the impact limiters and essentially no heat is rejected through these components (both ends of the model are considered adiabatic).

As shown in Figure 3.4-20, the internal cavity of the canister contains the active fuel region. No conduction elements are defined outside of this region. The top and bottom fittings of the fuel assemblies, fuel tubes enclosing the top and bottom fittings, the first stainless steel support disk (counted from top end) and the top and bottom weldments are not included in the model and conduction through these components is conservatively ignored.

Gas inside the canister is modeled as helium. Gas inside the NAC-STC cavity is also considered to be helium, since the cavity will be back-filled with helium just before transport. Conduction and radiation are modeled using ANSYS "SOLID70" and "LINK31" elements, respectively. The principal gaps as shown in Figure 3.1-2 and the gaps described in Section 3.2.2.6 are applied to the model. These gaps are conservatively established and consider the differential thermal expansion between the components.

Since the canister is in the horizontal position during transport, the elements for the canister shell are shifted downwards to simulate a contact with the inner shell of the NAC-STC. Similarly, the support disks and the heat transfer disks are shifted downward to simulate a contact with the canister shell. As shown in Figure 3.1-2, a 2-degree of arc contact is conservatively considered for the gaps between the canister shell and the NAC-STC inner shell, and between the support disk and the canister shell. At the 2-degree contact region in the model, an element 0.005-inch thick (in the radial direction) is modeled between the elements of the canister shell and cask inner shell, and between the elements for the support disk and canister shell. To simulate the contact condition, a conductivity of 100 Btu/hr-in-°F is assumed for the element. The value of conductivity used has a negligible effect on the thermal analysis results, since the thermal resistance across the element is negligible compared to the thermal resistance of the canister shell or the cask inner shell because the thickness of the element is only 0.005 inch. The aluminum heat transfer disks are assumed to have only a line contact with the canister shell since the heat transfer disks are not subjected to any loads other than their self-weight.

Gaps within the model are adjusted to account for differential expansion based on thermal and defined physical contact conditions. Solar insolance and ambient temperature conditions are applied to the neutron shield shell when appropriate. Heat flux due to solar insolance is as calculated in Section 3.4.1.1.1. The model is analyzed to determine the maximum temperatures for the fuel cladding, the basket, canister, cask shells, radial shielding and surface conditions. All material properties are shown in Tables 3.2-1 through 3.2-11.

The fuel regions (inside tubes) are modeled as homogenous regions with effective conductivities, determined by the 2-D Fuel Model as described in Section 3.4.1.2.2. The center slot of the basket contains is modeled as helium since it contains no fuel. The fuel assembly tube and the neutron absorber sheet, including helium gaps on both sides of the neutron absorber sheet and the gap between the stainless steel cladding for the neutron absorber and disk are modeled as one element thick with effective conductivities, as established using the 2-D Tube Model shown in Section 3.4.1.2.3. Conductivity for the aluminum honeycomb spacers is calculated to be 0.24 Btu/hr-in-°F (Hexcel) through the spacer from the canister to the ends of the NAC-STC, but is conservatively considered to be that of helium across the spacer parallel to the ends of the canister.

The neutron shield of the NAC-STC, consisting of NS-4-FR, steel and copper fins, is also modeled with effective conductivities. The radial conductivity (0.339 Btu/hr-in-°F) is obtained from Section 3.4.1.1.1.3. The effective conductivity in the cask longitudinal direction is 0.403 Btu/hr-in-°F, calculated based on area ratio. Conductivity of the neutron shield material, NS-4-FR (0.031 Btu/hr-in-°F) is used as the conductivity in the circumferential direction.

In the model, radiation heat transfer is considered from the top of the fuel region to the bottom surface of the canister lid, from the bottom of the fuel region to the top surface of the canister bottom plate, and from exterior surfaces of the fuel tubes to the inner surface of the canister shell.

This radiation is modeled using LINK31 radiation elements. Radiation across gaps in the model described in Section 3.2.2.6 are accounted for using the effective conductivities for the gas in the gap using the method described in Section 3.2.2.3.

Radiation at the neutron shield shell surface to ambient is combined with the convection effect using the method described in Section 3.2.2.2. The convection heat transfer coefficient is calculated based on the formula as shown in Section 3.2.3.1. Effective emissivities are used for all radiation calculations, with the form factor taken to be unity. Effective emissivity is computed using the following formula (Kreith) based on corresponding material emissivities:

$$\epsilon_{eff} = 1 / (1/\epsilon_1 + 1/\epsilon_2 - 1)$$

Radiation between the exterior surfaces of the fuel assembly tubes and the radiation between the stainless steel support disk and the aluminum heat transfer disk are conservatively ignored in this model.

Solar insolance is applied to the neutron shield shell surface for the "Heat" case (Ambient temperature = 100°F) in accordance with 10 CFR 71. Heat flux equal to 0.150 Btu/hr-in^2 is used at the neutron shield shell surface based on the 1,475 Btu/hr-ft^2 heat flux for a curved surface over a 12 hour period (Section 3.4.1.1.1).

Volumetric heat generation (Btu/hr-in^3) is applied to the active fuel region based on a total heat load of 12.5 kW, an active fuel length of 91 inches and an axial power as shown in Figure 3.4-21. The axial power distribution curve is discussed in Section 5.2.3.

3.4.1.2.2 Two-Dimensional Fuel Model for the Yankee-MPC Configuration

The effective conductivity of the fuel is determined by a second model, which is a detailed two-dimensional thermal model of the fuel assembly. The model includes the fuel pellets, cladding, gas between fuel rods and gas (considered to be helium) occupying the gap between the fuel pellets and cladding. Modes of heat transfer modeled include conduction and radiation between individual fuel rods for the steady state condition. The model is shown in Figure 3.4-22.

ANSYS PLANE55 conduction elements and LINK31 radiation elements are used in the model, which includes a total of 240 fuel rods. Each fuel rod consists of the pellet, Zircaloy cladding, and a gap between the pellet and clad. The gas in the gap between the pellet and clad, as well as the gas between fuel rods, is considered to be helium. Radiation elements are defined between rods and from rods to the boundary of the model (inside surface of fuel tube). Radiation effect at the gaps between the pellet and clad is conservatively ignored. Effective emissivities are determined using the formula shown in Section 3.4.1.2.1.

The effective conductivity for the fuel is determined using the method described in Section 3.4.1.1.3.2. Volumetric heat generation (Btu/hr-in^3) based on the design heat load of 12.5 kW is applied to the pellets. The temperature at the boundary of the model is constrained to be uniform. The effective conductivity is determined based on the heat generated and the temperature difference between the center and the edge of the model. The temperature-dependent effective properties as shown below are established by using different boundary temperatures. The effective conductivity in the axial direction of the fuel assembly is calculated based on the material area ratio.

Temperature (°F)	k_{xx}	k_{yy}	k_{zz}
125	0.0171	0.0171	0.169
321	0.0208	0.0208	0.156
517	0.0267	0.0267	0.145
713	0.0335	0.0335	0.142
911	0.0409	0.0409	0.144

Where the x and y axes are in the plane of the model, z is in the cask axial direction and the temperature associated with each row of properties is the average temperature of the fuel assembly determined by each analysis.

3.4.1.2.3 Two-Dimensional Fuel Tube Model for the Yankee-MPC

The purpose of the two dimensional fuel tube model is to determine the effective conductivity of the fuel tube and neutron absorber plate, which is used in the three-dimensional canister model. As shown in Figure 3.4-23, this model includes the fuel tube, a neutron absorber sheet (including the core matrix sandwiched by aluminum claddings as the bounding heat transfer case for a neutron absorber material), helium gaps on both sides of the neutron absorber sheet and helium gap between the stainless steel cladding for neutron absorber sheet and the support disk or heat transfer disk.

ANSYS PLANE55 conduction elements and LINK31 radiation elements are used to construct the model. The model consists of eight layers of conduction elements and six radiation elements that are defined at the helium gaps (two per gap). The thickness of the model (x-direction) is the distance measured from the inside dimension of the fuel tube to the inside dimension of the slot in the support disk (assuming the fuel tube is located at the center of the disk slot). The tolerance of the neutron absorber sheet thickness, 0.003 inch, is used as gap size for both sides of the neutron absorber sheet. The height of the model is defined as the same dimension as the thickness of the model.

Heat flux is applied at the left side of the model and the temperature at the right boundary of the model is constrained. The heat flux is determined based on the design heat load of 12.5 kW. The maximum temperature of the model (at left boundary) and the temperature difference (ΔT) across the model are calculated by ANSYS. The effective conductivity is determined using the following formula:

$$q = k\ (A/L)\ \Delta T$$

or

$$k = q\ L\ /\ A\ \Delta T$$

where:

q = heat rate (Btu/hr)
A = area (in^2)
L = length of model (in)
ΔT = Temperature difference across the model (°F)
k = effective conductivity (Btu/hr-in-°F)

The temperature-dependent conductivity (k) is determined by varying the temperature constraints at one boundary of the model and re-solving for the heat rate (q) and temperature difference. The effective conductivity for the parallel path is calculated based on area ratio of material.

3.4.1.2.4 Two-Dimensional Yankee Reconfigured Fuel Assembly Model

The two-dimensional Reconfigured Fuel Assembly model is generated to calculate the temperature distribution of the hottest cross-section (1-inch long in the cask axial direction) of the Reconfigured Fuel Assembly. Because of symmetry, the model considers one-fourth of a cross-section. The model is shown in Figure 3.4-24. ANSYS 'PLANE55' conduction elements and "LINK31" radiation elements are used in the model. The model includes a total of 16 fuel rods, 16 fuel tubes, the shell casing (the square tube with the same external dimensions as an intact fuel assembly) and the cover gas (considered to be helium). Each fuel rod is located inside a stainless steel fuel tube. The fuel rod, which consists of the Zircaloy clad, the fuel pellet (UO_2) and a small gap between the clad and fuel pellet, is modeled as a solid rod with the thermal conductivity of the UO_2. This is conservative, since the conductivity of UO_2 is less than that of the Zircaloy and the main interest of the fuel rod is the cladding temperature. The gas between the fuel rod and the fuel tube, the gas between fuel tubes and the gas outside of the shell casing are considered to be helium.

As shown in Figure 3.4-24, radiation elements are defined between tubes and from tubes to the inner surface of the shell casing. A form factor of 1 is used for the radiation elements. Effective emissivity is computed using the following formula (Keith) based on corresponding material emissivities:

$$\in_{eff} = 1/\,(1/\in_1 + 1/\in_2 - 1)$$

where $\in_1$ & $\in_2$ are the emissivities of two parallel plates

Radiation between the fuel rod and the fuel tube is conservatively ignored. Radiation between the shell casing and the inner surface of the fuel assembly tube is accounted by establishing effective conductivities for the gas in the gap using the method described in Section 3.2.2.3.

Volumetric heat generation (Btu/hr-in^3) based on the design heat load of 0.0016 kW/rod is applied to the fuel rod elements. An active fuel length of 91 inches and a peaking factor of 1.15 are used.

Heat generation rate $= Q / V$
$= 0.6595$ Btu/hr-in^3

where:

$Q =$ heat rate per rod (unit height)
$= (0.0016)\,(3413)\,(1.15)\,/(91) = 0.069$ Btu/hr
$V =$ volume of rod (unit height)
$= \pi\, 0.365^2\,/4 = 0.1046$ inch^3

Boundaries of the model at planes of symmetry (at X=0 and at Y=0) are considered to be adiabatic. The temperature at the right and top boundaries (at X=3.9 inch and at Y=3.9 inch) of the model is constrained to be uniform based on the maximum calculated temperatures of the fuel assembly tube for the design basis Yankee Class fuel assembly. This is conservative, since the heat load for the Reconfigured Fuel Assembly (0.102 kW) is less than one-third of the heat load for the design basis fuel (0.347 kW).

3.8.3 Technical Specifications for Components – the STC-HBU

The bounding major components of the STC-HBU basket that must be maintained within its safe operating temperature range during transport in the NAC-STC are the aluminum heat transfer disk and the aluminum shunt in the fuel basket.

The heat rejection capability of the STC-HBU is the result of passive heat transfer within the cask and from the cask surface. Heat is transferred from the fuel assemblies through the gap between the fuel and fuel tube to the fuel tubes, and through the tubes to steel support disks and aluminum heat transfer disks, then to the fuel basket surface, by conduction and radiation. Aluminum shunts also transfer heat out of the basket in both cask radial and axial directions. The steel support disks are considered to be the structural member, and the aluminum heat transfer disks are supported by the steel structure and enhance the heat rejection capacity of the basket. Heat is transferred from the basket surface to the cask inner shell, primarily by conduction and radiation. Heat is then transferred by conduction through the cask wall to the inside of the neutron shield. For the gap considered to be present between the lead and the outer shell, radiation is also considered to be active. There are 24 full-length, explosively bonded copper/stainless steel heat transfer fins in the neutron shield region. The stainless steel portion of the fin is primarily a structural member supporting the neutron shield. The copper is explosively bonded to the steel to aid in heat transfer through the neutron shield. The solid neutron shield region that covers the majority of the length of the cask transfers the heat by conduction to the neutron shield shell surface. Because of the presence of the impact limiters, no heat is assumed to be transferred to the environment through the ends of the cask. From the radial surfaces, heat is rejected to the environment by radiation and convection. The STC-HBU heat rejection components are analyzed for normal transport conditions in Section 3.8.4 and for hypothetical accident conditions in Section 3.8.5.

3.8.3.1 Radiation Protection Components

Radiation protection is provided by the STC-HBU gamma and neutron shielding. The primary gamma radiation shielding components are the materials used in fabricating the multiwall body, the end forgings of the cask body, the inner lid and the outer lid. The multiwall body consists of the cast lead enclosed between the inner and outer stainless steel shells. Neutron shielding is provided by a radial solid neutron shield and the disks in the bottom of the cask and in the inner lid. The neutron shields are borated to suppress secondary gamma generation. The capture of neutrons by many materials produces a secondary gamma ray that must also be shielded; however, when ^{10}B absorbs a neutron, an alpha particle is emitted that is stopped locally. Thus, the secondary gamma dose rate is minimized.

3.8.3.2 Safe Operating Ranges

There are five major components that must be maintained within their safe operating temperature ranges: the O-rings in the inner lid and inner lid port coverplate, the lead gamma shield, the NS-4-FR solid neutron shield, aluminum shunts, and the aluminum heat transfer disks.

The safe operating ranges for the lead gamma shield, solid neutron shield, aluminum shunts, aluminum heat transfer disks and O-rings are:

Component	Safe Operating Range
Lead gamma shield	-40°F to +600°F
Radial NS-4-FR neutron shield	-40°F to +300°F
Aluminum heat transfer disks	-40°F to +600°F
Aluminum shunts	-40°F to +600°F
PTFE O-rings	-40°F to +735°F
Metallic O-rings	-40°F to +500°F
Viton O-rings	-40°F to +400°F

The safe operating range of the O-rings is obtained from the technical information presented in Section 4.5, and ensures that the contents are contained within the cask and are not released to the atmosphere due to thermal failure of the O-rings. As shown in the Viton O-ring technical information in Section 4.5.5, a temperature of +400°F for continuous service is acceptable in the accident condition. The analyses in Sections 3.8.4 and 3.8.5 show that the temperatures of the O-rings are maintained within the safe operating range during normal transport and hypothetical accident conditions.

The safe operating range of the lead gamma shield is based on preventing the lead from reaching its melting point of 620°F (Baumeister). The cask design includes Fiberfrax 972-H Ceramic Fiber Paper to provide insulation at the corners of the lead at each end of the cask during the 10 CFR 71 hypothetical fire accident. The Fiberfrax is optional since the fire accident analysis in Section 3.8.5 shows that the lead temperature is maintained in its safe operating range.

Solar insolance and ambient temperature conditions are applied to the neutron shield shell for the analyses with ambient temperature of 100°F and no solar insolance is applied for the analyses with ambient temperature of -40°F. Heat flux due to solar insolance is as calculated in Section 3.4.1.2.1 and is applied by a distribution of cosine function. The model is analyzed to determine the maximum temperatures for the fuel cladding, the basket, cask shells, radial shielding and surface conditions. All material properties are shown in Tables 3.2-1 through 3.2-10 and Table 3.8-2.

As shown in Figure 3.8-1, the aluminum shunts fill the slots where fuel assemblies are not presented for Configurations A, B and C. The one-inch thick aluminum shunt is made of Aluminum 6061. The stainless steel tube inside the aluminum shunt is conservatively modeled as helium and the void inside the stainless steel tube is also modeled as helium. The fuel regions (inside tubes) are modeled as homogenous regions with effective conductivities, determined by the two-dimensional fuel model as described in Section 3.8.4.1.1.2. The fuel tubes are modeled as homogeneous regions with effective conductivities, as established using the two-dimensional tube model shown in Section 3.8.4.1.1.3. The gap between the basket top and the inner surface of the cask lid is modeled as helium with radiation. The gap between the basket bottom and the inner surface of the cask bottom plate is also modeled as helium with radiation.

The radial neutron shield of the NAC-STC cask, consisting of NS-4-FR, steel and copper fins, is also modeled with effective conductivities. The radial conductivity (0.39 Btu/hr-in-°F) is computed in Section 3.4.1.1.1.3. The effective conductivity in the cask longitudinal direction is 0.403 Btu/hr-in-°F, calculated based on area ratio. Conductivity of the neutron shield material, NS-4-FR (0.031 Btu/hr-in-°F), is used as the conductivity in the circumferential direction of the cask radial neutron shield. The conductivity of the neutron shield material, NS-4-FR (0.031 Btu/hr-in-°F), is used for the cask top and bottom neutron shield disks.

Radiation across gaps in the model listed in Table 3.8-3 is accounted for using the effective conductivities for the gas in the gap using the method described in Section 3.2.2.3. The radiation from the tube surface to the inner surface of the cask inner shell is computed by ANSYS radiation link elements (LINK31).

Radiation at the neutron shield shell surface to ambient is combined with the convection effect using the method described in Section 3.2.2.2. The convection heat transfer coefficient is calculated based on the formula as shown in Section 3.2.3.1. Effective emissivities are used for all radiation calculations, with the form factor taken to be unity. Effective emissivity is computed using the following formula (Kreith) based on corresponding material emissivities:

$$\epsilon_{eff} = 1 / (1/\epsilon_1 + 1/\epsilon_2 - 1)$$

Solar insolance is applied by a cosine function to the neutron shield shell surface for the "Hot" case (ambient temperature = 100°F) in accordance with 10 CFR 71. The peak heat flux equal to 0.15 Btu/hr-in^2 used at the neutron shield shell surface is based on the 1,475 Btu/hr-ft^2 heat flux for a curved surface over a 12-hour period (Section 3.4.1.2.1).

[redacted]
region of the fuels based on the heat load, an active fuel length of 144 inches, and an axial power distribution as shown in Figure 3.8-4. The axial power distribution curve is discussed in Section 5.2.1.3.

As discussed in Section 3.4.1.1.1.4, the optional shield ring bolted to the cask top forging has an insignificant effect on the thermal performance of the cask.

3.8.4.1.1.2 Two-Dimensional Fuel Model for the STC-HBU

The effective conductivity of the fuel is determined by the second model, which is a detailed two-dimensional thermal model of the fuel assembly. A quarter symmetry of the fuel (PWR 17×17) is modeled due to the symmetry of geometry and the heat load. The model includes the fuel pellets, cladding, gas between fuel rods and gas (considered to be helium) occupying the gap between the fuel pellets and cladding. Modes of heat transfer modeled include conduction and radiation between individual fuel rods for the steady state condition. The model is shown in Figure 3.8-5.

ANSYS PLANE55 conduction elements and LINK31 radiation elements are used in the model. The fuel assembly of PWR 17×17 pin arrays is analyzed. Each fuel rod consists of the pellet, cladding, and a gap between the pellet and clad. The gas in the gap between the pellet and clad, as well as the gas between fuel rods, is considered to be helium. ANSYS radiation elements (LINK31) are defined between fuel rods. Radiation across the gap between the pellet and clad is conservatively ignored. The effective conductivity for the fuel is determined using the method

[redacted]

applied to the pellets. The temperature at the boundary of the fuel assembly model is constrained to be uniform. The effective conductivity is determined based on the heat generated and the temperature difference between the center and the edge of the model. The temperature-dependent effective properties that follow are established by using different boundary temperatures. The effective conductivity in the axial direction of the fuel assembly is calculated based on the material area ratio.

Temperature (°F)	**k_x (Btu/hr-in-°F)**	**k_y (Btu/hr-in-°F)**	**k_z (Btu/hr-in-°F)**
3	0.0207	0.0207	0.1393
146	0.0239	0.0239	0.1379
288	0.0294	0.0294	0.1326
431	0.0355	0.0355	0.1259
576	0.0425	0.0425	0.1235
721	0.0506	0.0506	0.1248

Where the x and y axes in the above Table are perpendicular to the cask axis and define the plane of the model. The z axes are parallel to the cask axial direction. The temperature associated with each row of properties is the average temperature of the fuel assembly determined by each analysis.

3.8.4.1.1.3 Two-Dimensional Fuel Tube Model for the STC-HBU

The purpose of the two-dimensional fuel tube model is to determine the effective thermal property of the fuel tube, which is used in the three-dimensional transport cask and the basket model.

The model of the fuel tube with neutron absorber is shown in Figure 3.8-6. This model has five layers, which includes the fuel tubing, the neutron absorber, media gaps on both sides of the neutron absorber, and the stainless steel retainer. The media is considered as helium for the model.

Modes of heat transfer modeled include conduction and radiation. Convection is conservatively neglected. ANSYS PLANE55 conduction elements and LINK31 radiation elements are used to construct the model. The model consists of layers of conduction elements and radiation elements that are defined at the helium gaps (two for each gap). The thickness of the model is the distance measured from the inside face of the fuel tubing to the outer surface of the stainless steel retainer. The height of the model is defined as equal to the width of the model.

[redacted] temperature at the right boundary of the model is constrained. The maximum temperature of the model (at the left boundary) and the temperature difference (ΔT) across the model are calculated by ANSYS. The effective conductivities for the fuel tube are determined using the same methodology described in Section 3.4.1.2.3.

3.8.4.1.1.4 Test Model

NAC International did not create a thermal test model. The methods previously described have been used in previous transport licensing and are sufficient to show that the STC-HBU meets the criteria set forth in Section 3.8.4.

3.8.4.2 Maximum Temperatures

This section presents the maximum component temperatures for the STC-HBU. Temperatures are calculated using the model described in Section 3.8.4.1.1.

Using the thermal model described in Section 3.8.4.1.1, temperatures for the major components of the cask body, basket, and fuel cladding are determined for the normal conditions of transport. The STC-HBU cask body maximum allowable component temperatures are shown in Section 3.8.3.2. The maximum temperatures of the major STC-HBU components, the basket components, and fuel rod cladding temperatures, are shown in Tables 3.8-4 and 3.8-5.

[redacted]

3.8.5 Hypothetical Accident Thermal Evaluation – the STC-HBU

The objective of the thermal analysis of the STC-HBU under hypothetical accident conditions is to demonstrate that the cask containment boundary structural components are maintained within their safe operating temperature ranges.

The cask body and the basket design used for the STC-HBU are identical to the cask body and basket for the directly loaded fuel. The heat transfer performance of the cask body and the basket support disks and aluminum heat transfer disk for both configurations would also be the same. The manner in which the fire accident heat is infused into the basket for both designs is therefore the same also. Due to this similarity, the component temperature increase due to the fire for the components of directly loaded fuel heat load of 22.1 kW is used to determine the component temperature increase of the STC-HBU for the fire condition. The fire condition temperature increase (ΔT) for the components of directly loaded fuel heat load of 22.1 kW is obtained based on the analysis results from Table 3.4-1 and Table 3.5-1. The temperature increase of the aluminum disk is used as the temperature increase for the aluminum shunt. By adding this temperature increase (ΔT) to the maximum temperature of the corresponding component for the STC-HBU (from Table 3.8-4), the maximum component temperatures due to the fire for the STC-HBU are obtained and are listed in Table 3.8-6. Note that this method is conservative since it ignores the thermal inertia of the loaded basket. To determine the lead temperature for the cask configuration without the Fiberfrax, a transient analysis is performed using a three-dimensional finite element model for the loaded NAC-STC cask. The model is constructed using the same modeling methodology as the three-dimensional finite model described in Section 3.8.4.1.1.1 for the normal condition of transport. The initial condition of the analysis corresponds to the steady analysis for normal condition with the maximum temperatures shown in Table 3.8-4. The transient analysis is performed for 30 minutes for the fire condition (1475°F) followed by 64-hour cool-down period. The maximum lead and O-ring temperatures for the cask without Fiberfrax are also provided in Table 3.8-6.

The analysis results of the STC-HBU under hypothetical accident conditions demonstrate that the cask containment boundary structural components are maintained within their safe operating temperature ranges.

Table 3.8-6 Maximum Temperature of the STC-HBU – Hypothetical Fire Accident Condition

	Max. Temperature (°F)	Allowable Temperature (°F)*
Inner Lid Bolts	402	-
Inner Lid and Port Cover Plate O-rings (Viton)**	387**	400**
Cask Radial Outer Surface	1368	-
Radial Neutron Shield	-	-
Lead Gamma Shield	503***	600
Aluminum Disk Interior	695	800
Support Disk Interior	721	800
Aluminum Shunt	644	800
Fuel Rod Cladding, Directly Loaded Fuel	823	1,058
Cask Cavity Gas (Average)	744	-

Notes:

* Allowable temperatures for fire accident condition are taken from Table 3.5-1.

** The stated allowable temperature of 400°F for the Viton seal is for a steady state condition. For the cask configuration without the Fiberfrax, the maximum inner lid O-ring temperature will be above 400°F for less than 1.5 hours with a maximum temperature of 418°F. This is acceptable based on manufacturer test data including a 70-hour dry heat resistance test at a temperature above 500°F.

*** For the cask configuration without the Fiberfrax, the maximum lead temperature is 556°F, which remains below the allowable temperature of 600°F.

Test Model

NAC International did not create a thermal test model. The methods previously described have been used in prior transport licensing and are sufficient to show that the STC-HBU meets the criteria set forth in Section 3.5.

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5.0 SHIELDING EVALUATION

The NAC-STC uses an optimized multiwall design to provide the most efficient shielding arrangement possible, and to comply with 10 CFR 71 limits. This chapter provides a description of the NAC-STC shield design, design basis contents for the shielding evaluation, and the conservative shielding analyses used to determine the transport dose rates.

The shielding evaluation of the NAC-STC for transport of the MPC-LACBWR canister is presented in Section 5.6 of this SAR.

The NAC-STC is designed to safely transport spent fuel assemblies in two configurations: directly loaded and canistered. In the directly loaded configuration, standard PWR fuel assemblies are placed directly into a fuel basket installed in the cask cavity. In the canistered configuration, a sealed transportable storage canister loaded with fuel assemblies is placed in an empty cask cavity with top and bottom spacers. In the directly loaded configuration, the NAC-STC can transport up to 26 standard PWR fuel assemblies. In the canistered configuration, the NAC-STC can transport up to 36 Yankee Class fuel assemblies in the Yankee-MPC configuration or up to 26 Connecticut Yankee fuel assemblies in the CY-MPC configuration.

For directly loaded fuel, the shielding evaluation considers reference fuel assemblies in 14×14, 15×15, 16×16 and 17×17 array sizes. The reference fuel assemblies have parameters selected from all of the fuel assemblies of the same array size to maximize the shielding source terms. The design basis fuel for the canistered configuration is the Yankee Class, Combustion Engineering, Type A, 16×16 PWR fuel assembly.

The NAC-STC can also safely transport Greater Than Class C (GTCC) waste in a canistered configuration. The Yankee Class GTCC waste consists primarily of activated steel sections or components, but may also include Zircaloy items. Core baffle sections and dross material are placed in a fuel assembly-sized container, as shown in Figure 5.1-4. Some stainless steel and Zircaloy items may be loaded directly into an interior GTCC loading position. The Connecticut Yankee GTCC waste, also consisting of activated steel, is also placed in a fuel assembly-sized can. The Yankee-MPC and CY-MPC GTCC canisters have 24 loading positions for GTCC waste.

The NAC-STC is assigned a nominal Transport Index of 47 (TI = 47) based on the requirement of 10 CFR 71.4 and the analysis results presented in Section 5.8.6. The maximum dose rate at 1 meter from the NAC-STC in normal conditions of transport is 46.3 mrem per hour, based on the directly loaded high burnup fuel. The actual measured dose rate is expected to be less.

The shielding evaluation for directly loaded fuel, canistered fuel and GTCC waste demonstrates compliance with 10 CFR 71 limits. The dose rates for both the canistered Yankee Class fuel and GTCC waste, and Connecticut Yankee Class fuel and GTCC waste, are shown to be significantly less than those for the directly loaded fuel configuration for both normal and accident conditions.

The shielding evaluation of the directly loaded configuration is performed using the SAS2H sequence (Hermann, 1995) of the SCALE-4.3 package for the PC (ORNL, 1995). This sequence uses the computer code ORIGEN-S (Hermann, 1989) to calculate the source terms. The MCBEND (AEA Technology, 2000) computer code is used to calculate the cask dose rates for normal transport and hypothetical accident conditions. The shielding analyses show that the dose rates are below regulatory limits.

The shielding evaluation of the Yankee Class canistered fuel and GTCC waste is performed using SCALE 4.3 for the PC (ORNL, 1995). This code uses SAS2H (Herman, 1995) to calculate source terms. One-dimensional shielding evaluations were performed using SAS1 (Knight, 1995). The shielding analyses show that the dose rates are well below the regulatory limits stated in 10 CFR 71 and are well below the dose rates reported for the design basis directly loaded fuel.

The shielding evaluation of the Connecticut Yankee canistered fuel and GTCC waste is performed using the MCBEND Monte Carlo transport code. Fuel source terms are developed using the SCALE isotopics sequence SAS2H (Herman, 1995).

Directly Loaded Fuel

The directly loaded basket construction is based on a tube and disk design. PWR fuel is loaded into 26 fuel tubes fabricated from Type 304 stainless steel sheets. BORAL or TalBor neutron absorber is encased in stainless steel on the outside face of the fuel tube. Twenty 5/8-inch thick aluminum disks are spaced between thirty-three 1/2-inch thick Type 17-4 PH stainless steel support disks to provide heat transfer. Radial shielding of PWR fuel in the directly loaded basket is provided by the multi-wall design of the NAC-STC cask body. Axial shielding is provided by the cask body closure lids and end forgings and the impact limiters.

5.8 Shielding Evaluation – Directly Loaded STC-HBU Evaluation

This section provides the shielding evaluation of the directly loaded NAC-STC with high burnup fuel (STC-HBU) contents. [redacted] The design basis spent fuel for the STC-HBU is 17×17 PWR fuel. The total cask heat load is limited to 24 kW/cask for the partially loaded transport cask. Shielded thermal shunts are loaded into the empty basket cells. The analysis of the high burnup fuel (HBU) is performed using the SAS2H module of the SCALE package for source terms and MCNP for shielding.

The STC-HBU is assigned a nominal Transport Index of 47 (TI = 47) based on the analysis results presented in Section 5.8.6. The maximum dose rate at 1 meter from the STC-HBU in normal conditions of transport is 46.3 mrem/hour. The actual measured dose rate is expected to be less.

For all burnups, enrichments, and cool times combinations allowed, the maximum cask heat load does not exceed 24 kW, the maximum surface dose rate does not exceed 1,000 mrem/hr, the maximum 2m from vehicle side dose rate does not exceed 10 mrem/hr, and the maximum accident condition dose rate at 1m from the cask does not exceed 1,000 mrem/hr.

While the personnel barrier is a requirement for the NAC-STC, and therefore meets the 1000 mrem/hr surface dose rate limit specified in NUREG-1609 Table 5.2, additional minimum cool time/dose rates analysis is performed to address a 200 mrem/hr cask surface dose limit. A 200 mrem/hr limit would be applicable to an exclusive use open (flat-bed) transport configuration without crediting the personnel barrier. The 200 mrem/hr surface dose rate limits are the result of an increase in cool time and/or reduced fuel hardware cobalt content per Section 5.8.7 or the optional use of a shield ring on the top forging as evaluated in Section 5.8.8.

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5.8.1 Discussion and Results – STC with HBU

The radiation protection provided by the NAC-STC is in the form of solid multi-walled shielding materials, which totally surround the fuel. These shielding materials include steel and lead for gamma shielding and a borated polymer (NS-4-FR) for neutron shielding. The multiwalled arrangement of steel and lead in the NAC-STC provides optimal weight for gamma attenuation. The NS-4-FR neutron shielding material has a hydrogen density close to that of water and serves to moderate fast neutrons which are then captured in the boron. Boron capture in the neutron shield minimizes the contribution of secondary capture gammas to surface dose rates.

The NAC-STC uses a multiwalled arrangement for both radial and axial shields. The arrangement of the radial gamma shielding in the cask body is a 1.5-inch thick stainless steel inner shell and a 2.65-inch thick stainless steel outer shell with a 3.70-inch thick lead filled annulus between them. The radial neutron shield is arranged around the outer steel shell with a 5.5-inch thick NS-4-FR layer, which is covered by a 0.25-inch (6 mm) thick neutron shield shell. The bottom of the cask contains a steel/NS-4-FR/steel shield arrangement with the two stainless steel components providing 11.65 inches of gamma shielding and 2 inches of NS-4-FR neutron shielding. The top of the cask has shields in the form of two closure lids. The inner lid also has a steel/NS-4-FR/steel arrangement with 6.0 inches of steel below 2 inches of NS-4-FR and 1.0 inch of steel above it. The outer lid is a 5.25-inch thick steel disk.

5.8.1.1 Design Criteria

The shielding design criteria for the NAC-STC meet the requirements of 10 CFR 71. For normal conditions, the dose rate limits specified in 10 CFR 71.47 for consignments under exclusive use are: 1,000 mrem/hour on the surface of the enclosed package, 200 mrem/hour on the outer surfaces of transport vehicle and 10 mrem/hour at 2 meters from the vertical planes represented by the outer lateral surfaces of the transport vehicle. Under hypothetical accident conditions, 10 CFR 71.51 specifies a dose rate limit of 1,000 mrem/hour at 1 meter from the surface of the cask. This criterion has also been met at all locations.

The vehicle surface is defined as the personnel barrier that will be on the same plane as the outer radial surface of the impact limiters. The personnel barrier will attach to the edge of the vehicle between the impact limiters. The personnel barrier location is shown in NAC License Drawing 423-901.

5.8.1.2 Design Basis Fuel

The NAC-STC can transport up to 26 directly loaded, intact PWR fuel assemblies over a range of [redacted] license drawing, 423-800. Shielded thermal shunts are loaded into the empty basket cells.

The general fuel characteristics for the analyzed fuel assembly are given in Table 5.8.1-1. A reference fuel assembly was developed and analyzed to envelop 17×17 PWR fuel assemblies (same reference assembly from Section 5.2.1). This assembly is constructed by surveying assembly data and using bounding fuel parameters to maximize fuel mass (MTU) and hardware source terms. Decay heats and dose rates have been calculated for a finite range of burnups, initial ^{235}U enrichments, and cool times to generate an allowable loading table, or minimum cool time table. Adherence to the cool timetable ensures that heat load and dose rate limits will not be [redacted]

Three-dimensional dose rates are calculated using a response function methodology. Each of the assembly loading configurations is analyzed over a range of source regions and source types with unit source in each relevant energy group. Source types considered are fuel neutron, fuel gamma fuel secondary gamma (n-gamma), in-core fuel hardware (grid spacers, steel guide tubes, etc.), plenum, and end fitting hardware. These sources are analyzed in a finite number of energy groups with a unit source in each group. The scalar product of source term and response function allows for the creation of large arrays of dose rate results, whether they are for a single detector, or the maximum or average over a detector surface. In this analysis, detector maximum responses have been used exclusively to generate minimum cool time tables.

5.8.1.3 Maximum STC-HBU Dose Rates

The maximum dose rates for the cask under normal and hypothetical accident conditions for all configurations are shown in Figure 5.8.1-1 and Figure 5.8.1-2, respectively. Maximum dose rates are provided in Section 5.8.6. Cask dose rates are below 10 CFR 71 limits.

The hypothetical accident conditions modeled consider gas depletion of the radial neutron shield, the postulated redistribution of the cask lead shielding as a result of a drop accident, and removal of the impact limiters. The cask lead shield is assumed to redistribute as a result of the plastic deformation of the lead shielding and consequent filling of the narrow gap that forms between the lead and cask outer shell during fabrication. Both axial and radial slump conditions are analyzed. In the axial case, the lead shift results from a postulated cask end drop and causes an annular gap to appear in the lead shield at both ends of the cask. In the radial case resulting from a cask side drop, the potential maximum reduction at any single section of the lead shielding is modeled around the circumference of the shield. Applying the maximum reduction at each end and over the circumference simultaneously is conservative for the accident condition shielding model.

Figure 5.8.1-1 Location of STC-HBU Maximum Dose Rates for Normal Conditions

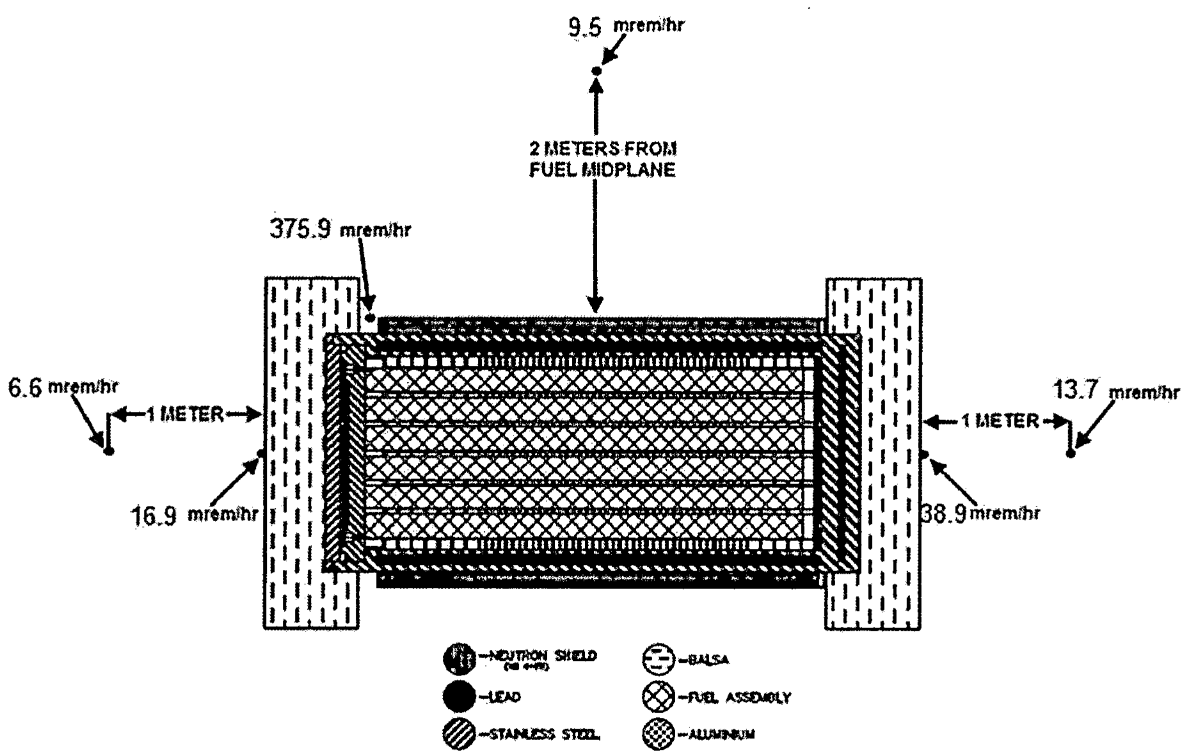

Figure 5.8.1-2 Location of STC-HBU Maximum Dose Rates for Hypothetical Accident Conditions

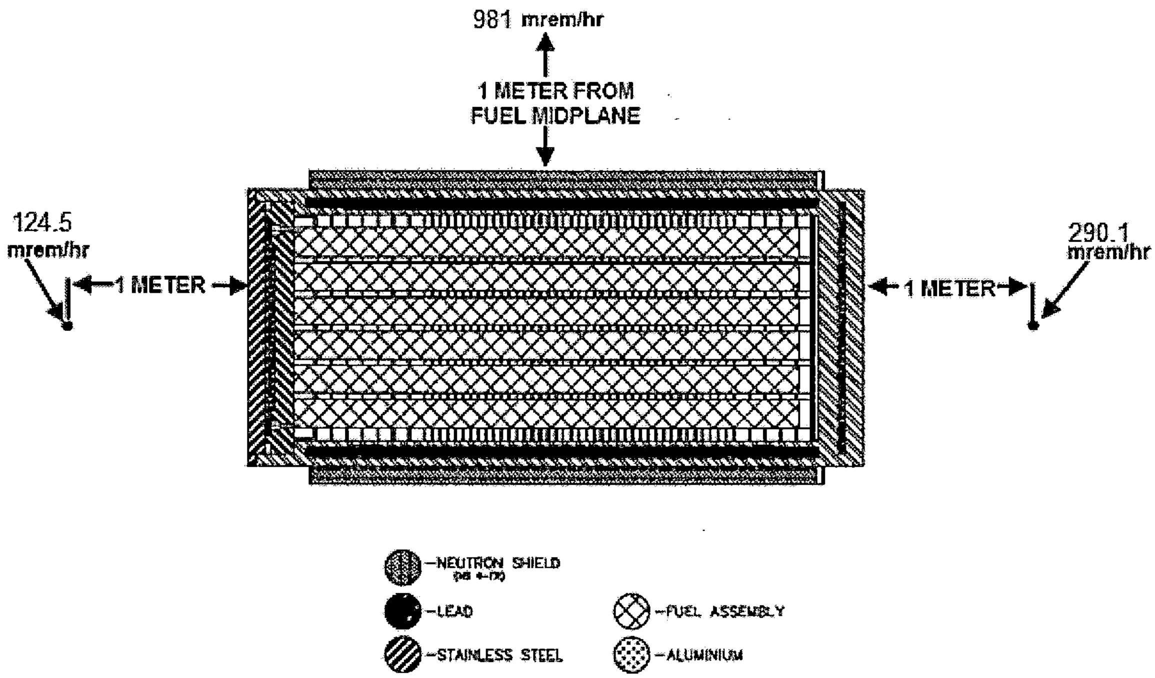

Table 5.8.1-1 Type, Form, Quantity and Potential Sources of the Fuel Used for Design Basis STC-HBU Contents

[redacted]

Table 5.8.1-2 Minimum Cool Time [years] Summary for [redacted] Loading of HBU

Enr. [wt. %]	Burnup [GWd/MTU] 45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55	55<B≤56	56<B≤57	57<B≤58	58<B≤59	59<B≤60
2.9 ≤ E < 3.1	4.0	4.3	4.6	4.9	5.3	5.7	6.2	6.7	7.3	-	-	-	-	-	-
3.1 ≤ E < 3.3	4.0	4.0	4.2	4.5	4.8	5.1	5.6	6.0	6.5	7.1	7.7	8.3	-	-	-
3.3 ≤ E < 3.5	4.0	4.0	4.0	4.1	4.4	4.7	5.0	5.4	5.8	6.3	6.9	7.4	-	-	-
3.5 ≤ E < 3.7	4.0	4.0	4.0	4.0	4.1	4.3	4.5	4.9	5.3	5.7	6.1	6.7	7.2	7.8	8.5
3.7 ≤ E < 3.9	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.5	4.8	5.1	5.5	6.0	6.5	7.0	7.6
3.9 ≤ E < 4.1	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.5	4.7	5.0	5.4	5.8	6.3	6.8
4.1 ≤ E < 4.3	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.9	5.3	5.7	6.1
4.3 ≤ E < 4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.8	5.1	5.6
4.5 ≤ E < 4.7	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0
4.7 ≤ E < 4.9	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	5.0
4.9 ≤ E	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.8	4.9

Table 5.8.1-3 Minimum Cool Time [years] Summary for [redacted] Loading of HBU

Enr. [wt. %]	Burnup [GWd/MTU] 45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55	55<B≤56	56<B≤57	57<B≤58	58<B≤59	59<B≤60
2.9 ≤ E < 3.1	4.7	5.0	5.4	5.9	6.3	6.9	7.6	8.3	9.1	-	-	-	-	-	-
3.1 ≤ E < 3.3	4.4	4.6	4.9	5.3	5.7	6.1	6.7	7.3	8.0	8.8	9.6	10.4	-	-	-
3.3 ≤ E < 3.5	4.3	4.4	4.5	4.8	5.1	5.6	6.0	6.5	7.0	7.8	8.5	9.3	-	-	-
3.5 ≤ E < 3.7	4.2	4.4	4.5	4.6	4.7	5.0	5.4	5.8	6.3	6.8	7.5	8.2	9.0	9.8	10.6
3.7 ≤ E < 3.9	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.3	5.7	6.1	6.6	7.3	8.0	8.7	9.5
3.9 ≤ E < 4.1	4.1	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.6	6.0	6.5	7.1	7.8	8.5
4.1 ≤ E < 4.3	4.1	4.2	4.3	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.5	5.8	6.3	6.9	7.5
4.3 ≤ E < 4.5	4.0	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.4	5.6	5.7	6.1	6.7
4.5 ≤ E < 4.7	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.8	5.0	5.1	5.3	5.5	5.7	5.8	6.0
4.7 ≤ E < 4.9	4.0	4.1	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.4	5.6	5.7	5.9
4.9 ≤ E	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.9	5.0	5.1	5.4	5.5	5.7	5.8

Table 5.8.1-4 Minimum Cool Time [years] Summary for [redacted] Loading of HBU

Enr.	Burnup [GWd/MTU]														
[wt. %]	45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55	55<B≤56	56<B≤57	57<B≤58	58<B≤59	59<B≤60
2.9 ≤ E < 3.1	6.1	6.6	7.2	7.8	8.4	9.1	9.9	10.8	11.7	-	-	-	-	-	-
3.1 ≤ E < 3.3	5.6	6.0	6.5	7.0	7.6	8.2	8.8	9.6	10.4	11.3	12.3	13.3	-	-	-
3.3 ≤ E < 3.5	5.4	5.7	5.9	6.3	6.8	7.4	8.0	8.6	9.3	10.1	11.0	11.9	-	-	-
3.5 ≤ E < 3.7	5.4	5.6	5.8	5.9	6.2	6.7	7.2	7.8	8.4	9.1	9.8	10.7	11.6	12.6	13.6
3.7 ≤ E < 3.9	5.3	5.5	5.7	5.9	6.0	6.3	6.6	7.0	7.6	8.2	8.9	9.6	10.4	11.3	12.2
3.9 ≤ E < 4.1	5.2	5.4	5.6	5.8	6.0	6.2	6.5	6.7	7.0	7.5	8.0	8.7	9.4	10.1	11.0
4.1 ≤ E < 4.3	5.2	5.4	5.6	5.7	5.9	6.1	6.4	6.7	6.9	7.2	7.5	7.9	8.5	9.2	9.9
4.3 ≤ E < 4.5	5.1	5.3	5.5	5.7	5.9	6.0	6.3	6.6	6.8	7.1	7.4	7.7	8.1	8.5	9.0
4.5 ≤ E < 4.7	5.0	5.3	5.4	5.6	5.8	6.0	6.2	6.5	6.7	7.0	7.3	7.6	7.9	8.3	8.8
4.7 ≤ E < 4.9	5.0	5.2	5.4	5.6	5.7	5.9	6.1	6.4	6.6	6.9	7.2	7.5	7.8	8.2	8.6
4.9 ≤ E	5.0	5.1	5.3	5.5	5.7	5.9	6.0	6.3	6.6	6.8	7.0	7.4	7.7	8.0	8.5

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5.8.2 Source Specification – STC-HBU

The directly loaded NAC-STC with HBU is designed to safely transport PWR 17×17 fuel assemblies. The analyzed fuel assembly is a reference fuel assembly (same reference assembly from Section 5.2.1), with assembly geometry and activated hardware masses chosen to maximum uranium loading (MTU) and activated hardware source term.

In order to generate a minimum cool time table for HBU, each fuel assembly is analyzed over a range of burnups, initial ^{235}U enrichments and cool times. Fuel assembly burnup is evaluated from 45,000 MWd/MTU to 60,000 MWd/MTU in 1,000 MWd/MTU increments. Initial ^{235}U enrichments are evaluated from 2.9 to 4.9 wt % ^{235}U in 0.2 wt % increments. Cool times range from 4 to 60 years with varying increments.

The SAS2H code sequence of the SCALE 4.4 package with the 44-group ENDF/B-V cross-section libraries is used to generate source terms for the shielding analysis. SAS2H includes an XSDRNPM neutronics model of the fuel assembly and the ORIGEN-S code for fuel depletion and source term calculations. Source terms are generated for both UO_2 fuel and fuel assembly hardware.

The 44-group library (44GROUPNDF5) is composed primarily of ENDF/B-V cross-sections with ENDF/B-VI data for a limited number of isotopes (e.g., ^{154}Eu and ^{155}Eu). The cross-section set is collapsed using an LWR spectrum. There is extensive SAS2H validation for PWR burnups up to 47 GWd/MTU (ORNL/TM-12667, ORNL/TM-13317, NUREG/CR-6798). As indicated in the reference documentation, the combination of the SCALE 4.4 SAS2H sequence and the 44 GROUPNDF5 cross-section library is applicable to LWR fuel assembly source term generation for high burnup fuel.

Open literature validations of the SCALE SAS2H/44 group library versus experimental data do not extend to the system allowable assembly average burnup of 60 GWd/MTU for PWR systems. Studies performed in NUREG/CR-6701 (Appendix A and Appendix B) indicate no analysis trends in system sensitivity for LWR SAS2H/44GROUPNDF5 evaluations up to a burnup of 75 GWd/MTU.

NUREG/CR-7012 contains the summary of various NUREGs that document publicly available (and in the case of MARIU, commercially protected) comparisons of experimental to code-generated isotope compositions based on the TRITON sequence of SCALE. Burnups included in the NUREG are very high burnups and cover a range of 8 to 79 GWd/MTU. The NUREG compares isotopes relevant to burnup credit, radiation protection and heat generation, and waste management. The comparison relies on the TRITON with NITWAL rather than the newer CENTRM sequence. Beyond the transport solution, which used NEWT in TRITON for a 2-D solution rather than XSDRNPM in SAS2H for a 1-D solution, the NUREG and STC analysis methods are very similar and are not expected to show divergent results in the analysis trend versus burnup. The conclusion in NUREG/CR-7012 is that there is no code bias trend of the depletion-generated isotopics and sources versus burnup level. In particular, there is no significant trend for very high burnup fuels. While absolute differences between SAS2H and TRITON are expected due to neutron transport method differences, trending is not expected for SAS2H. This conclusion is confirmed by reevaluating cases from NUREG/CR-6968, NUREG/CR-6969 and NUREG/CR-7013 using SAS2H. SAS2H modeled cases go up to 70 GWd/MTU. Similarly to the NUREG TRITON cases, the SAS2H result differences from experimental data are closer related to uncertainties within the experimental data (e.g., isotope measurement, depletion model inputs) and the uniqueness of the geometry or material composition (e.g., Gd poisoned fuel rods) than to burnup levels. There was no significant trending of the SAS2H results as a function of fuel burnup. As such, the SAS2H/44GROUPNDF5 sequence is applicable to the high burnup fuel evaluated.

As an additional comparison with SAS2H, the bounding neutron source for the [redacted] loading normal condition 2 meter dose rate (see Section 5.8.6) was recomputed using the TRITON/CENTRM modules of SCALE 6.1 with the 238-group ENDF-VII (v7-238) library. As shown in Table 5.8.2-2, the overall source is 12% less in TRITON when compared to SAS2H. Similarly, the source is less in the groups with a significant fraction (i.e., greater than 5%) of the computed source (groups 9 through 13). Therefore, the SAS2H source terms will produce conservative dose rates.

The hardware activation is calculated by light element transmutation using the in-core neutron flux spectrum produced by the SAS2H neutronics model. The effects of axial flux spectrum and magnitude variation on hardware activation are estimated by flux ratios determined from empirical data. Refer to Section 5.8.9 for sample PWR SAS2H input files.

Fuel neutron, fuel gamma, and hardware gamma radiation contribute at varying levels to cask dose rates due to significant changes in the material composition of the cask shields at different radial and axial locations. As such, no single source term produces a bounding set of dose rates at all locations. By employing the response function method to calculate maximum dose rates, the limiting source term becomes a result of the analysis, rather than an input, and the limiting source term and dose rate are captured for radial and axial detectors.

5.8.2.1 Directly Loaded Fuel Neutron Source

As described in Section 5.2.1, neutron source terms have been calculated for each directly loaded fuel assembly. Neutron source terms have been rebinned onto the ANSWERS (MCBEND) 28 group structure, shown in Table 5.2-21, using ORIGEN-S as part of the source term decay evaluation. The effect of subcritical neutron multiplication is directly computed in the MCNP analysis using an enrichment of 5 wt. % ^{235}U for the fuel material definition.

5.8.2.2 Directly Loaded Fuel Gamma Sources

As described in Section 5.2.1, gamma source terms have been calculated for each directly loaded fuel assembly. Gamma source terms have been rebinned onto the ANSWERS (MCBEND) 22 group structure, shown in Table 5.2-22, using ORIGEN-S as part of the source term decay evaluation. The hardware gamma spectrum for directly loaded fuel contains contributions primarily from ^{60}Co due to the activation of Type 304 stainless steel with 1.2 g/kg ^{59}Co impurity and with some minor contributions from ^{59}Ni and ^{58}Fe. The magnitude of these spectra is based on the irradiation of 1 kg of stainless steel in the in-core flux spectrum produced by the SAS2H neutronics calculation.

The activated fuel assembly hardware source terms are found by multiplying the source strength from 1 kilogram by:

- the kilograms of steel or inconel material in the plenum, upper end fitting or lower end fitting regions,
- and the regional flux ratio.

Activated mass in each region and the corresponding flux factor are summarized in Table 5.2-4.

5.8.2.3 Directly Loaded Fuel Source Axial Profiles

The design basis axial burnup profile used in the HBU fuel shielding evaluation is shown in Figure 5.8.2-1 (NUREG/CR-6801). The axial burnup profile is converted into a source profile based on the following relation between burnup and source rate:

$$S = aB^b$$

where parameters *a* and *b* are determined based on fits to SAS2H computed source rates at various fuel burnups. The parameter *a* is simply a scaling factor and is not relevant to the analysis. For neutron sources parameter *b* is 4.22. For gamma sources, the relation between burnup and source rate is linear and *b* is 1.0.

The resulting source rate profile for PWR fuel is shown in Table 5.8.2-1. The profiles are in the columns labeled "Photon Source" and "Neutron Source" are simply the average source over each interval. Finally, the profile is derived by weighting the interval-averaged values by the relative size of the interval. The ratio of the resulting average source rate to the source rate at the average burnup is shown in the last row of the table. For photons, there is no effective increase in source rate since the relation between burnup and source rate is linear. For neutrons, the average source rate is about 1.18 times higher than the neutron source rate at the average burnup. This factor is explicitly used to scale neutron source rates since input source profile distributions are normalized. A schematic of the gamma and neutron source profiles is shown in Figure 5.8.2-2.

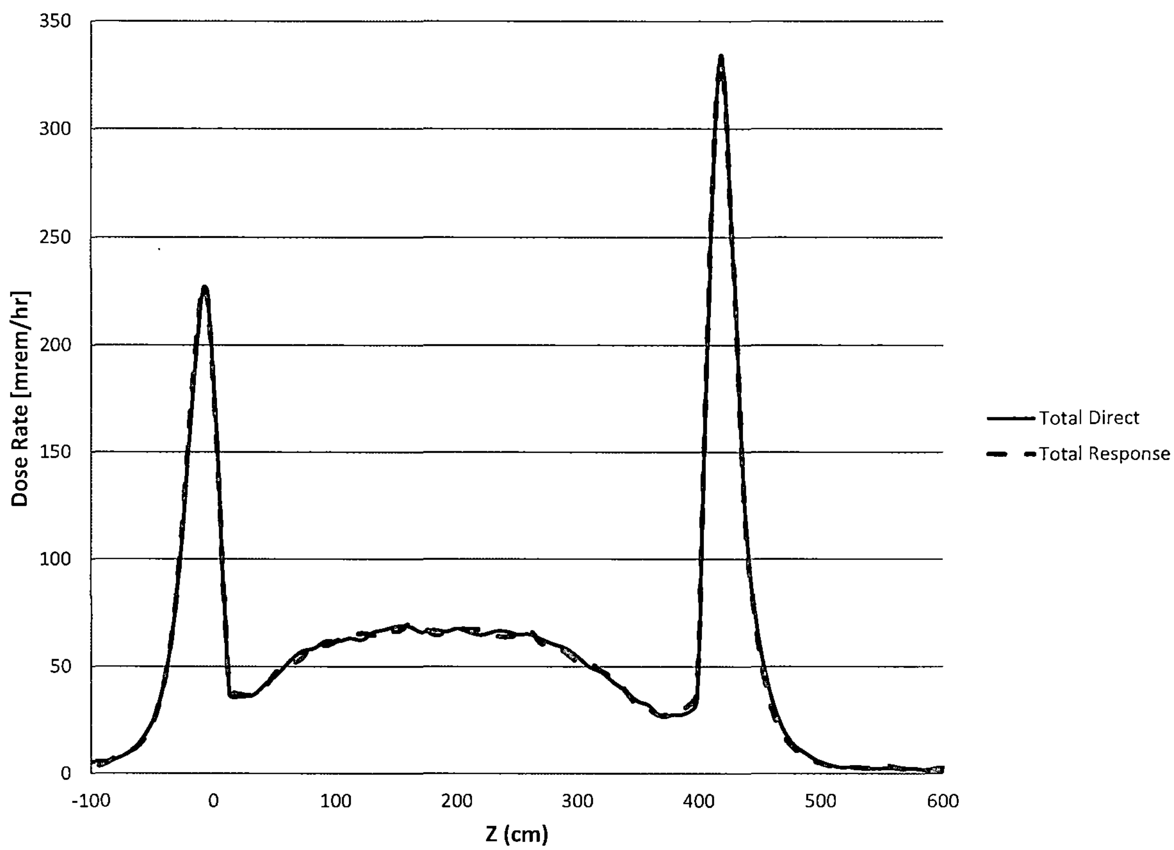
Table 5.8.2-1 NAC-STC Neutron and Gamma Source Term Axial Profile

% Core		Photon	Neutron	Photon	Neutron
H Lower	H Upper	Source	Source	Weight	Weight
0.0%	5.6%	0.652	1.645E-01	3.622E-02	9.138E-03
5.6%	11.1%	0.9670	8.680E-01	5.372E-02	4.822E-02
11.1%	16.7%	1.0740	1.352E+00	5.967E-02	7.509E-02
16.7%	22.2%	1.1030	1.512E+00	6.128E-02	8.402E-02
22.2%	27.8%	1.1080	1.542E+00	6.156E-02	8.564E-02
27.8%	33.3%	1.1060	1.530E+00	6.144E-02	8.499E-02
33.3%	38.9%	1.1020	1.507E+00	6.122E-02	8.370E-02
38.9%	44.4%	1.0970	1.478E+00	6.094E-02	8.211E-02
44.4%	50.0%	1.0940	1.461E+00	6.078E-02	8.117E-02
50.0%	55.6%	1.0940	1.461E+00	6.078E-02	8.117E-02
55.6%	61.1%	1.0950	1.467E+00	6.083E-02	8.148E-02
61.1%	66.7%	1.0960	1.472E+00	6.089E-02	8.180E-02
66.7%	72.2%	1.0950	1.467E+00	6.083E-02	8.148E-02
72.2%	77.8%	1.0860	1.416E+00	6.033E-02	7.869E-02
77.8%	83.3%	1.0590	1.274E+00	5.883E-02	7.076E-02
83.3%	88.9%	0.9710	8.832E-01	5.394E-02	4.907E-02
88.9%	94.4%	0.7380	2.775E-01	4.100E-02	1.541E-02
94.4%	100.0%	0.4620	3.844E-02	2.567E-02	2.136E-03
100.0%					
Average				1.0	1.176

Table 5.8.2-2 TRITON Neutron Source Term Comparison

Group	Neutron Source [n/sec/assy]	
	SAS2H	TRITON
1	0.00E+00	2.41E+04
2	5.26E+04	6.48E+04
3	2.19E+05	1.98E+05
4	7.28E+05	5.52E+05
5	2.28E+06	2.66E+06
6	6.13E+06	5.83E+06
7	1.06E+07	9.61E+06
8	3.54E+07	3.19E+07
9	6.00E+07	5.43E+07
10	8.07E+07	7.46E+07
11	1.92E+08	1.72E+08
12	3.01E+08	2.40E+08
13	7.85E+07	5.41E+07
14	2.72E+07	4.80E+07
15	5.57E+02	4.81E+06
16	0.00E+00	3.52E+06
17	0.00E+00	7.97E+05
18	0.00E+00	1.88E+05
19	0.00E+00	3.45E+04
20	0.00E+00	6.12E+03
21	0.00E+00	1.20E+03
22	0.00E+00	4.78E+02
23	0.00E+00	7.14E+01
24	0.00E+00	1.47E+01
25	0.00E+00	1.64E+00
26	0.00E+00	3.66E-01
27	0.00E+00	1.08E-01
28	0.00E+00	3.49E-03
Total	7.95E+08	7.03E+08

Figure 5.8.4-1 STC-HBU Normal Condition Radial Dose Rate Profiles for DRM and Direct Solutions



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5.8.5 Loading Tables – STC-HBU

Three-dimensional radial response functions are generated for both normal and accident conditions. Based on preliminary analysis, two bounding axial shift scenarios have been established: 1) maximum fuel assembly shift upward in the cask cavity without a corresponding shift in the basket and shunts and 2) no fuel assembly or basket shift. For axial biasing, the limiting shift scenario corresponds exactly to the position of the fuel assembly in the cavity, i.e., top dose rates are maximized when the fuel assembly is shifted up and bottom dose rates are maximized when the fuel assembly is as far down in the cavity as possible. For radial biasing, the maximum fuel assembly axial shift is limiting because upper plenum and upper end fitting hardware move adjacent to the location in the radial shield where the radial lead shield ends. Axial position of the fuel and basket has negligible effect for the accident conditions as dose rates peak at the fuel midplane.

The first step in determining limiting dose rate is the generation of dose rate response functions for generation of minimum cool time tables. At each of burnup, enrichment, and cool time combination, dose rate profiles are calculated for normal transport conditions. Using these dose rate profiles, the maximum radial surface, 2 meters from vehicle side, top axial surface, and bottom axial surface dose rates are tabulated.

Minimum cool times are calculated to ensure that a decay heat limit of 24 kW/cask, a dose rate of 1,000 mrem/hr at the surface, and a dose rate of 9.5 mrem/hr at 2 meters are not exceeded. The latter is applied to provide margin to the 10 mrem/hr regulatory limit. Cool times needed to reach these limits are calculated using linear interpolation on the entire array of maximum dose rates. The linear interpolation is valid because of the exponential decrease in source term and, thus, dose rate as a function of time. The interpolated cool time is rounded up to the next integer year. Repeating this analysis for all fuel types and burnups results in the complete loading table.

[redacted]

Source terms that produce maximum dose rates for each detector are determined using the loading tables. The source terms are listed in Tables 5.8.5-2 through 5.8.5-73.

Table 5.8.5-1 Example Loading Table for STC-HBU

Burnup	57 GWD/MTU	Minimum Cool Time [y]				Properties at Max							
	Limit	Decay Heat	NrmRadSrf	NrmRad2m	Max	Decay Heat	NrmRadSrf	NrmRad2m	NrmTopSrf	NrmBotSrf	AccRadSrf	AccTopSrf	AccBotSrf
Enrichment	Case	24 kW	1000 mrem/hr	9.5 mrem/hr		[kW/Cask]	[mrem/hr]	[mrem/hr]	[mrem/hr]	[mrem/hr]	[mrem/hr]	[mrem/hr]	[mrem/hr]
1 3	57b13e	-	-	-	-	-	-	-	-	-	-	-	-
1 5	57b15e	-	-	-	-	-	-	-	-	-	-	-	-
1 7	57b17e	-	-	-	-	-	-	-	-	-	-	-	-
1 9	57b19e	-	-	-	-	-	-	-	-	-	-	-	-
2 1	57b21e	-	-	-	-	-	-	-	-	-	-	-	-
2 3	57b23e	-	-	-	-	-	-	-	-	-	-	-	-
2 5	57b25e	-	-	-	-	-	-	-	-	-	-	-	-
2 7	57b27e	-	-	-	-	-	-	-	-	-	-	-	-
2 9	57b29e	5 2	0 5	9 2	-	-	-	-	-	-	-	-	-
3 1	57b31e	5 1	0 5	8 3	8 3	17 2	331 4	9 48	12 19	27 2	711 9	89 8	235 5
3 3	57b33e	5 0	0 5	7 4	7 4	18 2	337 9	9 50	12 57	28 0	686 3	86 6	226 2
3 5	57b35e	4 9	0 5	6 6	6 7	19 1	339 9	9 43	12 78	28 6	657 5	82 8	215 6
3 7	57b37e	4 8	0 5	5 9	6 0	20 2	342 8	9 40	13 04	29 3	632 2	79 3	205 7
3 9	57b39e	4 8	0 5	5 3	5 4	21 8	344 8	9 44	13 32	30 1	610 7	75 8	196 1
4 1	57b41e	4 7	0 5	4 8	4 9	23 2	343 7	9 43	13 46	30 7	588 0	72 2	186 2
4 3	57b43e	4 7	0 5	4 4	4 7	23 8	333 8	9 18	13 21	30 4	556 8	67 7	174 4
4 5	57b45e	4 6	0 5	4 1	4 6	24 0	321 2	8 84	12 80	29 6	523 7	63 3	162 6
4 7	57b47e	4 5	0 5	3 8	4 6	23 7	306 5	8 42	12 27	28 4	489 0	58 8	150 9
4 9	57b49e	4 5	0 5	3 6	4 5	23 9	296 0	8 15	11 95	27 8	462 0	55 2	141 2

Note: Loading tables conservatively round up the minimum cool time to the nearest tenth.

Table 5.8.5-2 [redacted] Loading Source Terms for Maximum Dose Rates - Normal Conditions

Radial Surface		Radial 2 Meter		Axial Top Surface		Axial Bottom Surface	
kW/Cask	Source	kW/Cask	Source	kW/Cask	Source	kW/Cask	Source
20.3	49b29e4.9y	18.2	57b33e7.4y	22.8	46b29e4.0y	22.8	46b29e4.0y

Table 5.8.5-3 [redacted] Loading Source Terms for Maximum Dose Rates - Accident Conditions

Radial Surface		Axial Top Surface		Axial Bottom Surface	
kW/Cask	Source	kW/Cask	Source	kW/Cask	Source
17.9	60b35e8.5y	17.9	60b35e8.5y	17.9	60b35e8.5y

Table 5.8.5-4 [redacted] Loading Source Terms for Maximum Dose Rates - Normal Conditions

Radial Surface		Radial 2 Meter		Axial Top Surface		Axial Bottom Surface	
kW/Cask	Source	kW/Cask	Source	kW/Cask	Source	kW/Cask	Source
20.9	48b29e5.4y	20.9	48b29e5.4y	22.2	46b29e4.7y	23.7	48b33e4.5y

Table 5.8.5-5 [redacted] Loading Source Terms for Maximum Dose Rates - Accident Conditions

Radial Surface		Axial Top Surface		Axial Bottom Surface	
kW/Cask	Source	kW/Cask	Source	kW/Cask	Source
18.5	60b35e10.6y	18.5	60b35e10.6y	18.5	60b35e10.6y

Table 5.8.5-6 [redacted] Loading Source Terms for Maximum Dose Rates - Normal Conditions

Radial Surface		Radial 2 Meter		Axial Top Surface		Axial Bottom Surface	
kW/Cask	Source	kW/Cask	Source	kW/Cask	Source	kW/Cask	Source
23.6	46b31e5.6y	20.8	52b31e8.8y	23.6	46b31e5.6y	23.6	46b31e5.6y

Table 5.8.5-7 [redacted] Loading Source Terms for Maximum Dose Rates - Accident Conditions

Radial Surface		Axial Top Surface		Axial Bottom Surface	
kW/Cask	Source	kW/Cask	Source	kW/Cask	Source
20.8	60b35e13.6y	20.8	60b35e13.6y	20.8	60b35e13.6y

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5.8.6 Open with Enclosure Configuration Results – STC-HBU

The baseline configuration for the STC-HBU contents is the open with enclosure configuration, which has a normal condition 1,000 mrem/hr dose rate limit at the package surface. This configuration provides bounding radial dose rates over the alternate flat-bed configurations presented in Sections 5.8.7 and 5.8.8. Maximum dose rates for normal and accident conditions are provided in Table 5.8.6-1 and Table 5.8.6-2, respectively.

The dose rate mesh and FSD profiles for the radial surface detector of the normal condition cask are provided in Figure 5.8.6-1 and Figure 5.8.6-2, respectively. The dose rate mesh and FSD profiles for the 2 meters from vehicle side detector of the normal condition cask are provided in Figure 5.8.6-3 and Figure 5.8.6-4, respectively. The origin for all profiles is at the center of the cask cavity bottom. Slices from the mesh profiles are used to generate profiles by source type for both normal surface and accident 1m detectors, as shown in Figure 5.8.6-5 and Figure 5.8.6-6, respectively. [redacted]

Figure 5.8.6-1 [redacted] Loading Radial Surface Dose Rate [mrem/hr] Mesh – Nrm

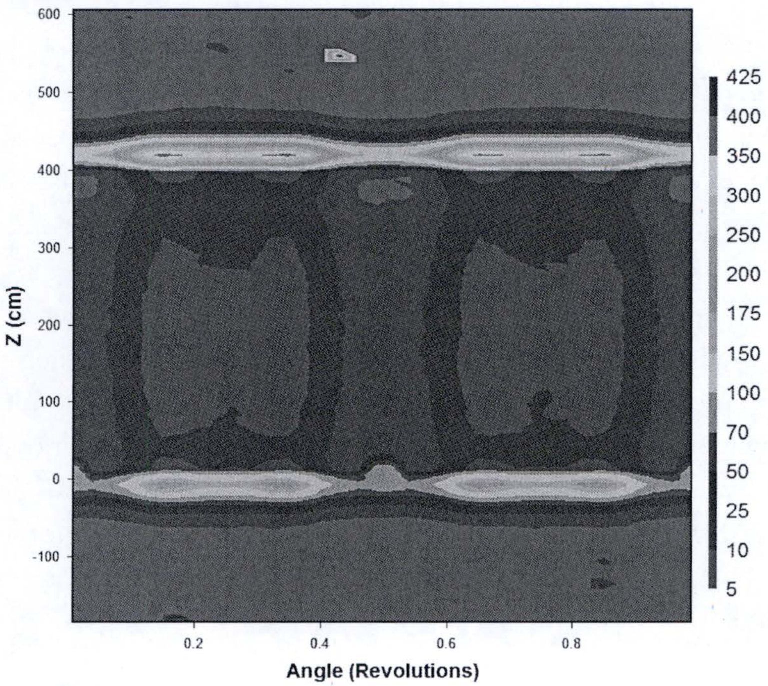

Figure 5.8.6-2 [redacted] Loading Radial Surface Dose Rate Mesh FSDs – Nrm

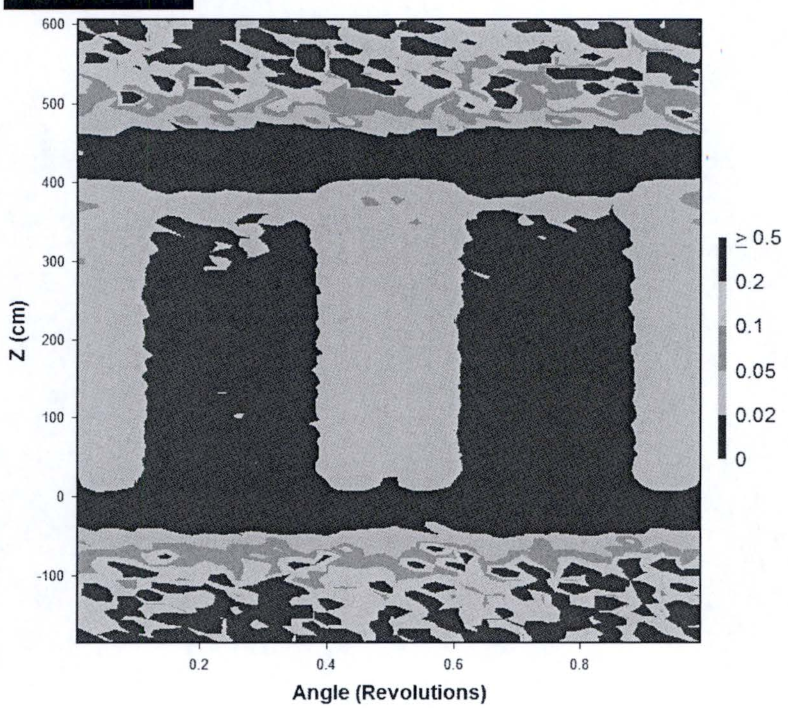

Figure 5.8.6-3 [redacted] Loading Side 2m + Vehicle Dose Rate [mrem/hr] Mesh – Nrm

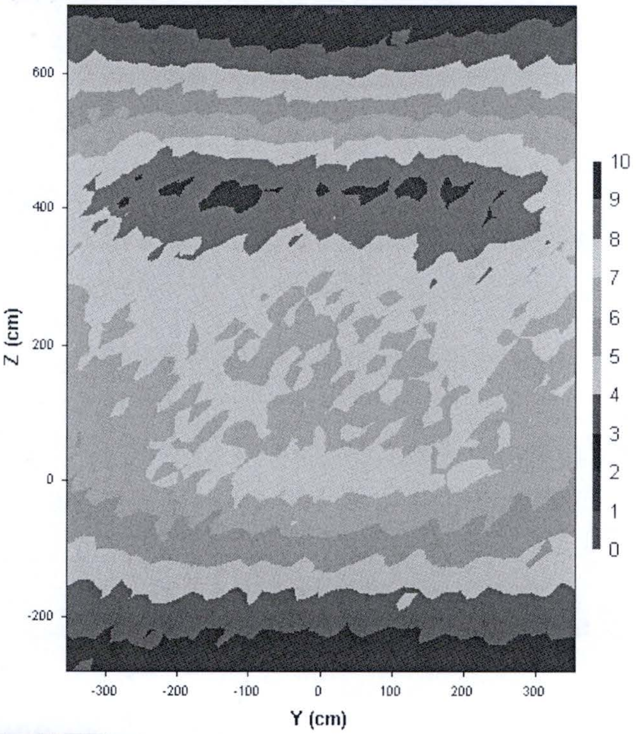

Figure 5.8.6-4 [redacted] Loading Side 2m + Vehicle Dose Rate Mesh FSDs– Nrm

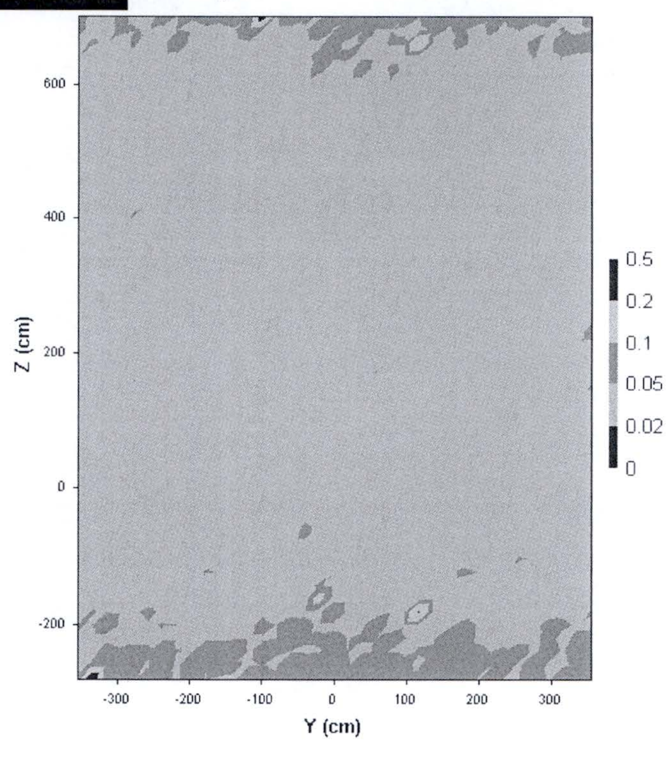

Figure 5.8.6-5 Surface Dose Rate Profile by Source Type for [redacted] Loading – Nrm

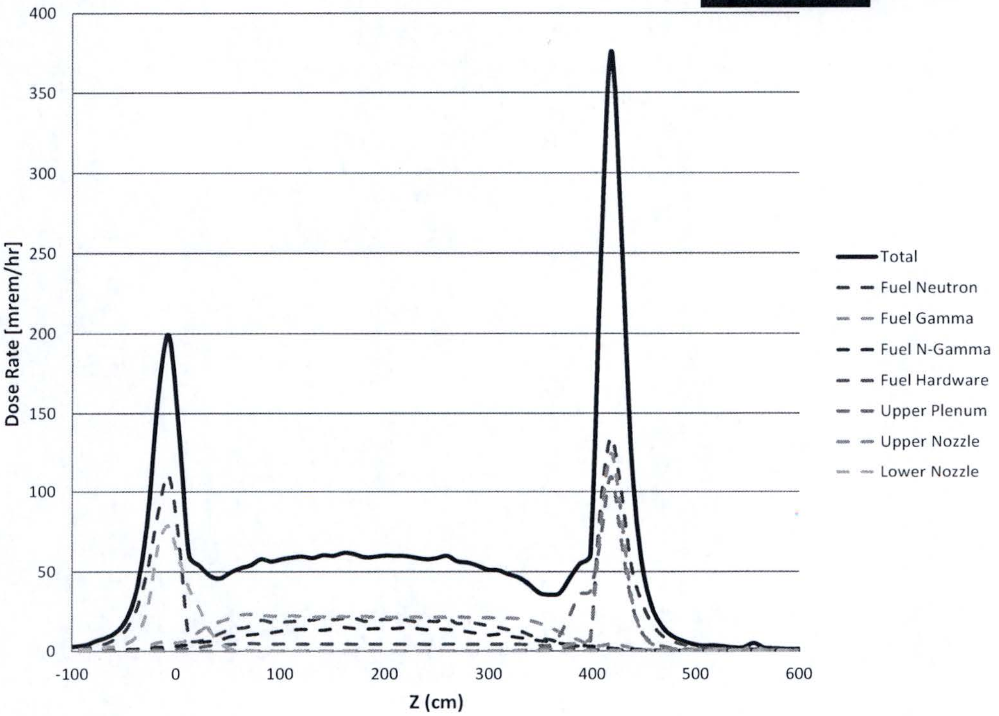

Figure 5.8.6-6 1m Dose Rate Profile by Source Type for [redacted] Loading – Acc

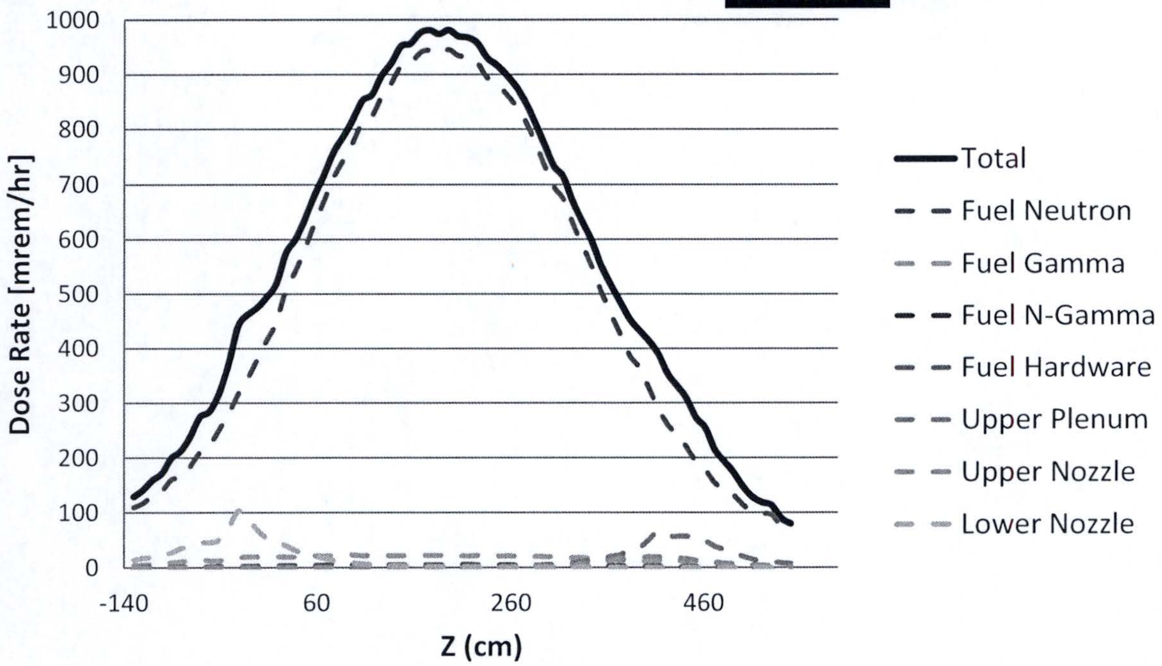

Table 5.8.6-1 HBU Maximum Dose Rates for Normal Conditions

Detector		[redacted]						Limit
		[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]
Surface	Rad	352.6	0.7%	348.4	0.7%	375.9	0.8%	1000
Surface of Vehicle	Rad	102.7	0.8%	109.6	1.0%	121.8	1.0%	200
1m (TI)	Rad	40.8	1.2%	40.4	1.3%	46.3	1.1%	--
2m + Vehicle	Rad	9.5	2.8%	9.5	2.9%	9.5	5.6%	10
Surface	Top	14.1	2.5%	16.9	1.5%	16.6	1.4%	200
1m (TI)	Top	5.7	6.6%	6.2	2.8%	6.6	2.9%	--
Surface	Bot	32.5	1.3%	38.9	1.3%	36.9	1.4%	200
1m (TI)	Bot	12.6	2.7%	13.2	2.6%	13.7	2.7%	-

Table 5.8.6-2 HBU Maximum 1m Dose Rates for Accident Conditions

Detector	[redacted]						Limit
	[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]
Rad	720.5	0.8%	720.2	0.8%	980.9	0.7%	1000
Top	90.5	7.6%	101.0	6.1%	124.5	7.2%	
Bot	237.8	3.5%	264.8	5.4%	290.1	5.3%	

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5.8.7 Flat Bed Configuration Results – STC-HBU

The flat-bed configuration has a normal condition external surface dose rate limit of 200 mrem/hr. Minimum cool times for this configuration are shown in Tables 5.8.7-1 through 5.8.7-3. Bounding source terms are shown in Tables 5.8.7-4 and 5.8.7-5. Maximum dose rates for normal and accident conditions are provided in Tables 5.8.7-6 through 5.8.7-11. The applied limit of 200 mrem/hr at the surface results in dose rates significantly below limits for all detectors. Reduced cobalt impurity levels of 0.4 and 0.8 g/kg are provided for added loading flexibility. Reduced cobalt content is evaluated by applying a ratio of evaluated cobalt impurity to the cobalt impurity level in the source term calculation (1.2 g/kg) to the non-fuel hardware source.

The dose rate mesh and FSD profiles for the radial surface detector of the normal condition cask are provided in Figure 5.8.7-1 and Figure 5.8.7-2, respectively. The dose rate mesh and FSD profiles for the 2 meters from vehicle side detector of the normal condition cask are provided in Figure 5.8.7-3 and Figure 5.8.7-4, respectively. The origin for all profiles is at the center of the cask cavity bottom. Slices from the mesh profiles are used to generate profiles by source type for both normal surface and accident 1-meter detectors, as shown in Figure 5.8.7-5 and Figure 5.8.7-6, respectively. Profiles shown are limited to the 0.4 g/kg cobalt content results.

Figure 5.8.7-1 HBU Flat Bed Configuration [redacted] Loading Radial Surface Dose Rate [mrem/hr] Mesh – Nrm – 0.4 g/kg Cobalt Content

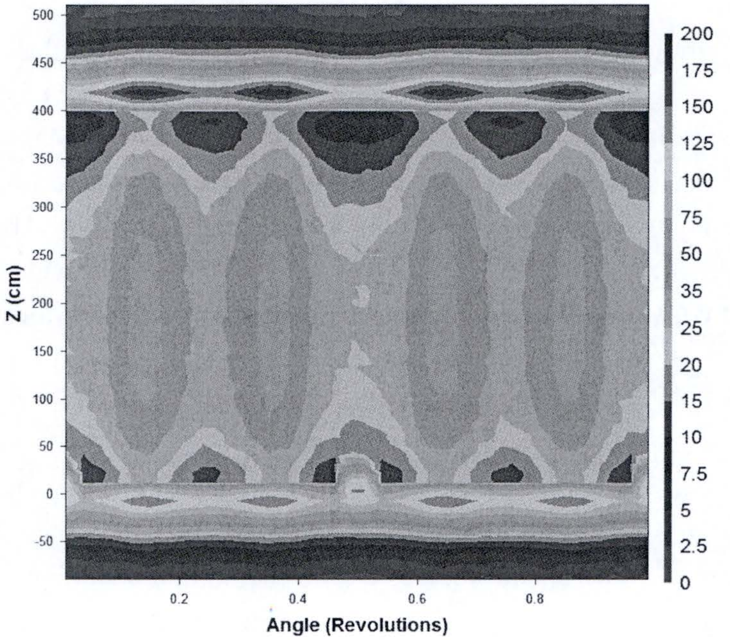

Figure 5.8.7-2 HBU Flat Bed Configuration [redacted] Loading Radial Surface Dose Rate Mesh FSDs – Nrm – 0.4 g/kg Cobalt Content

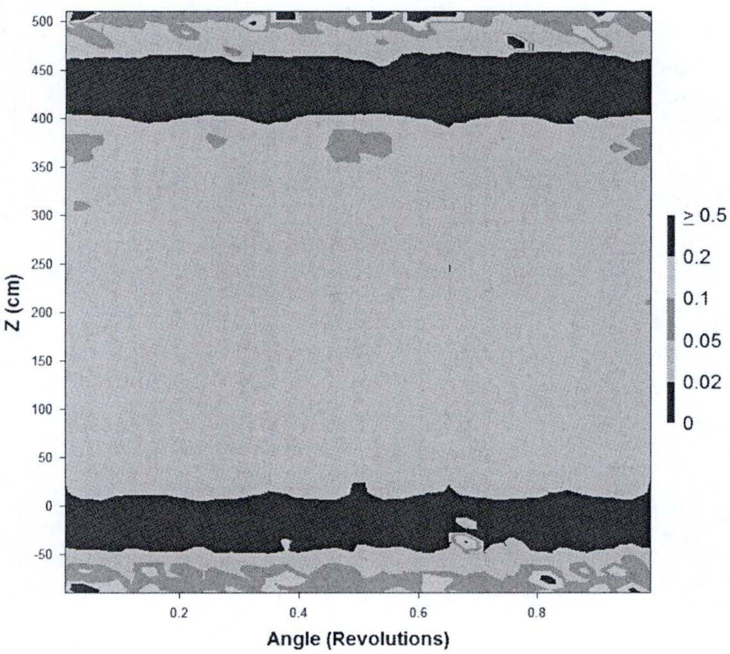

Figure 5.8.7-3 HBU Flat Bed Configuration [redacted] Loading Side 2m + Vehicle Dose Rate [mrem/hr] Mesh – Nrm – 0.4 g/kg Cobalt Content

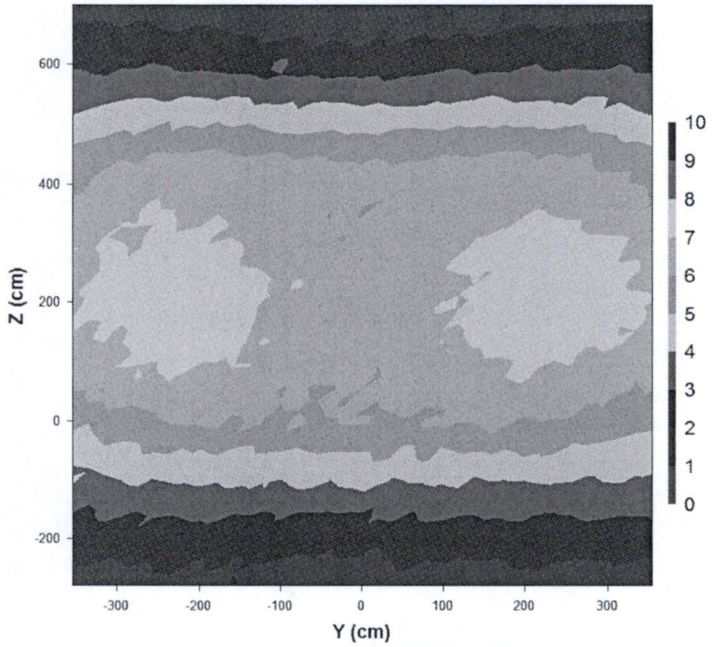

Figure 5.8.7-4 HBU Flat Bed Configuration [redacted] Loading Side 2m + Vehicle Dose Rate Mesh FSDs – Nrm – 0.4 g/kg Cobalt Content

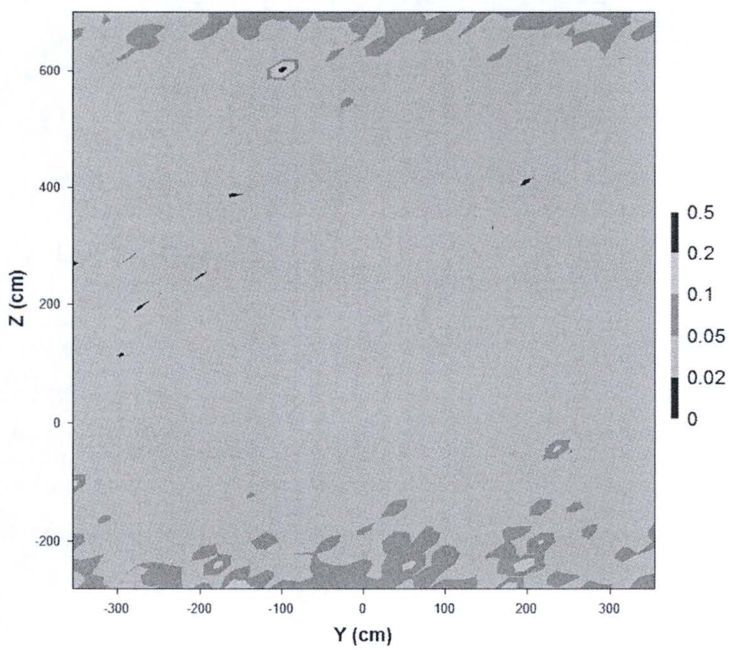

Figure 5.8.7-5 HBU Flat Bed Configuration Surface Dose Rate Profile by Source Type for [redacted] Loading – Nrm – 0.4 g/kg Cobalt Content

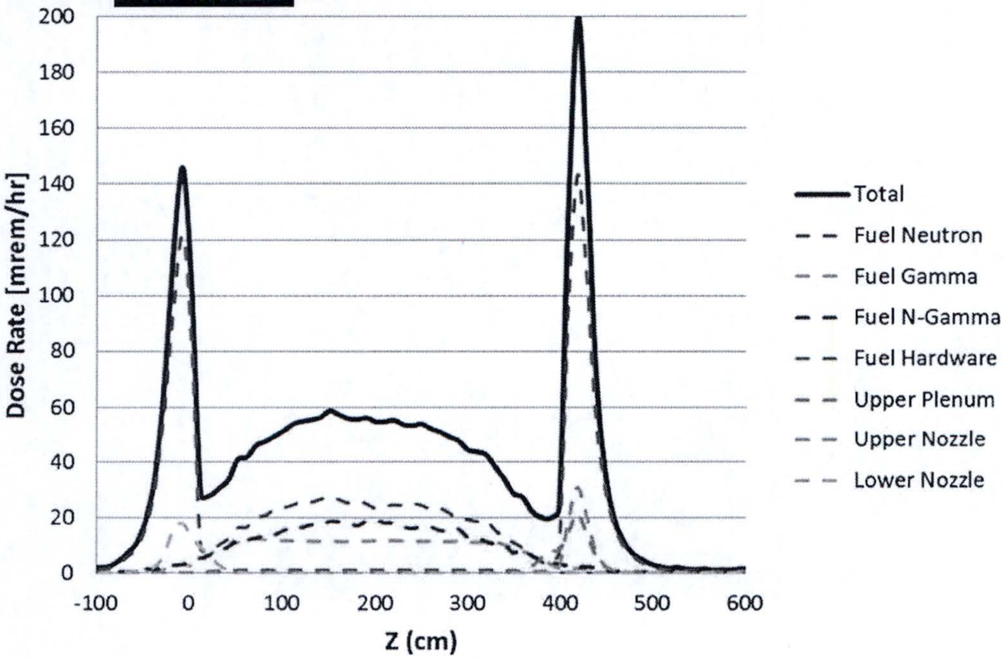

Figure 5.8.7-6 HBU Flat Bed Configuration 1m Dose Rate Profile by Source Type for [redacted] Loading – Acc – 0.4 g/kg Cobalt Content

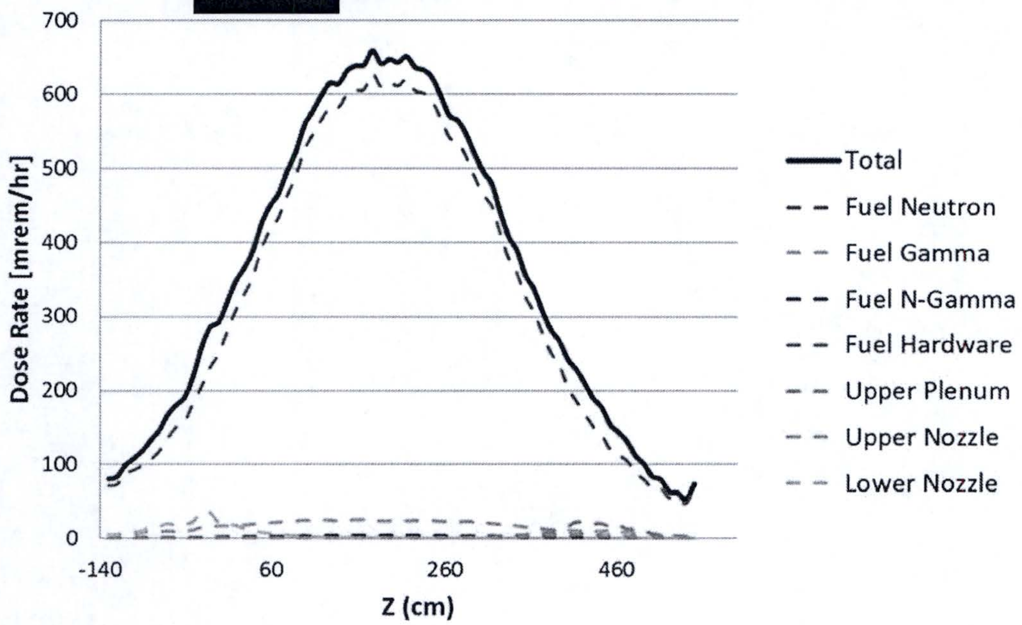

Table 5.8.7-1 HBU Flat-Bed Configuration Minimum Cool Times –[redacted]Loading

Cobalt [g/kg]	Enr. [wt. %]	Burnup [GWd/MTU] 45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
0.4	2.9	4.0	4.0	4.0	4.3	4.9	5.6	6.3	7.0	7.8	8.7	-	-	-	-	-	-
	3.1	4.0	4.0	4.0	4.0	4.1	4.7	5.3	6.0	6.8	7.5	8.3	9.2	10.1	-	-	-
	3.3	4.0	4.0	4.0	4.0	4.0	4.1	4.5	5.1	5.8	6.5	7.2	8.0	8.9	-	-	-
	3.5	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.9	5.5	6.2	7.0	7.8	8.6	9.4	10.3
	3.7	4.0	4.0	4.0	4.0	4.0	4.0	4.2	4.3	4.4	4.7	5.3	6.0	6.7	7.5	8.3	9.1
	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	5.1	5.8	6.5	7.2	8.0
	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.9	5.6	6.3	7.0
	4.3	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.7	4.8	5.4	6.1
	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.9	5.2
	4.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.4	4.4	4.5	4.7	4.8	4.9
	4.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.8	4.9
0.8	2.9	6.4	6.9	7.4	8.0	8.6	9.1	9.8	10.4	11.1	11.8	-	-	-	-	-	-
	3.1	5.7	6.2	6.7	7.2	7.8	8.3	8.9	9.5	10.1	10.8	11.5	12.2	12.9	-	-	-
	3.3	5.1	5.6	6.0	6.5	7.0	7.6	8.1	8.7	9.3	9.9	10.6	11.2	11.9	-	-	-
	3.5	4.6	5.0	5.4	5.9	6.4	6.8	7.4	7.9	8.5	9.0	9.7	10.3	11.0	11.6	12.3	13.1
	3.7	4.1	4.5	4.9	5.3	5.7	6.2	6.7	7.2	7.7	8.3	8.8	9.4	10.1	10.7	11.4	12.0
	3.9	4.0	4.0	4.4	4.7	5.2	5.6	6.0	6.5	7.0	7.5	8.1	8.7	9.2	9.8	10.5	11.2
	4.1	4.0	4.0	4.0	4.3	4.6	5.0	5.5	5.9	6.4	6.9	7.4	7.9	8.5	9.0	9.6	10.3
	4.3	4.0	4.0	4.0	4.0	4.2	4.5	4.9	5.4	5.8	6.3	6.7	7.2	7.8	8.3	8.9	9.4
	4.5	4.0	4.0	4.0	4.0	4.0	4.1	4.5	4.9	5.3	5.7	6.1	6.6	7.1	7.6	8.1	8.7
	4.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.4	4.8	5.2	5.6	6.0	6.5	7.0	7.5	8.0
	4.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3	4.7	5.1	5.5	5.9	6.4	6.9	7.4
1.2	2.9	8.9	9.4	9.9	10.4	11.0	11.5	12.0	12.6	13.3	13.8	-	-	-	-	-	-
	3.1	8.3	8.8	9.2	9.7	10.2	10.7	11.3	11.8	12.4	13.0	13.6	14.2	14.9	-	-	-
	3.3	7.7	8.1	8.6	9.0	9.5	10.0	10.5	11.1	11.6	12.1	12.7	13.3	13.9	-	-	-
	3.5	7.2	7.6	8.0	8.4	8.9	9.3	9.8	10.3	10.9	11.4	11.9	12.5	13.1	13.7	14.3	15.0
	3.7	6.7	7.0	7.4	7.9	8.3	8.7	9.2	9.6	10.1	10.7	11.2	11.7	12.3	12.9	13.5	14.0
	3.9	6.2	6.6	6.9	7.3	7.7	8.1	8.6	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.6	13.2
	4.1	5.8	6.1	6.5	6.8	7.2	7.6	8.0	8.4	8.9	9.3	9.8	10.3	10.8	11.3	11.9	12.4
	4.3	5.4	5.7	6.0	6.4	6.7	7.1	7.5	7.9	8.3	8.8	9.2	9.7	10.1	10.7	11.2	11.7
	4.5	5.0	5.3	5.6	6.0	6.3	6.7	7.0	7.4	7.8	8.2	8.6	9.1	9.5	10.0	10.5	11.0
	4.7	4.6	4.9	5.2	5.6	5.9	6.2	6.6	6.9	7.3	7.7	8.1	8.5	8.9	9.4	9.9	10.3
	4.9	4.3	4.6	4.9	5.2	5.5	5.8	6.2	6.5	6.9	7.2	7.6	8.0	8.4	8.8	9.3	9.7

Table 5.8.7-2 HBU Flat-Bed Configuration Minimum Cool Times – [redacted] Loading

Cobalt	Enr.	Burnup [GWd/MTU]															
[g/kg]	[wt. %]	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
0.4	2.9	4.3	4.4	5.0	5.7	6.5	7.3	8.2	9.1	10.0	11.0	-	-	-	-	-	-
	3.1	4.2	4.3	4.4	4.8	5.5	6.2	7.0	7.9	8.8	9.7	10.7	11.7	12.7	-	-	-
	3.3	4.1	4.3	4.4	4.5	4.6	5.2	6.0	6.7	7.6	8.4	9.4	10.3	11.3	-	-	-
	3.5	4.1	4.2	4.3	4.4	4.5	4.7	5.0	5.7	6.5	7.3	8.2	9.0	10.0	11.0	11.9	13.0
	3.7	4.0	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.5	6.3	7.0	7.9	8.8	9.7	10.6	11.6
	3.9	4.0	4.1	4.2	4.3	4.5	4.6	4.7	4.8	5.0	5.3	6.1	6.8	7.6	8.5	9.4	10.3
	4.1	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.9	6.6	7.4	8.2	9.1
	4.3	4.0	4.0	4.1	4.3	4.4	4.5	4.6	4.7	4.9	5.0	5.2	5.3	5.7	6.4	7.2	8.0
	4.5	4.0	4.0	4.1	4.2	4.3	4.4	4.6	4.7	4.8	5.0	5.1	5.3	5.4	5.6	6.2	7.0
	4.7	4.0	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.8	4.9	5.0	5.2	5.4	5.6	5.7	6.1
	4.9	4.0	4.0	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.8	5.0	5.1	5.3	5.5	5.6	5.8
0.8	2.9	7.4	8.0	8.6	9.2	9.9	10.6	11.4	12.1	12.9	13.7	-	-	-	-	-	-
	3.1	6.6	7.2	7.8	8.4	9.0	9.7	10.4	11.1	11.8	12.6	13.4	14.2	15.1	-	-	-
	3.3	5.9	6.5	7.0	7.6	8.1	8.8	9.4	10.1	10.8	11.5	12.3	13.1	13.9	-	-	-
	3.5	5.3	5.8	6.3	6.8	7.4	8.0	8.6	9.2	9.9	10.6	11.3	12.0	12.8	13.6	14.4	15.3
	3.7	4.8	5.2	5.7	6.1	6.7	7.2	7.8	8.4	9.0	9.6	10.3	11.1	11.8	12.5	13.3	14.1
	3.9	4.3	4.7	5.1	5.6	6.0	6.5	7.0	7.6	8.2	8.8	9.4	10.1	10.8	11.5	12.3	13.1
	4.1	4.0	4.2	4.6	5.0	5.4	5.9	6.4	6.9	7.5	8.0	8.6	9.3	9.9	10.6	11.3	12.0
	4.3	4.0	4.0	4.2	4.5	4.9	5.3	5.8	6.3	6.8	7.3	7.9	8.5	9.1	9.7	10.4	11.1
	4.5	4.0	4.0	4.1	4.2	4.4	4.8	5.3	5.7	6.2	6.7	7.2	7.8	8.3	8.9	9.6	10.2
	4.7	4.0	4.0	4.1	4.2	4.3	4.4	4.8	5.2	5.6	6.1	6.6	7.1	7.6	8.2	8.8	9.4
	4.9	4.0	4.0	4.1	4.1	4.3	4.4	4.5	4.7	5.1	5.6	6.0	6.5	7.0	7.5	8.1	8.6
1.2	2.9	9.8	10.4	11.0	11.6	12.1	12.8	13.5	14.1	14.8	15.6	-	-	-	-	-	-
	3.1	9.1	9.6	10.2	10.8	11.3	11.9	12.5	13.2	13.8	14.5	15.3	16.0	16.8	-	-	-
	3.3	8.5	9.0	9.5	10.0	10.6	11.1	11.7	12.3	12.9	13.6	14.2	15.0	15.7	-	-	-
	3.5	7.9	8.3	8.8	9.3	9.8	10.4	10.9	11.5	12.0	12.7	13.4	14.0	14.7	15.4	16.1	16.9
	3.7	7.3	7.8	8.2	8.7	9.1	9.6	10.2	10.7	11.3	11.9	12.5	13.1	13.8	14.4	15.2	15.9
	3.9	6.8	7.2	7.6	8.1	8.5	9.0	9.5	10.0	10.6	11.1	11.7	12.3	12.9	13.5	14.2	14.9
	4.1	6.3	6.7	7.1	7.5	8.0	8.4	8.9	9.4	9.9	10.4	11.0	11.5	12.1	12.7	13.3	14.0
	4.3	5.9	6.3	6.6	7.0	7.4	7.9	8.3	8.8	9.2	9.7	10.2	10.8	11.4	11.9	12.5	13.1
	4.5	5.5	5.9	6.2	6.6	6.9	7.4	7.8	8.2	8.7	9.1	9.6	10.1	10.7	11.2	11.7	12.3
	4.7	5.1	5.5	5.8	6.1	6.5	6.9	7.3	7.7	8.1	8.6	9.0	9.5	10.0	10.5	11.1	11.6
	4.9	4.8	5.1	5.4	5.8	6.1	6.5	6.8	7.2	7.6	8.0	8.5	8.9	9.4	9.9	10.4	10.9

Table 5.8.7-3 HBU Flat-Bed Configuration Minimum Cool Times -[redacted]Loading

Cobalt [g/kg]	Enr. [wt. %]	Burnup [GWd/MTU] 45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
0.4	2.9	7.1	8.0	9.1	10.3	11.6	12.9	14.2	15.6	17.0	18.4	-	-	-	-	-	-
	3.1	6.0	6.9	7.8	8.8	10.0	11.2	12.5	13.8	15.2	16.5	17.9	19.4	20.8	-	-	-
	3.3	5.2	5.8	6.7	7.5	8.5	9.7	10.9	12.1	13.4	14.8	16.1	17.5	18.9	-	-	-
	3.5	5.1	5.3	5.7	6.5	7.3	8.3	9.4	10.6	11.8	13.1	14.4	15.7	17.1	18.4	19.8	21.3
	3.7	5.1	5.3	5.4	5.6	6.3	7.1	8.0	9.1	10.2	11.5	12.7	14.0	15.3	16.7	18.0	19.4
	3.9	5.0	5.2	5.4	5.6	5.8	6.1	6.9	7.8	8.9	10.0	11.2	12.4	13.7	15.0	16.3	17.6
	4.1	5.0	5.1	5.3	5.5	5.7	5.9	6.0	6.8	7.6	8.6	9.7	10.9	12.1	13.4	14.6	15.9
	4.3	4.9	5.1	5.3	5.5	5.6	5.8	6.0	6.2	6.6	7.5	8.5	9.5	10.7	11.8	13.1	14.3
	4.5	4.9	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.4	6.7	7.3	8.3	9.3	10.4	11.6	12.8
	4.7	4.8	5.0	5.1	5.4	5.5	5.7	5.9	6.1	6.3	6.6	6.8	7.2	8.1	9.1	10.2	11.4
	4.9	4.8	4.9	5.1	5.3	5.5	5.7	5.8	6.0	6.2	6.5	6.7	7.0	7.3	8.0	9.0	10.0
0.8	2.9	10.6	11.4	12.2	13.1	14.0	15.1	16.2	17.4	18.6	19.8	-	-	-	-	-	-
	3.1	9.6	10.4	11.2	11.9	12.8	13.7	14.7	15.8	17.0	18.1	19.4	20.6	21.9	-	-	-
	3.3	8.8	9.4	10.2	10.9	11.7	12.5	13.4	14.4	15.5	16.6	17.7	19.0	20.2	-	-	-
	3.5	8.0	8.6	9.3	10.0	10.7	11.5	12.3	13.2	14.1	15.1	16.2	17.4	18.6	19.8	21.0	22.3
	3.7	7.5	7.8	8.5	9.1	9.8	10.5	11.3	12.0	12.9	13.8	14.8	15.9	17.1	18.2	19.4	20.6
	3.9	7.2	7.4	7.7	8.3	9.0	9.6	10.4	11.1	11.9	12.7	13.6	14.6	15.6	16.7	17.9	19.0
	4.1	6.9	7.1	7.3	7.6	8.2	8.8	9.5	10.2	10.9	11.7	12.5	13.4	14.3	15.4	16.4	17.6
	4.3	6.7	6.8	7.0	7.2	7.5	8.1	8.7	9.4	10.0	10.8	11.5	12.3	13.2	14.0	15.1	16.1
	4.5	6.4	6.6	6.7	6.9	7.1	7.4	8.0	8.6	9.2	9.9	10.6	11.4	12.1	13.0	13.8	14.9
	4.7	6.2	6.3	6.5	6.7	6.8	7.0	7.4	7.9	8.5	9.1	9.8	10.5	11.2	12.0	12.8	13.7
	4.9	5.9	6.1	6.3	6.4	6.6	6.8	6.9	7.3	7.8	8.4	9.0	9.7	10.4	11.1	11.8	12.6
1.2	2.9	12.9	13.6	14.3	15.1	15.9	16.7	17.7	18.7	19.8	20.9	-	-	-	-	-	-
	3.1	12.0	12.7	13.4	14.0	14.8	15.6	16.4	17.3	18.3	19.4	20.5	21.6	22.8	-	-	-
	3.3	11.4	11.8	12.5	13.1	13.8	14.6	15.3	16.1	17.0	17.9	19.0	20.1	21.2	-	-	-
	3.5	10.9	11.2	11.7	12.3	12.9	13.6	14.3	15.1	15.9	16.7	17.7	18.7	19.7	20.8	21.9	23.1
	3.7	10.5	10.8	11.1	11.5	12.1	12.8	13.4	14.1	14.9	15.6	16.5	17.4	18.3	19.4	20.5	21.6
	3.9	10.3	10.4	10.7	11.0	11.4	11.9	12.6	13.3	13.9	14.7	15.4	16.2	17.1	18.0	19.1	20.1
	4.1	10.0	10.1	10.3	10.6	10.8	11.2	11.8	12.4	13.1	13.8	14.5	15.2	16.0	16.9	17.8	18.8
	4.3	9.7	9.9	10.1	10.2	10.5	10.7	11.1	11.7	12.3	12.9	13.6	14.3	15.0	15.8	16.6	17.5
	4.5	9.5	9.7	9.8	10.0	10.1	10.4	10.6	11.0	11.6	12.1	12.8	13.5	14.1	14.9	15.6	16.4
	4.7	9.2	9.4	9.6	9.7	9.9	10.1	10.3	10.5	10.9	11.5	12.0	12.7	13.3	14.0	14.7	15.4
	4.9	9.0	9.2	9.4	9.5	9.7	9.8	10.0	10.2	10.4	10.8	11.4	11.9	12.6	13.2	13.8	14.5

Table 5.8.7-4 HBU Flat-Bed Configuration Bounding Source Terms – Normal Conditions

	Cobalt	Radial Surface		Radial 2 Meter		Axial Top Surface		Axial Bottom Surface		
	Content (g/kg)	kW/Cask	Source	kW/Cask	Source	kW/Cask	Source	mrem/hr	kW/Cask	Source
[redacted]	0.4	16.2	55b31e8.3y	23.7	49b31e4.1y	23.7	49b31e4.1y	20.8	23.7	49b31e4.1y
	0.8	16.0	54b39e7.5y	14.8	60b35e13.1y	23.3	51b47e4.0y	21.2	23.3	51b47e4.0y
	1.2	12.6	50b31e10.7y	14.0	60b35e15.0y	18.7	45b49e4.3y	20.0	18.7	45b49e4.3y
	0.4	19.2	52b33e6.7y	16.9	60b35e13.0y	23.5	46b29e4.4y	24.0	23.5	46b29e4.4y
	0.8	17.5	51b39e7.0y	15.9	60b35e15.3y	23.1	46b41e4.2y	25.8	23.5	45b41e4.0y
	1.2	16.2	47b43e6.6y	15.2	60b35e16.9y	19.2	45b49e4.8y	24.3	19.2	45b49e4.8y
	0.4	19.3	53b37e10.2y	17.1	60b35e21.3y	23.9	45b33e5.2y	20.8	23.9	45b33e5.2y
	0.8	17.8	60b39e19.0y	16.8	60b35e22.3y	21.3	51b49e6.9y	19.6	21.3	51b49e6.9y
	1.2	16.5	59b35e21.9y	16.5	60b35e23.1y	18.6	54b49e10.8y	18.6	18.6	54b49e10.8y

Table 5.8.7-5 HBU Flat-Bed Configuration Bounding Source Terms – Accident Conditions

	Cobalt	Radial Surface		Axial Top Surface		Axial Bottom Surface	
	Content (g/kg)	kW/Cask	Source	kW/Cask	Source	kW/Cask	Source
[redacted]	0.4	16.3	60b35e10.3y	16.3	60b35e10.3y	16.3	60b35e10.3y
	0.8	14.8	60b35e13.1y	14.8	60b35e13.1y	14.8	60b35e13.1y
	1.2	14.0	60b35e15.0y	14.0	60b35e15.0y	14.0	60b35e15.0y
	0.4	16.9	60b35e13.0y	16.9	60b35e13.0y	16.9	60b35e13.0y
	0.8	15.9	60b35e15.3y	15.9	60b35e15.3y	15.9	60b35e15.3y
	1.2	15.2	60b35e16.9y	15.2	60b35e16.9y	15.2	60b35e16.9y
	0.4	17.1	60b35e21.3y	17.1	60b35e21.3y	17.1	60b35e21.3y
	0.8	16.8	60b35e22.3y	16.8	60b35e22.3y	16.8	60b35e22.3y
	1.2	16.5	60b35e23.1y	16.5	60b35e23.1y	16.5	60b35e23.1y

Table 5.8.7-6 HBU Flat-Bed Configuration Maximum Dose Rates for Normal Conditions – [redacted] Loading

Detector		Cobalt content						Limit
		0.4 g/kg		0.8 g/kg		1.2 g/kg		
		[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]
Surface	Rad	199.8	0.6%	199.7	0.6%	199.1	0.7%	1000
Surface of Vehicle	Rad	59.8	0.9%	60.9	0.8%	60.6	0.8%	200
1m (TI)	Rad	23.1	1.3%	23.0	1.2%	22.5	1.2%	--
2m + Vehicle	Rad	8.0	3.0%	6.6	3.2%	6.4	3.2%	10
Surface	Top	8.0	2.5%	8.5	1.7%	8.6	1.4%	200
1m (TI)	Top	3.4	9.3%	3.5	5.4%	3.4	2.8%	--
Surface	Bot	20.7	1.5%	21.2	1.3%	19.9	1.3%	200
1m (TI)	Bot	7.7	2.8%	8.1	2.6%	7.8	2.9%	-

Table 5.8.7-7 HBU Flat-Bed Configuration Maximum 1m Dose Rates for Accident Conditions – [redacted] Loading

Detector	Cobalt content 0.4 g/kg [mrem/hr]	FSD	0.8 g/kg [mrem/hr]	FSD	1.2 g/kg [mrem/hr]	FSD	Limit [mrem/hr]
Rad	658.8	0.8%	589.4	0.8%	544.9	0.7%	1000
Top	79.1	7.7%	72.0	7.6%	67.7	7.6%	
Bot	213.0	3.5%	192.8	3.5%	180.4	3.5%	

Table 5.8.7-8 HBU Flat-Bed Configuration Maximum Dose Rates for Normal Conditions – [redacted] Loading

Detector		Cobalt content 0.4 g/kg [mrem/hr]	FSD	0.8 g/kg [mrem/hr]	FSD	1.2 g/kg [mrem/hr]	FSD	Limit [mrem/hr]
Surface	Rad	199.8	0.6%	200.0	0.7%	199.6	0.8%	1000
Surface of Vehicle	Rad	60.9	0.8%	62.3	0.9%	63.3	1.1%	200
1m (TI)	Rad	23.2	1.2%	23.2	1.2%	23.2	1.4%	--
2m + Vehicle	Rad	7.1	3.6%	7.2	3.5%	6.8	3.5%	10
Surface	Top	9.2	2.1%	10.3	1.4%	10.4	1.4%	200
1m (TI)	Top	3.5	4.1%	3.8	2.7%	3.8	2.7%	--
Surface	Bot	24.0	1.3%	25.8	1.2%	24.2	1.3%	200
1m (TI)	Bot	8.1	2.9%	8.9	2.4%	8.4	2.6%	-

Table 5.8.7-9 HBU Flat-Bed Configuration Maximum 1m Dose Rates for Accident Conditions – [redacted] Loading

Detector	Cobalt content 0.4 g/kg [mrem/hr]	FSD	0.8 g/kg [mrem/hr]	FSD	1.2 g/kg [mrem/hr]	FSD	Limit [mrem/hr]
Rad	648.0	0.8%	593.4	0.8%	558.8	0.8%	1000
Top	88.2	6.2%	81.6	6.2%	77.4	6.2%	
Bot	232.5	3.5%	214.9	3.5%	203.6	3.5%	

Table 5.8.7-10 HBU Flat-Bed Configuration Maximum Dose Rates for Normal Conditions – [redacted] Loading

Detector		Cobalt content						Limit
		0.4 g/kg		0.8 g/kg		1.2 g/kg		
		[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]
Surface	Rad	199.8	0.6%	199.7	0.6%	199.9	0.6%	1000
Surface of Vehicle	Rad	62.6	0.8%	61.3	0.9%	61.5	0.9%	200
1m (TI)	Rad	24.9	1.1%	24.1	1.2%	24.2	1.2%	--
2m + Vehicle	Rad	6.5	3.9%	6.3	3.9%	6.1	3.9%	10
Surface	Top	8.4	1.7%	8.5	1.5%	8.3	1.5%	200
1m (TI)	Top	3.3	2.6%	3.4	2.7%	3.3	2.9%	--
Surface	Bot	20.7	1.5%	19.6	1.4%	18.5	1.5%	200
1m (TI)	Bot	7.5	2.8%	7.2	2.7%	6.8	2.9%	-

Table 5.8.7-11 HBU Flat-Bed Configuration Maximum 1m Dose Rates for Accident Conditions – [redacted] Loading

Detector	Cobalt content						Limit
	0.4 g/kg		0.8 g/kg		1.2 g/kg		
	[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]	FSD	[mrem/hr]
Rad	726.5	0.8%	700.5	0.8%	680.5	0.8%	1000
Top	90.05	6.2%	87.3	6.2%	85.2	6.2%	
Bot	210.5	3.5%	203.9	3.5%	198.8	3.5%	

5.8.8 Flat Bed with Shield Ring Configuration Results – STC-HBU

Minimum cool times for the flat bed configuration are also computed crediting the added shielding provided by the shield ring located between the neutron shield and the upper impact limiter. Minimum cool times for this configuration are shown in Tables 5.8.8-1 through 5.8.8-3. To provide system margin, a limit of 190 mrem/hr is applied at the surface. Bounding dose rates are summarized in Tables 5.8.8-4 through 5.8.8-6.

Normal surface and 2-meter dose rate and uncertainty plots for the [redacted] loading are shown in Figure 5.8.8-1 through 5.8.8-4.

Figure 5.8.8-1 HBU Flat Bed with Shield Ring Configuration [redacted] Loading Radial Surface Dose Rate [mrem/hr] Mesh – Nrm

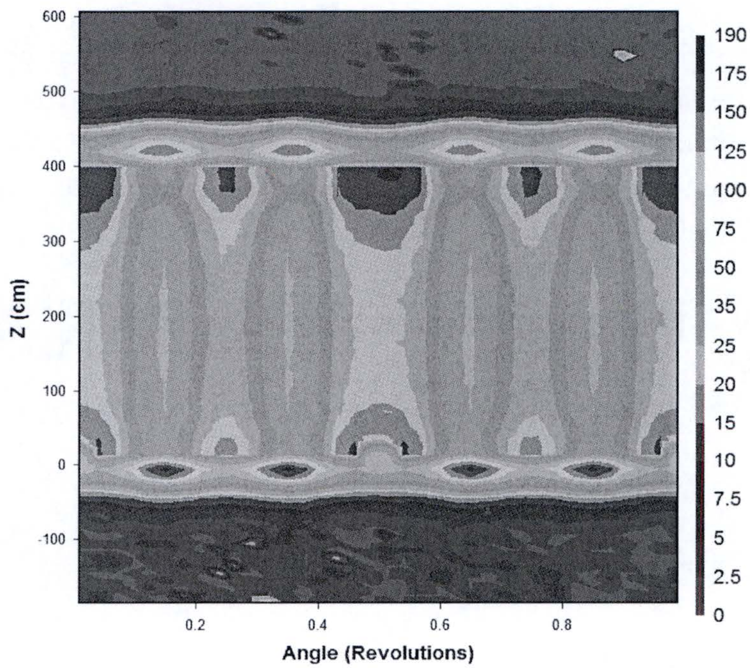

Figure 5.8.8-2 HBU Flat Bed with Shield Ring Configuration [redacted] Loading Radial Surface Dose Rate Mesh FSDs – Nrm

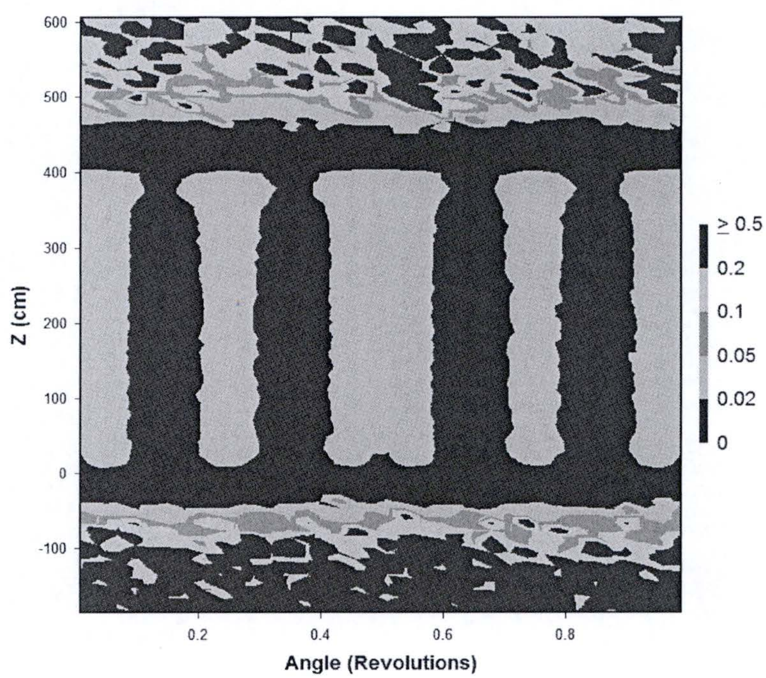

Figure 5.8.8-3 HBU Flat Bed with Shield Ring Configuration [redacted] Loading Side 2m + Vehicle Dose Rate [mrem/hr] Mesh – Nrm

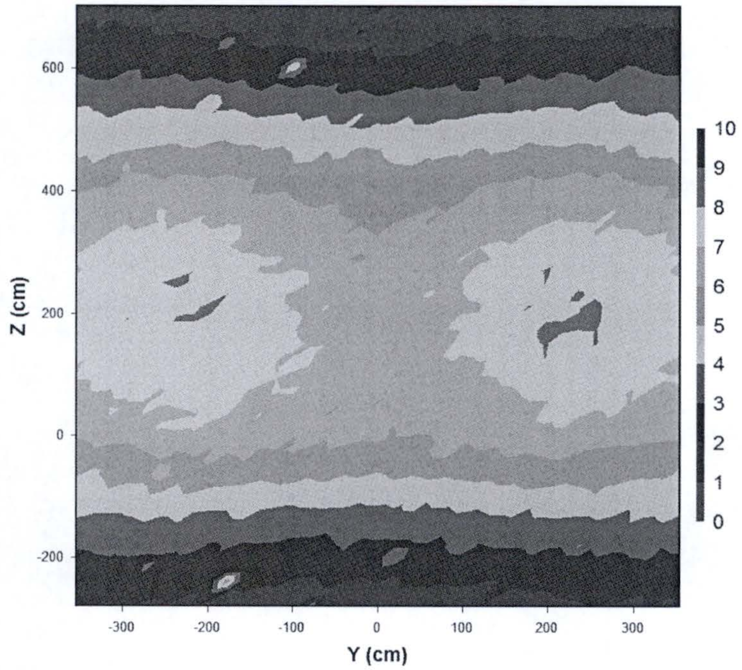

Figure 5.8.8-4 HBU Flat Bed with Shield Ring Configuration [redacted] Loading Side 2m + Vehicle Dose Rate Mesh FSDs– Nrm

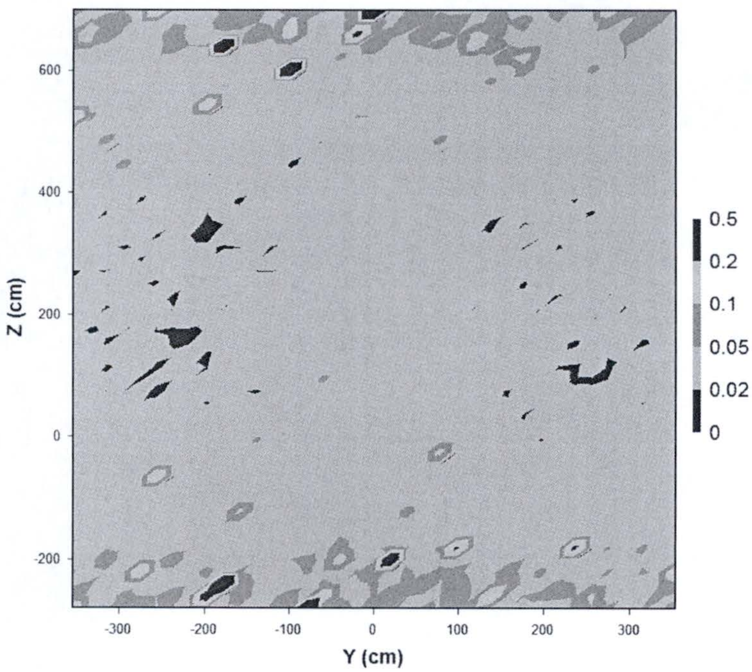

Table 5.8.8-1 HBU Flat Bed with Shield Ring Configuration Minimum Cool Times - [redacted] Loading

Enr.	Burnup [GWd/MTU]														
[wt. %]	45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55	55<B≤56	56<B≤57	57<B≤58	58<B≤59	59<B≤60
2.9 ≤ E < 3.1	4 0	4.0	4.5	5.0	5.7	6.3	6 9	7.6	8.4	-	-	-	-	-	-
3.1 ≤ E < 3.3	4 0	4.0	4.0	4.3	4.8	5.4	6 0	6.7	7.4	8.1	8.8	9.6	-	-	-
3.3 ≤ E < 3.5	4 0	4.0	4.0	4.1	4.2	4.7	5 2	5.8	6.4	7.1	7.8	8.5	-	-	-
3.5 ≤ E < 3.7	4 0	4.0	4.0	4.0	4.1	4.2	4 5	5.0	5.6	6.2	6.8	7.5	8.2	9 0	9.8
3.7 ≤ E < 3.9	4 0	4.0	4.0	4.0	4.1	4.2	4 3	4.4	4 8	5.4	6.0	6.6	7.3	8 0	8.7
3.9 ≤ E < 4.1	4 0	4.0	4.0	4.0	4.0	4.1	4 2	4.3	4 5	4.7	5.2	5.8	6.4	7.1	7.7
4.1 ≤ E < 4.3	4 0	4.0	4.0	4.0	4.0	4.1	4 2	4.3	4.4	4.5	4.6	5.1	5.6	6 2	6.9
4.3 ≤ E < 4.5	4 0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.9	5 5	6.0
4.5 ≤ E < 4.7	4 0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4 3	4.4	4.5	4.6	4.8	4 9	5.3
4.7 ≤ E < 4.9	4 0	4.0	4.0	4.0	4.0	4.0	4.1	4.2	4 3	4.4	4.5	4.6	4.7	4 8	5.0
4 9 ≤ E	4 0	4.0	4.0	4.0	4.0	4.0	4 0	4.1	4 2	4.3	4.4	4.5	4.6	4 8	4.9

Table 5.8.8-2 HBU Flat Bed with Shield Ring Configuration Minimum Cool Times - [redacted] Loading

Enr.	Burnup [GWd/MTU]														
[wt. %]	45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55	55<B≤56	56<B≤57	57<B≤58	58<B≤59	59<B≤60
2.9 ≤ E < 3.1	4.4	4.9	5.5	6.1	6.8	7.6	8 3	9.1	10.0	-	-	-	-	-	-
3.1 ≤ E < 3.3	4.4	4.5	4.7	5.3	5.9	6.6	7 3	8.0	8 8	9.7	10.6	11 5	-	-	-
3.3 ≤ E < 3.5	4 3	4.4	4.5	4.7	5.1	5.7	6 3	7.0	7 8	8.6	9.4	10 2	-	-	-
3.5 ≤ E < 3.7	4 2	4.4	4.5	4.6	4.7	4.9	5 5	6.1	6 8	7.5	8.3	9.1	9.9	10.8	11.7
3.7 ≤ E < 3.9	4 2	4.3	4.4	4.5	4.7	4.8	4 9	5.3	5 9	6.6	7.3	8.0	8.8	9.6	10.5
3.9 ≤ E < 4.1	4.1	4.3	4.4	4.5	4.6	4.8	4 9	5.0	5 2	5.7	6.4	7.1	7.8	8.6	9.4
4.1 ≤ E < 4.3	4.1	4.2	4.3	4.4	4.5	4.7	4 8	5.0	5.1	5.3	5.6	6.2	6.9	7.6	8.3
4.3 ≤ E < 4.5	4 0	4.2	4.3	4.4	4.5	4.6	4 8	4.9	5 0	5.2	5.4	5.6	6.0	6.7	7.4
4.5 ≤ E < 4.7	4 0	4.1	4.2	4.4	4.5	4.6	4.7	4.8	5 0	5.1	5.3	5.5	5.7	5 9	6.5
4.7 ≤ E < 4.9	4 0	4.1	4.2	4.3	4.4	4.5	4.7	4.8	4 9	5.1	5.2	5.4	5.6	5.7	5.9
4 9 ≤ E	4 0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4 9	5.0	5.1	5.4	5.5	5.7	5.8

Table 5.8.8-3 HBU Flat Bed with Shield Ring Configuration Minimum Cool Times - [redacted] Loading

Enr.	Burnup [GWd/MTU]														
[wt. %]	45<B≤46	46<B≤47	47<B≤48	48<B≤49	49<B≤50	50<B≤51	51<B≤52	52<B≤53	53<B≤54	54<B≤55	55<B≤56	56<B≤57	57<B≤58	58<B≤59	59<B≤60
2.9 ≤ E < 3.1	7.4	8.2	9.1	10 0	11.0	12 0	13.1	14.3	15.5	-	-	-	-	-	-
3.1 ≤ E < 3.3	6.4	7.1	7.9	8.8	9.7	10.7	11.6	12.7	13.9	15.1	16.3	17.7	-	-	-
3.3 ≤ E < 3.5	5 5	6.2	6.9	7.7	8.5	9.4	10.4	11.3	12.4	13.5	14.7	15 9	-	-	-
3.5 ≤ E < 3.7	5.4	5.6	6.0	6.7	7.5	8.3	9 2	10.1	11.0	12.0	13.2	14 3	15.5	16.8	18.1
3.7 ≤ E < 3.9	5 3	5.5	5.7	5.9	6.6	7.3	8.1	8.9	9 8	10.8	11.7	12 8	13.9	15.2	16.4
3.9 ≤ E < 4.1	5 2	5.4	5.6	5.8	6.0	6.4	7.1	7.9	8.7	9.6	10.5	11 5	12.5	13.6	14.8
4.1 ≤ E < 4.3	5 2	5.4	5.6	5.7	5.9	6.1	6.4	7.0	7.7	8.5	9.4	10 3	11.2	12.2	13.3
4.3 ≤ E < 4.5	5.1	5.3	5.5	5.7	5.9	6.0	6 3	6.6	6 8	7.6	8.3	9.2	10.0	11.0	11.9
4.5 ≤ E < 4.7	5 0	5.3	5.4	5.6	5.8	6.0	6 2	6.5	6.7	7.0	7.4	8.2	9.0	9 8	10.8
4.7 ≤ E < 4.9	5 0	5.2	5.4	5.6	5.7	5.9	6.1	6.4	6.6	6.9	7.2	7.5	8.0	8 8	9.7
4 9 ≤ E	5 0	5.1	5.3	5.5	5.7	5.9	6 0	6.3	6.6	6.8	7.0	7.4	7.7	8 0	8.7

Table 5.8.8-4 HBU Flat Bed with Shield Ring Configuration Bounding Dose Rates – [redacted] Loading

Dose Rate Location	Dose Rate [mrem/hr]	Source Term	Cask Decay Heat [kW]
Normal Condition Radial Surface	190.0	50b31e4.8y	21.0
Normal Condition Radial 2m	8.3	47b29e4.0y	23.5
Normal Condition Top Surface	14.6	47b29e4.0y	23.5
Normal Condition Bottom Surface	33.7	47b29e4.0y	23.5
Accident Condition Radial Surface	1,146.8*	60b35e9.8y	16.7
Accident Condition Top Surface	146.7	60b35e9.8y	16.7
Accident Condition Bottom Surface	341.5	60b35e9.8y	16.7

* At 9 years cool time, the maximum 1 meter dose rate is 704.1 mrem/hr.

Table 5.8.8-5 HBU Flat Bed with Shield Ring Configuration Bounding Dose Rates – [redacted] Loading

Dose Rate Location	Dose Rate [mrem/hr]	Source Term	Cask Decay Heat [kW]
Normal Condition Radial Surface	190.0	55b39e5.7y	22.7
Normal Condition Radial 2m	8.3	60b35e11.7y	17.7
Normal Condition Top Surface	17.6	46b29e4.4y	23.7
Normal Condition Bottom Surface	40.7	46b29e4.4y	23.7
Accident Condition Radial Surface	1,059.7**	60b35e11.7y	17.7
Accident Condition Top Surface	135.1	60b35e11.7y	17.7
Accident Condition Bottom Surface	314.6	60b35e11.7y	17.7

**At 10 years cool time, the maximum 1 meter dose rate is 673.6 mrem/hr.

Table 5.8.8-6 HBU Flat Bed with Shield Ring Configuration Bounding Dose Rates – [redacted] Loading

Dose Rate Location	Dose Rate [mrem/hr]	Source Term	Cask Decay Heat [kW]
Normal Condition Radial Surface	190.0	50b33e8.5y	19.8
Normal Condition Radial 2m	7.4	60b35e18.1y	18.5
Normal Condition Top Surface	16.0	46b33e5.5y	23.6
Normal Condition Bottom Surface	35.7	46b33e5.5y	23.6
Accident Condition Radial Surface	823.1	60b35e18.1y	18.5
Accident Condition Top Surface	103.6	60b35e18.1y	18.5
Accident Condition Bottom Surface	241.7	60b35e18.1y	18.5

5.8.9 Sample Input Files – STC-HBU

Sample input files are included here. Figure 5.8.9-1 shows the MCNP input file for the [redacted] normal condition model radial analysis for the fuel gamma response. Figure 5.8.9-2 shows the MCNP input file for the [redacted] accident condition model radial analysis for the fuel neutron response. Figure 5.8.9-3 shows the SAS2H input file for fuel and hardware source terms with 49 GWd/MTU burnup, 2.7 wt. % initial fuel enrichment, and cool time range of 18 to 40 years.

Figure 5.8.9-1 STC-HBU MCNP Input File for [redacted] Normal Conditions Radial Biasing – Fuel Gamma Response from Energy Group 7

[redacted]

5.9 Shielding Evaluation – Directly Loaded Low Burnup Fuel, Flat Bed with Shield Ring Configuration

Using the same methodology discussed in Section 5.8.8, cool times and dose rates are computed for 26 directly loaded low burnup fuel (maximum burnup of 45 GWd/MTU) in the flat bed with shield ring configuration. Cool times and dose rates are based on normal conditions surface and 2-meter dose rate limits of 190 and 9.5 mrem/hr, respectively.

Cool times are shown in Table 5.9-1. Bounding dose rates are shown in Table 5.9-2.

Normal surface and 2-meter dose rate and uncertainty plots are shown in Figures 5.9-1 through 5.9-4.

Figure 5.9-1 LBU Flat Bed with Shield Ring Configuration Radial Surface Dose Rate [mrem/hr] Mesh – Nrm

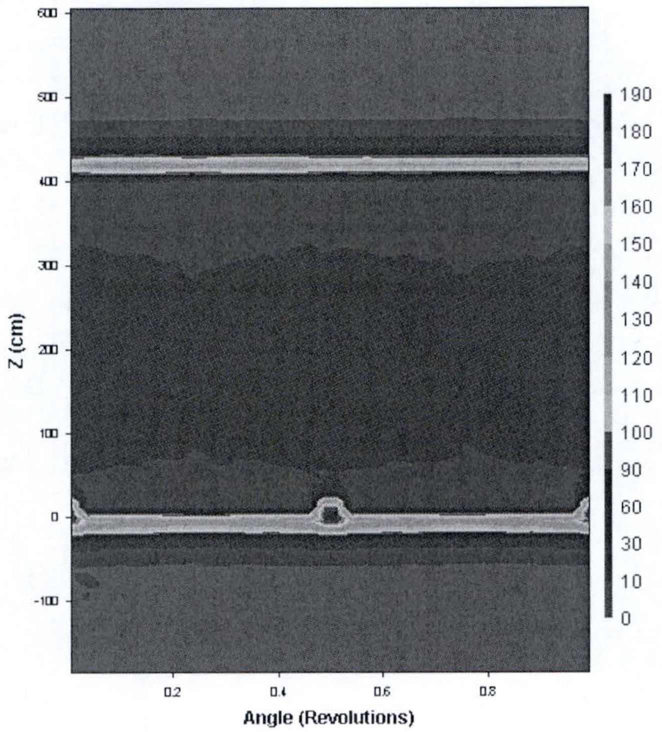

Figure 5.9-2 LBU Flat Bed with Shield Ring Configuration Radial Surface Dose Rate Mesh FSDs – Nrm

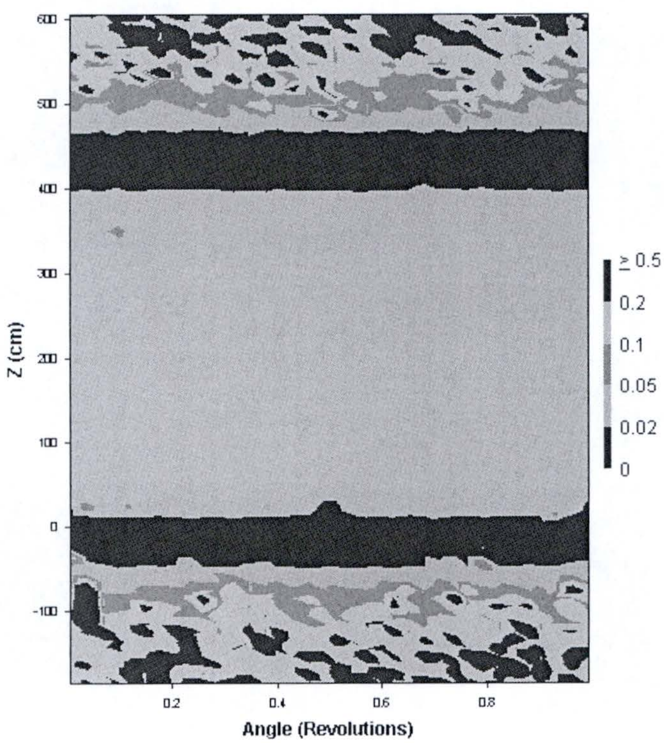

Figure 5.9-3 LBU Flat Bed with Shield Ring Configuration Side 2m + Vehicle Dose Rate [mrem/hr] Mesh – Nrm

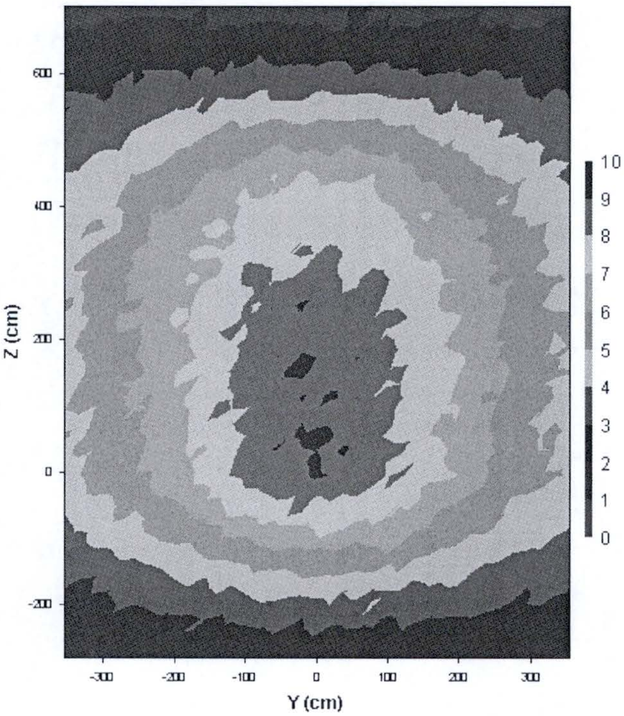

Figure 5.9-4 LBU Flat Bed with Shield Ring Configuration Side 2m + Vehicle Dose Rate Mesh FSDs– Nrm

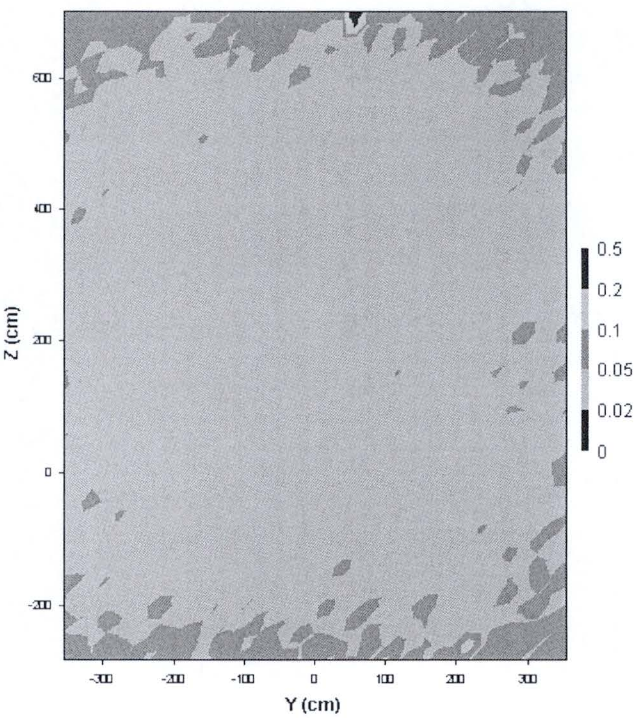

Table 5.9-1 LBU Flat Bed with Shield Ring Configuration Minimum Cool Times

Enr.	Burnup [GWd/MTU]													
[wt. %]	B≤10	10<B≤15	15<B≤20	20<B≤25	25<B≤30	30<B≤32.5	32.5<B≤35	35<B≤37.5	37.5<B≤40	40<B≤41	41<B≤42	42<B≤43	43<B≤44	44<B≤45
1.7 ≤ E < 1.9	4.0	4.0	4.0	4.5	5.9	7.2	9.8	-	-	-	-	-	-	-
1.9 ≤ E < 2.1	4.0	4.0	4.0	4.4	5.5	6.4	8.3	11.4	15.3	-	-	-	-	-
2.1 ≤ E < 2.3	4.0	4.0	4.0	4.3	5.2	5.9	7.2	9.7	13.2	-	-	-	-	-
2.3 ≤ E < 2.5	4.0	4.0	4.0	4.2	4.9	5.6	6.6	8.4	11.4	12.8	14.3	15.9	17.6	19.2
2.5 ≤ E < 2.7	4.0	4.0	4.0	4.1	4.8	5.3	6.0	7.4	9.8	11.1	12.5	13.9	15.5	17.1
2.7 ≤ E < 2.9	4.0	4.0	4.0	4.0	4.7	5.0	5.7	6.7	8.5	9.6	10.8	12.1	13.6	15.1
2.9 ≤ E < 3.1	4.0	4.0	4.0	4.0	4.6	5.0	5.6	6.2	7.6	8.4	9.4	10.6	11.9	13.3
3.1 ≤ E < 3.3	4.0	4.0	4.0	4.0	4.6	5.0	5.5	6.0	6.9	7.6	8.3	9.2	10.4	11.7
3.3 ≤ E < 3.5	4.0	4.0	4.0	4.0	4.6	4.9	5.4	6.0	6.7	7.0	7.5	8.2	9.1	10.2
3.5 ≤ E < 3.7	4.0	4.0	4.0	4.0	4.5	4.9	5.4	5.9	6.6	6.9	7.2	7.6	8.2	9.0
3.7 ≤ E < 3.9	4.0	4.0	4.0	4.0	4.5	4.9	5.3	5.9	6.5	6.8	7.1	7.5	7.9	8.4
3.9 ≤ E < 4.1	4.0	4.0	4.0	4.0	4.5	4.8	5.3	5.8	6.5	6.8	7.0	7.4	7.8	8.3
4.1 ≤ E < 4.3	4.0	4.0	4.0	4.0	4.5	4.8	5.3	5.8	6.4	6.7	7.0	7.4	7.7	8.1
4.3 ≤ E < 4.5	4.0	4.0	4.0	4.0	4.4	4.8	5.2	5.8	6.4	6.6	6.9	7.3	7.7	8.1
4.5 ≤ E < 4.7	4.0	4.0	4.0	4.0	4.4	4.7	5.2	5.7	6.3	6.6	6.9	7.2	7.6	8.0
4.7 ≤ E < 4.9	4.0	4.0	4.0	4.0	4.4	4.7	5.1	5.7	6.2	6.5	6.8	7.1	7.5	7.9
4.9 ≤ E	4.0	4.0	4.0	4.0	4.4	4.7	5.1	5.6	6.2	6.5	6.8	7.1	7.5	7.8

Table 5.9-2 LBU Flat Bed with Shield Ring Configuration Bounding Dose Rates

Dose Rate Location	Dose Rate [mrem/hr]	Source Term	Cask Decay Heat [kW]
Normal Condition Radial Surface	188.7	45b23e19.2y	16.5
Normal Condition Radial 2m	9.5	45b23e19.2y	16.5
Normal Condition Top Surface	15.0	30b17e5.9y	18.3
Normal Condition Bottom Surface	28.2	30b17e5.9y	18.3
Accident Condition Radial 1m	614.1	45b23e19.2y	16.5
Accident Condition Top 1m	81.2	45b23e19.2y	16.5
Accident Condition Bottom 1m	167.7	45b23e19.2y	16.5

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Table 7-1 Torque Table

Component	No. Used	Fastener[1]	Torque Value[2]
Outer Lid Bolt	36	1-8 - UNC Socket Head Cap Screw	550 ± 50 ft.-lb (746 ± 68 N-m)
Inner Lid Bolt	42	1 ½ - 8 UN-2A Socket Head Cap Screw	2,540 ± 200 ft-lb (3,443 ± 271 N-m)
Port Cover Bolt	6	⅜ - 16 UNC Socket Head Cap Screw	140 ± 10 in-lb (16 ± 1 N-m)
Coverplate Bolt	8	½ - 13 UNC Socket Head Cap Screw	300 ± 20 in-lb (34 ± 2 N-m)
Test Plug	1	Part No. 423-803-13	30 ± 3 ft-lb (41 ± 4 N-m)
Test Plug	2	Part No. 423-806-3	70 ± 5 in-lb (8 ± 0.6 N-m)
Test Plug	2	Part No. 423-807-8	70 ± 5 in-lb (8 ± 0.6 N-m)
Redwood Impact Limiter Retaining Rods	32	Part No. 423-811-7	75 ± 5 ft-lb (102 ± 7 N-m)
Balsa Impact Limiter Retaining Rods	32	Part No. 423-859-1	75 ± 5 ft-lb (102 ± 7 N-m)
Impact Limiter Nut	32	1 - 8 UNC – 2B Heavy Hex Nut	35 ± 2 ft-lb (47 ± 3 N-m)
Impact Limiter Jam Nut	32	1 - 8 UN - 2B Heavy Hex Nut	75 ± 5 ft-lb (102 ± 7 N-m)
Adapter Ring	3	1 ½ -8UN-2A Socket Head Cap Screw	100 ± 20 ft-lb (136 ± 27 N-m)
Shield Ring Upper and Lower Sectors (3)	8	1 - 8UNC Socket Head Cap Screw	100 ± 20 ft-lb (136 ± 27 N-m)
Shield Ring Side Sectors (3)	8	½ - 13 UNC Hex Bolt	20 ± 5 ft-lb (27 ± 7 N-m)

1 Torque values for fasteners not shown are provided on the appropriate license drawing in Section 1.3.2.

2 All threaded fasteners shall be lightly lubricated using Nuclear Grade Pure Nickel NEVER-SEEZ® or equivalent.

3. Shield Ring Assembly is an optional item used at the discretion of the User for direct loaded fuel.

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7.1 Outline of Procedures for Receipt and Loading the Cask

The following receipt and loading procedures are based on an acceptable cask receipt inspection for first time loading with spent fuel. For casks previously loaded and transported, the receiving inspections will require performance of radiation and removable contamination surveys of the empty cask and vehicle in accordance with 10 CFR 71 and 49 CFR 173 in the U.S. Similar requirements are contained in IAEA SSR-6.

7.1.1 Receiving Inspection

1. Perform radiation and removable contamination surveys in accordance with 49 CFR 173.441 and 173.443 requirements.
2. Move the transport vehicle with the cask to the cask receiving area.
3. Secure the transport vehicle. Remove the personnel barrier hold down bolts from both sides of the personnel barrier. Using the lifting sling, lift the personnel barrier off of the cask and store it in a designated area.
4. Visually inspect the NAC-STC while secured to the transport vehicle in the horizontal orientation for any signs of damage.
5. Attach slings to the top impact limiter lifting points, remove impact limiter lock wires, impact limiter jam nuts, impact limiter nuts and retaining rods. Remove impact limiter and store upright. Repeat operation for the bottom impact limiter.
6. Release the tiedown assembly from the front support by removing the front tiedown bolts and lock washers.
7. Attach a sling to the tiedown assembly lifting eyes and remove the tiedown assembly from the transport vehicle.
8. If installed, then remove the optional shield ring side sectors by attaching a sling to the left-hand side sector, remove the lock wires, hex bolts from the side sector piece and remove the left-hand sector piece from the shield ring assembly. Repeat operation for the right-hand side sector piece.
9. If installed, then attach a sling to the top sector piece of the optional shield ring assembly release the top sector of the shield ring assembly by removing the socket head screws and remove the top sector from the upper forging.
10. Attach the cask lifting yoke to a crane hook with the appropriate load rating. Engage the two yoke arms with the lifting trunnions at the top (front) end of the cask. Rotate/lift the cask to the vertical orientation and raise the cask off of the blocks of the rear support structure of the transport vehicle. Place the cask in the vertical orientation in a

decontamination area or other suitable location identified by the user. Disengage the cask lifting yoke from the lifting trunnions.

7.1.2 Preparation of Cask for Loading

The loading procedures are based on the assumption that the cask is being prepared for first time fuel loading following fabrication, or that the scheduled annual maintenance required by the Certificate of Compliance has been successfully completed within the previous 12 months. If the cask has been used previously, at the start of this procedure, the cask is assumed to be externally decontaminated, empty of fuel contents, and sitting in the decontamination area, or in another location convenient for preparing the cask.

There are two (2) loading options for the NAC-STC. Each requires different preparation steps. The first is direct loading of fuel assemblies into a fuel basket installed in the cask, which is typically performed under water in the spent fuel pool cask loading area. The second is dry loading of a welded transportable storage canister that is already loaded with spent fuel assemblies, Reconfigured Fuel Assemblies, damaged fuel in damaged fuel cans or Greater Than Class C (GTCC) waste, or HLW Overpack. Dry loading of the canister into the cask is performed in the cask receiving area, or another convenient location established by the user, using a transfer cask system. This section presents the generic procedures used to prepare the cask for loading for either wet direct fuel loading or dry canister loading.

7.1.2.1 Preparation for Direct Fuel Loading (Uncanistered)

This procedure presents the steps necessary to prepare the cask for under water direct loading of fuel into a basket contained in the NAC-STC cask. This procedure may be modified to accommodate the dry direct loading of fuel in a hot cell.

1. Install appropriate work platforms/scaffolding to allow access to the top of the cask.
2. Detorque in reverse torquing sequence and remove the outer lid bolts. Install the two outer lid alignment pins.
3. Install lifting eyes in the outer lid lifting holes and attach the outer lid lifting sling to the outer lid and overhead crane. Remove the outer lid and place it aside in a temporary storage area. When setting the outer lid down, protect the O-ring and the O-ring groove of the lid from damage. Remove the outer lid alignment pins. Decontaminate the surface of the inner lid and top forging as required. At a convenient time, if a metallic O-ring is used, remove

and replace the metallic O-ring in the outer lid. If a Viton O-ring is used, inspect the O-ring and replace as necessary.

4. Detorque drain and vent coverplate bolts and remove the drain port and the vent port coverplates from the inner lid. Store in temporary storage area.
5. Connect demineralized water supply to drain port quick-disconnect. Connect vent hose to vent port quick-disconnect. Fill cask using demineralized water supply until water discharges from the vent hose. Ensure that the vent hose discharges into an appropriate rad waste handling system, as the cask interior may contain residual contamination.
6. Detorque and remove two inner lid bolts and install the two inner lid alignment pins at locations marked on the inner lid.
7. Detorque and remove the remaining inner lid bolts. Clean and visually inspect the outer lid bolts, inner lid bolts, and coverplate bolts for damage or excessive wear. Remove the vent and drain port Snap-tite quick disconnects valved couplings (QDVC) to allow cask cavity to vent following fuel loading in the spent fuel pool.
8. Attach the lifting eyes to the inner lid. Install the inner lid lifting sling to the eyes in the inner lid and to the cask handling crane.
9. Remove the cask inner lid and store the inner lid in a temporary storage area.
10. When setting the inner lid down, ensure that the O-rings and O-ring grooves of the inner lid are protected from damage. Decontaminate inner lid, as necessary. At a convenient time, if metallic O-rings are used, remove and replace the metallic O-rings in the inner lid and in the vent and drain port coverplates. If Viton O-rings are used, inspect the O-rings immediately and replace as necessary.

    Note: If the inner Viton O-ring containment seal is replaced for a NAC-STC to be loaded with HBU spent fuel, it will be necessary to perform the inner lid maintenance leakage test prior to placement of the cask in the spent fuel pool. Procedure sequence to perform the inner lid maintenance leakage test shall be as follows:

    a. Following inner Viton O-ring replacement dry all inner lid seating surfaces and reinstall inner lid on the cask using the inner lid alignment pins to assist in proper lid seating and orientation. Visually verify proper lid position.
    b. Remove the inner lid alignment pins and install the inner lid bolts and torque all of the bolts to the torque value specified in Table 7-1. The bolt torquing sequence is shown on the inner lid.
    c. Re-install the QDVCs in the vent and drain port opening and torque to the value specified in Table 7-1.

d. Drain approximately 50 gallons from the cask cavity by connecting a helium (99.9% minimum purity) supply to the vent port quick-disconnect (located in the inner lid) and a drain line to the drain port quick disconnect. Purge the water from the cask by pressurizing to 35 to 40 psig. Following removal of approximately 50 gallons, turn the helium supply off and maintain the helium pressure above the cavity water.

e. Remove the inner lid interseal test port plug and connect the helium Mass Spectrometer Leak Detector (MSLD) to the interseal test port to verify the new inner lid inner Viton O-ring leakage rate is $\leq 2.0 \times 10^{-7}$ cm^3/sec (helium) with a minimum test sensitivity of 1.0×10^{-7} cm^3/sec (helium).

f. After successful completion of the inner lid Viton O-ring maintenance leakage rate test, restart cask preparation activities at Step 5, Section 7.1.2.1.

11. Detorque and remove the port cover bolts and the interlid port and pressure port covers from the top forging. Store and protect all removed parts.
12. Attach the lifting yoke to a crane hook with the appropriate load rating and engage the yoke arms with the lifting trunnions.
13. Move the cask to the pool over the cask loading area. As the cask is lowered onto the cask loading area in the pool, spray the external surface of the cask with clean demineralized water to minimize external decontamination efforts.
14. After the cask is resting on the floor of the pool, disconnect the lifting yoke from the lifting trunnions and slowly raise the yoke.
15. Remove the lifting yoke and inner lid from the pool. Spray the yoke as it comes out of the water to remove contamination.
16. Visually examine the internal cavity, fuel basket and drain line to ensure that: (a) no damage has occurred during transit; (b) no foreign materials are present that would inhibit cavity draining; and (c) all required components are in place.
17. For the loading of HBU fuel assemblies, install or verify the appropriate number of Shielded Thermal Shunts are installed in the fuel basket corresponding to the planned HBU fuel loading configuration as shown for Assembly 97 on NAC License Drawing No. 423-800. [redacted] shielded thermal shunts installed. Perform an independent visual verification that the loading and placement of the required number of shielded thermal shunts conform to the required pattern for the intended loading configuration.

7.1.2.2 Preparation for Canister Loading

This procedure presents the steps required for loading canistered fuel, canistered GTCC waste, or canistered HLW into the NAC-STC. A canister of fuel or GTCC waste is loaded dry into the cask, using a transfer cask and attendant support hardware. Configuration control of the NAC-STC is required to ensure the cask has the correct impact limiters and internal spacer(s) for the canister that is to be transported. The operation of the transfer cask is described in NAC approved site-specific procedures. Loading of canistered fuel, canistered GTCC waste, or canistered HLW into the NAC-STC is done in the cask receiving area, adjacent to a storage pad at an Interim Storage Facility, or other suitable location specified by the user. The NAC-STC is assumed to be positioned vertically in the area designated for dry canister loading and configured with metallic O-rings.

1. Install appropriate work platforms/scaffolding to allow access to the top of the cask.
2. Detorque in reverse torquing sequence and remove the outer lid bolts. Install the two outer lid alignment pins.
3. Install lifting eyes in the outer lid lifting holes and attach the outer lid lifting device to the outer lid and overhead crane. Remove the outer lid and place it aside in a temporary storage area. When storing the outer lid, protect the O-ring and the O-ring groove of the lid from damage. Remove the outer lid alignment pins. Decontaminate the surface of the inner lid and top forging as required.
4. Detorque the vent and drain coverplate bolts and remove the drain port coverplate and the vent port coverplate from the inner lid. Store the coverplates and bolts in a designated temporary storage area.
5. Detorque and remove two inner lid bolts and install the two inner lid alignment pins at locations marked on the inner lid.
6. Attach the inner lid lifting eyebolts and the inner lid lifting slings to the inner lid.
7. Detorque and remove the remaining inner lid bolts. Clean and visually inspect the outer lid bolts, inner lid bolts, and coverplate bolts for damage or excessive wear. Record inspection results on cask loading report. Replace damaged bolts with approved spare parts.
8. Detorque and remove the bolts and covers from the interlid port and the pressure port in the top forging. Store and protect all removed parts.
9. Lower auxiliary hook to above inner lid and engage lid lifting sling to auxiliary crane hook.
10. Slowly lift and remove the inner lid. The inner lid alignment pins will guide the inner lid until it clears the top forging.

11. Store the inner lid in a temporary storage area. When storing the inner lid, ensure that the O-rings and O-ring grooves of the lid are protected from damage. Decontaminate the inner lid, as necessary.
12. Visually examine the internal cavity to ensure that the cavity is free of damage and foreign materials.
13. Install the appropriate bottom spacer(s) for the canister to be loaded. (Note: The MPC-LACBWR canister requires the Yankee-MPC bottom spacer and the MPC-LACBWR supplemental bottom spacer. The MPC-WVDP Overpacks require the use of the MPC-WVDP bottom and top transport spacers.) Attach the spacer lift fixture to the spacer(s). Using a suitable crane, lower the spacer(s) into the cask cavity and remove the lift fixture.
14. Install the adapter ring and torque the three bolts to 100 ± 20 ft.-lb.
15. Install the transfer cask adapter plate on top of the NAC-STC cask.

7.1.3 Loading the NAC-STC Cask

There are three loading options for the NAC-STC cask, with each requiring different steps. The first is direct loading of fuel assemblies for transport without interim storage and the second option is for transport after a period of interim storage. These loading configurations are assumed to be performed under water in the spent fuel pool cask loading area. The third option is dry loading into the cask of a sealed transportable storage canister or HLW overpack that already contains spent fuel, GTCC waste, or canistered HLW contents. Dry loading of the canister into the cask is performed in the cask receiving area, adjacent to a storage pad at an Interim Storage Facility, or other convenient location established by the user, using a transfer cask. This section presents the generic loading procedures for these options. In all cases, the fuel assemblies to be directly loaded, or those contained within the sealed canister, canistered GTCC waste, or HLW contents must conform to the content conditions of the NAC-STC Certificate of Compliance (COC).

7.1.3.1 Direct Loading of Fuel (Uncanistered)

The NAC-STC may be closed with either double metallic seals, or double nonmetallic (e.g., Viton) O-rings, or inner metallic seal and outer Viton O-ring in the containment boundary. The outer lid may have either metallic seals or Viton O-rings. Metallic O-rings are required: 1) when directly loading spent fuel for extended storage; and 2) when loading canistered fuel, GTCC waste, or canistered HLW (for transport). Metallic O-rings or Viton O-rings may be used when directly loading standard PWR or HBU spent fuel for transport without interim storage.

However, the metallic and non-metallic O-rings may not be used interchangeably, as the O-ring grooves in the lids and port covers are different for each O-ring type. As specified in the appropriate steps of this procedure and detailed in Table 7.4-1, the three configurations of O-rings have different allowable leak rates so the lid and O-ring configurations to be used must be confirmed and the associated leak test requirements identified.

1. Using approved fuel identification and handling procedures and fuel handling equipment, engage the fuel handling tool to the top of the fuel assembly, lift it from the storage rack location, transfer it to above the cask, and carefully lower it into the designated location in the fuel basket. Be careful not to contact any of the sealing surfaces on the top forging, or to come in contact with the inner lid guide pins during fuel assembly movement.

   Note: a. Each fuel assembly shall contain the standard number of fuel rods for an assembly of that type. Dummy rods of equivalent water displacement must be substituted for removed fuel rods.

   b. Perform an independent verification that the spent fuel assemblies loaded in the fuel basket are in full compliance with the content conditions of the NAC-STC Certification of Compliance (CoC) No. 9235.

   c. Following loading of HBU fuel assemblies, perform an independent verification that the HBU fuel contents comply with the designated maximum heat load per assembly specified for the loading configuration and that the correct number and loading positions for the fuel assemblies and shielded thermal shunts correspond to the applicable loading configuration identified on NAC License Drawing No. 423-800.

2. Record in the cask loading report the fuel identification number and basket position where the fuel assembly was placed.
3. Repeat steps 1 and 2 until the basket is fully loaded or until all desired fuel assemblies have been loaded. If the cask is going to be partially loaded, the fuel assemblies should be loaded, if possible, in a fully symmetric pattern to ensure that the center of gravity of the cask remains aligned as close as possible to the longitudinal axis of the cask.
4. Attach the inner lid lifting sling to an auxiliary crane hook and lift the inner lid. If not performed previously, remove the inner lid metallic O-ring assembly, clean the groove surfaces, and install new metallic O-rings. Inspect new O-rings for damage prior to installation. Secure the metallic O-rings in the groove by the use of the O-ring clips and screws. Similarly, replace the metallic O-rings in the vent and drain port coverplates, or inspect the Viton O-rings and replace if required. Replaced vent and drain port coverplates inner Viton O-rings are required to be helium leakage tested to the

maintenance leakage rate per Table 7.4-1. Verify vent and drain port QDVCs are removed to allow cask cavity to vent.

5. After replacing the inner lid O-rings, as required, lift the inner lid and place it on the cask using the inner lid alignment pins to assist in proper lid seating and orientation. Visually verify proper lid position.
6. Disconnect the lid lifting device from the auxiliary crane hook and remove crane hook from area.
7. Attach the lifting yoke to the crane hook, lower the lifting yoke into the lifting position over the cask lifting trunnions, and engage the lifting arms to the lifting trunnions. Slowly lift the cask out of the pool until the top of the cask is slightly above the pool water level.

   Note: As an alternative method, the cask and inner lid may be handled simultaneously. In the event that this method is chosen, instead of performing steps 5, 6 and 7, attach the lifting yoke to a crane hook and the inner lid lifting eyes to the lift yoke. Lower the lid and engage to the cask using the lid alignment pins. Engage lifting arms to lifting trunnions. Slowly lift the cask out of the pool until the top of the cask is slightly above the pool water level.

   Note: For the loading of the NAC-STC containing HBU spent fuel, the time allowed for completion of the NAC-STC loading sequence from the time cask breaks the surface of the spent fuel pool (Section 7.1.3.1, end of Step 7), draining and vacuum drying (Section 7.1.3.1, Steps 18 and 19), and through placement of the cask in a horizontal position on the transport vehicle (Section 7.2.1, Step 2) is limited to a total of 72 hours. In the event that the time limit cannot be met, corrective actions to prepare the NAC-STC for fuel cooldown operations shall be implemented by returning the NAC-STC to the cask preparation area for the controlled cooldown of the spent fuel contents and cask in accordance with the procedures in Section 7.3.2.1, Step 4 through Step 6. After completion of the minimum 24-hour cooldown operation, depending on the number of vacuum drying cycles authorized for HBU fuel in the CoC, the cask shall be prepared for additional vacuum drying cycles in accordance with Section 7.1.3.1, Step 19, or for fuel unloading operations in accordance with Section 7.3.2.1, Step 7 through Step 15 depending on the number of authorized cooldown events for the specific HBU fuel type. If HBU fuel unloading operations are required they shall be performed in accordance with Sections 7.3.3.1, Steps 1-3, except the removed HBU fuel assemblies shall be segregated and/or otherwise identified in fuel records as not acceptable for transport as undamaged fuel assemblies under the current NAC-STC CoC. The discharged HBU fuel assemblies are to be considered as potentially damaged requiring canning (e.g., in damaged fuel canisters [DFCs]) in accordance with ISG-11, Revision 3 guidance. Transport of directly loaded HBU damaged fuel in the NAC-STC is not currently authorized or proposed for authorization.

At the discretion of the Licensee a replacement standard PWR or HBU fuel loading can be initiated beginning at Section 7.1.3.1, Step 1 and continuing through fuel loading and cask preparation for transport operations.

Note: The time limit specified in the previous Note are for the maximum allowable heat loads in the NAC-STC transport cask. Although cask preparation and vehicle loading times would be longer for lower content decay heat loads, the time limit for the maximum heat load is conservatively implemented for all content decay heat loads.

8. Attach a drain line to the quick-disconnect in the interlid port (located in the top forging) and allow the water to drain from the interlid region. Once drained, disconnect the drain line.
9. Install at least 10 inner lid bolts equally spaced on the bolt circle to hand tight.
10. Continue raising the cask from the pool while spraying the external cask surfaces with clean water to minimize surface contamination levels.
11. Move the cask to the cask decontamination area, lower the cask to the floor and disengage the lift yoke (or lift beam and inner lid lifting slings if the alternate method of handling the inner lid was used). Remove the lift yoke and crane from the area.
12. Re-install the QDVC in the vent port and connect a vent line to the vent port quick-disconnect. Direct the free end of the vent line to a radioactive waste handling system capable of handling liquids and gas.
13. Remove the inner lid alignment pins and install the remaining inner lid bolts and torque all of the bolts to the torque value specified in Table 7-1. The bolt torquing sequence is shown on the inner lid.
14. Re-install the QDVC in the drain port and connect a drain line to the drain port quick-disconnect (located in the inner lid). For HBU PWR spent fuel contents proceed to Step 15, and for standard (≤ 45,000 MWd/MTU) PWR fuel assemblies, proceed to Step 18.
15. For HBU PWR fuel assemblies with a containment boundary provided by Viton O-rings, drain approximately 50 gallons from the cask cavity by connecting a helium supply to the vent port quick-disconnect (located in the inner lid). Purge the water from the cask by pressurizing to 35 to 40 psig. Following removal of approximately 50 gallons, turn the helium supply off and disconnect the drain line from the drain port quick-disconnect. Reconnect the vent line to the vent port quick disconnect to vent cask cavity.

    Note: See Table 7.4-1 for details on required containment boundary seals leakage test requirements and allowable leakage rates.

16. Connect a vacuum pump to the inner lid interseal port via the quick-disconnect in the inner lid. Evacuate the inner lid interseal volume between the inner and outer Viton O-rings until a pressure of 4 mbar is reached to remove water and moisture from the inner lid interseal volume.
17. Perform a leak test on the inner lid inner Viton O-ring of a NAC-STC containing HBU fuel assemblies as follows:
    a. Perform the preshipment leakage rate test by pressurizing the inner lid interseal volume with helium to a pressure of 15 psig (+2, -0 psi). The test is acceptable if there is no loss of pressure during a 15 minute minimum hold period, which meets the required test sensitivity 10^{-3} ref.cm^3/s.
    b. After successful completion of the preshipment leakage rate test of the inner lid O-ring seals, the cask preparation procedures will restart at Step 18 except that Step 22 does not need to be performed as the preshipment leakage rate test has been completed.
    c. If preshipment leakage rate test is not acceptable after two attempts, prepare cask for re-immersion in the spent fuel pool for lid and spent fuel removal, and Viton O-ring seal replacement, as described in Section 7.3.2.1, Steps 8 through 15, and Section 7.3.3.1, Steps 1 thru 3, and then perform the following procedure sequence:
        1) Attach the lifting yoke to the crane hook, lower the lifting yoke into the lifting position over the cask lifting trunnions, and engage the lifting arms to the lifting trunnions. Slowly lift the cask out of the pool and move it to the cask preparation area
        2) Following inner Viton O-ring replacement, dry all inner lid sealing surfaces and reinstall inner lid on the cask using the inner lid alignment pins to assist in proper lid seating and orientation. Visually verify proper lid position.
        3) Remove the inner lid alignment pins and install the inner lid bolts and torque all of the bolts to the torque value specified in Table 7-1. The bolt torquing sequence is shown on the inner lid.
        4) Re-install the QDVCs in the vent and drain port opening and torque to the value specified in Table 7-1.
        5) Drain approximately 50 gallons from the cask cavity by connecting a helium (99.9% minimum purity) supply to the vent port quick-disconnect (located in the inner lid) and a drain line to the drain port quick disconnect. Purge the water from the cask by pressurizing to 35 to 40 psig. Following removal of approximately 50 gallons, turn the helium supply off and maintain the helium pressure above the cavity water.

6) Remove the inner lid interseal test port plug and connect the helium Mass Spectrometer Leak Detector (MSLD) to the interseal test port to verify the new inner lid inner Viton O-ring leakage rate is $\leq 2.0 \times 10^{-7}$ cm^3/sec (helium) with a minimum test sensitivity of 1.0×10^{-7} cm^3/sec (helium).
7) After successful completion of the maintenance leakage rate test of the inner lid O-ring seals, the cask preparation and loading procedures will restart at Step 5 in Section 7.1.2.1.

18. Drain the cask cavity by connecting a helium supply to the vent port quick-disconnect and a drain line to the drain port quick-disconnect. Purge the water from the cask by pressurizing to 35 to 40 psig and hold until all water is removed (observed when no water is coming from the drain line). Turn the helium supply off, vent the helium from the cavity and disconnect the helium supply line from the vent port. Then, disconnect the drain line from the drain port quick-disconnect.
19. Connect a vacuum drying system to the cask cavity via the vent and drain port quick-disconnects in the inner lid. Evacuate the cask cavity until a pressure of 4 mbar is reached. Continue pumping for a minimum of 1 hour after reaching 4 mbar. Valve off vacuum pump from system and turn vacuum pump off. Using a calibrated vacuum gauge (minimum gauge readability of 2.5 mbar), observe for a cask cavity pressure rise. If a pressure rise (ΔP) of more than 12 mbar in ten minutes is observed, continue pumping until the pressure does not rise more than 12 mbar in ten minutes. Repeat dryness test until cavity dryness has been verified ($\Delta P < 12$ mbar in 10 minutes). Record test results in the cask loading report.

    Caution: As noted in Section 7.1.3.1, Step 7 for the loading of NAC-STC containing HBU spent fuel, the time allowed for completion of the NAC-STC loading sequence from the time the cask breaks the surface of the spent fuel pool, draining and vacuum drying, and through placement of the cask in a horizontal position on the transport vehicle is limited to a total of 72 hours. The vacuum drying time must be administratively limited to ensure the time limit of 72 hours is satisfied. If this time limit of 72 hours cannot be met, and dependent on the number of vacuum drying cycles (e.g., fuel cooling cycles exceeding 65°C) authorized by the CoC for the specific HBU fuel type, the appropriate corrective actions shall be implemented as described in the Note in Section 7.1.3.1, Step 7 to perform a controlled cooldown of the fuel contents and cask, and either restart vacuum drying operation or initiate fuel unloading operations.

20. Without disconnecting the vacuum drying system from the vent and drain port quick disconnects and allowing air to re-enter the cask cavity, turn off and isolate the vacuum

pump. Backfill the cask cavity with helium (99.9% minimum purity) through the vent port quick-disconnect to a final helium pressure of 0 psig helium pressure (+1, -0 psi).

21. Install the drain and vent port coverplates using new metallic O-rings or inspected Viton O-rings. Torque the bolts to the value indicated in Table 7-1.

22. Perform inner lid O-ring leakage testing of a NAC-STC containing standard PWR spent fuel ($\leq$ 45,000 MWd/MTU) with metallic or Viton containment seals and PWR HBU fuel (> 45,000 MWd/MTU) with metallic containment seals as follows:

22a. For the inner metallic seal and outer Viton O-ring assembly or the double inner and outer metallic seal assemblies for standard ($\leq$ 45,000 MWd/MTU) PWR fuel assemblies or PWR HBU assemblies, connect a vacuum pump to the inner lid interseal port via the quick-disconnect in the inner lid. Evacuate the inner lid interseal volume between the inner and outer O-rings until a pressure of 4 mbar is reached to remove water and moisture from the inner lid interseal volume. Disconnect vacuum pump and connect the helium Mass Spectrometer Leak Detector (MSLD) to the inner lid interseal test port and evacuate the volume between the O-rings to <1 mbar. Maintain the vacuum on the interseal for the metallic O-ring assembly region and using the helium leak detector, verify that any detectable leak rate for metallic O-rings is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The test sensitivity shall be $\leq 1 \times 10^{-7}$ cm^3/sec (helium).

22b. For inner and outer Viton O-rings, assembly for standard ($\leq$ 45,000 MWd/MTU) PWR fuel assemblies, connect a vacuum pump to the inner lid interseal port via the quick-disconnect in the inner lid and evacuate the inner lid interseal volume between the inner and outer Viton O-rings until a pressure of 4 mbar is reached. Continue pumping for a minimum of 30 minutes after reaching 4 mbar. Perform the preshipment leakage rate test to confirm no detected leakage to a test sensitivity of 1×10^{-3} ref cm^3/sec by pressurizing the O-ring annulus with helium gas to 15 (+2, -0) psig and isolating for a minimum of 15 minutes. There shall be no loss in pressure during the test period. If test is acceptable vent and disconnect the helium pressure test system from the interseal test port and proceed with cask preparation procedures per Step 23. If test is not acceptable after two attempts, prepare cask for re-immersion in the spent fuel pool for lid removal and Viton O-ring seal replacement.

22c. Following the replacement of inner lid inner Viton O-rings required due to excessive wear of the O-rings or failure of the preshipment leakage rate test for standard ($\leq$ 45,000 MWd/MTU) PWR fuel assemblies, the inner lid maintenance leakage rate test shall be performed. Connect a vacuum pump to the inner lid interseal port via the quick-disconnect in the inner lid and evacuate the inner lid interseal volume between the inner and outer Viton O-rings until a pressure of 4 mbar is reached. Continue pumping for a minimum of 30 minutes after reaching 4 mbar. Disconnect vacuum pump and connect the helium Mass Spectrometer Leak Detector (MSLD) to the inner lid interseal test port and evacuate the volume between the O-rings to <1 mbar. Perform the maintenance leakage rate test to verify the total cumulative leakage rate is $\leq 9.3 \times 10^{-5}$ cm^3/sec (helium)[1] with a minimum test sensitivity of 4.7×10^{-5} cm^3/sec (helium) for standard PWR spent fuel assemblies.

22d. Upon successful completion of the inner lid O-ring leakage test (e.g., maintenance or preshipment), vent and disconnect the leakage test equipment from the interseal test port and proceed with cask preparation procedures per Step 23.

23. Install the test port plug for the inner lid interseal test port using a new metallic or Viton O-ring and torque the plug to the value specified in Table 7-1.

24. Perform preshipment of maintenance leakage rate testing of vent and drain port coverplates as follows:

24a. For the inner metallic O-ring assembly, remove vent port coverplate interseal port plug and connect the helium Mass Spectrometer Leak Detector (MSLD) to the vent port interseal test port and evacuate the volume between the O-rings to <1 mbar. Perform the maintenance leakage rate test to verify the leakage rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The test sensitivity shall be $\leq 1 \times 10^{-7}$ cm^3/sec (helium).

24b. For Viton O-ring assembly, perform the preshipment leakage rate test to confirm no detected leakage to a test sensitivity of 1×10^{-3} ref cm^3/sec by pressurizing the O-ring annulus to 15 (+2, -0) psig and isolating for a minimum of 15 minutes. There shall be no loss in pressure during the test period.

24c. For new replacement Viton O-rings, use a leak detector connected to the interseal test port to verify the total cumulative leakage rate is $\leq 9.3 \times 10^{-5}$ cm^3/sec (helium) (1) with a minimum test sensitivity of 4.7×10^{-5} cm^3/sec (helium) [1] for standard PWR spent fuel assemblies and $\leq 2.0 \times 10^{-7}$ cm^3/sec (helium) (1) with a minimum test sensitivity of 1.0×10^{-7} cm^3/sec (helium) for HBU spent fuel assemblies (> 45 MWd/MTU).

24d. Upon successful completion of the port coverplate inner O-ring leakage test (e.g., maintenance or preshipment), vent and disconnect the leakage test equipment from the interseal test port.

25. Repeat Step 24 for drain port coverplate.

26. Install the test port plugs for the vent and drain port coverplates using a new metallic or Viton O-ring, as applicable, and torque the plugs to the value specified in Table 7-1.

27. Drain residual water from the pressure port, ensuring that the pressure port is clear to also allow water to drain from the interlid region.

28. Install the transport pressure port cover on the pressure port. Torque the port cover bolts to the value specified in Table 7-1.

[1] The sum of all containment boundary leakage rate tests shall be less than or equal to $\leq 9.3 \times 10^{-5}$ cm^3/sec (helium).

29. Perform a functional leak test on the pressure port cover by removing the O-ring test plug and using a test fixture, pressurize the annulus between the pressure port cover O-rings to 15 psig and isolate. During a 10-minute test period, there shall be no loss in pressure during the test period.
30. Install the pressure port cover interseal test port plug and O-ring and torque the plug to the value specified in Table 7-1.
31. For the metallic outer lid O-ring assembly, remove the O-ring, clean the O-ring seating surface and groove, and install a new metallic O-ring. For Viton O-ring assemblies, inspect the O-ring and replace if damaged.
32. Install outer lid and align vent pins.
33. Attach the outer lid lifting device to the outer lid and overhead crane. Install the outer lid using the alignment pins to assist in proper seating. Remove the outer lid alignment pins. Install the outer lid bolts and torque to the value specified in Table 7-1. The bolt torquing sequence is shown on the outer lid.
34. Attach a supply of air, nitrogen or helium to the interlid port quick-disconnect. Backfill the interlid volume to 15 psig air, nitrogen or helium and hold for 10 minutes. There shall be no pressure loss during the test period. Disconnect air or helium supply.
35. Install the interlid port cover using new metallic O-rings. Torque the interlid port cover bolts to the value specified in Table 7-1.
36. Remove the test plug from the interlid port cover and, using the O-ring test fixture, pressurize the O-ring annulus to 15 psig with air, nitrogen or helium. Isolate the annulus and hold for 10 minutes. No loss of pressure is permitted during the test period.
37. Remove the air, nitrogen or helium supply and vent the annulus pressure. Replace the metallic O-ring on the interlid port cover test plug, install the test plug and torque it to the value specified in Table 7-1.
38. If using the optional shield ring assembly, confirm the lower sector is installed. If necessary, install the lower section by attaching a sling to the lower sector and secure to the upper forging using the socket head cap screws. Torque the socket head cap screws to the value prescribed in Table 7-1.
39. Perform final external decontamination and perform survey to verify acceptable level of removable contamination to ensure compliance with 49 CFR 173.443. Perform final radiation survey. Record the survey results.
40. Perform final visual inspection to verify assembly of the NAC-STC in accordance with the Certificate of Compliance. Verify that the loading documentation has been appropriately completed and signed off.

7.1.3.2 Loading Canistered Fuel, Canistered GTCC Waste, or HLW Overpacks

Canistered fuel, canistered GTCC waste, or HLW Overpacks are loaded into the NAC-STC using a transfer cask. This procedure assumes that the canister, or overpack, has been previously loaded, drained, vacuum dried, backfilled with helium and welded closed, as applicable. The canister, or overpack, may have been retrieved from dry storage, or it may have been loaded and sealed immediately prior to loading in the NAC-STC.

Canisters containing spent nuclear fuel that are to be retrieved from storage for off-site transport will be evaluated to ensure that the specific canister stored in the storage overpack, which may have been subject to 10 CFR 72 normal, off-normal, accident and natural phenomena events, retain their ability to satisfy functional and performance requirements of the NAC-STC packaging certified content conditions. Similarly, GTCC Waste canisters and HLW Overpacks will be evaluated to ensure that the specific canister or overpack, which may have been exposed to off-normal, accident and/or natural phenomena events during storage operations prior to loading for transport, retain their ability to satisfy functional and performance requirements of the NAC-STC packaging certified content conditions.

Canisters containing spent nuclear fuel experiencing only normal or off-normal events during storage, and canistered GTCC waste and HLW Overpacks need only be evaluated for potential corrosion at the welds and any damage caused by removal from the storage cask.

In addition to the evaluation done for normal/off-normal storage, canisters containing spent nuclear fuel that have experienced accident or natural phenomena events must be evaluated for potential degradation of the fuel, basket and neutron absorbers. This evaluation will be performed for each canister as part of the preparation for loading for off-site transport using: 1) the annual inspection and surveillance records and off-normal and accident event reports that are maintained by the licensee for each loaded NAC-MPC system in compliance with 10 CFR 72 requirements; and 2) in the case of storage accidents and natural phenomena events, any necessary examinations at the time of transfer to ensure the condition of the canister and contents.

Dry storage systems that have been maintained within an Aging Management Program will include system specific review and assessment of this information record as part of the off-site transport evaluation to ensure the NAC-STC packaging certified content conditions are validated. Maximum assembly average burnup for fuel assemblies retrieved from dry storage for off-site transport is limited to 45,000 MWd/MTU. System loading into the NAC-STC will be observed by operations staff noting any system interferences that occur during canister retrieval from the storage overpack and placement of the canister into the transport overpack. The cause of the interference and potential damage caused by the interference will be determined prior to shipment. Noted interferences will be made part of the canister evaluation record to the extent required to validate NAC-STC packaging content conditions are satisfied when the spent fuel canister is placed within the NAC-STC containment boundary for off-site transport.

This procedure assumes that the sealed canister, or HLW Overpack, conforms to the design basis of the NAC-STC with appropriate spacer configuration and that the canister is already in the transfer cask.

1. Attach the transfer cask yoke to the cask handling crane hook.
2. Engage the transfer cask yoke to the trunnions of the transfer cask.
3. Raise the transfer cask over the NAC-STC cask and lower it until it rests on the transfer cask adapter plate. Remove and store the transfer cask lifting yoke. Remove the transfer cask shield door stops.
4. Attach the two (2) canister 3-legged lifting sling sets to the hoist rings in the canister lid. Attach the opposite end of the slings to the crane hook.

   Note: Alternative canister lifting systems may be utilized.
5. Attach the hydraulic system to the operating cylinders on the transfer cask adapter plate.
6. Using the crane, raise the canister just enough ($\leq$ 1 inch) to take the canister weight off of the transfer cask bottom shield doors.
7. Open the transfer cask shield doors.
8. Lower the canister or HLW overpack into the NAC-STC cask. Exercise caution to avoid contact with the interior cavity wall.

   Note: Prior to loading into the NAC-STC cavity the condition of the spent fuel canister, greater than class C (GTCC) waste canister, or the HLW overpack, and the canister/overpack internals shall be evaluated to verify the canisters/overpacks:

   a. Meet the design requirements and CoC content conditions of the NAC-STC package;
   b. Account for the effects of any accident or natural phenomena events that the canisters or overpacks may have been exposed to during storage operations prior to loading in the NAC-STC package, and,
   c. The vitrified HLW overpack meets the limits in 10 CFR 71.15 for classifying the contents as fissile exempt.
9. Disconnect and remove the canister lifting sling from the crane hook and lower it onto the top of the canister.

10. Close the transfer cask shield doors and install the door stops.
11. Retrieve the transfer cask lifting yoke and engage the transfer cask trunnions. Lift the transfer cask from the transfer cask adapter plate. Store the transfer cask and transfer cask lifting yoke in the designated locations.
12. After removal of the lift slings, install the NAC-MPC canister top spacer, as required (for the loading of Yankee-MPC, MPC-LACBWR and HLW Overpacks only).
13. Retrieve the cask adapter plate lifting sling and attach it to the transfer cask adapter plate.
14. Remove the transfer cask adapter plate and store it in the designated location. Using the appropriate lifting sling, remove the adapter ring and bolts. Install the inner lid alignment pins.
15. Remove the inner lid O-rings and clean inner lid O-ring groove surfaces. Replace the metallic O-rings on the inner lid, carefully inspecting the new O-rings for damage prior to installation. Secure the O-rings in the groove using the O-ring clips and screws.
16. Attach the inner lid lifting slings to an auxiliary crane hook, lift the inner lid and place it on the cask using the inner lid alignment pins to assist in proper lid seating and orientation. Visually verify proper lid position.
17. Disconnect the lid lifting device from the crane hook and remove it from the inner lid.
18. Install at least 10 inner lid bolts equally spaced on the bolt circle to hand tight. Remove the inner lid alignment pins.
19. Install the remaining inner lid bolts and torque all of the bolts to the torque value specified in Table 7-1. The bolt torquing sequence is shown on the inner lid.
20. Remove the metallic O-rings in the drain port coverplate, and clean and inspect the O-ring groove. Install new metallic O-rings and install the coverplate. Torque the coverplate bolts to the value specified in Table 7-1.
21. Connect the vacuum pump to the cask vent port and evacuate the cask cavity to a stable vacuum pressure of less than, or equal to, 4 mbar (approximately 3 mm of Hg) and backfill the cask cavity with helium (99.9% minimum purity) to 0 psig without allowing air to re-enter the cask. Disconnect the vacuum pump and helium supply from the vent port.
22. Remove the metallic O-rings in the vent port coverplate and clean and inspect the O-ring groove. Install new metallic O-rings in the vent port coverplate and install the coverplate. Torque the coverplate bolts to the value specified in Table 7-1.
23. Connect the leak detector to the inner lid interseal test port and evacuate the air between the metallic O-rings until a pressure of <1 mbar is reached. Using the helium leak detector, verify that any detectable leak rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The test sensitivity shall be $\leq 1 \times 10^{-7}$ cm^3/sec (helium).

Note: See Table 7.4-1 for details on required containment boundary seals leakage test requirements and allowable leakage rates.

24. Install the test port plug for the inner lid interseal test port using a new metallic O-ring and torque the plug to the value specified in Table 7-1.
25. Connect the leak detector to the vent port coverplate interseal test port. Evacuate the interseal volume until a pressure of <1 mbar is reached. Using the helium leak detector, verify that any detectable leak rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium). The test sensitivity shall be $\leq 1 \times 10^{-7}$ cm^3/sec (helium).
26. Install the test port plug for the vent port coverplate using a new metallic O-ring and torque the plug to the value specified in Table 7-1.
27. Repeat Steps 25 and 26 for the drain port coverplate test port.
28. Remove the outer lid metallic O-ring. Clean the outer lid O-ring seating surface and groove. Install a new metallic outer lid O-ring. Install the outer lid alignment pins.
29. Attach the outer lid lifting device to the outer lid and cask handling crane. Install the outer lid using the alignment pins to assist in proper seating. Remove the outer lid alignment pins. Install the outer lid bolts and torque to the value specified in Table 7-1. The bolt torquing sequence is shown on the outer lid.
30. Attach a supply of air, nitrogen, or helium to the interlid port quick-disconnect and backfill the interlid volume to 15 psig air, nitrogen, or helium and hold for 10 minutes. No loss of pressure is permitted during the 10-minute test period. Disconnect air, nitrogen, or helium supply.
31. Install the transport interlid port cover in the interlid port using new O-rings. Torque the interlid port cover bolts to the value specified in Table 7-1.
32. Remove the O-ring test plug from the interlid port cover and, using the O-ring test fixture, pressurize the O-ring annulus to 15 psig with air, nitrogen, or helium. Isolate the annulus and hold for 10 minutes. No loss of pressure is permitted during the test period.
33. Vent the annulus pressure, remove the air, nitrogen, or helium supply, replace the metallic O-ring on the interlid port cover test plug and install the test plug. Torque the plug to the value specified in Table 7-1.
34. Perform final external decontamination and perform survey to verify acceptable level of removable contamination to ensure compliance with 49 CFR 173.443. Perform final radiation survey. Record the survey results in the cask loading report.
35. Perform final visual inspection to verify assembly of the NAC-STC in accordance with the CoC. Verify that the loading procedure and checklist are appropriately completed and signed off.

7.2 Preparation for Transport

Perform the procedures of either Section 7.2.1 or 7.2.2, whichever is appropriate. Section 7.2.1 addresses preparation for transport without interim storage after loading the cask either with directly loaded fuel or with a previously loaded canister. Section 7.2.2 addresses transport following long-term storage of directly loaded fuel. Transport following long-term storage requires the verification of containment by leak testing the containment boundary formed by the outer O-rings of the inner lid and port covers and the O-ring test ports.

7.2.1 Preparation for Transport (Immediately After Loading)

1. Engage the lift beam to the cask lifting trunnions and move the cask to the cask loading area.
2. Load the cask onto the transport vehicle by gently lowering the rotation trunnion recesses into the rear support. Rotate the cask to horizontal by moving the overhead crane in the direction of the front support. Maintain the crane cables vertical over the lifting trunnions.

   Caution: As noted in Section 7.1.3.1, Step 7 for the loading of NAC-STC containing HBU spent fuel, the time allowed for completion of the NAC-STC loading sequence from the time the cask breaks the surface of the spent fuel pool, draining and vacuum drying, and through placement of the cask in a horizontal position on the transport vehicle is limited to a total of 72 hours. If this time limit of 72 hours cannot be met, corrective actions shall be implemented as described in the Note in Section 7.1.3.1, Step 7.
3. If use of the optional shield ring assembly is desired, then attach a lifting sling to the top sector of the optional shield ring assembly and place the top sector piece in position over the cask upper forging. Secure the top sector to the upper forging using the socket head cap screws and torque to the value prescribed in Table 7-1.
4. If use of the optional shield ring assembly is desired, then attach a sling to the left-hand side sector piece of the optional shield ring assembly and place in position between the top and bottom sector pieces. Secure the left-hand sector in place using the hex bolts torqued to the value prescribed in Table 7-1. Install the hex bolt lock wire. Repeat operation for the right-hand side sector piece of the optional shield ring assembly.
5. Using a lifting sling, place the tiedown assembly over the cask upper forging between the top neutron shield plate and front trunnions. Install the front tiedown bolts and lock washers to each side of the front support.

6. Complete a Health Physics removable contamination survey of the cask to ensure compliance with 49 CFR 173.443. Complete a Health Physics radiation survey of the entire package to ensure compliance with 49 CFR 173.441.
7. Using the designated lifting slings and a crane of appropriate capacity, install the top impact limiter. Install the impact limiter retaining rods into each hole and torque to the value specified in Table 7-1. Install the impact limiter attachment nuts and torque to the value specified in Table 7-1. Install the impact limiter jam nuts and torque to the value specified in Table 7-1. Install the impact limiter lock wires. Repeat the operation for the bottom impact limiter installation.

   Note: Balsa impact limiters shall be used for transport of the Connecticut Yankee fuel and GTCC waste canisters, MPC-LACBWR canisters, and HLW canisters loaded in HLW Overpacks. The balsa impact limiters may also be used for transport of directly loaded fuel and for Yankee-MPC fuel or GTCC waste canisters. Redwood impact limiters may only be used for transport of directly loaded fuel and for Yankee-MPC fuel or GTCC waste canisters.
8. Install security seals through holes provided in the upper impact limiter and one of the lifting trunnions; and through holes provided in all three bolts in the interlid port cover and the pressure port cover. Record the security seal identification numbers in the cask loading report.
9. Install the personnel barrier/enclosure and torque all attachment bolts to the prescribed torque value. Install padlocks on all personnel barrier/enclosure accesses.
10. Complete a Health Physics radiation survey of the entire package to ensure compliance with 49 CFR 173.441.
11. Complete a Health Physics removable contamination survey of the transport vehicle to ensure compliance with 49 CFR 173.443.
12. Determine the transport index (TI) corresponding to the maximum dose rate at 1 meter from the cask. Record on the shipping documents.
13. Determine the appropriate Criticality Safety Index (CSI) assigned to the package contents in accordance with the CoC, and indicate the correct CSI on the fissile material labels applied to the package.
14. Apply placards to the transport vehicle in accordance with 49 CFR 172.500 and provide special instructions to the carrier/shipper for an Exclusive Use Shipment.
15. Complete the shipping documentation in accordance with 49 CFR Subchapter C.

    Note: The allowable time for transport for HBU PWR spent fuel assemblies from completion of loading operations to arrival at the receiving facility is restricted to $\leq$ 6 months, as specified in the CoC.

7.2.2 Preparation for Transport (After Long-Term Storage)

This procedure applies to the transport of directly loaded fuel that has been in storage in the NAC-STC. Canistered fuel, canistered GTCC waste, and HLW Overpacks may not be loaded in the NAC-STC for storage. Canistered fuel, GTCC waste canisters, and HLW canisters loaded in HLW Overpacks may have been loaded just prior to shipment or may have been in interim storage in a separate storage overpack.

Prior to placing a directly loaded cask in long-term storage, the cask cavity is backfilled with 1.0 atmosphere (absolute) of helium (99.9% minimum purity) as the normal coolant for the spent fuel and to provide an inert atmosphere to prevent possible oxidation of the fuel. The inner lid interseal volume between the two inner lid metallic gaskets and the interseal volume between the O-rings in the vent and drain port covers are backfilled with 15 psig of helium (99.9% minimum purity). The interlid volume is pressurized to 100 psig and that pressure is monitored for pressure loss by a pressure transducer installed in the cask upper forging, and closed by a specially equipped port cover filled with a pressure feed-through tube (License Drawing No. 423-807). This overpressure system ensures that in the off-normal event of any leakage of the inner lid or port cover O-rings, the leakage path will be clean helium into the cavity. If, during the storage period, no significant pressure loss is observed in the pressure monitoring volume or system (normally recorded at a minimum of once every 24 hours during storage), it can be concluded that at the end of the storage period, the cask cavity remains backfilled with helium gas.

Prior to preparing the cask for transport, the pressure transducer wiring has been disconnected.

1. Move cask from extended storage location to a designated work area.
2. Evacuate a sample bottle using a vacuum pump and remove the interlid pressure port cover. Isolate the sample bottle and connect it to the interlid port quick-disconnect and fill it with interlid region atmosphere.

   Note: The interlid pressure may be as high as 100 psig. Use caution in collecting the gas sample.
3. Isolate the sample bottle and disconnect it from the interlid port quick-disconnect.
4. Bring the sample bottle to the appropriate facility and analyze the contents of the sample bottle.
5. If krypton-85 is present in the sample bottle, additional radiological precautions may be imposed by Health Physics personnel prior to proceeding with the removal of the outer lid. A determination shall also be made as to whether replacement of the inner lid seals is required. If the gas sample is acceptable, proceed with normal operations.

6. Attach valved venting hose to interlid port quick-disconnect and open valve to vent interlid region.
7. Remove the outer lid bolts and install the outer lid alignment pins and outer lid lifting eye bolts.
8. Attach the outer lid lifting device to the outer lid lifting eye bolts and overhead crane. Remove the outer lid and place it aside in a temporary storage area. Protect the O-ring and O-ring groove of the lid from damage. Remove the outer lid alignment pins.
9. Verify the torque of the inner lid bolts and vent and drain port coverplate bolts by torquing the bolts in accordance with the bolt torque sequence to the values specified in Table 7-1.

   Note: See Table 7.4-1 for details on required containment boundary seals leakage test requirements and allowable leakage rates.
10. Remove the drain port coverplate port plug. Connect the leak detector vacuum pump to the drain port coverplate test port and evacuate the helium between the metallic O-rings to a pressure of <1 mbar. Without allowing air to re-enter the interseal region, backfill the drain port coverplate interseal region with helium (99.9% minimum purity) to a pressure of 0 psig.
11. Install the drain port coverplate test plug using a new O-ring and torque to the value specified in Table 7-1.
12. Repeat steps 10 and 11 for the vent port coverplate test plug.
13. Remove the inner lid interseal test port plug and connect a vacuum pump to the inner lid interseal test port quick-disconnect. Evacuate the inner lid interseal volume until a pressure of <1 mbar.
14. Without allowing air to re-enter the interseal volume, backfill the interseal volume with helium (99.9% minimum purity) to 0 psig. Disconnect helium supply.
15. Install the inner lid interseal test port plug with a new metallic O-ring and torque the plug to the value specified in Table 7-1.
16. Clean the outer lid O-ring seating surface and groove surface. Install a new metallic O-ring in the outer lid. Reinstall the outer lid alignment pins.
17. Attach the outer lid lifting device to the outer lid lifting eye bolts and the overhead crane. Install the outer lid and visually verify proper seating. Remove the alignment pins and lifting eye bolts, and install the outer lid bolts and torque to the value specified in Table 7-1. The bolt torquing sequence is shown on the outer lid.
18. Perform an evacuated envelope leakage test on the outer O-rings of the vent and drain port coverplates, the outer O-ring of the inner lid, and the interseal test ports by

connecting a vacuum pump and a helium mass spectrometer leak detector connected to the interlid port quick-disconnect. Evacuate the interlid region to a vacuum of <1 mbar.

19. Using the helium leak detector, verify that the leakage rate into the evacuated envelope is $\leq 2 \times 10^{-7}$ cm^3/sec (helium) with a minimum leak test sensitivity of $\leq 1 \times 10^{-7}$ cm^3/sec.
20. Upon completion of the leak test, backfill the interlid region with helium (99.9% minimum purity) to 0 psig and disconnect the helium supply and leak test equipment.
21. Install the transport interlid port cover using new O-rings and torque the port cover bolts to the value specified in Table 7-1.
22. Remove the interseal port plug, attach the test fixture to the interlid port interseal test hole and perform a functional leak test on the interlid port cover O-rings by pressurizing the O-ring annulus to 15 psig and isolating for a minimum of 10 minutes. There shall be no loss in pressure during the test period. Record completion of an acceptable leakage test on the cask loading report. Upon completion of the test, equalize interseal region pressure with ambient and disconnect the test fixture. Install the interseal port plug and torque to the value specified in Table 7-1.
23. Using the lift yoke, load the cask on the transport vehicle.
24. Using a lifting sling, place the tiedown assembly over the cask upper forging between the top neutron shield plate and front trunnions. Install the front tiedown bolts and lock washers to each side of the front support.
25. Complete a Health Physics removable contamination survey of the entire package to ensure compliance with 49 CFR 173.443.
26. Using the designated lifting slings and a crane of appropriate capacity, install the top impact limiter. Install the impact limiter retaining rods into each hole and torque to the value specified in Table 7-1. Install the impact limiter attachment nuts and torque to the value specified in Table 7-1. Install the impact limiter jam nuts and torque to the value specified in Table 7-1. Install the impact limiter lock wires. Repeat the operation for the bottom impact limiter installation.
27. Install security seals through holes provided in the upper impact limiter and one of the lifting trunnions; and through holes provided in all three bolts in the interlid port cover and the pressure port cover.
28. Install personnel barrier/enclosure and torque all attachment bolts to the prescribed torque value. Install padlocks on all personnel barrier/enclosure accesses.
29. Complete radiation and contamination surveys to ensure compliance with 49 CFR 173.441 and 173.443 requirements.
30. Determine the transport index (TI) corresponding to the maximum dose rate at 1 meter from the cask. Record on the shipping documents.

31. Determine the appropriate Criticality Safety Index (CSI) assigned to the package contents in accordance with the CoC, and indicate the correct CSI on the fissile material labels applied to the package.
32. Apply placards to the transport vehicle in accordance with 49 CFR 172.500.
33. Complete the shipping documentation in accordance with 49 CFR Subchapter C and provide special instructions to the carrier/shipper for an Exclusive Use Shipment.

7.3 Outline of Procedures for Unloading the Cask

This section presents the procedures to be followed for unloading the cask following transport of directly loaded fuel, canistered fuel, canistered GTCC waste, or HLW canisters loaded in overpacks.

7.3.1 Receiving Inspection

1. Perform radiation and removable contamination surveys in accordance with 10 CFR 20.1906, 49 CFR 173.441 and 173.443 requirements.
2. Remove the personnel barrier/enclosure and complete radiation and removable contamination surveys at the cask surfaces.
3. Visually inspect the NAC-STC while secured to the transport vehicle in the horizontal orientation for any signs of damage and record any damage. Verify that the tamper-indicating seals are in place and verify their numbers.
4. Secure the transport vehicle. Attach slings to the top impact limiter lifting points, remove impact limiter lock wires, jam nuts, attachment nuts and retaining rods, and remove the impact limiter. Store the impact limiter upright. Repeat the operation to remove the bottom impact limiter. Complete radiation and removable contamination surveys for exposed cask surfaces.
5. Release the tiedown assembly from the front support by removing the front tiedown bolts and lock washers.
6. Attach a sling to the tiedown assembly lifting eyes and remove the tiedown assembly from the transport vehicle.
7. If installed, then remove the left-hand side sector of the optional shield ring assembly by attaching a sling to the left-hand side sector then remove the lock wires, hex bolts from the side sector piece and remove the left-hand sector piece from the shield ring assembly. Repeat operation for the right-hand side sector piece.
8. If installed, then attach a sling to the top sector piece of the optional shield ring assembly. Release the top sector of the optional shield ring assembly by removing the four socket head screws and remove the top sector piece.
9. Attach a sling to the top sector piece of the cask shield ring assembly and remove.
10. Attach the cask lifting yoke to a crane hook with the appropriate load rating. Engage the two yoke arms with the lifting trunnions at the top end of the cask. Rotate/lift the cask to the vertical orientation and raise the cask off of the rear support structure of the transport vehicle. Place the cask in the vertical orientation in a decontamination area or other location identified by the user.

11. Wash any road dust and dirt off of the cask and decontaminate cask exterior, as required by contamination survey results.

7.3.2 Preparation of the NAC-STC Cask for Unloading

The NAC-STC may contain fuel directly loaded into a basket within the cask, or a sealed transportable storage canister containing spent fuel assemblies, Reconfigured Fuel Assemblies, Recaged Fuel Assemblies, four fuel assemblies or fuel debris loaded in Damaged Fuel Cans, canistered GTCC waste, or HLW canisters loaded in an HLW Overpack. Directly loaded fuel includes the shipment of uncanistered high burnup (HBU) PWR fuel assemblies and associated shielded thermal shunts. The number and location of fuel assemblies and shunts depends on the HBU fuel configuration chosen.

Unloading of fuel from the directly loaded cask basket typically takes place under water in the spent fuel pool cask loading area. Canistered fuel and waste from unloading operations are performed dry using a transfer cask. Canister unloading will take place in the cask receiving area, or other location identified by the user.

7.3.2.1 Preparation for Unloading the NAC-STC Cask (Directly Loaded Fuel Configuration)

1. Verify that excessive pressure does not exist in the interlid region by removing the interlid port cover and attaching a pressure test fixture to the interlid port quick-disconnect that will allow the monitoring of the cask interlid region for any pressure buildup that may have occurred during transport. If a positive pressure exists, connect a vent/drain line to the interlid quick-disconnect and vent the pressure to the off-gas system.
2. Remove the outer lid bolts and install the outer lid alignment pins and outer lid lifting eye bolts.
3. Attach the outer lid lifting device to the outer lid lifting eye bolts and the overhead crane. Remove the outer lid and place it aside in a temporary storage area. Protect the O-ring and the O-ring groove of the lid from damage.
4. Access the NAC-STC cavity as follows:
   a. Remove the port cover plates from the drain and vent ports in the inner lid with caution.

b. Attach a pressure gauge/gas sampling fixture with an evacuated stainless steel sample bottle with valve to the vent port.
c. Measure and record cavity pressure for any pressure buildup that may have occurred during transport on the cask unloading report.
d. Open gas sample bottle valve and obtain a cavity gas sample, isolate sample bottle, and disconnect for analysis of cavity gaseous radioactivity to determine if spent fuel cladding failures occurred during transport.
e. Record the final cavity gaseous radioactivity levels on the cask unloading report.
f. If gaseous radioactivity levels in the cavity gas sample indicate that fuel rod cladding failure may have occurred during the transport operation, the Licensee, shall prepare and submit a written report to the USNRC within 60 days in accordance with 10 CFR 71.95 with a copy of the report provided to NAC as Certificate of Compliance Holder. The reports purpose would be to identify a potential non-compliance with the Certificate of Compliance authorized fuel contents conditions, as transport of damaged fuel and/or fuel having failed cladding are not authorized. The report shall include the details specified in 71.95(c) including an assessment of the safety consequences and implications of the event; and a description of any corrective actions planned or taken as a result of the event, including the means employed to repair any defects and actions taken to reduce the probability of similar events occurring in the future.
g. Connect a venting system to the pressure gauge/gas sampling fixture and discharge to the facility's off-gas system or to HEPA filter system to bring cavity gas pressure to atmospheric pressure, after determining total gaseous radioactivity of cavity gas and verifying that the release of the gaseous radioactivity through the facilities off-gas system will not violate license conditions.
h. Disconnect the pressure gauge/gas sampling fixture from the vent port.

5. Connect the cask cooldown system to the drain and vent quick-disconnects. The cask cooldown piping and controls schematic is shown in Figure 7.3-1.

   Caution: If fuel contents were identified as potentially damaged in Step 4.f above, monitor cooldown water discharge from the cask to observe for increased radiation levels, and establish appropriate radiological controls to minimize personnel exposure.
6. To facilitate cooldown and to minimize thermal effects to the cask and its contents, <u>slowly</u> (8 – 10 gpm) fill the cask cavity with clean demineralized water (cavity is full when water flows out of the vent port drain line). Circulate water through the cask until

the water leaving the vent port drain line is within 50°F of the average spent fuel pool water temperature.

7. Disconnect the fill line from the drain port quick-disconnect in the inner lid (Note: Leave a short drain line attached to the vent port quick-disconnect for continuous venting).
8. Loosen and remove all but 10, approximately equally spaced, inner lid bolts. Leave the 10 remaining inner lid bolts hand tight. Install the inner lid alignment pins at locations marked on the inner lid and the lid lifting eyebolts.
9. Remove the interlid port cover from the top forging. Disengage the vent line from the vent port quick-disconnect.
10. Attach the lifting yoke to a crane hook and engage the yoke arms with the lifting trunnions. Lift the cask and move it over to the cask loading area in the pool.
11. Spray the external surface of the cask with clean demineralized water to minimize external decontamination efforts. Slowly lower the cask into the pool. Just prior to submerging the top forging of the cask, complete the unthreading of the 10 remaining inner lid bolts and remove them.

    Note: Use caution when removing these bolts as pressure may rise slightly in the cask during the time since completion of Step 9.
12. Continue lowering the cask until it rests in the cask loading area on the pool floor.
13. Disconnect the lifting yoke from the lifting trunnions and move the yoke so that it will not interfere with fuel movements.
14. Using the inner lid lifting device attached to an auxiliary crane hook, remove the inner lid from the cask.

    Note: If the alternate method of handling the cask is being used, slowly raise the lift yoke and the inner lid using the lid alignment pins to guide movement. Move the lift yoke and the inner lid out of the area so that it will not interfere with fuel movements.
15. Place the inner lid aside ensuring that the O-rings and O-ring grooves are protected from damage. Decontaminate, as necessary, and clean all sealing surfaces.

7.3.2.2 Preparation for Unloading the NAC-STC Cask (Canistered Configuration)

1. Verify that excessive pressure does not exist in the interlid region by removing the interlid port cover and attaching a pressure test fixture to the interlid port quick-disconnect that will allow the monitoring of the cask interlid region for any pressure buildup that may have occurred during transport. If a positive pressure exists, connect a vent line to the interlid quick-disconnect and vent the pressure to the off-gas system.

2. Remove the outer lid bolts and install the outer lid alignment pins and outer lid lifting eye bolts.
3. Attach the outer lid lifting device to the outer lid lifting eye bolts and the overhead crane. Remove the outer lid and place it aside in a temporary storage area. Protect the O-ring and the O-ring groove of the lid from damage. Remove the outer lid alignment pins.
4. Remove the port coverplates from the drain and vent ports in the inner lid with caution. Attach a pressure test fixture to the vent port that will allow the monitoring of the cask cavity for any pressure buildup that may have occurred during transport. If a positive pressure exists, vent the pressure to the off-gas system.
5. Loosen and remove all inner lid bolts. Install the inner lid alignment pins at locations marked on the inner lid and the lid lifting hoist rings.
6. Using the inner lid lifting slings, attached to a suitable crane, remove the inner lid from the cask. Remove the inner lid alignment pins.
7. Place the inner lid aside ensuring that the O-rings and O-ring grooves are protected from damage. Decontaminate, as necessary, and clean all sealing surfaces.
8. If present, remove the top spacer from the NAC-STC cask cavity (Yankee-MPC canisters, MPC-LACBWR canisters, or MPC-WVDP-HLW overpacks only).
9. Install the adapter ring on the NAC-STC and torque the three captive bolts to the torque specified in Table 7-1.
10. Install the transfer cask adapter plate on the top surface of the cask and remove the handling slings.

7.3.3 Unloading the NAC-STC Cask

The NAC-STC may contain either fuel directly loaded in the cask basket, or a welded transportable storage canister. The procedures for unloading the directly loaded fuel or canisters are presented in the following.

7.3.3.1 Unloading Directly Loaded (Uncanistered) Fuel

1. Using approved fuel identification and handling procedures, withdraw one fuel assembly from the basket and deposit it in the proper storage rack location. Be careful not to contact any of the sealing surfaces on the top forging or the inner lid alignment pins.

   Note: If high levels of gaseous radioactivity were measured during initial cavity pressure measurements indicating the potential for failed fuel rod cladding, special procedures will need to be developed and implemented as follows:

a. Utilizing standard fuel handling equipment, engage the first assembly and remove the assembly from the fuel basket;
b. During fuel removal operations, perform visual inspection (by camera) of the fuel assemblies to observe for cladding damage;
c. Move the removed fuel assemblies from the cask loading area and place the fuel assemblies in the designated rack locations;
d. After removal and inspection of all potentially failed fuel assemblies perform a visual inspection (by camera) of the interior of the fuel tube cavities observing for any residual fuel material. If loose fuel material is noted, Licensee will need to develop special procedures and equipment to properly remove the fuel debris from the cask cavity prior to returning the cask to service;
e. As required, the unloaded fuel assemblies may require additional inspections of the fuel cladding based on the corrective actions identified in Section 7.3.2.1, Step 4.f.; and
f. As determined by removable contamination surveys of the cask interior after removal of the NAC-STC from the spent fuel pool, controlled flushing of the cask cavity may be performed to reduce contamination levels by re-installing the cask inner lid and initiating a borated water flow through the drain port with discharge from the vent port directed to the spent fuel pool until discharge water samples or additional cavity surveys indicate the interior surfaces of the cask cavity have been reduced to acceptable contamination levels.
g. The empty NAC-STC can then be returned to normal transport operations for next fuel loading.

2. Record and document the fuel movement from the cask to the fuel rack.
3. Repeat steps 1 and 2 until all fuel assemblies have been removed from the cask. If HBU fuel assemblies were transported and a different HBU fuel configuration is intended for the next loading, remove any installed shielded thermal shunts that are not part of that configuration. Similarly, if HBU fuel assemblies were transported and standard fuel assemblies are intended for the next loading, remove all the installed shielded thermal shunts from their fuel basket locations.
4. Attach the inner lid lifting slings to a crane hook, lift the inner lid and place it on the cask using the alignment pins to assist in proper seating. Visually verify proper lid position.

   Note: O-ring seals on the lids, port coverplates and test plugs do not require replacement for an empty packaging shipment.
5. Disconnect the lid-lifting sling from the crane hook.
6. Attach the lifting yoke to the crane hook, lower to lifting position and engage lifting arms to lifting trunnions. Slowly lift the cask out of the pool until the top of the cask is slightly above the pool water level.

Note: As an alternative method, the cask and inner lid may be handled simultaneously. In the event that this method is chosen, instead of performing steps 4, 5 and 6, attach the lifting yoke to a crane hook and the inner lid to the lift yoke. Lower the lid and engage to the cask using the lid alignment pins. Engage lifting arms to lifting trunnions. Slowly lift the cask out of the pool until the top of the cask is slightly above the pool water level.

7. Attach a drain line to the quick-disconnect in the interlid port (located in the top forging) and allow the water to drain from the interlid region.
8. Install at least four inner lid bolts approximately equally spaced on the bolt circle to hand tight. Remove the inner lid alignment pins.
9. Move the NAC-STC cask to the cask decontamination area and disengage the lift yoke or lift beam and inner lid lifting slings if the alternate method of handling the inner lid was used. Remove the inner lid lifting eye bolts.
10. Move the cask lifting equipment away from the cask work area.
11. Install the remaining inner lid bolts and torque all of the inner lid bolts to the value specified in Table 7-1 in accordance with the bolt torquing sequence shown on the inner lid.
12. Disconnect the drain line from the quick-disconnect in the interlid port.
13. Connect a drain line to the drain port quick-disconnect and a regulated air fill line to the vent port quick-disconnect.
14. Purge the water from the cask by pressurizing to 35 to 40 psig and hold until all water is removed (observed when no water is coming from the drain line). Adjust final internal cavity pressure to 0 psig.
15. Remove the lines from the drain and the vent port quick-disconnects.
16. Install the port coverplates over the vent and drain ports in the inner lid. Torque the coverplate bolts to the value specified in Table 7-1.
17. Decontaminate the surfaces of the inner lid and the inner surfaces of the top forging.
18. Install the outer lid alignment pins. Using the outer lid lifting device, install the outer lid using the alignment pins to assist in proper seating. Remove the lid lifting device, lid lifting eyebolts, and the outer lid alignment pins.
19. Install the outer lid bolts and torque them to the value specified in Table 7-1, using the bolt torquing sequence shown on the outer lid.
20. Install the interlid port cover and torque the bolts to the value specified in Table 7-1.

7.3.3.2 Unloading Canistered Fuel, Canistered GTCC Waste, or HLW Contained in HLW Overpacks

Canistered fuel and GTCC waste, and HLW contents loaded in an HLW Overpack are unloaded from the NAC-STC using a transfer cask. The transfer cask could be used to transfer the loaded canister to a work station where the canister could be opened, or to transfer it to another storage or disposal overpack.

1. Install the lift hoist rings in the canister lid.
   Note: The canister lid may be thermally hot.
2. Attach the canister lifting sling to the hoist rings in the canister lid. Position the sling so that the free end of the sling can be engaged by the cask handling crane hook.
3. Attach the transfer cask lifting yoke to the cask handling crane hook. Engage the yoke to the lifting trunnions of the transfer cask.
4. Lift the transfer cask and move it over the NAC-STC cask. Lower the transfer cask to engage the transfer cask adapter plate. Once the transfer cask is fully seated, remove the transfer cask lifting yoke and store it in the designated location.
5. Remove the shield door stops, connect the hydraulic operating system, and open the transfer cask bottom doors.
6. Using tag lines, lift the canister lifting slings through the transfer cask and attach them to the crane hook.
   Note: Alternative canister handling systems may be used.
7. Raise the canister into the transfer cask just far enough to allow the transfer cask bottom doors to close. Use caution to minimize the contact between the canister and the cavity walls of the NAC-STC and of the transfer cask.
8. Close the bottom doors and install the door stops.
9. Carefully lower the canister until it rests on the transfer cask bottom doors. Disengage the canister lifting sling from the crane hook.
10. Retrieve the transfer cask lifting yoke and attach it to the transfer cask trunnions. Lift the transfer cask from the NAC-STC cask and move it to its intended destination.
11. Attach the transfer cask adapter plate-lifting slings and disconnect the hydraulic operating system.
12. Using the crane, lift the transfer cask adapter plate from the top of the cask. Move the transfer cask adapter plate to the designated storage location.
13. Detorque the three bolts and remove the adapter ring.

14. At the option of the user, at this point the spacer(s) may be removed from the cask for decontamination and subsequent packaging for shipment.

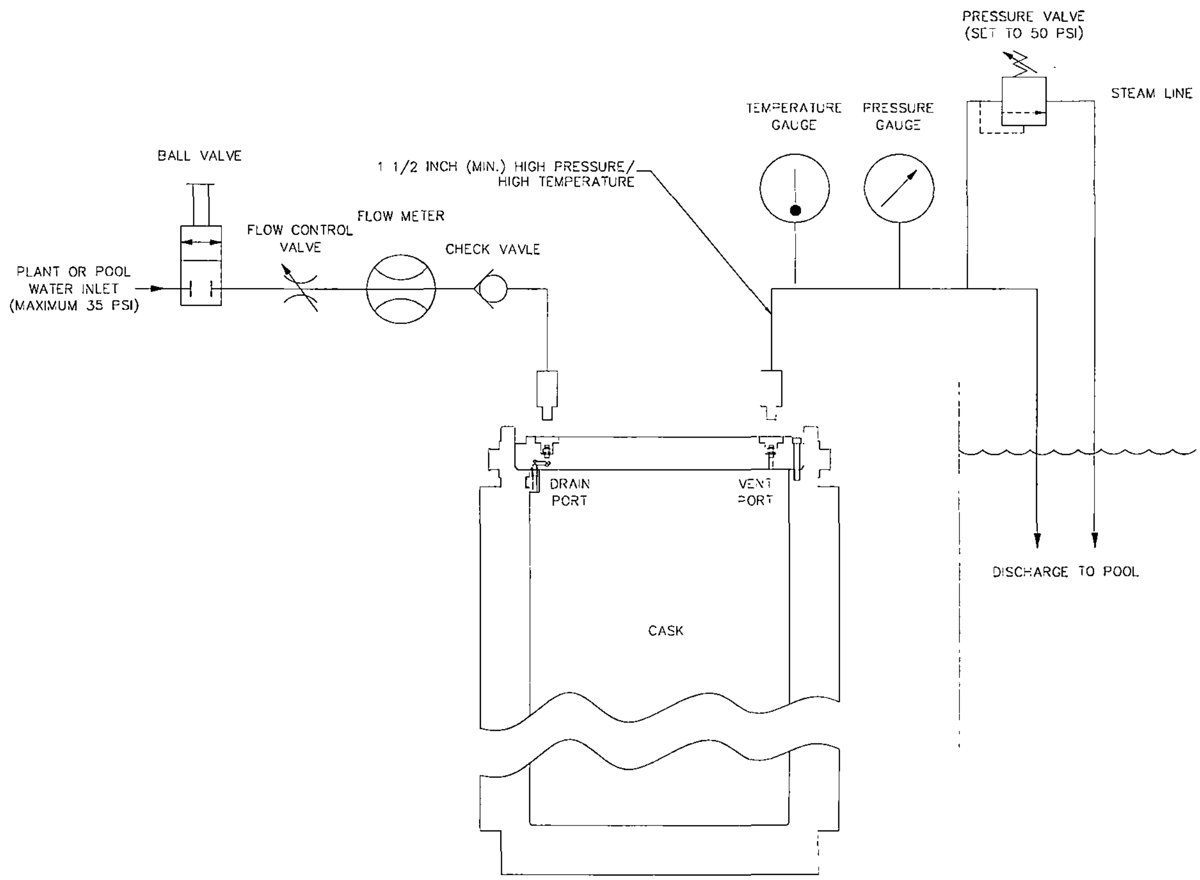
    Note: O-ring seals on the lids, port coverplates and test plugs do not require replacement for an empty packaging shipment.
15. Install the inner lid alignment pins.
16. Attach the inner lid lifting fixture to the inner lid and engage the lifting fixture to the auxiliary crane. Install the inner lid in the NAC-STC using the alignment pins to assist in proper seating.
17. Disconnect the lifting fixture and remove the guide pins.
18. Install and torque the inner lid bolts to the values specified in Table 7-1 using the bolt torquing sequence shown on the inner lid.
19. Install the port coverplates over the vent and drain ports in the inner lid. Torque the coverplate bolts to the values specified in Table 7-1.
20. Decontaminate the surfaces of the inner lid and the inner surfaces of the top forging.
21. Install the outer lid alignment pins. Using the outer lid lifting device, install the outer lid using the alignment pins to assist in proper seating. Remove the lid lifting device, lid lifting eyebolts, and the outer lid alignment pins.
22. Install the outer lid bolts and torque them to the value specified in Table 7-1 using the bolt torquing sequence shown on the outer lid.
23. Install the interlid port cover and torque the bolts to the value specified in Table 7-1.

7.3.4 Preparation of Empty Cask for Transport

1. Decontaminate all surfaces of the cask to acceptable release limits as defined in 49 CFR 173.
2. Attach the lifting yoke to a crane hook and engage the yoke arms with the lifting trunnions. Lift the cask onto the transport vehicle and lower to the horizontal position.
3. If the optional shield ring assembly is used, then attach a lifting sling to the top sector and place in position over the cask upper forging. Secure the top sector to the upper forging using the attachment socket head cap screws and torque to the value prescribed in Table 7-1.
4. If the optional shield ring assembly is used, then attach a sling to the left-hand side sector piece and secure in place using the hex bolts torqued to the value prescribed in Table 7-1. Install the hex bolt lock wire. Repeat for the right-hand side sector piece of the optional shield ring assembly.

5. Using a lifting sling, place the tiedown assembly over the cask upper forging between the top neutron shield plate and front trunnions. Install the front tiedown bolts and lock washers to each side of the front support. Torque each of the tiedown bolts.
6. Initiate Health Physics radiation and removable contamination surveys to ensure compliance with 49 CFR 173.441 and 49 CFR 173.443.
7. Using the designated lifting slings and a crane of appropriate capacity, install the top impact limiter. Install the impact limiter retaining rods into each hole and torque to the value specified in Table 7-1. Install the impact limiter attachment nuts and torque to the value specified in Table 7-1. Install the impact limiter jam nuts and torque to the value specified in Table 7-1. Install the impact limiter lock wires. Repeat the operation for the bottom impact limiter installation.
8. Apply labels to the package in accordance with 49 CFR 172.400.
9. Install the personnel barrier/enclosure and torque all attachment bolts to the prescribed torque value. Install padlocks on all personnel barrier/enclosure accesses.
10. Complete the Health Physics radiation and removable contamination surveys to ensure compliance with 49 CFR 173 requirements.
11. Complete the shipping documents.
12. Apply placards, if required, to the transport vehicle in accordance with 49 CFR 172.500.

Figure 7.3-1 Cask Cooldown Piping and Controls Schematic



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