April 2018

Revision 18C

NAC-STC

NAC Storage Transport Cask

SAFETY ANALYSIS REPORT

Modified Shielding Configuration

Non-Proprietary Version

Docket No. 71-9235

NAC INTERNATIONAL

Atlanta Corporate Headquarters: 3950 East Jones Bridge Road, Norcross, Georgia 30092 USA
Phone 770-447-1144, Fax 770-447-1797, www.nacintl.com

Enclosure 1

Additional Information and Supporting Documents for

NAC-STC SAR, Revision 18C

April 2018

List of Calculations and Supporting Documents

1. **Calculation 423-2010, Revision 4**

Calculation withheld in its entirety per 10 CFR 2.390.

Enclosure 2

List of Changes

NAC-STC SAR, Revision 18C

April 2018

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

Chapter 1

- Page 1-v, updated List of Drawings.

Chapter 2

- Page 2.6.12.6-1, modified text in the middle of the page, and modified the equation near the bottom of the page.
- Page 2.6.12.13-1, added third paragraph at the bottom of the page.
- Page 2.7.8.2-1, modified text in the middle of the page, and modified the equation at the bottom of the page.
- Page 2.7.8.2-2, modified the first equation on the page.
- Page 2.7.8.3-7, modified the last sentence of the fifth paragraph on the page.
- Page 2.7.8.3-8, modified the text and the equation in the middle of the page.
- Pages 2.7.8.3-10 thru 2.7.8.3-12, modified the text and equations throughout the pages.
- Page 2.7.8.5-1, added the third paragraph at the bottom of the page.

Chapter 3

- No changes.

Chapter 4

- No changes.

Chapter 5

- Pages 5-iii, 5-xii and 5-xix, modified table of contents, list of figures, and list of tables to reflect addition of new Sections 5.9 and 5.10.
- Pages 5.9-1 thru 5.9-7, added new Section 5.9.
- Pages 5.10-1 thru 5.10-3, added new Section 5.10.

Chapter 6

- No changes

Chapter 7

- No changes.

Chapter 8

- Page 8.1-12, modified the third paragraph of Section 8.1.5.1, and added new Section 8.1.5.1.1.

- Pages 8.1-13 thru 8.1-25, text flow changes.

Chapter 9

- No changes.

Enclosure 3

List of Drawing Changes

NAC-STC SAR, Revision 18C

April 2018

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

Drawing 423-872, Revision 7

1. B.O.M., Add Item 5, Qty "A/R" for Assy 99, Name "Shield Plate", Material "304 St. Stl.", Spec "ASTM A240" and Description "1 1/4 Plate".
2. Add a delta note 5 that reads "Item 5 (Shield Plate) is optional as defined by the NRC Certificate of Compliance."
3. Update graphics of Assy 99 to show Item 5 placed approximately as shown.

Enclosure 4

Proposed Changes for Certificate of Compliance Revision 18

NAC-STC SAR, Revision 18C

April 2018

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
423-802, sheets 1-7, Rev. 22
423-803, sheets 1-2, Rev. 14
423-804, sheets 1-3, Rev. 11
423-805, sheets 1-2, Rev. 7
423-806, sheets 1-2, Rev. 12
423-807, sheets 1-3, Rev. 4
423-811, sheets 1-2, Rev. 12
423-812, Rev. 6
423-900, Rev. 8
423-209, Rev. 0
423-210, Rev. 0
423-901, sheets 1-2, Rev. 3

(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
423-871, Rev. 5
423-872, Rev. 7
423-873, Rev. 2
423-874, Rev. 2
423-875, sheets 1-2, Rev. 11
423-878, sheets 1-2, Rev. 4
423-880, Rev. 2P & 1NP

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14. Transport by air is not authorized.

15. The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.

16. Expiration date: May 31, 2019

CoC Sections (new)

Page 21 of 22

13. For casks fabricated and accepted using the gamma shielding integrity acceptance criteria described in Chapter 8, Section 8.1.5.1.1 of the NAC-STC SAR for the upper 10.18 inches of the cask upper lead region, the cask user shall use the optional shield plate for the basket top weldment as detailed in license drawing 423-872 when conducting a shipment of directly loaded fuel. The cool times for the use of the alternate upper weldment basket configuration have been compared to the cool times for the design basis directly loaded low burnup and HBU fuel and are bounded.

Enclosure 5

NAC-STC SAR Changes Pages and LOEP

NAC-STC SAR, Revision 18C

April 2018

April 2018

Revision 18C

NAC-STC

NAC Storage Transport Cask

SAFETY ANALYSIS REPORT

Volume 1 of 2

Non-Proprietary Version

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423-802, sheets 1-7	Rev 22	Cask Body – NAC-STC Cask
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423-805, sheets 1-2	Rev 7	Lid Assembly – Outer, NAC-STC Cask
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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 7	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
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423-880	Rev 2P(1)	Shielded Thermal Shunt Assembly, NAC-STC Cask
423-880	Rev 1NP(1)	Shielded Thermal Shunt Assembly, NAC-STC Cask
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423-901, sheets 1-2	Rev 3	Transportation Package Concept, NAC-STC Cask
455-800, sheets 1-2	Rev 2	Assembly, Transport Cask, MPC-Yankee

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

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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
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414-870	Rev 3	Canister Shell, CY-MPC
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414-872, sheets 1-3	Rev 6	Assembly, Transportable Storage Canister (TSC), CY-MPC
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414-875	Rev 0	Spacer Shim, Canister, CY-MPC
414-881, sheets 1-2	Rev 4	Fuel Tube, Transportable Storage Canister (TSC), CY-MPC
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R-237609

REV	CHANGE
0	INITIAL ISSUE
1	INC DCR 0A
2	INC DCR 1A
3	INC DCR 2A
4	INC DCR 3A,3B
5	INC DCR 4A
6	INC DCR 5A,5B
7	INC DCR 6A

[redacted]

SECTION B—B

[redacted]

97	98	99	ITEM	NAME	MATERIAL	SPEC	DRAWING No.	DESCRIPTION
		A/R	5	SHIELD PLATE	304 ST.STL.	ASTM A240		1 1/4 PLATE
		1	4	CENTER SUPPORT	304 ST.STL.	ASME SA240		1 PLATE
		2	3	SUPPORT	304 ST.STL.	ASME SA240		1 PLATE
		1	2	RING	304 ST.STL.	ASME SA240 OR SA182		1 3/4 PLATE OR FORGING
		1	1	PLATE	304 ST.STL.	ASME SA240		1 PLATE

ASSY ASSY ASSY
QUANTITY

UNLESS OTHERWISE STATED
DIMENSIONING AND TOLERANCING SHALL BE PER ASME Y14.5M-94. UNSPECIFIED DIMENSIONAL TOLERANCES ARE SHOWN BELOW.
ALL THREAD DEPTH CALLOUTS ARE TO BE CONSIDERED AS A MIN. DEPTH OF PERFECT THREADS. THE ACTUAL DEPTH OF THE THREADS IS NOT SUBJECT TO TOLERANCE CONTROLS.

XXX	UNDER 3	±.003
	3–12	±.005
	OVER 12	±.010
XX	UNDER 6	±.01
	6–18	±.03
	OVER 18	±.06
M	ALL	±.1
FRACTIONAL		±1/8
ANGLES		±0.5°

WEIGHTS ARE APPROXIMATE AND ARE TO BE USED FOR HANDLING PURPOSES ONLY
ALL DIMENSIONS ARE IN INCHES
BORDER SIZE: F (40 X 28)
ALL UNSPECIFIED TOOL RADII: .015 – .030
BREAK ALL SHARP CORNERS .015 – .030
MACHINED SURFACES TO BE 125 OR BETTER
NEXT ASSEMBLY: 423-870
DRAWING TYPE: LICENSE

GROUP	NAME	DATE
PREPARER	[signature]	5-8-18
CHECKER	[signature]	5-8-18
PROJECT MANAGER	[signature]	5-8-18
ENGINEERING	[signature]	5-8-18
LICENSING	[signature]	5/8/18
QUALITY	[signature]	5/11/18

NAC INTERNATIONAL

TOP WELDMENT,
FUEL BASKET,
PWR, 26 ELEMENT,
NAC-STC CASK

PROJECT 423 | DRAWING 872 | REV 7
SCALE 1/5 | WEIGHT | SH 1 OF 1

2.6.12.6 Stress Evaluation of Threaded Rods and Spacer Nuts for a 1-Foot End Drop Load Condition (Directly Loaded Fuel Configuration)

The deceleration for the NAC-STC for the normal conditions of transport 1-foot end drop is 19.6 g. During the 1-foot end drop, the threaded rods and spacer nuts in the directly loaded fuel configuration fuel basket are loaded with the weight of the 31 support disks, 20 aluminum heat transfer disks, one end plate and the weights of the threaded rods and spacer nuts. A conservative basket weight of 17,000 pounds is used. The loads are calculated as follows:

Total weight of basket	=	17,000 lbs
Less weight of bottom weldment	=	-671 lbs
Less weight of fuel tubes	=	-3,666 lbs
1-g load on the tie rods and spacer nuts	=	12,663 lbs

A conservative load (1g) of 13,500 lbs is used for the evaluation of the tie rods and spacer nuts. This load bounds the weight of the top weldment configuration with optional shield plates at the periphery of the top weldment assembly (shielding augmented top weldment). For the 1-foot end drop (19.6g), the load on the tie rod and spacer nuts is 264,600 lbs (=13,500×19.6).

The effective area of one threaded rod and spacer nut at each of the six locations supporting the weight of the support disks is equivalent to the gross area of the square spacer nut and is calculated as:

$$A = (2.5)(2.5)$$
$$= 6.25 \text{ in}^2$$

The average compressive stress in the threaded rods and spacer nuts is:

$$S_c = 264.6/(6\times6.25) = 7.06 \text{ ksi}$$

The allowable stress of the 17-4 PH stainless steel under normal conditions of transport is S_m.

Then, the margin of safety is:

$$MS = \frac{(S_m)}{S_c} - 1 = \underline{+Large}$$

where:

S_m = 43.8 ksi (17-4 PH stainless steel at 405°F)

Therefore, the threaded rods and spacer nuts in the directly loaded fuel configuration of the fuel basket are structurally adequate for a 19.6-g end impact under normal conditions of transport.

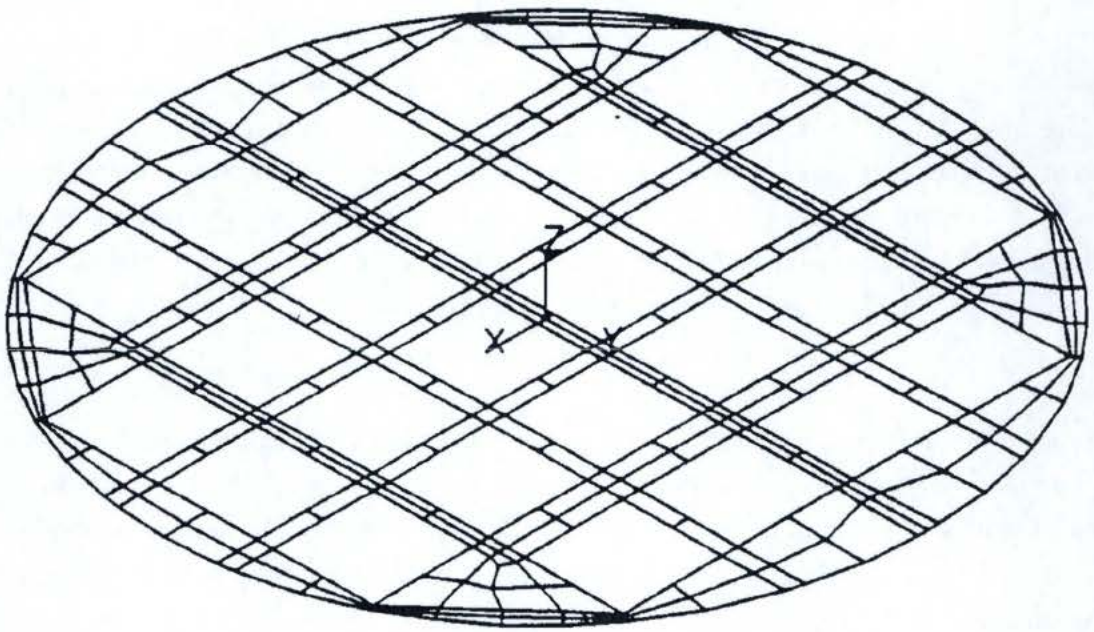
2.6.12.13 Fuel Basket (Directly Loaded Fuel Configuration) Weldment Analysis for 1-Foot End Drop

The responses of the top and the bottom weldment plates of the fuel basket assembly to a 19.6g normal operation deceleration load are examined. The top and the bottom weldment plates are both 1-inch thick and fabricated from SA 240, Type 304 stainless steel. The top weldment supports its own weight and 26 fuel tubes (without the fuel assemblies) during a 1-foot top end drop. Similarly the bottom weldment supports its own weight and 26 fuel tubes (without the fuel assemblies) during a 1-foot bottom end drop. The responses of the end plates to the 1-foot end drop are analyzed using ANSYS STIF63 three-dimensional, six degrees-of-freedom, elastic quadrilateral shell elements. The finite element model for both plates is shown in Figure 2.6.12.13-1. Figure 2.6.12.13-2 and 2.6.12.13-3 display the boundary conditions for the top weldment plate and the bottom weldment plate respectively. The evaluation is based on material properties of SA 240, Type 304 at a conservative temperature of 500°F. The hottest steel support disk during normal transport conditions is 498°F, see Table 3.4-1.

The primary membrane plus primary bending stress in the top weldment plate for the 1-foot top end drop is 21.5 ksi. The primary membrane plus primary bending stress in the bottom weldment plate for the 1-foot bottom end drop is 17.9 ksi. At 500°F, the normal condition stress allowable, 1.5 S_m, is 26.25 ksi. The minimum margin of safety for the top weldment plate and the bottom weldment plate are +0.22 and +0.47 respectively. Therefore, the structural adequacy of the NAC-STC fuel basket weldment end plates (directly loaded fuel configuration) for the normal condition of transport is demonstrated.

Note that optional shield plates may be added to the periphery of the top weldment to provide augmented shielding at top region of the fuel basket. The shield plates are 1.25 inches thick with a same height (width) as the existing support plates and the ring in basket axial direction. The shield plates are fabricated from the same material as the top weldment plates (SA 240, Type 304 stainless steel). Since the shield plates provide additional stiffness to the top weldment assembly, the 1-foot end drop analysis for top weldment presented above is bounding and no further analysis is required.

Figure 2.6.12.13-1 Fuel Basket Weldment Model (Directly Loaded Fuel Configuration)



2.7.8.2 Stress Evaluation of the Directly Loaded Fuel Basket Threaded Rods and Spacer Nuts - Accident Condition

In accordance with 10 CFR 71.73(c)(1), a spent-fuel shipping cask is subject to a free drop from a height of 30 feet onto a flat, unyielding surface. The design deceleration for the NAC-STC for the hypothetical accident 30-foot end drop is 56.1g (Table 2.6.7.4.1-2).

For a bottom end drop, the threaded rods and spacer nuts are loaded with the weight of the 31 support disks, the top plate, the 20 aluminum heat transfer disks, and the weights of the threaded rods and spacer nuts. These loads are calculated as follows:

Total weight of basket	=	17,000 lb
Less weight of bottom plate	=	-671 lb
Less weight of fuel tubes	=	-3,666 lb
1g load on the tie rods and spacer nuts	=	12,663 lb

A conservative load (1g) of 13,500 lbs is used for the evaluation of the tie rods and spacer nuts. This load bounds the weight of the top weldment configuration with optional shield plates at the periphery of the top weldment assembly (shielding augmented top weldment). For the 30-foot end drop (56.1g), the load on the tie rod and spacer nuts is 757,350 lbs (=13,500×56.1).

The effective area of one threaded rod and spacer nut at each of the six locations supporting the weight of the support disks is equivalent to the gross area of the square spacer nut and is calculated as:

$$A = (2.5)(2.5)$$

$$= 6.25 \text{ in}^2$$

The average compressive stress in the threaded rods and spacer nuts is:

$$S_c = 757.4/(6\times6.25) = 20.2 \text{ ksi}$$

Then, the margin of safety is:

$$\text{M.S.} = \frac{0.7\,S_u}{S_c} - 1 = +3.6$$

where

$S_u = 131.43$ ksi (17-4 PH stainless steel at 405°F)

Therefore, the threaded rods and spacer nuts are structurally adequate for a 56.1g end impact.

2.7.8.3.2 Assessment of Buckling of the 17-4 PH Threaded Rods

2.7.8.3.2.1 Maximum Compressive Load

The maximum compressive load applied to the threaded rods are during the 30 foot (9 meter) end drop, which corresponds to a maximum deceleration of 56.1 g's.

During the end impact, the weight of the support disks, aluminum heat transfer disks, are transferred to the threaded rods. The forces due to the weight of the fuel assemblies is transmitted directly to the end plate of the cask cavity.

The threaded rods transferring the load can be represented as a direct stress (i.e., uniaxial stress). This characterization categorizes the rod as a linear support (Section NF-3300).

To address the accident condition, Section NF-3340 can be applied which uses limit analyses to establish allowable loads acting on the support disks. Since out of plane loading is not present, the governing conditions are detailed in equation (5) of Section NF-3342.2, which specifies the allowable compressive force (P_{cr}).

$$P_{cr} = 1.7\ A\ F_a$$

The maximum force ($P_{max} \leq P_{cr}$) transmitted to a threaded rod is based on the weight of the basket less the weight of the fuel tubes and the bottom weldment (The bottom weldment weighs 671 pounds while the fuel tubes weight 3,666 pounds). A bounding weight of 13,500 pounds is conservatively used as the total weight transmitted by the six rods.

The design of the basket is not sufficiently symmetrical to distribute the loading to the threaded rods in an equal fashion. To determine the distribution of the loads to the threaded rods in an end drop orientation, a finite element model of a single support disk was generated. The model of the entire disk shown in Figure 2.7.8.3-1 uses the ANSYS plate element (STIF63). The material properties for 17-4 PH employed in the model corresponds to the maximum basket temperature at 500°F. While the temperature does vary throughout the basket, the effect on the variation

of the modulus of elasticity and the corresponding effect on the load distribution to the rods is considered to be insignificant.

The support of the threaded rod is simulated by restraining the out of plane degree of freedom at the centerline of the location of the threaded rod connection with the support disk. A 1g load was applied to the elements comprising the support disk. The nodal reactions were used to determine the load distribution to the threaded rods. The four threaded rods at location A in Figure 2.7.8.3-1 have the same reaction value and carry 74.5% of the weight of the support disk, 18.6% per rod. The remaining two threaded rods, which are also of equal value carry 25.5% of the weight of the disk, 12.8% per rod. The limiting load for the threaded rod is 18.6% of the weight of the support disk.

The maximum load to be considered for the threaded rod is 13,500 pounds amplified by 56.1 g and factored by 0.186, or P_{max} = 140.9 kips.

The axial compressive stress permitted in the threaded rod, F_a, is computed in the same manner as in Section 2.7.8.3.1. In the section of the threaded rod experiencing the maximum compressive load, the span is considered as a simple span configuration and the length corresponds to the centerline to centerline distance between the support disks. The simple span condition requires the effective length factor, K, to equal 1.0 (AISC Steel Construction Code, Eight Edition). Using the minor diameter to compute the radius of gyration, $Kl/r = 13.279 < C_c$. Using $C_c = 75.70$, F_a is determined to be 52.87 ksi and P_{cr} is 154.58 kips.

The margin of safety for equation (5) of NF-3342.2 is:

$$M.S. = 154.58/140.9 - 1 = + 0.10$$

2.7.8.3.2.2 Maximum Combined Axial and Bending Loads

In drop orientations other than the end drop, the aluminum heat transfer disks, which are supported by the threaded rods, will exert a lateral component on the threaded rods. This will induce bending moment into the threaded rod. It is assumed that the entire weight of one aluminum heat transfer disk will be carried by a single threaded rod carrying the maximum compressive load. This is conservative since the location of the closest aluminum fin to the

bottom of the cask will only experience the weight of 20 support disks instead of 31 disks as in this calculation.

The combined loading is governed by equations NF-3342.2 (6) and (7).

For equation NF-3342.2 (6),

$$\frac{P}{P_{cr}} + \frac{C_m M}{[1 - (P/P_e)] M_m} \leq 1.0$$

Assuming that the mass of the heat transfer disk acts as a point load at the mid span, the maximum moment for a simple span beam is:

$$M = F\,l / 4$$

where:

F = weight of the heat transfer disk times the lateral deceleration

As the cask assumes other angles, the maximum deceleration varies. Since the maximum decelerations decrease from 56.1 g's at 0° (end drop) to 33.8 g's at 60°, it is conservative to assume the maximum deceleration is 56.1 g's. The lateral deceleration is 56.1 sin q , where q is the angle measured from the vertical to the centerline of the cask body. The weight of the aluminum heat transfer disk is 105 pounds.

$$F = 56.1\,(.105)\,\sin q \text{ (kips)}$$

$$l = 4.88 \text{ inches}$$

$$M = 7.186\,\sin q \text{ (kip-in)}$$

The axial load on the rod at some angle of notation, q, is determined by 140.9 cos q kips, then P in the above equation is 140.9 cos q.

$$P_e = 1.92\ A\ F_e'$$

where $F_{e_}$ is defined by equation NF-3322.1 (e)

$$F_{e_} = \frac{12\pi^2 E}{23(Kl/r)^2}$$

$$F_{e_} = 773.87$$

$$P_e = 1.92\ A\ F_e'$$

$$P_e = 2644.78$$

$$M_p = S_y Z$$

where

Z = plastic modulus for the weak axis M bending
$1.333\ R^3$

$$Z = 1.333\ (.735)^3\ \text{inch}^3$$

$$M_p = 47.53\ \text{kip-in}$$

The maximum critical moment that can be resisted by a plastically designed member in the absence of axial load, $M_m = M_p$

$$M_m = 47.53\ \text{kip-in}$$

By substituting the computed quantities into equation (6) of NF-3342.2,

$$\frac{140.9\cos\theta}{154.58} + \frac{(1)(7.186\sin\theta)}{(1 - 140.9\cos\theta/2644.78)\ 47.53} \leq 1.0$$

or

$$0.9115\cos\theta + \frac{0.1512\sin\theta}{1 - .0533\cos\theta} \leq 1.0$$

It is necessary to determine the angle θ which maximizes the left side of the inequality. The maximum ratio of 0.925 occurs at θ = 9.9°.

The margin of safety for equation NF-3342.2 (6) is:

M.S. = 1.0/0.925 - 1 = <u>+0.08</u>

Equation (7) of NF-3342.2 is specified as:

$$\frac{P}{P_y} + \frac{M}{1.18\,M_p} \leq 1.0$$

where:

P_y = the axial plastic load = yield strength times cross sectional area

P_y = (1.78)(89.8) kips

P_y = 159.84 kips

substituting

$$\frac{140.9\cos\theta}{159.84} + \frac{(1)(7.186\sin\theta)}{1.18(47.53)}$$

or

$$0.8815\cos\theta + 0.1281\sin\theta \leq 1.0$$

By taking the derivative and setting it to zero the maximum angle is determined to be $\theta = 8.3°$.

Substituting for $\theta = 8.3$, Equation (7) of NF-3342.2 becomes:

$$0.891 \leq 1.0$$

The margin of safety for equation NF-3342.2 (7) is:

M.S. $= 1.0/0.891 - 1 = \underline{+0.12}$

Also note that for $M = 1.156$ kip-in and $M_p = 47.53$ kip-in, $M < M_p$ for which the margin of safety is:

M.S. $= 47.53/1.156 - 1 = \underline{+40.12}$

2.7.8.3.3 Summaries of Margins for NF-3400 Evaluation of Buckling

For the 17-4 PH stainless steel support disk and threaded rod, the margins of safety are summarized below:

Equation	Support Disk	Threaded Rod
NF-3342.2 (5)	+2.30	+0.10
NF-3342.2 (6)	+2.11	+0.08
NF-3342.2 (7)	+3.13	+0.12

Based on Subsection NF-3340 of the ASME Boiler and Pressure Vessel Code, Section III, the NAC 17-4 PH stainless steel basket design will maintain stability against buckling for the hypothetical 30 foot (9 meter) drop onto an unyielding surface.

2.7.8.5 Directly Loaded Fuel Basket Weldment Analysis for 30-Foot End Drop

The response of the top and the bottom weldment plates of the fuel basket assembly to a 56.1g accident condition deceleration load are examined. The top and bottom weldment plates are both 1-inch thick and fabricated from SA 240, Type 304 stainless steel. The top weldment supports its own weight as well as the weight of the 26 fuel tubes (without the fuel assemblies) during a 30-foot top end drop. Similarly the bottom weldment supports its own weight and also the weight of the 26 fuel tubes (without the fuel assemblies) during a 30-foot bottom end drop. The responses of the end plates to the 30-foot end drop are analyzed using ANSYS STIF63 three-dimensional, six degrees of freedom, elastic quadrilateral shell elements. The finite element model for both weldment plates and the corresponding boundary condition of each weldment plate are shown in Section 2.6.12.13, Figure 2.6.12.13-1 through Figure 2.6.12.13-3. The evaluation is based on material properties of SA 240, Type 304 at a conservative temperature of 500°F. The hottest steel support disk during normal transport conditions is 498°F, see Table 3.4-1.

The primary membrane plus primary bending stress in the top weldment plate for the 30-foot top end drop is 61.9 ksi. The primary membrane plus primary bending stress in the bottom weldment plate for the 30-foot bottom end drop is 51.3 ksi. At 500°F, the accident condition stress allowable, S_u is 63.5 ksi. The minimum margin of safety for the top weldment plate and the bottom weldment plate are +0.03 and +0.24 respectively. Therefore, the structural adequacy of the NAC-STC fuel basket weldment end plates for the accident condition of transport is demonstrated.

Note that optional shield plates may be added to the periphery of the top weldment to provide augmented shielding at the top region of the fuel basket. The shield plates are 1.25 inches thick with a same height (width) as the existing support plates and the ring in the basket axial direction. The shield plates are fabricated from the same material as the top weldment plates (SA 240, Type 304 stainless steel). Since the shield plates provide additional stiffness to the top weldment assembly, the 30-foot end drop analysis for top weldment presented above is bounding and no further analysis is required.

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April 2018

Revision 18C

NAC-STC

NAC Storage Transport Cask

SAFETY ANALYSIS REPORT

Volume 2 of 2

Non-Proprietary Version

Docket No. 71-9235

NAC INTERNATIONAL

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5.9 Shielding Evaluation – Directly Loaded STC-HBU Fuel, Flat Bed with Shielding Augmented Top Weldment and Reduced Lead Shielding Configuration

Using the same methodology discussed in Sections 5.8.6, 5.8.7 and 5.8.8 the directly loaded STC is evaluated with an alternative (shielding augmented via an optional shield plate) top weldment and reduced lead shielding requirement in the cask top forging area.

The reduction in lead is modeled as a 0.65-inch thick and 10-inch tall void around the top outer circumference of the lead shield. This 10-inch void starts at the bottom surface of the Fiberfrax coverplate, which results in the void extending 10.18 inches from the bottom of the upper forging as illustrated in Figure 5.9.1. The lead insulation is also modeled as void. A VISED slice of the modified lead shield is shown in Figure 5.9-1. The alternative top weldment is augmented with additional shield plates. A VISED slice of the modeled augmented top weldment is shown in Figure 5.9-2.

STC partial loadings [redacted] are evaluated. Cobalt impurity levels of 0.4, 0.8, and 1.2 g/kg are evaluated. The resulting cool time tables are compared to the cool time tables from Section 5.8.1-2, with cool times rounded up to the nearest tenth of a year. The change in cool times are shown in Table 5.9-1. Increased cool times do not exceed 0.1 years. This difference can be attributed to the statistical uncertainty in the mesh tally results.

The accident condition lead slump is evaluated with the augmented top weldment and reduced lead volume. A VISED slice of the lead slump with the reduced lead volume is shown in Figure 5.9-3. Note that lead slumps in both the radial and axial directions are modeled for all cases, conservatively increasing the lead void. All accident condition dose rates remain below the limit of 1000 mrem/hr at 1 meter. The maximum accident condition dose rate is 818 mrem/hr for the [redacted] loading with 0.4 g/kg cobalt impurity.

Figure 5.9-1 XZ VISED Slice for the STC with Reduced Lead

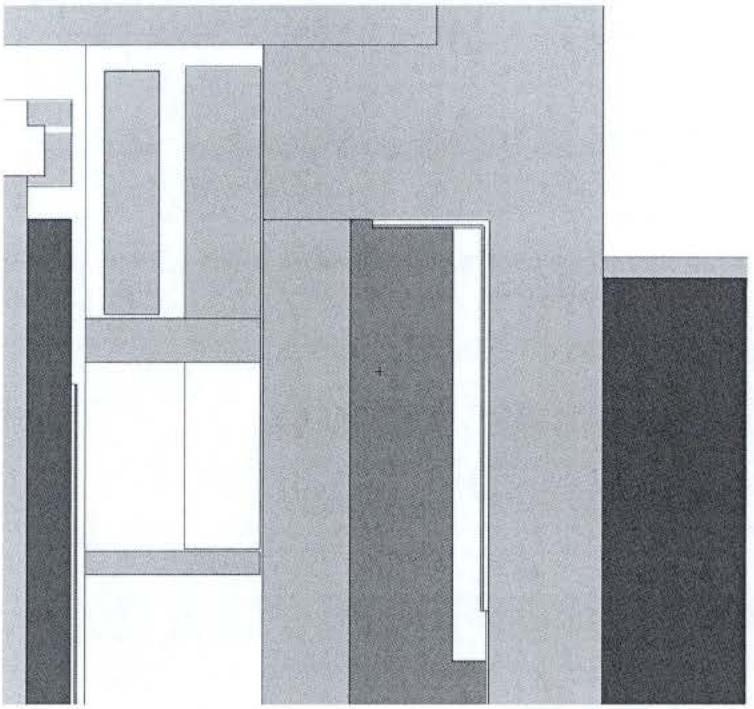

Figure 5.9-2 XY VISED Slice for the STC Augmented Top Weldment

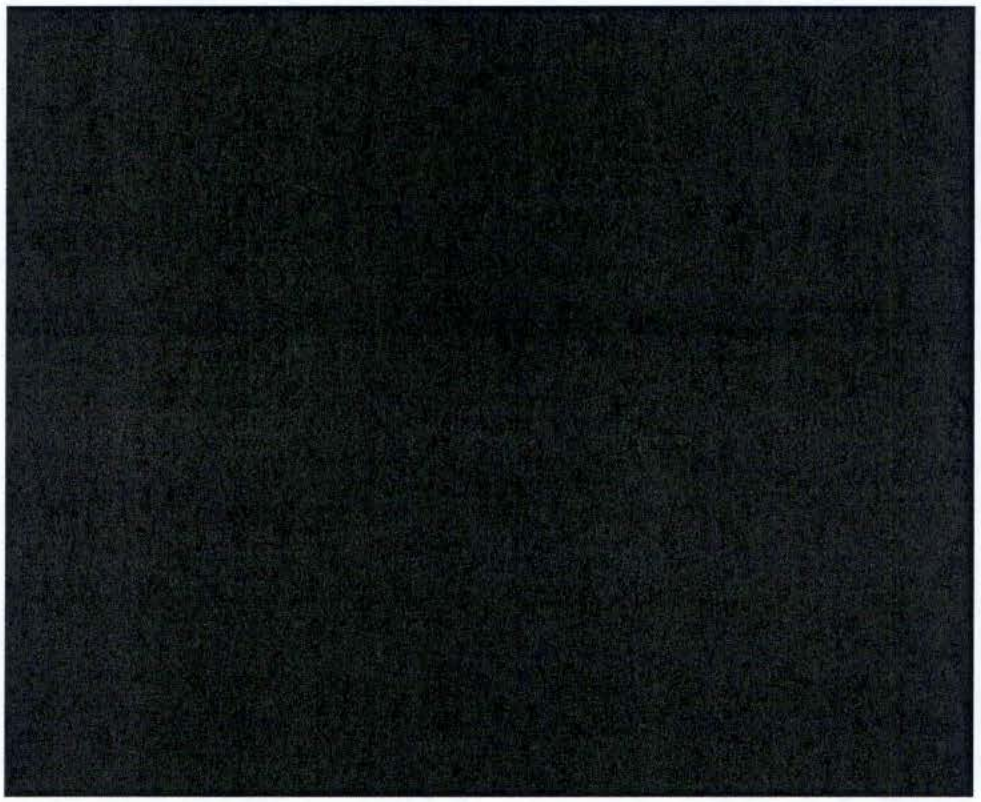

Figure 5.9-3 XZ VISED Slice for the STC Accident Condition Lead Slump with Reduced Lead

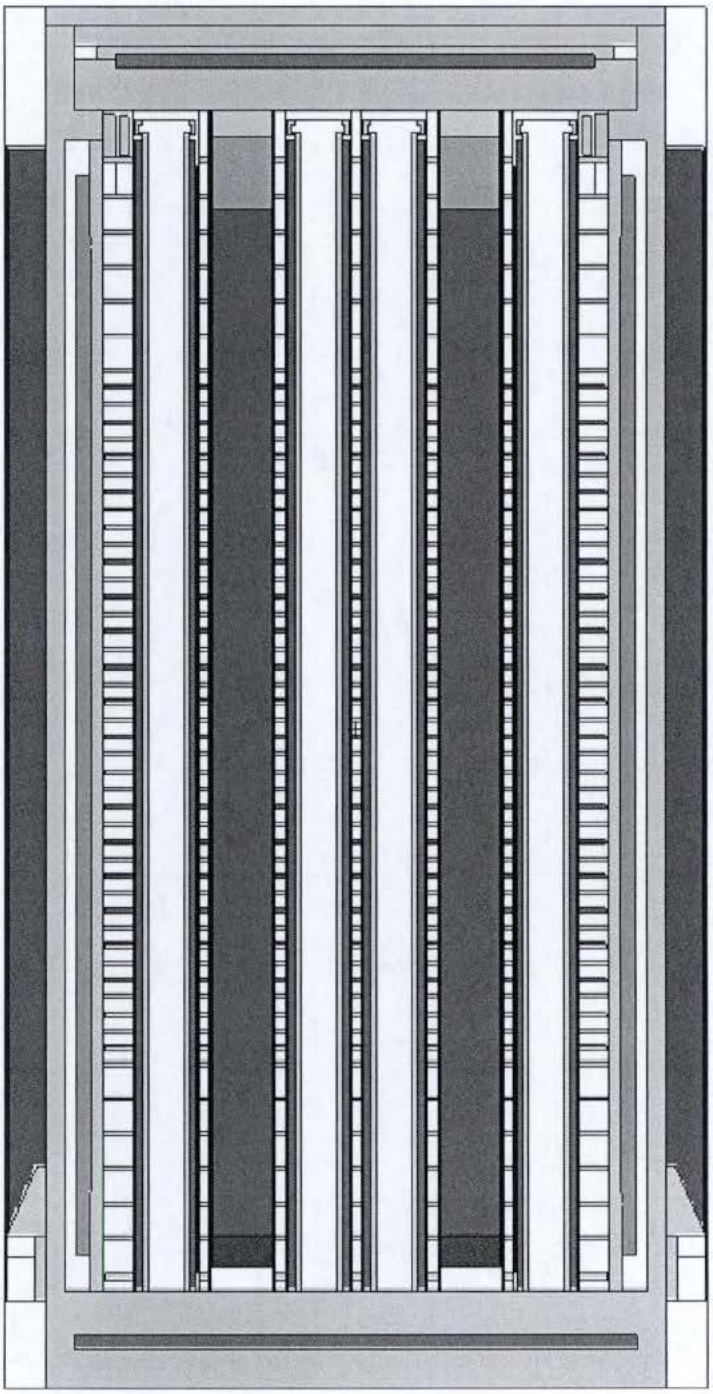

Table 5.9-1 HBU Flat Bed Change in Cool Time [years] with Augmented Top Weldment and Reduced Lead – [redacted]

Cobalt [g/kg]	Min. initial Assembly Avg. Enr. [wt. %]	Assembly Average Burnup [GWd/MTU]														
		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
0.4	2.9≤E<3.1	0.0	0.0	0.0	-0.1	-0.2	-0.2	-0.1	-0.2	-0.2	-	-	-	-	-	-
	3.1≤E<3.3	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-	-	-
	3.3≤E<3.5	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-	-	-
	3.5≤E<3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2
	3.7≤E<3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2
	3.9≤E<4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.2
	4.1≤E<4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.2
	4.3≤E<4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
	4.5≤E<4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4.7≤E<4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4.9≤E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.8	2.9≤E<3.1	-0.4	-0.4	-0.4	-0.4	-0.3	-0.4	-0.4	-0.3	-0.3	-	-	-	-	-	-
	3.1≤E<3.3	-0.3	-0.4	-0.3	-0.4	-0.3	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-	-	-
	3.3≤E<3.5	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.3	-0.4	-0.3	-0.3	-	-	-
	3.5≤E<3.7	-0.3	-0.3	-0.3	-0.4	-0.3	-0.4	-0.3	-0.4	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3
	3.7≤E<3.9	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.3	-0.4	-0.3	-0.3	-0.4	-0.3	-0.3	-0.2
	3.9≤E<4.1	0	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.3	-0.3	-0.4	-0.4
	4.1≤E<4.3	0	0	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.4	-0.3	-0.4	-0.3	-0.3	-0.4
	4.3≤E<4.5	0	0	0	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.3	-0.4	-0.3
	4.5≤E<4.7	0	0	0	0	-0.1	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
	4.7≤E<4.9	0	0	0	0	0	0	-0.2	-0.2	-0.3	-0.3	-0.2	-0.3	-0.3	-0.3	-0.3
	4.9≤E	0	0	0	0	0	0	0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4
1.2	2.9≤E<3.1	-0.4	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.3	-	-	-	-	-	-
	3.1≤E<3.3	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-	-	-
	3.3≤E<3.5	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.3	-0.3	-	-	-
	3.5≤E<3.7	-0.5	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
	3.7≤E<3.9	-0.4	-0.4	-0.5	-0.5	-0.4	-0.5	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3
	3.9≤E<4.1	-0.5	-0.4	-0.4	-0.4	-0.4	-0.5	-0.4	-0.5	-0.5	-0.5	-0.4	-0.4	-0.3	-0.4	-0.3
	4.1≤E<4.3	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.4	-0.4
	4.3≤E<4.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.5	-0.4	-0.5	-0.4	-0.5	-0.4	-0.4
	4.5≤E<4.7	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
	4.7≤E<4.9	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
	4.9≤E	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4

Table 5.9-2 HBU Flat Bed Change in Cool Time [years] with Augmented Top Weldment and Reduced Lead – [redacted]

Cobalt [g/kg]	Min. initial Assembly Avg. Enr. [wt. %]	Assembly Average Burnup [GWd/MTU]														
		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
0.4	2.9≤E<3.1	0.0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	0.0	-	-	-	-	-	-
	3.1≤E<3.3	0.1	0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	0.0	-	-	-
	3.3≤E<3.5	0.0	0.0	0.0	0.1	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.1	-	-	-
	3.5≤E<3.7	0.0	0.1	0.1	0.1	0.0	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	0.0	0.0
	3.7≤E<3.9	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-0.1	-0.2	-0.1	-0.2	-0.2	-0.1	0.0	0.0
	3.9≤E<4.1	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1
	4.1≤E<4.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	-0.2	-0.1	-0.1	-0.1	-0.1
	4.3≤E<4.5	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	-0.1	-0.1	-0.1	-0.1
	4.5≤E<4.7	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	-0.1	-0.1
	4.7≤E<4.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.1
	4.9≤E	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0
0.8	2.9≤E<3.1	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.3	-0.3	-0.2	-	-	-	-	-	-
	3.1≤E<3.3	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.3	-0.3	-0.2	-0.2	-0.2	-	-	-
	3.3≤E<3.5	-0.5	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-	-	-
	3.5≤E<3.7	-0.4	-0.4	-0.4	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2
	3.7≤E<3.9	-0.3	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.3	-0.4	-0.3	-0.3	-0.2	-0.2
	3.9≤E<4.1	-0.3	-0.3	-0.4	-0.3	-0.4	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
	4.1≤E<4.3	-0.1	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.2
	4.3≤E<4.5	0.0	0.0	-0.2	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.4	-0.3
	4.5≤E<4.7	0.0	0.0	0.0	0.0	-0.3	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.4	-0.3
	4.7≤E<4.9	0.0	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
	4.9≤E	0.0	0.0	0.1	0.0	0.0	0.0	-0.1	-0.3	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4	-0.3
1.2	2.9≤E<3.1	-0.5	-0.5	-0.5	-0.4	-0.5	-0.5	-0.4	-0.3	-0.4	-	-	-	-	-	-
	3.1≤E<3.3	-0.5	-0.5	-0.6	-0.4	-0.4	-0.4	-0.4	-0.3	-0.4	-0.4	-0.3	-0.3	-	-	-
	3.3≤E<3.5	-0.6	-0.6	-0.5	-0.6	-0.5	-0.5	-0.5	-0.4	-0.4	-0.3	-0.4	-0.3	-	-	-
	3.5≤E<3.7	-0.5	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.2	-0.2
	3.7≤E<3.9	-0.6	-0.5	-0.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.4	-0.4	-0.3	-0.4	-0.3
	3.9≤E<4.1	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.6	-0.4	-0.4	-0.5	-0.4	-0.3	-0.4	-0.3
	4.1≤E<4.3	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.3	-0.4
	4.3≤E<4.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.4	-0.5	-0.5	-0.4	-0.4	-0.3
	4.5≤E<4.7	-0.5	-0.5	-0.5	-0.4	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4
	4.7≤E<4.9	-0.5	-0.5	-0.4	-0.5	-0.5	-0.5	-0.5	-0.5	-0.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.4
	4.9≤E	-0.4	-0.4	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.4

Table 5.9-3 HBU Flat Bed Change in Cool Time [years] with Augmented Top Weldment and Reduced Lead – [redacted]

Cobalt [g/kg]	Min. initial Assembly Avg. Enr. [wt. %]	Assembly Average Burnup [GWd/MTU]														
		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
0.4	2.9≤E<3.1	-0.2	-0.3	-0.4	-0.6	-0.7	-0.8	-0.9	-1.0	-0.9	-	-	-	-	-	-
	3.1≤E<3.3	-0.3	-0.3	-0.3	-0.4	-0.5	-0.7	-0.8	-1.0	-0.9	-0.9	-0.9	-0.7	-	-	-
	3.3≤E<3.5	-0.2	-0.3	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.9	-1.0	-1.0	-0.9	-	-	-
	3.5≤E<3.7	0.1	-0.1	-0.3	-0.2	-0.3	-0.4	-0.6	-0.6	-0.8	-0.9	-0.9	-1.1	-0.8	-0.7	-0.7
	3.7≤E<3.9	0.0	0.1	0.1	-0.3	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-0.8	-0.9	-1.0	-0.9	-0.8
	3.9≤E<4.1	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.2	-0.4	-0.5	-0.6	-0.7	-0.8	-1.0	-1.0	-0.9
	4.1≤E<4.3	0.1	0.1	0.1	0.0	0.0	0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.6	-0.8	-0.9	-0.9
	4.3≤E<4.5	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	-0.2	-0.3	-0.4	-0.6	-0.6	-0.8	-0.8
	4.5≤E<4.7	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7
	4.7≤E<4.9	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	-0.2	-0.3	-0.4	-0.6
	4.9≤E	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.1	-0.3	-0.4	-0.4
0.8	2.9≤E<3.1	-0.4	-0.4	-0.4	-0.3	-0.5	-0.5	-0.7	-0.8	-0.8	-	-	-	-	-	-
	3.1≤E<3.3	-0.5	-0.5	-0.4	-0.4	-0.3	-0.4	-0.5	-0.7	-0.7	-0.9	-0.9	-1.0	-	-	-
	3.3≤E<3.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.3	-0.4	-0.5	-0.6	-0.6	-0.9	-0.9	-	-	-
	3.5≤E<3.7	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.5	-0.7	-0.8	-0.9	-1.0	-1.0
	3.7≤E<3.9	-0.2	-0.6	-0.5	-0.5	-0.5	-0.4	-0.3	-0.3	-0.3	-0.4	-0.5	-0.7	-0.7	-0.8	-0.9
	3.9≤E<4.1	-0.1	-0.2	-0.5	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.5	-0.5	-0.6	-0.7	-0.8
	4.1≤E<4.3	-0.1	-0.1	-0.2	-0.5	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7
	4.3≤E<4.5	0.0	0.0	-0.1	-0.2	-0.5	-0.5	-0.5	-0.4	-0.5	-0.4	-0.4	-0.4	-0.3	-0.5	-0.5
	4.5≤E<4.7	0.0	0.0	0.0	-0.1	-0.2	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.3	-0.4	-0.3	-0.5
	4.7≤E<4.9	0.0	0.0	0.0	0.0	0.0	-0.3	-0.5	-0.5	-0.4	-0.4	-0.4	-0.3	-0.4	-0.4	-0.4
	4.9≤E	0.0	0.0	0.0	0.0	-0.1	0.0	-0.3	-0.4	-0.5	-0.4	-0.5	-0.5	-0.4	-0.3	-0.3
1.2	2.9≤E<3.1	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7	-	-	-	-	-	-
	3.1≤E<3.3	-0.6	-0.6	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.6	-0.7	-0.7	-0.9	-	-	-
	3.3≤E<3.5	-0.3	-0.6	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.5	-0.6	-0.7	-	-	-
	3.5≤E<3.7	-0.2	-0.4	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.5	-0.5	-0.7	-0.7	-0.9
	3.7≤E<3.9	-0.1	-0.2	-0.3	-0.5	-0.6	-0.5	-0.4	-0.5	-0.3	-0.4	-0.4	-0.4	-0.6	-0.7	-0.8
	3.9≤E<4.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.5	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.6	-0.6
	4.1≤E<4.3	0.0	0.0	-0.1	-0.1	-0.2	-0.5	-0.5	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4	-0.5
	4.3≤E<4.5	0.0	-0.1	0.0	-0.1	-0.1	-0.2	-0.5	-0.5	-0.5	-0.5	-0.5	-0.4	-0.4	-0.4	-0.4
	4.5≤E<4.7	-0.1	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.5	-0.5	-0.5	-0.5	-0.4	-0.5	-0.4	-0.4
	4.7≤E<4.9	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.5	-0.5	-0.6	-0.4	-0.4	-0.4	-0.3
	4.9≤E	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.5	-0.5	-0.6	-0.5	-0.4	-0.4

5.10 Shielding Evaluation – Directly Loaded Low Burnup Fuel, Flat Bed with Shielding Augmented Top Weldment and Reduced Lead Shielding Configuration

The alternative (shielding augmented via an optional shield plate) top weldment and reduction in lead shielding, described in Section 5.9, is evaluated with low burnup fuel (≤ 45 GWd/MTU). Additional model updates are implemented to conform to the MCBEND analysis (Sections 5.1 through 5.5).

- Non-truncated impact limiters
- Low burnup axial source profile (shown in Table 5.2-5)
- Zircaloy in the lower nozzle and upper plenum homogenization (Table 5.3-4)
- A neutron source multiplier of 1.6667 (based on a k_{eff} of 0.4) in lieu of MCNP-calculated subcritical multiplication (Section 5.2.1.1).

A VISED slice of the cask model is shown in Figure 5.10-1. The reduced lead volume and alternative top weldment are shown in Figure 5.9-1 and Figure 5.9-2, respectively.

The difference in required cool time between the nominal model and the model with augmented top weldment and reduced lead is shown Table 5.10-1. All cool times remain the same or decrease with the augmented top weldment and reduced lead volume. The results use a 1.2 g/kg cobalt impurity.

The augmented top weldment and reduced lead accident results for HBU fuel from Section 5.9 show a significant margin to limits (~200 mrem/hr). The maximum 1 meter accident condition dose rate occurs over the middle of the fuel region and is dominated by the fuel neutron source. As the fuel neutron source is reduced with lower burnup, the low burnup fuel accident condition dose rates will remain below limits.

Figure 5.10-1 XZ VISED Slice LBU Flat Bed with Non-Truncated Impact Limiters

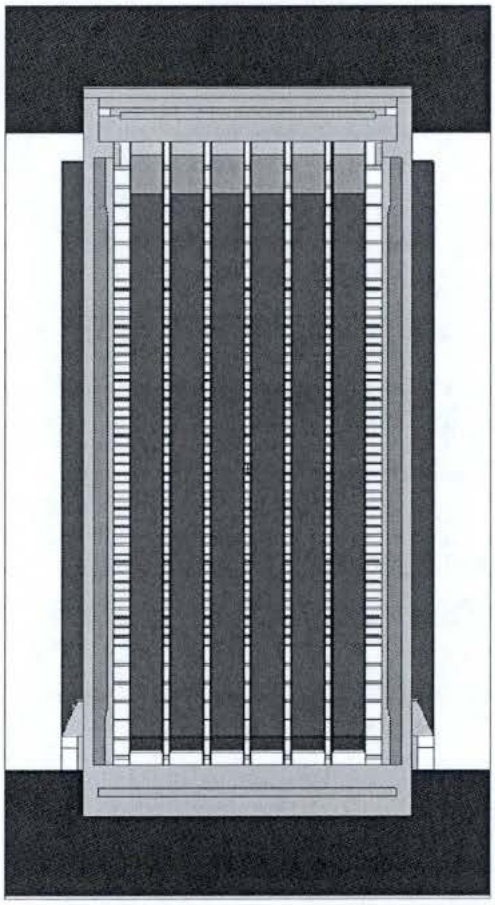

Table 5.10-1 LBU Flat Bed Change in Cool Time [years] with Augmented Top Weldment and Reduced Lead

Enr. [wt. %]	Burn up [GWd/MTU]			
	B≤30	30<B≤35	35<B≤40	40<B≤45
1.7 ≤ E < 1.9	-0.5	-0.7	-	-
1.9 ≤ E < 2.1	-0.4	-0.6	-1.7	-
2.1 ≤ E < 2.3	-0.4	-0.4	-1.5	-
2.3 ≤ E < 2.5	-0.3	-0.4	-1.4	-1.9
2.5 ≤ E < 2.7	-0.3	-0.4	-0.8	-1.7
2.7 ≤ E < 2.9	-0.3	-0.4	-0.7	-1.7
2.9 ≤ E < 3.1	-0.3	-0.4	-0.5	-1.6
3.1 ≤ E < 3.3	-0.2	-0.3	-0.4	-1.4
3.3 ≤ E < 3.5	-0.3	-0.3	-0.4	-1.2
3.5 ≤ E < 3.7	-0.2	-0.3	-0.4	-1.0
3.7 ≤ E < 3.9	-0.1	-0.2	-0.4	-0.6
3.9 ≤ E < 4.1	-0.2	-0.2	-0.4	-0.5
4.1 ≤ E < 4.3	-0.1	-0.2	-0.3	-0.4
4.3 ≤ E < 4.5	-0.1	-0.2	-0.2	-0.2

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The removable transport impact limiters consist of redwood and balsa wood. License drawings and the supporting analyses specify the crush strengths of the redwood and balsa wood to be 6240 psi ± 620 psi and 1550 psi ± 150 psi respectively. For manufacturing purposes, verification of the impact limiter material is accomplished by verifying the densities of the wood. Three samples from each redwood board are to be tested for density, and the average density of the samples shall be 23.5 ± 3.5 pounds/cubic foot. Each 15-degree and 30-degree pie shaped section of the impact limiter shall have a density of 22.3 ± 1.2 pounds/cubic foot in accordance with the License Drawings. The moisture content for any single redwood board must be greater than 5 percent, but less than 15 percent. The average moisture content for a lot of redwood used in impact limiter construction must not be greater than 12 percent.

Following final closure welding of the transport impact limiter stainless steel shell, a leak test of the shell welds shall be performed to verify weld integrity. The test shall be performed by evacuating the impact limiter to 75 mbar and performing a 30-minute test to determine if there is any increase in the impact limiter pressure. Any detected leak shall not exceed 1×10^{-2} cm^3/sec. If a leak exceeding this value is detected, the cause of the leak shall be determined, and the weld repaired and retested.

8.1.5 Tests for Shielding Integrity

8.1.5.1 Gamma Shield Test

The gamma scan test shall be conducted by continuous scanning or probing over 100 percent of all accessible cask surfaces using a 3-inch detector and a ^{60}Co source. The source strength shall be of an intensity sufficient to produce a count rate that equals or exceeds three times the background count rate on the external surfaces of the cask. The count rate shall be maintained for greater than one minute prior to the start of scanning. The detector scan path spacing (cask exterior surface) will be a maximum of 2.5 inches and the scanning speed will be 4.5 feet per minute or less. The source scan path spacing (cask interior surface) will be on a 2-inch grid pattern (when using a 3-inch detector). Flat surfaces, such as the cask bottom and closure lids, will use a 2.5 inch spacing for both the detector and source scan paths (when using a 3-inch detector).

The acceptance criteria for the shield test will be that the shield effectiveness of the cask body and lids shall be equal to or greater than the shield effectiveness of a lead and steel mock-up. The steel thickness of the mockup shall be equivalent to the minimum steel thickness specified on the

License Drawings and the lead thickness shall be equivalent to the minimum lead thickness specified in the License Drawings less 3 percent. The shielding mock-up will be produced using the same fabrication techniques as those approved for the cask.

Measured count rates that exceed those established by the test mock-up shall cause the component to be rejected, with exception to the alternate acceptance criteria as specified in Section 8.1.5.1.1 for the Fiberfrax region of the lead. The rejected areas/components shall be evaluated to determine the corrective action to be taken. Any repaired areas shall be retested prior to acceptance.

An additional gamma shield effectiveness test shall be performed on each cask following first fuel loading. The neutron and gamma shield effectiveness test procedures and acceptance criteria are described in Section 8.1.5.4.

8.1.5.1.1 Alternate Acceptance Criteria (Fiberfrax Region)

In the region of the Fiberfrax insulation, which is defined as the upper 10.18 inches of the cask upper lead region, a reduced lead thickness equivalent to 0.65 inches is acceptable for directly loaded fuel shipments. However, the cask shall be used with the optional shield plate on the basket top weldment as detailed in drawing 423-872, which compensates for this reduced lead shielding.

8.1.5.2 Neutron Shielding Test

The neutron shielding of the NAC-STC is provided by a solid layer of NS-4-FR, which is a hard polymer material. A 5.5-inch layer of NS-4-FR is located in the annulus formed by the outer shell and the 0.236-inch (6 mm) thick neutron shield shell. The neutron shield is divided in sections by the copper/stainless steel fins. A 2-inch thick layer of NS-4-FR is also installed in the cask inner lid and in the cask bottom.

The installation of NS-4-FR material in the fabrication of the cask is a special process and, as such, procedures will be prepared and qualified to ensure that the mix ratios, mixing method, degassing, pouring, and curing of the material is properly performed. The NS-4-FR raw material is provided in the form of a 3-part mixing kit. The material content of the raw material is tested and certified at the time of kit preparation. The neutron shielding material is installed into the annulus between the outer shell and the neutron shield shell by pouring it with the cask in an inverted vertical position. Prior to installation, samples from each mix of the actual material

being poured into the annulus are wet density tested to ensure that the material is properly mixed. Mixes that do not meet the wet density acceptance criteria are rejected. Procedures used for installation of the material are validated prior to use by destructive examination of a full scale mock-up of the neutron shield cavity. Qualification of the installation procedure verifies material homogeneous properties and minimizes the potential deleterious voids.

8.1.5.3 Neutron Shielding Material Testing

The neutron shield properties of NS-4-FR are provided in Chapters 1 and 3. Each lot (mixed batch) of neutron shield material shall be tested to verify that the hydrogen concentration, boron concentration, and neutron shield density meet the requirements specified in Chapters 1 and 3 and the License Drawings. Testing shall be performed by qualified laboratories in accordance with written and approved procedures. Hydrogen concentration, boron concentration, and density data for each lot of neutron shield material shall become part of the quality record documentation package.

Dimensional inspection of the cavities containing the neutron shielding material shall ensure that the required thickness specified in the License Drawings is incorporated into the cask.

The installation of the neutron shielding material shall be performed in accordance with written, approved, and qualified procedures. The procedures shall ensure that mix ratios and mixing methods are controlled in order to achieve proper material composition, boron concentration and distribution, and that pours are controlled in order to prevent gaps or unacceptable voids from occurring in the material. Procedures shall be qualified by the use of mock-ups to ensure that the NS-4-FR installation does not result in the creation of unacceptable voids. Wet density data for each mix of installed neutron shield material shall be maintained as part of the quality record documentation package.

8.1.5.4 Neutron and Gamma Shield Effectiveness Tests

Following first fuel loading, a neutron and gamma shield effectiveness test shall be performed for each cask prior to transport. The test shall be performed with the cask loaded with fuel, drained, vacuum dried and backfilled with helium. The purpose of the test is to document the effectiveness of the neutron and gamma shielding materials. The test shall be performed in accordance with detailed, approved written test procedures.

Calibrated neutron and gamma dose rate meters shall be used to measure the neutron and gamma dose rate at contact with the outer shell of the neutron shield and at 2.3 meters from the surface (equivalent to 2 meters from the sides of the railcar). Dose measurement points shall be established on the external surface of the shell at 30° intervals and at five points along the height of the shield (a total of 60 measuring points). In addition, neutron and gamma dose rate measurements shall be made of the trunnion areas above the neutron shield, at four points below the neutron shield, and at the edges and center of the cask top (outer lid) and cask bottom surfaces. Dose rates at the top and bottom of the cask shall be measured with the transport impact limiters installed. The dose rates measured at contact and at 2.3 meters shall be recorded on the test data sheet, along with the total power of the loaded fuel assemblies; date, time and location of test; identification and calibration of instrumentation; and identification of test engineer and operators.

To allow an evaluation of the measured dose rates to be completed, the burnup and cool time for the actual fuel assemblies loaded into the cask will be determined and recorded. From this fuel history data, the total actual neutron and gamma source terms will be estimated using ORIGEN or similar calculations.

If the measured dose rates exceed the applicable regulatory limits, the licensee shall notify the NRC. Appropriate corrective measures will be taken, including fuel unloading and correction of the shielding deficiency. Following corrective actions, the test will be re-performed to the original acceptance criteria prior to final acceptance.

8.1.6 Thermal Test

Prior to acceptance at the factory, a thermal test shall be performed on each fabricated packaging to confirm and verify that the fabricated and assembled cask possesses the heat rejection capabilities predicted by the thermal analyses. The thermal test shall be performed in accordance with approved written procedures.

8.1.6.1 Thermal Test Set-up

The thermal test set-up is shown in Figure 8.1-1(a). As depicted, the thermal test shall be performed with the cask positioned horizontally on a test frame. The transport impact limiter or equivalent insulating material shall be installed on each end of the cask to simulate the transport configuration. The cask will be located in a covered building in a still environment. The cask

shall be assembled with the basket installed. A thermal test lid with connections for thermocouple leads and electric heater power cables shall be installed in place of the inner lid. The outer lid will not be installed for the test. The thermal test lid will be provided with an O-ring seal capable of containing the containment cavity helium atmosphere.

Electric heaters shall be installed in each fuel tube. The electric heaters will have an active length of between 120 and 150 inches and be capable of generating a minimum of 22 kilowatts (kw). The heaters will be supported in the basket so as to not be in contact with the wall of the fuel tube. The power supplied to the heater will be recorded throughout the test duration.

Calibrated test thermocouples, with an accuracy of ±2°F, will be installed on the cask basket, inner shell, and outer neutron shield shell surfaces. The location of the test thermocouples are shown in Figure 8.1-1. The specific location of the thermocouples are as follows:

TC1 - basket top steel weldment
TC2 - steel disk at cask basket midpoint
TC3 - aluminum disk at cask basket midpoint
TC4 - basket bottom steel weldment
TC5; TC6; TC7; and TC8 - located at 90° intervals on the inner shell surface at cavity midpoint
TC9 - top of inner shell surface at 30-40 inches from top of cavity
TC10 - bottom of inner shell surface at 30 to 40 inches from base of the cavity
TC11; TC12; TC13; and TC14 - located at 90° intervals on the neutron shield shell surface (at fin tip) at cask midpoint
TC15 - top of neutron shield shell surface (at fin tip) at 30-40 inches from top of neutron shell
TC16 - bottom of neutron shield shell surface (at fin tip) at 30-40 inches from bottom of neutron shield shell
TC17 - top of upper forging
TC18 - outer shell surface at centerline of cask bottom face
TC19 - inner fuel tube wall surface near the center of the cask basket
TC20 - ambient temperature of testing area

The output of the test thermocouples will be recorded throughout the test by a strip chart recorder.

8.1.6.2 Test Procedure

With the cask assembled and instrumented as described above, the cask cavity is evacuated and backfilled to 1.0 atmosphere absolute (14.6 psia) with helium. Power will be applied to the heaters to simulate the cask contents. After initiation of power to the heaters, the temperatures of all thermocouples and heater power levels will be monitored and recorded on data sheets at 60 minute intervals. Power will be maintained to the electrical heaters until the cask has reached thermal equilibrium.

For the purpose of the test, thermal equilibrium is defined as being achieved when over two consecutive hours:

$\Delta t_{TC13} \leq 2°F/hr$, and
$\Delta t_{TC3} \leq 2°F/hr$

Based upon the thermal heat-up evaluation, thermal equilibrium should be achieved in approximately five days.

After verification of thermal equilibrium, final temperature measurements will be recorded for all test thermocouples. The final power readings for the electric heaters will also be recorded. The strip chart will be marked to indicate the time of the final cask measurements. The printout of the strip chart recorder and the completed test data sheets will be incorporated into an approved final thermal test report. The test will be determined to be acceptable if the acceptance criteria of Section 8.1.6.3 are met.

If the acceptance criteria are not met, the cask will not be accepted until appropriate corrective actions are completed. Upon completion of corrective actions, the cask shall be retested to the original test requirements and acceptance criteria.

8.1.6.3 Acceptance Criteria

The purpose of the thermal test is to confirm the heat rejection capabilities of the as-built cask are acceptable and correspond to the temperatures calculated by thermal analyses for the directly loaded (uncanistered) configuration presented in Chapter 3.0 of this application.

Package heat dissipation acceptance testing assures: 1) maximum material temperatures do not exceed material allowables; and that 2) measured temperature gradients are less than the thermal gradients calculated in the package thermal analyses.

The thermal acceptance test is accepted when the following criteria are met:

1) When corrected for physical test boundary conditions and heat load, the following measured temperatures are not exceeded:

TC No.	Location	Temperature °F
TC1	Top Basket Steel Weldment	435
TC3	Aluminum Disk Center	485
TC2	Steel Support Disk Center	495
TC4	Basket Bottom Steel Weldment	475
TC5-TC8	Cask Inner Shell	330
TC11-TC14	Neutron Shield Shell	240
TC17	Cask Top Forging	200
TC18	Cask Bottom	330
TC19	Tube Wall	540

2) The measured temperature gradient across the central steel disk from TC2 to the average of TC5, TC6; TC7 and TC8 is less than 200°F;
3) The measured temperature gradient across the central aluminum disk from TC3 to the average of TC5; TC6; TC7 and TC8 is less than 190°F; and
4) The measured temperature gradient across the cask body as measured by thermocouple pairs TC5-TC13; TC6-TC14; TC7-TC11; and TC8-TC12 are less than 90°F.

8.1.7 Neutron Absorber Tests for NAC-STC Directly-Loaded Fuel Basket and for Yankee-MPC and CY-MPC Canistered Fuel Baskets

Two alternate neutron poison materials, BORAL and TalBor, have been qualified by NAC for use in the NAC-STC directly loaded, the Yankee-MPC and the CY-MPC fuel baskets. For the NAC-STC directly loaded basket BORAL acceptance testing is described in this section (Section 8.1.7) while a generic metal matrix composite (aluminum based) and borated aluminum acceptance/qualification program is described in Section 8.1.11. The generic program is designed to demonstrate structural, thermal, and nuclear requirements are met without

specification of a particular manufacturer or material. TalBor, an MMC material, is excluded from the generic acceptance/qualification program, and is included in Section 8.1.7.

BORAL is manufactured by Ceradyne Corporation, Chicoutimi (Quebec), Canada under a Quality Assurance/Quality Control program in conformance with the requirements of 10 CFR 50, Appendix B. The manufacturing process consists of several steps: the first step is the mixing of the aluminum and boron-carbide powders that form the core of the finished material, with the amount of each powder a function of the desired ^{10}B areal density. The methods used to control the weight and blend of the powders are patented and proprietary processes of AAR Advanced Structures (AAR) (subsequently Ceradyne). The mixture of powders is placed in an aluminum box with walls approximately one inch thick. The top lid is welded in place. This "ingot" is heated for several hours and then is hot-rolled to produce the sheet of design thickness. The rolling process densifies and bonds the powder mixture. The aluminum box walls become the cladding for the Al-B_4C core.

TalBor is manufactured by Talon Composites, Inc. (TalBor was formerly called Boralyn, and was produced by Alyn Corporation. Alyn Corporation went out of business and Talon Composites acquired the major production equipment and the patent rights for Boralyn. TalBor is essentially identical to Boralyn.) TalBor is manufactured and controlled using a Quality Assurance program that is compliant with the applicable requirements of 10 CFR 50, Appendix, B. TalBor is a metal matrix composite (MMC). The aluminum and B_4C powders are mixed to the specified ^{10}B areal density and the powder mixture is vacuum sintered and hot pressed to achieve a fully dense billet. The billet is extruded, then cut and rolled to the design thickness.

After manufacturing, test samples from each batch of neutron absorber (poison) sheets shall be tested to verify the presence, proper distribution, and minimum weight percent of ^{10}B. Neutron transmission testing or augmented wet chemistry testing may be used. The tests shall be performed in accordance with approved written procedures.

8.1.7.1 Neutron Absorber Material Sampling Plan

The neutron absorber sampling plan is selected to demonstrate a 95/95 (95% probability and 95% confidence level) statistical confidence level in the neutron absorber sheet material compliance with the specification. In addition to the specified sampling plan, each sheet of material is visually and dimensionally inspected using at least 6 measurements (along the edges near each corner and the longitudinal centerline) on each sheet. No rejected neutron absorber sheet is used. The sampling plan is supported by written and approved procedures.

The sampling plan requires that a coupon sample be taken from each sheet of the first set of 100 sheets of absorber material. Thereafter, coupon samples are taken from 20 randomly selected sheets from each set of 100 sheets. This 1 in 5 sampling plan continues until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder, aluminum powder, or aluminum extrusion), or a process change, at which time the sampling process is reinitiated as previously described. The sheet samples are indelibly marked and recorded for identification. This identification is used to document neutron absorber test results, which become part of the quality record documentation package.

8.1.7.2 Wet Chemistry Test Performance

An approved facility with chemical analysis capability shall be selected to perform the wet chemistry tests. The tests will ensure the presence of boron and enable the calculation of the ^{10}B areal density. Acceptability of the uniformity of boron distribution is based on the manufacturer's material qualification tests.

The most common method of verifying the acceptability of neutron absorber material is the wet chemistry method—a chemical analysis where the aluminum is separated from a sample with known thickness and volume. The remaining boron-carbide material is weighed and the areal density of ^{10}B is computed. A statistical conclusion about the BORAL or TalBor sheet from which the sample was taken and that batch of sheets may then be drawn based on the test results and the established manufacturing processes previously noted.

BORAL and Talbor sheets are required to contain a minimum 0.020 g $^{10}B/cm^2$ which is credited at 75% effectiveness in Chapter 6.

8.1.7.3 Neutron Absorption Transmission Test Performance

An approved facility with a neutron source and neutron detection capability shall be selected to perform the described tests, if the neutron absorption transmission test method is used. The tests will assure that the neutron absorption capacity of the material tested is equal to, or higher than, the given reference value and will verify the uniformity of boron distribution. The principle of measurement of neutron absorption is that the presence of boron results in a reduction of neutron flux between the thermalized neutron source and the neutron detector—depending on the material thickness and boron content.

Typical test equipment will consist of thermal neutron source equipment, a neutron detector and a counting instrument. The test equipment is calibrated using a known standard, whose ^{10}B content has been checked and verified by an independent method such as chemical analysis. This calibration process shall be repeated daily (every 24 hours) while tests are being performed.

8.1.7.4 Acceptance Criteria

The neutron transmission test results shall be considered acceptable if the minimum ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube drawings. Any specimen not meeting the acceptance criteria shall be rejected and all of the sheets from that batch shall be similarly rejected unless coupons from each individual absorber plate are tested and confirmed to meet or exceed the specified areal density.

8.1.8 Neutron Absorber Tests for MPC-LACBWR Canistered Fuel Basket

Neutron absorber material (commercially available as BORAL®), in the form of sheets consisting of boron-carbide evenly dispersed within a matrix of aluminum and clad with aluminum, is used in the NAC-MPC transportable storage canister fuel baskets. The manufacturing process consists of several steps – the first being the mixing of the aluminum and boron-carbide powders that form the core of the finished material, with the amount of each powder a function of the desired ^{10}B areal density. The methods used to control the weight and to blend the powders were patented and proprietary processes of AAR and, subsequently, of Ceradyne Corporation of Chicoutimi (Quebec), Canada.

After manufacturing, test samples from each batch of BORAL® neutron absorber (poison) sheets shall be tested using wet chemistry or neutron absorption techniques to verify the presence, proper distribution, and minimum weight percent of ^{10}B. The tests shall be performed in accordance with approved written procedures.

8.1.8.1 Neutron Absorber Material Sampling Plan

The neutron absorber sampling plan is selected to demonstrate a 95/95 (95% probability and 95% confidence level) statistical confidence level in the neutron absorber sheet material compliance with the specification. In addition to the specified sampling plan, each sheet of material is visually and dimensionally inspected using at least six measurements (along the edges near each corner and the longitudinal centerline) on each sheet. No rejected neutron absorber sheet is used. The sampling plan is supported by written and approved procedures.

The sampling plan requires that a coupon sample be taken from each sheet of the first set of 50 sheets of absorber material. Thereafter, coupon samples are taken from 10 randomly selected sheets from each set of 50 sheets. This 1 in 5 sampling plan continues until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder, aluminum powder, or aluminum extrusion), or a process change, at which time the sampling process is reinitiated as previously described. The sheet samples are indelibly marked and recorded for identification. This identification is used to document neutron absorber test results, which become part of the quality record documentation package.

8.1.8.2 Wet Chemistry Test Performance

An approved facility with chemical analysis capability shall be selected to perform the wet chemistry tests. The tests will ensure the presence of boron and enable the calculation of the ^{10}B areal density. Acceptability of the uniformity of boron distribution is based on the manufacturer's material qualification tests.

The most common method of verifying the acceptability of neutron absorber material is the wet chemistry method - a chemical analysis where the aluminum is separated from a sample with known thickness and volume. The remaining boron-carbide material is weighed and the areal density of ^{10}B is computed. A statistical conclusion about the BORAL® sheet from which the sample was taken and that batch of BORAL® sheets may then be drawn based on the test results and the established manufacturing processes previously noted.

8.1.8.3 Neutron Absorption Test Performance

An approved facility with a neutron source and neutron detection capability shall be selected to perform the described tests, if the neutron absorption test method is used. The tests will assure that the neutron absorption capacity of the material tested is equal to, or higher than, the given reference value and will verify the uniformity of boron distribution. The principle of measurement of neutron absorption is that the presence of boron results in a reduction of neutron flux between the thermalized neutron source and the neutron detector—depending on the material thickness and boron content.

Typical test equipment will consist of thermal neutron source equipment, a neutron detector and a counting instrument. The test equipment is calibrated using standards whose ^{10}B content has been checked and verified by an independent method such as chemical analysis. The highest permissible counting rate is determined from the neutron counting rates of the reference sheet(s),

which should be ground to the minimum allowable plate thickness. This calibration process shall be repeated daily (every 24 hours) while tests are being performed.

8.1.8.4 Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube drawings. The neutron absorption test shall be considered acceptable if the neutron count determined for each test specimen is less than or equal to the highest permissible neutron count rate determined from the BORAL standard, which is based on the ^{10}B areal density specified on the fuel tube drawings. Any specimen not meeting the acceptance criteria for either test method shall be considered to be nonconforming material and shall be evaluated within the NAC International QA Program. Nonconforming material shall be assigned one of the following dispositions: "use-as-is," "rework" or "reject." Only material that is determined to meet all applicable conditions of the license will be accepted.

8.1.9 Transportable Storage Canister

The transportable storage canister is constructed of Type 304L (Yankee-MPC and CY-MPC) or 304/304L (MPC-LACBWR) stainless steel and is fabricated by welding. If circumferential welds are required to join two shell sections, the seam welds shall not be aligned within 45° circumferentially. The welded cylinder is closed at the bottom by a circular plate welded to the shell wall. The top of the cylinder is closed by two field-installed circular plates, welded to the canister shell wall following fuel loading.

The transportable storage canister is a welded closed component. The canister serves as the confinement boundary component of the NAC-MPC System during storage of spent fuel in the vertical concrete cask.

The finished surfaces of all canister welds are visually examined in accordance with ASME Code Section V, Article 9, to verify that the components are assembled in accordance with the License Drawings and that the components are free of nicks, gouges, and other damage. The acceptance criteria for the visually examined welds for the Yankee-MPC and the CY-MPC canisters is in accordance with ASME Code Section VIII, Division 1, UW-35 and UW-36 and Section III, Subsection NB, NB-4424 and NB-4427. The acceptance criteria for the visually examined welds of the MPC-LACBWR canister are in accordance with ASME Code, Section III, Subsection NF, NF-5360.

The seam and girth welds in the transportable storage canister shell are full-penetration welds that are radiographic (RT) examined in accordance with ASME Code Section V, Article 2. The acceptance criteria for the RT-examined welds is that specified in ASME Code Section III, Subsection NB, Article NB-5320. The canister shell to bottom plate weld is a full-penetration double-bevel weld with an inside fillet weld that is ultrasonic examined in accordance with ASME Code Section V, Article 5, with acceptance criteria as specified in ASME Code Section III, Subsection NB, Article NB-5330. The final surfaces of the seam and girth welds in the canister and the canister shell to bottom plate weld are also liquid penetrant examined in accordance with ASME Code Section V, Article 6, with the acceptance criteria being that specified in ASME Code Section III, Subsection NB, Article NB-5350.

Field installed partial-penetration groove welds attach the shield and structural lids (Yankee-MPC and CY-MPC) or the closure lid (MPC-LACBWR) to the canister shell, and the vent and the drain port covers to the shield lid (Yankee-MPC and CY-MPC) or the inner and outer vent and drain port covers to the closure lid (MPC-LACBWR) after the canister is loaded. The closure ring for the MPC-LACBWR canister is welded to both the canister shell and closure lid by partial penetration welds. For the Yankee-MPC and CY-MPC canister, the root and final surfaces of the shield lid weld are liquid penetrant examined. For the MPC-LACBWR canister, the closure lid to canister shell weld is progressively liquid penetrant examined at the root, mid-plane and final surfaces. The structural lid to shell weld for the Yankee-MPC and CY-MPC canisters is progressively liquid penetrant examined at the root, every 3/8-inch weld layer and final surface. Canister vent and drain port cover welds are liquid penetrant examined at the root and final surfaces unless the welds are completed in a single pass. Welds completed in a single pass require only final surface liquid penetrant examination.

All liquid penetrant examinations are completed in accordance with ASME Code, Section V, Article 6. Acceptance criteria for all liquid penetrant examinations are as specified in ASME Code Section III, Division 1, Subsection NB, Article NB-5350.

The Yankee-MPC and CY-MPC canister shield lid welds are helium leakage tested in accordance with ASME Code Section V, Article 10, Appendix V, using a minimum leak rate test sensitivity of 1×10^{-7} cm^3/sec (helium). The MPC-LACBWR canister closure lid to canister shell weld is hydrostatically tested following completion of the weld.

The fabricator of the transportable storage canister will establish a written weld inspection plan in accordance with an approved quality assurance program. The weld inspection plan will include visual, liquid penetrant, ultrasonic, and radiographic examination. In addition, the weld inspection plan will identify the welds to be examined, the sequence of the examinations, the type of examination method to be used, and the criteria for acceptance of the weld in accordance with the applicable sections of the ASME Code.

8.1.10 HLW Overpack and Basket

The HLW Overpack is constructed of Type 304/304L stainless steel and is fabricated by welding. If circumferential welds are required to join two shell sections, the seam welds shall not be aligned within 45° circumferentially. The welded cylinder is closed at the bottom by a circular plate welded to the shell wall. The top of the cylinder is closed by a field-installed circular plate, welded to the canister shell wall following HLW canister loading.

The HLW Overpack is a welded closed component.

The finished surfaces of all HLW Overpack welds are visually examined in accordance with ASME Code Section V, Articles 1 and 9, to verify that the components are assembled in accordance with the License Drawings and that the components are free of nicks, gouges, and other damage. The acceptance criteria for the visually examined welds for the HLW overpack are in accordance with ASME Code Section VIII, Division 2, Section 7.5.2.2.

The seam, girth, and shell to bottom plate welds in the HLW overpack shell are full-penetration welds that are dye penetrant (PT) examined in accordance with ASME Code Section V, Articles 1 and 6. The acceptance criteria for the PT examined welds are those specified in ASME Code Section VIII, Division 2, Section 7.5.7.2.

Field installed partial-penetration groove welds attach the closure lid to the HLW Overpack shell after HLW canister loading. The closure lid to canister shell weld is visually examined at the final surface. Visual examinations are completed in accordance with ASME Code, Section V, Articles 1 and 9. Acceptance criteria for all visual examinations are as specified in ASME Code Section VIII, Division 2, Section 7.5.2.2.

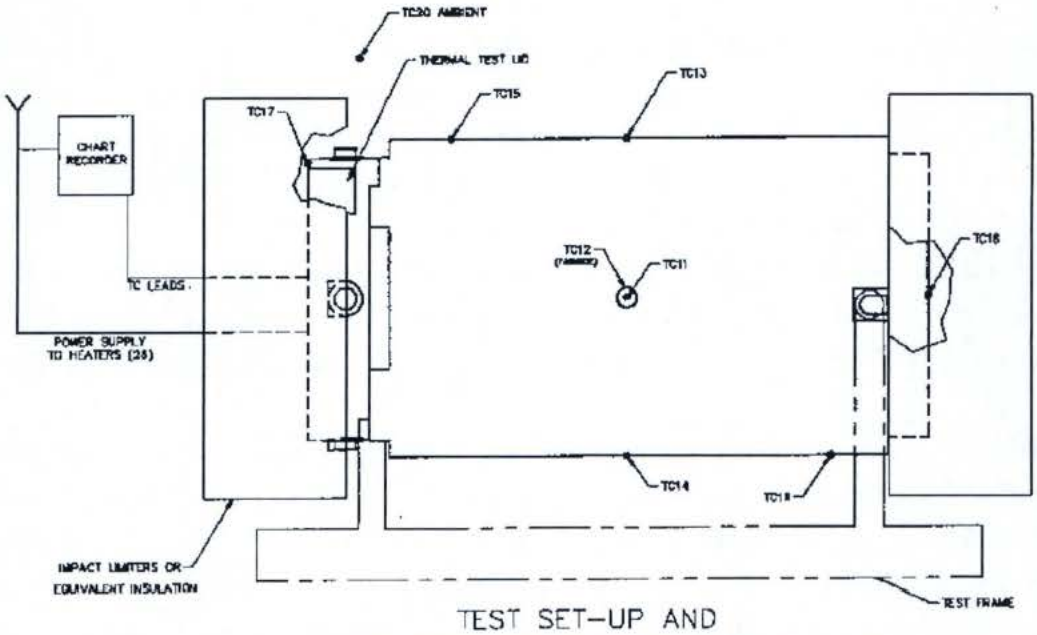
The HLW Overpack basket is fabricated from Type 304 stainless steel and is fabricated by welding. If circumferential welds are required to join two shell sections, the seam welds shall not be aligned within 45° circumferentially. The five (5) welded HLW cylinder cells are closed

at the bottom by a plate welded to the cell wall where accessible. The top of the HLW cylinder cell is open to allow vertical dry loading of a HLW canister.

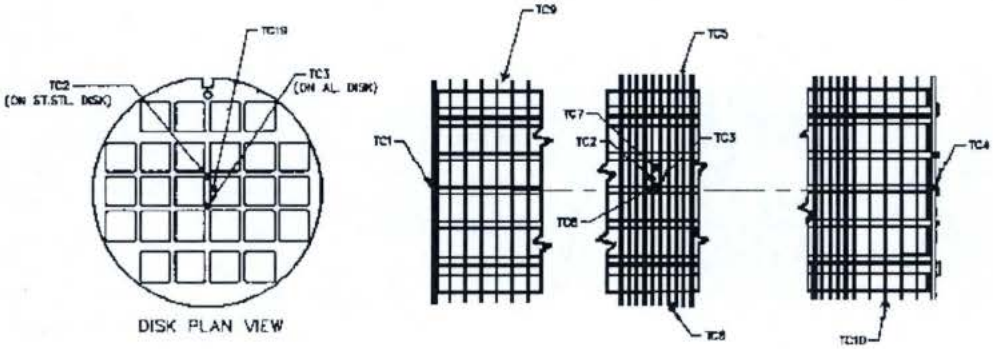
The finished surfaces of all HLW overpack basket assembly welds are visually examined in accordance with ASME Code Section V, Articles 1 and 9 to verify that the components are assembled in accordance with the License Drawings and that the components are free of nicks, gouges, and other damage. The acceptance criteria for the visually examined welds for the HLW overpack basket are in accordance with ASME Code Section III, Subsection NF, NF-5360. Liquid penetrant (PT) examination will be performed on all HLW Overpack basket welds in accordance with ASME Code, Section V, Articles 1 and 6. Acceptance criteria for the PT examined welds shall be in accordance with ASME Code, Section III, Subsection NF, NF-5350.

The fabricator of the HLW Overpack and basket assemblies will establish a written weld inspection plan in accordance with an approved quality assurance program. The weld inspection plan will include visual and liquid penetrant examination. In addition, the weld inspection plan will identify the welds to be examined, the sequence of the examinations, the type of examination method to be used, and the criteria for acceptance of the weld in accordance with the applicable sections of the ASME Code.

Figure 8.1-1 Thermal Test Arrangement



TEST SET-UP AND
(a) EXTERNAL THERMOCOUPLE LOCATIONS



(b) INTERNAL CAVITY AND BASKET THERMOCOUPLE LOCATIONS