January 2017

Revision 8

MAGNASTOR®

(Modular Advanced Generation Nuclear All-purpose STORage)

10 CFR 72.248 and 10 CFR 72.48(d)(2) Partial 24-Month Updates

NON-PROPRIETARY VERSION

Docket No. 72-1031

NAC INTERNATIONAL

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Enclosure 1

10 CFR 72.48 Determination Summary Report

for the

MAGNASTOR® FSAR, Revision 8

(Docket No 72-1031)

Period Covered: July 2015 thru February 2017

NAC International

72.48 Determination ID #NAC-15-MAG-009

Change Description

[redacted]

Source of Change: 72.48 Determination ID #NAC-15-MAG-009

Originating Document: Duke AR # 01931592

Disposition: Use-As-Is

[redacted]

72.48 Determination ID #NAC-15-MAG-014

Change Description

Clarified an inconsistency between MAGNASTOR FSAR Chapter 9 and 10 CFR 72.236 (K). Chapter 9, Section 9.1.3, Step 20 was revised to provide consistency with regulatory requirements.

Chapter 9, page 9.1-16.

Source of Change: 72.48 Determination ID #NAC-15-MAG-014

Originating Document: DCR(L) 71160-FSAR-7C

Update MAGNASTOR FSAR Chapter 9 to clarify an inconsistency between Section 9.1.3, step 20 and 10 CFR Part 72. Step 20 is revised to: "Scribe and/or stamp the concrete cask nameplate, if not already done, with the required information at a minimum."

The MAGNASTOR FSAR currently states "scribe and/or stamp the concrete cask nameplate to indicate the loading date. If not already done, scribe or stamp any other required information". The loading date is not required by 10 CFR Part 72.

72.48 Determination ID # NAC-15-MAG-018

Change Description

Updated MAGNASTOR Chapter 8 to clarify when special approved two-coat painting systems are required and included new coating system data sheets. Editorial changes to Section 8.13.3 and 8.13.4

Chapter 8 page 8-i, 8.6-2, 8.6-3, 8.13-1, 8.13-7, 8.13-9, 8.13-18 through 8.13-28

Source of Change: 72.48 Determination ID #NAC-15-MAG-018

Originating Document: DCR(L) 71160-FSAR-7B

1. Update MAGNASTOR FSAR Chapter 8 incorporating minor editorial revision to Section 8.6.2, as follows:
    a. In the second paragraph of the section, deleted "an approved two-coat" and replaced with "a painting" regarding painting of the Transfer Adapter;
    b. In the final paragraph of the section, deleted "As with nickel-coating, no positive characteristics are considered in the applicable safety analysis and therefore, minor scratches and wear of the coatings is not a concern"; and replaced with "Examples of acceptable coating systems are detailed in Section 8.13. Minor scratches and wear of coatings have an insignificant effect on the overall coating performance and are therefore permitted."
2. Revised Section 8.13 Vendor Supplied Information introduction to address inclusion of the B29 standard in the section.
3. Revise Section 8.13 to incorporate additional technical data sheets for acceptable coatings as follows: Section 8.13.8 AMERLOCK 2/400GF; Section 8.13.9 AMERSHIELD; and Section 8.13.10 DIMECOTE 9.
4. Revise Chapter 8 Table of Contents to incorporate new data sheets and clarification of titles of 8.13.3 and 8.13.4 to add coating series number.

72.48 Determination ID #NAC-15-MAG-020

Change Description

Revised Drawing 71160-562, required name plate data to be consistent with the specific regulation requirements of 10 CFR 72.236(k) in identifying the spent fuel storage casks. All other information on the nameplate is optional and not required.

Source of Change: 72.48 Determination ID #NAC-15-MAG-020

Originating Document: DCR(L) 71160-562-8A

1. Revise item 22 on drawing 71160-562 page 2, Zone B-4.
   Delete the first two lines of data on the nameplate that show owner and designer information. Also, delete the pointer which says "Information to be supplied later".

72.48 Determination ID #NAC-15-MAG-022

Change Description

Updated MAGNASTOR Chapter 3 to make consistent with the governing calculation 71160-2015, Revision 5.

Chapter 3, page 3.5-3 and 3.5-4

Source of Change: 72.48 Determination ID #NAC-15-MAG-022

Originating Document: DCR(L) 71160-FSAR-7D

Revise Section 3.5.1.4 TSC Handling Loads, as detailed in the attachment, to update the TSC lift lug evaluation for handling conditions to reflect an increased load for supplemental support equipment, a reduced weld area, and an increased bearing area consistent with the 71160-2015 calculation.

72.48 Determination ID #NAC-15-MAG-023

Change Description

Update MAGNASTOR FSAR Chapter 2, Table 2.1.2 code alternatives for NB-6111 and Chapter 10, Section 10.1.3 to clarify inconsistencies between the codes and the FSAR.

Chapter 2, page 2.1-4 and Chapter 10, page 10.1-5

Source of Change: 72.48 Determination ID #NAC-15-MAG-023

Originating Document: DCR(L) 71160-FSAR-7E

Update MAGNASTOR FSAR Chapter 2, Table 2.1.2 code alternatives for NB-6111 and Chapter 10, Section 10.1.3" to clarify inconsistencies between the codes and the FSAR.

1. Revise the second sentence to: "No observable water leakage from the closure lid to the TSC shell weld is allowed while maintaining test pressure." Was: "No observable pressure drop or water leakage from the closure lid to TSC shell weld is allowed."
2. Revise the sentence to: "the shop helium leakage test to approximately 2×10^{-7} cm^3/sec (helium) (as described in Section 10.1.3) provides reasonable assurance of the leak tightness of the TSC shell weldment." Was "2×10^{-7} cm^3/sec (as described in Section 10.1.3) provides reasonable assurance of the leak tightness of the TSC shell weldment."
3. MAGNASTOR FSAR Section 10.1.3, revise the leakage rate requirements in last paragraph to read: "The leakage test shall be performed in accordance with the requirements and approved methods of ASME Code, Section V, Article 10, and ANSI N14.5-1997 [20] to confirm the total leakage rate (i.e., leaktight) is less than, or equal to, 1×10^{-7} ref. cm^3/s (air) or approximately 2×10^{-7} cm^3/sec (helium). Was: "The leakage test shall be performed in accordance with the requirements and approved methods of ASME Code, Section V, Article 10, and ANSI N14.5-1997 [20] to confirm the total leakage rate is less than, or equal to, 1×10^{-7} ref. cm^3/s (i.e., leaktight)."

72.48 Determination ID #NAC-15-MAG-024

Change Description

Revise MAGNASTOR FSAR Chapter 7 to limit foreign materials permitted inside the TSC cavity to ensure that explosive levels of gases are not generated as a result of radiological decomposition.

Chapter 7, page 7.2-1

Source of Change: 72.48 Determination ID #NAC-15-MAG-024

Originating Documents: DCR(L) 71160-FSAR-7F

Section 7.2.2 shall be revised to read as follows:

Foreign materials will be excluded from the cavity to the extent required to ensure that explosive levels of gases due to radiological decomposition will not be generated.

72.48 Determination ID #NAC-15-MAG-025

Change Description

The change provides clarification that localized regions of the fuel tube (i.e., weld seam region) may have an under thickness tolerance of 0.03 inch, which is different than the ASME plate tolerance for the fuel tube wall material. Note that this applies to the PWR and PWR DF baskets. Tolerances for fuel tube wall thickness were not provided in the previous license drawing.

Change to drawing 71160-551-10PA/10NPA, Sheet 1

Source of Change: 72.48 Determination ID #NAC-15-MAG-025

Originating Document: DCR(L) 71160-551-10PA/10NPA

Sheet 1:

1. Revised Note 3 to "Tube wall thickness of the longitudinal weld seam regions may be 0.03 inches below nominal plate thickness. Transitions in thickness shall be blended." Was, "(Deleted)".

72.48 Determination ID #NAC-16-MAG-002

Change Description

Corrected a typographical error introduced by DCR(L)71160-FSAR-4E in MAGNASTOR FSAR Chapter 9. The Caution statement in Section 9.1 Step 20 should have a thermal time limit of 19 hours.

Chapter 9, page 9.1-4

Source of Change: 72.48 Determination ID #NAC-16-MAG-002

Originating Document: DCR(L) 71160-FSAR-7G

Correct a typographical error in MAGNASTOR FSAR Chapter 9, Section 9.1, step 20 is revised to: "Caution: Following closure lid installation, there is a thermal time limit of 19 hours to begin the Annulus Circulating Water System (ACWS), or approved alternative annulus flow system operation, and to begin temperature measurement of the MTC annulus outlet flow to verify MTC outlet temperature is maintained < 113°F. If ACWS flow cannot be initiated in the time allowed, return the MTC to the spent fuel pool and remove the closure lid to allow cooling by the spent fuel pool water.

72.48 Determination ID #NAC-16-MAG-003

Change Description

Revised MAGNASTOR FSAR Chapter 8 and 9 to include options to utilize either nitrogen or helium as the purge gas during TSC cooldown operations.

Chapter 8, page 8.10-7, Chapter 8, page 8.11-3 Chapter 9, page 9.3-2, and Chapter 9, page 9.1-17

Source of Change: 72.48 Determination ID #NAC-16-MAG-003

Originating Document: DCR(L) 71160-FSAR-7H

1. Revise FSAR Page 8.10-7, Section 8.10.3.2 as follows:
   - Was: Following removal of the vent and drain port covers, the TSC is sampled for radioactive gases, vented, flushed with nitrogen gas, and cooled down with water using the vent and drain ports.
     Is: Following removal of the vent and drain port covers, the TSC is sampled for radioactive gases, vented, flushed with nitrogen or helium gas, and cooled down with water using the vent and drain ports.
2. Revise Page 8.11-3, Section 8.11, sentence in paragraph at top of page as follows:
   - Was: When the canister is first prepared for unloading and the port covers are removed, nitrogen gas is initially cycled through the canister for a minimum of 10 minutes to flush the radioactive gases from the canister.
     Is: When the canister is first prepared for unloading and the port covers are removed, nitrogen or helium gas is initially cycled through the canister for a minimum of 10 minutes to flush the radioactive gases from the canister.
   - Was: Following the nitrogen flush, water is introduced into the canister at a maximum rate of 8 gpm.
     Is: Following the nitrogen or helium flush, water is introduced into the canister at a maximum rate of 8 gpm.
   - Was: The combination of initial nitrogen purge, followed by the cooling transition of the steam created in the canister cavity, provides a relatively smooth transition to water cooling and insignificant thermal stress in the fuel rod cladding.
     Is: The combination of initial nitrogen or helium purge, followed by the cooling transition of the steam created in the canister cavity, provides a relatively smooth transition to water cooling and insignificant thermal stress in the fuel rod cladding.

72.48 Determination ID #NAC-16-MAG-003 (continued)

3. Revise FSAR Page 9.3-2, step 18 of the FSAR as follows:
   - Was: Initiate nitrogen gas flow through the TSC to flush out residual radioactive gases. Continue nitrogen flow for a period of 10 minutes.
     Is: Initiate purge gas flow (nitrogen or helium) through the TSC to flush out residual radioactive gases. Continue nitrogen or helium flow for a period of 10 minutes.
4. Revise FSAR Table 9.1-1, Item – Cooldown System:
   - Was: Introduces nitrogen, helium, and cooling water to the TSC cavity to cooldown the TSC internals and stored spent fuel to allow the return of the TSC to the spent fuel pool for the unloading of the fuel assemblies.
     Is: Introduces nitrogen (and/or helium), helium, and cooling water to the TSC cavity to cooldown the TSC internals and stored spent fuel to allow the return of the TSC to the spent fuel pool for the unloading of the fuel assemblies.

72.48 Determination ID #NAC-16-MAG-004

Change Description

Revised MAGNASTOR FSAR Chapter 8 which clarifies that fuel assemblies with carbon steel plenum springs are acceptable contents for the MAGNASTOR system.

Chapter 8, page 8.10-2

Source of Change: 72.48 Determination ID #NAC-16-MAG-004

Originating Document: DCR(L) 71160-FSAR-7I

Change the last two sentences of the Section 8.10.1 of the MAGNASTOR FSAR to:
"Fuel assemblies typically do not contain aluminum or carbon steel parts exposed to coolant/moderator or are in contact with non-fuel hardware, and therefore are not subject to significant gas generation or corrosion during prolonged water immersion (20-40 years). Carbon steel plenum springs, which are not normally exposed to water, may be used in some fuel designs. Clad failure could expose the springs. Small quantities of uncoated exposed carbon steel are permitted in the system as discussed in Section 8.6.1. Thus, no adverse reactions occur with the control and nonfuel components over prolonged periods of dry storage."

Was: "There are no aluminum or carbon steel fuel assembly parts, and no gas generation or corrosion occurs during prolonged water immersion (20 – 40 years). Thus, no adverse reactions occur with the control and nonfuel components over prolonged periods of dry storage."

72.48 Determination ID #NAC-16-MAG-009

Change Description

Revised MAGNASTOR FSAR Chapter 4, 9 and 12 to provide clarification and update of thermal contingency actions related to transfer operations of the TSC.

Chapter 4, page 4.9.1-1, 4.9.2-1 through 4.9.2-4, and 4.9.3-1, Chapter 9, page 9.1-4 through 9.1-15, and Chapter 12, page 12.1-8

Source of Change: 72.48 Determination ID #NAC-16-MAG-009

Originating Document: DCR(L) 71160-FSAR-7M

Revised Chapters 4, 9 and 12 to provide clarification and update of thermal contingency actions related to transfer operations of the TSC. The changes include:

1. Section 4.9.1 and 4.9.2 are revised to provide clarification and additional contingency options.
   (1) In Section 4.9.1, add an allowable time of 5 hours to start in-pool cooling when the TSC cavity temperature reaches 180°F (Section 4.9.1)
   (2) In Sec 4.9.2, add an allowable time of 4 hours for loss of ACWS contingency events for PWR TSCs with decay heat loads of ≤ 30 kW for the second and subsequent vacuum drying cycles as defined in LCO 3.1.1, Item 2.
2. Section 4.9.3 is revised to use heat loads as specified in previous version of this Section.
3. Chapter 9 is revised to incorporate revised contingency options presented in Chapter 4.
4. Section 12.1.6.3 is revised to use heat loads consistent with heat loads specified in the revised Section 4.9.3.

72.48 Determination ID #NAC-16-MAG-010

Change Description

Revised MAGNASTOR FSAR Chapter 8, removing 97-695/97-697P Zinc primer because it is being phased out by PPG and replaced with Dimetcote 9. However, the Dimetcote 9 VOCs are too high in some parts of the USA, so Dimetcote 9VOC and Dimetcote 9H are being added as options. All of the Dimetcote 9 products have similar properties as the 97-695/97-697P Zinc primer.

Chapter 8, page 8-i, 8.13-29 through 8.13-40

Source of Change: 72.48 Determination ID #NAC-16-MAG-010

Originating Document: DCR(L) 71160-FSAR-7N

1. Revise Chapter 8 Table of Contents to add 8.13.11, Dimetcote 9VOC and 8.13.12, Dimetcote 9H.
2. Add new sections 8.13.11, Data sheets for Dimetcote 9VOC and 8.13.12, Dimetcote 9H.

72.48 Determination ID #NAC-16-MAG-011

Change Description

[redacted]

Source of Change: 72.48 Determination ID #NAC-16-MAG-011

Originating Document: NAC NCR 16-004 (VNCR 845165-01)

Disposition Use-As-Is

[redacted]

72.48 Determination ID #NAC-16-MAG-011 (Continued)

[redacted]

72.48 Determination ID #NAC-16-MAG-012

Change Description

Revised MAGNASTOR FSAR Chapter 1 and 3 to incorporate the option for a wider closure ring configuration with the solid closure lid configuration, which is consistent with the composite closure lid assembly.

Chapter 1, page 1.3-13, Chapter 3, page 3.10.3-1, 3.10.3-2, and 3.10.3-24

Source of Change: 72.48 Determination ID #NAC-16-MAG-012

Originating Documents: DCR(L) 71160-FSAR-7O, DCR(L) 71160-585-11A, DCR(L) 71160-685-5A

Originating Document: DCR(L) 71160-FSAR-7O

1. Change Table 1.3-1 "Design Characteristics" Nominal Value for TSC Closure Ring to "(0.7 to 1.5) x 0.75". Was, 0.75 square for TSC1/TSC2 and 0.75 square or 1.5 x 0.75 for TSC3/TSC4
2. Change Section 3.10.3.1 "TSC1/TSC2 Finite Element Model Description" to add the following to the last paragraph: "Note that a review of the finite element analysis results for the TSC3/TSC4 with ¾-inch and 1½-in wide closure rings (See Section 3.10.3.2 for model description) indicates that the difference in the analysis results is insignificant for all normal, off-normal and accident conditions of storage. Accordingly, the TSC model results for the single-piece closure lid assembly (i.e., TSC1 and TSC2) are applicable to TSCs with closure rings approximately ¾-inch and 1½-in wide. "
3. Change Section 3.10.3.2 "TSC3/TSC4 Finite Element Model Description" to add the following to the end of the first paragraph: "A review of the finite element analysis results for the TSC3/TSC4 with ¾-inch and 1½-in wide closure rings indicates that the difference in the analysis results is insignificant for all normal, off-normal and accident conditions of storage. Accordingly, the model results are applicable to TSCs with closure rings approximately ¾-inch and 1½-in wide. "

71160-585, TSC Assembly, MAGNASTOR, Revision 12

Originating Document: DCR(L) 71160-585-11A

Revised Drawing 71160-585, Delta Note 10 permitting the use of segmented closure rings and updated the delta note callout to multiple items. Modified the bill of material quantities for items 16 and 18

72.48 Determination ID #NAC-16-MAG-012 (continued)

Sheet 1:

1. Revised delta note 10 by adding the following sentence: "Multiple segments from different closure rings of similar size may be used, blending sections at seams."
2. Zone A6, attach a delta note l0 symbol next to item 18 balloon.
3. Zone A5, revise the following statement below Detail A-A to: "(Optional configuration)", was "(Optional configuration of Assy 92 & 93 only)" and add two zone boxes referencing "SH1/F5" and "SH2/F5".
4. Zone A4 add item 5 balloon next to item 17 balloon callout.
5. Modify the Quantity columns of ltem 16 within the BOM by replacing all values of "1" with "A/R".
6. Modify the Quantity columns of ltem 18 within the BOM by populating all empty columns with the value of "A/R" and remove delta note 10 symbol.

Sheet 2

7. Zone F5, add zone box referencing "SHl/A5".
8. Zone A6, add zone box referencing "SH3/F5".
9. Zone A8, add delta note 10 symbol next to item 16 balloon.
10. Zone A4, add Zone Box referencing Sheet 3 and Zone E5.

71160-685, DF, TSC Assembly, MAGNASTOR, Revision 6

Originating Document: DCR(L) 71160-685-5A

Revised Drawing 71160-685, Delta Note 3 to allow cutting the closure ring into segments to aid in fit-up. Added callouts for Delta Note 3 in the B.O.M for item 9 and on Sheet 2 Zone D8.

Sheet 1:

1. Zone A8, revise Note 3 to Delta Note 3 and revise text as follows: "The closure ring may be field dressed in localized areas to accommodate fit-up to the shell weldment. Extent of localized closure ring field dressing shall maintain minimum weld configuration. Closure ring may be cut into segments prior to installation to assist in fitup. Multiple segments from different closure rings of similar size may be used, blending sections at seams.", was "The closure ring may be field dressed in localized areas to accommodate fit-up of the closure ring to the shell weldment."
2. Add callout for Delta Note 3 adjacent to ltem 9 in B.O.M.

Sheet 2

3. Zone D8, add delta note 3 symbol next to delta note 6.

72.48 Determination ID #NAC-16-MAG-013

Change Description

Revised MAGNASTOR FSAR Chapter 4 and 9 details regarding the thermal contingency actions related to operation of the MTC for TSC lid placement, drainage, vacuum drying, helium backfill and transfer are updated consistent with the thermal evaluation basis for the transfer cask as documented in NAC Calculation No. 71160-3020.

Chapter 4, page 4-i, 4-ii, 4.9.1-1, 4.9.2-1 through 4.9.2-4, 4.9.3-1, 4.9.3-2, 4.9.4-1 and Chapter 9, page 9-i, 9.1-3 through 9.1-20

Source of Change: 72.48 Determination ID #NAC-16-MAG-013
This 72.48 determination supersedes 72.48 determination no. NAC-16-MAG-006.

Originating Document: DCR(L) 71160-FSAR-7J

Details of thermal contingency actions related to operation of the MTC for TSC lid placement, drainage, vacuum drying, helium backfill and transfer are updated consistent with the thermal evaluation basis for the transfer cask as documented in NAC Calculation No. 71160-3020.
Changes include:

1. Administrative changes are made for capitalization, section titles and clarification of the helium backfill cooling being addressed in the draining and vacuum drying section (Section 4.9.2).
2. Clarifications are made to specify the particular sections/tables of LCO 3.1.1 that are being referenced in the affected pages versus more general reference to LCO 3.1.1.
3. Change made for consistency with the thermal evaluation that following closure lid installation, there is a thermal time limit of 19 hours versus 18 hours as previously stated to begin the Annulus Circulating Water System (ACWS), or approved alternative annulus flow system operation, and to begin temperature measurement of the MTC annulus outlet flow to verify MTC outlet temperature is maintained < 113°F.
4. Provided explanation that the 4.5 hours allowance for loss of ACWS contingency events is a total value from the start of draining through the end of the minimum helium backfill/cool time. An analysis was performed and documented in NAC Calculation No. 71160-3020 providing justification for the change. As a result, discussion of the TSC cooling being initiated immediately (within 2 hours) has been removed as the time falls under the 4.5 hour total allowance.
5. Discussion of the TSC to be backfilled with 75 psig (+10, -0 psi) with helium immediately (within 2 hours) for the failed vacuum drying condition (Section 4.9.2) has been revised to remove the "immediately (within 2 hours)", and state the backfill has to be complete and TSC cooling initiated within the Maximum Vacuum Drying time limit. This change makes the text consistent with the requirements of LCO 3.1.1.

72.48 Determination ID #NAC-16-MAG-013 (continued)

6. Add description of the Supplemental Annulus Cooling System (SACS) and the discussion that it is to be used to bring the TSC shell temperature down to allow the upper transfer cask seal to be used prior to using ACWS or equivalent system.
7. Add statements that equivalent cooling systems for SACS and ACWS may be used.
8. Provide clarification of the thermal time limits for heat loads > 25kW and ≤ 35.5 kW consistent with the thermal evaluation. For crane malfunction contingencies change discussion of actions based on 20 kW (e.g., < 20 kW or ≥ 20 kW) to be based on 25 kW. Additionally, change heat load threshold for convective air flow through the MTC annulus providing sufficient cooling from 20 kW to 25 kW.
9. Change TSC water temperature threshold and corresponding time to initiate 24 hours cooling from 200°F and 2 hours, to 180°F and 5 hours.

72.48 Determination ID #NAC-16-MAG-015

Change Description

The Bill of Materials on Drawing 71160-561, for Item 14 was revised changing the material specified to ASTM A36/A992.

Source of Change: 72.48 Determination ID #NAC-16-MAG-015

Originating Document: DCR(L) 71160-561-8A

71160-561, Structure, Weldment, Concrete Cask, MAGNASTOR, Revision 6

Bill of Material Item 14 Spec was "ASTM A36" change to "ASTM A36/A992"

72.48 Determination ID #NAC-16-MAG-018

Change Description

Revised MAGNASTOR FSAR Chapter 1,3, 4 and 5 adding the CC5 concrete cask configuration which is an increased length CC3 design with a 3-inch thick steel liner, inlet shield bars, thicker lid and embedded lift anchors.

Chapter 1, page 1.3-5, 1.3-15, Chapter 3, page 3.1-3, 3.1-4, 3.2-1, 3.2-2, 3.2-3, 3.5-27 through 30, 3.7-59 through 3.7-61, 3.7-65, 3.7-67, 3.7-68, 3.7-70 through 3.7-72, and 3.7-80, Chapter 4, page 4.4-4, 4.4-5, 4.4-32, and 4.4-64, Chapter 5, page 5-vi, 5-ix, 5-x, 5-2, 5.1-4, 5.1-5, 5.1-9, 5.1-10, 5.5-2, 5.5-3, 5.5-14, 5.6-4, 5.8.3-4, 5.8.3-32, 5.8.5-4, 5.8.5-8, 5.8.5-9, 5.8.7-4, 5.8.8-1, 5.8.8-66 through 5.8.8-79 and 5.8.12-1

Source of Change: 72.48 Determination ID #NAC-16-MAG-018

Originating Documents: DCR(L) 71160-FSAR-7Q, DCR(L) 71160-561-8B, DCR(L) 71160-562-8B, DCR(L) 71160-590-7A

Originating Document: DCR(L) 71160-FSAR-7Q

The CC5 concrete cask configuration is added as an increased length CC3 design with a 3-inch thick steel liner, inlet shield bars, thicker lid and embedded lift anchors. The CC5 configuration has a 225.9-inch height which is similar to the 225.27-inch height of the CC1 & CC2 configurations. The CC5 cask design is the tallest and heaviest configuration and results in the greatest loads and stresses for normal thermal (i.e., vertical rebar), wind, seismic, flood and tornado loading conditions The CC5 configuration is evaluated using the same methodology as the previous casks and shown to meet the applicable design requirements. The cask is handled the same as the CC3 and CC1 configurations such that no procedural changes are required for its implementation.

71160-561, Structure, Weldment, Concrete Cask, MAGNASTOR, Revision 9

Originating Document: DCR(L) 71160-561-8B

Revised Drawing 71160-561 adding assembly 86 and assigned quantities to items needed for the CC5 concrete cask configuration.

Sheet 1:

1. B.O.M., add assembly 86 and assign items quantities as follows: item 2 – "1", item 14 – "24", item 37 – "4" , item 40 – "1", item 51 – "A/R".
2. Zone B8, revise dimension to add "(219.4) – 86".
3. Zone F6, add assembly 86 label "Liner Weldment"

72.48 Determination ID #NAC-16-MAG-018 (continued)

71160-562, Reinforcing Bar and Concrete Placement, Concrete Cask, MAGNASTOR, Revision 9

Originating Document: DCR(L) 71160-562-8B

Revised Drawing 71160-562 adding assembly 93 and assigned quantities to items needed for the CC5 concrete cask configuration. Added item 27 to the Bill of Materials

Sheet 1:

1. B.O.M., add item 27 as follows: Name – "Liner Weldment", Drawing No. – "71160-561-86".
2. B.O.M., add assembly 93 and assign items quantities as follows: items 1, 2, 4, 5, 6, 9, 13, 14, 15, 19, 21, & 25 – "A/R"; item 7 – "4"; items 16 & 17 – "20"; item 18 – "8"; item 20 – "4"; items 22, 24 & 27 – "1".

Sheet 2:

3. Zone E5, revise dimension to add "(225.9) – 93".
4. Zone D6, add assembly 93 label "Concrete Cask".
5. Zone F5, add ilem27 identification balloon.

71160-590, Loaded Concrete Cask, MAGNASTOR, Revision 8

Originating Document: DCR(L) 71160-590-7A

Revised Drawing 71160-590 adding assembly 90 and 91. Assigned quantities to items needed for the CC5 concrete cask configuration. Added item 24 to the Bill of Materials.

Sheet 1:

1. B.O.M., add item 24 as follows: Name – "Concrete Cask Assembly", Drawing No. "71160-562-93".
2. B.O.M., add assembly 91 and assign items quantities as follows: items 2, 3, 22 & 23 – A/R", items 8, 13 & 24 – "1", items 10 & 11 – "6", item 12 – "2".
3. B.O.M,, add assembly 90 and assign items quantities as follows: items 2, 3, 22 & 23 –"A/R", items 8, 20 & 24 – "1", items 10 & 11 – "6", item 12 – "2".
4. Zone B6, add assemblies 91 & 90 labels "Loaded Concrete Cask – 37 PWR".

Sheet 2:

5. Zone D5, revise dimension to add "(225.9) – 91, 90"
6. Zone D2, add item 24 identification balloon.

72.48 Determination ID #NAC-17-MAG-001

Change Description

Section 4.4.1.5 "Evaluation of the Helium Phase With Reverse Annulus Circulating Water Cooling System" is being revised to allow for reverse annulus circulation water flow for heat loads of 25kW using 40 GPM water flow at 100°F.

Chapter 4, page 4.4-26

Source of Change: 72.48 Determination ID #NAC-17-MAG-001

Originating Document: DCR(L) 71160-FSAR-7S

Change Section 4.4.1.5 "Evaluation of the Helium Phase with Reverse Annulus Circulating Water Cooling System" (last two sentences) to: "The condition of the reverse annulus flow for 25kW using 40 GPM water flow at 100°F was also evaluated. The evaluations of these conditions are performed to demonstrate an alternate method (equivalent to or better than ACWS) for cooling a PWR TSC of the same heat loads." From: "The evaluations of these conditions are performed to demonstrate an alternate method (equivalent to or better than ACWS) for cooling a 35.5 kW PWR TSC."

72.48 Determination ID #NAC-17-MAG-002

Change Description

Revised MAGNASTOR FSAR Chapter 4 and 9 to address the use of reverse ACWS cooling for a PWR TSC with a heat load up to 25 kW using 100°F/40 GPM inlet conditions

Chapter 4, page 4.4-33, 4.4-34, 4.9.2-1; Chapter 9, page 9.1-4, 9.1-5, 9.1-6

Source of Change: 72.48 Determination ID #NAC-17-MAG-002

Originating Document: DCR(L) 71160-FSAR-7T

1. Revise the following sections to provide further details on the use of reverse ACWS for 25 kW heat loads using 100°F/40GPM inlet conditions as detailed in the attachment.
   - Section 4.4.3 "Maximum Temperatures for PWR and BWR Fuel Configurations" subsection "Transfer Condition for 24-Hour Cooling and Multiple Vacuum Drying Cycles".
   - Section 4.9.2 "Draining, Vacuum Drying and Helium Backfill Phase Contingency Event for PWR Fuel"
   - Section 9.1.1 "Loading and Closing the TSC" first note to step 29.
2. Revise the following procedural steps detailed in Section 9.1.1 "Loading and Closing the TSC" to clarify time limits evaluated for the PWR TSCs as detailed in the attachment.
   - Caution to step 20
   - Second Note to step 29.

72.48 Determination ID #NAC-17-MAG-003

Change Description

The list of License Drawings for the proprietary and non-proprietary versions of the FSAR are being revised for changes made via the 72.48 process.

Chapter 1, page 1.8-1

Source of Change: 72.48 Determination ID #NAC-17-MAG-003

Originating Document: DCR(L)s 71160-FSAR-7U

This DCR(L) also incorporates the list of License Drawings with the latest approved drawing revisions to the following license drawings.

1. 71160-561, Rev. 9
2. 71160-562, Rev. 9
3. 71160-585, Rev. 12
4. 71160-590, Rev. 8
5. 71160-685, Rev. 6

72.48 Determination ID #NAC-17-MAG-004

Change Description

The FSAR is being revised to incorporate changes made via the DCR(L) process

Chapter 1, 2, 3, 4, 5, 7, 8, 9, 10, and 12

Source of Change: 72.48 Determination ID #NAC-17-MAG-004

Originating Document: DCR(L) 71160-FSAR-7V

The following DCR(L)s are being incorporated: 71160-FSAR; -7B, -7C, -7D, -7E, -7F, -7G, -7H, -7I, -7J, -7M, -7N, -7O, -7Q, -7S, -7T, and 7U. Additionally minor editorial / grammatical corrections have been made within the changed areas of the FSAR to improve their readability.

72.48 Determination ID #NAC-17-MAG-008

Change Description

During the closure operations of KPS TSC-11 it was identify that the as welded outer port cover extended beyond the top surface of the lid, which does not meet the requirement detailed in the design and license drawing. As a corrective action, a reduced outer port cover thickness of 0.30" is dispositioned. NAC Memorandum no. ED2017005 provides an evaluation of the reduced port cover thickness (i.e., 0.30") using the NAC Calculation No. 71160-2142 port cover evaluation as the basis. Note that corrective actions and changes do not affect the size of the port cover attachment weld. The stresses in the port and the weld have been analyzed and shown to meet design requirements. The field modified reduce thickness outer port cover is structurally adequate for all conditions of storage.

Source of Change: 72.48 Determination ID #NAC-17-MAG-008

Originating Document: NAC-VNCR 845165-03

During closure operations of KPS TSC-11 it was identify that the as welded outer port cover extended beyond the top surface of the lid, which does not meet the requirement detailed in the design and license drawing. Drawing specifications require the port cover, closure ring, and the associated weld to be below the top surface of the lid. The drawings permit field grind or machining of the port cover to aid fit-up up to a minimum thickness as defined by the ASME SA240 304 plate specification (i.e., 0.365"). The port cover has been determine to extend 0.039" beyond the surface of the lid. The fabrication document package documents that the outer port cover has a thickness of 0.39". Thus, grinding the outer port cover flush to the top surface of the TSC closure lid will require reducing the localized thickness to less than the 0.365" minimum specified in the drawing. As a corrective action, a reduced outer port cover thickness of 0.30" is dispositioned. NAC Memorandum no. ED2017005 provides an evaluation of the reduced port cover thickness (i.e., 0.30") using the NAC Calculation No. 71160-2142 port cover evaluation as the basis. Note that corrective actions and changes do not affect the size of the port cover attachment weld. The stresses in the port and the weld have been analyzed and shown to meet design requirements. The field modified reduce thickness outer port cover is structurally adequate for all conditions of storage.

Enclosure 2

List of Changes

for

MAGNASTOR® FSAR, Revision 8

(Docket No 72-1031)

NAC International

List of Changes for the MAGNASTOR® FSAR, Revision 8

Incorporates 72.48 changes for the period July 2015 thru February 2017

Chapter/Page/ Figure/Table	Source of Change	Description of Change
Note: The List of Effective Pages and the Chapter Table of Contents, List of Figures, and List of Tables have been revised accordingly to reflect the list of changes detailed below.		
Chapter 1		
Page 1.3-5	NAC-16-MAG-018 71160-FSAR-7Q	Modified the third paragraph of Section 1.3.1.3 (first full paragraph on the page).
Page 1.3-13	NAC-16-MAG-012 71160-FSAR-7O	Modified the first row of Table 1.3-1.
Page 1.3-15	NAC-16-MAG-018 71160-FSAR-7Q	Modified the last row of Table 1.3-1.
Page 1.8-1	NAC-17-MAG-003 71160-FSAR-7U	Updated the list of License Drawings.
Chapter 2		
Page 2.1-4	NAC-15-MAG-023 71160-FSAR-7E	Modified the second row of Table 2.1-2 on the page.
Chapter 3		
Pages 3.1-3 thru 3.1-4	NAC-16-MAG-018 71160-FSAR-7Q	Modified the third through fifth paragraphs in Section 3.1.2.
Pages 3.2-1 thru 3.2-3	NAC-16-MAG-018 71160-FSAR-7Q	Modified the third paragraph of Section 3.2.1; modified Table 3.2.1-1, and the table Notes.
Page 3.5-3 thru 3.5-4	NAC-15-MAG-022 71160-FSAR-7D	Modified text in third paragraph and equations throughout Section 3.5.1.4.
Pages 3.5-27 thru 3.5-30	NAC-16-MAG-018 71160-FSAR-7Q	Modified text, tables and equations throughout Section 3.5.3.
Pages 3.7-59 thru 3.7-61	NAC-16-MAG-018 71160-FSAR-7Q	Modified text and equations throughout the pages.
Pages 3.7-65	NAC-16-MAG-018 71160-FSAR-7Q	Modified the last line of the first paragraph on the page.
Pages 3.7-67 thru 3.7-68	NAC-16-MAG-018 71160-FSAR-7Q	Modified the equations at the end of Section 3.7.3.3.
Pages 3.7-70 thru 3.7-72	NAC-16-MAG-018 71160-FSAR-7Q	Modified text and equations throughout the last pages of Section 3.7.3.4 and the beginning of Section 3.7.3.5.
Pages 3.7-80	NAC-16-MAG-018 71160-FSAR-7Q	Modified Table 3.7.3-1.
Page 3.10.3-1	NAC-16-MAG-012 71160-FSAR-7O	Added text to the end of the second paragraph of Section 3.10.3.1.
Page 3.10.3-2	NAC-16-MAG-012 71160-FSAR-7O	Text flow changes.

Chapter/Page/ Figure/Table	Source of Change:	Description of Change
Page 3.10.3-24	NAC-16-MAG-012 71160-FSAR-7O	Added text to the end of the first paragraph of Section 3.10.3.2.
Chapter 4		
Page 4.4-4 thru 4.4-5	NAC-16-MAG-018 71160-FSAR-7Q	Added the last paragraph on page 4.4-4, which carries to the top of page 4.4-5.
Page 4.4-6 thru 4.4-7	NAC-16-MAG-018 71160-FSAR-7Q	Text flow changes.
Page 4.4-26	NAC-17-MAG-001 71160-FSAR-7S	Modified text at the end of the second full paragraph on the page.
Page 4.4-27	NAC-17-MAG-001 71160-FSAR-7S	Text flow changes.
Page 4.4-32	NAC-16-MAG-018 71160-FSAR-7Q	Modified the first paragraph on the page.
Pages 4.4-33 thru 4.4-34	NAC-17-MAG-002 71160-FSAR-7T	Modified text near the end of the third paragraph on page 4.4-33, continuing to the top of page 4.4-34.
Pages 4.4-35 thru 4.4-36	NAC-17-MAG-002 71160-FSAR-7T	Text flow changes.
Page 4.4-64	NAC-16-MAG-018 71160-FSAR-7Q	Modified Table 4.4-3.
Page 4.9.1-1	NAC-16-MAG-013 71160-FSAR-7J	Modified the third and fifth paragraphs on the page in Section 4.9.1.
	NAC-16-MAG-009 71160-FSAR-7M	Created and modified the fourth paragraph on the page in Section 4.9.1.
Page 4.9.2-1	NAC-17-MAG-002 71160-FSAR-7T	Added text to the end of the first paragraph in Section 4.9.2; added paragraph and third bullet before "Notes" following the first two bullets on the page.
Pages 4.9.2-1 thru 4.9.2-4	NAC-16-MAG-013 71160-FSAR-7J	Modified title and text throughout Section 4.9.2, with text flow changes into page.4.9.2-4
	NAC-16-MAG-009 71160-FSAR-7M	Continued text modification throughout Section 4.9.2.
Page 4.9.3-1	NAC-16-MAG-013 71160-FSAR-7J	Modified the second, third and fourth paragraphs on the page in Section 4.9.3.
	NAC-16-MAG-009 71160-FSAR-7M	Continued text modifications in the second and third paragraphs of Section 4.9.3.
Page 4.9.4-1	NAC-16-MAG-013 71160-FSAR-7J	Editorial edit to Section 4.9.4 heading. Modified the last paragraph on the page.
Chapter 5		
Page 5-2	NAC-16-MAG-018 71160-FSAR-7Q	Modified the second bullet at the top of the page.
Pages 5.1-4 thru 5.1-5	NAC-16-MAG-018 71160-FSAR-7Q	Added the second paragraph and modified the third paragraph of Section 5.1.2.; modified the fourth paragraph of Section 5.1.2.2.
Page 5.1-6	NAC-16-MAG-018 71160-FSAR-7Q	Text flow changes.

Chapter/Page/ Figure/Table	Source of Change:	Description of Change
Pages 5.1-9 thru 5.1-10	NAC-16-MAG-018 71160-FSAR-7Q	Modified the titles of Tables 5.1.3-5 and 5.1.3-6.
Pages 5.5-2 thru 5.5-3	NAC-16-MAG-018 71160-FSAR-7Q	Modified the last row paragraphs of Section 5.5.1.2.
Page 5.5-14	NAC-16-MAG-018 71160-FSAR-7Q	Modified the title of Figure 5.5.5-9 and modified the “Note” at the bottom of the figure.
Page 5.6-4	NAC-16-MAG-018 71160-FSAR-7Q	Modified the last sentence of Section 5.6.4.
Page 5.8.3-4	NAC-16-MAG-018 71160-FSAR-7Q	Modified the heading title of Section 5.8.3.4.2.
Page 5.8.3-32	NAC-16-MAG-018 71160-FSAR-7Q	Modified the title of Table 5.8.3-8.
Page 5.8.5-4	NAC-16-MAG-018 71160-FSAR-7Q	Modified the embedded table in Section 5.8.5.2.3.
Pages 5.8.5-8 thru 5.8.5-9	NAC-16-MAG-018 71160-FSAR-7Q	Modified Tables 5.8.5-4 and 5.8.5-6.
Page 5.8.7-4	NAC-16-MAG-018 71160-FSAR-7Q	Modified Table 5.8.7-1.
Page 5.8.8-1	NAC-16-MAG-018 71160-FSAR-7Q	Modified the last sentence in Section 5.8.8.3.
Pages 5.8.8-66 thru 5.8.8-79	NAC-16-MAG-018 71160-FSAR-7Q	Modified the title of Figure 5.8.8-10.0
Page 5.8.12-1	NAC-16-MAG-018 71160-FSAR-7Q	Modified the sixth paragraph in Section 5.8.12.
Chapter 6		
No Changes.		
Chapter 7		
Page 7.2-1	NAC-15-MAG-024 71160-FSAR-7F	Modified the last sentence of the third paragraph in Section 7.2.2.
Chapter 8		
Page 8.6-2 thru 8.6-3	NAC-15-MAG-018 71160-FSAR-7B	Modified the second and fifth paragraphs of Section 8.6.2.
Page 8.10-2	NAC-16-MAG-004 71160-FSAR-7I	Modified the last half of the first paragraph on the page.
Page 8.10-7	NAC-16-MAG-003 71160-FSAR-7H	Modified the middle of the second paragraph of Section 8.10.3.2.
Page 8.11-3	NAC-16-MAG-003 71160-FSAR-7H	Modified throughout the first paragraph on the page.
Page 8.13-1	NAC-15-MAG-018 71160-FSAR-7B	Added text to paragraph in Section 8.13.
Page 8.13-7	NAC-15-MAG-018 71160-FSAR-7B	Modified heading title for Section 8.13.3.
Page 8.13-9	NAC-15-MAG-018 71160-FSAR-7B	Modified heading title for Section 8.13.4.

Chapter/Page/ Figure/Table	Source of Change:	Description of Change
Pages 8.13-18 thru 8.13-28	NAC-15-MAG-018 71160-FSAR-7B	Added new Sections 8.13.8, 8.13.9 and 8.13.10.
Pages 8.13-29 thru 8.13-40	NAC-16-MAG-010 71160-FSAR-7N	Added new Sections 8.13.11 and 8.13.12.
Chapter 9		
Page 9.1-4	NAC-16-MAG-002 71160-FSAR-7G	Modified the first line of the "Caution" following Step 20.
	NAC-16-MAG-013 71160-FSAR-7J	Added text to the end of the "Caution" following Step 20, causing text flow changes on page 9.1-5.
	NAC-16-MAG-009 71160-FSAR-7M	Modified text to the end of the "Caution" following Step 20.
	NAC-17-MAG-002 71160-FSAR-7T	Modified the first line of the "Caution" following Step 20.
Page 9.1-5	NAC-16-MAG-009 71160-FSAR-7M	Editorial changes to the first line of Step 28.
	NAC-17-MAG-002 71160-FSAR-7T	Modified text on the first line of the "Note" following Step 29.
Page 9.1-6	NAC-16-MAG-013 71160-FSAR-7J	Modified text in the last "Note" of Step 29.
	NAC-16-MAG-009 71160-FSAR-7M	Continued modifications to the last "Note" of Step 29.
	NAC-17-MAG-002 71160-FSAR-7T	Continued modifications to the text throughout the two "Notes" following Step 29.
Page 9.1-7	NAC-16-MAG-013 71160-FSAR-7J	Text flow changes.
Pages 9.1-8 thru 9.1-9	NAC-16-MAG-013 71160-FSAR-7J	Added second "Note" to Step 52; added "Note" to Step 55. Deleted the first part of the second "Note" of Step 58.
Page 9.1-9	NAC-16-MAG-009 71160-FSAR-7M	Modified the "Note" to Step 55.
Page 9.1-10	NAC-16-MAG-013 71160-FSAR-7J	Modified the second "Note" of Step 58.
	NAC-16-MAG-009 71160-FSAR-7M	Added the third "Note" to the end of Step 58.
Page 9.1-11	NAC-16-MAG-013 71160-FSAR-7J	Modified the "Note" of Step 68.
Pages 9.1-12 thru 9.1-15	NAC-16-MAG-013 71160-FSAR-7J; NAC-16-MAG-009 71160-FSAR-7M	Text flow changes.
Page 9.1-16	NAC-15-MAG-014 71160-FSAR-7C	Modified Step 20.
Page 9.1-17	NAC-16-MAG-003 71160-FSAR-7H	Modified the first line of the last row ["Cooldown System (CDS)"] of Table 9.1-1.
Page 9.1-18	NAC-16-MAG-013 71160-FSAR-7J	Added 8th row ["Supplemental Annulus Cooling System (SACS)"] to Table 9.1-1.

Chapter/Page/ Figure/Table	Source of Change:	Description of Change
Page 9.1-19	NAC-16-MAG-013 71160-FSAR-7J	Text flow changes.
Page 9.3-2	NAC-16-MAG-003 71160-FSAR-7H	Modified Step 18.
Chapter 10		
Page 10.1-5	NAC-15-MAG-023 71160-FSAR-7E	Modified the second paragraph of Section 10.1.3.
Chapter 11		
No changes.		
Chapter 12		
Page 12.1-8	NAC-16-MAG-009 71160-FSAR-7M	Modified Section 12.1.6.3.
Chapter 13		
No changes.		
Chapter 14		
No changes.		
Chapter 15		
No changes.		

Enclosure 3

Certification of Accuracy

of the

MAGNASTOR® FSAR, Revision 8

(Docket No 72-1031)

NAC International

NAC INTERNATIONAL

CERTIFICATION OF ACCURACY
PURSUANT TO 10 CFR 72. 248(c)(4)(i)

George Carver (Affiant), Vice President, Engineering and Licensing, of NAC International, hereinafter referred to as NAC, at 3930 East Jones Bridge Road, Norcross, Georgia 30092, being duly sworn, deposes and certifies that:

1. Affiant has reviewed the information described in Item 2, is personally familiar with the preparation, checking and verification of that information and is authorized to certify its accuracy.

2. The information being certified as accurate includes all of the changes incorporated into the MAGNASTOR Final Safety Analysis Report, Revision 8.

STATE OF GEORGIA, COUNTY OF GWINNETT

Mr. George Carver, being duly sworn, deposes and says:

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

Executed at Norcross, Georgia, this 30th day of January, 2017.

George Carver
Vice President, Engineering and Licensing
NAC International

Subscribed and sworn before me this 30th day of January, 2017.

Jeannie Klinetob
Notary Public

JEANNIE KLINETOB
MY COMMISSION EXPIRES
SEPT
25
2019
GWINNETT CO. GEORGIA
NOTARY PUBLIC

Enclosure 4

FSAR Changed Pages and LOEP

Docket No. 72-1031

MAGNASTOR® FSAR, Revision 8

NAC International

January 2017

Revision 8

MAGNASTOR®

(Modular Advanced Generation Nuclear All-purpose STORage)

FINAL SAFETY ANALYSIS REPORT

NON-PROPRIETARY VERSION

Docket No. 72-1031

NAC INTERNATIONAL

Atlanta Corporate Headquarters: 3930 East Jones Bridge Road, Norcross, Georgia 30092 USA
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List of Effective Pages

List of Effective Pages (cont'd)

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List of Effective Pages (cont'd)

structural strength to protect the TSC and its contents in natural phenomena events such as tornado wind loading and wind-driven missiles and during nonmechanistic tip-over events (refer to Figure 1.3-3). The concrete surfaces remain accessible for inspection and maintenance over the life of the cask, so that any necessary restoration actions may be taken to maintain shielding and structural conditions.

The concrete cask may be supplied in five different configurations designated CC1 through CC5. CC1 and CC5 are the standard 225.27-in and 225.9 in high cylinders, respectively. CC2 is also 225.27-in high, but is a segmented design. The CC3 and CC4 configurations are shorter variants at 218.3 inches high. CC1, CC2 and CC4 are equipped with a 1.75-in thick carbon steel liner, while CC3 and CC5 have a 3-in thick carbon steel liner. CC1, CC2 and CC4 are equipped with standard concrete lids, having a constant thickness, while CC3 and CC5 lid has a thicker center section for enhanced shielding. The CC3, CC4 and CC5 cask configurations are equipped with additional shielding at the air inlets.

The concrete cask provides an annular air passage to allow the natural circulation of air around the TSC to remove the decay heat from the contents. The lower air inlets and upper air outlets are steel-lined penetrations in the concrete cask body. Each air inlet/outlet is covered with a screen. The weldment baffle directs the air upward and around the pedestal that supports the TSC. Decay heat is transferred from the fuel assemblies to the TSC wall by conduction, convection, and radiation. Heat is removed by convection and radiation from the TSC shell to the air flowing upward through the annular air passage and to the concrete cask inner liner, respectively. Heat radiated to the liner can be transferred to the air annulus and by conduction through the concrete cask wall. The heated air in the annulus exhausts through the air outlets. The passive cooling system is designed to maintain the peak fuel cladding temperature below acceptable limits during long-term storage [10]. The concrete cask thermal design also maintains the bulk concrete temperature and surface temperatures below the American Concrete Institute (ACI) limits under normal operating conditions. The inner liner of the concrete cask incorporates standoffs that provide lateral support to the TSC in side impact accident events.

A carbon steel and concrete lid is bolted to the top of the concrete cask. (See Table 1.3-4 for the Concrete Cask Lid – Concrete Specification Summary.) The lid reduces skyshine radiation and provides a cover to protect the TSC from the environment and postulated tornado missiles.

Fabrication of the concrete cask requires no unique or unusual forming, concrete placement, or reinforcement operations. The concrete portion of the cask is constructed by placing concrete between a reusable, exterior form and the steel liner. Reinforcing bars are used near the inner and outer concrete surfaces to provide structural integrity. Note: inner rebar cage is optional. The structural steel liner and base are shop fabricated. Refer to Table 1.3-3 for the fabrication specifications for the concrete cask.

Daily visual inspection of the air inlet and outlet screens for blockage assures that airflow through the cask meets licensed requirements. A description of the visual inspection is included

in the Technical Specifications, Chapter 13. As an alternative to daily visual inspections, the loaded concrete cask in storage may include the capability to measure air temperature at the four outlets. Each air outlet may be equipped with a remote temperature detector mounted in the outlet air plenum. The air temperature-monitoring system, designed to provide verification of heat dissipation capabilities, can be designed for remote or local read-out capabilities at the option of the licensee. The temperature-monitoring system can be installed on all or some of the concrete casks at the Independent Spent Fuel Storage Installation (ISFSI) facility.

1.3.1.4 Transfer Cask

The transfer cask is designed, fabricated, and tested to meet the requirements of ANSI N14.6 [11] as a special lifting device. The transfer cask provides biological shielding and structural protection for a loaded TSC, and is used to lift and move the TSC between workstations. The transfer cask is also used to shield the vertical transfer of a TSC into a concrete cask or a transport cask.

The transfer cask is available in two configurations—MTC1 and MTC2. MTC1 consists of carbon steel shells. MTC2 is a shorter version consisting of stainless steel shells. The principal dimensions and materials of fabrication of the transfer cask are provided in Table 1.3-1.

The transfer cask designs incorporate a retaining ring or three retaining blocks, pin-locked in place, or a bolted retaining ring, to prevent a loaded TSC from being inadvertently lifted through its top opening. The transfer cask has retractable bottom shield doors. During TSC loading and handling operations, the shield doors are closed and secured. After placement of the transfer cask on the concrete cask, the doors are retracted using hydraulic cylinders and a hydraulic supply. The TSC is then lowered into a concrete cask for storage. Refer to Figure 1.3-1 for the general arrangement of the transfer cask, TSC, and concrete cask during loading.

Sixteen penetrations, eight at the top and eight at the bottom, are available to provide a water supply to the transfer cask annulus. Penetrations not used for water supply or draining are capped. The transfer cask annulus is isolated using inflatable seals located between the transfer cask inner shell and the TSC near the upper and lower ends of the transfer cask

During TSC closure, clean or demineralized spent fuel pool water is circulated through these penetrations into the annulus region to minimize component temperatures and improve canister preparation time limits. The annulus circulating water system can be utilized through completion of TSC activities. The annulus circulating water system is turned off and disconnected prior to movement of the transfer cask for TSC transfer operations into the concrete cask.

A similar process of clean or demineralized spent fuel pool water flow into the annulus is used during in-pool fuel loading to minimize the potential for contamination of the TSC exterior surfaces.

Table 1.3-1 Design Characteristics

	Design Characteristic	Nominal Value (in)[a]	Material
TSC	Shell	0.5 × 72 dia.	Stainless Steel
	Bottom	2.75	Stainless Steel
	Closure Lid Assembly		
	TSC1 & TSC2	9.0-in. thick	Stainless Steel
	TSC3 & TSC4	4.0-in thick/5.0-in thick	Stainless Steel/Carbon Steel
	Closure Ring	(0.7 to 1.5) × 0.75	Stainless Steel
	Length		
	TSC1 & TSC3	191.8	
	TSC2 & TSC4	184.8	
	Capacity (# of fuel assemblies)	37 PWR/87 BWR	
Fuel Basket	PWR Fuel Tube Wall	0.31	Carbon Steel
	BWR Fuel Tube Wall	0.25	Carbon Steel
	Neutron Absorber	0.125 (PWR), 0.1 (BWR)	Metallic Composite/Matrix
	Neutron Absorber Retainer	0.015	Stainless Steel
	Support Plates & Gussets	0.5 to 0.75	Carbon Steel
	Support Bars (PWR)	0.875	Carbon Steel
	Support Plate (BWR)	0.75	Carbon Steel
	Length	172.5 or 179.5	
	Assembly dia.	70.76	
	# of Fuel Tubes/Fuel Loading Positions		
	PWR	21/37	
	BWR	45/87	
	DFC Corner Support Weldment		
	Inner-Formed Plate	1.125	Carbon Steel
	Outer-Formed Plate	0.75	Carbon Steel
	Ridge Gusset	0.75	Carbon Steel
	Damaged Fuel Can Wall		
	Tube Body	0.048	Stainless Steel
	Side Plate	0.15	Stainless Steel
Transfer Cask	MTC1		
	Outer Shell	1.25 × 88 dia.	Low Alloy Steel
	Inner Shell	0.75 × 74.5 dia.	Low Alloy Steel
	Retaining Block	8 × 8.75 × 1.50	Stainless Steel
	Trunnions	9 dia.	Low Alloy Steel
	Bottom Forging	12 × 88 dia.	Low Alloy Steel
	Top Forging	14 × 88 dia.	Low Alloy Steel
	Shield Doors	5.0	Low Alloy Steel
	Door Rails	5.25 × 7.5 × 52.0	Low Alloy Steel
	Gamma Shield	3.25	Lead
	Neutron Shield	2.25	NS-4-FR, Solid Synthetic Polymer
	Length	202.0	

[a] Thickness unless otherwise indicated.

Table 1.3-1 Design Characteristics (continued)

	Design Characteristic	Nominal Value (in)[a]	Material
Transfer Cask (continued)	MTC2		
	Outer Shell	1.25 × 88 dia.	Stainless Steel
	Inner Shell	0.75 × 74.5 dia.	Stainless Steel
	Retaining Ring	1 × 84 dia.	Stainless Steel
	Retaining Block	8 × 8.75 × 1.50	Stainless Steel
	Trunnions	9 dia.	Stainless Steel
	Bottom Forging	12 × 88 dia.	Stainless Steel
	Top Forging	14 × 88 dia.	Stainless Steel
	Shield Doors	5.0	Stainless Steel
	Door Rails	5.25 × 7.5 × 52.0	Stainless Steel
	Gamma Shield	3.25	Lead
	Neutron Shield	2.25	NS-4-FR, Solid Synthetic Polymer
	Length	192.2	
Transfer Adapter	Base Plate	2.0	Carbon Steel
	Guide Ring	2.5 × 79 dia.	Carbon Steel
Concrete Cask	CC1 & CC2		
	Weldment Structures		
	Liner	1.75 × 83 dia	Carbon Steel
	Top Flange	1 × 91.0 dia.	Carbon Steel
	Standoffs (Channels)	3 × 7.5 (s-beam)	Carbon Steel
	Pedestal Plate	2 × 72 dia.	Carbon Steel
	Base Plate	1 × 128 dia.	Carbon Steel
	Inlet Top	2 × 136 dia.	Carbon Steel
	Concrete Cask		Carbon Steel
	Concrete Shell	26.5 × 136 dia.	Type II Portland Cement
	Lid	6.8 × 88 dia.	Carbon Steel Type II Portland Cement
	Rebar	various lengths	Carbon Steel
	Length	225.3	
	CC3		
	Weldment Structures		
	Liner	3 × 83 dia	Carbon Steel
	Top Flange	1 × 93.5 dia.	Carbon Steel
	Standoffs (Channels)	3 × 7.5 (s-beam)	Carbon Steel
	Pedestal Plate	2 × 72 dia.	Carbon Steel
	Base Plate	1 × 128 dia.	Carbon Steel
	Inlet Top	2 × 136 dia.	Carbon Steel
	Concrete Cask		Carbon Steel
	Concrete Shell	25.3 × 136 dia.	Type II Portland Cement
	Lid	12.8 × 91.5 dia.	Carbon Steel Type II Portland Cement
	Rebar	various lengths	Carbon Steel
	Length	218.3	

[a] Thickness unless otherwise indicated.

Table 1.3-1 Design Characteristics (continued)

	Design Characteristic	Nominal Value (in)[a]	Material
Concrete Cask (continued)	CC4		
	Weldment Structures		
	Liner	1.75 × 83 dia	Carbon Steel
	Top Flange	1 × 93.5 dia.	Carbon Steel
	Standoffs (Channels)	3 × 7.5 (s-beam)	Carbon Steel
	Pedestal Plate	2 × 72 dia.	Carbon Steel
	Base Plate	1 × 128 dia.	Carbon Steel
	Inlet Top	2 × 136 dia.	Carbon Steel
	Concrete Cask		Carbon Steel
	Concrete Shell	26.5 × 136 dia.	Type II Portland Cement
	Lid	6.8 × 91.5 dia.	Carbon Steel Type II Portland Cement
	Rebar	various lengths	Carbon Steel
	Length	218.3	
	CC5		
	Weldment Structures		
	Liner	3 × 83 dia.	Carbon Steel
	Top Flange	1 × 93.5 dia.	Carbon Steel
	Standoffs (Channels)	3 × 7.5 (s-beam)	Carbon Steel
	Pedestal Plate	2 × 72 dia.	Carbon Steel
	Base Plate	1 × 128 dia.	Carbon Steel
	Inlet Top	2 × 136 dia.	Carbon Steel
	Concrete Cask		Carbon Steel
	Concrete Shell	25.3 × 136 dia.	Type II Portland Cement
	Lid	12.8 × 91.5 dia.	Carbon Steel Type II Portland Cement
	Rebar	various lengths	Carbon Steel
	Length	225.9	

[a] Thickness unless otherwise indicated.

Table 1.3-2 TSC Fabrication Specification Summary

Materials

- All materials shall be governed by the referenced drawings and meet the applicable ASME Code sections.

Welding

- Welds shall be in accordance with the referenced drawings.
- Filler metals shall be appropriate ASME Code materials.
- Welders and welding operators shall be qualified in accordance with ASME Code Section IX [12].
- Welding procedures shall be written and qualified in accordance with ASME Code Section IX.
- Personnel performing weld examinations shall be qualified in accordance with the NAC International Quality Assurance Program and SNT-TC-1A [13].
- Weld inspection and examination requirements and acceptance criteria are specified in Chapter 10.

Fabrication

- Cutting, welding, and forming shall be in accordance with ASME Code, Section III, NB-4000 [8] unless otherwise specified. Code stamping is not required.
- Surfaces shall be cleaned to a surface cleanness classification C, or better, as defined in ANSI N45.2.1 [14], Section 2.
- Fabrication tolerances shall meet the requirements of the referenced drawings after fabrication.

Packaging

- Packaging and shipping shall be in accordance with ANSI N45.2.2 [15].

Quality Assurance

- The TSC shall be fabricated under a quality assurance program that meets 10 CFR 72, Subpart G, and 10 CFR 71, Subpart H.

1.8 License Drawings

This section presents the list of License Drawings for MAGNASTOR.

Drawing Number	Title	Revision No.
71160-551	Fuel Tube Assembly, MAGNASTOR – 37 PWR	10NP*
71160-556	Assembly, MAGNASTOR Transfer Cask (MTC), Stainless Steel	4
71160-560	Assembly, Standard Transfer Cask, MAGNASTOR	2
71160-561	Structure, Weldment, Concrete Cask, MAGNASTOR	9
71160-562	Reinforcing Bar and Concrete Placement, Concrete Cask, MAGNASTOR	9
71160-571	Details, Neutron Absorber, Retainer, MAGNASTOR – 37 PWR	8
71160-572	Details, Neutron Absorber, Retainer, MAGNASTOR – 87 BWR	8NP*
71160-574	Basket Support Weldments, MAGNASTOR – 37 PWR	6
71160-575	Basket Assembly, MAGNASTOR – 37 PWR	11NP*
71160-581	Shell Weldment, TSC, MAGNASTOR	5
71160-584	Details, TSC, MAGNASTOR	8
71160-585	TSC Assembly, MAGNASTOR	12
71160-590	Loaded Concrete Cask, MAGNASTOR	8
71160-591	Fuel Tube Assembly, MAGNASTOR – 87 BWR	8NP*
71160-598	Basket Support Weldments, MAGNASTOR – 87 BWR	7NP*
71160-599	Basket Assembly, MAGNASTOR – 87 BWR	8NP*
71160-600	Basket Assembly, MAGNASTOR – 82 BWR	5NP*
71160-601	Damaged Fuel Can (DFC), Assembly, MAGNASTOR	0
71160-602	Damaged Fuel Can (DFC), Details, MAGNASTOR	1
71160-671	Details, Neutron Absorber, Retainer, For DF Corner Weldment, MAGNASTOR – 37 PWR	0
71160-673	Damaged Fuel Can (DFC), Spacer, MAGNASTOR	0
71160-674	DF Corner Weldment, MAGNASTOR	3NP*
71160-675	DF Basket Assembly, 37 Assembly PWR, MAGNASTOR	3NP*
71160-681	DF, Shell Weldment, TSC, MAGNASTOR	1
71160-684	Details, DF Closure Lid, MAGNASTOR	2
71160-685	DF, TSC Assembly, MAGNASTOR	6

* Proprietary drawing replaced by nonproprietary version.

REV	CHANGE
0	INITIAL ISSUE
1	INC DCR 0A
2	INC DCR 1A
3	INC DCR 2A
4	INC DCR 3A
5	INC DCR 4A & 4B
6	INC DCR 5A, 5B, 5C, 5D
7	INC DCR 6A, 6B
8	INC DCR 7A
9	INC DCR 8A, 8B

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

UNLESS OTHERWISE STATED

GROUP	NAME	DATE
		11-14-16
		11-15-16
		12-30-16
		12-30-16
		12/30/16
		12-30-16

NEXT ASSEMBLY: 71160-562

DRAWING TYPE: LICENSE

NAC INTERNATIONAL

STRUCTURE, WELDMENT, CONCRETE CASK, MAGNASTOR

PROJECT 71160 DRAWING 561 REV 9

SH 1 OF 5

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

STRUCTURE, WELDMENT, CONCRETE CASK, MAGNASTOR

PROJECT 71160 DRAWING 561 REV 9

SH 2 OF 5

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

STRUCTURE, WELDMENT, CONCRETE CASK, MAGNASTOR

PROJECT	DRAWING	REV
71160	561	9
	SH 3 OF 5	

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

STRUCTURE, WELDMENT, CONCRETE CASK, MAGNASTOR

PROJECT 71160	DRAWING 561	REV 9	SH 4 OF 5

Security-Related Information

Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

STRUCTURE, WELDMENT,
CONCRETE CASK,
MAGNASTOR

PROJECT 71160	DRAWING 561	REV 9	SH 5 OF 5

REV	CHANGE
0	INITIAL ISSUE
1	INC DCR 0A
2	INC DCR 1A
3	INC DCR 2A
4	INC DCR 3A
5	INC DCR 4A
6	INC DCR 5A, 5B, 5C
7	INC DCR 6A
8	INC DCR 7A
9	INC DCR 8A, 8B

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

UNLESS OTHERWISE STATED

ALL DIMENSIONS ARE IN INCHES

NEXT ASSEMBLY: 71160-590

DRAWING TYPE: LICENSE

NAC INTERNATIONAL

REINFORCING BAR AND CONCRETE PLACEMENT, CONCRETE CASK, MAGNASTOR

PROJECT 71160 DRAWING 562 REV 9

SH 1 OF 2

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

REINFORCING BAR AND CONCRETE PLACEMENT, CONCRETE CASK, MAGNASTOR

PROJECT 71160 DRAWING 562 REV 9

SH 2 OF 2

REV	CHANGE
0	INITIAL ISSUE
1	INC DCR 0A
2	INC DCR 1A
3	INC DCR 2A
4	INC DCR 3A
5	INC DCR 4A
6	INC DCR 5A
7	INC DCR 6A
8	INC DCR 7A, 7B
9	INC DCR 8A
10	INC DCR 9A
11	INC DCR 10A
12	INC DCR 11A

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

UNLESS OTHERWISE STATED

NEXT ASSEMBLY: 71160-590/500

DRAWING TYPE: LICENSE

GROUP	NAME	DATE
	[signature]	6-9-16
	[signature]	6-15-16
	[signature]	6-15-16
	[signature]	6-15-16
	[signature]	6/16/16
	[signature]	6-16-16

NAC INTERNATIONAL

TSC ASSEMBLY, MAGNASTOR

PROJECT 71160 DRAWING 585 REV 12

SH 1 OF 3

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

TSC ASSEMBLY,
MAGNASTOR

PROJECT 71160		DRAWING 585	REV 12
		SH 2 OF 3	

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

TSC ASSEMBLY, MAGNASTOR

PROJECT 71160	DRAWING 585	REV 12	SH 3 OF 3

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

Security-Related Information Figure Withheld Under 10 CFR 2.390.

UNLESS OTHERWISE STATED

NEXT ASSEMBLY: N/A

DRAWING TYPE: LICENSE

GROUP	NAME	DATE
		11-14-16
		11-15-16
		12-20-16
		12-30-16
		12/30/16
		12-30-16

NAC INTERNATIONAL

LOADED CONCRETE CASK, MAGNASTOR

PROJECT 71160

DRAWING 590 REV 8

SH 1 OF 2

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

LOADED CONCRETE CASK,
MAGNASTOR

PROJECT	DRAWING	REV
71160	590	8
	SH 2 OF 2	

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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

UNLESS OTHERWISE STATED

ALL DIMENSIONS ARE IN INCHES

NEXT ASSEMBLY 71160-590/501

DRAWING TYPE LICENSE

GROUP	NAME	DATE
		6-10-16
		6-15-16
		6-15-16
		6-15-16
		6/16/16
		6-16-16

NAC INTERNATIONAL

DF, TSC ASSEMBLY, MAGNASTOR

PROJECT 71160 DRAWING 685 REV 6

SH 1 OF 3

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

DF, TSC ASSEMBLY,
MAGNASTOR

PROJECT 71160		DRAWING 685	REV 6
		SH 2 OF 3	

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

DF, TSC ASSEMBLY, MAGNASTOR

PROJECT 71160 | DRAWING 685 | REV 6

SH 3 OF 3

Table 2.1-2 ASME Code Alternatives for MAGNASTOR Components

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
TSC and Fuel Basket	NCA-1000, NCA-2000, NCA-3000, NCA-4000, NCA-5000, NCA-8000, NB-1110, and NG-1110	Requirements for Code stamping of NB components and preparation of Code Design Specifications, Design Reports, Overpressure Protection Report (TSC only), and Data Reports, and Quality Assurance requirements in accordance with Code requirements.	Code stamping is not required for the TSC, fuel basket or damaged fuel can. Code Design Specifications, Design Reports, Overpressure Protection Report, and Data Reports are not required. The TSC, Fuel Basket and Damaged Fuel Can are designed, procured, fabricated, inspected and tested in accordance with a QA Program meeting 10 CFR 72, Subpart G. Authorized Nuclear Inspection Agency Services are not required.
TSC Pressure-Retaining Materials	NB-2000	Pressure-retaining material to be provided by ASME-approved Material Organization.	Materials will be supplied with Certified Material Test Reports by NAC approved suppliers.
TSC Closure Lid-to-Shell Weld	NB-4243	Full penetration welds required for Category C joints.	The closure lid-to-shell weld is not a full penetration weld. The design and analysis of the closure lid weld utilizes a 0.8 stress reduction factor in accordance with ISG-15 [23].
Port Cover-to-Closure Lid Weld	NB-5230	Radiographic (RT) examination required.	Final surface liquid penetrant examination to be performed per ASME Code Section V, Articles 6 and 24. PT acceptance criteria is to be in accordance with NB-5350.
TSC Closure Lid-to-Shell Weld	NB-5230	Radiographic (RT) examination required.	In accordance with ISG-15, the TSC closure lid-to-shell weld is to be inspected by progressive surface liquid penetrant (PT) examination of the root, midplane and final surface layers. The progressive PT examination of the weld will be performed in accordance with ASME Code, Section V, Articles 6 and 24, and acceptance criteria per NB-5350.

Table 2.1-2 ASME Code Alternatives for MAGNASTOR Components (Continued)

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
TSC Closure Ring-to-TSC Shell & TSC Closure Ring-to-Closure Lid	NB-5230	Radiographic (RT) examination required.	Final surface liquid penetrant examination to be performed per ASME Code Section V, Article 6 and 24. PT acceptance criteria is to be in accordance with NB-5350.
TSC	NB-6111	All completed pressure retaining systems shall be pressure tested.	Following closure lid to TSC shell welding, each TSC shall be hydrostatically pressure tested to 125% of MNOP. No observable water leakage from the closure lid to the TSC shell weld is allowed while maintaining test pressure. Since the shell welds of the TSC cannot be checked for leakage during this pressure test, as required by the Code, the shop helium leakage test to 2×10^{-7} cm^3/sec (helium) (as described in Section 10.1.3) provides reasonable assurance of the leak tightness of the TSC shell weldment.
TSC	NB-7000	Pressure vessels shall be protected from the consequences of pressure conditions exceeding design pressure.	No overpressure protection is provided. The function of the TSC is to confine radioactive contents without release under normal conditions, or off-normal and accident events of storage. The TSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure and maximum accident condition temperatures.
TSC	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The TSC is marked and identified to ensure proper identification of the contents. Code stamping is not required.
Fuel Basket Assembly & Damaged Fuel Can Structural Materials	NG-2000	Core support structural materials are to be provided by an ASME approved Material Organization.	Fuel basket and damaged fuel can structural materials with Certified Material Test Reports to be supplied by NAC approved suppliers.

3.1.2 Discussion of MAGNASTOR

MAGNASTOR has multiple configurations to accommodate all PWR and BWR fuel assemblies. The type (PWR or BWR) and overall length of the fuel assembly determine the basic storage configuration, or group. The TSC is designed in two different lengths to accommodate the four groupings of PWR (2) and BWR (2) fuel assemblies. The concrete cask and transfer cask are also designed in two different lengths. The long concrete cask and transfer cask configurations are designed to accommodate the two TSC lengths, and the short concrete cask and transfer cask configurations are designed to only accommodate the short TSCs. The bounding weights and center of gravity of a loaded concrete cask are presented in Table 3.2.1-1.

The evaluations presented in this chapter are based on the bounding, or limiting, configuration of the components for the condition being evaluated. In most cases, the bounding condition evaluates the heaviest configuration, with either a total weight or bounding weight used as specified in the analysis. Factors of safety greater than ten are generally stated in the analyses as "Large." Numerical values are shown for factors of safety that are less than ten.

Concrete Cask

The concrete cask is provided in five different configurations designated CC1, CC2, CC3, CC4 and CC5. The concrete cask is a reinforced concrete cylinder with an outside diameter of 136 inches and an overall height of approximately 226 inches (CC1, CC2 and CC5) or 218 inches (CC3 and CC4). The internal cavity of the concrete cask is lined by a carbon steel shell with an inside diameter of 79.5 inches and a thickness of either 1.75 inches (CC1, CC2 and CC4) or 3.0 inches (CC3 and CC5). There are 24 standoffs (3 × 7½ S-Beam) welded to the inner diameter of the liner. The overall cavity opening in the concrete cask is 73.5 inches. The liner thickness is designed primarily on radiation shielding requirements, but is also related to the need to establish a practical limit for the diameter of the concrete shell. The concrete shell, constructed using Type II Portland Cement, has a nominal density of 145 lb/ft^3 and a compressive strength of 4,000 psi at ambient temperature. Vertical hook bars and horizontal hoop bars form the inner and outer rebar cages. The inner rebar cage is optional for all concrete cask configurations.

A ventilation airflow path is formed by inlets at the bottom of the concrete cask, the annular space between the concrete cask inner shell and the TSC, and outlets in the concrete cask lid assembly. The passive ventilation system operates by natural convection as cool air enters the bottom inlets, is heated by the TSC, and exits from the outlets. Both the air inlets and air outlets are formed with carbon steel in the concrete cask body. For the CC3, CC4 and CC5 configurations, a labyrinth of steel bars is included in each inlet vent for enhanced radiation shielding.

The top end of the concrete cask is closed by a lid assembly that is attached by six ∅5/8-inch lid bolts. The lid assembly is composed of a carbon steel top plate and a cylindrical concrete plug that is encased in 1/4-inch thick carbon steel plate. The lid assembly used with the CC1, CC2 and CC4 configurations has an overall thickness of 6.8 inches and an overall diameter of 88.0 inches. The CC3 and CC5 lid assemblies have a slightly larger overall diameter (91.5 inches) and also includes an additional 6.0 inches of concrete (over a 60.0-inch diameter) for enhanced radiation shielding.

TSC

The TSC consists of a cylindrical shell closed at its top end by a closure lid assembly. The bottom of the TSC is a 2.75-inch thick stainless steel plate that is welded to the TSC shell. The TSC forms the confinement boundary for the PWR or BWR spent fuel that is contained in the fuel basket assembly. The TSC is designed to accommodate both PWR and BWR classes of spent fuel assemblies. The TSC shell is fabricated from dual-certified SA240 Type 304/304L stainless steel. The TSC closure lid is fabricated from Type 304 or 304L stainless steel, with material yield and ultimate strengths equal to, or greater than, those of Type 304. The TSC shell is a 0.5-inch thick plate formed into a 72-inch outer diameter cylinder. The TSC closure lid assembly is provided as either a single-piece 9-inch thick stainless steel plate (i.e., the TSC1 and TSC2 configurations) or a two-piece composite lid assembly (i.e., the TSC3 and TSC4 configurations). The TSC3 and TSC4 composite lid assembly design consists of a 4-inch thick closure lid and a 5-inch thick shield plate. The closure lid forms the TSC confinement boundary and provides radiation shielding. The shield plate, which is fabricated from A36 carbon steel that is coated with electroless nickel plating, provides radiation shielding and structural support for the closure lid. The shield plate is attached to the closure lid by ten 1-½ inch diameter A193, Grade B6 bolts.

The fuel basket assembly is provided in two configurations – one for up to 37 PWR fuel assemblies and one for up to 87 BWR fuel assemblies. The baskets are manufactured from SA537 Class 1 Carbon Steel. For both the PWR basket and BWR basket, the basic components are the same. The baskets are assembled from three major components – fuel tube assemblies, corner support weldments, and side support weldments. The fuel tube assemblies are equipped with neutron absorbers and stainless steel covers on up to four interior surfaces of the fuel tubes. When neutron absorbers are not needed, they may be replaced by aluminum sheets. The geometric integrity of the fuel tube array (21 fuel tubes – PWR, 45 fuel tubes – BWR) is maintained by the corner and side support weldments, which are bolted to the fuel tube array.

3.2 Weights and Centers of Gravity

3.2.1 Calculated Maximum Weights and Centers of Gravity

The maximum calculated weights and centers of gravity (CGs) for MAGNASTOR PWR, PWR with Damaged Fuel Cans, and BWR configurations are presented in Table 3.2.1-1. The weights and CGs presented in this section are calculated based on nominal design dimensions.

The stainless steel TSC assembly holds the fuel basket structure and confines the contents. TSCs are provided in four configurations designated TSC1 through TSC4. The TSC configurations are distinguished by their length and closure lid assembly design, as detailed on the drawings. TSC1 and TSC3 are 191.8 inches long; TSC2 and TSC4 are 184.4 inches long. TSC1 and TSC2 include a 9-in thick solid stainless steel closure lid assembly. TSC3 and TSC4 include a composite closure lid assembly consisting of a 4-in thick stainless steel closure lid and a 5-in thick carbon steel shield plate. The solid stainless steel standard closure lid assembly is heavier than the composite closure lid assembly. Therefore, the bounding weight of the standard closure lid assembly is used for all weight and CG calculations.

The concrete cask is a reinforced concrete structure with a structural steel inner liner and base. The concrete cask may be supplied in five different configurations designated CC1 through CC5. CC1 is the standard 225.27-in high cylinder. CC2 is also 225.27-in high, but is a segmented design. CC1, CC2 and CC4 are equipped with a 1.75-in thick carbon steel liner. CC3 is a 218.3-in high standard design cylinder equipped with a 3-in thick carbon steel liner and additional shielding at the air inlets. CC4 is a 218.3-in high standard design cylinder with inlet shield bars. CC5 is a 225.9-in high standard design cylinder with a 3-in thick carbon steel liner and inlet shield bars. The shorter length of CC3 and CC4 limit their use to the shorter canisters, i.e., TSC2 and TSC4, while the longer CC1, CC2 and CC5 can be used with all canister designs. The top of the concrete cask is closed by a lid assembly. The lid assembly is composed of a carbon steel top plate and a cylindrical concrete plug that is encased in ¼-in thick carbon steel plate. The lid assembly used with the CC1 and CC2 configurations have an overall thickness of 6.8 inches and an overall diameter of 88.0 inches. The CC3 and CC5 lid assemblies have a slightly larger overall diameter (91.5 inches) and also includes an additional 6.0 inches of concrete (over a 60.0-in diameter) for enhanced radiation shielding. The CC4 lid assembly has the same overall diameter as the CC3 lid configuration and the same thickness of the CC1 and CC2 lid configuration.

There are two MAGNASTOR Transfer Casks (MTCs) considered in this calculation, i.e., MTC1 and MTC2. The MTC1 transfer cask is longer and made of carbon steel, while the MTC2 transfer cask is shorter and made of stainless steel.

Table 3.2.1-1 MAGNASTOR Storage Weight and Center of Gravity Summary

Description	CC1, CC2 & CC5 / MTC1 (1)						CC3 & CC4 (2) / MTC2 (2)			
	PWR		BWR		DF - PWR		PWR		DF - PWR	
	Weight (lb)(3)	CG (in)(4)	Weight (lb)(3)	CG (in)(4)	Weight (lb)(3)	CG (in)(4)	Weight (lb)(3)	CG (in)(4)	Weight (lb)(3)	CG (in)(4)
Maximum Contents (fuel, DFC and/or spacers, if used)	62,160	-	61,248	-	61,184	-	62,160	-	61,184	-
Basket	20,500	-	22,000	-	24,000	-	19,500	-	24,000	-
TSC w/o Lid	9,500	-	9,500	-	9,500	-	9,500	-	9,500	-
Closure Lid	10,500	-	10,500	-	10,500	-	10,500	-	10,500	-
Loaded TSC (TSC, lid, basket, contents)	102,000	100	103,000	99	104,500	96	101,000	96	104,500	96
Water in TSC and Annulus	17,500	-	16,500	-	16,500	-	17,000	-	16,500	-
Transfer Cask(5) (does not include lifting yoke or transfer adapter)	108,500	-	108,500	-	108,500	-	106,000	-	106,000	-
Lifting Yoke (6) (not included in transfer cask weight)	5,500	-	5,500	-	5,500	-	5,500	-	5,500	-
Concrete Cask (7, 8) (does not include concrete cask lid)	214,500 (14) 229,000 (15)	-	214,500 (14) 229,000 (15)	-	214,500 (14) 229,000 (15)	-	225,000 (12) 210,000 (13)	-	225,000 (12) 210,000 (13)	-
Concrete Cask Lid (8)	4,500 (14) 6,000 (15)	-	4,500 (14) 6,000 (15)	-	4,500 (14) 6,000 (15)	-	6,000 (12) 4,500 (13)	-	6,000 (12) 4,500 (13)	-
Storage Cask Loaded (concrete cask w/ lid, TSC w/ lid, basket, contents)	320,500 (14) 336,500 (15)	113 (14) 113 (15)	321,500 (14) 337,500 (15)	113 (14) 113 (15)	323,500 (14) 329,500 (15)	112 (14) 113 (15)	332,500 (12) 315,000 (13)	108 (12) 109 (13)	335,500 (12) 318,500 (13)	108 (12) 109 (13)
Transfer Cask, TSC w/o Lid, Basket, Lifting Yoke – Empty	143,500	-	145,500	-	146,500	-	140,000	-	144,500	-
Loaded Transfer Cask Wet Weight (9)	228,000	-	228,000	-	229,500	-	223,500	-	226,500	-
Under Hook Wet Weight (10)	233,500	-	233,500	-	234,500	-	228,500	-	232,000	-
Under Hook Dry Weight (11)	216,000	-	217,000	-	218,500	-	212,000	-	216,000	-

See following page for Notes.

Table 3.2.1-1 MAGNASTOR Storage Weight and Center of Gravity Summary (continued)

Notes:

1. Bounding weights and centers of gravity for CC1, CC2 and CC5 concrete casks and MTC1 transfer cask with all TSC configurations.
2. Bounding weights and centers of gravity for CC3 and CC4 concrete casks and MTC2 with TSC2 or TSC4.
3. Weights and CGs are maximum calculated values based on nominal component dimensions. All weights rounded to the nearest 500 pounds, except for the maximum contents. Component weights are rounded individually, so total assembly weights may not equal the sum of the component weights.
4. CG is measured from the bottom of each component and CG of TSC contents is assumed to equal the mid-length of the TSC cavity.
5. The MTC1 and MTC2 transfer casks can be used with all three concrete cask configurations (i.e., CC1, CC2, CC3, CC4 and CC5). The MTC2 transfer cask can only be used for a short TSC configuration (i.e., TSC2 and TSC4), while MTC1 can be used with any TSC configuration.
6. Transfer cask lifting yoke weight for specific sites may vary from listed weight. The site-specific yoke weight should be used for site-specific applications.
7. Bounding weight with inner rebar cage, which bounds the weight of construction aids used with the no inner rebar cage configuration.
8. Average concrete density is considered to be 148 pcf for conservative weight calculation.
9. Loaded Transfer Cask Wet Weight (transfer cask, TSC, basket, closure lid, contents, water in TSC and transfer cask annulus).
10. Under Hook Wet Weight (transfer cask, TSC, basket, lifting yoke, closure lid, contents, water in TSC and transfer cask annulus).
11. Under Hook Dry Weight (transfer cask, TSC, basket, lifting yoke, closure lid, contents).
12. Value for the CC3 concrete cask configuration
13. Value for the CC4 concrete cask configuration
14. Value for the CC1 and CC2 concrete cask configuration
15. Value for the CC5 concrete cask configuration

A_w = d_p t_w -------------------------- Weld area
d_p = 5.83 in -------------------------- Maximum lid port counterbore diameter
t_w = 1/8 in -------------------------- Port cover weld thickness
q = 110 psi -------------------------- Normal condition pressure and inertial loading

Conservatively using the temperature of 650°F, the factor of safety is:

$$FS = \frac{S_{allow}}{\tau_w} = \frac{0.6\ S_m}{\tau_w} = 7.6$$

where:
S_m = 16.2 ksi --------------- design stress intensity, SA-240 Type 304 at 650°F

3.5.1.4 TSC Handling Loads

The TSC is analyzed for handling loads using the finite element models described in Section 3.10.3. Normal handling is simulated by constraining the model at nodes on the closure lid simulating three lift points. A 1.1g acceleration load, which corresponds to the dead weight with a 10% dynamic load factor, is applied to the model in the axial direction. Pressure is applied to the TSC bottom plate to simulate the weight of the basket and fuel with an acceleration of 1.1g.

The resulting maximum stresses in the TSC due to handling loads are bounded by the maximum stresses for the normal handling loads plus normal pressure condition presented in Section 3.5.1.5; therefore, the stress results for the handling condition are not presented separately.

The stresses in the TSC lift lugs or restraining blocks resulting from normal handling loads are evaluated using classical methods. The TSC lift lugs (PWR configurations) and restraining blocks (BWR configurations), which are welded to the inner surface of the TSC shell, are designed to support the combined weight of the TSC lid and supplemental support equipment prior to placement of the closure welds. The total weight imposed on the lift lugs, W, conservatively considers the combined weight of the TSC closure lid assembly (10,500 pounds) and supplemental support equipment (11,500 pounds). A 10% load factor is also applied to ensure all normal operating loads are bounded. Evaluation of the PWR lift lugs is presented as it provides a bounding analysis enveloping the BWR restraining block configuration. The stresses evaluated are bearing stress on the top end of the lift lugs and shear stress through the lift lug attachment welds.

The bearing stress on the top end of the lift lugs is calculated as follows.

$$\sigma_{bearing} = \frac{W}{4A} = \frac{24{,}200\ \text{lb}}{4(1.53\ \text{in}^2)} = 3{,}954\ \text{psi}$$

where:

W = (10,500 lb + 11,500 lb) × 1.1 = 24,200 lb

A = 1.53 inch^2 -------------------------------- Bearing area of each lifting lug

The allowable bearing stress is equal to the yield strength of Type 304 stainless steel at a temperature of 125°F, or 27,885 psi. Therefore, the factor of safety (FS) is as follows.

$$FS = \frac{1.0\ S_y}{\sigma_{bearing}} = \frac{27{,}885\ psi}{3{,}954\ psi} = 7.05$$

The attachment weld for the lift lugs is an all-around 3/8-inch effective throat groove weld. The shear stress in the lift lug attachment weld ($_w$) is calculated as follows.

$$_w = \frac{W}{4A_{eff}} = \frac{24{,}200\ lb}{4(5.32\ in^2)} = 1{,}137\ psi$$

where:

A_{eff} = 5.32 inch^2 -------------------------------- Area of lifting lug weld

The factor of safety (FS) for the lift lug shear stress is as follows.

$$FS = \frac{S_{allow}}{\tau_w} = \frac{0.6\ S_m}{\tau_w} = \frac{0.6 \times 20{,}000\ psi}{1{,}137\ psi} = 10.6$$

where:

S_m = 20,000 psi -------------------------------- Design stress intensity of SA-240, Type 304 stainless steel at 125°F

3.5.1.5 TSC Load Combinations

The TSC is structurally analyzed for combined thermal, dead, maximum internal pressure, and handling loads using the finite element models described in Section 3.10.3.

The resulting maximum stresses in the TSC for combined loads are summarized in Table 3.5.1-2, Table 3.5.1-3, and Table 3.5.1-4 for primary membrane, primary membrane plus primary bending, and primary plus secondary stresses, respectively. The sectional stresses are evaluated at each of the TSC section locations described in Section 3.10.3 for each angular division of the model. The locations for the stress sections are shown in Figure 3.10.3-2 and Figure 3.10.3-5 in Section 3.10.3.

provided in Section 3.5.2.1 for retainer for the PWR is applicable to that for the BWR. No further analysis is required.

3.5.3 Concrete Cask Evaluations for Normal Operating Conditions

The structural evaluation of the concrete cask for normal conditions considers the combination of thermal stresses, dead and live loads, and wind loads (see Chapter 2 for load combinations). The analysis results are presented in Section 3.5.3.3. The conservative stress due to wind loads is obtained from Section 3.7.3.2.

3.5.3.1 Concrete Cask Thermal Stresses

Using the finite element models presented in Section 3.10.4, structural evaluations of the concrete cask are performed for normal conditions thermal loads, both with and without the optional inner rebar cage. The analysis conservatively considered a bounding temperature profile corresponding to the off-normal thermal event (106°F ambient).

The following summarizes the bounding thermal stresses in the concrete cask for normal conditions.

Component	Stress (ksi)
Circumferential Rebar	20.2
Vertical Rebar	21.6
Concrete, Compression	1.63
Concrete, Tension	0.129

3.5.3.2 Dead and Live Loads

Dead Loads

The concrete cask dead load consists primarily of the weight of the concrete. Assuming all dead loads are reacted by the lower concrete surface only, stress levels can be determined. Under these conditions, the only stress component is the vertical axial compression stress. The maximum stress ($_{cask}$) at the base of the concrete cask in the concrete is as follows.

$$_{cask} = \frac{W_{cask}}{A} = \frac{235{,}000}{8{,}785} = 27 \text{ psi}$$

where:

W_{cask} = 235,000 lb -------------------------------- Bounding weight for empty concrete cask
D_o = 136.0 inch

D_i = 85.5 inch
$A = \pi (D_o^2 - D_i^2) / 4 = 8{,}785\ \text{inch}^2$

The concrete bearing strength (f_b) is much larger than the applied load.

$$f_b = \phi(0.85 f'_c A) = 0.85(0.85 \times 3800 \times 8785) = 19.9 \times 10^6\ \text{lb} > 235{,}000\ \text{lb}$$

where:

f_c' = 3,800 psi ---------------------------------- Compressive strength, concrete, at 300°F
ϕ = 0.7 -- Strength reduction factor [5]

Live Loads

The live load calculation considers the loaded transfer cask positioned on top of the concrete cask for transfer of the TSC for development of the peak live load bounding condition. Assuming live loads are reacted by concrete sections (no credit taken for steel liner), stress levels are conservatively determined. Under these conditions, the only stress component is the vertical axial compression stress ($_{\text{concrete cask}}$).

$$_{\text{concrete cask}} = \frac{W_{TFR}}{A} = \frac{252{,}000}{8{,}785} = 29\ \text{psi}$$

where:

W_{TFR} = 252,000 lb -------------------------------- Loaded transfer cask with transfer adapter
D_o = 136.0 inch
D_i = 85.5 inch
$A = \pi (D_o^2 - D_i^2) / 4 = 8{,}785\ \text{inch}^2$

3.5.3.3 Concrete Cask Combined Stresses

The load combinations described in Chapter 2 are used to evaluate the concrete cask for normal conditions of storage (Load Conditions 1, 2, and 3). Bounding stresses for all concrete cask configurations are summarized in Table 3.5.3-1, Table 3.5.3-2, and Table 3.5.3-3 for the various loading conditions on the concrete cask.

The allowable compressive stress for concrete (S_{con}) is as follows.

$$S_{con} = \phi f_c' = 2{,}660\ \text{psi}$$

where:

ϕ = 0.7 -- Strength reduction factor [5]

f_c' = 3,800 psi---------------------------------- Compressive strength of concrete at 300°F

The concrete ultimate strength allowable is 8% to 15% of the compressive stress [14]; therefore, the allowable ultimate strength (S_{tc}) is as follows.

$$S_{tc} = 0.08 \times S_{con} = 0.08 \times 2{,}660 = 213 \text{ psi or } 0.21. \text{ ksi}$$

The maximum concrete compressive stress is 2,165 psi (see Table 3.5.3-2); therefore, the minimum factor of safety (FS) for normal conditions is as follows.

$$FS = \frac{2{,}660}{2{,}165} = 1.23$$

From Section 3.5.3.1, the maximum concrete tensile stress due to thermal load is 0.129 ksi. Multiplying the stress by a 1.275 factor for normal conditions thermal stresses (see Chapter 2), the factor of safety (FS) for concrete ultimate strengths is as follows.

$$FS = \frac{S_{tc}}{S_t \times 1.275} = \frac{0.213}{0.129 \times 1.275} = 1.30$$

The allowable stress for rebar (S_{rebar}) is as follows.

$$S_{rebar} = \phi F_r = 54.0 \text{ ksi}$$

where:

ϕ = 0.9 --------------------------------------- Strength reduction factor [5]

F_r = 60.0 ksi ---------------------------------- Yield strength, rebar

From Section 3.5.3.1, the maximum rebar stress due to thermal load is 21.6 ksi. The stresses due to other loadings are negligible for normal conditions. Compressive loads are carried by the concrete. Multiplying the stress by a 1.275 factor for normal conditions thermal stresses (see Chapter 2), the factor of safety (FS) for the rebar is as follows.

$$FS = \frac{S_{rebar}}{S_t \times 1.275} = \frac{54.0}{21.6 \times 1.275} = 1.96$$

Table 3.5.3-1 Concrete Cask Vertical Stress Summary – Outer Surface, psi

Condition	Dead	Live	Wind	Thermal	Seismic	Flood	Tornado	Total
1	-39	-50	0	0	0	0	0	-89
2	-29	-37	0	0	0	0	0	-66
3	-29	-37	-25	0	0	0	0	-91

Table 3.5.3-2 Concrete Cask Vertical Stress Summary – Inner Surface, psi

Condition	Dead	Live	Wind	Thermal	Seismic	Flood	Tornado	Total
1	-39	-50	0	0	0	0	0	-89
2	-29	-37	0	-2083	0	0	0	-2149
3	-29	-37	-16	-2083	0	0	0	-2165

Table 3.5.3-3 Concrete Cask Circumferential Stress Summary – Inner Surface, psi

Condition	Dead	Live	Wind	Thermal	Seismic	Flood	Tornado	Total
1	0	0	0	0	0	0	0	0
2	0	0	0	-2083	0	0	0	-2083
3	0	0	0	-2083	0	0	0	-2083

W_{cc} = 230,000 lb ------------------------------ Lower bound concrete cask loaded weight.

ASCE 7-93 requires that the overturning moment due to wind load shall not exceed two-thirds of the dead load stabilizing moment unless the structure is anchored. Therefore, the minimum factor of safety (FS) against overturning is as follows.

$$FS = \frac{0.67M_s}{M_w} = 2.24$$

The stresses in the concrete due to the tornado wind load are conservatively calculated (based on the governing CC5 configuration). The concrete cask is considered to be fixed at its base. The stresses in the concrete are as follows.

$$_{outer} = \frac{M_{max}c_{outer}}{I} = 19.6 \text{ psi (tension or compression)}$$

$$_{inner} = \frac{M_{max}c_{inner}}{I} = 12.3 \text{ psi (tension or compression)}$$

where:

$$D_o = 136.0 \text{ inches}$$
$$D_i = 85.5 \text{ inches}$$
$$H = 225.9 \text{ inches}$$
$$A = \frac{\pi\left(D_o^2 - D_i^2\right)}{4} = 8{,}785 \text{ inch}^2$$
$$I = \frac{\pi\left(D_o^4 - D_i^4\right)}{64} = 14.17\times10^6 \text{ inch}^4$$
$$M_{max} = \frac{F_w \times H}{2} = 4.07\times10^6 \text{ lb-inch}$$
$$c_{outer} = 136.0/2 = 68.0 \text{ inches}$$
$$c_{inner} = 82.98/2 = 42.75 \text{ inches}$$

Tornado Missiles

The concrete cask is designed to withstand the effects of impacts associated with postulated tornado-driven missiles identified in NUREG-0800 [16], Section 3.5.1.4.III.4, Spectrum I missiles. These missiles are listed as follows.

- A massive high kinetic-energy missile (4,000 lb automobile, with a frontal area of 20 square feet that deforms on impact).
- A 280 lb, 8.0-inch-diameter armor piercing artillery shell.
- A 1.0-inch-diameter solid steel sphere.

All of these missiles are assumed to impact in a manner that produces the maximum damage at a velocity of 126 mph (35% of the maximum tornado wind speed of 360 mph). The concrete cask is evaluated for impact effects associated with each of the previously listed missiles.

The concrete cask has no openings except for the four air outlets at the top and four air inlets at the bottom. The outlets are configured such that a one-inch diameter solid steel missile cannot directly enter the concrete cask interior. Additionally, the basket is protected by the TSC closure lid assembly. The TSC is protected from small missiles entering the inlets by the pedestal plate; therefore, a detailed analysis of the impact of a one-inch diameter steel missile is not required.

Concrete Shell Local Damage (Penetration Missile)

Local damage to the concrete cask body is assessed by using the methodology presented by NSS 5-940.1 [18]. This method predicts the depth of penetration and minimum concrete thickness requirements to prevent scabbing. Penetration depths calculated by using this formula have been shown to provide reasonable correlation with test results. The penetration depth is as follows.

$$x = \left[4KNW\left(d^{-0.8}\right)\left(\frac{V}{1000}\right)^{1.8}\right]^{0.5} = 5.82 \text{ inch}$$

where:

d	=	8.0 inch	Missile diameter
K	=	$180/(f_c')^{1/2} = 2.92$	Coeff. depending on concrete strength
N	=	1.14	Shape factor for sharp nosed missiles
W	=	280 lb	Missile weight
V	=	126 mph = 185 ft/sec	Missile velocity
f_c'	=	3,800 psi	Concrete compressive strength at conservative 300°F

The minimum concrete shell thickness to prevent scabbing is three times the penetration depth (17.46 inch). The minimum thickness of the concrete shell is 25.25 inches (CC3 and CC5). The minimum factor of safety (FS) is as follows.

$$FS = \frac{25.25}{17.46} = 1.45$$

Note that the steel liner and rebar of the concrete cask is conservatively ignored in the previously listed evaluation.

Closure Plate Local Damage (Penetration Missile)

The concrete cask is closed with a carbon steel and concrete lid assembly of varying geometry and depths depending upon the specific concrete cask design. The top plate of all lid designs is ¾-inch thick carbon steel plate. Beneath the top plate is a carbon steel clad disk of concrete varying in geometry and depth based on the specific concrete cask design. In this evaluation, only the ¾-inch thick carbon steel top plate is considered to withstand the impact of the 280-lb armor-piercing missile, impacting at 126 mph. The perforation thickness (T) of the closure steel plate is calculated by using the methodology presented in BC-TOP-9A [19].

$$T = \frac{\left(m_m V_s^2 / 2\right)^{2/3}}{672D} = 0.52 \text{ inch}$$

where:

m_m = 280 lb/32.174 ft/sec^2 = 8.70 slugs (lb-sec^2/ft) ---------------------------- Missile mass

V_s = 185 ft/sec --Missile velocity

D = 8 inch --Missile diameter

The report recommends that the plate thickness be 25% greater than the calculated perforation thickness (T) to prevent perforation. The recommended plate thickness is as follows.

$$T = 1.25 \times 0.52 = 0.65 \text{ inch}$$

The factor of safety (FS) is as follows.

$$FS = \frac{0.75}{0.65} = 1.15$$

High-Energy Missile Impact Damage Prediction

The concrete cask is a freestanding structure. Therefore, the principal consideration in overall damage response is the potential for overturning the concrete cask as a result of the high-energy missile impact. From the principle of conservation of momentum, the impulse of the force from the missile impact on the concrete cask must equal the change in angular momentum of the concrete cask. Also, the impulse force due to the impact of the missile must equal the change in linear momentum of the missile. These relationships may be expressed as follows:

Change in momentum of the missile, during the deformation phase

$$\int_{t_1}^{t_2} (F)(dt) = m_m (v_2 - v_1)$$

where:

F -- Impact impulse force on missile

m_m = 4,000 lb/g = 124 slugs/12 = 10.4 (lb sec^2 /inch) -- Missile mass
t_1 -- Time at missile impact
t_2 -- Time at conclusion of deformation phase
v_1 = 126 mph = 185 ft/sec ------------------ Missile velocity at impact
v_2 -- Velocity of missile at time t_2

The change in angular momentum of the concrete cask, about the bottom outside edge/rim, opposite the side of impact is as follows.

$$\int_{t_1}^{t_2} M_c(dt) = \int_{t_1}^{t_2} (H)(F)(dt) = I_m(\omega_1 - \omega_2)$$

Substituting,

$$\int (F)(dt) = m_m(v_2 - v_1) = \frac{I_m(\omega_1 - \omega_2)}{H}$$

where:

M_c -- Moment of the impact force on the concrete cask
I_m -- Concrete cask mass moment of inertia, about point of rotation on the bottom rim
ω_1 -- Angular velocity at time t_1
ω_2 -- Angular velocity at time t_2
m_c = 230,000/32.174 = 7,149 slugs/12 = 596 lb sec^2 /inch -- Mass of concrete cask
I_{mx} = $1/12(m_c)(3r^2 + H^2) = 3.21\times10^6$ lb-sec^2-inch
I_m = $I_{mx} + (m_c)(d_{CG})^2 = 12.75 \times10^6$ lb-sec^2-inch
r = 68.0 inches ------------------------------- Concrete cask radius
r_{ro} = 58.915 inches --------------------------- Concrete cask radius of rotation
H = 225.27 inches ---------------------------- Concrete cask height
d_{CG} = $\sqrt{112^2 + 58.915^2} = 126.55$ inches ---- Distance from CG to rotation point

Based on conservation of momentum, the impulse of the impact force on the missile is equated to the impulse of the force on the concrete cask.

$m_m(v_2 - v_1) = I_m(\omega_1 - \omega_2)/H$
at time t_1, v_1 = 185 ft/sec and ω_1 = 0 rad/sec
at time t_2, v_2 = 0 ft/sec

During the restitution phase, the final velocity of the missile depends upon the coefficient of restitution of the missile, the geometry of the missile and target, the angle of incidence, and on the amount of energy dissipated in deforming the missile and target. On the basis of tests conducted by EPRI, the final velocity (v_f) of the missile following the impact is assumed to be zero. This conservatively assumes that all of the missile energy is transferred to the concrete

Local Shear Strength Capacity of Concrete Shell (High-Energy Missile)

This section evaluates the punching shear strength of the concrete shell when impacted by a high-energy missile. The high-energy missile is equivalent to a 20-ft^2 cross-sectional area object moving at 185 ft/sec, weighing 4,000 lb, having proportions of 2 horizontal to 1 vertical. The missile is assumed to impact flush with the top of the concrete shell. The concrete area required to resist the high-energy missile impact is conservatively calculated based on the concrete cask configuration with the thinnest concrete shell (CC3 and CC5) as follows.

$$A = 2b \times b = 2(11.41)^2 = 260.4 \text{ inch}^2 = 1.8 \text{ ft}^2 < 20 \text{ ft}^2$$

where:

Setting the factored shear force, V_u, equal to the force of the high kinetic-energy missile, F_u, the leg dimension, b, of the equivalent impacting area is as follows.

$$V_u = F_u \Rightarrow \phi V_c = F_u \Rightarrow \phi 4\sqrt{f_c'}\, b_o d = F_u \Rightarrow \phi 4\sqrt{f_c'}(4b + 50.5)d \Rightarrow b = 11.41 \text{ inch}$$

and

$$V_c = \left(2 + \frac{4}{\beta_c}\right)\sqrt{f_c'}(b_o d) = 4\sqrt{f_c'}(b_o d)$$ ------- Concrete punching shear strength capacity [5, Eq. 11-36]

β_c	= 2/1 = 2	Ratio of long side to short side
d	= 25.25 inch	Concrete thickness
f_c'	= 3,800 psi	Concrete strength, 300°F
b_o	= (2b+d) + 2(b+d/2) = 4b + 50.5	Perimeter of punching shear area at approximately d/2 from the missile contact area
ϕ	= 0.85	Strength reduction factor [5]
F_u	= LF × F = 508.8 kip	Force of high kinetic energy missile with load factor [19]
F	= 0.625(v)(W_m) = 462.5 kip	Force of high-energy missile [19]
v	= 185 ft/sec	Velocity of the missile
W_m	= 4,000 lb	Weight of high-energy missile
LF	= 1.1	10% load factor

Therefore, the concrete shell alone has sufficient capacity to resist the high-energy missile impact force.

3.7.3.3 Flood

This section will verify the stability of the concrete cask against overturning during a design basis flood accident, and ensure that the design is adequate to withstand stresses induced by the flood.

Overturning of the concrete cask due to the drag force of the flood water flow is resisted by the weight of the loaded cask. Assuming a full submersion and steady-state flow conditions, the drag force (F_D) on the concrete cask is calculated using classical fluid mechanics for turbulent flow conditions. The resultant drag force acts horizontally through the CG of the cask. The effective weight of the concrete cask acts vertically downward through the CG. The tendency of the concrete cask to overturn is determined by comparing the moment of the drag force about a point on the bottom edge of the concrete cask to the moment of effective concrete cask weight about the same point.

The effective weight of the fully submerged concrete cask is the actual weight minus the buoyancy force due to the displaced water. The bounding condition for buoyancy occurs for the concrete cask configuration with the greatest volume to weight ratio. Thus, for conservatism, the concrete cask is assumed to be empty.

The capacity of the concrete cask to react to the stresses induced by the flood water flow drag forces is evaluated using the methodology described in ACI 349-85 [5]. For conservatism, only the concrete shell is considered.

Assuming a hollow cylinder, the volume of the concrete cask (V_{cc}) is as follows.

$$V_{cc} = \frac{\pi}{4}\left(D_o^2 - D_i^2\right)h = \frac{\pi}{4}\left(136.0^2 - 79.48^2\right)225.27 = 2{,}154{,}777 \text{ inch}^3$$

where:

D_o = 136.0 inches ---------------------------- Concrete cask outer diameter
D_i = 79.48 inches ---------------------------- Concrete cask inner diameter
h = 225.27 inches --------------------------- Concrete cask height

The buoyancy force (F_b) is equal to the weight of water (62.4 lb/ft^3) displaced by the fully submerged concrete cask.

$$F_b = \frac{V_{cc}}{12^3} W_{h20} = \frac{2{,}154{,}777}{12^3} 62.4 \quad 77{,}800 \text{ lb}$$

Assuming complete submersion and steady-state flow for a rigid cylinder, the drag force (F_{D15}) of the water on the concrete cask is as follows.

$$F_{D15} \quad = \quad C_D \rho V^2 \left(\frac{A}{2}\right) = 0.7 \times 1.94 \times 15.0^2 \left(\frac{212.7}{2}\right) \quad 32{,}500 \text{ lb} \qquad [20]$$

where:

C_D = 0.7 -- Drag coefficient [20]
= 1.94 slugs/ft^3 ---------------------------- Density of water
V = 15 ft/sec ---------------------------------- Flow velocity
A = $H \times D_o$ = 30,637 inch^2 = 212.7 ft^2 ---- Projected area
H = 225.27 inches ----------------------------- Concrete cask height
D_o = 136.0 inches ------------------------------ Concrete cask outer diameter

The force (F_D) required to overturn the concrete cask is determined by summing the moments of the drag force and the submerged concrete cask about a point on the bottom of the concrete cask. Assuming an empty concrete cask, the minimum required overturning force is as follows.

$$F_D = \frac{(W_{CC} - F_b)r_{ro}}{h/2} = \frac{(200{,}000 - 77{,}800)58.915}{225.27/2} = 63{,}918 \text{ lb}$$

where:

W_{cc} = 200,000 lb---------------------------- Conservatively defined minimum empty concrete cask weight
r_{ro} = 58.915 inches------------------------ Concrete cask rotation radius
h = 225.27 inches------------------------ Concrete cask height

The water velocity (V) required to overturn the concrete cask is as follows.

$$V = \sqrt{\frac{2F_D}{C_D \rho A}} = \sqrt{\frac{2 \times 63{,}918}{0.7 \times 1.94 \times 212.7}} = 21.0 \text{ ft/sec}$$

Therefore, the factor of safety (FS) is as follows.

$$FS = \frac{21.0}{15.0} = 1.4$$

The stresses in the concrete due to the drag force (F_D) are conservatively calculated by considering the concrete cask to be fixed based on the governing dimension of CC5 configuration.

$\sigma_{v\ outer}$ = M / S_{outer} = 17.7 psi (tension or compression)

$\sigma_{v\ inner}$ = M / S_{inner} = 11.1 psi (tension or compression)

where:

D_o = 136.0 inches

D_i = 85.5 inches
h = 225.9 inchs
A = $\pi (D_o^2 - D_i^2) / 4 = 8{,}785$ inch^2
I = $\pi (D_o^4 - D_i^4) / 64 = 14.17 \times 10^6$ inch^4
S_{outer} = $2I/D_o = 208{,}382$ inch^3
S_{inner} = $2I/(D_i) = 331{,}462$ inch^3
w = $F_{D15}/h = 144.3$ lb/inch
M = $w (h)^2 / 2 = 3.66 \times 10^6$ inch-lb

3.7.3.4 Earthquake

The maximum horizontal acceleration at the surface of the concrete storage pad due to an earthquake is evaluated. Per 10 CFR 72.102 [1], the required minimum earthquake ground acceleration is 0.25g. This evaluation will show that MAGNASTOR is stable during a 0.37g earthquake horizontal acceleration (including a 1.1 factor of safety). The vertical acceleration is defined as two-thirds of the horizontal acceleration in accordance with ASCE 4-86 [21].

This calculation determines the effects of ground accelerations (components a_x, a_y and a_z) on the concrete cask for tip-over. The peak ground acceleration is associated with a safe shutdown earthquake. For this evaluation, the maximum overturning moment is compared to the restoring moment required to keep the concrete cask in a stable upright position (i.e., a concrete cask will not tip over due to the earthquake). The maximum ground accelerations and overturning/ restoring forces and moment are calculated for both empty and fully loaded concrete cask configurations.

In the event of earthquake, there exists a base shear force or overturning force due to the horizontal ground acceleration, and a restoring force due to the net force of vertical ground acceleration and gravity. This ground motion tends to rotate the concrete cask about its bottom corner at the point of rotation (at the chamfer). The horizontal moment arm is from the center of gravity (CG) toward the outer radius of the concrete cask. The vertical moment arm is from the CG to the bottom of the concrete cask. If the overturning moment is greater than the restoring moment, the concrete cask may tip over. Using the geometry of the concrete cask design, the maximum horizontal and vertical ground accelerations that the concrete cask can safely withstand without becoming unstable are identified.

The two orthogonal horizontal acceleration components (a_x and a_z) are combined for maximum horizontal acceleration magnitude. The result is applied simultaneously with the vertical component to statically evaluate the overturning force and moment. Upward ground acceleration reduces the vertical force that restores the cask to its undisturbed vertical position. Based upon the requirements presented in NUREG-0800 [16], the static analysis method is considered

applicable if the natural frequency of the structure is greater than 33 cps. The natural frequency of the MAGNASTOR concrete cask is 138 Hz for CC1 and CC2, which bounds the natural frequency of CC4, and 127 Hz for CC3. During the design basis earthquake event, a factor of safety of 1.1 against tip-over of the concrete cask must be maintained.

Tip-Over Evaluation

To maintain the concrete cask in equilibrium, the restoring moment, M_R, must be greater than, or equal to, the overturning moment, M_o. The combination of horizontal and vertical acceleration components is based on the 100-40-40 approach of ASCE 4-86 [21], which considers that when the maximum response from one component occurs, the responses from the other two components are 40% of the maximum. The vertical component of acceleration can be obtained by scaling the corresponding ordinates of the horizontal components by two-thirds. The vertical component is conservatively considered to be the same as the horizontal component.

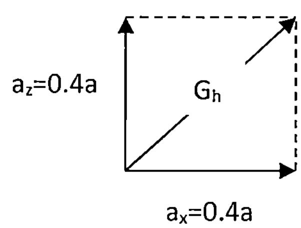
Let:

$a_x = a_z = a$ ------------------------------------ Horizontal acceleration components
$a_y = a$ ------------------------------------ Vertical acceleration component
G_h ------------------------------------ Vector sum of two horizontal acceleration components
G_v ------------------------------------ Vertical acceleration component

Two cases are analyzed:

Case 1) The vertical acceleration, a_y, is at its peak:

($a_y = 1.0a$, $a_x = 0.4a$, and $a_z = 0.4a$)

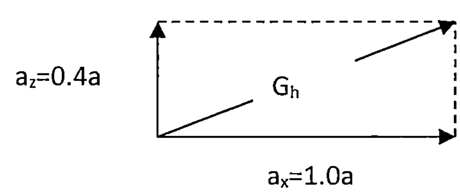


$$G_h = \sqrt{a_x^2 + a_z^2} = \sqrt{(0.4a)^2 + (0.4a)^2} = 0.566a$$

$$G_v = 1.0a_y = 1.0a$$

Case 2) One horizontal acceleration, a_x, is at its peak:

($a_y = 0.4 \times a$, $a_x = a$, and $a_z = 0.4a$)



$$G_h = \sqrt{a_x^2 + a_z^2} = \sqrt{(1.0a)^2 + (0.4a)^2} = 1.077a$$

$$G_v = 0.4a_y = 0.4a$$

For the cask to resist overturning, the restoring moment (M_R) about the point of rotation must be greater than the overturning moment (M_o).

$$M_R \geq M_O, \text{ or } F_r b \geq F_o d \Rightarrow (W\times 1 - W\times Gv) \times b \geq (W \times Gh) \times d$$

d -- Vertical distance measured from the base of the concrete cask to the center of gravity

b -- Horizontal distance measured from the point of rotation to the C.G.

W -- Weight of the concrete cask

F_o -- Overturning force

F_r -- Restoring force

Substituting for G_y and G_x gives:

Case 1

$$(1-a)\frac{b}{d} \geq 0.566a$$

$$a \leq \frac{b/d}{0.566 + b/d}$$

Case 2

$$(1-0.4a)\frac{b}{d} \geq 1.077a$$

$$a \leq \frac{b/d}{1.077 + 0.4\, b/d}$$

Empty concrete cask:

Case 1

$$a \leq \frac{58.92/114}{0.566 + 58.9/114} = 0.477$$

Case 2

$$a \leq \frac{58.92/114}{1.077 + 0.4(58.9/114)} = 0.403$$

where:

b = 58.92 inch
d = 114 inch

Loaded concrete cask:

Case 1

$$a \leq \frac{58.7/113}{0.566 + 58.7/113} = 0.479$$

Case 2

$$a \leq \frac{58.7/113}{1.077 + 0.4(58.7/113)} = 0.404$$

where:

d = 113 inch
b = 58.92 – x = 58.92 – 0.221 = 58.7 inches

$$e = \frac{73.44 - 72.0}{2} = 0.72 \text{ inch} \text{---------------} \text{TSC CG shift}$$

$$x = \frac{W_{can} e}{W_{CC}} = \frac{105{,}500 \times 0.72}{324{,}500} = 0.221 \text{ inch- Loaded concrete cask CG shift}$$

The minimum acceleration is 0.403g. A factor of safety of 1.1 is required for an earthquake evaluation; therefore, the maximum allowable horizontal acceleration (a_{max}) at the top of the concrete pad that will preclude a cask tip-over is as follows.

$$a_{max} = \frac{0.403}{1.1} = 0.37g$$

Concrete Cask Stress

To demonstrate the ability of the concrete cask to withstand earthquake loading conditions, the fully loaded cask is conservatively evaluated for seismic loads of 0.5g in the horizontal and 0.5g in the vertical direction. These accelerations reflect a more rigorous seismic loading and, therefore, bound the design basis earthquake. No credit is taken for the concrete cask steel liner. The highest concrete compressive stresses due to the design basis seismic load are shown to occur in the CC3 concrete cask. Although CC3 is the shortest concrete cask, it is the heaviest configuration and its concrete shell has a larger inside diameter than the other concrete cask configurations and, thus, the lowest section modulus.

The maximum compressive stresses at the concrete shell outer and inner surfaces (based on the governing CC5 configuration) are conservatively calculated by considering the cask as a cantilever beam with its bottom end fixed. The maximum compressive stresses are as follows.

$$v_{outer} = \frac{M}{S_{outer}} + \frac{(1 + a_y) W_{CC}}{A} = 150 \text{ psi}$$

$$v_{inner} = \frac{M}{S_{inner}} + \frac{(1 + a_y) W_{CC}}{A} = 116 \text{ psi}$$

where

a_x = 0.50g -------------------------------------- Horizontal direction
a_y = 0.50g -------------------------------------- Vertical direction
W_{cc} = 340,000 lb -------------------------------- Bounding weight of concrete cask
D_o = 136.0 inches
D_i = 85.5 inches
$A = \pi (D_o^2 - D_i^2) / 4 = 8{,}785 \text{ inch}^2$
$I = \pi (D_o^4 - D_i^4) / 64 = 14.17 \times 10^6 \text{ inch}^4$

S_{outer} = $2I/D_o = 208{,}382$ inch^3
S_{inner} = $2I/(D_i) = 331{,}462$ inch^3
w = $(a_x \times W_{cc}) / 225.9 = 752.55$ lb-inch
M = $(w \times 225.9^2)/2 = 1.92 \times 10^7$ lb-inch

3.7.3.5 Concrete Cask Combined Stresses

The load combinations described in Table 2.3-1 are used to evaluate the concrete cask for accident events of storage. The bounding stresses for all storage cask configurations are summarized in Table 3.7.3-1 and Table 3.7.3-2 for the loading combination Nos. 4, 5, 7, and 8. Loading combination No. 6 corresponds to drop accidents, 24-inch end drop and tip-over, which are evaluated in Section 3.7.3.6 and Section 3.7.3.7, respectively.

As shown in Table 3.7.3-1, the maximum concrete compressive stress is 1,806 psi; therefore, the minimum compressive factor of safety (FS) for accident events is as follows.

$$FS = \frac{S_{con}}{S_c} = \frac{2{,}660}{1{,}806} = 1.47$$

where:

$S_{con} = \phi F_c = 0.7 \times 3{,}800 = 2{,}660$ psi--------------- Concrete compressive allowable

From Section 3.7.3.1, the maximum tensile stress in the concrete due to the accident thermal load is 0.138 ksi. The factor of safety (FS) for concrete tensile stress is as follows.

$$FS = \frac{S_{tc}}{S_t} = \frac{0.213}{0.138} = 1.54$$

where:

$S_{tc} = 0.08 \times S_{con} = 0.08 \times 2660 = 213$ psi or 0.213 ksi.................. Concrete ultimate strength

From Section 3.7.3.1, the maximum rebar tensile stress (S_{rb}) due to accident thermal load is 22.7 ksi. The factor of safety (FS) for the rebar tensile stress is as follows.

$$FS = \frac{S_{rebar}}{S_{rb}} = \frac{54.0}{22.7} = 2.38$$

where:

$S_{rebar} = \phi F_r = 0.9 \times 60.0 = 54.0$ ksi------------------ Rebar stress allowable

Figure 3.7.3-4 Acceleration Time History of Oversized Pad

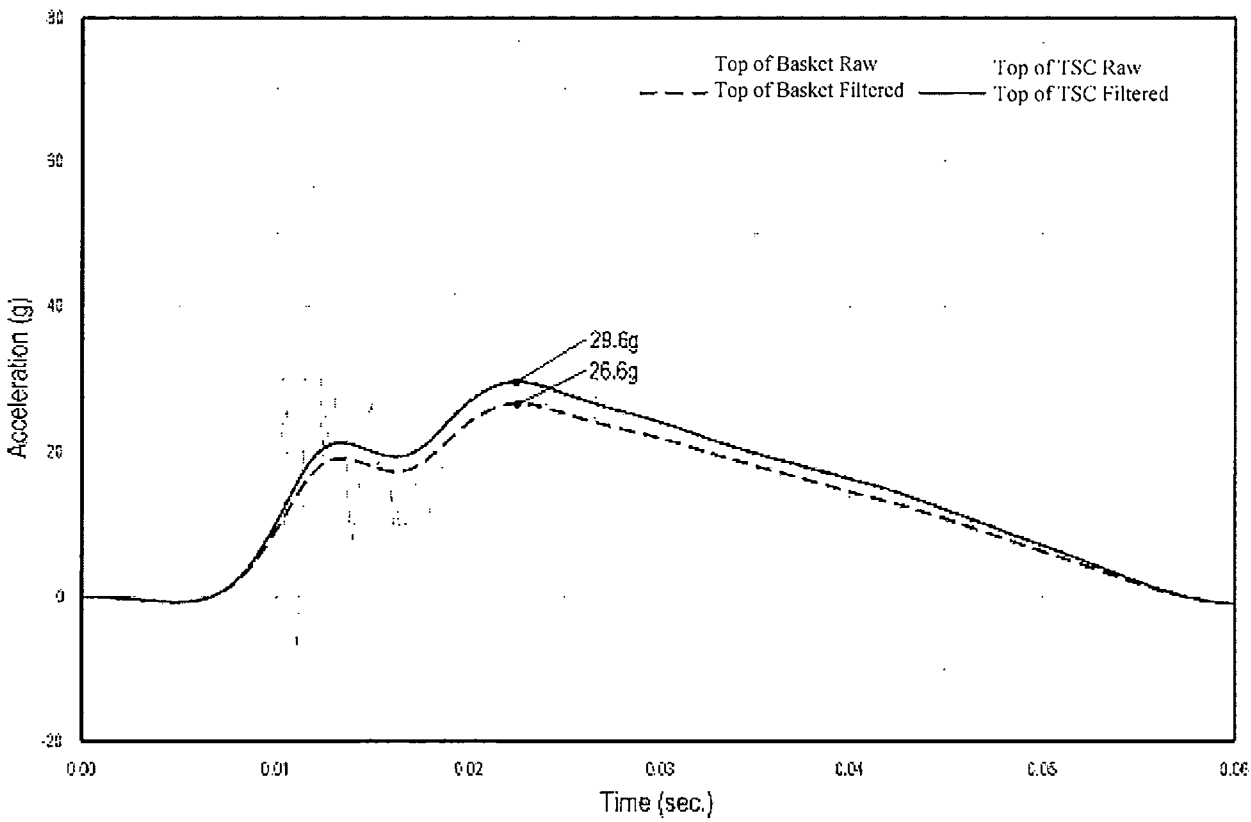


Table 3.7.3-1 Concrete Cask Vertical Stress Summary – Inner Surface, psi

Condition	Dead	Live	Wind	Thermal	Seismic	Flood	Tornado	Total
4	-28	-29	0	-1626	0	0	0	-1683
5	-28	-29	0	-1633	-116	0	0	-1806
7	-28	-29	0	-1633	0	-11	0	-1701
8	-28	-29	0	-1633	0	0	-12	-1702

Table 3.7.3-2 Concrete Cask Circumferential Stress Summary – Inner Surface, psi

Condition	Dead	Live	Wind	Thermal	Seismic	Flood	Tornado	Total
4	0	0	0	-1626	0	0	0	-1626
5	0	0	0	-1633	0	0	0	-1633
7	0	0	0	-1633	0	0	0	-1633
8	0	0	0	-1633	0	0	0	-1633

3.10.3 TSC Finite Element Models

This section presents details on the TSC finite element models used in the structural evaluation of the different TSC configurations for lift, normal conditions and off-normal or accident events of storage. The finite element model used for the structural evaluation of the TSC configurations with the single-piece closure lid assembly design (i.e., TSC1 and TSC2) is described in Section 3.10.3.1. The finite element models used for the structural evaluation of the TSC configurations with the composite closure lid assembly design (i.e., TSC3 and TSC4) are described in Section 3.10.3.2.

3.10.3.1 TSC1/TSC2 Finite Element Model Description

The three-dimensional finite element model of the TSC configuration with the single-piece closure lid assembly (i.e., TSC1 and TSC2) is constructed using ANSYS SOLID45 elements. By taking advantage of the symmetry of the TSC, the model represents one-half (180° section) of the TSC, including the TSC shell, bottom plate, and closure lid. The finite element model of the TSC is shown in Figure 3.10.3-1. ANSYS CONTAC52 elements are used to model the interaction between the closure lid and the TSC shell. Gap elements are also used to simulate the interaction with the concrete cask inner liner standoffs or transfer cask inner shell during a side impact and pedestal during an end impact. The size of the CONTAC52 gaps is determined from nominal dimensions of contacting components. Due to the relatively large gaps resulting from the nominal geometry, these gaps remain open during all loadings considered. All gap elements are assigned a stiffness of 1×10^8 lb/in.

This model represents a "bounding" combination of geometry and loading that envelops all MAGNASTOR PWR and BWR TSC configurations with single-piece lids (i.e., TSC1 and TSC2 configurations). Specifically, the longest TSC is modeled in conjunction with a conservative fuel and basket combination. By using the longest TSC with the conservative content weight, bending stresses are maximized at the junction of the shell and lid. Thus, the analysis yields conservative results relative to the expected performance of the actual TSC configurations. Note that a review of the finite element analysis results for the TSC3/TSC4 with ¾-inch and 1½-in wide closure rings (See Section 3.10.3.2 for model description) indicated that the difference in the analysis results is insignificant for all normal, off-normal and accident conditions of storage. Accordingly, the TSC model results for the single-piece closure lid assembly (i.e., TSC1 and TSC2) are applicable to TSCs with closure rings approximately ¾-inch and 1½-in wide.

Boundary Conditions for TSC Lift

The lifting configuration for the TSC consists of six hoist rings bolted to the closure lid at equally spaced angular intervals. To simulate the lifting of the TSC, nodes representing the hoist rings on the closure lid are constrained in the Y-direction. For heavy lift evaluation, only three of the hoist rings are considered. Due to the symmetry of the model, only the nodes at 60° and 180°

are constrained. Symmetry boundary conditions are applied at the plane of symmetry of the model. Pressure representing the weight of the fuel and basket is applied to the TSC bottom. A 1.1g inertia load is applied in the axial direction.

Boundary Conditions for Normal Conditions and Off-normal or Accident Events

Model Constraints

The model is constrained in the global Z-direction for all nodes in the plane of symmetry. Other constraints for different loading conditions are summarized below. The directions of the coordinate system are shown in Figure 3.10.3-1.

Model Constraint Summary

Condition	Constraint
Dead Weight	Y-direction at TSC bottom
Normal Handling	Y-direction – lift points in TSC lid
Off-normal Handling - axial	Y-direction – lift points in TSC lid
Off-normal Handling – lateral	Gap elements at TSC shell in radial direction
24-inch drop	Y-direction at TSC bottom
Tip-over	Gap elements at TSC shell in radial direction

Inertial Load

Inertial loads resulting from the weight of the TSC and contents are considered by applying an appropriate deceleration factor (g-load). Inertial loads are summarized below.

Inertial Load Summary

Condition	Inertial Load
Dead Weight	1g – axial
Normal Handling	1.1g – axial
Off-normal Handling	1.5g – axial, 0.707g – lateral
24-inch drop	60g – axial
Tip-over	Tapered 40g – lateral (40g at top of TSC closure lid, 1g at base of concrete cask)

Pressure Load – Internal Pressure

A uniform pressure is applied to all internal surfaces of the TSC shell, bottom plate and closure lid. The TSC pressures used for the normal condition (110 psig), off-normal (130 psig) and accident events (250 psig) bound all pressure conditions.

Pressure Load – Dead Load, Handling, and 24-inch Drop

For the dead load, handling, and 24-inch drop analyses, the inertial load produced by the contents weight is considered to be uniformly distributed on the inner surface of TSC bottom plate. Based on the contents weight of 90,000 lb and the TSC inside radius of 35.5 inches, the pressure corresponding to the contents weight is as follows.

Table 3.10.3-17 TSC1/TSC2 Tip-Over plus Normal Pressure, P_m+P_b, ksi

Section[a]	Angle	Component Stresses						S_{int}	S_{allow}	FS
		S_x	S_y	S_z	S_{xy}	S_{yz}	S_{xz}			
1	69	-0.54	-5.28	10.47	0.15	0.51	-0.44	15.81	69.80	4.41
2	66	2.77	-13.66	-2.50[b]	0.07	0.78	-1.17	16.74	69.80	4.17
3	66	-0.17	-4.90	16.94	-0.06	1.33	1.18	22.09	68.60	3.11
4	27	-0.07	19.54	3.84	0.01	4.15	0.01	20.64	64.00	3.10
5	60	0.68	59.72	41.78	0.02	0.81	0.28	59.06	63.75	1.08
6	60	-0.08	20.79	11.91	-0.01	-0.75	-0.02	20.94	63.30	3.02
7	0	-0.55	18.40	0.89	-0.23	-0.11	0.00	18.96	63.00	3.32
8	0	-0.87	18.35	4.84	0.01	-0.02	0.00	19.22	63.00	3.28
9	30	5.14	55.19	39.08	0.00	-1.26	-1.52	50.22	63.50	1.26
10[c]	6	-13.17	17.49	7.56	-2.41	2.07	-2.76	31.85	63.50	1.99
11[d]	0 - 6	-23.93	-16.43	-16.49	11.98	1.54	-13.41	36.44	50.80[d]	1.39
12	0	18.01	16.62	1.95	0.55	0.71	-1.04	16.40	68.60	4.18
13	0	-4.19	-2.86	-1.41	0.12	0.55	-3.61	7.82	63.50	8.12
14[c]	6	2.57	-10.04	0.16	5.22	5.18	-2.61	18.87	63.50	3.36
15[c]	6	8.66	-1.44	0.34	-1.10	0.55	-1.76	10.79	63.50	5.88

[a] See Figure 3.10.3-2 for section locations.
[b] Localized bending stresses are secondary and are excluded from evaluation.
[c] Bearing stress evaluation is not required for accident conditions.
[d] Stresses are determined by averaging the stresses over the impact region. Allowable stress includes a reduction factor of 0.8 for the closure lid weld.

3.10.3.2 TSC3/TSC4 Finite Element Model Description

The stresses in the TSC3 and TSC4 configurations (i.e., TSCs with composite closure lid assembly designs) resulting from the design basis normal, off-normal, and accident loads for storage conditions are determined using the three-dimensional ½-symmetry finite element models shown in Figure 3.10.3-3 and Figure 3.10.3-4. These finite element models are similar to the finite element model used for the evaluation of the TSC1/TSC2 configuration (i.e., single-piece closure lid assembly design) that is described in Section 3.10.3.1, differing only in the geometry of the TSC closure lid assembly and closure ring. The finite element model shown in Figure 3.10.3-3 represents the TSC3 with the ¾-inch wide closure ring, whereas, the finite element model shown in Figure 3.10.3-4 represents the TSC3 with the 1½-inch wide closure ring. A review of the finite element analysis results for the TSC3/TSC4 with ¾-inch and 1½-in wide closure rings indicates that the difference in the analysis results is insignificant for all normal, off-normal and accident conditions of storage. Accordingly, the model results are applicable to TSCs with closure rings approximately ¾-inch and 1½-in wide.

The 4-inch thick closure lid and a 5-inch thick shield plate are both modeled using 3-D structural solid elements (SOLID45). The shield plate and closure lid are modeled using the temperature-dependent material properties of SA-36 carbon steel and Type 304 stainless steel, respectively. The nonlinear interaction between the shield plate and closure lid is modeled using 3-D point-to-point contact elements (CONTAC52). The gap elements are modeled initially closed with a contact stiffness of 1×10^8 lb/inch. The ten 1 ½-6 UNC-2A bolts (five bolts for ½-symmetry model) that connect the shield plate to the closure lid are modeled using 3-D spar elements (LINK10) that transfer only tensile loads. The bolt element tensile area (A_t) and an initial strain (ε_o) are defined by real constants. The initial strain corresponding to a maximum bolt torque is:

$$\varepsilon_o = \sigma_o/E_b = 0.000303 \text{ in/in}$$

where:

σ_o = 8,098 psi, Bolt tensile stress due to preload

= F_B/A_t

E_b = $26.7\text{x}10^6$ psi, Elastic modulus of SA-193, Grade B6 material at 500°F.

F_B = $Q/(KD_b)$, Bolt tensile force due to torque [30].

= 11,200 lbs.

Q = 1,680 in-lbs., Maximum bolt torque

K = 0.1, Lower-bound nut factor for a lubricated bolt [30]

D_b = 1.5 in., Nominal bolt diameter

A_t = 1.383 in^2, Tensile area of 1 ½-6 UNC-2A bolt

Chapter 4
Thermal Evaluation

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The flow of helium in the fuel region is affected by the wetted perimeter associated with the fuel pins. To represent the flow of helium in the fuel region, which is represented as a homogenized entity, porous media is used in the modeling. The porous media model allows the effect of the reduced flow area of the fuel rods and the fuel assembly grids to be considered in representing the momentum of the helium flow by including a pressure drop based on the geometry of the fuel assembly, i.e., the pitch of the fuel rods, the fuel rod diameter, and the fuel assembly grid geometry. Additional fluid flow analyses are required to determine the constants inherit in the porous media use for flow between cylindrical-shaped fuel rods and for fuel assembly grids. The determination of porous media constants is presented in Section 4.8.2. The flow of helium in the downcomer regions in the TSC does not require special consideration of effective flow conditions. To confirm that the use of a two-dimensional model for the TSC is an acceptable and conservative methodology, a benchmark is provided in Section 4.8.1.

Additional analysis results have demonstrated that a TSC that is less than fully loaded, i.e., with empty fuel storage locations in its center region, is bounded by the results of a fully loaded TSC. Therefore, empty fuel storage locations shall begin at the center of the basket and continue outward, as required, in an approximately symmetric pattern.

The thermal evaluation for the transfer conditions is performed using the two-dimensional axisymmetric models of the transfer cask and TSC, as presented in Section 4.4.1.5. Similar to the model of the concrete cask and TSC, the fuel basket and fuel assemblies inside the TSC in the transfer cask are modeled as homogeneous regions using effective thermal properties.

4.4.1.1 Two-Dimensional Axisymmetric Concrete Cask and TSC Models

This section describes the finite volume models used to evaluate the thermal performance of the concrete cask and TSC for the PWR and BWR fuel configurations. As shown in Figure 4.4-1, the two-dimensional axisymmetric concrete cask and TSC model includes the following:

- Concrete cask, including lid, liner, pedestal and stand
- Air in the air inlets, the annulus and the air outlet
- TSC shell, lid and bottom plate
- Basket with fuel (including damaged fuel cans, as applicable) and neutron absorber
- Helium internal to the TSC

The fuel basket, fuel and neutron absorber are modeled as homogeneous regions with effective properties. The effective thermal conductivities for the TSC internals in the radial and axial directions are determined using the two-dimensional models as detailed in Section 4.4.1.2.

The two-dimensional axisymmetric concrete cask and TSC model is used to perform computational fluid dynamics analyses to determine the component temperature, the mass flow

rate, velocity and temperature of the airflow in the annulus region, as well as for the helium flow internal to the TSC. Since the concrete cask and its components are contained in the model, the temperature distributions in the concrete and the concrete cask steel liner are also determined. Three separate models are generated for the evaluations of the following configurations:

1. CC1/CC2 concrete cask with a PWR TSC.
2. CC1/CC2 concrete cask with a BWR TSC.
3. CC3 concrete cask with a PWR TSC.

The first two models are identical, except for differences in dimensions of the downcomer regions and the effective properties of the TSC internals. Note that these two models are applicable to both the CC1 and CC2 cask configurations since CC2 is a segmented version of CC1. Figure 4.4-2 shows an overall view of the cells employed in the model representing both the concrete cask and the TSC containing a design basis fuel heat load. The third model is identical to the first model, with the following differences:

1. The overall height of the concrete cask is reduced to 218.3 inches (CC3).
2. The concrete cask liner thickness is increased from 1.75 inches to 3 inches (CC3).
3. The concrete thickness of the center of the concrete cask lid is increased by 6 inches (CC3).
4. Shield bars are modeled in the concrete cask air inlets (CC3).
5. TSC with composite closure lid assembly (4-inch stainless steel closure lid with a 5-inch thick carbon steel shield plate) is modeled.

The CC4 configuration is similar to the CC1/CC2 and CC3 configurations, with the same lid and steel liner thickness as CC1/CC2 and the same height and additional shielding at the air inlets as CC3. A sensitivity study was performed using the governing CC3 model with a steel liner thickness corresponding to the CC4 configuration. The analysis results showed that maximum fuel/basket temperature for CC4 is approximately 1°F less than that for the CC3 configuration, indicating that the differences between CC4 and other cask configurations do not have a significant effect on the thermal performance of the casks. Therefore, no additional thermal model is needed for the CC4 configuration. The bounding component temperatures from the thermal analysis results using the models for CC1/CC2 and CC3 are applicable to the CC4 configuration.

The CC5 configuration is also similar to the CC1/CC2 and CC3 configurations, with a similar height as CC1/CC2 and the same lid, steel liner thickness and additional shielding at the air inlets as CC3. Based on similarity of these configurations and the sensitivity analysis results for CC4 as discussed above, the bounding component temperatures from the thermal analysis results

using the models for CC1/CC2 and CC3 are applicable to the CC5 configuration. No additional thermal model is needed for the CC5 configuration.

The models used for the thermal evaluation are explained in greater detail as follows:

Modeling of the Concrete Cask

The concrete cask body has four air inlets at the bottom and four air outlets at the top. Since the configuration is symmetrical, it can be simplified into a two-dimensional axisymmetric model by using equivalent dimensions for the air inlets and outlets, which are assumed to extend around the concrete cask periphery. In the model for the CC3 concrete cask, additional shielding in the inlet vent is considered by a lumped porous zone that is represented by viscous and inertial flow resistance coefficients. The flow resistances are determined using a geometrically correct three-dimensional computational fluid dynamics (CFD) model of the air inlet that includes shield bars. The vertical air gap is an annulus, with a radial width of 3.5 inches. This radial dimension of the air annulus between the TSC shell and the concrete cask liner is modified to a smaller effective value to account for the reduction of the airflow cross-sectional area due to the standoffs welded to the liner. The bottom ends of the standoffs are more than 63 inches from the bottom of the TSC, which means that for over 30% of the length of the annulus, the standoffs do not exist. The model conservatively represents them as being the full length of the TSC. The additional axial conductance from the standoffs is conservatively neglected. Thermal radiation across the annulus gap is considered in the model, and the emissivities of the TSC surface and the concrete cask liner are reported in Chapter 8. Heat being radiated to the concrete cask liner is transferred into the annulus by convection, as well as being conducted through the concrete cask wall.

The most significant mechanism for rejecting heat into the environment is through the movement of air up through the annulus. The airflow in the vertical annulus is modeled as transitional turbulent flow using the k- turbulence model in FLUENT [12]. This determination was made through the use of a thermal test of PWR canistered fuel contained in a vertical concrete cask, which is described in EPRI Report TR-100305 [21] and provides a description of the test canister, the concrete cask, the fuel assemblies, and the boundary conditions employed in a series of tests. The total heat load of the fuel used in the tests was 14.9 kW. Extensive temperature measurements were made for the basket, fuel, canister and concrete cask for each test conducted. The thermal test of interest employed the vacuum condition for the canister. This test was selected since it removed the influence of convection inside the canister and simplified the thermal model inside the canister. FLUENT was used to perform a two-dimensional steady-state axisymmetric analysis of the system described in [21] using two turbulent flow models: a low Reynold's number turbulence model (low Re k-) and a transitional turbulence model (k-). Technical details for these turbulence models are contained in the documentation for FLUENT.

The thermal models and boundary conditions used in the analyses are detailed in Section 4.8.3. Results for the temperature profiles for the canister surface and the concrete liner surfaces for both turbulence models are shown in Figure 4.8-12 and Figure 4.8-13. The results indicate that both turbulence models yield conservative predictions for the temperature profiles and that both the low Reynold's number k- and the k- models are appropriate for use in the analysis of air flow up through the annulus between the canister and the concrete cask. Since the use of the k- model provides conservative results for the canister shell and concrete cask for a test corresponding to 14.9 kW, the use of the k- model is also considered to be appropriate for analyses having larger heat loads. As the heat load is increased, the turbulence in the annulus air flow is also expected to increase. The results of the analysis for the thermal tests are considered as validation for the use of the k- turbulence model for the annulus region of MAGNASTOR.

The mesh for the annulus region of the CC3 model is similar to the mesh for the annulus region of the CC1/CC2 model that is shown in Figure 4.4-2. Increased cell density is used in the annulus region adjacent to the wall to allow the y+ at the wall to be on the order of unity, ensuring proper turbulence modeling.

The TSC model is included with the concrete cask model as shown in Figure 4.4-1. Boundary conditions at the edges of the model to the ambient are applied to the concrete cask surfaces. The heat flux being transferred from the helium internal to the TSC through the TSC shell and into the air annulus region is not considered to be a boundary condition for the concrete cask since all of these components are included in the same model. The boundary conditions applied to the outer surface of the concrete cask include the following.

- Solar insolation to the outer surfaces of the concrete cask.
- Natural convection heat transfer at the outer surfaces of the concrete cask.
- Radiation heat transfer at the concrete cask outer surfaces.

Solar Insolation

The solar insolation on the concrete cask outer surfaces is considered in the model. The incident solar energy is applied based on 24-hour averages as shown:

Side surface: $$\frac{1475\text{Btu/ft}^2}{24\text{hrs}} = 61.46\text{Btu/hr}\cdot\text{ft}^2$$

Top surface: $$\frac{2950\text{Btu/ft}^2}{24\text{hrs}} = 122.92\text{Btu/hr}\cdot\text{ft}^2$$

Natural Convection

Natural convection heat transfer at the outer surfaces of the concrete cask is evaluated by using the heat transfer correlation for vertical and horizontal plates. This method assumes a surface

temperature and then estimates Grashof (Gr) or Rayleigh (Ra) numbers to determine whether a heat transfer correlation for a laminar flow model or for a turbulent flow model should be used. Since Grashof or Rayleigh numbers are much higher than the values defining the transition from laminar to turbulent flow, correlation for the turbulent flow model is used as shown in the following.

Side surface (Kreith) [13]:

$$Nu = 0.13(Gr \cdot Pr)^{1/3} \qquad \text{for } Gr > 10^9$$
$$h_c = Nu \cdot k_f / H_{VCC}$$

Top surface (Incropera) [14]:

$$Nu = 0.15 Ra^{1/3} \qquad \text{for } Ra > 10^7$$
$$h_c = Nu \cdot k_f / L$$

where:

Gr	--	Grashof number
h_c	--	Average natural convection heat transfer coefficient
H_{vcc}	--	Height of the concrete cask
k_f	--	Conductivity
L	--	surface characteristic length, L = area / perimeter
Nu	--	Average Nusselt number
Pr	--	Prandtl number
Ra	--	Rayleigh number

All material properties required in these equations are evaluated based on the film temperature defined as the average value of the surface temperature and the ambient temperature.

Radiation Heat Transfer

The radiation heat transfer between the outer surfaces of the concrete cask and the ambient environment is evaluated in the model by calculating an equivalent radiation heat transfer coefficient.

$$h_{rad} = \frac{\sigma(T_1^2 + T_2^2)(T_1 + T_2)}{1/\varepsilon_1 + 1/\varepsilon_2 + 1/F_{12} - 2} \qquad [14]$$

where:

h_{rad}	--	Equivalent radiation heat transfer coefficient
F_{12}	--	View factor
T_1 & T_2	--	Surface (T_1) and ambient (T_2) temperatures
ε_1 & ε_2	--	Surface (ε_1) and ambient (ε_2=1) emissivities

σ --- Stefan-Boltzmann Constant

At the concrete cask side, an emissivity for a concrete surface of $\varepsilon_1 = 0.9$ is used and a calculated view factor (F_{12}) = 0.182 [14] is applied. The view factor is determined by conservatively assuming that the cask is surrounded by eight casks. At the cask top, an emissivity, ε_1, of 0.8 is conservatively used (emissivity for concrete is 0.9), and a view factor, F_{12}, of 1 is applied.

Modeling of the TSC

The TSC is a closed system designed so that pressurized helium can circulate inside the TSC and transfer heat from the fuel in the basket to the TSC shell. Circulating helium is modeled as laminar flow inside the TSC. Additionally, the basket permits heat to be conducted from the interior regions of the basket to the periphery of the basket, then radiated and convected to the TSC shell surface. The stiffeners at the periphery of the basket do provide a path of conduction to the TSC shell, even though a small gap exists between the stiffeners and the TSC shell. The heat conduction through these stiffeners is neglected in the evaluation, which is considered to be conservative. Radiation is modeled in the fuel assemblies, as well as in gaps in the basket. Heat transfer to the TSC lid and bottom plate is considered in the analysis, but it is not a major contributor to the heat-rejection process. Two separate models are generated for the CC1/CC2 concrete cask—one for the PWR fuel configuration and one for the BWR fuel configuration. The differences between the two models are in the dimensions of the basket region and the effective properties derived for each basket and fuel region. The TSC model for the CC3 concrete cask is identical to the model for the CC1 PWR configuration.

The TSC region consists of the following: the TSC shell, the TSC bottom plate, the TSC lid, the fuel basket region, and the helium-filled volume outside the fuel basket region. The fuel basket region is subdivided into three sections to reflect the location of the active fuel region with the associated heat generation and the fuel regions above and below the active fuel regions. These three separate regions are shown in Figure 4.1-1. In addition to the three sections to reflect the location of the active fuel region with the associated heat generation and the fuel regions above and below the active fuel regions, the fuel region for the DF basket assembly is modeled in two ways, which are differentiated by basket radial zones. One model considers the active fuel region as a single porous zone in the radial direction with resistance coefficients for the entire DF basket. The second model considers the active fuel region as two zones in the radial direction with two sets of flow resistances – an outer zone that models the outer 16 basket slots (which include the four damaged fuel can slots) and an inner zone that models the inner 21 basket slots. For both models, when computing the flow resistance at the basket slot for the DFC, helium flow is considered only at the gap between the DFC side plates and the basket corner support weldment. Note that the TSC lid in the model corresponds to the 9-inch thick stainless steel lid.

The FLUENT model used to analyze the cooldown transient defines the locations at which initial temperatures are required from the ANSYS results. For each node in the FLUENT model, there are eight node points in the circumferential direction in the ANSYS 45-degree symmetry model to compute the average temperature for the respective locations. The ANSYS model employs linear temperature shape functions across each element, so that interpolation between nodes and within an element provides temperatures that are consistent with the nodal temperature in the ANSYS results. The peak temperatures, which occur at the center line of the model, are transferred to the respective FLUENT node locations as initial temperatures in order to provide an upper bounding initial condition, conserving system heat provided to the FLUENT model.

The design basis heat load provides bounding temperatures and minimum times for vacuum and the longest time for helium cooling when needed. With the identification of the temperature after the backfill condition, the time in vacuum for the potential cooling cycles can be determined, since the temperature time history will follow the same time dependency as for the initial vacuum condition.

The system thermal transient history may be represented by an initial vacuum drying cycle followed by a postulated system cooling cycle of 24 hours, followed by a second system vacuum drying cycle that is followed by a second 24-hour cooling period preceding the TSC transfer to the concrete cask. It is noted that the 24-hour cooling period returns the system to a steady-state condition for the design basis heat load, providing a bounding operating cycle for all heat loads less than the design basis. Similarly, cooling the system for a period of 24 hours provides maximum TSC transfer time from the transfer cask to the concrete cask when the water is drained from the annulus cooling system. Additional analyses defining system response to these conditions are addressed in the following discussions.

Mesh Sensitivity Evaluation

The vacuum drying operation uses a three-dimensional ANSYS model to determine the thermal response of the fuel, shown in Figure 4.4-16 and Figure 4.4-18 for PWR and BWR fuel, respectively. Sensitivity of the mesh density is performed for the PWR design basis heat load of 35.5 kW. The finite element model uses an ANSYS element with a linear shape function for calculating the temperature within each element and uses a minimum of six elements in the fuel assembly cross-section plane. Temperature variation in the fuel region is expected to be parabolic since the heat generation is constant within any specified axial cross-section. Using a minimum of six elements permits development of an analytical parabolic distribution. To confirm the adequacy of the mesh density for the axial divisions, the number of elements in the basket region shown in Figure 4.4-16 was doubled, and the transient condition using design basis heat was rerun. The maximum fuel clad temperature was determined to be 1°F less than the

temperature for the solution with one-half the element density. The results from this mesh sensitivity evaluation validate that the maximum fuel temperature is relatively insensitive to mesh refinement in the fuel region.

Evaluation of the Helium Phase With Annulus Circulating Water Cooling System

Following the completion of vacuum drying and final cavity evacuation, the TSC is backfilled and pressurized with a measured mass of helium per the Technical Specifications to establish the cavity atmosphere for the normal condition of storage. The transfer cask and TSC remain in this helium phase condition until the TSC is placed into the concrete cask. During the helium phase, the transfer cask annulus cooling system will be used until the TSC preparations for transfer to the concrete cask are completed. Steady-state analyses for heat loads of 15, 20, 25, 30 and 35.5 kW for PWR fuel, and with heat loads of 15, 20, 25, 30 and 33 kW for BWR fuel, are performed using the model for the helium phase. The evaluation of this condition is performed to determine the initial condition for the operation in which the TSC is placed into the concrete cask with the transfer cask annulus cooling system drained.

[redacted]

[redacted]

Evaluation of Moving the TSC into the Concrete Cask

The transfer cask is used to load the TSC into the concrete cask. During this phase, there is no active auxiliary annulus cooling of the transfer cask, i.e. annulus cooling water system disconnected from the transfer cask, seals deflated, and annulus water drained. The transfer cask annulus is filled with ambient air, which is allowed to flow in through the reduced annulus inlet. This operation is time-limited to control the fuel cladding temperature to less than 752°F (400°C). The thermal performance of the transfer cask in this operation is evaluated for four transient conditions. Two transient conditions are for the PWR fuels with heat loads of 25 kW and 35.5kW, and two cases are for the BWR fuels with heat loads of 25 kW and 33 kW. The initial conditions for the four transient analyses are obtained from the steady-state analyses with water in the transfer cask annulus described previously in the section titled "Evaluation of the Helium Phase with Annulus Circulating Water Cooling System" for the corresponding heat load.

[redacted]

4.4.1.6 Two-Dimensional Transfer Cask and TSC Model for Operations Involving Minimum Cooling Time and a Loading Time of Eight Hours

Operational experience can lead to enhancement in the draining, vacuum drying and welding operations to minimize the need for maximum times for drying and loading operations or the potential need for cycles in the vacuum drying phase. Operational experience will reduce loading times and reduce staff radiation exposure. The following discussion presents the operational controls to be implemented.

Even with the absence of additional cycles for vacuum drying or the use of the 24-hour cool time, the TSC in the transfer cask is still subjected to four separate operational boundary conditions.

- The water phase when the lid is being welded to the TSC.
- The drying phase during which helium is present while vacuum drying to remove moisture from the TSC.
- The helium-backfilled phase is minimized to seven hours or less. It is during this time that the TSC port covers are welded and the transfer cask annulus circulating water cooling system (or equivalent) is operating, or the TSC is submerged in the spent fuel pool (with the annulus seals deflated).
- The eight hours for the operation of transferring the helium-backfilled TSC into the concrete cask with the transfer cask annulus circulating water cooling system drained.

Regardless of the time in the vacuum drying or loading operation, the response of the TSC and transfer cask in the water phase (inside the TSC) is not affected. With cooling water in the annulus, the time to remain in this condition is not altered from the system analyses or results reported in Section 4.4.1.5 for the water phase.

Without the additional cool time (of 24 hours), the initial temperatures of the TSC and fuel are significantly increased upon entering the loading phase (where the water in the annulus is drained and replaced by air). Reducing the time in the vacuum phase, as compared to the times shown in Table 4.4-9 (PWR) and Table 4.4-10 (BWR), the temperatures at the start of the condition leading to the transfer of the TSC to the concrete cask can be reduced to a level that allows eight hours for the transfer loading time.

To determine the vacuum and cool time limits, the models and their results described in Section 4.4.1.5 are used. The temperature time histories computed for the heat loads identified in Table 4.4-9 (PWR) and Table 4.4-10 (BWR) are used to identify the maximum fuel clad temperatures at the end of the reduced vacuum times for the individual heat loads. The transient analyses for the condition of the helium backfill, in conjunction with water in the annulus as described in Section 4.4.1.5, identify the temperature increase expected for the fuel clad for the range of heat loads upon backfilling the TSC with helium. Analyses in Section 4.4.1.5 identify that the maximum increase in the temperature of the fuel for the bounding PWR and BWR heat loads is 44°F and 34°F, respectively. The 44°F PWR increase and the 34°F BWR increase correspond to the design basis heat load bound the temperature for all other heat loads of the PWR or BWR fuel assemblies. The maximum temperature increase is conservatively added to the maximum fuel clad temperature occurring at the end of the reduced time in vacuum. This temperature is used to confirm that an additional eight hours for the TSC in the transfer cask with air in the annulus is equal to, or less than, the maximum fuel clad temperatures determined in Section 4.4.1.5.

4.4.2 Test Model

MAGNASTOR is conservatively designed by analysis. Therefore, no physical model is employed for thermal analysis. The benchmark provided in Section 4.8.1 provides confirmation that the analysis methodology employed for the MAGNASTOR design is conservative.

4.4.3 Maximum Temperatures for PWR and BWR Fuel Configurations

Normal Conditions of Storage

The temperature distributions and maximum component temperatures for MAGNASTOR for normal conditions of storage are provided in this section. System components of the CC1/CC2 concrete cask containing a PWR and BWR TSC and the CC3 concrete cask containing a PWR TSC are addressed separately. The temperature distributions in the CC1/CC2 concrete cask containing the BWR TSC are similar to those of the same system with the PWR TSC and are, therefore, not presented.

The temperature distribution in the CC1/CC2 concrete cask and the TSC containing the PWR design basis fuel (uniform heat load) for normal conditions of storage is shown in Figure 4.4-14. The air velocity distribution in the annulus between the TSC and the concrete cask liner for the normal conditions of storage for PWR fuel for the CC1/CC2 configuration is shown in Figure 4.4-15. The maximum component temperatures for the normal conditions of storage are summarized in Table 4.4-3. Note that the bounding temperatures from CC1/CC2 and CC3 analyses are conservatively used as the maximum component temperatures for the CC4 configuration. It is noted that these system thermal performance results are based on an average annual ambient temperature of 76°F at sea level pressure and standard air density properties. Site-specific conditions are to be evaluated to assure thermal margins are maintained for steady-state storage conditions at the intended MAGNASTOR ISFSI site.

As shown in Figure 4.4-14, the peak fuel temperature for the normal storage condition occurs near the top of the fuel basket and, based on the uniform spacing of the isotherms at the centerline of the TSC, the temperature varies monotonically from the TSC bottom to the peak near the top of the fuel basket. This is indicative that the dominant mode of heat rejection from the fuel is by convection due to the helium flow circulating within the TSC.

The calculated temperatures at the TSC surface for the normal storage condition are higher than the concrete liner or surface, indicating that radiation heat transfer occurs across the concrete cask to TSC annulus.

To confirm that the concrete cask heat removal system is operable, one of the following two surveillance options with a frequency of 24 hours is required: (1) Visually verify all concrete

cask air inlet and outlet screens are free of blockage; (2) Verify the difference between the concrete cask air outlet average temperature and the ambient temperature is less than 119°F, 127°F, 134°F, 119°F and 119°F for the concrete cask configuration CC1/CC2-PWR, CC1/CC2-BWR, CC3-PWR, CC4-PWR and CC5-PWR, respectively. The allowable temperature differences are determined based on the maximum calculated temperature difference between air outlet and ambient and the calculated minimum temperature margin for concrete and fuel temperatures for all normal and off-normal conditions.

Normal Conditions of Storage – PWR Configuration with DF Basket Assembly

The thermal evaluation for the concrete cask loaded with a TSC containing a DF basket assembly in storage conditions is performed based on configuration CC3 using the two-dimensional axisymmetric FLUENT CFD models described in Section 4.4.1.1. Three cases are considered:

Case 1: The active fuel region is modeled as a single porous zone with a single lumped resistance coefficient. The uniform loading heat generation rate (based on a total heat load of 35.5 kW) is applied to the active fuel region. The calculated maximum fuel temperature is 704°F.

Case 2: The active fuel region is modeled as two parallel porous zones radially, with a resistance coefficient for the outer zone of 16 basket slots (which include the four damaged fuel can slots) and a separate resistance coefficient for the inner zone of 21 basket slots. The uniform loading heat generation rate is applied to the active fuel region. The calculated maximum fuel temperature is 707°F.

Case 3: The active fuel region is modeled the same way as in Case 2. The uniform loading heat generation rate is considered for the standard fuel assemblies. The decay heat is considered to be concentrated at the lower 103 inches of the active fuel region based on a 50% compaction ratio of debris for the four damaged fuel can slots. The calculated maximum fuel temperature is 709°F.

The maximum fuel temperatures from the Case 1 through Case 3 analyses are lower than the maximum fuel temperature (718°F) for the corresponding standard PWR basket, as shown in Table 4.4-3. Therefore the standard PWR basket analyses bound those for the DF basket assembly.

Normal Conditions of Storage – PWR Minimum Reduced Cool Time Fuel Basket Assembly

The thermal evaluation for the concrete cask loaded with a TSC containing the PWR minimum reduced cool time fuel basket assembly for normal storage condition is performed based on configuration CC3 using the modified two-dimensional axisymmetric FLUENT CFD model described in Section 4.4.1.1. The model used for the analysis of the TSC containing PWR minimum reduced cool time fuel basket assembly for normal storage conditions is identical to the model described in Section 4.4.1.1, except for the re-meshed basket zones in the basket radial direction to match locations of the heat generation due to the preferential loading.

The maximum fuel temperature of the analysis is 698°F, 20°F lower than the maximum fuel temperature (718°F) for the corresponding standard PWR basket, as shown in Table 4.4-3. The maximum temperature for the fuel heat load in Figure 4.1-2 is lower since the maximum fuel heat load is no longer at the center of the basket. Therefore the standard PWR basket analyses bound those for the PWR minimum reduced cool time fuel basket assembly.

Transfer Condition for 24-Hour Cooling and Multiple Vacuum Drying Cycles

The maximum component temperatures for MAGNASTOR during the transfer operation are reported in this section for operational procedures using 24 hours of cooling. The transfer operation is comprised of four separate phases: the water phase, the drying phase, the helium phase, and the TSC transfer phase. The water phase and the helium phase are not time limited due to the normal use of the transfer cask annulus cooling water system (ACWS), reverse ACWS, or site-approved ACWS equivalent. The transfer cask annulus cooling system is an operational convenience and not a safety-related system, since the transfer cask can be fully submerged (with the annulus seals deflated) in the spent fuel pool at any point in time during the transfer operation without resulting in thermal shock to the transfer cask system. The annulus cooling system maintains the TSC shell at a temperature significantly lower than the temperature corresponding to the normal conditions of storage. The maximum temperatures for the water phase are listed in Table 4.4-5 and Table 4.4-6 for PWR fuel and BWR fuel, respectively. The maximum temperatures for the helium phase are listed in Table 4.4-7 and Table 4.4-8 for PWR fuel and BWR fuel, respectively. Using the reverse ACWS model described in Section 4.4.1.5, [redacted]

[redacted] Table 4.4-9 and Table 4.4-10 present times for the vacuum drying for heat loads greater than 25 kW for PWR fuel and greater than 29 kW for BWR fuel that are administratively controlled to maintain the fuel cladding temperature below the 752°F limit.

If additional vacuum drying is required for heat loads requiring administrative controls to meet the specified cavity dryness criteria, additional drying cycles can be performed following 24 hours of cooling the TSC, either with the annulus cooling water system or by returning the transfer cask and TSC to the spent fuel pool. Table 4.4-11 and Table 4.4-12 show the second vacuum time and maximum fuel temperatures at the end of the duration for PWR fuel and BWR fuel, respectively. Note that the PWR fuel cladding temperatures shown in Table 4.4-5, 4.4-7, and 4.4-9 are bounded by the PWR fuel cladding temperatures for the normal storage steady-state conditions in Table 4.4-3. Therefore, the normal condition design bases PWR heat load fuel cladding and component temperatures, such as for the fuel basket (including damaged fuel cans, as applicable) and the TSC, bound the maximum temperatures for any phase of the transfer condition for the fuel basket and TSC components.

The time for TSC transfer to the concrete cask is administratively limited to ensure that the maximum fuel cladding temperature is bounded by the design bases heat load normal condition storage temperature. Table 4.4-13 and Table 4.4-14 show the duration and the maximum fuel temperature at the end of the TSC placement in the concrete cask for both PWR fuel and BWR fuel, respectively. The time duration for the transfer operation is determined by modeling the water material properties in the annulus as air, as described in Section 4.4.1.5.

[redacted]

The off-normal condition for use of the annulus cooling system corresponds to loss of cooling by the ACWS, or equivalent site-approved annulus cooling system. This can occur during the water phase or the drying phase of transfer operations.

[redacted]

[redacted]

In the event of loss of cooling occurring during the vacuum drying phase, the TSC is first backfilled with 75 psig (+10, -0 psi) helium, and is then returned to the pool, where it is cooled for a minimum of 24 hours prior to continuing vacuum drying operations.

The loading procedures in Chapter 9 provide normal operational loading sequences. The MAGNASTOR System Operating Manual prepared in accordance with the FSAR analyses provides cask loading and unloading sequence alternatives, including time limitations for all evaluated loss of cooling and off-normal conditions. [redacted] These operational sequences, time limits and corrective actions will ensure that the fuel cladding and system component temperatures do not exceed design allowable values.

Transfer Condition for Minimum Cooling Time and Eight Hours of Canister Transfer

The maximum component temperatures for MAGNASTOR during the transfer operation are reported in this section for operational procedures using the minimum cooling time and eight hours of TSC transfer time (as determined by the evaluation in Section 4.4.1.6). The transfer operation is comprised of four separate phases: the water phase, the drying phase (reduced time as compared to the evaluations in Section 4.4.1.5), the helium phase (minimized cooling time), and the TSC transfer phase (limited to eight hours). The water phase and the helium phase permit indefinite time due to the normal use of the transfer cask annulus cooling system, or an

equivalent cooling system. The annulus cooling system maintains the TSC shell at a temperature significantly lower than the temperature corresponding to the normal conditions of storage. The maximum temperatures for the water phase are listed in Table 4.4-5 and Table 4.4-6 for PWR fuel and BWR fuel, respectively.

Heat load-dependent vacuum drying times reported in Table 4.4-9 and Table 4.4-10 confirm that for the same heat loads, the PWR fuel clad temperatures bound the BWR fuel clad temperatures. The temperatures reported in Table 4.4-16 and Table 4.4-17 are for the maximum PWR and BWR clad temperatures, respectively, at the end of the reduced vacuum time, the reduced cool time, and the eight hours of transfer time. These results confirm that the maximum clad temperatures have significant margin relative to the 752°F fuel clad temperature limit.

For system operations that are outside the sequence presented in Table 4.4-16 or Table 4.4-17, as a result of equipment failure or some other event that extends drying and transfer operations, additional vacuum drying, helium cooling, and/or transfer times will be implemented in accordance with the actions described in the preceding section, "Transfer Condition for 24-Hour Cooling and Multiple Vacuum Drying Cycles."

Maximum TSC Transfer Temperatures for PWR 20 kW (no additional cooling) and 25kW Heat Loads with 7 hours of cooling

[redacted]

Table 4.4-1 Effective Thermal Conductivities for 14×14 PWR Fuel Assemblies for Helium Backfill

For fuel assemblies in fuel tubes with the neutron absorber:

Conductivity [a] (Btu/hr-in-°F)	Temperature (°F)			
	221	415	612	813
K_{xx}	0.019	0.026	0.036	0.048
K_{yy}	0.019	0.026	0.036	0.048
K_{zz}	0.124	0.115	0.111	0.112

For fuel assemblies in positions without the neutron absorber:

Conductivity [a] (Btu/hr-in-°F)	Temperature (°F)			
	222	417	615	816
K_{xx}	0.019	0.025	0.034	0.044
K_{yy}	0.019	0.025	0.034	0.044
K_{zz}	0.127	0.117	0.114	0.115

Table 4.4-2 Effective Thermal Conductivities for 10×10 BWR Fuel Assemblies for Helium Backfill

Conductivity [a] (Btu/hr-in-°F)	Temperature (°F)			
	192	394	597	801
K_{xx}	0.020	0.028	0.039	0.052
K_{yy}	0.020	0.028	0.039	0.052
K_{zz}	0.134	0.125	0.122	0.125

[a] K_{xx} and K_{yy} correspond to the in-plane directions and K_{zz} corresponds to the axial direction in the basket.

Table 4.4-3 Maximum Component Temperatures for Normal Condition Storage of Design Basis PWR and BWR Heat Loads

Component		Maximum Temperatures (°F) CC1/CC2 PWR	CC1/CC2 BWR	CC3 PWR	CC4 PWR	CC5 PWR	Allowable Temperature (°F)
Fuel Cladding		714	695	718	718	718	752
Fuel Basket [a]		714	695	718	718	718	800
TSC Shell		457	436	462	462	462	800
Concrete	local	271	241	256	271	271	300
	bulk	160	153	155	160	160	200

Table 4.4-4 Helium Mass Per Unit Volume for MAGNASTOR TSCs

Fuel Type	Helium Density (g/liter) Nominal	Lower Bound	Upper Bound
PWR	0.763	0.694	0.802
BWR	0.774	0.704	0.814

[a] The maximum fuel cladding temperature is conservatively used.

4.9.1 Water Phase Contingency Events for PWR Fuel

Water phase contingency events are applicable after closure lid installation through initiation of draining operations. This includes operations such as TSC removal from the spent fuel pool, TSC lid closure welding, and TSC hydrostatic testing. Time and temperature limitations are based on full heat load PWR decay heat (maximum of 35.5 kW) and are bounding of lower decay heat loads.

The following water phase contingency events have been analyzed:

[redacted]

4.9.2 Draining, Vacuum Drying and Helium Backfill Phase Contingency Events for PWR Fuel

Draining, vacuum drying and helium backfill/cooling phase contingency events are applicable from the start of TSC cavity water draining operations through completion of the final helium backfill and completion of Minimum Helium Backfill Time in accordance with Technical Specification LCO 3.1.1. Normal operations include continuous ACWS or equivalent cooling, throughout the draining, vacuum drying, and helium backfill phases to maintain TSC temperatures below normal allowable/operational limits. Cooling is confirmed during ACWS by monitoring the transfer cask (MTC) annulus outlet temperature and ensuring it is ≤ 113°F. For reverse ACWS flow, the inlet temperature and flow rate are monitored to ensure they meet the following approved operational limits for PWR heat loads ≤ 35.5 kW:

[redacted]

[redacted]

[redacted]

[redacted]

4.9.3 TSC Transfer Phase Contingencies for PWR Fuel

The TSC Transfer Phase contingency events are applicable during the period from the termination of ACWS cooling following completion of the required Minimum Helium Backfill Time (i.e. cooling time) per LCO 3.1.1 through completion of TSC transfer from the MTC into the VCC. The allowable TSC Transfer Times are as specified in Technical Specification LCO 3.1.1, as applicable to the decay heat load and Minimum Helium Backfill Time (i.e. cooling time) utilized.

[redacted]

[redacted]

4.9.4 Post-TSC Transfer Phase Contingency Events for PWR Fuel

The Post-TSC Transfer Phase contingency events are applicable following completion of the TSC transfer to the VCC and relate to the potential for final measurements of TSC exterior surfaces removable surface contamination levels exceeding Technical Specification allowable levels.

The following Post-TSC Transfer phase contingency events have been analyzed:

[redacted]

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5 SHIELDING EVALUATION

Specific dose rate limits for individual casks in a storage array are not established by 10 CFR 72 [1]. Annual dose limit criteria for the ISFSI-controlled area boundary are established by 10 CFR 72.104 and 10 CFR 72.106 for normal operating conditions and for design basis accident conditions, respectively. These regulations require that, for an array of casks in an ISFSI, the annual dose to an individual outside the controlled area boundary must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ during normal operations. For a design basis accident, the dose to an individual outside the controlled area boundary must not exceed 5 rem to the whole body. In addition, the occupational dose limits and radiation dose limits established in 10 CFR Part 20 (Subparts C and D) [2] for individual members of the public must be met.

This chapter describes the shielding design and the analysis used to establish bounding radiological dose rates for the safe storage of up to 37 undamaged PWR fuel assemblies in the 37 PWR basket assembly or up to 87 undamaged BWR fuel assemblies in the 87 BWR basket assembly. The system is also designed to store up to four damaged fuel cans (DFCs) in the DF Basket Assembly. The DF Basket Assembly has a capacity of up to 37 undamaged PWR fuel assemblies, including four DFC locations. DFCs may be placed in up to four of the DFC locations. Each DFC may contain an undamaged PWR fuel assembly or damaged fuel, which may be a damaged PWR fuel assembly or PWR fuel debris equivalent to one PWR fuel assembly. Undamaged PWR fuel assemblies may be placed directly in the DFC locations of a DF Basket Assembly.

PWR fuel assemblies may contain nonfuel hardware – i.e., reactor control components (RCCs), burnable poison rod assemblies (BPRAs), guide tube plug devices (GTPDs), neutron sources/neutron source assemblies (NSAs), hafnium absorber assemblies (HFRAs), instrument tube tie components, in-core instrument thimbles, and steel rod inserts (used to displace water from the lower section of guide tubes), and components of these devices, such as individual rods. The analysis shows that for the design basis fuel, the system meets the requirements of 10 CFR 72.104 and 10 CFR 72.106 and complies with the requirements of 10 CFR 20 with regard to annual and occupational doses at the owner-controlled area boundary.

The system is designed with two transfer cask and four concrete cask configurations. Transfer casks are designed with either carbon steel shells for PWR and BWR systems (MTC1) or stainless steel shells for the PWR system (MTC2). Concrete casks are designed in:

- A standard shielding configuration (one piece – CC1 and segmented – CC2) with a 1.75-inch liner thickness (PWR and BWR systems);
- An augmented shielding configuration (CC3/CC5) with a 3-inch liner thickness, an increased lid thickness and additional shielding at the air inlets (PWR system);
- And a short, standard shielding configuration cask (CC4) with a 1.75-inch liner thickness and additional shielding at the air inlets (PWR system).

Canisters may be sealed with either an all stainless steel closure lid (PWR and BWR systems) or a composite carbon steel and stainless steel lid assembly (PWR system). BWR evaluations are performed with the all stainless steel closure lid and PWR evaluations are performed with the composite closure lid assembly. The composite lid assembly bounds the all stainless steel lid in shielding evaluations due to the lower density of carbon steel.

Minimum cool times prior to fuel transfer and storage are specified as a function of minimum assembly average fuel enrichment and maximum assembly average burnup (MWd/MTU). To minimize the number of loading tables, PWR and BWR fuel assemblies are grouped by bounding fuel and hardware mass. Key characteristics of each assembly grouping are shown in Section 5.2. Refer to Section 5.8.9 for detailed loading tables meeting the system heat load limits.

Source terms for the various vendor-supplied fuel types are generated using the SCALE 4.4 sequence as discussed in Section 5.2. Three-dimensional MCNP [3] shielding evaluations provide dose rates for transfer and concrete casks at distances up to four meters. NAC-CASC, a modified version of the SKYSHINE-III code [4], calculates site boundary dose rates for either a single cask or cask array. See Section 5.6 for more detail on the shielding codes.

Transfer cask top-, side-, and bottom-surface average dose rates are 254 (1.1 %) mrem/hr, 895 (<1%) mrem/hr, and 3,000 (<1%) mrem/hr, respectively. Access to the bottom of the cask is limited to pool-to-workstation transfer operations and the workstation-to-vertical concrete cask transfer operations. Site ALARA plans should specify limited access to areas below and around the loaded transfer cask during lifting and transfer operations.

5.1.1.2 Damaged PWR Fuel Dose Rates

Damaged PWR fuel assemblies may be loaded in damaged fuel cans in the four corner assembly locations of the PWR damaged fuel basket. DFC slots are locations 4, 8, 30 and 34 in Figure 5.8.12-10. To ensure that the worst case configuration is considered, two damaged fuel scenarios are evaluated.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. This scenario is modeled by filling the fuel assembly interstitial volume with UO_2 and increasing the fuel neutron, gamma and n-gamma source consistent with this increase in mass. Dose rate profiles for the 37-assembly undamaged assemblies are compared with profiles for 33 undamaged and 4 damaged assemblies in Section 5.8.12. Based on the self-shielding of the added mass compensating for the increase in source, damaged fuel dose rates for the first scenario are bounded by either the corresponding undamaged fuel dose rates or the second damaged fuel scenario.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. However, no credit is taken for the reduction in the lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region. In this case, transfer cask bottom surface dose rates increase due to the addition of damaged fuel. The transfer cask bottom axial dose rate increases 53 mrem/hr, increasing the bottom axial dose rate by approximately 0.9 percent. Radial dose rates for PWR fuel increase, but remain less than the bounding BWR fuel.

Damaged fuel dose rates are computed using the carbon steel transfer cask, as it produces higher dose rates than the stainless steel transfer cask due to the higher density of stainless steel versus carbon steel.

Damaged fuel maximum dose rates in the carbon steel transfer cask are summarized in Table 5.1.3-9.

5.1.2 Concrete Cask Shielding Discussion and Dose Results

The concrete cask is composed of body and lid components. The body contains the air inlets, air outlets, and the cavity for TSC placement. The lid provides environmental closure for the TSC. The radial shield design is comprised of a carbon steel inner liner surrounded by concrete. The concrete contains radial and axial rebar for structural support. As in the transfer cask, the TSC shell provides additional radial shielding. The concrete cask top shielding design is comprised of the TSC lid and concrete cask lid. The concrete cask lid incorporates both concrete and steel plate to provide additional gamma shielding. The bottom shielding is comprised of the stainless steel TSC bottom plate, the pedestal/air inlet structure, and a carbon steel base plate. Radiation streaming paths consist of air inlets located at the bottom and air outlets located above the top of the TSC, and above the annulus between the concrete cask body and the TSC. Air inlets and outlets are radial openings to the concrete cask. The inlets and outlets are axially offset from the source regions to minimize dose and meet ALARA principles.

No auxiliary shielding is considered in the concrete cask shielding evaluation. All components relevant to safety performance are explicitly included in the concrete cask model. Homogenization of materials used in the models is limited to the fuel assembly as described in Section 5.1.1.

5.1.2.1 Undamaged Fuel Dose Rates

Refer to Table 5.1.3-2, Table 5.1.3-5, and Table 5.1.3-7 for a summary of the concrete cask normal condition and accident event maximum calculated dose rates for the standard (CC1/ CC2), augmented shield (CC3), and short, standard (CC4) cask configurations. Listed maximum dose rates include fuel and nonfuel hardware contributions. Payload types producing maximum surface dose rates are listed in Table 5.1.3-3, Table 5.1.3-6, and Table 5.1.3-8. Refer to Section 5.6.5 for TSC surface contamination release dose rates. Dose rates are based on three-dimensional Monte Carlo analysis using surface detectors. Further detail on the detector geometry is included in Section 5.5.

The CC5 configuration is not specifically evaluated as it represented an increased length CC3 with similar exterior dimensions as the CC1/CC2 but with significantly augmented shielding (thicker liner and lid plus air inlet shield bars). The CC5 is designed to hold a TSC longer than capable of placement into a CC3. The longer TSC in turn is capable of storing CE System 80 type fuel (C 16a) and BWR/4-6 fuels. Dose rates shown for the CC1/CC2 evaluations bound those produced by the CC5 configuration.

The maximum concrete cask side (cylindrical) average surface dose rate is 58 (<1%) mrem/hour. On the concrete cask top (disk), the average surface dose rate is 104 (2%) mrem/hour. Average dose rates for the standard shielding concrete cask are more than twice as high on the radial surface and approximately 20% higher on the axial surface than the augmented (CC3) shielding cask configuration for the PWR system (augmented cask shield analysis limited to PWR payloads). The maximum inlet and outlet dose rates are 434 and 59 mrem/hr, respectively. No design basis normal condition or accident event exposes the bottom of the concrete cask.

5.1.2.2 Damaged PWR Fuel Dose Rates

The two damaged fuel scenarios described in Section 5.1.1.2 are also evaluated for the concrete cask.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. Dose rate profiles for the 37- undamaged assemblies are compared with profiles for 33 undamaged and 4 damaged assemblies in Section 5.8.12. Based on the self-shielding of the added mass compensating for the increase in source, damaged fuel dose rates for the first scenario are bounded by either the corresponding undamaged fuel dose rates or the second damaged fuel scenario.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. In this case, concrete cask inlet and radial dose rates increase due to the addition of damaged fuel. The concrete cask inlet dose rate increase is 38 mrem/hr, increasing the inlet dose rate by approximately 9 percent. The maximum concrete cask radial dose rate increases to 82.3 mrem/hr, an increase of approximately 4 percent.

Damaged fuel dose rates are computed using the standard concrete cask (CC1/CC2) or the short, standard concrete cask (CC4), as they produce higher dose rates than the augmented shield concrete casks (CC3/CC5).

Damaged fuel maximum dose rates in the standard concrete cask are summarized in Table 5.1.3-10.

5.1.3 Offsite Dose Discussion and Results

Contributions from concrete casks to site radiation dose exposure are limited to either radiation emitted from the concrete cask surface or a hypothetical release of surface contamination from the TSC. As documented in Section 5.6.5, there is no significant site dose effect from the

expected surface contamination of the system. The TSCs are comprised of a welded shell, bottom plate and lid structure. The vent and drain ports in the lid are covered by redundant welded plates. There is, therefore, no credible leakage from the system, and no significant effluent source can be released from the TSC contents. Details on the TSC confinement boundary are provided in Chapter 7, with leakage test information provided in Section 10.1.3.

Controlled area boundary exposure from the concrete cask surface radiation is evaluated using the NAC-CASC code. (As previously stated, NAC-CASC is a modified version of SKYSHINE-III.) NAC-CASC calculates the direct dose rate as well as the air scattered contribution of the total dose rate. As the detectors are below the top surface of the cask, only the cylindrical shell (radial) cask surface current contributes a direct component to the total dose rate. NAC-CASC primary enhancements to SKYSHINE-III allow the input of an angular surface current, the input of cylindrical shell (side) and disk (top) geometries, and the accounting of concrete cask self-shielding (i.e., radiation emitted from one cask intersecting another cask in the array—in particular, front/back row interaction in the array). The cylindrical shell and top surfaces are Monte Carlo sampled to generate the surface current input into the code. Each of the sampled locations represents a point source to which the SKYSHINE-III line beam response functions are applicable.

The NAC-CASC (SKYSHINE-III) method assumes that radiation emitted from the source does not interact with the cask/source structure after emission (beyond the additional routines added by NAC to account for self-shielding). This assumption does not represent a significant effect on site dose rates as the calculated surface current is near normal to the surface and any backscatter to the cask from the air surrounding the array would then require a second backscatter from the cask surface to reach a detector location. As detector locations for site exposure are at significant distances from the array (typically 100+ meters), there would not be a significant contribution from radiation having undergone such repeated large angle scatter.

Both a single cask and a 2×10 array of casks are evaluated for site exposure evaluations. Each cask in the array is assigned the maximum dose (surface current) source allowed by the cask loading tables. A combination of the maximum cask side and top dose cases provides for a conservative estimate on the controlled area boundary exposure, since the different fuel types produce the highest cask surface dose components.

The full-year exposure for site boundary (controlled area boundary) results is based on 8,760 hours of exposure.

Table 5.1.3-4 Summary of Stainless Steel Transfer Cask Maximum Dose Rates (35.5 kW PWR)

	Transfer Cask Surface (mrem/hr with relative uncertainty)			1 Meter from Surface (mrem/hr with relative uncertainty)		
Source	Side	Top	Bottom[a]	Side	Top	Bottom
Neutron	706 (0.8%)	88 (1.6%)	1,056 (6.9%)	244 (0.6%)	22 (1.5%)	255 (3.9%)
Gamma	239 (2.2%)	480 (1.2%)	4,270 (2.8%)	108 (1.4%)	121 (1.8%)	2,213 (1.2%)
Total	945 (0.8%)	568 (1.0%)	5,326 (2.6%)	352 (0.6%)	143 (2.6%)	2,468 (1.1%)

Table 5.1.3-5 Summary of Augmented Shield Concrete Cask (CC3) Maximum Dose Rates (35.5 kW PWR)

		Cask Surface (mrem/hr with relative uncertainty)		1 Meter from Surface (mrem/hr with relative uncertainty)	
Condition	Source	Side[b]	Top	Side[b]	Top
Normal[c]	Neutron	0.8 (3.8%)	17 (4.5%)	0.4 (2.5%)	2.7 (4.6%)
	Gamma	36.3 (3.2%)	391 (2.9%)	19.3 (2.1%)	65.5 (1.7%)
	Total	37.1 (3.1%)	408 (2.8%)	19.7 (2.0%)	68.2 (1.7%)

[a] Includes fuel, thimble plug, and BPRA contribution. A full loading of 9 CEAs will increase bottom dose by 2,304 mrem/hr on contact.

[b] Not including air inlet and outlet streaming paths. Maximum air inlet and outlet dose rates including fuel, BPRA, and thimble plug contributions are 119 (3.1%) and 26.2 (1.3%) mrem/hr, respectively. At a distance of 1 m from the cask surface, the air inlet and outlet maximum dose rates are 17.1 (6.2%) and 4.2 (2.1%) mrem/hr, respectively. CEAs may add an additional 6.7 mrem/hr to the inlet dose. There is no CEA contribution to the outlet dose.

[c] Accident condition dose rates are bounded by the values in Table 5.1.3-2.

Table 5.1.3-6 Bounding Payload Type for Each Stainless Steel Transfer and Augmented Shield (CC3) Concrete Cask Surface

Cask	Surface	Insert	Core Type[a]	Max MTU	ID[b]	Cool Time (yrs)	Assembly Average Burnup (GWd/MTU)[c]	Initial Enrichment (wt% ^{235}U)
Transfer	Radial	BPRA	WE 14×14	0.4114	14b	12.4	59	3.1
Transfer	Top	TP	WE 14×14	0.4144	14b	6.0	44	2.5
Transfer	Bottom	BPRA	WE 14×14	0.4144	14b	6.0	44	2.5
Concrete	Radial	BPRA	WE 14×14	0.4144	14b	4.1	32.5	2.1
Concrete	Top	TP	WE 14×14	0.4144	14b	4.8	37.5	2.3
Concrete	Air Inlet	BPRA	WE 14×14	0.4144	14b	6.0	44	2.5
Concrete	Air Outlet	TP	WE 14×14	0.4144	14b	6.0	44	2.5

Table 5.1.3-7 Summary of the Short, Standard Concrete Cask (CC4) Maximum Dose Rates (35.5 kW PWR)

Condition	Source	Cask Surface (mrem/hr with relative uncertainty)		1 Meter from Surface (mrem/hr with relative uncertainty)	
		Side[d]	Top	Side[d]	Top
Normal[e]	Neutron	0.6 (8.3%)	12 (7.3%)	0.3 (5.9%)	3 (3.4%)
	Gamma	78.9 (1.4%)	353 (3.8%)	40.3 (0.9%)	86.3 (2.2%)
	Total	79.5 (1.4%)	365 (3.7%)	40.6 (0.9%)	89.3 (2.1%)

[a] Refers to general core configuration on which assembly hybrid was based (e.g., Westinghouse 14×14).
[b] Indicates identifier for fuel characteristics documented in Section 5.2 of the SAR.
[c] Maximum fuel assembly average burnup limited to 60 GWd/MTU.
[d] Not including air inlet and outlet streaming paths. Maximum air inlet and outlet dose rates including fuel, BPRA, and thimble plug contributions are 115 (4.8%) and 42.8 (1.6%) mrem/hr, respectively. At a distance of 1 m from the cask surface, the air inlet and outlet maximum dose rates are 16.5 (9.1%) and 4.4 (3.4%) mrem/hr, respectively. CEAs may add an additional 6.3 mrem/hr to the inlet dose. There is no CEA contribution to the outlet dose.
[e] Accident condition dose rates are bounded by the values in Table 5.1.3-2.

5.5 Model Specification

The transfer and concrete casks are evaluated using the MCNP three-dimensional Monte Carlo code. In the MCNP fuel assembly model, the fuel and hardware source regions are homogenized within a volume defined by the fuel assembly width and height. This volume is subdivided axially into active fuel, upper and lower plenum, and upper and lower end fitting source regions. Within these axial volumes, the material masses of the fuel assembly are homogenized. In all models, the cask and TSC shield thicknesses and axial extents are explicitly represented, including streaming paths. Surface detectors are used to estimate the dose profiles at the cask surface and at distances of 1ft, 1m, 2m, and 4m from the cask surface. The MCNP code employs an automated biasing technique for the Monte Carlo calculation based on weight window adjustments in mesh cells. Radial biasing is performed to estimate dose rates at the transfer cask radial surface and concrete cask radial surface, including air inlets and outlets. Axial biasing is used for cask top and bottom surface rates. Angular biasing components are used to capture azimuthal variations in bulk shielding properties. Primary examples of azimuthal variations within bulk shields are the concrete cask air inlets and outlets and the vent/drain port location in the TSC closure lid.

The geometric description of an MCNP model is based on the combinatorial geometry system embedded in the code. In this system, surfaces and bodies, such as cylinders and rectangular parallelepipeds, and their logical intersections and unions, are used to describe the extent of material zones.

NAC-CASC, a modified version of SKYSHINE-III, uses the MCNP generated cask surface current to estimate site boundary exposures. NAC-CASC allows for self-shielding of casks and permits input of an angular surface current emission spectrum. In the NAC-CASC evaluations, the concrete casks are modeled as “black body” cylinders. Given the concrete cask thickness, radiation emitted from one cask and impacting an adjacent cask will not significantly impact site boundary dose rates. To verify the acceptability of this assumption, a radial neutron and gamma source MCNP analysis was performed on a 2×10 cask array with the front row assigned either an importance of 1 (same as back row casks) or assigned an importance of 0 (terminating the particle tracking). Results of this analysis are shown in Figure 5.5.5-7 for the short array axis (facing the x direction 2 cask side of the array in Figure 5.5.5-6) and Figure 5.5.5-8 for the long array axis (facing the y direction 10 cask side of the array in Figure 5.5.5-6). While significantly affecting the radial dose contribution from the “shielded” back row of casks along the y-axis, the “black body” assumption does not significantly affect total dose rates in this direction, as the majority of dose is contributed by the front row of casks (i.e., casks facing the detector). Including the axial contribution in the comparison, which is not affected by the “black body” assumption, would further decrease the relative effect of the “black body” assumption. The

energy and angular spectrum of radiation emitted from the cask surface are retained when transitioning from the MCNP to the NAC-CASC model.

5.5.1 Description of Radial and Axial Shielding Configurations

The three-dimensional shielding analysis allows detailed modeling of the source and shield regions, including streaming paths. Cask and TSC details include the axial extent of the radiation shields. This section includes system sketches, discussion of the general TSC shell (including closure lid and bottom plate) and features, and detailed information on the transfer cask and concrete cask shield configurations. Content dependent TSC, basket and fuel specific model details are included in Sections 5.8.3 and 5.8.4.

5.5.1.1 MCNP Canister Model

Key TSC shielding features are listed in Table 5.5.5-1. The TSC closure lid, shell, and bottom plate are explicitly modeled. Port covers are modeled as open in transfer cask evaluations and closed in concrete cask evaluations. The TSC elevations with respect to the cask shields are illustrated in the cask shield configuration descriptions.

5.5.1.2 MCNP Concrete Cask Model

The three-dimensional model of the concrete cask contains the following features:

- heat transfer annulus with standoffs
- bottom weldment, including pedestal, bottom plate, and air inlet structure
- radial concrete cask body with rebar
- concrete lid
- concrete pad below base plate

Detailed model parameters used in creating the three-dimensional model are taken directly from the relevant drawings. Key shielding features are listed in Table 5.5.5-2. Elevations associated with the concrete cask three-dimensional model are established with respect to the bottom plate of the TSC for the global model. Sketches of the three-dimensional concrete cask model are shown in Figure 5.5.5-1 and Figure 5.5.5-2 for the standard shield cask configuration, Figure 5.5.5-9 and Figure 5.5.5-10 for the augmented shield configuration (CC3), and Figure 5.5.5-11 for the short, standard shield cask configuration (CC4).

The standard shield concrete cask design is specified as 1) a standard assembly, one-piece version, with optional embedded lift anchors, and 2) an alternate, segmented assembly with two covered lift anchor cavities. The modeled geometry reflects a conservative combination of both models, with two uncovered lift anchor cavities added to the standard assembly geometry as

shown in Figure 5.5.5-3. The augmented shield concrete casks (CC3/CC5) and CC4 are designed in a one-piece version.

5.5.1.3 MCNP Transfer Cask Model

The transfer cask is evaluated in detail for the welding, draining, and drying operations. As with the concrete cask models, all basket areas, with the exception of the fuel assembly, are discretely modeled. Six inches of auxiliary shielding are included in the transfer cask evaluation, as is the water in the TSC/transfer cask annulus between the upper and lower inflatable seals. A foreign material exclusion bar is modeled over the TSC to transfer cask annulus. Key transfer cask shield features are listed in Table 5.5.5-3. Figure 5.5.5-4 provides a model sketch of the carbon steel transfer cask with TSC. The stainless steel transfer cask is identical in configuration to the carbon steel cask shown with the exception of the carbon steel component replacement by stainless steel and a reduced overall height of 191 inches.

5.5.2 MCNP Detector Mesh Definition

MCNP surface detectors are used to calculate dose rates at various distances from the casks. The surface tallies are subdivided using the FS tally segmentation card. A graphical illustration of the detector overlay on a cask is shown in Figure 5.5.5-5. Depicted are 1ft, 1m, 2m, and 4m detector surfaces on the concrete cask. For clarity, the cask surface detector and azimuthal (angular) divisions are not shown. Typical detector grids for the transfer and concrete cask analysis are shown in Table 5.5.5-4 to Table 5.5.5-6. The dose maps produced by this method completely enclose the accessible cask surfaces and capture all locations necessary for the evaluation of occupational exposures.

5.5.3 NAC-CASC Model

The site boundary evaluation relies on single cask and 2×10 cask array models. An illustration of the 2×10 cask array is shown in Figure 5.5.5-6. The nominal cask pitch for the array is 15 feet. A conservative 16-ft pitch is evaluated to minimize cask self-shielding.

In each of the models, the concrete cask is represented as a cylindrical body onto which detailed surface radiation currents are applied. Cask surface currents are extracted from the 3-D MCNP shielding evaluation of each payload/configuration. The MCNP evaluation also provides the angular distribution of the cask surface current for sampling in the NAC-CASC skyshine code. The cask surface currents are based on the fuel type, assembly average burnup, initial enrichment, and cool time combination that produce the maximum cask radial and axial surface dose rates. In the PWR system, the source also accounts for the addition of nonfuel hardware.

Separating the TSC contents evaluation of the cask body from the site air transport exposure evaluation minimizes analysis complexity. All cask gamma source components, including the n- production in the cask, are combined into a single gamma source for the skyshine analysis. The model includes a representation of the cask pad, soil surrounding the pad, and an air envelope (air density applied is 0.001225 g/cm^3, which is the density of dry air at 20°C). The air envelope provides both an n- source as well as radiation scatter. Air density of 0.001225 g/cm^3 applied in the analysis formed the basis for the development of the line beam response functions used in the NAC-CASC (SKYSHINE-III) code. Variations in the air density are permitted within the code input deck but were not utilized in the dose rate evaluations. Variations in site conditions, including expected atmospheric conditions, should be addressed per Appendix A (Chapter 13) Section 5.5 "Radiation Protection Program" evaluations. Detectors are spaced along the rectangular outline of the ISFSI to a maximum extent of 2,000 ft (610 m) from the center of the array or single cask. NAC-CASC detectors are located at an elevation of 3 ft relative to the bottom of the cask. To obtain a sufficiently detailed dose rate map, dose rate results were evaluated at intervals of 5 ft from 85 ft to 100 ft and at 25-ft intervals from 100 ft to 2000 ft. A detector grid spacing of less than 10 meters is sufficient to provide the generic information necessary to determine system array or single cask effects on site boundary dose. The dose rate data plotted in Section 5.8.3-5 for PWR and BWR systems demonstrates a smooth drop off of dose rate (or yearly dose) that could be fit with a larger detector spacing than that employed in this evaluation.

An ISFSI containing a significant number of casks may be surrounded by a berm or wall structure to reduce offsite doses. The model generated here, conservatively, does not consider any other shielding components with the exception of the other casks on the pad.

5.5.4 Offsite Particulate and Gas Release

The TSC is welded closed using controlled welding processes to ensure that the TSC is in a configuration where no credible leakage of the TSC's radionuclide contents can occur. Since the TSC was submerged in the spent fuel pool for loading, a limited amount of surface contamination may be released from the TSC.

A calculation is made to determine dose rate as a function of distance based on residual contamination limits of β-γ and α activity, released from the TSC surface, using the plume dispersion method of Regulatory Guides 1.109 [19] and 1.145 [20].

The χ/Q factor is determined according to the formula from Reg. Guide 1.145.

Figure 5.5.5-7 NAC-CASC "Black Body" Assumption Test Along Short (X-Axis) Side of Array

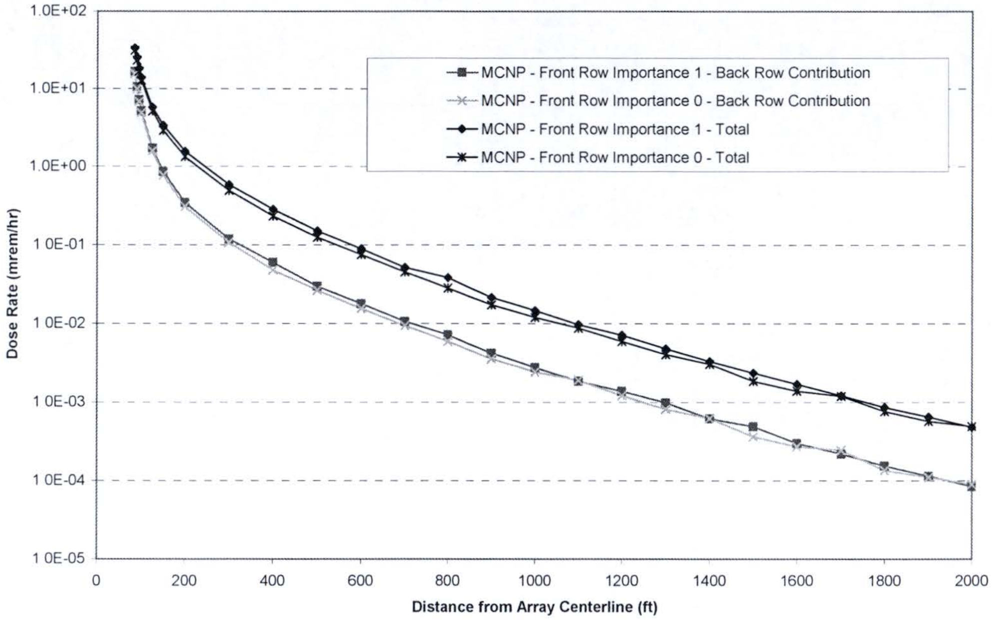

Figure 5.5.5-8 NAC-CASC "Black Body" Assumption Test Along Long (Y-Axis) Side of Array

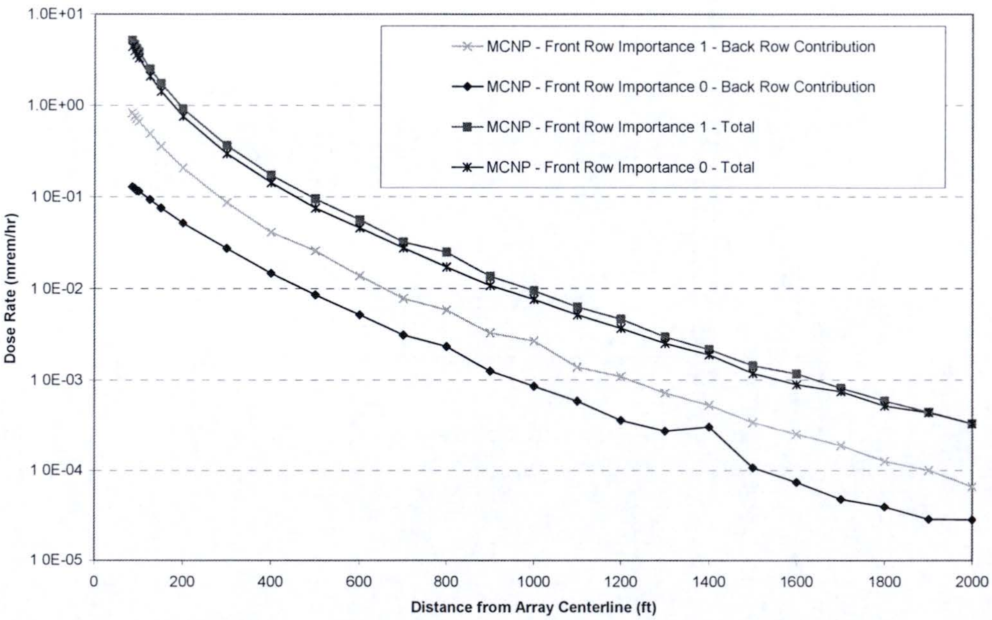

Figure 5.5.5-9 Augmented Shield Concrete Cask (CC3) Model – Primary Shield Dimensions

Security-Related Information
Figure Withheld Under 10 CFR 2.390.

Dimensions in inches.

Note: Cask sketch includes composite carbon/stainless steel TSC lid assembly. The CC5 configuration contains the same radial shield configuraiton but has an increased length.

computational benchmarks. The code compared well with these benchmarks for both neutron and gamma doses versus distance.

5.6.2 Flux-to-Dose Rate Conversion Factors

The ANSI/ANS 6.1.1-1977 [26] flux-to-dose rate conversion factors are used in all cask shielding evaluations. Neutron and gamma dose conversion factors are listed in Table 5.6.5-1 and Table 5.6.5-2, respectively.

5.6.3 Cask Dose Rate and Exposure Results

This section provides bounding dose profiles for the concrete and transfer cask based on the source terms presented in Section 5.2. Fuel source terms include contributions from fuel neutron, fuel gamma, and activated hardware gamma. The fuel assembly activated hardware gamma source terms include: steel and inconel in the upper and lower fuel assembly end fittings, upper and lower fuel rod plenum hardware, and activated nonfuel material in the active fuel region. The three-dimensional model dose rates include the effects of axial profiles.

5.6.3.1 Concrete Cask Dose Rates

Maximum concrete cask radial and top axial normal condition dose rates at the cask surface and distances of 1ft, 1 m and 2 m are shown in Figure 5.6.5-1 and Figure 5.6.5-2. In the axial profile plots, each datum represents the circumferentially averaged dose rate at the corresponding elevation. Figure 5.6.5-3 and Figure 5.6.5-4 contain an azimuthal breakdown of the bounding (standard shield) air outlet and inlet dose rate cases. Refer to Sections 5.8.3.4 and 5.8.4.4 for further detail, such as content and cask configuration specific dose rates, and a breakdown in dose by source region.

Concrete cask top dose rates peak at 430 mrem/hr, with the gamma dose accounting for 99% of the total. Gamma radiation exiting the concrete cask top surface has a minimal impact on site-boundary exposure.

The missile impact scenario represents the only accident condition significantly impacting the system shielding performance. The conservative removal of 6 inches of concrete from the entire cask body radial surface results in a maximum 1-m dose of 286 mrem/hr. This is extremely conservative, as the missile impact is limited to an 8-in diameter projectile and the 1-m dose would not be significantly affected by a localized reduction in the concrete cask shield. Missile impact dose rates are conservatively calculated based on PWR and BWR heat loads of 40 and 38 kW, respectively.

5.6.3.2 Transfer Cask Dose Rates

Bounding transfer cask dose rates as a function of distance from the cask are shown in Figure 5.6.5-5, Figure 5.6.5-6 and Figure 5.6.5-7. Dose peaks occur on the radial cask surface near the top and bottom weldment locations where activated end-fitting contributions control dose rate. Over the fuel region, the dose shape follows the burnup shape. On the top axial cask surface, dose rates rise in the cask to the TSC annulus area where significant radiation streaming occurs.

5.6.4 NAC-CASC Dose Evaluation

Bounding site boundary dose rates from direct radiation for the limiting contents, as a function of distance from the single concrete cask and the 2×10 concrete cask array, are plotted in Figure 5.6.5-8. Distances are taken along the axis perpendicular to the 10-cask side of the array. The limiting contents are the PWR TSC, as documented in Section 5.8.3.5. Site boundary evaluations are presented in Sections 5.8.3.4.3 and 5.8.3.5, respectively. The CC4 is not evaluated, as there are no radial shield differences from the CC1, and radial dose is the primary dose contributor for the site boundary (greater than 80%). The negligible differences would be bounded by the 40 kW PWR payload evaluation. CC3/CC5 configurations are not evaluated for off-site exposure as they contain significantly more shielding than the CC1 configuration.

5.6.5 Surface Contamination Release

Offsite release exposures from particulate contamination are evaluated at a conservative distance of 100 meters and a residual contamination limit of 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α.

The selected dose conversion factors are based on using the highest conversion factor for each radiologically significant group of nuclides expected on the TSC surface. ^{60}Co conversion factors are applied to β-γ activity and ^{241}Am factors are applied to the α activity. Dose conversion factors are taken from EPA Federal Guidance Report No. 11 [27], Table 2.1 and Federal Guidance Report No. 12 [28], Table III.1. Both Class Y (oxide) and W compound dose conversion factors were extracted. Class Y (oxide) conversion factors are bounding for the β-γ cobalt release. Only class W conversion factors are available for the ^{241}Am release. The dose conversion factors employed are:

Dose Type	Unit	(^{60}Co)	(^{241}Am)
Submersion – Skin	[rem-m^3/Ci-yr]	1.69E+07	--
Inhalation – Lung	[rem/Ci]	1.28E+06	6.81E+07
Inhalation – Whole Body	[rem/Ci]	2.19E+05	4.44E+08
Inhalation – Bone	[rem/Ci]	--	8.03E+09

5.8.3.3 Transfer Cask Dose Rates

Using the dose response method, transfer cask dose rates are tabulated for all allowed cool times, assembly average burnup, and initial enrichment combinations for each of the assembly types.

5.8.3.3.1 Carbon Steel Transfer Cask

Maximum dose rates as a function of distance from the transfer cask surface are shown in Figure 5.8.3-3 for the cask radial surface, Figure 5.8.3-5 for the cask top, and Figure 5.8.3-7 for the cask bottom. Breakdowns of the cask surface radial and top dose rates into the source components are shown in Figure 5.8.3-4 and Figure 5.8.3-6. The bounding payloads with cask surface maximum and average dose rate for each cask surface are:

Surface	Fuel Type	Cool Time (yrs)	Assembly Average Burnup (GWd/MTU)	Initial Enrichment (wt% ^{235}U)	Maximum Dose Rate (mrem/hr)	Average Dose Rate (mrem/hr)
Radial	14a	11.5	59	3.1	939	650
Top	14b	6.0	44	2.5	451	172
Bottom	14b	6.0	44	2.5	5,824	2,953

5.8.3.3.2 Stainless Steel Transfer Cask

Maximum dose rates as a function of distance from the transfer cask surface are shown in Figure 5.8.3-17 for the cask radial surface, Figure 5.8.3-19 for the cask top, and Figure 5.8.3-21 for the cask bottom. Breakdowns of the cask surface radial and top dose rates into the source components are shown in Figure 5.8.3-18 and Figure 5.8.3-20. The bounding payloads with cask surface maximum and average dose rate for each cask surface are:

Surface	Fuel Type	Cool Time (yrs)	Assembly Average Burnup (GWd/MTU)	Initial Enrichment (wt% ^{235}U)	Maximum Dose Rate (mrem/hr)	Average Dose Rate (mrem/hr)
Radial	14a	11.5	59	3.1	922	630
Top	17b	5.6	37.5	2.3	505	206
Bottom	14b	6.0	44	2.5	5,239	2,713

5.8.3.4 Concrete Cask Dose Rates

Using the dose response method, concrete cask dose rates are tabulated for all allowed cool times, assembly average burnup, and initial enrichment combinations for each of the assembly types.

5.8.3.4.1 Standard Shield Concrete Cask (1.75-inch Liner)

Maximum dose rates as a function of distance from the concrete cask surface are shown in Figure 5.8.3-8 for the cask radial surface, Figure 5.8.3-10 for the cask top, and Figure 5.8.3-12 and Figure 5.8.3-13 for the cask air outlet and inlets, respectively. Breakdowns of the cask surface radial and top dose rates into the source components are shown in Figure 5.8.3-9 and Figure 5.8.3-11. Refer to Table 5.8.3-5 for the maximum concrete cask surface dose rates and the contents that develop the dose rates.

5.8.3.4.2 Augmented Shield Concrete Cask (3-inch Liner / CC3)

Maximum dose rates as a function of distance from the concrete cask surface are shown in Figure 5.8.3-22 for the cask radial surface, Figure 5.8.3-24 for the cask top, and Figure 5.8.3-26 and Figure 5.8.3-27 for the cask air outlet and inlets, respectively. Breakdowns of the cask surface radial and top dose rates into the source components are shown in Figure 5.8.3-23 and Figure 5.8.3-25. Refer to Figure 5.8.3-8 for the maximum concrete cask surface dose rates and the contents that develop the dose rates.

5.8.3.4.3 CC4

Maximum dose rates as a function of distance from the concrete cask surface are shown in Figure 5.8.3-28 for the cask radial surface and Figure 5.8.3-30 for the cask top. Breakdowns of the cask surface dose rates into the source components are shown in Figure 5.8.3-29 for radial, Figure 5.8.3-31 for top, Figure 5.8.3-32 for outlets, and Figure 5.8.3-33 for inlets. Refer to Table 5.8.3-9 for the maximum concrete cask surface dose rates and the contents that develop the dose rates.

5.8.3.5 NAC-CASC Site Boundary Evaluation

Detailed direct and skyshine dose rates as a function of distance are calculated for a single concrete cask and a 2×10 array of concrete casks based on the model description and method outlined in Section 5.5.3. All allowable payload combinations (i.e., fuel type, initial enrichment, assembly average burnup, and cool time) that meet per assembly heat load limits were reviewed to determine the payloads producing maximum top (axial) and side (radial) dose rates. These payload cases were then run through MCNP using a "direct" solution approach (full source spectrum), rather than the response function method, to generate cask top and side surface radiation currents. The surfaces were treated independently to generate a conservative hybrid source model for a design basis analysis cask.

The maximum TSC heat load applied in the site boundary evaluation is 40 kW versus the 35.5 kW applied in the cask surface dose evaluations. The site boundary results obtained from the 40 kW pattern and standard shield concrete cask conservatively bound those of the maximum 35.5 kW pattern and use of the augmented shield concrete cask.

Table 5.8.3-4 17a Minimum Cool-time Solution, 45 GWd/MTU at 3.9 wt% ^{235}U

Parameter	Value
6 yr Heat Load (W)	1036
7 yr Heat Load (W)	933
Minimum Cool Time[a] (yr)	6.74
Rounded Limit (yr)	6.8
Heat Load at Limit (W)	954

[a] Conservatively based on a linear interpolation of the exponential decay curve.

Table 5.8.3-5 Maximum Standard Shield Concrete Cask Surface Dose Rates

Surface	Fuel Type	Cool Time (yrs)	Assembly Average Burnup (GWd/MTU)	Initial Enrichment (wt% ^{235}U)	Maximum Dose Rate (mrem/hr)	Average Dose Rate (mrem/hr)
Radial	14a	4	32.5	2.3	76.7	54.4
Top	16a	4.4	32.5	2.1	378	82.3
Air Inlet	14b	4.8	37.5	2.3	425	--
Air Outlet	16a	4.4	32.5	2.1	38.3	--

Table 5.8.3-6 PWR Bounding Surface Current Input Data[a]

Surface	Fuel Type	Cool Time (yrs)	Assembly Average Burnup (GWd/MTU)	Initial Enrichment (wt% ^{235}U)	Cask Surface Neutron Source (n/sec)	Cask Surface Gamma Source (γ/sec)
Radial	14a	4.1	37.5	2.5	2.768E+07	2.602E+10
Top	16a	4.6	37.5	2.3	2.331E+07	1.350E+10

Table 5.8.3-7 Rectangular Controlled Area Boundary for the 2×10 PWR Cask Array

Direction Basis	Distance From the Center of the Array [ft]	Distance from the Center of the Array [m]
x direction (Perpendicular to Long Side of the Array)	1521	463
y direction (Perpendicular to the Short Side of the Array)	1319	402

Table 5.8.3-8 Maximum Augmented Shield Concrete Cask (CC3) Surface Dose Rates

Surface	Fuel Type	Cool Time (yrs)	Assembly Average Burnup (GWd/MTU)	Initial Enrichment (wt% ^{235}U)	Maximum Dose Rate (mrem/hr)	Average Dose Rate (mrem/hr)
Radial	14a	4.0	32.5	2.3	36.5	25.2
Top	14b	4.8	37.5	2.3	350	58.2
Air Inlet	14b	6.0	44	2.5	117	--
Air Outlet	17b	5.6	37.5	2.3	21.8	--

[a] Based on cask heat load of 40 kW

term. Therefore, the strict application of increased fuel assembly minimum cool time without considering the corresponding reduction in fuel dose rates is conservative.

5.8.5.2.2 Thimble Plugs

Table 5.8.5-5 lists the allowed thimble plug loading configurations expressed in burnup and cool-time limits or curie limits. The radiation source for the thimble plugs is dominated by ^{60}Co gammas. Therefore, the spectrum of the activated thimble plugs is not decay time sensitive. As a result of the dominant ^{60}Co contribution, the burnup/cool-time loading table reflects the cool time increase required to decay to a limiting ^{60}Co curie content for each assembly type at each burnup level. System users may choose to directly implement the burnup/cool-time tables on a generic fuel type basis or to determine site-specific minimum thimble plug cool times based on the ^{60}Co curie limit in Table 5.8.5-5.

Maximum and average dose rate contributions from thimble plugs on the concrete and transfer cask surfaces are listed in Table 5.8.5-6. The concrete cask axial profile for the thimble plugs is shown in Figure 5.8.5-3. The addition of the thimble plugs does not increase the maximum reported dose rates, as demonstrated in Figure 5.8.5-4 for a Westinghouse 14×14 assembly.

The maximum decay heat produced by a full cask load of thimble plugs (37) is 0.04 kW. For any of the fuel assemblies evaluated, an increase in cool time, shown in Table 5.8.5-7, is necessary to accommodate loading the thimble plugs. An increase in cool time will also decrease the fuel source term. Therefore, the strict application of increased fuel assembly minimum cool time without considering the corresponding reduction in fuel dose rates is conservative.

5.8.5.2.3 Combination of Fuel, BPRA, and Thimble Plug Dose Rates

Maximum PWR system dose rates are reported for the conservative combination of fuel, BPRA, and thimble plug dose rates. At each cask/detector surface combination, with the exception of the concrete and transfer cask sides, this combination is straightforward based on the hardware sources being the dominant contributor to the total. On the sides of the casks, the fuel sources comprise most of the total, and the elevation of the maximum dose rate due to fuel, BPRA, and thimble plug may not coincide. As shown in the previous sections, BPRA loading affects the maximum dose rate while thimble plugs do not.

The combined maxima are listed as follows.

Cask / Dose Location	Fuel		Combined	
	Assembly	Max. Dose Rate (mrem/hr)	Assembly	Max. Dose Rate (mrem/hr)
Standard Shield Concrete Cask Top	CE 16×16	378	CE 16×16	378
Standard Shield Concrete Cask Radial	CE 14×14	76.7	WE 14×14	79.3
Standard Shield Concrete Cask Inlet	WE 14×14	425	WE 14×14	434
Standard Shield Concrete Cask Outlet	CE 16×16	38.3	CE 16×16	38.3
Carbon Steel Transfer Cask Top	WE 14×14	451	WE 14×14	546
Carbon Steel Transfer Cask Radial	CE 14×14	939	WE 14×14	942
Carbon Steel Transfer Cask Bottom	WE 14×14	5,824	WE 14×14	5,908
Augmented Shield Concrete Cask (CC3) Top	WE 14×14	350	WE 14×14	408
Augmented Shield Concrete Cask (CC3) Radial	CE 14×14	36.5	WE 14×14	37.1
Augmented Shield Concrete Cask (CC3) Inlet	WE 14x14	117	WE 14×14	119
Augmented Shield Concrete Cask (CC3) Outlet	B&W 17×17	21.8	WE 14×14	26.2
Stainless Steel Transfer Cask Top	B&W 17×17	505	WE 14×14	568
Stainless Steel Transfer Cask Radial	CE 14×14	922	WE 14×14	945
Stainless Steel Transfer Cask Bottom	WE 14×14	5,239	WE 14×14	5,326
CC4 Top	WE 14×14	316	WE 14×14	365
CC4 Radial	CE 14×14	76.8	WE 14×14	79.5
CC4 Inlet	WE 14×14	112.4	WE 14×14	115
CC4 Outlet	B&W 17×17	36.8	B&W 17×17	42.8

Table 5.8.5-1 Sample Core Type BPRA Hardware Summary – Westinghouse 15×15 Core

Absorber Type	Regional Stainless Steel/Inconel Mass (kg)		
	Upper End-Fitting	Upper Plenum	Active Fuel
Pyrex (4 rods)	2.14	1.78	2.28
Pyrex (5 rods)	2.16	1.68	2.85
Pyrex (6 rods)	2.18	1.58	3.42
Pyrex (13 rods)	2.33	0.88	7.48
Pyrex (16 rods)	2.39	0.58	9.11
Pyrex (20 rods)	2.47	0.18	11.39
WABA (4 rods)	2.23	2.18	0.00
WABA (6 rods)	2.24	1.91	0.00
WABA (8 rods)	2.26	1.63	0.00
WABA (12 rods)	2.30	1.09	0.00
WABA (16 rods)	2.33	0.54	0.00
Maximum	2.47	2.18	11.39

Table 5.8.5-2 Bounding Regional Nonfuel Hardware Masses

Assembly	Component	Regional Mass (kg)		
		Upper Nozzle	Upper Plenum	Active Fuel
Westinghouse 14×14	Thimble Plug	2.12	2.18	0
	BPRA	2.41	2.07	9.22
Westinghouse 15×15	Thimble Plug	2.19	2.72	0
	BPRA	2.47	2.18	11.39
Westinghouse 17×17	Thimble Plug	2.73	3.16	0
	BPRA	3.04	2.85	10.995
B&W 15×15	Thimble Plug	3.641	3.41	0
	BPRA	3.602	0	0
B&W 17×17	Thimble Plug	3.641	3.41	0
	BPRA	3.602	0	0

Table 5.8.5-3 Allowed BPRA Burnup and Cool-time Combinations

Burnup (GWd/MTU)	Cool Time (yrs)				
	WE 14×14	WE 15×15	B&W 15×15	WE 17×17	B&W 17×17
10	0.5	0.5	0.5	0.5	0.5
15	0.5	0.5	0.5	0.5	0.5
20	0.5	1.0	2.0	2.0	0.5
25	1.0	2.5	3.5	3.5	1.0
30	2.5	4.0	5.0	5.0	2.5
32.5	3.0	4.5	6.0	6.0	3.0
35	3.5	5.0	6.0	6.0	3.5
37.5	4.0	6.0	7.0	7.0	4.0
40	4.5	6.0	7.0	7.0	4.5
45	5.0	7.0	8.0	8.0	6.0
50	6.0	8.0	9.0	9.0	7.0
55	7.0	8.0	10.0	9.0	7.0
60	7.0	9.0	10.0	10.0	8.0
65	8.0	10.0	12.0	12.0	8.0
70	8.0	10.0	12.0	12.0	9.0
^{60}Co Activity (Ci)	718	733	19	637	26

Table 5.8.5-4 BPRA Dose Rate Contributions – Westinghouse 14×14

Cask / Dose Location	Maximum Dose (mrem/hr)	Average Dose (mrem/hr)
Standard Shield Concrete Cask Top	39	9.6
Standard Shield Concrete Cask Radial	7.8	4.9
Standard Shield Concrete Cask Inlet	8.7	--
Standard Shield Concrete Cask Outlet	2.8	--
Carbon Steel Transfer Cask Top	77	23
Carbon Steel Transfer Cask Radial	118	57
Carbon Steel Transfer Cask Bottom	86	47
Augmented Shield Concrete Cask (CC3) Top	52	8.8
Augmented Shield Concrete Cask (CC3) Radial	3.4	2.3
Augmented Shield Concrete Cask (CC3) Inlet	2.2	--
Augmented Shield Concrete Cask (CC3) Outlet	3.3	--
Stainless Steel Transfer Cask Top	83	31
Stainless Steel Transfer Cask Radial	121	57
Stainless Steel Transfer Cask Bottom	86	44
CC4 Top	44.8	9.5
CC4 Radial	7.5	5.0
CC4 Inlet	2.6	--
CC4 Outlet	6.0	--

Table 5.8.5-5 Allowed Thimble Plug Burnup and Cool-time Combinations

Burnup (GWd/MTU)	Cool Time (yrs)				
	WE 14×14	WE 15×15	B&W 15×15	WE 17×17	B&W 17×17
45	2.0	3.5	7.0	5.0	6.0
90	6.0	7.0	10.0	9.0	10.0
135	7.0	9.0	12.0	10.0	12.0
180	8.0	9.0	14.0	12.0	12.0
^{60}Co Activity (Ci)	63.5	64.1	56.9	64.0	63.6

Table 5.8.5-6 Thimble Plug Dose Rate Contributions – Westinghouse 14×14

Cask / Dose Location	Maximum Dose (mrem/hr)	Average Dose (mrem/hr)
Standard Shield Concrete Cask Top	42	11
Standard Shield Concrete Cask Radial	7.3	1.4
Standard Shield Concrete Cask Outlet	3.4	--
Carbon Steel Transfer Cask Top	95	28
Carbon Steel Transfer Cask Radial	152	16
Augmented Shield Concrete Cask (CC3) Top	57	9.9
Augmented Shield Concrete Cask (CC3) Radial	4.0	0.7
Augmented Shield Concrete Cask (CC3) Outlet	4.1	--
Stainless Steel Transfer Cask Top	102	38
Stainless Steel Transfer Cask Radial	154	16
CC4 Top	48.9	10.8
CC4 Radial	8.6	10.8
CC4 Outlet	7.3	--

Table 5.8.5-7 Additional Assembly Cool Time (Years) Required to Load BPRA or TP (Uniform Loading)

	BPRA	TP
CE 14x14[a]	--	--
WE 14x14	0.5	0.1
WE 15x15	0.5	0.1
B&W 15x15	0.1	0.1
CE 16x16[a]	--	--
WE 17x17	0.5	0.1
B&W 17x17	0.1	0.1

[a] BPRAs and TPs are not evaluated for CE fuel.

Figure 5.8.7-1 Schematic of PWR Fuel Preferential Loading Pattern

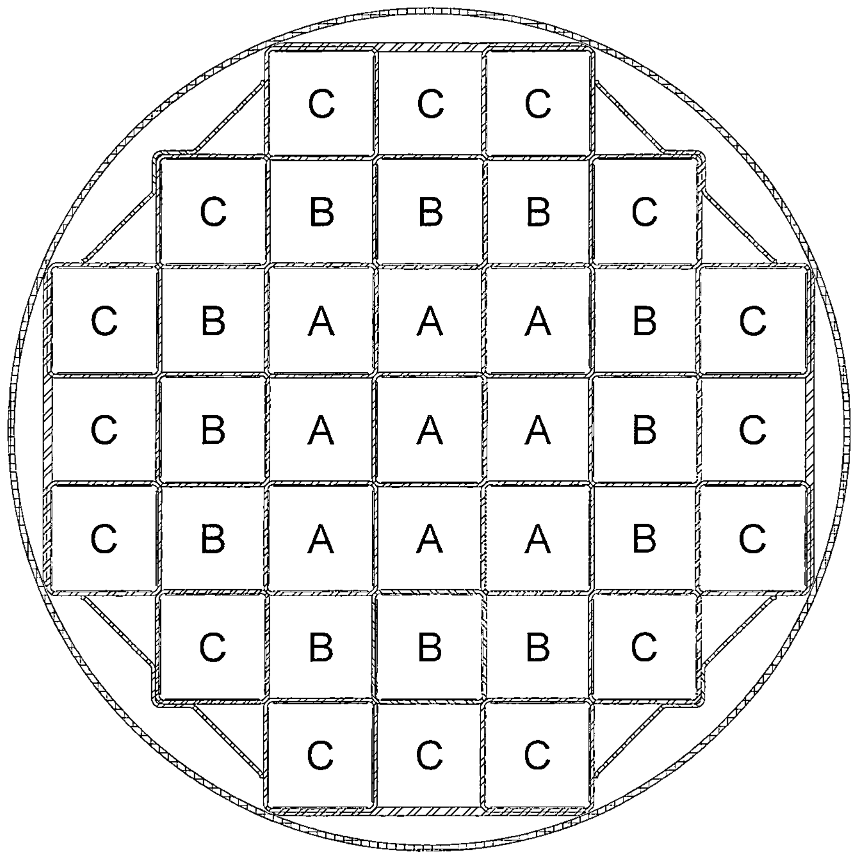

Table 5.8.7-1 Preferential Pattern Dose Rate Results

Cask / Dose Location	Uniform		Preferential	
	Avg. Dose Rate (mrem/hr)	Max. Dose Rate (mrem/hr)	Avg. Dose Rate (mrem/hr)	Max. Dose Rate (mrem/hr)
Augmented Shield Concrete Cask (CC3) Radial	24.7	35.5	22.5	31.9
Augmented Shield Concrete Cask (CC3) Top	56.2	350	50.0	294
Augmented Shield Concrete Cask (CC3) Inlet	--	116.8	--	110.4
Augmented Shield Concrete Cask (CC3) Outlet	--	21.8	--	20.8
Stainless Steel Transfer Cask Radial	683	969	651	899
Stainless Steel Transfer Cask Top	225	509	239	500
Stainless Steel Transfer Cask Bottom	3,034	5,880	2,982	5,964
Standard Shield Concrete Cask Radial	54.4	76.7	47.8	70.6
Standard Shield Concrete Cask Top	82.3	378	77.3	350
Standard Shield Concrete Cask Inlet	--	425	--	410
Standard Shield Concrete Cask Outlet	--	38.3	--	38.8
Carbon Steel Transfer Cask Radial	650	939	615	904
Carbon Steel Transfer Cask Top	172	451	180	433
Carbon Steel Transfer Cask Bottom	2,953	5,824	2,976	5,899
CC4 Radial	52.9	76.8	53.0	77.4
CC4 Top	61.5	315	60.7	308
CC4 Inlet	--	112.4	--	111.4
CC4 Outlet	--	36.8	--	37.3

5.8.8 Sample Input Files

This section contains sample input files for the source term and shielding evaluations.

5.8.8.1 Sample Source Term Input Files

Figure 5.8.8-1 contains a sample PWR SAS2H input file. Figure 5.8.8-2 contains a sample input for the BWR model. The ORIGEN-S decay calculation section of the input file is removed from the BWR input file. The input data is identical to the PWR file.

5.8.8.2 Undamaged Fuel Basket Transfer Cask Sample Shielding Input Files

PWR and BWR sample MCNP5 input files for the carbon steel transfer cask are shown in Figure 5.8.8-3 and Figure 5.8.8-4, respectively. As indicated previously in this chapter, shielding evaluations are performed using the response function method. Only one energy line is therefore defined in the source description. A sample input file for the PWR stainless steel transfer cask, including a full source spectrum, is shown in Figure 5.8.8-9.

5.8.8.3 Undamaged Fuel Basket Concrete Cask Sample Shielding Input Files

PWR and BWR sample MCNP5 input files for the standard shield concrete cask are shown in Figure 5.8.8-5 and Figure 5.8.8-6, respectively. A sample input file for the PWR augmented shield concrete cask (CC3), including a full source spectrum, is shown in Figure 5.8.8-10.

5.8.8.4 Sample NAC-CASC Input Files

Figure 5.8.8-7 contains a sample PWR NAC-CASC model input file. Figure 5.8.8-8 contains a sample input file for the BWR NAC-CASC model. Detector locations are truncated in the sample files.

5.8.8.5 Damaged Fuel Basket Sample Shielding Input Files

Figure 5.8.8-11 and Figure 5.8.8-12 contain sample PWR damaged fuel basket input files for the transfer cask and the concrete cask, respectively.

Figure 5.8.8-1 PWR Fuel Assembly Source Term Sample Input File

```
=SAS2H       PARM=(HALT03,SKIPSHIPDATA)
17a - 3.7 w/o U235, 45000 MWD/MTU, 5 - 16 years cool time
44GROUPNDF5 LATTICECELL
UO2         1 0.950 900 92235 3.7 92238 96.3 END
ZR 2 1.0 620. END
H2O         3 DEN=0.725 1.0 580 END
ARBM-BORMOD 0.725 1 1 0 0 5000 100 3 550.0E-6 580 END
ZR  4 1.0 580 END
H2O         5 DEN=0.725 0.9751 580 END
ZR  5 0.0249 580 END
END COMP
SQUAREPITCH 1.2598 0.8192 1 3 0.9500 2 0.8357 0 END
NPIN=264 FUEL=365.760 NCYC=3 NLIB=1 PRIN=6 LIGH=5
INPL=1 NUMH=24 NUMI=1 MXTUBE=4 ORTU=0.6121 SRTU=0.5740 END
' Path B not used
POWER=18.5535 BURN=377.6050 DOWN=60 END
POWER=18.5535 BURN=377.6050 DOWN=60 END
POWER=18.5535 BURN=377.6050 DOWN=1461 END
' Cycle not used
' Cycle not used
FE 0.6738 CR 0.1900 NI 0.1150 MN 0.0200 CO 0.0012
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 YEARS AND FISSION PRODUCT GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 9 A13 -2 5 3 E
57**  4.0 E T
COOLING 5 - 16 YEARS AND FISSION PRODUCT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 5.0 6.0 7.0 8.0 9.0 10.0 12.0 14.0 16.0
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
81$$  2 51 26 1 E
82$$  F6
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
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FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 YEARS AND ACTINIDE GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 9 A13 -2 5 3 E
57**  4.0 E T
COOLING 5 - 16 YEARS AND ACTINIDE GAMMA REBIN
SINGLE REACTOR ASSEMBLY
```

Figure 5.8.8-9 Stainless Steel Transfer Cask Sample Input File – PWR TSC (cont'd)

```
*TR8 0.0 0.0 0.0 45.000 135.000 90 -45.000 45.000 90 90 90 0
C 50.625 degree rotation around z-axis
*TR9 0.0 0.0 0.0 50.625 140.625 90 -39.375 50.625 90 90 90 0
C 56.25 degree rotation around z-axis
*TR10 0.0 0.0 0.0 56.250 146.250 90 -33.750 56.250 90 90 90 0
C 61.875 degree rotation around z-axis
*TR11 0.0 0.0 0.0 61.875 151.875 90 -28.125 61.875 90 90 90 0
C 67.5 degree rotation around z-axis
*TR12 0.0 0.0 0.0 67.500 157.500 90 -22.500 67.500 90 90 90 0
C 73.125 degree rotation around z-axis
*TR13 0.0 0.0 0.0 73.125 163.125 90 -16.875 73.125 90 90 90 0
C 78.75 degree rotation around z-axis
*TR14 0.0 0.0 0.0 78.750 168.750 90 -11.250 78.750 90 90 90 0
C 84.375 degree rotation around z-axis
*TR15 0.0 0.0 0.0 84.375 174.375 90 -5.625 84.375 90 90 90 0
C 95.625 degree rotation around z-axis
*TR16 0.0 0.0 0.0 95.625 185.625 90 5.625 95.625 90 90 90 0
C 101.25 degree rotation around z-axis
*TR17 0.0 0.0 0.0 101.250 191.250 90 11.250 101.250 90 90 90 0
C 106.875 degree rotation around z-axis
*TR18 0.0 0.0 0.0 106.875 196.875 90 16.875 106.875 90 90 90 0
C 112.5 degree rotation around z-axis
*TR19 0.0 0.0 0.0 112.500 202.500 90 22.500 112.500 90 90 90 0
C 118.125 degree rotation around z-axis
*TR20 0.0 0.0 0.0 118.125 208.125 90 28.125 118.125 90 90 90 0
C 123.75 degree rotation around z-axis
*TR21 0.0 0.0 0.0 123.750 213.750 90 33.750 123.750 90 90 90 0
C 129.375 degree rotation around z-axis
*TR22 0.0 0.0 0.0 129.375 219.375 90 39.375 129.375 90 90 90 0
C 135 degree rotation around z-axis
*TR23 0.0 0.0 0.0 135.000 225.000 90 45.000 135.000 90 90 90 0
C 140.625 degree rotation around z-axis
*TR24 0.0 0.0 0.0 140.625 230.625 90 50.625 140.625 90 90 90 0
C 146.25 degree rotation around z-axis
*TR25 0.0 0.0 0.0 146.250 236.250 90 56.250 146.250 90 90 90 0
C 151.875 degree rotation around z-axis
*TR26 0.0 0.0 0.0 151.875 241.875 90 61.875 151.875 90 90 90 0
C 157.5 degree rotation around z-axis
*TR27 0.0 0.0 0.0 157.500 247.500 90 67.500 157.500 90 90 90 0
C 163.125 degree rotation around z-axis
*TR28 0.0 0.0 0.0 163.125 253.125 90 73.125 163.125 90 90 90 0
C 168.75 degree rotation around z-axis
*TR29 0.0 0.0 0.0 168.750 258.750 90 78.750 168.750 90 90 90 0
C 174.375 degree rotation around z-axis
*TR30 0.0 0.0 0.0 174.375 264.375 90 84.375 174.375 90 90 90 0
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC

```
MAGNASTOR Augmented Shield VCC - strShlDryRadFg_ng14b_32b21e4.1y
C Radial Biasing - Fuel Gamma Source
C Fuel Assembly Cells - ng14b - v1.0
1 1 -2.5071 -1     u=6 $ Lower Nozzle
2 2 -2.7253 -2 +1    u=6 $ Lower Plenum
3 3 -3.9171 -3 +2    u=6 $ Fuel
4 4 -1.0067 -4 +3    u=6 $ Upper Plenum
5 5 -2.8608 -5 +4    u=6 $ Upper Nozzle
6 0         +5     u=6 $ Outside
C Cells - Fuel Tube  v1.0
7 8 -7.8212 -8 +7    u=5 $ Tube
8 0          #7  -6    u=5 $ Outside below PFE
9 0          #7  +6    u=5 $ Outside above PFE
C Cells - PWR Basket v1.0
10 0          -9 -10 fill=5 trcl = ( -23.5331 70.5993 0.0000 )    u=4 $ Assy loc 1
11 like 10 but fill=5 trcl = ( 23.5331 70.5993 0.0000 )    u=4 $ Assy loc 3
12 like 10 but fill=5 trcl = ( -47.0662 47.0662 0.0000 )    u=4 $ Assy loc 4
13 like 10 but fill=5 trcl = ( 0.0000 47.0662 0.0000 )    u=4 $ Assy loc 6
14 like 10 but fill=5 trcl = ( 47.0662 47.0662 0.0000 )    u=4 $ Assy loc 8
15 like 10 but fill=5 trcl = ( -70.5993 23.5331 0.0000 )    u=4 $ Assy loc 9
16 like 10 but fill=5 trcl = ( -23.5331 23.5331 0.0000 )    u=4 $ Assy loc 11
17 like 10 but fill=5 trcl = ( 23.5331 23.5331 0.0000 )    u=4 $ Assy loc 13
18 like 10 but fill=5 trcl = ( 70.5993 23.5331 0.0000 )    u=4 $ Assy loc 15
19 like 10 but fill=5 trcl = ( -47.0662 0.0000 0.0000 )    u=4 $ Assy loc 17
20 like 10 but fill=5 trcl = ( 0.0000 0.0000 0.0000 )    u=4 $ Assy loc 19
21 like 10 but fill=5 trcl = ( 47.0662 0.0000 0.0000 )    u=4 $ Assy loc 21
22 like 10 but fill=5 trcl = ( -70.5993 -23.5331 0.0000 )    u=4 $ Assy loc 23
23 like 10 but fill=5 trcl = ( -23.5331 -23.5331 0.0000 )    u=4 $ Assy loc 25
24 like 10 but fill=5 trcl = ( 23.5331 -23.5331 0.0000 )    u=4 $ Assy loc 27
25 like 10 but fill=5 trcl = ( 70.5993 -23.5331 0.0000 )    u=4 $ Assy loc 29
26 like 10 but fill=5 trcl = ( -47.0662 -47.0662 0.0000 )    u=4 $ Assy loc 30
27 like 10 but fill=5 trcl = ( 0.0000 -47.0662 0.0000 )    u=4 $ Assy loc 32
28 like 10 but fill=5 trcl = ( 47.0662 -47.0662 0.0000 )    u=4 $ Assy loc 34
29 like 10 but fill=5 trcl = ( -23.5331 -70.5993 0.0000 )    u=4 $ Assy loc 35
30 like 10 but fill=5 trcl = ( 23.5331 -70.5993 0.0000 )    u=4 $ Assy loc 37
31 8 -7.8212 -11 #18 #25      u=4 $ Side support +x
32 8 -7.8212 -12 #15 #22      u=4 $ Side support -x
33 8 -7.8212 -13 #10 #11      u=4 $ Side support +y
34 8 -7.8212 -14 #29 #30      u=4 $ Side support -y
35 8 -7.8212 -15 +16 +17      u=4 $ Corner
36 8 -7.8212 -17 +18 +16  +11.2 +12.1 +13.4 +14.3
             #10 #11 #15 #18 #22 #25 #29 #30       u=4 $ Corner diagonal
37 0         -6 #10 #11 #12 #13 #14 #15 #16 #17 #18 #19 #20
                #21 #22 #23 #24 #25 #26 #27 #28 #29 #30
                #31 #32 #33 #34 #35 #36      u=4 $ Basket below PFE
38 0         +6 #10 #11 #12 #13 #14 #15 #16 #17 #18 #19 #20
               #21 #22 #23 #24 #25 #26 #27 #28 #29 #30
               #31 #32 #33 #34 #35 #36      u=4 $ Basket above PFE
C Cells - PWR Canister Cavity v1.0
39 0          -19 fill=6 trcl = ( -23.5331 70.5993 0.0000 )    u=3 $ Assy loc 1
40 like 39 but fill=6 trcl = ( 0.0000 70.5993 0.0000 )    u=3 $ Assy loc 2
41 like 39 but fill=6 trcl = ( 23.5331 70.5993 0.0000 )    u=3 $ Assy loc 3
42 like 39 but fill=6 trcl = ( -47.0662 47.0662 0.0000 )    u=3 $ Assy loc 4
43 like 39 but fill=6 trcl = ( -23.5331 47.0662 0.0000 )    u=3 $ Assy loc 5
44 like 39 but fill=6 trcl = ( 0.0000 47.0662 0.0000 )    u=3 $ Assy loc 6
45 like 39 but fill=6 trcl = ( 23.5331 47.0662 0.0000 )    u=3 $ Assy loc 7
46 like 39 but fill=6 trcl = ( 47.0662 47.0662 0.0000 )    u=3 $ Assy loc 8
47 like 39 but fill=6 trcl = ( -70.5993 23.5331 0.0000 )    u=3 $ Assy loc 9
48 like 39 but fill=6 trcl = ( -47.0662 23.5331 0.0000 )    u=3 $ Assy loc 10
49 like 39 but fill=6 trcl = ( -23.5331 23.5331 0.0000 )    u=3 $ Assy loc 11
50 like 39 but fill=6 trcl = ( 0.0000 23.5331 0.0000 )    u=3 $ Assy loc 12
51 like 39 but fill=6 trcl = ( 23.5331 23.5331 0.0000 )    u=3 $ Assy loc 13
52 like 39 but fill=6 trcl = ( 47.0662 23.5331 0.0000 )    u=3 $ Assy loc 14
53 like 39 but fill=6 trcl = ( 70.5993 23.5331 0.0000 )    u=3 $ Assy loc 15
54 like 39 but fill=6 trcl = ( -70.5993 0.0000 0.0000 )    u=3 $ Assy loc 16
55 like 39 but fill=6 trcl = ( -47.0662 0.0000 0.0000 )    u=3 $ Assy loc 17
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
56 like 39 but fill=6 trcl = ( -23.5331 0.0000 0.0000 )    u=3 $ Assy loc 18
57 like 39 but fill=6 trcl = ( 0.0000 0.0000 0.0000 )    u=3 $ Assy loc 19
58 like 39 but fill=6 trcl = ( 23.5331 0.0000 0.0000 )    u=3 $ Assy loc 20
59 like 39 but fill=6 trcl = ( 47.0662 0.0000 0.0000 )    u=3 $ Assy loc 21
60 like 39 but fill=6 trcl = ( 70.5993 0.0000 0.0000 )    u=3 $ Assy loc 22
61 like 39 but fill=6 trcl = ( -70.5993 -23.5331 0.0000 )    u=3 $ Assy loc 23
62 like 39 but fill=6 trcl = ( -47.0662 -23.5331 0.0000 )    u=3 $ Assy loc 24
63 like 39 but fill=6 trcl = ( -23.5331 -23.5331 0.0000 )    u=3 $ Assy loc 25
64 like 39 but fill=6 trcl = ( 0.0000 -23.5331 0.0000 )    u=3 $ Assy loc 26
65 like 39 but fill=6 trcl = ( 23.5331 -23.5331 0.0000 )    u=3 $ Assy loc 27
66 like 39 but fill=6 trcl = ( 47.0662 -23.5331 0.0000 )    u=3 $ Assy loc 28
67 like 39 but fill=6 trcl = ( 70.5993 -23.5331 0.0000 )    u=3 $ Assy loc 29
68 like 39 but fill=6 trcl = ( -47.0662 -47.0662 0.0000 )    u=3 $ Assy loc 30
69 like 39 but fill=6 trcl = ( -23.5331 -47.0662 0.0000 )    u=3 $ Assy loc 31
70 like 39 but fill=6 trcl = ( 0.0000 -47.0662 0.0000 )    u=3 $ Assy loc 32
71 like 39 but fill=6 trcl = ( 23.5331 -47.0662 0.0000 )    u=3 $ Assy loc 33
72 like 39 but fill=6 trcl = ( 47.0662 -47.0662 0.0000 )    u=3 $ Assy loc 34
73 like 39 but fill=6 trcl = ( -23.5331 -70.5993 0.0000 )    u=3 $ Assy loc 35
74 like 39 but fill=6 trcl = ( 0.0000 -70.5993 0.0000 )    u=3 $ Assy loc 36
75 like 39 but fill=6 trcl = ( 23.5331 -70.5993 0.0000 )    u=3 $ Assy loc 37
76 0         #39 #40 #41 #42 #43 #44 #45 #46 #47 #48 #49 #50 #51
             #52 #53 #54 #55 #56 #57 #58 #59 #60 #61 #62 #63 #64
             #65 #66 #67 #68 #69 #70 #71 #72 #73 #74 #75      fill=4 u=3 $ Cavity
C Cells - Canister v1.0
77 0         -20 fill=3      u=2 $ Cavity
78 7 -7.9400 -27 +20.3      u=2 $ Canister Bottom
79 7 -7.9400 -21 +20.2 -24 trcl = ( 62.7565 43.1314 0.0000 )    u=2 $ Bottom Drain Port
80 7 -7.9400 -22 +24 -26 trcl = ( 62.7565 43.1314 0.0000 )    u=2 $ Middle Drain Port
81 7 -7.9400 -23 +26 -27.2 trcl = ( 62.7565 43.1314 0.0000 )    u=2 $ Top Drain Port
82 like 79 but   trcl = ( -62.7565 -43.1314 0.0000 )    u=2 $ Bottom Vent Port
83 like 80 but   trcl = ( -62.7565 -43.1314 0.0000 )    u=2 $ Middle Vent Port
84 like 81 but   trcl = ( -62.7565 -43.1314 0.0000 )    u=2 $ Top Vent Port
85 7 -7.9400 -27 -20.3 +20.1     u=2 $ Canister Shell
86 8 -7.8212 -27 -20.1 +20.2 -25 #79 #80  #82 #83   u=2 $ Lower lid
87 7 -7.9400 -27 -20.1 +25 #80 #81  #83 #84    u=2 $ Upper lid
88 0         +27       u=2 $ Outside
C VCC Cells - v1.1_ng14b
89 8 -7.8212 -28       u=1 $ Pedestal plate
90 8 -7.8212 -29 +30      u=1 $ Stand
91 8 -7.8212 -35 +36 +42 +43     u=1 $ Bottom plate outer
92 8 -7.8212 (-36 +37 -31) : (-36 +37 -32)       u=1 $ Bottom plate connector
93 8 -7.8212 -37       u=1 $ Bottom plate inner
94 8 -7.8212 (-30 -57 +58 -39) : (-30 -55 +56 +57 -39)       u=1 $ Support rail inside
stand
95 8 -7.8212 (+29 -57 +58 -38) : (+29 -55 +56 +57 -38)       u=1 $ Support rail outside
stand
96 8 -7.8212 (-47 +49 +31 +32 -40) :
             (-48 +49 +31 +32 -40 +47)       u=1 $ Air inlet top
97 8 -7.8212 (-44 +42 +46 -40 +31 +32 +35) :
             (-45 +43 +46 -40 +31 +32 +35)       u=1 $ Air inlet wall
98 8 -7.8212 (-31 +33 +29 -40 +35) : (-32 +34 +29 -40 +35)       u=1 $ Air inlet angular
wall
99 8 -7.8212 (-46 -44 +42 +31 +32 +43 +35) :
             (-46 -45 +43 +31 +32 +42 +35)       u=1 $ Air inlet remaining wall
100 8 -7.8212 -50 +52 +39 -40    u=1 $ Air outlet steel X
101 8 -7.8212 -51 +53 +39 -40    u=1 $ Air outlet steel Y
102 12 -2.3234 -40 +38 +31 +32 +35 +47 +48 +44 +45 +41 +59 +50 +51
              fill=7 u=1 $ Concrete
103 12 -2.3234 -41       u=1 $ Concrete pad
104 8 -7.8212 -38 +39 +50 +51 +55 +57  u=1 $ Liner
105 8 -7.8212 -59 +60      u=1 $ Top flange
106 0         -59 -60 +62      u=1 $ Flange void
107 8 -7.8212 -61       u=1 $ Lid top
108 8 -7.8212 -62 +64      u=1 $ Lid middle steel A
109 8 -7.8212 -62 -64 -66 +65    u=1 $ Lid middle steel B
110 12 -2.2432 (-62 -64 +66):(-62 -65 -66)       u=1 $ Lid middle concrete
111 8 -7.8212 -63 +65      u=1 $ Lid bottom steel A
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
112 8 -7.8212 -63 -65 -67      u=1 $ Lid bottom steel B
113 12 -2.2432 -63 -65 +67     u=1 $ Lid bottom concrete
114 8 -7.8212 (-68 +80 -39) :
              (-69 +81 -39) :
              (-70 +82 -39) :
              (-71 +83 -39) :
              (-72 +84 -39) :
              (-73 +85 -39) :
              (-74 +86 -39) :
              (-75 +87 -39) :
              (-76 +88 -39) :
              (-77 +89 -39) :
              (-78 +90 -39) :
              (-79 +91 -39)       u=1 $ Standoffs
115 8 -7.8212 -92       u=1 $ -x inlet pipe 1
116 8 -7.8212 -93       u=1 $ -x inlet pipe 2
117 8 -7.8212 -94       u=1 $ -x inlet pipe 3
118 8 -7.8212 -95       u=1 $ -x inlet pipe 4
119 8 -7.8212 -96       u=1 $ -x inlet pipe 5
120 8 -7.8212 -97       u=1 $ -x inlet pipe 6
121 8 -7.8212 -98       u=1 $ -x inlet pipe 7
122 8 -7.8212 -99       u=1 $ -x inlet pipe 8
123 8 -7.8212 -100       u=1 $ -x inlet pipe 9
124 8 -7.8212 -101       u=1 $ -x inlet pipe 10
125 8 -7.8212 -102       u=1 $ -x inlet pipe 11
126 8 -7.8212 -103       u=1 $ -x inlet pipe 12
127 8 -7.8212 -104       u=1 $ -x inlet pipe 13
128 8 -7.8212 -105       u=1 $ -x inlet pipe 14
129 8 -7.8212 -106       u=1 $ -x inlet pipe 15
130 8 -7.8212 -107       u=1 $ -x inlet pipe 16
131 8 -7.8212 -108       u=1 $ -x inlet pipe 17
132 8 -7.8212 -109       u=1 $ +x inlet pipe 1
133 8 -7.8212 -110       u=1 $ +x inlet pipe 2
134 8 -7.8212 -111       u=1 $ +x inlet pipe 3
135 8 -7.8212 -112       u=1 $ +x inlet pipe 4
136 8 -7.8212 -113       u=1 $ +x inlet pipe 5
137 8 -7.8212 -114       u=1 $ +x inlet pipe 6
138 8 -7.8212 -115       u=1 $ +x inlet pipe 7
139 8 -7.8212 -116       u=1 $ +x inlet pipe 8
140 8 -7.8212 -117       u=1 $ +x inlet pipe 9
141 8 -7.8212 -118       u=1 $ +x inlet pipe 10
142 8 -7.8212 -119       u=1 $ +x inlet pipe 11
143 8 -7.8212 -120       u=1 $ +x inlet pipe 12
144 8 -7.8212 -121       u=1 $ +x inlet pipe 13
145 8 -7.8212 -122       u=1 $ +x inlet pipe 14
146 8 -7.8212 -123       u=1 $ +x inlet pipe 15
147 8 -7.8212 -124       u=1 $ +x inlet pipe 16
148 8 -7.8212 -125       u=1 $ +x inlet pipe 17
149 8 -7.8212 -126       u=1 $ -y inlet pipe 1
150 8 -7.8212 -127       u=1 $ -y inlet pipe 2
151 8 -7.8212 -128       u=1 $ -y inlet pipe 3
152 8 -7.8212 -129       u=1 $ -y inlet pipe 4
153 8 -7.8212 -130       u=1 $ -y inlet pipe 5
154 8 -7.8212 -131       u=1 $ -y inlet pipe 6
155 8 -7.8212 -132       u=1 $ -y inlet pipe 7
156 8 -7.8212 -133       u=1 $ -y inlet pipe 8
157 8 -7.8212 -134       u=1 $ -y inlet pipe 9
158 8 -7.8212 -135       u=1 $ -y inlet pipe 10
159 8 -7.8212 -136       u=1 $ -y inlet pipe 11
160 8 -7.8212 -137       u=1 $ -y inlet pipe 12
161 8 -7.8212 -138       u=1 $ -y inlet pipe 13
162 8 -7.8212 -139       u=1 $ -y inlet pipe 14
163 8 -7.8212 -140       u=1 $ -y inlet pipe 15
164 8 -7.8212 -141       u=1 $ -y inlet pipe 16
165 8 -7.8212 -142       u=1 $ -y inlet pipe 17
166 8 -7.8212 -143       u=1 $ +y inlet pipe 1
167 8 -7.8212 -144       u=1 $ +y inlet pipe 2
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
168 8 -7.8212 -145       u=1 $ +y inlet pipe 3
169 8 -7.8212 -146       u=1 $ +y inlet pipe 4
170 8 -7.8212 -147       u=1 $ +y inlet pipe 5
171 8 -7.8212 -148       u=1 $ +y inlet pipe 6
172 8 -7.8212 -149       u=1 $ +y inlet pipe 7
173 8 -7.8212 -150       u=1 $ +y inlet pipe 8
174 8 -7.8212 -151       u=1 $ +y inlet pipe 9
175 8 -7.8212 -152       u=1 $ +y inlet pipe 10
176 8 -7.8212 -153       u=1 $ +y inlet pipe 11
177 8 -7.8212 -154       u=1 $ +y inlet pipe 12
178 8 -7.8212 -155       u=1 $ +y inlet pipe 13
179 8 -7.8212 -156       u=1 $ +y inlet pipe 14
180 8 -7.8212 -157       u=1 $ +y inlet pipe 15
181 8 -7.8212 -158       u=1 $ +y inlet pipe 16
182 8 -7.8212 -159       u=1 $ +y inlet pipe 17
183 0           -35 +36 -42 +93 +96 +110 +113
                +92 +93 +94 +95 +96 +97 +98
                +99 +100 +101 +102 +103 +104 +105
                +106 +107 +108 +109 +110 +111 +112
                +113 +114 +115 +116 +117 +118 +119
                +120 +121 +122 +123 +124 +125       u=1 $ Bottom plate outer void x
184 0           -35 +36 -43 +115 +118 +120 +123
                +126 +127 +128 +129 +130 +131 +132
                +133 +134 +135 +136 +137 +138 +139
                +140 +141 +142 +143 +144 +145 +146
                +147 +148 +149 +150 +151 +152 +153
                +154 +155 +156 +157 +158 +159       u=1 $ Bottom plate outer void y
185 0           -36 +37 +31 +32    u=1 $ Bottom plate connector void
186 0           (-30 -58 -39) : (-30 -56 +57 -39)       u=1 $ Support rail inside stand
void
187 0           (+29 -58 -38) : (+29 -56 +57 -38)       u=1 $ Support rail outside stand
void
188 0           -42 +29 +31 +32 -40 +35
                +92 +93 +94 +95 +96 +97 +98
                +99 +100 +101 +102 +103 +104 +105
                +106 +107 +108 +109 +110 +111 +112
                +113 +114 +115 +116 +117 +118 +119
                +120 +121 +122 +123 +124 +125       u=1 $ Air inlet void x
189 0           -43 +29 +31 +32 -40 +35 +42
                +126 +127 +128 +129 +130 +131 +132
                +133 +134 +135 +136 +137 +138 +139
                +140 +141 +142 +143 +144 +145 +146
                +147 +148 +149 +150 +151 +152 +153
                +154 +155 +156 +157 +158 +159       u=1 $ Air inlet void y
190 0           -49 +29 +31 +32       u=1 $ Air inlet top void
191 0           (-33 +35 +29) : (-34 +35 +29)       u=1 $ Connector void
192 0           -30 +55 +57       u=1 $ Stand void
193 0           -52 +39 -40     u=1 $ Air outlet void X
194 0           -53 +39 -40     u=1 $ Air outlet void Y
195 0           -39 +28 +29 +55 +57 +62 +63 #114
                fill=2 ( 0.0000 0.0000 6.9850 )       u=1 $ Cavity
196 0           +40 +38 +59 +61    u=1 $ Outside
C VCC Rebar Cells - v1.1_ng14b
197 8 -7.8212 -160       u=7 $ Outer hoop 1
198 8 -7.8212 -161       u=7 $ Outer hoop 2
199 8 -7.8212 -162       u=7 $ Outer hoop 3
200 8 -7.8212 -163       u=7 $ Outer hoop 4
201 8 -7.8212 -164       u=7 $ Outer hoop 5
202 8 -7.8212 -165       u=7 $ Outer hoop 6
203 8 -7.8212 -166       u=7 $ Outer hoop 7
204 8 -7.8212 -167       u=7 $ Outer hoop 8
205 8 -7.8212 -168       u=7 $ Outer hoop 9
206 8 -7.8212 -169       u=7 $ Outer hoop 10
207 8 -7.8212 -170       u=7 $ Outer hoop 11
208 8 -7.8212 -171       u=7 $ Outer hoop 12
209 8 -7.8212 -172       u=7 $ Outer hoop 13
210 8 -7.8212 -173       u=7 $ Outer hoop 14
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
211 8 -7.8212 -174       u=7 $ Outer hoop 15
212 8 -7.8212 -175       u=7 $ Outer hoop 16
213 8 -7.8212 -176       u=7 $ Outer hoop 17
214 8 -7.8212 -177       u=7 $ Outer hoop 18
215 8 -7.8212 -178       u=7 $ Outer hoop 19
216 8 -7.8212 -179       u=7 $ Outer hoop 20
217 8 -7.8212 -180       u=7 $ Outer hoop 21
218 8 -7.8212 -181       u=7 $ Outer hoop 22
219 8 -7.8212 -182       u=7 $ Outer hoop 23
220 8 -7.8212 -183       u=7 $ Outer hoop 24
221 8 -7.8212 -184       u=7 $ Outer hoop 25
222 8 -7.8212 -185       u=7 $ Outer hoop 26
223 8 -7.8212 -186       u=7 $ Outer hoop 27
224 8 -7.8212 -187       u=7 $ Outer hoop 28
225 8 -7.8212 -188       u=7 $ Outer hoop 29
226 8 -7.8212 -189       u=7 $ Outer hoop 30
227 8 -7.8212 -190       u=7 $ Outer hoop 31
228 8 -7.8212 -191       u=7 $ Outer hoop 32
229 8 -7.8212 -192       u=7 $ Outer hoop 33
230 8 -7.8212 -193       u=7 $ Outer hoop 34
231 8 -7.8212 -194       u=7 $ Outer hoop 35
232 8 -7.8212 -195       u=7 $ Outer hoop 36
233 8 -7.8212 -196       u=7 $ Outer hoop 37
234 8 -7.8212 -197       u=7 $ Outer hoop 38
235 8 -7.8212 -198       u=7 $ Outer hoop 39
236 8 -7.8212 -199       u=7 $ Outer hoop 40
237 8 -7.8212 -200       u=7 $ Outer hoop 41
238 8 -7.8212 -201       u=7 $ Outer hoop 42
239 8 -7.8212 -202       u=7 $ Outer hoop 43
240 8 -7.8212 -203       u=7 $ Outer hoop 44
241 8 -7.8212 -204       u=7 $ Outer hoop 45
242 8 -7.8212 -205       u=7 $ Outer hoop 46
243 8 -7.8212 -206       u=7 $ Outer hoop 47
244 8 -7.8212 -207       u=7 $ Outer hoop 48
245 12 -2.3234 #197 #198 #199 #200 #201 #202 #203        $ Concrete
        #204 #205 #206 #207 #208 #209 #210 #211 #212 #213
        #214 #215 #216 #217 #218 #219 #220 #221 #222 #223
        #224 #225 #226 #227 #228 #229 #230 #231 #232 #233
        #234 #235 #236 #237 #238 #239 #240 #241 #242 #243
        #244      fill=8 u=7
246 8 -7.8212 -208   trcl = ( 160.3375 0.0000 0.0000 )    u=8 $ Outer bar 1
247 like 246 but   trcl = ( 159.3293 17.9521 0.0000 )    u=8 $ Outer bar 2
248 like 246 but   trcl = ( 156.3175 35.6785 0.0000 )    u=8 $ Outer bar 3
249 like 246 but   trcl = ( 151.3399 52.9561 0.0000 )    u=8 $ Outer bar 4
250 like 246 but   trcl = ( 144.4591 69.5678 0.0000 )    u=8 $ Outer bar 5
251 like 246 but   trcl = ( 135.7616 85.3047 0.0000 )    u=8 $ Outer bar 6
252 like 246 but   trcl = ( 125.3569 99.9688 0.0000 )    u=8 $ Outer bar 7
253 like 246 but   trcl = ( 113.3757 113.3757 0.0000 )    u=8 $ Outer bar 8
254 like 246 but   trcl = ( 99.9688 125.3569 0.0000 )    u=8 $ Outer bar 9
255 like 246 but   trcl = ( 85.3047 135.7616 0.0000 )    u=8 $ Outer bar 10
256 like 246 but   trcl = ( 69.5678 144.4591 0.0000 )    u=8 $ Outer bar 11
257 like 246 but   trcl = ( 52.9561 151.3399 0.0000 )    u=8 $ Outer bar 12
258 like 246 but   trcl = ( 35.6785 156.3175 0.0000 )    u=8 $ Outer bar 13
259 like 246 but   trcl = ( 17.9521 159.3293 0.0000 )    u=8 $ Outer bar 14
260 like 246 but   trcl = ( 0.0000 160.3375 0.0000 )    u=8 $ Outer bar 15
261 like 246 but   trcl = ( -17.9521 159.3293 0.0000 )    u=8 $ Outer bar 16
262 like 246 but   trcl = ( -35.6785 156.3175 0.0000 )    u=8 $ Outer bar 17
263 like 246 but   trcl = ( -52.9561 151.3399 0.0000 )    u=8 $ Outer bar 18
264 like 246 but   trcl = ( -69.5678 144.4591 0.0000 )    u=8 $ Outer bar 19
265 like 246 but   trcl = ( -85.3047 135.7616 0.0000 )    u=8 $ Outer bar 20
266 like 246 but   trcl = ( -99.9688 125.3569 0.0000 )    u=8 $ Outer bar 21
267 like 246 but   trcl = ( -113.3757 113.3757 0.0000 )    u=8 $ Outer bar 22
268 like 246 but   trcl = ( -125.3569 99.9688 0.0000 )    u=8 $ Outer bar 23
269 like 246 but   trcl = ( -135.7616 85.3047 0.0000 )    u=8 $ Outer bar 24
270 like 246 but   trcl = ( -144.4591 69.5678 0.0000 )    u=8 $ Outer bar 25
271 like 246 but   trcl = ( -151.3399 52.9561 0.0000 )    u=8 $ Outer bar 26
272 like 246 but   trcl = ( -156.3175 35.6785 0.0000 )    u=8 $ Outer bar 27
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
273 like 246 but   trcl = ( -159.3293 17.9521 0.0000 )    u=8 $ Outer bar 28
274 like 246 but   trcl = ( -160.3375 0.0000 0.0000 )    u=8 $ Outer bar 29
275 like 246 but   trcl = ( -159.3293 -17.9521 0.0000 )    u=8 $ Outer bar 30
276 like 246 but   trcl = ( -156.3175 -35.6785 0.0000 )    u=8 $ Outer bar 31
277 like 246 but   trcl = ( -151.3399 -52.9561 0.0000 )    u=8 $ Outer bar 32
278 like 246 but   trcl = ( -144.4591 -69.5678 0.0000 )    u=8 $ Outer bar 33
279 like 246 but   trcl = ( -135.7616 -85.3047 0.0000 )    u=8 $ Outer bar 34
280 like 246 but   trcl = ( -125.3569 -99.9688 0.0000 )    u=8 $ Outer bar 35
281 like 246 but   trcl = ( -113.3757 -113.3757 0.0000 )    u=8 $ Outer bar 36
282 like 246 but   trcl = ( -99.9688 -125.3569 0.0000 )    u=8 $ Outer bar 37
283 like 246 but   trcl = ( -85.3047 -135.7616 0.0000 )    u=8 $ Outer bar 38
284 like 246 but   trcl = ( -69.5678 -144.4591 0.0000 )    u=8 $ Outer bar 39
285 like 246 but   trcl = ( -52.9561 -151.3399 0.0000 )    u=8 $ Outer bar 40
286 like 246 but   trcl = ( -35.6785 -156.3175 0.0000 )    u=8 $ Outer bar 41
287 like 246 but   trcl = ( -17.9521 -159.3293 0.0000 )    u=8 $ Outer bar 42
288 like 246 but   trcl = ( 0.0000 -160.3375 0.0000 )    u=8 $ Outer bar 43
289 like 246 but   trcl = ( 17.9521 -159.3293 0.0000 )    u=8 $ Outer bar 44
290 like 246 but   trcl = ( 35.6785 -156.3175 0.0000 )    u=8 $ Outer bar 45
291 like 246 but   trcl = ( 52.9561 -151.3399 0.0000 )    u=8 $ Outer bar 46
292 like 246 but   trcl = ( 69.5678 -144.4591 0.0000 )    u=8 $ Outer bar 47
293 like 246 but   trcl = ( 85.3047 -135.7616 0.0000 )    u=8 $ Outer bar 48
294 like 246 but   trcl = ( 99.9688 -125.3569 0.0000 )    u=8 $ Outer bar 49
295 like 246 but   trcl = ( 113.3757 -113.3757 0.0000 )    u=8 $ Outer bar 50
296 like 246 but   trcl = ( 125.3569 -99.9688 0.0000 )    u=8 $ Outer bar 51
297 like 246 but   trcl = ( 135.7616 -85.3047 0.0000 )    u=8 $ Outer bar 52
298 like 246 but   trcl = ( 144.4591 -69.5678 0.0000 )    u=8 $ Outer bar 53
299 like 246 but   trcl = ( 151.3399 -52.9561 0.0000 )    u=8 $ Outer bar 54
300 like 246 but   trcl = ( 156.3175 -35.6785 0.0000 )    u=8 $ Outer bar 55
301 like 246 but   trcl = ( 159.3293 -17.9521 0.0000 )    u=8 $ Outer bar 56
302 12 -2.3234 #246 #247 #248
        #249 #250 #251 #252 #253 #254 #255 #256 #257 #258
        #259 #260 #261 #262 #263 #264 #265 #266 #267 #268
        #269 #270 #271 #272 #273 #274 #275 #276 #277 #278
        #279 #280 #281 #282 #283 #284 #285 #286 #287 #288
        #289 #290 #291 #292 #293 #294 #295 #296 #297 #298
        #299 #300 #301        u=8
C Detector Cells - Radial Biasing
399  0  -399  fill=1  $ Cask
400  0  -400  +399  $ Surface
500  0  -500  +399  +400  $ 1ft
600  0  -600  +399  +400  +500  $ 1m
700  0  -700  +399  +400  +500  +600  $ 2m
800  0  -800  +399  +400  +500  +600  +700  $ 4m
900  0  +399  +400  +500  +600  +700  +800  $ Exterior

C Fuel Assembly Surfaces - ng14b - v1.0
1 RPP -9.8590 9.8590 -9.8590 9.8590 0.0000 8.0975  $ Lower Nozzle
2 RPP -9.8590 9.8590 -9.8590 9.8590 0.0000 9.8374  $ Lower Plenum
3 RPP -9.8590 9.8590 -9.8590 9.8590 0.0000 378.6454  $ Fuel
4 RPP -9.8590 9.8590 -9.8590 9.8590 0.0000 400.3040  $ Upper Plenum
5 RPP -9.8590 9.8590 -9.8590 9.8590 0.0000 409.1940  $ Upper Nozzle
6 PZ 255.7094        $ Flood elevation
C Surfaces - Fuel Tube v1.0
7 RPP -11.6015 11.6015 -11.6015 11.6015 7.6200 439.4200  $ Tube void
8 RPP -12.3952 12.3952 -12.3952 12.3952 7.6200 430.5300  $ Tube
C Surfaces - PWR Basket v1.0
9  RPP -12.3952 12.3952 -12.3952 12.3952 0.0000 439.4200  $ Tube opening
10 9 RPP -16.6370 16.6370 -16.6370 16.6370 0.0000 439.4200  $ Tube radius
11  RPP 81.8833 83.7883 -33.1851 33.1851 7.6200 430.5300  $ Side support +x
12  RPP -83.7883 -81.8833 -33.1851 33.1851 7.6200 430.5300  $ Side support -x
13  RPP -33.1851 33.1851 81.8833 83.7883 7.6200 430.5300  $ Side support +y
14  RPP -33.1851 33.1851 -83.7883 -81.8833 7.6200 430.5300  $ Side support -y
15  RPP -60.2552 60.2552 -60.2552 60.2552 7.6200 430.5300  $ Corner outer
16  RPP -59.4614 59.4614 -59.4614 59.4614 7.6200 430.5300  $ Corner inner
17 9 RPP -78.6267 78.6267 -78.6267 78.6267 7.6200 430.5300  $ Corner dia. outer
18 9 RPP -77.83291 77.8329 -77.83291 77.8329 7.6200 430.5300  $ Corner dia. inner
C Surfaces - PWR Canister Cavity v1.0
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
19 RPP -9.8595 9.8595 -9.8595 9.8595 0.0000 409.1941   $ Assy opening
C Surfaces - Canister v1.0
20 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 439.4200 90.1700   $ Cavity
21 CZ 2.6924          $ Bot Cylinder Radius
22 CZ 6.7691          $ Mid Cyclinder Radius
23 CZ 7.4041          $ Top Cylinder Radius
24 PZ 450.8500          $ Port plane bot/mid
25 PZ 452.1200          $ Lower/upper lid
26 PZ 459.4860          $ Port plane mid/top
27 RCC 0.0000 0.0000 -6.9850 0.0000 0.0000 469.2650 91.4400   $ Canister
C VCC Surfaces - v1.1_ng14b
28  RCC 0.0000 0.0000 -5.0800 0.0000 0.0000 5.0800 91.4401  $ Pedestal plate
29  RCC 0.0000 0.0000 -30.4800 0.0000 0.0000 25.4000 63.4999  $ Stand outer
30  RCC 0.0000 0.0000 -30.4800 0.0000 0.0000 25.4000 62.3888  $ Stand inner
31 9 RPP -100.3300 100.3300 -10.4775 10.4775 -33.0200 -16.5100   $ Connector plate A
32 10 RPP -100.3300 100.3300 -10.4775 10.4775 -33.0200 -16.5100   $ Connector plate B
33 9 RPP -99.0600 99.0600 -9.2075 9.2075 -33.0200 -16.5100   $ Air inlet angled wall A
34 10 RPP -99.0600 99.0600 -9.2075 9.2075 -33.0200 -16.5100   $ Air inlet angled wall B
35  RCC 0.0000 0.0000 -33.0200 0.0000 0.0000 2.5400 172.7200  $ Bottom plate outer
36  RCC 0.0000 0.0000 -33.0200 0.0000 0.0000 2.5400 100.3300  $ Connector radius
37  RCC 0.0000 0.0000 -33.0200 0.0000 0.0000 2.5400 63.5000  $ Bottom plate inner
38  RCC 0.0000 0.0000 -16.5100 0.0000 0.0000 535.4828 108.585  $ VCC liner outer
39  RCC 0.0000 0.0000 -16.5100 0.0000 0.0000 535.4828 100.965  $ VCC liner inner
40  RCC 0.0000 0.0000 -133.0200 0.0000 0.0000 654.5328 172.7200  $ Concrete
41  RCC 0.0000 0.0000 -133.0200 0.0000 0.0000 100.0000 172.7200  $ Concrete pad
42  RPP -172.7200 172.7200 -63.5000 63.5000 -33.0200 -21.5900   $ Air inlet void X
43  RPP -63.5000 63.5000 -172.7200 172.7200 -33.0200 -21.5900   $ Air inlet void Y
44  RPP -172.7200 172.7200 -64.7700 64.7700 -33.0200 -21.5900   $ Air inlet wall X
45  RPP -64.7700 64.7700 -172.7200 172.7200 -33.0200 -21.5900   $ Air inlet wall Y
46  RCC 0.0000 0.0000 -33.0200 0.0000 0.0000 11.4300 100.3300  $ Air inlet divider
47  RPP -172.7200 172.7200 -64.7700 64.7700 -21.5900 -16.5100   $ Air inlet top X
48  RPP -64.7700 64.7700 -172.7200 172.7200 -21.5900 -16.5100   $ Air inlet top Y
49  RCC 0.0000 0.0000 -21.5900 0.0000 0.0000 5.0800 93.9800  $ Air inlet top plate radius
50  RPP -172.7200 172.7200 -64.7700 64.7700 494.3348 504.4948   $ Air outlet steel X
51  RPP -64.7700 64.7700 -172.7200 172.7200 494.3348 504.4948   $ Air outlet steel Y
52  RPP -172.7200 172.7200 -63.5000 63.5000 494.9698 503.8598   $ Air outlet void X
53  RPP -63.5000 63.5000 -172.7200 172.7200 494.9698 503.8598   $ Air outlet void Y
54  CZ 100.3300          $ Air outlet radius
55  RPP -108.5850 108.5850 -5.7150 5.7150 -16.5100 -5.0800   $ Support rail exterior X
56  RPP -108.5850 108.5850 -4.4450 4.4450 -16.5100 -5.0800   $ Support rail interior X
57  RPP -5.7150 5.7150 -108.5850 108.5850 -16.5100 -5.0800   $ Support rail exterior Y
58  RPP -4.4450 4.4450 -108.5850 108.5850 -16.5100 -5.0800   $ Support rail interior Y
59  RCC 0.0000 0.0000 518.9728 0.0000 0.0000 2.5400 118.7450  $ Top flange
60  CZ 102.8700          $ Top flange ID
61  RCC 0.0000 0.0000 521.5128 0.0000 0.0000 1.9050 116.2050  $ Lid top
62  RCC 0.0000 0.0000 506.1458 0.0000 0.0000 15.3670 100.3300  $ Lid middle
63  RCC 0.0000 0.0000 490.9058 0.0000 0.0000 15.2400 76.2000  $ Lid bottom
64  CZ 99.6950          $ Middle concrete radius
65  CZ 75.5650          $ Bottom concrete radius
66  PZ 506.7808          $ Lid middle upper
67  PZ 491.5408          $ Lid bottom upper
68  RPP -100.9650 100.9650 -0.4432 0.4432 172.2628 477.0628   $ Standoff outer 1
69 11 RPP -100.9650 100.9650 -0.4432 0.4432 172.2628 477.0628   $ Standoff outer 2
70 12 RPP -100.9650 100.9650 -0.4432 0.4432 172.2628 477.0628   $ Standoff outer 3
71 9 RPP -100.9650 100.9650 -0.4432 0.4432 172.2628 477.0628   $ Standoff outer 4
72 13 RPP -100.9650 100.9650 -0.4432 0.4432 172.2628 477.0628   $ Standoff outer 5
73 14 RPP -100.9650 100.9650 -0.4432 0.4432 172.2628 477.0628   $ Standoff outer 6
74  RPP -0.4432 0.4432 -100.9650 100.9650 172.2628 477.0628   $ Standoff outer 7
75 11 RPP -0.4432 0.4432 -100.9650 100.9650 172.2628 477.0628   $ Standoff outer 8
76 12 RPP -0.4432 0.4432 -100.9650 100.9650 172.2628 477.0628   $ Standoff outer 9
77 9 RPP -0.4432 0.4432 -100.9650 100.9650 172.2628 477.0628   $ Standoff outer 10
78 13 RPP -0.4432 0.4432 -100.9650 100.9650 172.2628 477.0628   $ Standoff outer 11
79 14 RPP -0.4432 0.4432 -100.9650 100.9650 172.2628 477.0628   $ Standoff outer 12
80  RPP -93.3450 93.3450 -0.4432 0.4432 172.2628 477.0628   $ Standoff inner 1
81 11 RPP -93.3450 93.3450 -0.4432 0.4432 172.2628 477.0628   $ Standoff inner 2
82 12 RPP -93.3450 93.3450 -0.4432 0.4432 172.2628 477.0628   $ Standoff inner 3
83 9 RPP -93.3450 93.3450 -0.4432 0.4432 172.2628 477.0628   $ Standoff inner 4
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
84 13 RPP -93.3450 93.3450 -0.4432 0.4432 172.2628 477.0628   $ Standoff inner 5
85 14 RPP -93.3450 93.3450 -0.4432 0.4432 172.2628 477.0628   $ Standoff inner 6
86  RPP -0.4432 0.4432 -93.3450 93.3450 172.2628 477.0628   $ Standoff inner 7
87 11 RPP -0.4432 0.4432 -93.3450 93.3450 172.2628 477.0628   $ Standoff inner 8
88 12 RPP -0.4432 0.4432 -93.3450 93.3450 172.2628 477.0628   $ Standoff inner 9
89 9 RPP -0.4432 0.4432 -93.3450 93.3450 172.2628 477.0628   $ Standoff inner 10
90 13 RPP -0.4432 0.4432 -93.3450 93.3450 172.2628 477.0628   $ Standoff inner 11
91 14 RPP -0.4432 0.4432 -93.3450 93.3450 172.2628 477.0628   $ Standoff inner 12
92  RCC -146.0500 58.4200 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 1
93  RCC -146.0500 36.5760 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 2
94  RCC -146.0500 14.7320 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 3
95  RCC -146.0500 -7.1120 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 4
96  RCC -146.0500 -28.9560 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 5
97  RCC -146.0500 -50.8000 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 6
98  RCC -133.3500 50.8000 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 7
99  RCC -133.3500 28.9560 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 8
100  RCC -133.3500 7.1120 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 9
101  RCC -133.3500 -14.7320 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 10
102  RCC -133.3500 -36.5760 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 11
103  RCC -133.3500 -58.4200 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 12
104  RCC -120.6500 43.1800 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 13
105  RCC -120.6500 21.3360 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 14
106  RCC -120.6500 -0.5080 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 15
107  RCC -120.6500 -22.3520 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 16
108  RCC -120.6500 -44.1960 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -x inlet pipe 17
109  RCC 146.0500 -58.4200 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 1
110  RCC 146.0500 -36.5760 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 2
111  RCC 146.0500 -14.7320 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 3
112  RCC 146.0500 7.1120 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 4
113  RCC 146.0500 28.9560 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 5
114  RCC 146.0500 50.8000 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 6
115  RCC 133.3500 -50.8000 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 7
116  RCC 133.3500 -28.9560 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 8
117  RCC 133.3500 -7.1120 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 9
118  RCC 133.3500 14.7320 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 10
119  RCC 133.3500 36.5760 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 11
120  RCC 133.3500 58.4200 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 12
121  RCC 120.6500 -43.1800 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 13
122  RCC 120.6500 -21.3360 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 14
123  RCC 120.6500 0.5080 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 15
124  RCC 120.6500 22.3520 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 16
125  RCC 120.6500 44.1960 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +x inlet pipe 17
126  RCC -58.4200 -146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 1
127  RCC -36.5760 -146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 2
128  RCC -14.7320 -146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 3
129  RCC 7.1120 -146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 4
130  RCC 28.9560 -146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 5
131  RCC 50.8000 -146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 6
132  RCC -50.8000 -133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 7
133  RCC -28.9560 -133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 8
134  RCC -7.1120 -133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 9
135  RCC 14.7320 -133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 10
136  RCC 36.5760 -133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 11
137  RCC 58.4200 -133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 12
138  RCC -43.1800 -120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 13
139  RCC -21.3360 -120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 14
140  RCC 0.5080 -120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 15
141  RCC 22.3520 -120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 16
142  RCC 44.1960 -120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ -y inlet pipe 17
143  RCC 58.4200 146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 1
144  RCC 36.5760 146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 2
145  RCC 14.7320 146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 3
146  RCC -7.1120 146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 4
147  RCC -28.9560 146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 5
148  RCC -50.8000 146.0500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 6
149  RCC 50.8000 133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 7
150  RCC 28.9560 133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 8
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
151  RCC 7.1120 133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 9
152  RCC -14.7320 133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 10
153  RCC -36.5760 133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 11
154  RCC -58.4200 133.3500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 12
155  RCC 43.1800 120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 13
156  RCC 21.3360 120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 14
157  RCC -0.5080 120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 15
158  RCC -22.3520 120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 16
159  RCC -44.1960 120.6500 -33.0200 0.0000 0.0000 11.4300 3.8100  $ +y inlet pipe 17
C VCC Rebar Surfaces - v1.1_ng14b
160  TZ 0.0000 0.0000 -1.3218 162.2425 0.9525 0.9525   $ Outer hoop 1
161  TZ 0.0000 0.0000 8.7863 162.2425 0.9525 0.9525   $ Outer hoop 2
162  TZ 0.0000 0.0000 18.8945 162.2425 0.9525 0.9525   $ Outer hoop 3
163  TZ 0.0000 0.0000 29.0027 162.2425 0.9525 0.9525   $ Outer hoop 4
164  TZ 0.0000 0.0000 39.1108 162.2425 0.9525 0.9525   $ Outer hoop 5
165  TZ 0.0000 0.0000 49.2190 162.2425 0.9525 0.9525   $ Outer hoop 6
166  TZ 0.0000 0.0000 59.3271 162.2425 0.9525 0.9525   $ Outer hoop 7
167  TZ 0.0000 0.0000 69.4353 162.2425 0.9525 0.9525   $ Outer hoop 8
168  TZ 0.0000 0.0000 79.5435 162.2425 0.9525 0.9525   $ Outer hoop 9
169  TZ 0.0000 0.0000 89.6516 162.2425 0.9525 0.9525   $ Outer hoop 10
170  TZ 0.0000 0.0000 99.7598 162.2425 0.9525 0.9525   $ Outer hoop 11
171  TZ 0.0000 0.0000 109.8680 162.2425 0.9525 0.9525   $ Outer hoop 12
172  TZ 0.0000 0.0000 119.9761 162.2425 0.9525 0.9525   $ Outer hoop 13
173  TZ 0.0000 0.0000 130.0843 162.2425 0.9525 0.9525   $ Outer hoop 14
174  TZ 0.0000 0.0000 140.1924 162.2425 0.9525 0.9525   $ Outer hoop 15
175  TZ 0.0000 0.0000 150.3006 162.2425 0.9525 0.9525   $ Outer hoop 16
176  TZ 0.0000 0.0000 160.4088 162.2425 0.9525 0.9525   $ Outer hoop 17
177  TZ 0.0000 0.0000 170.5169 162.2425 0.9525 0.9525   $ Outer hoop 18
178  TZ 0.0000 0.0000 180.6251 162.2425 0.9525 0.9525   $ Outer hoop 19
179  TZ 0.0000 0.0000 190.7333 162.2425 0.9525 0.9525   $ Outer hoop 20
180  TZ 0.0000 0.0000 200.8414 162.2425 0.9525 0.9525   $ Outer hoop 21
181  TZ 0.0000 0.0000 210.9496 162.2425 0.9525 0.9525   $ Outer hoop 22
182  TZ 0.0000 0.0000 221.0578 162.2425 0.9525 0.9525   $ Outer hoop 23
183  TZ 0.0000 0.0000 231.1659 162.2425 0.9525 0.9525   $ Outer hoop 24
184  TZ 0.0000 0.0000 241.2741 162.2425 0.9525 0.9525   $ Outer hoop 25
185  TZ 0.0000 0.0000 251.3822 162.2425 0.9525 0.9525   $ Outer hoop 26
186  TZ 0.0000 0.0000 261.4904 162.2425 0.9525 0.9525   $ Outer hoop 27
187  TZ 0.0000 0.0000 271.5986 162.2425 0.9525 0.9525   $ Outer hoop 28
188  TZ 0.0000 0.0000 281.7067 162.2425 0.9525 0.9525   $ Outer hoop 29
189  TZ 0.0000 0.0000 291.8149 162.2425 0.9525 0.9525   $ Outer hoop 30
190  TZ 0.0000 0.0000 301.9231 162.2425 0.9525 0.9525   $ Outer hoop 31
191  TZ 0.0000 0.0000 312.0312 162.2425 0.9525 0.9525   $ Outer hoop 32
192  TZ 0.0000 0.0000 322.1394 162.2425 0.9525 0.9525   $ Outer hoop 33
193  TZ 0.0000 0.0000 332.2476 162.2425 0.9525 0.9525   $ Outer hoop 34
194  TZ 0.0000 0.0000 342.3557 162.2425 0.9525 0.9525   $ Outer hoop 35
195  TZ 0.0000 0.0000 352.4639 162.2425 0.9525 0.9525   $ Outer hoop 36
196  TZ 0.0000 0.0000 362.5720 162.2425 0.9525 0.9525   $ Outer hoop 37
197  TZ 0.0000 0.0000 372.6802 162.2425 0.9525 0.9525   $ Outer hoop 38
198  TZ 0.0000 0.0000 382.7884 162.2425 0.9525 0.9525   $ Outer hoop 39
199  TZ 0.0000 0.0000 392.8965 162.2425 0.9525 0.9525   $ Outer hoop 40
200  TZ 0.0000 0.0000 403.0047 162.2425 0.9525 0.9525   $ Outer hoop 41
201  TZ 0.0000 0.0000 413.1129 162.2425 0.9525 0.9525   $ Outer hoop 42
202  TZ 0.0000 0.0000 423.2210 162.2425 0.9525 0.9525   $ Outer hoop 43
203  TZ 0.0000 0.0000 433.3292 162.2425 0.9525 0.9525   $ Outer hoop 44
204  TZ 0.0000 0.0000 443.4373 162.2425 0.9525 0.9525   $ Outer hoop 45
205  TZ 0.0000 0.0000 453.5455 162.2425 0.9525 0.9525   $ Outer hoop 46
206  TZ 0.0000 0.0000 463.6537 162.2425 0.9525 0.9525   $ Outer hoop 47
207  TZ 0.0000 0.0000 473.7618 162.2425 0.9525 0.9525   $ Outer hoop 48
208  RCC 0.0000 0.0000 -11.4300 0.0000 0.0000 495.3000 0.9525  $ Bar
C Storage Cask & Pad Container
399  RCC  0.0000  0.0000  -133.0200  0.0000  0.0000  656.4378  172.7201
C Radial Detector DRA (Surface)
400  RCC  0.0000  0.0000  -33.0200  0.0000  0.0000  556.5378  172.8201
401  PZ  13.3582
402  PZ  59.7363
403  PZ  106.1145
404  PZ  152.4926
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
405  PZ  198.8708
406  PZ  245.2489
407  PZ  291.6271
408  PZ  338.0052
409  PZ  384.3834
410  PZ  430.7615
411  PZ  477.1397
C Radial Detector DRB (1ft)
500  RCC  0.0000  0.0000  -33.0200  0.0000  0.0000  587.0178  203.3001
501  PZ  15.8982
502  PZ  64.8163
503  PZ  113.7345
504  PZ  162.6526
505  PZ  211.5708
506  PZ  260.4889
507  PZ  309.4071
508  PZ  358.3252
509  PZ  407.2434
510  PZ  456.1615
511  PZ  505.0797
C Radial Detector DRC (1m)
600  RCC  0.0000  0.0000  -33.0200  0.0000  0.0000  656.5378  272.8201
601  PZ  10.7492
602  PZ  54.5184
603  PZ  98.2876
604  PZ  142.0567
605  PZ  185.8259
606  PZ  229.5951
607  PZ  273.3643
608  PZ  317.1335
609  PZ  360.9027
610  PZ  404.6719
611  PZ  448.4411
612  PZ  492.2102
613  PZ  535.9794
614  PZ  579.7486
C Radial Detector DRD (2m)
700  RCC  0.0000  0.0000  -33.0200  0.0000  0.0000  756.5378  372.8201
701  PZ  4.8069
702  PZ  42.6338
703  PZ  80.4607
704  PZ  118.2876
705  PZ  156.1145
706  PZ  193.9413
707  PZ  231.7682
708  PZ  269.5951
709  PZ  307.4220
710  PZ  345.2489
711  PZ  383.0758
712  PZ  420.9027
713  PZ  458.7296
714  PZ  496.5565
715  PZ  534.3834
716  PZ  572.2102
717  PZ  610.0371
718  PZ  647.8640
719  PZ  685.6909
C Radial Detector DRE (4m)
800  RCC  0.0000  0.0000  -33.0200  0.0000  0.0000  956.5378  572.8201
801  PZ  14.8069
802  PZ  62.6338
803  PZ  110.4607
804  PZ  158.2876
805  PZ  206.1145
806  PZ  253.9413
807  PZ  301.7682
808  PZ  349.5951
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
809  PZ  397.4220
810  PZ  445.2489
811  PZ  493.0758
812  PZ  540.9027
813  PZ  588.7296
814  PZ  636.5565
815  PZ  684.3834
816  PZ  732.2102
817  PZ  780.0371
818  PZ  827.8640
819  PZ  875.6909

C
C Materials List - Common Materials - v1.0
C
C Homogenized Lower Nozzle
m1     24000 -1.9000E-01 25055 -2.0000E-02 26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized Lower Plenum
m2     24000 -1.0000E-03 50000 -1.5000E-02
       26000 -1.2500E-03  7014 -5.0000E-04
       40000 -9.8225E-01
C Homogenized UO2 Fuel - Dry
m3     92235 -3.6891E-02 40000 -1.6011E-01 24000 -1.6300E-04
       92238 -7.0092E-01 50000 -2.4450E-03  7014 -8.1499E-05
        8016 -9.9186E-02 26000 -2.0375E-04
C Homogenized Upper Plenum
m4     24000 -1.4890E-01 50000 -3.2622E-03 25055 -1.5650E-02
       26000 -5.4413E-01  7014 -1.0874E-04 28000 -7.4340E-02
       40000 -2.1362E-01
C Homogenized Upper Nozzle
m5     24000 -1.9000E-01 25055 -2.0000E-02 26000 -6.9500E-01
       28000 -9.5000E-02
C Water
m6     1001 2 8016 1
C Stainless Steel
m7     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Carbon Steel
m8     26000 -0.99  6012 -0.01
C Aluminum
m9     13027 -1.0
C Lead
m10    82000 -1.0
C NS-4-FR
m11    5010 -9.3127E-04 13027 -2.1420E-01 6000 -2.7627E-01
       5011 -3.7721E-03 1001 -6.0012E-02 7014 -1.9815E-02
       8016 -4.2500E-01
C Concrete
m12    26000 -0.014 20000 -0.044 14000 -0.337
        1001 -0.010  8016 -0.532 11023 -0.029
       13027 -0.034
C Vent Port Middle Cylinder
m13    24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
phys:p 100 0 0 0 1    $ Disable Doppler energy broadening
C
C Cell Importances
C
imp:p 1 307r 0
C
C Source Definition - Fuel Gamma - ng14b_32b21e4.1y
C
sdef x=d1 y=d2 z=d3 erg=d4 cell=399:195:77:d5:3
si1   -9.85901 9.85901
sp1   0 1
si2   -9.85901 9.85901
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
sp2   0 1
si3 a 9.8374 19.0576 28.2778 37.4980 46.7182 55.9384 65.1586
      323.3242 332.5444 341.7646 350.9848 360.2050 369.4252 378.6454
sp3 d 0.5470 0.6358 0.7247 0.8135 0.9023 0.9912 1.0800
      1.0800 0.9912 0.9023 0.8135 0.7247 0.6358 0.5470
sb3 d 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00
      1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00 1.00E+00
si4   1.000E-02 2.000E-02 5.000E-02 1.000E-01 2.000E-01 3.000E-01
      4.000E-01 6.000E-01 8.000E-01 1.000E+00 1.220E+00 1.440E+00
      1.660E+00 2.000E+00 2.500E+00 3.000E+00 4.000E+00 5.000E+00
      6.500E+00 8.000E+00 1.000E+01 1.200E+01 1.400E+01
sp4   0.0000E+00 6.2752E+14 8.7664E+14 4.0250E+14 3.3810E+14 9.5410E+13
      7.0043E+13 7.5264E+14 1.9045E+15 2.9488E+14 4.5444E+13 4.6708E+13
      5.6468E+12 1.7127E+12 4.1272E+12 1.3579E+11 1.6921E+10 8.6551E+06
      3.4736E+06 6.8141E+05 1.4468E+05 7.4804E+03 0.0000E+00
C Source Information
si5 l       39 40 41
         42 43 44 45 46
      47 48 49 50 51 52 53
      54 55 56 57 58 59 60
      61 62 63 64 65 66 67
         68 69 70 71 72
            73 74 75
C Source Probability
sp5            1.0 1.0 1.0
           1.0 1.0 1.0 1.0 1.0
       1.0 1.0 1.0 1.0 1.0 1.0 1.0
       1.0 1.0 1.0 1.0 1.0 1.0 1.0
       1.0 1.0 1.0 1.0 1.0 1.0 1.0
           1.0 1.0 1.0 1.0 1.0
               1.0 1.0 1.0
mode p
nps 400000000
C
C ANSI/ANS-6.1.1-1977 - Gamma Flux-to-Dose Rate Conversion Factors
C (mrem/hr)/(photons/cm2-sec)
C
de0   0.01 0.03 0.05 0.07 0.1 0.15 0.2
      0.25 0.3 0.35 0.4 0.45 0.5 0.55
      0.6 0.65 0.7 0.8 1 1.4 1.8
      2.2 2.6 2.8 3.25 3.75 4.25 4.75
      5 5.25 5.75 6.25 6.75 7.5 9
      11 13 15
df0   3.96E-03 5.82E-04 2.90E-04 2.58E-04 2.83E-04 3.79E-04 5.01E-04
      6.31E-04 7.59E-04 8.78E-04 9.85E-04 1.08E-03 1.17E-03 1.27E-03
      1.36E-03 1.44E-03 1.52E-03 1.68E-03 1.98E-03 2.51E-03 2.99E-03
      3.42E-03 3.82E-03 4.01E-03 4.41E-03 4.83E-03 5.23E-03 5.60E-03
      5.80E-03 6.01E-03 6.37E-03 6.74E-03 7.11E-03 7.66E-03 8.77E-03
      1.03E-02 1.18E-02 1.33E-02
C
C Weight Window Generation - Radial
C
wwg 2 0 0 0 0
wwp:p 5 3 5 0 -1 0
mesh geom=cyl ref=89 0 201 origin=0.1 0.1 -134
     imesh 90.2 91.4 101.0 108.6 172.7 672.7
     iints 5 1 1 2 5 1
     jmesh 101 104 112 118 129 141 151 520 550 580 603 625 656 657 1157
     jints 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
     kmesh 1
     kints 1
wwge:p  1e-3 1 20
fc2 Radial Surface Tally
f2:p +400.1
fm2 2.0224E+17
fs2  -401  -402  -403  -404  -405  -406
     -407  -408  -409  -410  -411  T
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
tf2
fc12 Radial 1ft Tally
f12:p +500.1
fm12 2.0224E+17
fs12  -501  -502  -503  -504  -505  -506
     -507  -508  -509  -510  -511  T
tf12
fc22 Radial 1m Tally
f22:p +600.1
fm22 2.0224E+17
fs22  -601  -602  -603  -604  -605  -606
     -607  -608  -609  -610  -611  -612
     -613  -614  T
tf22
fc32 Radial 2m Tally
f32:p +700.1
fm32 2.0224E+17
fs32  -701  -702  -703  -704  -705  -706
     -707  -708  -709  -710  -711  -712
     -713  -714  -715  -716  -717  -718
     -719  T
tf32
fc42 Radial 4m Tally
f42:p +800.1
fm42 2.0224E+17
fs42  -801  -802  -803  -804  -805  -806
     -807  -808  -809  -810  -811  -812
     -813  -814  -815  -816  -817  -818
     -819  T
tf42
C
C
C Print Control
C
prdmp -30 -60 1 2
print
C
C Random Number Generator
C
rand gen=2 seed=19073486328125 stride=152917 hist=1
C
C Rotation Matrix
C
C 18 degree rotation around z-axis
*TR1 0.0 0.0 0.0 18 108 90 -72 18 90 90 90 0
C 36 degree rotation around z-axis
*TR2 0.0 0.0 0.0 36 126 90 -54 36 90 90 90 0
C 54 degree rotation around z-axis
*TR3 0.0 0.0 0.0 54 144 90 -36 54 90 90 90 0
C 72 degree rotation around z-axis
*TR4 0.0 0.0 0.0 72 162 90 -18 72 90 90 90 0
C 108 degree rotation around z-axis
*TR5 0.0 0.0 0.0 108 198 90 18 108 90 90 90 0
C 126 degree rotation around z-axis
*TR6 0.0 0.0 0.0 126 216 90 36 126 90 90 90 0
C 144 degree rotation around z-axis
*TR7 0.0 0.0 0.0 144 234 90 54 144 90 90 90 0
C 162 degree rotation around z-axis
*TR8 0.0 0.0 0.0 162 252 90 72 162 90 90 90 0
C 45 degree rotation around z-axis
*TR9 0.0 0.0 0.0 45 135 90 -45 45 90 90 90 0
C 135 degree rotation around z-axis
*TR10 0.0 0.0 0.0 135 225 90 45 135 90 90 90 0
C 15 degree rotation around z-axis
*TR11 0.0 0.0 0.0 15 105 90 -75 15 90 90 90 0
C 30 degree rotation around z-axis
*TR12 0.0 0.0 0.0 30 120 90 -60 30 90 90 90 0
```

Figure 5.8.8-10 Augmented Shield Concrete Cask (CC3) Sample Input File – PWR TSC (cont'd)

```
C 60 degree rotation around z-axis
*TR13 0.0 0.0 0.0 60 150 90 -30 60 90 90 90 0
C 75 degree rotation around z-axis
*TR14 0.0 0.0 0.0 75 165 90 -15 75 90 90 90 0
```

Figure 5.8.8-11 Transfer Cask Sample Input File – Damaged PWR Fuel TSC – Active Fuel Damaged Fuel

```
MAGNASTOR Transfer Cask - trfShwDryBotFgd_ng14b_44b25e06y
C Bottom Axial Biasing - Fuel Gamma Source
C Fuel Assembly Cells - ng14b - v1.1
1 1 -2.5071 -1     u=7 $ Lower Nozzle
2 2 -2.7253 -2 +1    u=7 $ Lower Plenum
3 3 -3.9171 -3 +2    u=7 $ Fuel
4 4 -1.0067 -4 +3    u=7 $ Upper Plenum
5 5 -2.8608 -5 +4    u=7 $ Upper Nozzle
6 0          +5     u=7 $ Outside
C Cells - Fuel Tube  v1.3
13 8 -7.8212 -8 +7    u=5 $ Tube
14 9 -2.6336 -9 : -10 : -11 : -12     u=5 $ Poison
15 0          #13  #14  -6    u=5 $ Outside below PFE
16 0          #13  #14  +6    u=5 $ Outside above PFE
C Cells - PWR Basket v1.5
17 0          -13 -14 fill=5 trcl = ( -23.5331 70.5993 0.0000 )    u=4 $ Assy loc 1
18 like 17 but fill=5 trcl = ( 23.5331 70.5993 0.0000 )    u=4 $ Assy loc 3
19 like 17 but fill=5 trcl = ( -47.0662 47.0662 0.0000 )    u=4 $ Assy loc 4
20 like 17 but fill=5 trcl = ( 0.0000 47.0662 0.0000 )    u=4 $ Assy loc 6
21 like 17 but fill=5 trcl = ( 47.0662 47.0662 0.0000 )    u=4 $ Assy loc 8
22 like 17 but fill=5 trcl = ( -70.5993 23.5331 0.0000 )    u=4 $ Assy loc 9
23 like 17 but fill=5 trcl = ( -23.5331 23.5331 0.0000 )    u=4 $ Assy loc 11
24 like 17 but fill=5 trcl = ( 23.5331 23.5331 0.0000 )    u=4 $ Assy loc 13
25 like 17 but fill=5 trcl = ( 70.5993 23.5331 0.0000 )    u=4 $ Assy loc 15
26 like 17 but fill=5 trcl = ( -47.0662 0.0000 0.0000 )    u=4 $ Assy loc 17
27 like 17 but fill=5 trcl = ( 0.0000 0.0000 0.0000 )    u=4 $ Assy loc 19
28 like 17 but fill=5 trcl = ( 47.0662 0.0000 0.0000 )    u=4 $ Assy loc 21
29 like 17 but fill=5 trcl = ( -70.5993 -23.5331 0.0000 )    u=4 $ Assy loc 23
30 like 17 but fill=5 trcl = ( -23.5331 -23.5331 0.0000 )    u=4 $ Assy loc 25
31 like 17 but fill=5 trcl = ( 23.5331 -23.5331 0.0000 )    u=4 $ Assy loc 27
32 like 17 but fill=5 trcl = ( 70.5993 -23.5331 0.0000 )    u=4 $ Assy loc 29
33 like 17 but fill=5 trcl = ( -47.0662 -47.0662 0.0000 )    u=4 $ Assy loc 30
34 like 17 but fill=5 trcl = ( 0.0000 -47.0662 0.0000 )    u=4 $ Assy loc 32
35 like 17 but fill=5 trcl = ( 47.0662 -47.0662 0.0000 )    u=4 $ Assy loc 34
36 like 17 but fill=5 trcl = ( -23.5331 -70.5993 0.0000 )    u=4 $ Assy loc 35
37 like 17 but fill=5 trcl = ( 23.5331 -70.5993 0.0000 )    u=4 $ Assy loc 37
38 8 -7.8212 -15 #25 #32      u=4 $ Side support +x
39 8 -7.8212 -16 #22 #29      u=4 $ Side support -x
40 8 -7.8212 -17 #17 #18      u=4 $ Side support +y
41 8 -7.8212 -18 #36 #37      u=4 $ Side support -y
42 8 -7.8212 -19 +20 +21      u=4 $ Corner
43 8 -7.8212 -21 +22 +20  +15.2 +16.1 +17.4 +18.3
             #17 #18 #22 #25 #29 #32 #36 #37      u=4 $ Corner diagonal
44 0         -6 #17 #18 #19 #20 #21 #22 #23 #24 #25 #26 #27
                #28 #29 #30 #31 #32 #33 #34 #35 #36 #37
                #38 #39 #40 #41 #42 #43      u=4 $ Basket below PFE
45 0         +6 #17 #18 #19 #20 #21 #22 #23 #24 #25 #26 #27
               #28 #29 #30 #31 #32 #33 #34 #35 #36 #37
               #38 #39 #40 #41 #42 #43      u=4 $ Basket above PFE
C Cells - PWR Canister Cavity v1.5
46 0         -23 fill=7 trcl = ( -23.5331 70.5993 0.0000 )    u=3 $ Assy loc 1
47 like 46 but fill=7 trcl = ( 0.0000 70.5993 0.0000 )    u=3 $ Assy loc 2
48 like 46 but fill=7 trcl = ( 23.5331 70.5993 0.0000 )    u=3 $ Assy loc 3
49 like 46 but fill=6 trcl = ( -47.0662 47.0662 0.0000 )    u=3 $ Assy loc 4
50 like 46 but fill=7 trcl = ( -23.5331 47.0662 0.0000 )    u=3 $ Assy loc 5
51 like 46 but fill=7 trcl = ( 0.0000 47.0662 0.0000 )    u=3 $ Assy loc 6
52 like 46 but fill=7 trcl = ( 23.5331 47.0662 0.0000 )    u=3 $ Assy loc 7
53 like 46 but fill=6 trcl = ( 47.0662 47.0662 0.0000 )    u=3 $ Assy loc 8
54 like 46 but fill=7 trcl = ( -70.5993 23.5331 0.0000 )    u=3 $ Assy loc 9
55 like 46 but fill=7 trcl = ( -47.0662 23.5331 0.0000 )    u=3 $ Assy loc 10
56 like 46 but fill=7 trcl = ( -23.5331 23.5331 0.0000 )    u=3 $ Assy loc 11
57 like 46 but fill=7 trcl = ( 0.0000 23.5331 0.0000 )    u=3 $ Assy loc 12
58 like 46 but fill=7 trcl = ( 23.5331 23.5331 0.0000 )    u=3 $ Assy loc 13
59 like 46 but fill=7 trcl = ( 47.0662 23.5331 0.0000 )    u=3 $ Assy loc 14
60 like 46 but fill=7 trcl = ( 70.5993 23.5331 0.0000 )    u=3 $ Assy loc 15
61 like 46 but fill=7 trcl = ( -70.5993 0.0000 0.0000 )    u=3 $ Assy loc 16
```

5.8.12 PWR Damaged Fuel

Damaged PWR fuel assemblies may be loaded in damaged fuel cans in the four corner assembly locations of the PWR damaged fuel basket. DFC slots are locations 4, 8, 30 and 34 in Figure 5.8.12-10. To ensure that the worst case configuration is considered, two damaged fuel scenarios are evaluated. Damaged fuel includes fuel debris.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. This scenario is modeled by filling the fuel assembly interstitial volume with UO_2 and increasing the fuel neutron, gamma and n-gamma source consistent with this increase in mass.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. However, no credit is taken for the reduction in lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region.

The resulting material compositions are shown in Table 5.8.12-1 for WE 14×14 (14b) PWR fuel.

In the model, no credit is taken for the thicker plates in the corner locations of the damaged fuel basket or the thickness of the damaged fuel cans themselves.

For the transfer cask, damaged fuel dose rates are computed using the carbon steel transfer cask, as it produces higher dose rates than the stainless steel transfer cask due to the higher density of stainless versus carbon steel. For the concrete cask, damaged fuel dose rates are computed using the standard concrete cask (CC1/CC2) and the short, standard concrete cask (CC4), as they produce higher dose rates than the augmented shield concrete casks (CC3/CC5).

Cask array site boundary dose/exposure calculations performed for the undamaged fuel basket are bounding for the damaged fuel basket, as cask sources employed in the undamaged fuel basket cask array calculations are significantly higher than those used in the minimum cool time evaluation (40 kW for site boundary/cask array analysis versus 35.5 kW maximum in cool time/ cask dose analysis). Furthermore, the damaged fuel analysis results in Section 5.8.12.2 have demonstrated that the inclusion of damaged fuel has no significant effect on system surface dose rates. Therefore, there is not a significant effect on site exposure.

5.8.12.1 Transfer Cask Dose Rates

5.8.12.1.1 Active Fuel Scenario

Transfer cask dose rates are computed using the bounding fuel assembly source terms from Section 5.8.3.3.1 for the first scenario (fuel material filling void space at the active fuel region elevation). In addition to these source terms, the WE 14 ×14 (14b) bounding rail source term

from Section 5.8.5.2.3 was also included for comparison with the bounding combined maximum dose rates.

A comparison of transfer cask surface dose rates for undamaged and damaged fuel is shown in Figure 5.8.12-1 through Figure 5.8.12-3. At the top and bottom surfaces of the cask, the results for the damaged fuel model are less than those of the undamaged fuel model due to the additional self-shielding offsetting the increase in source in the four damaged fuel can basket locations. Results are based on a comparison of fuel neutron and fuel gamma sources only, as this scenario considers an increased density fuel source that would serve as additional shield material for any hardware gamma source in the region.

On the radial surface of the cask, the damaged PWR fuel results are greater than those in section 5.8.3.3.1. In order to compare the radial results to the lower nozzle scenario, the remaining source regions and BPRA results are added to the radial surface dose rate profiles for both CE 14×14 (14a) and WE 14×14 (14b) fuel assemblies resulting in maximum dose rates of 983 and 951 mrem/hr respectively. The radial surface dose rate profiles for all source regions and BPRA results are shown in Figure 5.8.12-11 and Figure 5.8.12-12. These values are less than the lower nozzle scenario maximum dose rate of 1,036 mrem/hr shown in Table 5.8.12-2.

5.8.12.1.2 Lower End Fitting Scenario

Transfer cask dose rates are computed using the bounding fuel assemblies from Section 5.8.5.2.3 for the second scenario.

The increase in radial and bottom axial dose rates from damaged fuel in the lower end fitting region of the four damaged fuel can basket locations is shown in Figure 5.8.12-4 and Figure 5.8.12-5. Damaged fuel maximum dose rates are greater than those in Section 5.8.5.2.3. Dose rates are summarized in Table 5.8.12-2.

5.8.12.2 Standard Concrete Cask Dose Rates

5.8.12.2.1 Active Fuel Scenario

Standard concrete cask dose rates are computed using the bounding fuel assembly source terms from Section 5.8.3.4.1 for the first scenario. In addition to these bounding source terms, the WE 14×14 (14b) bounding radial source term from Section 5.8.5.2.3 was also included for comparison with the bounding combined maximum dose rates.

Undamaged and damaged fuel radial and top axial dose surface rates are compared in Figure 5.8.12-6 and Figure 5.8.12-7. At the top surface of the cask, the results for the damaged fuel model are less than those of the undamaged fuel model due to the additional self-shielding

7.2 Requirements for Normal Conditions of Storage

The TSC is transferred to a concrete cask using a transfer cask. Once the TSC is placed inside of the concrete cask, it is effectively protected from direct structural loading due to natural phenomena, such as wind, snow, and ice loading. The principal direct loading for normal operating conditions results from increased internal pressure caused by decay heat, solar insolation, and ambient temperature. Loading due to transient handling may occur during the transfer of the loaded TSC to the concrete cask.

7.2.1 Release of Radioactive Material

The structural analysis of the TSC for normal conditions of storage presented in Chapter 3 demonstrates that the confinement boundary is not breached in any of the normal operating events. Therefore, there is no release of radioactive material during normal storage conditions.

7.2.2 Pressurization of the Confinement Vessel

The TSC cavity is dried and pressurized with helium prior to installing and welding the vent and drain port covers. Under normal conditions, the internal pressure increases due to an increase in temperature of the helium and the postulated normal storage cladding failure of 1% of the stored fuel rods, which is assumed to release 30% of the available fission gases in the rods.

The TSC, closure lid, fittings, and the basket assembly are fabricated from materials that either do not react with ordinary or borated spent fuel pool water to generate gases, or which have an electroless nickel plating to significantly reduce, or eliminate, the potential for interaction with water. Refer to Chapter 8 for a description of the electroless nickel plating and process. The neutron absorber sheets in the fuel baskets, as described in Chapter 8, and the stainless steel covers are held in place by weld posts attached to the fuel tubes. The neutron absorber is a borated aluminum composite, which is protected by an oxide film that forms shortly after fabrication of the plates. This oxide layer effectively precludes further oxidation that could result in the generation of gases in the TSC.

As the TSC is dried and helium backfilled prior to sealing, no significant moisture or other gases, such as air, remain in the TSC. Consequently, there is no potential that radiolytic decomposition could cause an increase in TSC internal pressure or result in a buildup of explosive gases in the TSC. Foreign materials will be excluded from the cavity to the extent required to ensure that explosive levels of gases due to radiological decomposition will not be generated.

The calculated TSC pressure for normal conditions of storage is presented in Chapter 4 and is less than the pressure evaluated in Chapter 3 for the maximum normal operating pressure. Consequently, there is no adverse consequence due to the internal pressure resulting from normal storage conditions.

As the confinement boundary is closed by welding and does not contain seals or O-rings, and the boundary is not ruptured or otherwise compromised under any normal handling event, the release of contents during normal conditions of storage is precluded.

Chapter 8
Materials Evaluation

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List of Tables

8.6 Coatings

The exposed surfaces of carbon steel and concrete components of MAGNASTOR are coated with specially designed and applied coating systems. The coatings are provided to reduce corrosion of exposed carbon steel surfaces, to minimize adverse reactions between dissimilar materials, and to minimize adverse interactions of components with their operating environment during in-pool loading, dry transfer and storage. The details on the various types of coating systems utilized on MAGNASTOR components are discussed in the following sections.

8.6.1 Electroless Nickel

The PWR and BWR fuel baskets are fabricated primarily of carbon steel. Additionally, the shield plate of the TSC composite closure lid assembly is fabricated from carbon steel. The potential for corrosion exists from fabrication through spent fuel loading up to final closure operations. After final closure welding, drying and inert gas backfill of the TSC cavity, the potential for corrosion of the carbon steel baskets is effectively eliminated.

The most critical period, both from a material corrosion aspect and an operational aspect, is the time period when the TSC is submerged in the fuel pool during the fuel loading cycle. Specifically, at PWR sites, the fuel pool water may contain boric acid in solution in the range of 2,500 ppm. To minimize the level of corrosion during fuel loading, the carbon steel components of the fuel baskets and the shield plate of the TSC composite closure lid assembly will be electroless nickel-coated. The electroless nickel coating provides the appropriate protection to restrict material reduction due to corrosion and minimize the loss of water clarity that can affect the fuel loading process. The electroless nickel coating is also effective in eliminating the potential for production of explosive levels of hydrogen due to cathodic reaction of basket components with spent fuel pool water. The cavity gas volume will be sampled for explosive levels of hydrogen before and during closure lid root pass welding and closure lid weld removal operations.

During the TSC and fuel basket assembly process, coating damage can occur. Localized scratches, etc., can result in coating damage, but are considered insufficient to cause concerns relative to the functional and structural performance of the basket. Additionally, due to the configuration of the fuel basket, some areas of the fuel basket may not be completely coated. These areas are also considered minor and insufficient to affect either the functional or operational aspects of the fuel basket.

The electroless nickel coating process applied to the basket components and shield plate of the TSC composite closure lid assembly will use ASTM B733 [30] for guidance. The coating thickness shall be in the service condition SC3, and Alloy Type IV or V will be specified with no post-heat treatment invoked. Lot testing will be performed on batch specimens and acceptance will be based on appearance and adhesion. Specimens will be representative of the material and condition of the pieces to be coated.

8.6.2 Other Coating Systems

The exposed carbon steel surfaces of the MTC1 transfer cask, other than wear surfaces, i.e., shield door and rail mating surfaces, are coated with an epoxy enamel coating system tested and certified for use in Nuclear Service Level 1 conditions such as Carboline Carboguard 890N and Keeler & Long/PPG KLE Series. Uncoated exposed wear surfaces are protected from corrosion and adverse interactions with spent fuel pool water by the application of approved nuclear grade lubricants during use and storage of the MTC1 transfer cask. Proper lubrication is confirmed or augmented prior to each TSC loading sequence. The enamel coating system and lubricated wear surfaces ensure that interactions with the spent fuel pool water will not generate excessive hydrogen gas, corrosion of the carbon steel, or loss of the coating materials in the spent fuel pool. Nitronic 30 wear strips are incorporated on the MTC1 transfer cask inner surface and the top of the shield doors to provide protection of the coating system from excessive wear caused by TSC handling operations.

The exposed carbon steel surfaces of the transfer adapter, other than the shield door rail surfaces, are coated with a painting system designed to minimize corrosion under long-term exposure in air. The transfer adapter is only used for the dry loading and transfer of a TSC into a concrete cask, or retrieval. Therefore, a special nuclear-grade coating system is not required. Wear surfaces are lubricated with a nuclear-grade lubricant. There are no potential adverse interactions of the transfer adapter surfaces with the operating environment.

The carbon steel components of the concrete cask that are not covered by installed concrete are coated with a heat-resistant coating system. The coating system is designed to provide protection against corrosion when exposed to an external environment, while being capable of withstanding long-term exposure to the elevated temperatures of the concrete cask components during the storage operations.

The exposed concrete surfaces of the concrete cask are coated with a commercial-grade sealant to provide protection to the cask surfaces during curing and long-term storage operations.

Examples of acceptable coating systems are detailed in Section 8.13. Minor scratches and wear of coatings have an insignificant effect on the overall coating performance and are therefore permitted. The coating systems of the accessible exposed carbon steel surfaces of MAGNASTOR components are inspected annually. Required repairs to coating systems are completed as part of the maintenance program in accordance with the manufacturer's recommendations.

8.10 Chemical and Galvanic Reactions

The materials used in the fabrication and operation of MAGNASTOR are evaluated to determine whether chemical, galvanic or other reactions among the materials, contents, and environments can occur. All phases of operation — loading, unloading, handling, and storage — are considered for the environments that may be encountered under normal conditions and off-normal or accident events. Based on the evaluation, no potential reactions that could adversely affect the overall integrity of the concrete cask, the fuel basket, the TSC, or the structural integrity and retrievability of the fuel from the TSC have been identified. The evaluation conforms to the guidelines of ISG-15 [10].

No potential chemical, galvanic, or other reactions have been identified for MAGNASTOR. Therefore, the overall integrity of the TSC and the structural integrity and retrievability of the spent fuel are not adversely affected for any operations throughout the design basis life of the TSC. Based on the evaluation, no change in the TSC or fuel cladding thermal properties is expected, and no corrosion of mechanical surfaces is anticipated. No change in basket clearances or degradation of any safety components, either directly or indirectly, is likely to occur since no potential reactions have been identified.

8.10.1 Component Operating Environment

Most of the component materials of MAGNASTOR are exposed to two typical operating environments: 1) an open TSC containing fuel pool water or borated water with a pH of 4.5 and spent fuel or other radioactive material; or 2) a sealed TSC containing helium, but with external environments that include air, rain water/snow/ice and marine (salty) water/air. Each category of TSC component materials is evaluated for potential reactions in each of the operating environments to which those materials are exposed. These environments may occur during fuel loading or unloading, handling or storage, and include normal conditions or off-normal and accident events.

The long-term environment to which the TSC's internal components are exposed is dry helium. Both moisture and oxygen are removed prior to sealing the TSC. The helium displaces the oxygen in the TSC, effectively precluding chemical corrosion. The dry environment inside the sealed TSC also inhibits galvanic corrosion between dissimilar metals in electrical contact.

In addition to the spent fuel, the fuel assemblies in the basket may hold control element assemblies, thimble plugs or other nonfuel components that are nonreactive with the fuel assembly. By design, the control components and nonfuel components are inserted in the guide tubes of a fuel assembly. During reactor operation, the control and nonfuel components are

immersed in acidic water having a high flow rate and are exposed to significantly higher neutron flux, radiation and pressure than will exist in dry storage. The control and nonfuel components are physically placed in storage in a dry, inert atmosphere in the same configuration as when used in the reactor. Therefore, there are no adverse reactions, such as gas generation, galvanic or chemical reactions or corrosion, since these components are nonreactive with the zirconium-alloy guide tubes and fuel rods. Fuel assemblies typically do not contain aluminum or carbon steel parts exposed to coolant/moderator or are in contact with non-fuel hardware, and therefore are not subject to significant gas generation or corrosion during prolonged water immersion (20-40 years). Carbon steel plenum springs, which are not normally exposed to water, may be used in some fuel designs. Clad failure could expose the springs. Small quantities of uncoated exposed carbon steel are permitted in the system as discussed in Section 8.6.1. Thus, no adverse reactions occur with the control and nonfuel components over prolonged periods of dry storage.

8.10.2 Component Material Categories

The component materials are categorized in this section for their chemical and galvanic corrosion potential on the basis of similarity of physical and chemical properties and component functions. The categories are stainless steels, nonferrous metals, carbon steel, coatings, concrete, and criticality control materials. The evaluation is based on the environment to which these categories could be exposed during operation or use.

The TSC component materials are not reactive among themselves with the TSC's contents, or with the TSC's operating environments during any phase of normal conditions, off-normal or accident events, loading, unloading, handling or storage operations. Since no reactions will occur, no gases or other corrosion by-products will be generated.

The control component and nonfuel component materials are those that are typically used in the fabrication of fuel assemblies, i.e., stainless steels, Inconel 625, and zirconium-based alloy, so no adverse reactions occur in the inert atmosphere that exists in storage. The control element assembly, thimble plugs and nonfuel components—including start-up sources or instrument segments to be inserted into a fuel assembly—are nonreactive among themselves with the fuel assembly or with the TSC's operating environment for any storage condition.

8.10.2.1 Stainless Steels

No reaction of the TSC and MTC2 component stainless steels is expected in any environment, except for the marine environment where chloride-containing salt spray could potentially initiate pitting of the TSC stainless steel if the chlorides are allowed to concentrate and stay wet for extended periods of time (weeks). Only the external TSC surface could be so exposed. The corrosion rate will, however, be so low that no detectable corrosion products or gases will be generated. MAGNASTOR has smooth external surfaces to minimize the collection of such materials as salts.

Hydrogen is not expected to be detected prior to, or during, the welding operations. During the completion of the closure lid to TSC shell root pass, the hydrogen gas detector accesses the vent port and is used to monitor the hydrogen gas levels. Following closure lid welding and TSC hydrostatic testing, the TSC is drained. Once the TSC is dry, no combustible gases form within the TSC.

8.10.3.2 Evaluation of Unloading Operations

The TSC is dried and backfilled with helium immediately prior to final closure welding operations, thereby eliminating all oxidizing gases and water. Therefore, it is not expected that the TSC will contain any combustible gases during the time period of storage. To ensure the safe, wet unloading of the TSC, the unloading procedure described in Chapter 9 provides for monitoring for hydrogen gas during closure lid weld cutting/removal operations.

The principal steps in opening the TSC are the removal of the vent and drain port cover welds, and the removal of the closure lid weld. The welds are expected to be removed by cutting or grinding. Following removal of the vent and drain port covers, the TSC is sampled for radioactive gases, vented, flushed with nitrogen or helium gas, and cooled down with water using the vent and drain ports. Prior to cutting the closure lid weld, the cavity water level is lowered to permit removal of the closure lid weld in a dry environment, and the cavity gas volume is sampled for hydrogen gas levels ≥2.4% using a hydrogen gas detector connected to the vent port. If unacceptable hydrogen levels are detected during closure lid weld removal operations, weld removal operations are terminated and the cavity is flushed with air, nitrogen, argon or helium, or the cavity is evacuated with a vacuum pump.

8.10.3.3 Conclusions

The steps taken to monitor for the presence of hydrogen will ensure that combustion of any hydrogen gas does not occur due to either closure lid welding or lid removal operations. Based on this evaluation, which results in no identified reactions, it is concluded that MAGNASTOR operating controls and procedures for loading and unloading the TSC presented in Chapter 9 are adequate to minimize the occurrence of hazardous conditions.

Investigation of the canister unloading sequence presented in Section 9.3 leads to similar conclusions as those for the introduction of helium gas discussed above. When the canister is first prepared for unloading and the port covers are removed, nitrogen or helium gas is initially cycled through the canister for a minimum of 10 minutes to flush the radioactive gases from the canister. This gas cycling is similar to the helium backfill. Although nitrogen has a higher thermal capacitance than helium (about a factor of 10), when compared to the mass of the metal canister, basket and fuel, the influence of the nitrogen gas on the thermal gradient response in the fuel cladding remains insignificant. Following the nitrogen or helium flush, water is introduced into the canister at a maximum rate of 8 gpm. The maximum flow rate is based on reflood thermal hydraulic analyses of a bounding canister configuration. The bounding maximum flow rate, water temperature and pressure are defined in step 14 of Section 9.3, "Wet Unloading a TSC." The water initially introduced into the canister flashes to steam in the drain tube and on contact with the bottom plate. Steam in the cavity permits additional heat to be removed from the basket and fuel in a smooth transition without introducing thermal shock through wall stresses. Once water is permitted to form on the canister bottom plate, the canister starts to fill at a maximum rate of 8 gpm. Addition of water at 8 gpm permits the water to rise in the canister at a maximum rate of 0.8 inch per minute. The RELAP thermal hydraulic analyses used to evaluate the TSC reflood operation show thermal cladding temperature radial gradients are less than 1°F during the reflooding of the canister. Such a small increase is consistent with the gradual cooling process created by the initial steam condition followed by water. The axial temperature gradient along the fuel assembly is actually larger than the radial gradient. However, in the fuel axial direction, thermal stresses are not developed since the fuel cladding is free to expand in the axial direction. The combination of initial nitrogen or helium purge, followed by the cooling transition of the steam created in the canister cavity, provides a relatively smooth transition to water cooling and insignificant thermal stress in the fuel rod cladding.

There are no evaluated normal conditions, transfer conditions, off-normal events or accident conditions that result in deterioration of, or damage to, the fuel cladding or the TSC that preclude retrieval of the fuel from the TSC or retrieval of the TSC from the concrete cask for transport and ultimate disposal.

8.13 Vendor Supplied Documentation

This section provides copies of technical data sheets for the coatings described in Section 8.6.2, and the ASTM Specification B29 for refined lead used for the transfer cask gamma shielding per Section 8.7.1.

8.13.1 Electroless Nickel Coating

Nonelectrolytic Nickel Plating

*By the ASM Committee on Nickel Plating**

THREE METHODS may be employed for depositing nickel coatings without the use of electric current:

1. Immersion plating
2. Chemical reduction of nickelous oxide at 1600 to 2000 F
3. Autocatalytic chemical reduction of nickel salts by hypophosphite anions in an aqueous bath at 190 to 205 F ("electroless" nickel plating).

All three methods are, under certain limited conditions, useful substitutes for nickel electroplating; they are particularly useful in applications in which electroplating is impracticable or impossible because of cost or technical difficulties. Of the three methods, electroless nickel plating is in widest use, and is the method to which the most attention is devoted in this article.

Immersion Plating

The composition and operating conditions of an aqueous immersion plating bath are as follows:

Nickel chloride ($NiCl_2 \cdot 6H_2O$)	80 oz per gal
Boric acid (H_3BO_3)	4 oz per gal
pH	3.5 to 4.5
Temperature	160 F

When using this bath, it is desirable, but not mandatory, to move the work at a rate of about 16 ft per min.

This solution is capable of depositing a very thin (about 0.025 mil) and uniform coating of nickel on steel in periods of up to 30 min. The coating is porous and possesses only moderate adhesion, but these conditions can be improved by heating the coated part at 1200 F for 45 min in a nonoxidizing atmosphere. (Higher temperatures will promote diffusion of the coating.)

High-Temperature Chemical-Reduction Coating

By the reduction of a mixture of nickelous oxide and dibasic ammonium phosphate in hydrogen or other reducing atmosphere at 1600 to 2000 F, a nickel coating can be deposited without the use of electric current. This method (U. S. Patent 2,633,631) consists of applying a slurry of the two chemicals to all or selected surfaces of the workpiece, drying the slurry in air, and performing the chemical reduction at elevated temperature. No special tanks or other plating facilities are required. Some diffusion of nickel and phosphorus into the basis metal occurs at elevated temperature; when the coating is applied to steel, it will consist of nickel, iron, and about 3% phosphorus. The slurry may be used for brazing.

Electroless Nickel Plating

The electroless nickel plating process employs a chemical reducing agent (sodium hypophosphite) to reduce a nickel salt (such as nickel chloride) in hot aqueous solution and to deposit nickel on a catalytic surface. The deposit obtained from an electroless nickel solution is an alloy containing from 4 to 12% phosphorus and is quite hard. (As indicated later in this article, the hardness of the as-plated deposit can be increased by heat treatment.) Because the deposit is not dependent on current distribution, it is uniform in thickness, regardless of the shape or size of the plated surface.

Electroless nickel deposits may be applied to provide the basis metal with resistance to corrosion or wear, or for the buildup of worn areas. Typical applications of electroless nickel for these purposes are given in Table 1, which also indicates plate thicknesses and postplating heat treatments.

Surface Cleaning. In general, the methods employed for cleaning and preparing metal surfaces for electroless nickel plating are the same as those used for conventional electroplating. Heavy oxides are removed mechanically, and oils and grease are removed by vapor degreasing. A typical precleaning cycle might consist of alkaline cleaning (either agitated soak or anodic) and acid pickling, both followed by water rinsing.

Prior to electroless plating, the surfaces of all stainless steel parts must be chemically activated in order to obtain satisfactory adhesion of the plate. One activating treatment consists of immersing the work for about 3 min in a hot (200 F) solution containing equal volumes of water and concentrated sulfuric acid. Another treatment consists of immersing the work for 2 to 3 min in the following solution at 160 F:

Sulfuric acid (66° Bé)	25% by volume
Hydrochloric acid (18° Bé)	5% by volume
Ferric chloride hexahydrate	0.53 oz per gal

Pretreatments that are unique to electroless nickel plating include:

1. A strike copper plate must be applied to parts made of or containing lead, tin, cadmium or zinc, to insure adequate coverage and to prevent contamination of the electroless solution.
2. Massive parts are preheated to bath temperature to avoid delay in the deposition of nickel from the hot electroless bath.

Bath Characteristics. A simplified equation that describes the formation of electroless nickel deposits is:

$$NiSO_4 + NaH_2PO_2 + H_2O \xrightarrow[\text{catalyst}]{\text{heat}} Ni + NaH_2PO_3 + H_2SO_4$$

The essential requirements for any electroless nickel solution are:

1. A salt to supply the nickel
2. A hypophosphite salt to provide chemical reduction
3. Water
4. A complexing agent
5. A buffer to control pH
6. Heat
7. A catalytic surface to be plated.

Detailed discussions of the chemical characteristics of electroless baths, and of the critical concentration limits of the various reactants, can be found in several of the references listed at the end of this article.

Both alkaline (pH, 7.5 to 10) and acid (pH, 4.5 to 6) electroless nickel baths are used in industrial production. Although the acid baths are easier to maintain and are more widely used, the alkaline baths are reported to have greater compatibility with sensitive substrates (such as magnesium, silicon and aluminum).

Catalysis. Nickel and hypophosphite ions can exist together in a dilute solution without interaction, but will react on a catalytic surface to form a deposit. Furthermore, the surface of the deposit is also catalytic to the reaction, so that the catalytic process continues until any reasonable plate thickness is applied. This autocatalytic effect is the principle upon which all electroless nickel solutions are based.

Metals that catalyze the plating reaction are members of group VIII in the periodic table, which group includes nickel, cobalt and palladium. A deposit will begin to form on surfaces of these metals by simple contact with the solution. Other metals, such as aluminum or low-alloy steel, first form an

*See page 432 for committee list.

8.13.3 PPG METALHIDE 97-694 (typical)

PPG METALHIDE® 97-694 Series

HPC/Industrial Maintenance

METALHIDE® 2000 Inorganic Zinc Rich Coating

GENERAL DESCRIPTION

Heavy duty corrosion resistant primer for ferrous metal surfaces in industrial environments. Provides galvanic protection similar to galvanizing. Particularly suited as a lining for the interior, and as a primer to be topcoated for the exterior of tanks containing organic solvents, gasoline, and other fuels. It is also excellent for application in coastal, marine, and other offshore environments.

RECOMMENDED USES

Ferrous Metal

FEATURES AND BENEFITS

Provides galvanic corrosion protection
Excellent resistance to organic solvents
Can be handled with slings in 5-6 hours (77°F at 50% relative humidity)
Class B Slip Coefficent under ASTM A-325

PACKAGING

1-Gallon (3.78L)
3-Gallon (11.3L)
5-Gallon (18.9L)

Not all products are available in all sizes. Not all containers are full-filled.

TINTING AND BASE INFORMATION

97-694	Liquid Component A - Red
97-695	Liquid Component A - Green
97-697P	Powder Component

DO NOT TINT.

PRODUCT DATA

PRODUCT TYPE: Inorganic self-curing ethyl silicate-metallic zinc
GLOSS: Matte
VOC*: 3.88 lbs./gal. (466 g/L)
COVERAGE: 330 to 500 sq. ft./gal. (31 to 46 sq.m/3.78L)

WEIGHT/GALLON*: 20.3 lbs. (9.2 kg) +/- 0.3 lbs. (136 g)
WEIGHT SOLIDS*: 80.3% +/- 2%
Results will vary by color, thinning and other additives.
*Product data calculated on mixed 97-695/97-697P.
Dry Film Thickness*: 2 to 5 mils not to exceed 8 mils on spot readings

POT LIFE: 16 hours
MIX RATIO: Mix as packaged.
See mixing instructions.
IN SERVICE TEMPERATURE: 750°F (399°C) Dry heat
140°F (60°C) Wet heat
DRYING TIME@ 77°F (25°C); 50% relative humidity.
To Touch: 15 minutes
To Handle: 4 hours
To Recoat: 24 hours
Drying times listed may vary depending on temperature, humidity, color and air movement.

CLEANUP: 97-727 PPG Thinner
FLASH POINT: 97-695 60°F (15.6°C)

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METALHIDE® — 97-694 Series

METALHIDE® 2000 Inorganic Zinc Rich Coating — HPC/Industrial Maintenance

GENERAL SURFACE PREPARATION

Remove all paint, mill scale, and rust. The surface to be coated must be dimensionally stable, dry, clean, and free of oil, grease, and other foreign materials.

WARNING! If you scrape, sand, or remove old paint, you may release lead dust or fumes. LEAD IS TOXIC. EXPOSURE TO LEAD DUST OR FUMES CAN CAUSE SERIOUS ILLNESS, SUCH AS BRAIN DAMAGE, ESPECIALLY IN CHILDREN. PREGNANT WOMEN SHOULD ALSO AVOID EXPOSURE. Wear a properly fitted NIOSH-approved respirator and prevent skin contact to control lead exposure. Clean up carefully with a HEPA vacuum and a wet mop. Before you start, find out how to protect yourself and your family by contacting the USEPA National Lead Information Hotline at 1-800-424-LEAD or log on to www.epa.gov/lead. In Canada contact a regional Health Canada office. Follow these instructions to control exposure to other hazardous substances that may be released during surface preparation.

STEEL: Non-Immersion Service -- The minimum surface preparation for ferrous metal substrates is SSPC-SP6 Commercial Blast cleaning. Service life of coating is in direct proportion to surface preparation. Immersion Service – Near White Metal Blast SSPC-SP10 is mandatory for ferrous metals. The surface to be coated must be clean, dry, and well prepared to receive the coating. For specific recommendations, see your PITTSBURGH® Paints dealer or call 1-800-441-9695.

RECOMMENDED PRIMERS

Self priming on properly prepared surfaces.

MIXING AND APPLICATIONS INFORMATION

MIXING INSTRUCTIONS: Mix the 97-694 or 695 opaque liquid base using a mechanical mixer until no pigment remains at the bottom of the container. Transfer to a large container to facilitate mixing, and slowly sift in the zinc dust, 97-697P under continuous agitation. Mix until blend is uniform and free of lumps. Strain through a 30-60 mesh screen. DO NOT MIX IN REVERSE ORDER. Maintain constant agitation during use to prevent zinc dust from settling. The liquid component and the mixed paint must be protected from moisture. Relatively small amounts of contamination will cause gelation.

Changes in application equipment, pressures and/or tip sizes may be required on ambient temperatures and application conditions.

Airless Spray: Pressure 1500 psi, tip 0.017" - 0.021" Filter: 30 mesh

Conventional Spray: Fluid Nozzle: DeVilbiss MBC-510 gun, with 64 air cap with E tip and needle, or comparable equipment. Atomization Pressure: 55 - 70 Fluid Pressure: Can not specify, dependent on numerous factors.

Spray equipment must be handled with due care and in accordance with manufacturer's recommendation. High-pressure injection of coatings into the skin by airless equipment may cause serious injury.

Brush: Not recommended

Roller: Not recommended

Thinning: Thinning not normally required. If thinning is desired do not thin more than 12% with 97-727.

MIXING AND APPLICATIONS INFORMATION (cont.)

Permissible temperatures during application:

Material:	50 to 90°F	10 to 32°C
Ambient:	0 to 100°F	-18 to 38°C
Substrate:	0 to 140°F	-18 to 60°C

LIMITATIONS OF USE

Apply in good weather when air and surface temperatures are between 50°F (10°C) and 100°F (37.8°C) with maximum relative humidity of 85%. Optimum paint temperatures is 70°F (21°C) - 80°F (26.7°C). Surface temperatures must be at least 5°F (3°C) above the dew point. Do not expose container to temperatures greater than 135°F (57°C). Do not use for potable water.

For Professional Use Only; Not Intended for Household Use.

SAFETY

Proper safety procedures should be followed at all times while handling this product. USE WITH ADEQUATE VENTILATION. KEEP OUT OF REACH OF CHILDREN. Explosion-proof equipment must be used when coating with these materials in confined areas. Keep containers closed and away from heat, sparks, and flames when in use. Spray equipment must be handled with due care and in accordance with manufacturer's recommendation. High-pressure injection of coatings into the skin by airless equipment may cause serious injury. Read all label and Material Safety Data Sheet for important health/safety information prior to use. MSDS are available through our website www.ppghpc.com or by calling 1-800-441-9695.

PPG Industries, Inc.
Architectural Coatings
One PPG Place
Pittsburgh, PA 15272
www.ppghpc.com

Technical Services
1-800-441-9695
1-888-807-5123 fax

Architect/Specifier
1-800-PPG-IDEA

PPG Canada, Inc.
Architectural Coatings
4 Kenview Blvd
Brampton, ON L6T 5E4

I23 11/2011
Supersedes (2/2009)

8.13.4 PPG PITT-THERM 97-724/UC59571 (typical)

PPG **PITT-THERM®** **97-724 Series**

HPC/Industrial Maintenance — PITT-THERM® High Heat & Stress Corrosion Coating

Generic Type

Air Dry Silicone, One Component

General Description

This coating is intended for use on austenitic stainless and carbon steel to provide protection against chloride attack and stress corrosion cracking on both insulated and uninsulated surfaces. PITT-THERM® has excellent thermal shock and barrier properties, and may be used as a heat resistant coating for carbon steel.

Recommended Uses

Austenitic Stainless Steel
Carbon Steel

Features / Benefits

High heat and thermal stress resistance.
Protects stainless steel against chloride attack and stress corrosion cracking.

Limitations of Use

For Professional Use Only; Not Intended for Household Use. Apply only when air, product and surface temperatures are 40°F (4.4°C) and when surface temperature is at least 5°F (3°C) above the dew point. Avoid exterior painting late in the day when dew or condensation are likely to form, or when rain is threatening. Special attention should be given to insure that this product is not contaminated by moisture during the application process. Drying times listed may vary depending on temperature, humidity, color and air movement.

Tinting and Base Information

97-724	Black
UC59571	Gray

Product Data

Gloss:	Matte
VOC*:	4.62 lbs/gal 554.00 g/L
Coverage:	279 to 372 sq ft/gal (26 to 35 sq. m/3.78L)

Note: Does not include loss due to varying application method, surface porosity, or mixing.

DFT:	1.5 minimum to 2.0 maximum
Weight/Gallon*:	9.6 lbs. (4.5 kg) +/- 0.2 lbs. (91 g)
Volume Solids*:	34.8% +/- 2%
Weight Solids*:	52.1% +/- 2%
Clean-up:	97-727 PPG Xylol Thinner

Results will vary by color, thinning and other additives.
*Product data calculated on full formula.

Drying Time:

To Touch:	20 minutes
To Handle:	2 hours
To Recoat:	16 hours

Dry Time @77°F (25°C); 50% relative humidity

In Service Temperature:

Dry Heat (F): 850° Dry Heat (C): 454°

Flash Point: 62°F, (16.7°C)

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PITT-THERM® 97-724 Series

HPC/Industrial Maintenance — **PITT-THERM® High Heat & Stress Corrosion Coating**

General Surface Preparation

Remove all loose paint, mill scale, and rust. The surface to be coated must be dimensionally stable, dry, clean, and free of oil, grease, and other foreign materials. Service life of coating is in direct proportion to surface preparation. WARNING! If you scrape, sand, or remove old paint, you may release lead dust or fumes. LEAD IS TOXIC. EXPOSURE TO LEAD DUST OR FUMES CAN CAUSE SERIOUS ILLNESS, SUCH AS BRAIN DAMAGE, ESPECIALLY IN CHILDREN. PREGNANT WOMEN SHOULD ALSO AVOID EXPOSURE. Wear a properly fitted NIOSH-approved respirator and prevent skin contact to control lead exposure. Clean up carefully with a HEPA vacuum and a wet mop. Before you start, find out how to protect yourself and your family by contacting the USEPA National Lead Information Hotline at 1-800-424-LEAD or log on to www.epa.gov/lead. In Canada contact a regional Health Canada office. Follow these instructions to control exposure to other hazardous substances that may be released during surface preparation.

For application to Austenitic Stainless Steel SSPC-SP1 Solvent Wash is the minimum surface preparation. For Carbon Steel applications, SSPC-SP10 Near White Metal Blast is required. Where appropriate bare areas should be primed with a suitable primer.

HPC Systems in Detail Brochure (H10788) COATING SYSTEMS: 225-HD, 226-HD, 227-HD

Recommended Primers

none	Refer to HD Coating Systems.
Steel	Self Priming, 97-673/674 or 675, 97-676 or 677

Directions for Use

Mix thoroughly to suspend all pigmentation before, and during use. Explosion-proof equipment must be used when coating with these materials in confined areas. Keep containers closed and away from heat, sparks, and flames when not in use. USE WITH ADEQUATE VENTILATION. KEEP OUT OF REACH OF CHILDREN. Read all label and Material Safety Data Sheet (MSDS) information prior to use. MSDS are available through our website or by calling 1-800-441-9695.

Permissible temperatures during application:

Material:	40 to 90°F	4 to 32°C
Ambient:	40 to 100°F	4 to 38°C
Substrate:	40 to 130°F	4 to 54°C

Application Information

Recommended Spread Rates:

Wet Mils :	4.3	minimum to	5.7	maximum
Wet Microns:	109.2	minimum to	144.8	maximum
Dry Mils :	1.5	minimum to	2.0	maximum
Dry Microns:	38.1	minimum to	50.8	maximum

Application Equipment: Changes in application equipment, pressures and/or tip sizes may be required depending on ambient temperatures and application conditions. Spray equipment must be handled with due care and in accordance with manufacturer's recommendation. High-pressure injection of coatings into the skin by airless equipment may cause serious injury.

Conventional Spray: Fluid Nozzle: DeVilbiss MBC gun, with 704 or 777 air cap with E or FF tip and needle, or comparable equipment. Atomization Pressure: 55 - 70 Fluid Pressure: Can not specify, dependent on numerous factors.

Airless Spray: Pressure 1500 psi, tip 0.011" - 0.015"

Brush: Not Recommended

Roller: Not Recommended

Thinning:

DO NOT THIN. Spray product as received.

Packaging: 1-Gallon (3.78L)

Not all products are available in all sizes. All containers are not full-filled.

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Louisville, KY 40203

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Architectural Coatings
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I7 10/2006

The melting temperature must not exceed 685°F (363°C) to prevent excessive drossing. The lead must be stirred immediately prior to sampling. The molten lead shall be cast into shapes suitable for use in spectrographic analysis, cast into thin sample bars not to exceed ⅜ in. (9.5 mm) thick for sawing, or granulated by pouring into distilled water and drying the material thoroughly. For sample bars, saw cuts shall be made halfway across the bar from each side and staggered so that they are about ½ in. (12.7 mm) apart. The sawings so produced are treated in accordance with 9.3.3.1.

9.3.4 *Sample Size*:

9.3.4.1 For spectrographic analysis, three samples shall be prepared of a size and shape satisfactory for use by the laboratory at which the analysis is to be made.

9.3.4.2 For wet chemical analysis, each prepared sample (sawings, drillings, or granules) shall weigh at least 600 g.[4]

9.3.5 Aspects of sampling and sample preparation not specifically covered in this specification shall be carried out in accordance with Practice E 88.

10. Methods of Chemical Analyses

10.1 The chemical compositions enumerated in Table 1 of this specification shall, in case of disagreement, be determined by wet chemical or spectrographic methods mutually agreed upon by the supplier and the purchaser.

10.2 By agreement between the purchaser and the supplier, analyses may be required and limits established for elements or compounds not specified in Table 1.

11. Inspection

11.1 Inspection of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the supplier promptly and in writing. In case of dissatisfaction with the results of the test, the supplier may make claim for a rehearing.

12.2 Rejection shall be considered as follows:

12.2.1 Variation of weight, quantity, dimensions, or workmanship.

12.2.2 Chemical composition.

12.2.2.1 In case of dispute, the material shall be sampled in the presence of both parties in accordance with 9.3.

12.2.2.2 The resulting sample (at least 1800 g) shall be mixed and separated into three equal parts, each of which shall be placed in a sealed package, one for the supplier, one for the purchaser, and one for the umpire if necessary, and analyzed in accordance with Test Methods E 37.

12.3 When the lead metal satisfies the chemical and physical requirements of this specification, it shall not be condemned for defects in manufacturing or for defects of alloys or products in which it is used.

13. Certification

13.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been tested as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a certified report of the test results shall be furnished.

14. Marking and Special Requirements

14.1 A brand, by which the supplier can be identified, shall be cast or marked legibly upon each pig, block, or hog. In addition, other markings shall identify the material by type and lot number.

14.2 (Any) special marking, color code, and other quality requirements not covered by this specification shall be agreed upon between the supplier and the purchaser.

15. Keywords

15.1 chemical-copper lead; lead; lead metal; pure lead; refined pure lead

[4] "Determination of As, Sb, and Te in Lead and Lead Alloys Using Hydride Generation Atomic Absorption Spectrometry," G.J. Fox, *Atomic Spectroscopy*, Vol 11, No.1, January 1990, p. 13.

8.13.8 PPG AMERLOCK 2/400GF (typical)

PPG Protective & Marine Coatings

AMERLOCK® 2/400GF

May 2013
Revision of October 2012

DESCRIPTION

High solids glass flake epoxy coating

PRINCIPAL CHARACTERISTICS

- High build, up to 20 mils in one coat
- Compatible with adherent rust remaining on prepared surfaces
- Continuous dry temperature resistance of 425°F on insulated or uninsulated surfaces
- Resistant to well defined cathodic protections
- Decreased film permeability due to glass flake pigmentation

COLOR AND GLOSS

Flat

Standard primer colors and custom colors

** Epoxy coatings will characteristically chalk and fade upon exposure to sunlight. Light colors are prone to ambering to some extent. Only use factory colors for immersion service.*

BASIC DATA

Volume solids	87% ± 3%
VOC	1.4 lbs/gal (172 g/L)
Recommended Dry film thickness (per coat)*	8 – 20 mils (200 – 500 microns) ** For high temperature applications above 250°F, limit total film thickness to 10 mils dft with spot readings to 12 mils.*
Theoretical Spread Rate	@ 1 mils dft 1347 ft²/gallon @ 8 mils dft 168 ft²/gallon @ 20 mils dft 67 ft²/gallon
Components	3
Shelf Life	3 years from date of manufacture

SURFACE PREPARATION

Coating performance is, in general, proportional to the degree of surface preparation.

Steel

- Remove weld spatter, protrusions, and laminations in steel. Grind welds smooth in accordance with NACE RP-0178. Remove all surface contaminants, oil and grease in accordance with SSPC SP-1.

  Abrasive blast with an angular abrasive to an SSPC SP-10 cleanliness or higher for immersion service. Achieve a surface profile of 2.0-4.0 mils. For atmospheric service, abrasive blast to SSPC SP-6 standards.

  The product may be applied over an SSPC SP-12 WJ-2(L) where a previous blast profile can be exposed.

  For maintenance and repair in atmospheric service, the product can be applied over surfaces prepared in accordance with SSPC SP-2 or SSPC SP-3 (hand and power tool cleaning).

  Amercoat 114A may be used as a pit filler for severely pitted steel and surface discontinuities.

  Check with PPG technical service for the maximum allowable soluble salt level for water immersion service. This will vary based on the water chemistry and service temperatures.

Concrete

- Remove all surface contaminants such as oil, grease, and embedded chemicals. Abrade the surface per ASTM D 4259 to remove all chalk and surface glaze or laitance. Mechanical surface preparation should expose sub-surface voids and provide a surface profile equivalent to 60 grit sandpaper or coarser. Surface should be free from moisture in accordance with ASTM D4263. Refer to Information Sheet #1496ACUS for further details regarding moisture measurements. Slabs on grade should have a maximum moisture content of 3 lbs/1,000 ft²/24 hours when measured by calcium chloride test.

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PPG Protective & Marine Coatings

AMERLOCK 2/400GF

Non-ferrous metals	–	Lightly abrasive blast in accordance with SSPC SP-16 to achieve a uniform and dense 1.5-4.0 mil anchor profile.
Stainless Steel	–	Abrasive blast with a hard angular abrasive to achieve a uniform and dense anchor profile of 1.5-4.0 mils.
Aged Coatings and Repairs	–	Ensure the coating system is sound and well adhered. Do not apply over acrylic coatings or coatings that exhibit poor solvent resistance. A test patch is recommended. Sweep blast or otherwise thoroughly abrade the existing coating in accordance with SSPC SP-7. Alternately, Prep 88 may be used to prepare some existing coatings. Please refer to Prep 88 data sheet for details. Feather the edges of tightly adhered, in-tact coatings at the perimeter of repair areas. Power tool clean the existing steel in accordance with SSPC SP-3 (atmospheric service) or SSPC SP-11 (immersion service).

ENVIRONMENTAL CONDITIONS

Ambient temperatures*	20°F to 122°F (-6°C to 50°C) * *Amerlock 400 hardener can be used with the Amerlock 2/400 base component for applications that require a long pot life. The A component is the same for Amerlock 400 and Amerlock 2. The B components are inter-changeable*
Material temperatures	40° to 90°F (5° to 32°C)
Relative humidity	0 to 100%, surface must be free of visible moisture. For immersion service and for optimum performance, surface temperature must be at least 5°F above the dew point temperature.
Surface temperature	20°F to 122°F (-6°C to 50°C)
General air quality	Area should be sheltered from airborne particulates and pollutants. Avoid combustion gases or other sources of carbon dioxide that may promote amine blush and ambering of light colors. Ensure good ventilation during application and curing. Provide shelter to prevent wind from affecting spray patterns.

INSTRUCTIONS FOR USE

Mixing ratio by volume	1 part base to 1 part hardener Pre-mix pigmented components with a pneumatic air mixer at moderate speeds to homogenize the container. Add hardener to base and agitate with a power mixer for 1-2 minutes until completely dispersed. Slowly incorporate glass flake additive under agitation over 1-2 minutes to ensure the glass flake is thoroughly mixed.

Pot life

	50°F	70°F	90°F
2GF	2 hours	1 hour	0.5 hours
400GF	3 hours	2 hours	1 hour

Induction time	None required
Airless spray	45:1 pump or larger, 0.027-0.035 fluid tip Can be sprayed with plural component application equipment.
Air spray	Thin up to 20%, standard conventional equipment, 0.070" fluid orifice
Brush & roll	Use a high quality natural bristle brush and / or solvent resistant, 3/8" nap roller. Ensure brush / roller is well loaded to avoid air entrainment. Multiple coats may be necessary to achieve adequate film build.
Thinner	*Amercoat* 65 (xylene), *Amercoat* 101 (recommended for > 90°F), *Amercoat* 8 (to extend pot life 10-20%)
Cleaning solvent	*Amercoat* 12 Cleaner or *Amercoat* 65 thinner (xylene)
Primers	Direct to substrate; *Dimetcote* series primers, *Amercoat* 68HS, *Amercoat* 68MCZ, *Amerlock* 2/400, *Amerlock* Sealer
Topcoats	*Amercoat* 450 series polyurethanes, *Amershield*, *PSX* 700, *PSX* ONE, *Pitthane* polyurethanes

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PPG Protective & Marine Coatings

AMERLOCK 2/400GF

Safety precautions

For paint and recommended thinners see safety sheet 1430, 1431 and relevant material safety data sheets
This is a solvent borne paint and care should be taken to avoid inhalation of spray mist or vapor as well as contact between the wet paint and exposed skin or eyes.

DRY/CURE TIMES

Amerlock 2GF @ 8 mils dft

	32°F	50°F	70°F	90°F
Dry to touch	48 hours	16 hours	6 hours	2 hours
Dry through	72 hours	24 hours	8 hours	5 hours
Dry to recoat/topcoat	48 hours	16 hours	7 hours	4 hours
Max recoat, self	90 days	60 days	30 days	14 days
Max topcoat, urethanes, *PSX*	30 days	14 days	7 days	4 days
Cure to immersion	21 days	7 days	3 days	2 days

Amerlock 400GF @ 8 mils dft

	50F	70°F	90°F
Dry to touch	28 hours	9 hours	4.5 hours
Dry through	48 hours	20 hours	12 hours
Dry to recoat/ topcoat	36 hours	16 hours	10 hours
Max recoat, self	90 days	90 days	45 days
Max topcoat, urethanes, *PSX*	60 days	30 days	14 days
Cure to immersion	21 days	7 days	4 days

* *Dry times are dependent on air and surface temperatures as well as film thickness, ventilation, and relative humidity. Maximum recoating time is highly dependent upon actual surface temperatures – not simply air temperatures. Surface temperatures should be monitored, especially with sun-exposed or otherwise heated surfaces. Higher surface temperatures shorten the maximum recoat window.*

Surface must be clean and dry. Any contamination must be identified and removed. A detergent wash with Prep 88 or equivalent is required prior to application of topcoats after 30 days of exposure. However, particular attention must be paid to surfaces exposed to sunlight where chalking may be present. In those situations, a further degree of cleaning may be required. PPG Technical Service can advise on suitable cleaning methods. If maximum recoat/topcoat time is exceeded, then roughen surface.

PRODUCT QUALIFICATIONS

- Compliant with USDA Incidental Food Contact Requirements
- LEED's compliant for Anti-corrosive Paint category

AVAILABILITY

Packaging

Available in 2-gallon and 5-gallon kits
2-gallon kits have 1 full gallon of base and 1 full gallon of hardener
5 gallon kits have 2.5 gallons of base and 2.5 gallons of hardener
Add one 3-gallon can of *Amercoat* 880 glass flake additive for each 5 gallon kit.
Add one 1-gallon can of *Amercoat* 880 glass flake for each 2 gallon kit.

Inventory (made to order, etc..)

Global availability

PPG Protective & Marine Coatings

AMERLOCK 2/400GF

Product codes	AK2-1	Buff
	AK2-3	White
	AK2-9	Black
	AK2-23	Pearl Gray
	AK2-72	Oxide Red
	AK2-81	Safety Yellow
	AK2-T1	Deep Tint base
	AK2-T2	Light Tint base
	AK2-T3	Neutral Tint base
	AK2-T4	Red Tint base
	AK2-T5	High HidingYellow Tint base
	AK2-B	Hardener component for *Amerlock* 2GF
	AK400-B	Hardener component for *Amerlock* 400GF
	AT880	Glass flake additive

Worldwide statement

While it is always the aim of PPG Protective & Marine Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.

WARRANTY STATEMENT

PPG warrants (i) its title to the product, (ii) that the quality of the product conforms to PPG's specifications for such product in effect at the time of manufacture and (iii) that the product shall be delivered free of the rightful claim of any third person for infringement of any U.S. patent covering the product.

THESE ARE THE ONLY WARRANTIES THAT PPG MAKES AND ALL OTHER EXPRESS OR IMPLIED WARRANTIES, UNDER STATUTE OR ARISING OTHERWISE IN LAW, FROM A COURSE OF DEALING OR USAGE OF TRADE, INCLUDING WITHOUT LIMITATION, ANY OTHER WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR USE, ARE DISCLAIMED BY PPG.

Any claim under this warranty must be made by Buyer to PPG in writing within five (5) days of Buyer's discovery of the claimed defect, but in no event later than the expiration of the applicable shelf life of the product, or one year from the date of the delivery of the product to the Buyer, whichever is earlier. Buyer's failure to notify PPG of such non-conformance as required herein shall bar Buyer from recovery under this warranty.

LIMITATION OF LIABILITY

IN NO EVENT WILL PPG BE LIABLE UNDER ANY THEORY OF RECOVERY (WHETHER BASED ON NEGLIGENCE OF ANY KIND, STRICT LIABILITY OR TORT) FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN ANY WAY RELATED TO, ARISING FROM, OR RESULTING FROM ANY USE MADE OF THE PRODUCT.

The information in this sheet is intended for guidance only and is based upon laboratory tests that PPG believes to be reliable. PPG may modify the information contained herein at any time as a result of practical experience and continuous product development. All recommendations or suggestions relating to the use of the PPG product, whether in technical documentation, or in response to a specific inquiry, or otherwise, are based on data, which to the best of PPG's knowledge, is reliable. The product and related information is designed for users having the requisite knowledge and industrial skills in the industry and it is the end-user's responsibility to determine the suitability of the product for its own particular use and it shall be deemed that Buyer has done so, as its sole discretion and risk.

PPG has no control over either the quality or condition of the substrate, or the many factors affecting the use and application of the product. Therefore, PPG does not accept any liability arising from any loss, injury or damage resulting from such use or the contents of this information (unless there are written agreements stating otherwise). Variations in the application environment, changes in procedures of use, or extrapolation of data may cause unsatisfactory results.

This sheet supersedes all previous versions and it is the Buyer's responsibility to ensure that this information is current prior to using the product.

Current sheets for all PPG Protective & Marine Coatings Products are maintained at www.ppgpmc.com. The English text of this sheet shall prevail over any translation thereof.

PPG Protective & Marine Coatings

AMERLOCK 2/400GF

Product codes	AK2-1	Buff
	AK2-3	White
	AK2-9	Black
	AK2-23	Pearl Gray
	AK2-72	Oxide Red
	AK2-81	Safety Yellow
	AK2-T1	Deep Tint base
	AK2-T2	Light Tint base
	AK2-T3	Neutral Tint base
	AK2-T4	Red Tint base
	AK2-T5	High HidingYellow Tint base
	AK2-B	Hardener component for *Amerlock* 2GF
	AK400-B	Hardener component for *Amerlock* 400GF
	AT880	Glass flake additive
Worldwide statement	While it is always the aim of PPG Protective & Marine Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.	

WARRANTY STATEMENT

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LIMITATION OF LIABILITY

IN NO EVENT WILL PPG BE LIABLE UNDER ANY THEORY OF RECOVERY (WHETHER BASED ON NEGLIGENCE OF ANY KIND, STRICT LIABILITY OR TORT) FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN ANY WAY RELATED TO, ARISING FROM, OR RESULTING FROM ANY USE MADE OF THE PRODUCT.

The information in this sheet is intended for guidance only and is based upon laboratory tests that PPG believes to be reliable. PPG may modify the information contained herein at any time as a result of practical experience and continuous product development. All recommendations or suggestions relating to the use of the PPG product, whether in technical documentation, or in response to a specific inquiry, or otherwise, are based on data, which to the best of PPG's knowledge, is reliable. The product and related information is designed for users having the requisite knowledge and industrial skills in the industry and it is the end-user's responsibility to determine the suitability of the product for its own particular use and it shall be deemed that Buyer has done so, as its sole discretion and risk.

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This sheet supersedes all previous versions and it is the Buyer's responsibility to ensure that this information is current prior to using the product.

Current sheets for all PPG Protective & Marine Coatings Products are maintained at www.ppgpmc.com. The English text of this sheet shall prevail over any translation thereof.

8.13.9 PPG AMERSHIELD (typical)

PPG Protective &
Marine Coatings

AMERSHIELD™

October 2012
Revision of April 2012

DESCRIPTION	Polyester-Acrylic Aliphatic Polyurethane Topcoat
PRINCIPAL CHARACTERISTICS	– Unique, high-solids, high build coatings – Outstanding weather resistance with excellent color and gloss retention – VOC compliant – Tough, flexible, and abrasion resistant finish – Good chemical and stain resistance – Direct to metal and concrete in protected environments – SSPC SP 36 Level 3
COLOR* AND GLOSS	Gloss Custom Colors ** Certain colors (especially yellow, orange and red) may require additional coats to achieve adequate hiding, particularly when applied over dark or contrasting primer colors. Yellow, red, and other bright colors will typically fade faster than other colors due to the replacement of lead-based pigments with lead-free pigments in those colors.*
BASIC DATA	
Volume solids	73% ± 3%
VOC*	2.2 lbs/gal (264 g/L) ** For compliance with regulations which require < 100 g/L, Amershield VOC can be specified interchangeably*
Recommended Dry film thickness	3-6 mils per coat (75-150 microns)
Theoretical Spread Rate	@ 1 mils dft 1171 ft²/gal @ 5 mils dft 234 ft²/gal
Components	2
Dry Temperature Resistance*	Continuous — 200°F Intermittent — 250°F (<5% of the time, max 24 hours) ** Color will drift at elevated temperatures.*
Shelf Life	2 years from date of manufacture ** when stored in original sealed containers in dry conditions between 40-100°F*
SURFACE PREPARATION	Coating performance is proportional to the degree of surface preparation. Refer to the application instructions for specific primers and intermediate coats for application and curing procedures. Ensure epoxies are free from amine blush prior to overcoating. All previous coats must dry and free of contaminants. Adhere to all minimum and maximum topcoat times for specific primers and intermediate coats. Aged epoxy coatings may require abrading prior to applying *Amershield.*
Steel	– Abrasive blast to SSPC SP-6 or higher with a 1.0-3.0 mils surface profile
Aluminum	– Lightly abrasive blast with a fine abrasive
Concrete / Masonry	– See specific primer
ENVIRONMENTAL CONDITIONS	
Ambient temperatures	40°F to 120°F (5°C to 49°C) With *Amercoat* 866M Accelerator 32°F to 100°F (0°C to 36°C) Surface temperature must be at least 5°F above the dew point temperature.
Material temperatures	With *Amercoat* 866M Accelerator 40°F to 90°F (5°C to 32°C)
Relative humidity	85% maximum
Surface temperature	*Amershield* 40°F to 120°F (5°C to 49°C) With *Amercoat* 866M Accelerator 32°F to 100°F (0°C to 36°C) Surface temperature must be at least 5°F above the dew point temperature.

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PPG Protective & Marine Coatings

AMERSHIELD

General air quality — Area should be sheltered from airborne particulates and pollutants. Ensure good ventilation during application and curing. Provide shelter to prevent wind from affecting spray patterns.

INSTRUCTIONS FOR USE

Mixing ratio by volume — 4 parts base to 1 part hardener

Pre-mix base component with a pneumatic air mixer at moderate speeds to homogenize the container. Add hardener to base and agitate with a power mixer for 1-2 minutes until completely dispersed

Pot life

Temperature	50°F	70°F	90°F
Amershield	5 hours	2.5 hours	1.5 hours
Amershield with 866M accelerator	2 hours	1 hours	30 minutes

Airless spray — 28:1 pump or larger, 0.013-0.016 fluid tip
Can be applied with plural component equipment

Air spray — Thin up to 20%, standard conventional equipment, 0.070" fluid orifice. A moisture and oil trap in the main line is essential. Product is sensitive to moisture contamination.

Brush & roll — Use a high quality natural bristle brush and / or solvent resistant, 1/4" or 3/8" nap roller. Ensure brush / roller is well loaded to avoid air entrainment. Multiple coats may be necessary to achieve adequate film build. *Amercoat* 851 flow control additive can be used to for enhanced flow and leveling with brush and roll application. Multiple coats may be required to achieve proper film build and hiding with roller application.

Thinner — *Amercoat* 923, *Amercoat* 65 (xylene), *Amercoat* 101 (recommended for > 90 °F), *Amercoat* 911

Cleaning solvent — *Amercoat* 12 Cleaner or *Amercoat* 65 thinner (xylene)

Primers — *Amercoat* 68HS, *Amercoat* 68MCZ, *Amercoat* 370, *Amercoat* 385, *Amercoat* 399, *Amerlock* 2/400, *Pittguard* Epoxies, *Amercoat* 435, *Amercoat* 256

Safety precautions — For paint and recommended thinners see safety sheet 1430, 1431 and relevant material safety data sheets

This is a solvent borne paint and care should be taken to avoid inhalation of spray mist or vapor as well as contact between the wet paint and exposed skin or eyes.

DRY/CURE TIMES

Amershield @ 5 mils dft

	40°F	50°F	70°F	90°F
Dry to touch	8 hours	4 hours	2.5 hours	1 hour
Dry through	5 days	72 hours	10 hours	5 hours
Dry to recoat	72 hours	48 hours	8 hours	4 hours
Maximum recoat	168 hours	168 hours	96 hours	12 hours

Amershield with 866M Accelerator @ 5 mils dft

	20°F	32°F	50°F	70°F	90°F
Dry to touch	8 hours	4 hours	75 minutes	25 minutes	10 minutes
Dry through	16 hours	10 hours	6 hours	3 hours	2 hours
Dry to recoat	16 hours	8 hours	4 hours	2 hours	1.5 hours
Maximum recoat	96 hours	48 hours	24 hours	12 hours	6 hours

PRODUCT QUALIFICATIONS

- Compliant with USDA Incidental Food Contact Requirements
- Nuclear Service Level 2
- NFPA Class A Flame Spread

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PPG Protective & Marine Coatings

AMERSHIELD

AVAILABILITY

Packaging	Available in 1-gallon and 5-gallon kits 1-gallon kits have 0.8 gallons of base and 0.2 gallons of hardener 5- gallon kits have 4 gallons of base and 1 gallon of hardener	
Product codes	AM -3	White base
	AM -9	Black base
	AM -T1	Deep Tint base*
	AM -T2	Light Tint base*
	AM -T3	Neutral Tint base*
	AM -T4	Red Tint base*
	AM -T5	High Hiding Yellow Tint base*
	AM -71	Safety Red base
	AM-81	Safety Yellow base
	AM-23	Pearl Gray base
	AM -B	Hardener (Part B)
	* *Tintable using UCD V-Line colorants only.*	
Worldwide statement	While it is always the aim of PPG Protective & Marine Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.	

WARRANTY STATEMENT

PPG warrants (i) its title to the product, (ii) that the quality of the product conforms to PPG's specifications for such product in effect at the time of manufacture and (iii) that the product shall be delivered free of the rightful claim of any third person for infringement of any U.S. patent covering the product.

THESE ARE THE ONLY WARRANTIES THAT PPG MAKES AND ALL OTHER EXPRESS OR IMPLIED WARRANTIES, UNDER STATUTE OR ARISING OTHERWISE IN LAW, FROM A COURSE OF DEALING OR USAGE OF TRADE, INCLUDING WITHOUT LIMITATION, ANY OTHER WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR USE, ARE DISCLAIMED BY PPG.

Any claim under this warranty must be made by Buyer to PPG in writing within five (5) days of Buyer's discovery of the claimed defect, but in no event later than the expiration of the applicable shelf life of the product, or one year from the date of the delivery of the product to the Buyer, whichever is earlier. Buyer's failure to notify PPG of such non-conformance as required herein shall bar Buyer from recovery under this warranty.

LIMITATION OF LIABILITY

IN NO EVENT WILL PPG BE LIABLE UNDER ANY THEORY OF RECOVERY (WHETHER BASED ON NEGLIGENCE OF ANY KIND, STRICT LIABILITY OR TORT) FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN ANY WAY RELATED TO, ARISING FROM, OR RESULTING FROM ANY USE MADE OF THE PRODUCT.

The information in this sheet is intended for guidance only and is based upon laboratory tests that PPG believes to be reliable. PPG may modify the information contained herein at any time as a result of practical experience and continuous product development. All recommendations or suggestions relating to the use of the PPG product, whether in technical documentation, or in response to a specific inquiry, or otherwise, are based on data, which to the best of PPG's knowledge, is reliable. The product and related information is designed for users having the requisite knowledge and industrial skills in the industry and it is the end-user's responsibility to determine the suitability of the product for its own particular use and it shall be deemed that Buyer has done so, as its sole discretion and risk.

PPG has no control over either the quality or condition of the substrate, or the many factors affecting the use and application of the product. Therefore, PPG does not accept any liability arising from any loss, injury or damage resulting from such use or the contents of this information (unless there are written agreements stating otherwise). Variations in the application environment, changes in procedures of use, or extrapolation of data may cause unsatisfactory results.

This sheet supersedes all previous versions and it is the Buyer's responsibility to ensure that this information is current prior to using the product.

Current sheets for all PPG Protective & Marine Coatings Products are maintained at www.ppgpmc.com. The English text of this sheet shall prevail over any translation thereof.

8.13.10 PPG DIMECOTE 9 (typical)

PPG Protective & Marine Coatings

DIMETCOTE® 9

December 2013
Revision of October 2013

DESCRIPTION	Inorganic Zinc Silicate Primer
PRINCIPAL CHARACTERISTICS	– >85% zinc in dry film – Provides outstanding corrosion resistance – Abrasion resistant – Resistant to dry film temperatures of up to 750°F – Recommended for ISO 12944 C5I and C5M Conditions
COLOR AND GLOSS	Green Flat
BASIC DATA	
Volume solids	63% ± 3% (based on applied film, including porosity)
VOC*	4.1 lbs/gal (491 g/L) * *For compliance with regulations which require < 420 g/L, Dimetcote 9VOC can be specified interchangeably. For compliance with regulations which require <340 g/L, Dimetcote 9H can be specified interchangeably.*
Recommended Dry film thickness (per coat)	2 - 4 mils (50-100 microns) * *Applications up to 6 mils are acceptable with random spot readings up to 8 mils. For high temperature applications, a maximum of 3 mils is allowed.*
Theoretical Spread Rate	@ 1 mil dft 1,011 ft²/gal @ 3 mils dft 337 ft²/gal
Components	2 (liquid, zinc powder)
Dry Temperature Resistance	Continuous — 750°F *Color will drift at elevated temperatures.*
Shelf Life	Liquid – 9 months from date of manufacture when stored indoors in the original unopened container. Storage temperature should be 40-100°F and in dry conditions. Powder – 24 months from date of manufacture when stored indoors in the original unopened container.
SURFACE PREPARATION	Coating performance is proportional to the degree of surface preparation.
Steel	– Abrasive blast to SSPC SP-6 or higher with a 1.5-3.0 mil surface profile. Higher surface profiles up to 5 mils are acceptable, but the product must be applied in a thickness great enough to achieve a minimum of 2.5 mils dry film thickness. Apply *Dimetcote* 9 as soon as possible to prevent the blasted surface from rusting. Keep moisture, oil, grease, or other organic matter off surface before coating. For touch up and repair, power tool cleaning in accordance with SSPC SP-11 is acceptable.
ENVIRONMENTAL CONDITIONS	
Ambient temperatures	0°F to 120°F (-18°C to 49°C) Surface temperature must be at least 5°F above the dew point temperature.
Material temperatures	40°F to 90°F (10°C to 32°C)
Relative humidity	50% minimum * *Work area can be artificially humidified by atomized water spray and/or ponding water under the coated structures. After the film is dry-to-touch, a fine mist may be applied over the coating to expedite curing in low humidity environments.*
Surface temperature	0°F to 130°F (-18°C to 54°C) Surface temperature must be at least 5°F above the dew point temperature.
General air quality	Area should be sheltered from airborne particulates and pollutants. Ensure good ventilation during application and curing. Provide shelter to prevent wind from affecting spray patterns.

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PPG Protective & Marine Coatings

DIMETCOTE 9

INSTRUCTIONS FOR USE

Mixing

77 parts liquid :: 23 parts powder by volume.

Pre-mix base component with a pneumatic air mixer at moderate speeds to homogenize the container. Add powder component slowly under agitation until fully mixed. Strain the mixture from one container to another through a 30 mesh filter/strainer to remove any undispersed lumps.

Pot life*

Temperature	70°F
Dimetcote 9	8 hours

* *Maintain agitation throughout application to prevent settling of the zinc. Protect product from moisture contamination*

Airless spray

Standard airless spray equipment, 30:1 pump or larger, 0.019 – 0.023, reversible fluid tip recommended

Air spray

Thin up to 10%, dedicated equipment for inorganic zinc is highly recommend, standard conventional equipment, 0.070" fluid orifice. A moisture and oil trap in the main line is recommended. Separate regulators for air and fluid pressure are recommended. Use an agitated pressure pot. Limit fluid hose length to 50 feet.

Brush & roll

Use a high quality natural bristle. Brush application is only recommended for small touch up and/or repair areas. Roller application is not recommended.

Repair

When dry though, measure the dry film thickness. If film thickness is lower than specified, additional material can be applied up 24 hours from the previous application. Thin the second coat with *Amercoat* 101 thinner or *Amercoat* 930 thinner. Ensure any dry spray is removed.

For aged inorganic zinc coatings, spot blast rusted areas in accordance with the surface preparation instructions before touching up with *Dimetcote* 9. When blasting is not practical, *Amercoat* 68HS or *Dimetcote* 302H may be used for repair.

Thinner

Amercoat 65 (xylene), *Amercoat* 101 (recommended for > 60°F), *Amercoat* 930 (recommended for applications > 80°F or when dry spray is a problem)

Cleaning solvent

Amercoat 12 Cleaner or *Amercoat* 65 thinner (xylene)

Primers

Direct to metal

Topcoats

PSX 700, *Amerlock* 2/400, *Amercoat* 385, *Amercoat* 370, others

A mist coat / full coat application technique is required when topcoating to prevent application bubbling. Ensure dry spray is removed from the surface.

Product can be un-topcoated in certain applications.

Safety precautions

For paint and recommended thinners see safety sheet 1430, 1431 and relevant material safety data sheets

This is a solvent borne paint and care should be taken to avoid inhalation of spray mist or vapor as well as contact between the wet paint and exposed skin or eyes.

DRY/CURE TIMES

Dimetcote 9 @ 3 mils dft and 50% relative humidity

	32°F	50°F	70°F	90°F
Dry to handle	2 hours	1 hour	30 minutes	20 minutes
Dry to overcoat*	48 hours	36 hours	24 hours	18 hours
Full Cure	4 days	72 hours	46 hours	36 hours

* *A MEK rub resistance rating of 4 or higher, indicates the film has cured sufficiently for topcoating.*

** *Surface must be power washed as needed to remove all surface contaminants including zinc salts. Surface must be clean and dry.*

PRODUCT QUALIFICATIONS

- SSPC Paint 20, Type IC, Level 1
- RCSC Class B Slip Coefficient for High Strength Bolted Connections
- Zinc Dust meets ASTM D520 Type 2 standards
- AASHTO M300
- Nuclear Qualified version available

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PPG Protective & Marine Coatings

DIMETCOTE 9

AVAILABILITY

Packaging	Available in 1-gallon and 5-gallon kits	
Product codes	D19-A	Liquid component
	D19-P	Zinc Powder component
Worldwide statement	While it is always the aim of PPG Protective & Marine Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.	

WARRANTY STATEMENT

PPG warrants (i) its title to the product, (ii) that the quality of the product conforms to PPG's specifications for such product in effect at the time of manufacture and (iii) that the product shall be delivered free of the rightful claim of any third person for infringement of any U.S. patent covering the product.

THESE ARE THE ONLY WARRANTIES THAT PPG MAKES AND ALL OTHER EXPRESS OR IMPLIED WARRANTIES, UNDER STATUTE OR ARISING OTHERWISE IN LAW, FROM A COURSE OF DEALING OR USAGE OF TRADE, INCLUDING WITHOUT LIMITATION, ANY OTHER WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR USE, ARE DISCLAIMED BY PPG.

Any claim under this warranty must be made by Buyer to PPG in writing within five (5) days of Buyer's discovery of the claimed defect, but in no event later than the expiration of the applicable shelf life of the product, or one year from the date of the delivery of the product to the Buyer, whichever is earlier. Buyer's failure to notify PPG of such non-conformance as required herein shall bar Buyer from recovery under this warranty.

LIMITATION OF LIABILITY

IN NO EVENT WILL PPG BE LIABLE UNDER ANY THEORY OF RECOVERY (WHETHER BASED ON NEGLIGENCE OF ANY KIND, STRICT LIABILITY OR TORT) FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN ANY WAY RELATED TO, ARISING FROM, OR RESULTING FROM ANY USE MADE OF THE PRODUCT.

The information in this sheet is intended for guidance only and is based upon laboratory tests that PPG believes to be reliable. PPG may modify the information contained herein at any time as a result of practical experience and continuous product development. All recommendations or suggestions relating to the use of the PPG product, whether in technical documentation, or in response to a specific inquiry, or otherwise, are based on data, which to the best of PPG's knowledge, is reliable. The product and related information is designed for users having the requisite knowledge and industrial skills in the industry and it is the end-user's responsibility to determine the suitability of the product for its own particular use and it shall be deemed that Buyer has done so, as its sole discretion and risk.

PPG has no control over either the quality or condition of the substrate, or the many factors affecting the use and application of the product. Therefore, PPG does not accept any liability arising from any loss, injury or damage resulting from such use or the contents of this information (unless there are written agreements stating otherwise). Variations in the application environment, changes in procedures of use, or extrapolation of data may cause unsatisfactory results.

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8.13.11 PPG DIMETCOTE® 9 VOC (typical)

PRODUCT DATA SHEET

August 7, 2015 (Revision of July 22, 2015)

DIMETCOTE® 9 VOC

DESCRIPTION

Inorganic Zinc Silicate Primer

PRINCIPAL CHARACTERISTICS

- High level of zinc in dry film
- VOC compliant for <420 g/L requirements
- Provides outstanding corrosion resistance
- Good abrasion resistance
- Resistant to dry temperature up to 750°F(399°C)
- Recommended for ISO 12944 C5I and C5M conditions
- >80% zinc in dry film

COLOR AND GLOSS LEVEL

- Green
- Flat

BASIC DATA AT 68°F (20°C)

Data for mixed product	
Number of components	Two
Volume solids	71 ± 4%
VOC (Supplied)	max. 3.4 lb/US gal (approx. 411 g/l)
Temperature resistance (Continous)	To 750°F (399°C)
Recommended dry film thickness	2.0 - 5.0 mils (50 - 125 µm) depending on system
Theoretical spreading rate	569 ft²/US gal for 2.0 mils (10.0 m²/l for 50 µm)
Shelf life	Liquid: at least 9 months when stored cool and dry Powder: at least 24 months when stored cool and dry

Notes:
- See ADDITIONAL DATA – Overcoating intervals
- See ADDITIONAL DATA – Curing time
- Color will drift at elevated temperatures
- Applications up to 6.0 mils (150 µm) are acceptable with random spot readings up to 8.0 mils (200 µm). For high temperature applications, a maximum of 3.0 mils (75 µm) is allowed
- VOC (Supplied): For compliance with regulations which require < 2.8 lb/US gal (340 g/L), DIMETCOTE 9 H can be specified interchangeably
- volume solids is based on applied properties and accounts for film porosity

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PRODUCT DATA SHEET

August 7, 2015 (Revision of July 22, 2015)

DIMETCOTE® 9 VOC

RECOMMENDED SUBSTRATE CONDITIONS AND TEMPERATURES

- Coating performance is prpoportional to the degree of surface preparation.

Steel

- Abrasive Blast to SSPC SP-6 or higher with a 1.0-3.0 mil surface profile
- Higher surface profiles up to 5 mils (125 µm) are acceptable, but the product must be applied in a thickness great enough to achieve a minimum of 2.5 mils (65 µm) dry film thickness
- Apply this product as soon as possible to avoid rusting of blasted surfaces
- Keep moisture, oil, grease and other organic matter off surface before coating
- For touch up and repair, power tool cleaning in accordance with SSPC SP-11 is acceptable

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Substrate temperature and application conditions

- Surface temperature during application should be between 20°F (-7°C) and 130°F (54°C)
- Surface temperature during application should be at least 5°F (3°C) above dew point
- Ambient temperature during application and curing should be between 20°F (-7°C) and 120°F (49°C)
- Relative humidity during application and curing should be above 50% to obtain optimal curing properties

Note: Work area can be artificially humidified by atomized water spray and/or ponding water under the coated structures. After the film is dry-to-touch, a fine mist may be applied over the coating to expedite curing in low humidity environments

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SYSTEM SPECIFICATION

- Primers: Direct to metal
- Topcoats: PSX 700, AMERLOCK 2/400, AMERCOAT Epoxies and PITTGUARD Epoxies

Note: Product can be un-topcoated in certain applications

INSTRUCTIONS FOR USE

- Only mix full kits
- Pre-mix base component with a pneumatic air mixer at moderate speeds to homogenize the container. Add powder component slowly under agitation until fully mixed. Strain the mixture from one container to another through a 30 mesh filter/strainer to remove any undispersed lumps.

Pot life

12 hours at 70°F (21°C)

Note: See ADDITIONAL DATA – Pot life

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PRODUCT DATA SHEET

August 7, 2015 (Revision of July 22, 2015)

DIMETCOTE® 9 VOC

Application

- Area should be sheltered from airborne particulates and pollutants
- Ensure good ventilation during application and curing
- Provide shelter to prevent wind from affecting spray patterns
- Mist spray: A mist coat / full coat application technique is required when topcoating to prevent application bubbling. Ensure dry spray is removed from the surface
- Repair: For aged inorganic zinc coatings, spot blast rusted areas in accordance with the surface preparation instructions before touching up with this product. When blasting is not practical, AMERCOAT 68 HS or DIMETCOTE 302 H may be used for repair.
- Repair: When dry though, measure the dry film thickness. If film thickness is lower than specified, additional material can be applied up 24 hours from the previous application. Thin the second coat with AMERCOAT 101 thinner or AMERCOAT 930 thinner. Ensure any dry spray is removed

Material temperature
Material temperature during application should be between 40°F (4°C) and 100°F (38°C)

Air spray

- Separate air and fluid pressure regulators and a moisture and oil trap in the main air supply line are recommended.
- Maintain continuous agitation to keep zinc in suspension
- Limit fluid hose lenght to 50 feet
- Use standard conventional equipment

Recommended thinner
THINNER 21-06 (AMERCOAT 65) (xylene)), THINNER 21-25 (AMERCOAT 101) (recommended for > 60°F (16°C)), AMERCOAT 930 (recommended for applications > 80°F (27°C) or when dry spray is a problem)

Volume of thinner
0 - 8%

Nozzle orifice
Approx. 0.070 in (1.8 mm)

Airless spray

- 30:1 pump or larger
- A reversible fluid tip recommended
- Use standard airless spray equipment
- Hoses should normally be kept as short as possible
- Maintain continuous agitation to keep zinc in suspension

Recommended thinner
THINNER 21-06 (AMERCOAT 65) (xylene)), THINNER 21-25 (AMERCOAT 101) (recommended for > 60°F (16°C)), AMERCOAT 930 (recommended for applications > 80°F (27°C) or when dry spray is a problem)

Nozzle orifice
0.019 – 0.023 in (approx. 0.48 – 0.58 mm)

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PRODUCT DATA SHEET

August 7, 2015 (Revision of July 22, 2015)

DIMETCOTE® 9 VOC

Brush/roller

- Use a high-quality natural-bristle brush. Brush application is only recommended for small touch-up and/or repair areas. Roller application is not recommended

Recommended thinner

AMERCOAT 65 (xylene)| AMERCOAT 101 (recommended for >60°F (16°C)). AMERCOAT 930 (recommended for applications >80°F (27°C) or when dry spray is a problem)

Volume of thinner

0 – 5%

Cleaning solvent

AMERCOAT 12 CLEANER or AMERCOAT 65 THINNER (xylene)

ADDITIONAL DATA

Overcoating interval for DFT up to 3 mils and 50% relative humidity					
Overcoating with...	Interval	40°F (4°C)	50°F (10°C)	70°F (21°C)	90°F (32°C)
itself	Minimum	48 hours	30 hours	20 hours	16 hours
	Maximum	Extended	Extended	Extended	Extended

Notes:

- To confirm cure to topcoat, conduct a MEK rub test per ASTM D4752. A rating of 4 or higher is sufficient for topcoating
- Maximum interval is only unlimited when the surface is free from any contamination
- When re-coating to build film thickness within 24 hours of the initial application and prior to the film reaching an MEK resistance of 3 or higher per ASTM D4752, use a wire screen to remove any dry spray and apply a thinned down coat using 25-30% AMERCOAT 101 thinner (Thinner 21-25) to achieve the specified film thickness and apply in a wet coat.
- When re-coating to build film thickness after product has reached an MEK resistance of 3 or higher and passes a coin rub test, uniformly abrade the surface taking caution not to polish/burnish the film. This is best done by light abrasive blasting followed by cleaning of any particulate contamination on the surface. Apply a thinned down coat using Amerocat 101 (Thinner 21-25) as described above.

Curing time for DFT up to 3.0 mils and 50% relative humidity		
Substrate temperature	Dry to touch	Dry to handle
40°F (4°C)	45 minutes	75 minutes
50°F (10°C)	30 minutes	50 minutes
70°F (21°C)	15 minutes	25 minutes
90°F (32°C)	5 minutes	10 minutes

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PRODUCT DATA SHEET

August 7, 2015 (Revision of July 22, 2015)

DIMETCOTE® 9 VOC

Pot life (at application viscosity)	
Mixed product temperature	Pot life
50°F (10°C)	16 hours
70°F (21°C)	12 hours
90°F (32°C)	8 hours

Note: Maintain agitation throughout application to prevent settling of the zinc. Protect product from moisture contamination

Product Qualifications

- SSPC Paint 20, Type IC, Level 2
- RCSC Class B slip coefficient for high strenght bolted connections
- Zinc dust meets ASTM D520 type 2 standards
- AASHTO M300

SAFETY PRECAUTIONS

- For paint and recommended thinners see INFORMATION SHEETS 1430, 1431 and relevant Material Safety Data Sheets
- This is a solvent-borne paint and care should be taken to avoid inhalation of spray mist or vapor, as well as contact between the wet paint and exposed skin or eyes

WORLDWIDE AVAILABILITY

It is always the aim of PPG Protective and Marine Coatings to supply the same product on a worldwide basis. However, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.

REFERENCES

• CONVERSION TABLES	INFORMATION SHEET	1410
• EXPLANATION TO PRODUCT DATA SHEETS	INFORMATION SHEET	1411
• SAFETY INDICATIONS	INFORMATION SHEET	1430
• SAFETY IN CONFINED SPACES AND HEALTH SAFETY, EXPLOSION HAZARD – TOXIC HAZARD	INFORMATION SHEET	1431

WARRANTY

PPG warrants (i) its title to the product, (ii) that the quality of the product conforms to PPG's specifications for such product in effect at the time of manufacture and (iii) that the product shall be delivered free of the rightful claim of any third person for infringement of any U.S. patent covering the product. THESE ARE THE ONLY WARRANTIES THAT PPG MAKES AND ALL OTHER EXPRESS OR IMPLIED WARRANTIES, UNDER STATUTE OR ARISING OTHERWISE IN LAW, FROM A COURSE OF DEALING OR USAGE OF TRADE, INCLUDING WITHOUT LIMITATION, ANY OTHER WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR USE, ARE DISCLAIMED BY PPG. Any claim under this warranty must be made by Buyer to PPG in writing within five (5) days of Buyer's discovery of the claimed defect, but in no event later than the expiration of the applicable shelf life of the product, or one year from the date of the delivery of the product to the Buyer, whichever is earlier. Buyer's failure to notify PPG of such non-conformance as required herein shall bar Buyer from recovery under this warranty.

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PRODUCT DATA SHEET

August 7, 2015 (Revision of July 22, 2015)

DIMETCOTE® 9 VOC

LIMITATIONS OF LIABILITY

Packaging: Available in 0.85 gallon and 4.25-gallon kits

Product code	Description
D9V-A	Liquid
D9-P	Zinc Powder

PPG Protective & Marine Coatings
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8.13.12 PPG DIMETCOTE® 9 H (typical)

PRODUCT DATA SHEET

August 7, 2015 (Revision of April 27, 2015)

DIMETCOTE® 9 H

DESCRIPTION

Inorganic Zinc Silicate Primer

PRINCIPAL CHARACTERISTICS

- >85% zinc in dry film
- VOC Compliant <2.8 lb/ gal
- Provides outstanding corrosion resistance
- Good abrasion resistance
- Resistant to dry temperature up to 750°F(399°C)
- Recommended for ISO 12944 C5I and C5M conditions

COLOR AND GLOSS LEVEL

- Green
- Flat

BASIC DATA AT 68°F (20°C)

Data for mixed product	
Number of components	Three
Volume solids	60 ± 4%
VOC (Supplied)	max. 2.7 lb/US gal (approx. 324 g/l)
Temperature resistance (Continous)	To 750°F (399°C)
Recommended dry film thickness	2.0 - 5.0 mils (50 - 125 μm) depending on system
Theoretical spreading rate	642 ft²/US gal for 2.0 mils (16.0 m²/l for 50 μm)
Shelf life	Liquid: at least 9 months when stored cool and dry Activator: at least 24 months when stored cool and dry Powder: at least 24 months when stored cool and dry

Notes:
- See ADDITIONAL DATA – Overcoating intervals
- See ADDITIONAL DATA – Curing time
- Color will drift at elevated temperatures
- Applications up to 6.0 mils (150 μm) are acceptable with random spot readings up to 8.0 mils (200 μm). For high temperature applications, a maximum of 3.0 mils (75 μm) is allowed
- volume solids is based on applied properties and accounts for film porosity

RECOMMENDED SUBSTRATE CONDITIONS AND TEMPERATURES

- Coating performance is proportional to the degree of surface preparation.

PPG Protective & Marine Coatings
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PRODUCT DATA SHEET

August 7, 2015 (Revision of April 27, 2015)

DIMETCOTE® 9 H

Steel
- Abrasive Blast to SSPC SP-6 or higher with a 1.0-3.0 mil surface profile
- Higher surface profiles up to 5 mils (125 µm) are acceptable, but the product must be applied in a thickness great enough to achieve a minimum of 2.5 mils (65 µm) dry film thickness
- Apply this product as soon as possible to avoid rusting of blasted surfaces
- Keep moisture, oil, grease and other organic matter off surface before coating
- For touch up and repair, power tool cleaning in accordance with SSPC SP-11 is acceptable

Substrate temperature and application conditions
- Surface temperature during application should be between 20°F (-7°C) and 130°F (54°C)
- Surface temperature during application should be at least 5°F (3°C) above dew point
- Ambient temperature during application and curing should be between 20°F (-7°C) and 120°F (49°C)
- Relative humidity during application and curing should be above 50% to obtain optimal curing properties

Note: Work area can be artificially humidified by atomized water spray and/or ponding water under the coated structures. After the film is dry-to-touch, a fine mist may be applied over the coating to expedite curing in low humidity environments

SYSTEM SPECIFICATION

- Primers: Direct to metal
- Topcoats: PSX 700, AMERLOCK 2/400, AMERCOAT Epoxies and PITTGUARD Epoxies

INSTRUCTIONS FOR USE

Mix as packaged
- Only mix full kits. Liquid, powder and activator are packaged in the correct proportions which, when mixed together, yield 0.68 gallons or 3.4 gallons of DIMETCOTE 9 H
- Pre-mix base component with a pneumatic air mixer at moderate speeds to homogenize the container. Add powder component slowly under agitation until fully mixed. Strain the mixture from one container to another through a 30 mesh filter/strainer to remove any undispersed lumps.

Pot life
8 hours at 70°F (21°C)

Note: See ADDITIONAL DATA – Pot life

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PRODUCT DATA SHEET

August 7, 2015 (Revision of April 27, 2015)

DIMETCOTE® 9 H

Application

- Area should be sheltered from airborne particulates and pollutants
- Ensure good ventilation during application and curing
- Provide shelter to prevent wind from affecting spray patterns
- Repair: When dry though, measure the dry film thickness. If film thickness is lower than specified, additional material can be applied up 24 hours from the previous application. Thin the second coat with AMERCOAT 101 thinner or AMERCOAT 930 thinner. Ensure any dry spray is removed
- Repair: For aged inorganic zinc coatings, spot blast rusted areas in accordance with the surface preparation instructions before touching up with this product. When blasting is not practical, AMERCOAT 68 HS or DIMETCOTE 302 H may be used for repair
- Mist spray: A mist coat / full coat application technique is required when topcoating to prevent application bubbling. Ensure dry spray is removed from the surface
- Product can be un-topcoated in certain applications

Material temperature

Material temperature during application should be between 40°F (4°C) and 90°F (32°C)

Air spray

- Separate air and fluid pressure regulators and a moisture and oil trap in the main air supply line are recommended.
- Maintain continuous agitation to keep zinc in suspension
- Limit fluid hose lenght to 50 feet

Recommended thinner

THINNER 21-06 (AMERCOAT 65) (xylene)). THINNER 21-25 (AMERCOAT 101) (recommended for > 60°F (16°C)). AMERCOAT 930 (recommended for applications > 80°F (27°C) or when dry spray is a problem)

Volume of thinner

0 - 8%

Nozzle orifice

Approx. 0.070 in (1.8 mm)

Airless spray

- 30:1 pump or larger
- Use standard airless spray equipment
- A reversible fluid tip recommended

Recommended thinner

THINNER 21-06 (AMERCOAT 65) (xylene)). THINNER 21-25 (AMERCOAT 101) (recommended for > 60°F (16°C)). AMERCOAT 930 (recommended for applications > 80°F (27°C) or when dry spray is a problem)

Nozzle orifice

0.019 – 0.023 in (approx. 0.48 – 0.58 mm)

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Brush/roller

- Use a high-quality natural-bristle brush. Brush application is only recommended for small touch-up and/or repair areas. Roller application is not recommended

Recommended thinner

AMERCOAT 65 (Xylene)] AMERCOAT 101 (recommended for >60°F (16°C)). AMERCOAT 930 (recommended for applications >80°F (27°C) or when dry spray is a problem)

Cleaning solvent

AMERCOAT 12 CLEANER or AMERCOAT 65 THINNER (xylene)

ADDITIONAL DATA

Overcoating interval for DFT up to 3 mils and 50% relative humidity					
Overcoating with...	Interval	40°F (4°C)	50°F (10°C)	70°F (21°C)	90°F (32°C)
itself	Minimum	48 hours	36 hours	24 hours	16 hours
	Maximum	Unlimited	Unlimited	Unlimited	Unlimited

Notes:

- A MEK rub resistance test according to ASTM D4752 can be performed to confirm cure to topcoat. A rating of 4 or higher indicates sufficient cures. A minimum rating of 3 should be obtained prior to overcoating.
- Surface must be power washed as needed to remove all surface contaminants including zinc salts. Surface must be clean and dry
- When re-coating to build film thickness within 24 hours of the initial application and prior to the film reaching an MEK resistance of 3 or higher per ASTM D4752, use a wire screen to remove any dry spray and apply a thinned down coat using 25-30% AMERCOAT 101 thinner (Thinner 21-25) to achieve the specified film thickness and apply in a wet coat.
- When re-coating to build film thickness after product has reached an MEK resistance of 3 or higher and passes a coin rub test, uniformly abrade the surface taking caution not to polish/burnish the film. This is best done by light abrasive blasting followed by cleaning of any particulate contamination on the surface. Apply a thinned down coat using Amercoat 101 (Thinner 21-25) as described above.

Curing time for DFT up to 3.0 mils and 50% relative humidity		
Substrate temperature	Dry to touch	Dry to handle
40°F (4°C)	40 minutes	70 minutes
50°F (10°C)	30 minutes	40 minutes
70°F (21°C)	15 minutes	20 minutes
90°F (32°C)	5 minutes	10 minutes

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Pot life (at application viscosity)	
Mixed product temperature	Pot life
50°F (10°C)	12 hours
70°F (21°C)	8 hours
90°F (32°C)	4 hours

Note: Maintain agitation throughout application to prevent settling of the zinc. Protect product from moisture contamination

Product Qualifications

- SSPC Paint 20, Type IC, Level 1
- RCSC Class B slip coefficient for high strenght bolted connections
- Zinc dust meets ASTM D520 type 2 standards
- AASHTO M300

SAFETY PRECAUTIONS

- For paint and recommended thinners see INFORMATION SHEETS 1430, 1431 and relevant Material Safety Data Sheets
- This is a solvent-borne paint and care should be taken to avoid inhalation of spray mist or vapor, as well as contact between the wet paint and exposed skin or eyes

WORLDWIDE AVAILABILITY

It is always the aim of PPG Protective and Marine Coatings to supply the same product on a worldwide basis. However, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.

REFERENCES

• CONVERSION TABLES	INFORMATION SHEET	1410
• EXPLANATION TO PRODUCT DATA SHEETS	INFORMATION SHEET	1411
• SAFETY INDICATIONS	INFORMATION SHEET	1430
• SAFETY IN CONFINED SPACES AND HEALTH SAFETY, EXPLOSION HAZARD – TOXIC HAZARD	INFORMATION SHEET	1431

WARRANTY

PPG warrants (i) its title to the product, (ii) that the quality of the product conforms to PPG's specifications for such product in effect at the time of manufacture and (iii) that the product shall be delivered free of the rightful claim of any third person for infringement of any U.S. patent covering the product. THESE ARE THE ONLY WARRANTIES THAT PPG MAKES AND ALL OTHER EXPRESS OR IMPLIED WARRANTIES, UNDER STATUTE OR ARISING OTHERWISE IN LAW, FROM A COURSE OF DEALING OR USAGE OF TRADE, INCLUDING WITHOUT LIMITATION, ANY OTHER WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR USE, ARE DISCLAIMED BY PPG. Any claim under this warranty must be made by Buyer to PPG in writing within five (5) days of Buyer's discovery of the claimed defect, but in no event later than the expiration of the applicable shelf life of the product, or one year from the date of the delivery of the product to the Buyer, whichever is earlier. Buyer's failure to notify PPG of such non-conformance as required herein shall bar Buyer from recovery under this warranty.

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LIMITATIONS OF LIABILITY

Packaging: Available in 0.67 gallon and 3.4-gallon kits

Product code	Description
D9H-A	Liquid
D9H-B	Activator
D9-P	Zinc Powder

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6. Fill the TSC with clean or pool water. For PWR spent fuel contents, the soluble boron concentration in the TSC shall be verified and monitored in accordance with the LCO 3.2.1.
7. Attach the lift yoke to a crane suitable for handling the loaded TSC, transfer cask and yoke. Position the lift yoke over the transfer cask and engage it with the two transfer cask trunnions.

   Note: The temperature of the transfer cask (surrounding ambient air temperature) must be verified to be at or above the minimum operating temperature of 0°F, per Section 4.3.1.f. of the Technical Specifications (not applicable to the stainless steel MTC2 design).
8. Lift the transfer cask containing the empty TSC and move it to the spent fuel pool following the prescribed load path.

   Note: An optional protective cover, attached to the bottom of the transfer cask, may be used to prevent imbedding contaminated particles in the shield doors and door rails.
9. Connect the clean water lines to the lower annulus fill ports of the transfer cask. Ensure that the unused ports are closed or capped to prevent pool water in-leakage.
10. Lower the transfer cask to the pool surface and turn on the clean water supply lines to the lower annulus fill ports to fill the transfer cask/TSC annulus.

    Note: Sequence on connection and filling/draining transfer cask/TSC annulus is at the discretion of the user based on approved site-specific procedures.
11. Spray the transfer cask and lift yoke with clean water to wet the exposed surfaces.

    Note: Wetting the components that enter the spent fuel pool and spraying the components leaving the pool will reduce the effort required to decontaminate the components.
12. Lower the transfer cask as the annulus fills with clean water until the upper annulus fill ports are accessible. Hold this position and connect the clean water annulus fill lines to the upper fill ports. Ensure the unused ports are closed or capped to prevent pool water in-leakage.
13. Lower the transfer cask to the bottom of the pool in the cask loading area.
14. Disengage the lift yoke and visually verify that the lift yoke is fully disengaged. Remove the lift yoke from the spent fuel pool while spraying the yoke and crane cables with clean water.
15. Load the previously selected fuel assemblies into the TSC basket.

    Note: The fuel assemblies shall be selected in compliance with the requirements of the approved contents specified in Appendix B of the Technical Specifications and the boron concentration limits of the Technical Specifications, including limitations on fuel assembly positions within the basket. Specific fuel assembly positions for preferential and zoned loading patterns shall be in full compliance with the requirements of Appendix B of the Technical Specifications. Assembly selection, placement and compliance with preferential zone loading patterns within the basket shall be independently verified.

Note: Up to four DFCs containing authorized PWR contents may be loaded in a TSC with a DF Basket Assembly. A DFC spacer is required to be positioned in the Designated DF Basket Assembly corner locations for the shorter length DFCs. Independently, visually verify proper placement and correct orientation of each required DFC spacer.

Note: At the option of the user, install fuel assembly spacers for the axial positioning of the PWR fuel assembly types to be loaded. Verify spacer identification and install fuel spacers in each intended fuel loading location based on the fuel spacer plan prepared, which is based on the fuel assembly inventory and nonfuel hardware to be loaded. Independently, visually verify proper placement and correct orientation of each required fuel spacer.

16. Visually verify the fuel assembly (and DFC, as applicable) identifications to confirm the serial numbers match the approved fuel-loading pattern.
17. Install three swivel hoist rings hand tight in the three closure lid lifting holes or in three of the six TSC lift holes. Install a three-legged sling set to the hoist rings and connect the sling set to the crane hook or the attachment point on the lift yoke.

    Note: At the discretion of the user, the closure lid can be attached to the lift yoke and the lid installed during the lowering of the lift yoke.
18. Raise the closure lid. Adjust closure lid rigging to level the closure lid.
19. Move the closure lid over the spent fuel pool and align the lift yoke (if used) to the transfer cask trunnions and align the closure lid to the match marks of the TSC.
20. Lower the closure lid until it enters the TSC and seats in the top of the TSC. Visually verify closure lid alignment using the match marks (± ½ inch).

    Caution: Following closure lid installation of the PWR TSC, there is a thermal time limit of 19 hours to begin the Annulus Circulating Water System (ACWS), or approved alternative annulus flow system operation, and to begin temperature measurement of the MTC annulus outlet flow to verify MTC outlet temperature is maintained < 113°F. However, if the circulating water cooling system is not utilized, or becomes nonoperational, measure the cavity water temperature every 2 hours. If TSC preparation operations through draining are not completed prior to the cavity water temperature reaching 180°F (5 hr. time) or 200°F (2 hr. time), a cooling water flow will be established through the cavity to lower the water temperature, or the TSC shall be returned to the spent fuel pool for in-pool cooling within 5 hours for 180°F or 2 hours for 200°F. TSC in-pool cooling (seals deflated) will be continued until the ACWS operation is restored or initiated.
21. Allow sling cables to go slack and move the lift yoke into position to engage the transfer cask trunnions. Engage the lift yoke to the trunnions, apply a slight tension, and visually verify engagement.

22. Raise the transfer cask until its top clears the pool surface. Visually verify that the closure lid is properly seated. If necessary, lower the transfer cask and reinstall the closure lid. Rinse the lift yoke and transfer cask with clean water as the equipment is removed from the pool.
23. Rinse and flush the top of the transfer cask and TSC with clean water as necessary to remove any radioactive particles. Survey the top of the TSC closure lid and the top of the transfer cask to check for radioactive particles.
24. As the transfer cask is removed from the spent fuel pool, terminate the annulus fill water supply, remove the annulus fill system hoses, and allow annulus water to drain into the spent fuel pool.
25. Following the prescribed load path, move the transfer cask to the designated workstation for TSC closure operations.

    Note: At the option of the user, the TSC closure operations may be performed with the transfer cask partially submerged in the spent fuel pool, cask loading pit, or an equivalent structure. This operational alternative provides additional shielding for the cask operators.
26. Disengage the three-legged sling set from the closure lid and the lift yoke from the transfer cask trunnions. Place lift yoke and sling set in storage/lay-down area.
27. Inflate the transfer cask lower annulus seal with air or nitrogen. Disconnect the gas supply from the transfer cask.

    Note: The installation, use, and operational sequence of the lower annulus seal is at the discretion of the user based on approved site-specific procedures. At the option of the user, the gas supply can be maintained continuously to the annulus seals.
28. Install the Annulus Circulating Water Cooling System (ACWS), or alternative annulus flush/cooling system, to the lower and upper annulus fill lines. Unused fill lines are to be closed or capped.

    Note: For TSCs prepared with the transfer cask partially submerged on an in-pool shelf, partially drained cask loading pit or equivalent partial submerged condition, alternative ACWS operations (e.g., reverse flow ACWS) may be utilized to maintain TSC and fuel clad temperatures within normal operational limits.

    Note: ACWS operation allows the vacuum drying and TSC transfer times in LCO 3.1.1 to be utilized.
29. Initiate clean water flow into the transfer cask lower fill lines with annulus water discharging through the upper fill lines. Ensure water flow is maintained to keep the outlet water temperature ≤ 113°F.

    Note: Analysis of alternative reverse flow ACWS operations for PWR fuel are detailed in Chapter 4, demonstrating that the fuel clad and TSC temperatures are bounded by

standard ACWS cooling operations for the following reverse flow limits for PWR heat loads ≤ 35.5 kW:

- A maximum inlet water temperature of ≤ 100°F, which requires a minimum inlet flow rate of ≥ 60 GPM
- A minimum inlet flow rate of ≥ 40 GPM, which limits the maximum inlet water temperature of ≤ 70°F

Additionally, for PWR heat loads ≤ 25 kW the following alternate operational limits are approved for reverse ACWS:

- A maximum inlet water temperature of ≤ 100°F, which requires a minimum inlet flow rate of ≥ 40 GPM

Note: With the ACWS, or site-approved alternative ACWS, operating, there is no time limit through initiation of the draining of the PWR TSC. However, if the circulating water cooling system is not utilized, or becomes nonoperational, measure the cavity water temperature every 2 hours. If PWR TSC preparation operations through draining are not completed prior to the cavity water temperature reaching 180°F (5 hr.) or 200°F (2 hr.), a cooling water flow will be established through the cavity to lower the water temperature or the TSC shall be returned to the spent fuel pool within 5 hours for 180°F or 2 hours for 200°F. TSC in-pool cooling will be continued until the ACWS operation is restored or initiated.

30. Detorque and remove the lifting hoist rings from the closure lid.
31. Using a portable suction pump, remove any standing water from the closure lid weld groove, and the vent and drain ports.
32. Decontaminate the top of the transfer cask and TSC closure lid to allow installation of the welding equipment. Decontaminate external surfaces of the transfer cask and remove the bottom protective cover, if installed.
33. Insert the drain line with a quick-connector attached through the drain port opening and into the basket drain port sleeve. Remove the quick-disconnect and any contaminated water displaced from the cavity.
34. Torque the drain tube connector to the drain opening to the value specified in Table 9.1-2. Verify quick-disconnect is installed and properly torqued in the vent port opening.
35. Install a venting device to the vent port quick-disconnect to prevent combustible gas or pressure buildup below the closure lid.
36. Verify that the top of the closure lid is level (flush) with, or slightly above, the top of the TSC shell.
37. At the discretion of the user, establish foreign material exclusion controls to prevent objects from being dropped into the annulus or TSC.
38. Install the welding system, including supplemental shielding, to the top of the closure lid.

Note: At the discretion of the user, supplemental shielding may be installed around the transfer cask to reduce operator dose. Use of supplemental shielding shall be evaluated to ensure its use does not adversely affect the safety performance of MAGNASTOR.

39. Connect a suction pump to the drain port quick-disconnect and verify venting through the vent port quick-disconnect.
40. Operate the suction pump to remove approximately 70 gallons of water from the TSC. Disconnect the suction pump.

    Note: The radiation level will increase as water is removed from the TSC cavity, as shielding material is being removed.

    Note: Fuel rods shall not be exposed to air during the 70-gallon pump-down.
41. Attach a hydrogen detector to the vent line. Ensure that the vent line does not interfere with the operation of the weld machine.
42. Sample the gas volume below the closure lid and observe hydrogen detector for H_2 concentration prior to commencing closure lid welding operations. Monitor H_2 concentration in the TSC until the root pass of the closure lid-to-shell weld is completed.

    Note: If H_2 concentration exceeds 2.4% prior to or during root pass welding operations, immediately stop welding operations. Evacuate the TSC gas volume or purge the gas volume with helium. Verify H_2 levels are <2.4% prior to restarting welding operations.

    Note: In place of continuous H_2 monitoring, continuous gas purging of the volume below the lid may be used in concert with initial (prior to start of welding) and intermittent H_2 monitoring (upon termination of gas purging and prior to re-starting welding operations).
43. Install shims into the closure lid-to-TSC shell gap, as necessary, to establish a uniform gap for welding. Tack weld the closure lid and shims, as required.
44. Operate the welding equipment to complete the closure lid-to-TSC shell root pass weld in accordance with the approved weld procedure.
45. Perform visual and liquid penetrant (PT) examinations of the root pass and record the results.
46. Remove the H_2 detector from the vent line while ensuring the TSC cavity vent line remains installed and allows venting of gases from the cavity.
47. Operate the welding equipment to perform the closure lid-to-shell weld to the midplane between the root and final weld surfaces. Perform visual and PT examinations for the midplane weld pass, and record the results.
48. Complete welding through the completion of the final pass of the closure lid weld, perform final visual and PT examinations, and record the results.
49. Perform the hydrostatic test of the TSC as follows:

a. Connect a drain line to the vent port and a pressure test system to the drain port.
b. Refill the TSC with clean water until water is observed flowing from the vent port drain line. Close the vent line isolation valve. Ensure continuing compliance with the boron concentration requirements of LCO 3.2.1.
c. Pressurize the TSC to 150 (+10, -0) psig and isolate the TSC.
d. Maintain the TSC pressure for a minimum 10-minute hold period. At the end of the 10-minute hold period, visually examine the closure lid-to-TSC shell weld for leakage of water, while maintaining the test pressure. The test pressure shall be maintained until the completion of the visual inspection of the closure lid-to-TSC shell weld.
e. The hydrostatic test is acceptable if there is no visible water leakage from the closure lid-to-TSC shell weld based on a visual examination of the weld after a minimum 10-minute hold period, while maintaining the test pressure.
f. Vent the TSC cavity and remove the pressure test system from the drain port and the drain line from the vent line. Reinstall a vent line to the vent port to prevent pressurization of the TSC.

50. Install and tack the closure ring in position in the closure lid-to-TSC shell weld groove.

    Note: Depending on the operational loading procedure and intended minimum helium backfill time (per LCO 3.1.1) to be utilized, the closure ring installation, welding and NDE sequence can be performed following final helium mass backfill (i.e., after Step 60).

51. Weld the closure ring to the TSC shell and to the closure lid. Perform visual and PT examinations of the final surfaces of the welds and record the results.

    Note: At the option of the user and in order to facilitate the Maximum Transfer Time of Technical Specification LCO 3.1.1 the installation, welding, and NDE of the closure ring may be performed immediately after helium backfill (Step 61) or after completion of the welding, testing, and NDE of the vent and drain inner or outer port covers (Step 63 or 67).

52. Remove the water from the TSC using one of the following methods: drain down using a suction pump with a pressurized helium cover gas; or blow down using pressurized helium gas. Ensure the totalizer in the drain line is reset to zero prior to the start of draining.

    Note: Fuel rods shall not be exposed to air during canister draining operations. Record the start time of TSC draining operations. The maximum drying times of LCO 3.1.1 are based on the total time from start of the draining through completion of helium backfilling of the TSC cavity.

    Note: Vacuum drying and TSC transfer times of LCO 3.1.1, Table 1.B are based on the cavity water temperature of ≤ 130°F prior to draining. If ACWS cooling was not

provided during welding operations, measure TSC cavity water to confirm temperature is < 130°F.

53. Connect a drain line with or without suction pump to the drain port connector.
54. Connect a regulated helium gas supply to the vent port connector.
55. Open gas supply valve and start suction pump, if used, and drain water from the TSC until water ceases to flow out of the drain line. Close gas supply valve and stop suction pump.

    Note: A total allowable time of 4.5 hours is available for loss of ACWS contingency events for PWR TSCs with decay heat loads of ≤ 30 kW from the start of draining through completion of the minimum helium backfill/cooling time (e.g., first vacuum drying cycle per LCO 3.1.1, Item 1). Loss of ACWS time shall be monitored to ensure that the 4.5 hours is not exceeded. Licensees shall take appropriate corrective actions to ensure that contingency cooling is available (either in-pool cooling or backup ACWS or equivalent site-approved cooling system) or implemented to ensure that the total loss of ACWS time of 4.5 hours is not exceeded. For any loss of ACWS event during draining, vacuum drying or helium backfill cooling evolutions, the TSC shell is required to be cooled by using the Supplemental Annulus Cooling System (SACS) or equivalent site-approved system until steaming stops prior to re-initiating normal ACWS operations.

56. Record the time at the completion of the draining of the TSC. Record the volume of water drained from the TSC (V_{TSC}) as measured by the totalizer. At the option of the user, disconnect suction pump, close discharge line isolation valve, and open helium gas supply line. Pressurize TSC to approximately 25 psig and open discharge line isolation valve to blow down the TSC. Repeat blow down operations until no significant water flows out of the drain line. Note that time used for system draining and blow down is considered part of the vacuum drying time.
57. Disconnect the drain line and gas supply line from the drain and vent port quick-disconnects.
58. Dry the TSC cavity using vacuum drying methods as follows.

    Note: Ensure heat load dependent vacuum drying time limits are not exceeded so that fuel cladding temperatures are maintained below 752°F. Vacuum drying cycle time limits in LCO 3.1.1 are based on utilizing the ACWS, reverse flow ACWS or equivalent annulus cooling/flush system.

    a. Connect the vacuum drying system to the vent and drain port openings.
    b. Operate the vacuum pump until a vapor pressure of ≤ 10 torr is achieved in the TSC. The time durations of the first vacuum drying cycle shall be in accordance with the time limits of LCO 3.1.1.
    c. Isolate the vacuum pump from the TSC and turn off the vacuum pump. Observe the vacuum gauge connected to the TSC for an increase in pressure for a minimum

period of 10 minutes. If the TSC pressure is ≤ 10 torr at the end of 10 minutes, the TSC is dry of free water in accordance with LCO 3.1.1.

Note: [redacted] cooling period, subsequent drying cycle operations can continue for the times indicated in LCO 3.1.1, Table 2. Drying cycles and cooling periods may be continued until the TSC cavity passes the dryness verification per LCO 3.1.1. For fuel burnup greater than 45 GWd/MTU, the total number of cooling cycles is limited to ten, with cladding temperature variations more than 65 °C (117°F).

Note: A total allowable time of 4 hours is available for loss of ACWS contingency events for PWR TSCs with decay heat loads of ≤ 30 kW from the start of helium evacuation through completion of the minimum helium backfill/cooling time for the second and subsequent vacuum drying cycles performed in accordance with LCO 3.1.1, Item 2. Loss of ACWS time shall be monitored to ensure that the 4 hours is not exceeded. Licensees shall take appropriate corrective actions to ensure that contingency cooling is available (either in-pool cooling or backup ACWS or equivalent site-approved cooling system) or implemented to ensure that the total loss of ACWS time of 4 hours is not exceeded.

59. Upon satisfactory completion of the dryness verification, evacuate the TSC cavity to a pressure of ≤ 3 torr. Isolate and turn off the vacuum pump, and backfill and pressurize the TSC cavity with 99.995% (minimum) pure helium as follows:
    a. Determine the free volume of the TSC (V_{TSC}) per Step 56.
    b. Multiply the V_{TSC} free volume by the helium loading value per unit volume (L_{helium}) to determine required helium mass (M_{helium}) to be backfilled into the cavity.
    c. Set the helium bottle regulator to 90 (+5,-0) psig.
    d. Connect the helium backfill system to the vent port and reset the mass-flow meter to zero.
    e. Slowly open the helium supply valve and backfill the TSC with the required helium mass (M_{helium}) in accordance with LCO 3.1.1.
60. Disconnect the vacuum drying helium backfill system from the vent and drain openings. Note the time the helium backfill is completed.

    Note: At the option of the user, Steps 50 and 51 can alternatively be performed at this point or immediately following Steps 63 or 67. The user to establish appropriate radiological controls to maintain operator dose ALARA.

61. Install and weld the inner port cover on the drain port opening.
62. Install and weld the inner port cover on the vent port opening.
63. Perform visual and PT examinations of the final surface of the port cover welds and record the results.
64. Perform helium leak test on each of the inner port cover welds to verify the absence of helium leakage past the inner port cover welds.
65. Install and weld the outer port cover on the drain port opening. Perform visual and PT examinations of the final weld surface and record the results.
66. Install and weld the outer port cover on the vent port opening. Perform visual and PT examinations of the final weld surface and record the results.
67. Using an appropriate crane, remove the weld machine and supplemental shield.
68. The ACWS, reverse flow ACWS or equivalent annulus cooling/flush system will be utilized throughout the TSC closing operations until the helium backfill time is satisfied (see LCO 3.1.1). Drain the TSC/transfer cask annulus by stopping ACWS flow to the annulus and connecting one or more drain lines to the lower annulus fill ports. Once the annulus is drained, deflate the top and bottom annulus seals. Note the time the MTC/TSC annulus cooling flow is terminated. Remove the temporary plugs or ensure that a minimum of four annulus fill lines are open in the base of the transfer cask.

    Note: The time duration of the sequence of operations from stopping the MTC/TSC annulus cooling, or completing the helium backfill if the annulus circulating water cooling system is not used, through completion of TSC transfer into the concrete cask shall not exceed the transfer time limits in LCO 3.1.1. If the TSC transfer to the concrete cask cannot be completed in the defined time period, the transfer operation will be suspended and the TSC shall be cooled by the Supplemental Annulus Cooling System (SACS) or equivalent system until steaming stops and followed by continued cooling for a period of 30 hours using SACS and ACWS, reverse flow ACWS or site-approved alternative cooling system prior to restarting TSC transfer operations. The second, and subsequent, minimum helium backfill time and maximum TSC transfer time shall be limited to the heat load specific cooling and specific transfer times in the maximum TSC transfer Tables 1.B and 1.D of LCO 3.1.1. For PWR fuel, the 24-hour minimum helium backfill time is followed by a maximum TSC transfer time of 48 hours for heat loads $\leq$ 25 kW or 22 hours for heat loads >25 kW but $\leq$ 35.5 kW. For BWR fuel, the 24-hour minimum helium backfill time is followed by a maximum TSC transfer time of 65 hours for heat loads $\leq$ 25 kW or 32 hours for heat loads >25 kW but $\leq$ 33 kW.

69. If using MTC1 or MTC2 with retaining blocks, remove the lock pins and move the transfer cask retaining blocks inward into their functional position, and reinstall the lock pins. If using MTC2 with retaining ring, install the transfer cask retaining ring.

70. Install the six swivel hoist rings into the six threaded holes in the closure lid if TSC transfer is to be performed by two sets of redundant slings. Torque the hoist rings to the manufacturer's recommended value.

    Note: Utilize high temperature-resistant slings (≤ 350°F).

    Note: Alternative site-specific TSC lifting systems and equipment may be used for lowering and lifting the TSC in the transfer cask. The lifting system design must comply with the user's heavy load program and the applicable requirements of ANSI N14.6, NUREG-0612, and/or ASME/ANSI B30.1, as appropriate.

71. Complete final decontamination of the transfer cask exterior surfaces. Final TSC contamination surveys may be performed after TSC transfer following Step 21 in Section 9.1.2 when TSC surfaces are more accessible.
72. Proceed to Section 9.1.2.

9.1.2 Transferring the TSC to the Concrete Cask

This section describes the sequence of operations required to complete the transfer of a loaded TSC from the transfer cask into a concrete cask, and preparation of the concrete cask for movement to the ISFSI pad.

1. Position an empty concrete cask with the lid assembly removed in the designated TSC transfer location.

    Note: The concrete cask can be positioned on the ground, or on a deenergized air pad set, roller skid, heavy-haul trailer, rail car, or transfer cart. The transfer location can be in a truck/rail bay inside the loading facility or an external area accessed by the facility cask handling crane.

    Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥ 0°F for the use of the concrete cask, per Section 4.3.1.g. of the Technical Specifications.

2. Inspect all concrete cask openings for foreign objects and remove if present; install supplemental shielding in four outlets.
3. Install a four-legged sling set to the lifting points on the transfer adapter.
4. Using the crane, lift the transfer adapter and place it on top of the concrete cask ensuring that the guide ring sits inside the concrete cask lid flange. Remove the sling set from the crane and move the slings out of the operational area.
5. Connect a hydraulic supply system to the hydraulic cylinders of the transfer adapter.
6. Verify the movement of the connectors and move the connector tees to the fully extended position.

7. Connect the lift yoke to the crane and engage the lift yoke to the transfer cask trunnions. Ensure all lines, temporary shielding and work platforms are removed to allow for the vertical lift of the transfer cask.

   Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥ 0°F for the use of the transfer cask, per Section 4.3.1.f. of the Technical Specifications.
8. Raise the transfer cask and move it into position over the empty concrete cask.
9. Slowly lower the transfer cask into the engagement position on top of the transfer adapter to align with the door rails and engage the connector tees.
10. Following set down, remove the lock pins from the shield door lock tabs.
11. Install a stabilization system for the transfer cask, if required by the facility heavy load handling or seismic analysis programs.
12. Disengage the lift yoke from the transfer cask trunnions and move the lift yoke from the area.
13. As appropriate to the TSC lifting system being used, move the lifting system to a position above the transfer cask. If redundant sling sets are being used, connect the sling sets to the crane hook.
14. Using the TSC lifting system, lift the TSC slightly (approximately ½-1 inch) to remove the TSC weight from the shield doors.

    Note: The lifting system operator must take care to ensure that the TSC is not lifted such that the retaining blocks (MTC1/MTC2) or the retaining ring (MTC2) is engaged by the top of the TSC.
15. Open the transfer cask shield doors with the hydraulic system to provide access to the concrete cask cavity.
16. Using the cask handling crane in slow speed (or other approved site-specific handling system), slowly lower the TSC into the concrete cask cavity until the TSC is seated on the pedestal.

    Note: The transfer adapter and the standoffs in the concrete cask will ensure the TSC is appropriately centered on the pedestal within the concrete cask.

    Note: The completion of the transfer of the TSC to the concrete cask (i.e., the top of the TSC is in the concrete cask cavity) completes the TSC transfer evolution time from Step 69 in Section 9.1.1.
17. When the TSC is seated, disconnect the slings (or other handling system) from the lifting system, and lower the sling sets through the transfer cask until they rest on top of the TSC.
18. Retrieve the lift yoke and engage the lift yoke to the transfer cask trunnions.
19. Remove the seismic/heavy load restraints from the transfer cask, if installed.
20. Close the shield doors using the hydraulic system and reinstall the lock pins into the shield door lock tabs.

21. Lift the transfer cask from the top of the concrete cask and return it to the cask preparation area for next fuel loading sequence or to its designated storage location.
22. Disconnect hydraulic supply system from the transfer adapter hydraulic cylinders.
23. Remove redundant sling sets, swivel hoist rings, or other lifting system components from the top of the TSC, if installed.
24. Verify all equipment and tools have been removed from the top of the TSC and transfer adapter.
25. Connect the transfer adapter four-legged sling set to the crane hook and lift the transfer adapter off the concrete cask. Place the transfer adapter in its designated storage location and remove the slings from the crane hook. Remove supplemental shielding from outlets.

    Note: If the optional low profile concrete cask is used, proceed to Step 26. If the standard concrete cask is provided, proceed to Step 38.
26. Install three swivel hoist rings and the three-legged sling set on the concrete cask shield ring.
27. Using the crane, lift the shield ring and place it into position inside of the concrete cask top flange.
28. Remove the three-legged sling and swivel hoist rings.
29. Using the designated transport equipment, move the loaded concrete cask out of the low clearance work area or truck/rail bay.
30. Install the three swivel hoist rings into the three threaded holes and attach the three-legged sling set to the shield ring.
31. Using an external or mobile crane, lift and remove the shield ring. Place the shield ring in position for the next loading sequence or return it to its designated storage location.
32. Install four swivel hoist rings in the threaded holes of the concrete cask extension using the manufacturer-specified torque.
33. Install the four-legged sling set and attach to the crane hook.

    Note: A mobile crane of sufficient capacity may be required for concrete cask extension and lid installations performed outside the building.
34. Perform visual inspection of the top of the concrete cask and verify all equipment and tools have been removed.

    Note: Take care to minimize personnel access to the top of the unshielded loaded concrete cask due to shine from the TSC.
35. Lift the concrete cask extension and move it into position over the concrete cask, ensuring alignment of the two anchor cavities with their mating lift anchor embedment.
36. Lower the concrete cask extension into position and remove the sling set from the crane hook.
37. Remove the four swivel hoist rings and cables from the concrete cask extension.

    Note: If concrete cask transport is to be performed by a vertical cask transporter, proceed to Step 38. If transport is to be performed using air pads in conjunction with a flat-bed transporter, proceed to Step 40.

38. Install the lift lugs into the anchor cavities of the concrete cask extension, or directly on top of the lifting embedment for the standard concrete cask, if applicable to the concrete cask design utilized.
39. Install the lift lug bolts through each lift lug and into the threaded holes in the embedment base. Torque each of the lug bolts to the value specified in Table 9.1-2.
40. Install three swivel hoist rings into the concrete cask lid and attach the three-legged sling set. Attach the lifting sling set to the crane hook.
41. At the option of the user, install the weather seal on the concrete cask lid flange. Lift the concrete cask lid and place it in position on the top of the flange.
42. Remove the sling set and swivel hoist rings and install the concrete cask lid bolts. Torque to the value specified in Table 9.1-2.
43. Move the loaded concrete cask into position for access to the site-specific transport equipment.
44. Proceed to Section 9.1.3.

9.1.3 Transporting and Placing the Loaded Concrete Cask

The section describes the general procedures for moving a loaded concrete cask to the ISFSI pad using either a vertical cask transporter (Step 1 through Step 9) or a flat-bed transport vehicle (Steps 10 through 17). Steps following Step 17 are performed for all concrete casks.

Vertical Cask Transporter

1. Using the vertical cask transporter lift fixture or device, engage the two concrete cask lifting lugs.
2. Lift the loaded concrete cask and move it to the ISFSI pad following the approved onsite transport route.

   Note: Ensure vertical cask transporter lifts the concrete cask evenly using the two lifting lugs.

   Note: Do not exceed the maximum lift height for a loaded concrete cask of 24 inches, per Section 4.3.1.h. of the Technical Specifications.
3. Move the concrete cask into position over its intended ISFSI pad storage location. Ensure the surface under the concrete cask is free of foreign objects and debris.

   Note: The spacing between adjacent loaded concrete casks must be at least 15 feet.
4. Using the vertical transporter, slowly lower the concrete cask into position.
5. Disengage the vertical transporter lift connections from the two concrete cask lifting lugs. Move the cask transporter from the area.
6. Detorque and remove the lift lug bolts from each lifting lug, if the lugs are to be reused.

   Note: At the option of the user, the lift lugs may be left installed during storage operations.

7. Lift out and remove the concrete cask lift lugs. Store the lift lugs for the next concrete cask movement.
8. Install the lug bolts through the extension base (or through the cover plate for the standard concrete cask) and into the threaded holes. Torque each bolt to the value specified in Table 9.1-2.
9. For the casks with extensions containing anchor cavities, install the weather seal and cover plates. Install the bolts and washers and torque to the value specified in Table 9.1-2.

Flat-bed Transport Vehicle Loaded with the Closed Concrete Cask

10. Move the transport vehicle with the closed concrete cask to a position adjacent to the ISFSI pad.
11. If required, install a bridging plate to cover the gap between the vehicle and the ISFSI pad.
12. If not already installed, insert four deflated air pads into the four inlets.
13. Attach a restraining device around the concrete cask and connect to a tow vehicle suitable for pushing or pulling the concrete cask off of the transport vehicle.
14. Using an air supply and an air pad controller, inflate the air pads.
15. Verify the ISFSI pad surface in the storage location is free of foreign objects and debris.
16. Using the tow vehicle, move the concrete cask into its position on the storage pad.
    Note: The center-to-center spacing of loaded concrete casks shall be a minimum of 15 feet.
17. Lower the concrete cask into position by deflating and removing the four air pads.
    Note: Ensure that air pads are not installed longer than eight hours to complete the concrete cask transfer.

All Concrete Casks

18. If optional temperature monitoring is implemented, install the temperature monitoring devices in each of the four outlets of the concrete cask and connect to the site's temperature monitoring system.
19. Install inlet and outlet screens to prevent access by debris and small animals.
    Note: Screens may be installed on the concrete cask prior to TSC loading to minimize operations personnel exposure.
20. Scribe and/or stamp the concrete cask nameplate, if not already done, with the required information at a minimum.
21. Perform a radiological survey of the concrete cask within the ISFSI array to confirm dose rates comply with ISFSI administrative boundary and site boundary dose limits.
22. Initiate a daily temperature monitoring program or daily inspection program of the inlet and outlet screens to verify continuing effectiveness of the heat removal system.

Table 9.1-1 Major Auxiliary Equipment

Item	Description
Air Pad Rig Set	A device consisting of four air pads, a controller, and an air supply source that lifts the concrete cask using air supplied at a high volume.
Annulus Fill System	System that supplies clean/filtered spent fuel pool water through the transfer cask/TSC annulus using the lower and upper transfer cask fill lines. The system maintains a positive clean water flow to minimize the exposure of the TSC external surfaces to contaminated spent fuel pool water.
Annulus Circulating Water Cooling System	The system provides a circulating water flow through the annulus to maintain the TSC shell temperature during TSC preparation and drying evolutions. The system includes appropriate circulating pump, pressure gauges, and inlet and outlet water thermometer.
Annulus Seals	Inflatable seals provided at the top and bottom of the transfer cask/TSC annulus for use with the annulus fill and annulus circulating water cooling systems.
Bottom Protective Cover	Optional plate temporarily attached to the base of the transfer cask to prevent particulate contamination of the transfer cask shield doors and rails.
Canister Upender	Lifting device used to upright a TSC from the horizontal position to a vertical orientation to allow vertical handling.
Cask Transporter	A heavy-haul trailer, a rail car, a vertical cask transporter, or other specially designed equipment used onsite to move the concrete cask. The loaded concrete cask is transported vertically resting on its base (requiring a flat-bed transporter) or it is transported vertically suspended from its lifting lugs (requiring a vertical cask transporter).
Closure Lid Lifting Sling System	Sling system used to install the closure lid into the TSC in the spent fuel pool. At the user's option, the sling system can be suspended from the lift yoke and used to install the lid and engage the yoke with one crane sequence.
Cooldown System (CDS)	Introduces nitrogen (and/or helium), helium, and cooling water to the TSC cavity to cooldown the TSC internals and stored spent fuel to allow the return of the TSC to the spent fuel pool for the unloading of the fuel assemblies. This system would only be required in the highly unlikely event that a loaded TSC had to be unloaded.

Table 9.1-1 Major Auxiliary Equipment (continued)

Drain and Blow Down System (DBS)	System used to pump out and/or blow down the water from the TSC cavity prior to the start of drying operations, and to refill the cavity and hydrostatic test the closure lid weld. The system includes the appropriate suction pump, piping/hoses, flow meter/totalizer, helium cover gas supply, pressure gauges, and valves to connect to the TSC vent and drain port connections to complete the draining and hydrostatic testing of the cavity.
Hydrogen Detection System	System that detects increased concentration of H_2 in the cavity resulting from material reactions during closure lid root pass welding operations and for closure lid weld removal operations.
Helium Mass Spectrometer Leak Detector (MSLD)	A system utilized to perform the helium leakage testing of the inner vent and drain port cover welds.
Lid Retention System	An optional component installed on top of the TSC closure lid to secure the lid during cask handling operations between the spent fuel pool and the workstation used to close the TSC.
Lift Yoke (with Crane Hook Extension, if required)	Device for lifting and moving MAGNASTOR transfer cask by engaging the lifting trunnions.
Loaded TSC Sling System	Redundant sling system (two 3-legged slings) used to transfer a TSC into a concrete cask or a transfer cask and meeting the requirements of ANSI N14.6 and the facility crane. Alternative TSC handling systems that meet site-specific or client requirements and comply with the facility's heavy lift program developed per NUREG-0612 may be utilized.
Remote/Robotic Welding System	System that completes the closure lid and port cover welds with minimal operator assistance. The system may include video cameras and a recording device to remotely observe the welding activities and to videotape the results of the closure lid PT examinations.
Supplemental Annulus Cooling System (SACS)	Cooling system utilized to provide cooling water to the transfer cask annulus and is designed to cool a TSC if a TSC transfer to the concrete cask cannot be completed in the time allowed by LCO 3.1.1. SACS is used when TSC shelll temperatures will produce steam impeding TSC cooling via ACWS. Cooling of the TSC with SACS is performed until steaming stops, permitting ACWS cooling operations to continue.
Supplemental Weld Shield	Optional steel plate installed on the closure lid to provide additional shielding to the cask operators during TSC welding, preparation, and test activities. The supplemental weld shield may be installed separately or as the base plate for the welding system.

Table 9.1-1 Major Auxiliary Equipment (continued)

Vacuum Drying and Helium Backfill System	The system used to vaporize and remove residual water, water vapor, and oxidizing gases from the TSC cavity prior to backfilling with helium. The system includes the appropriate vacuum pump(s), vacuum and pressure gauges, helium supply connections and valves, and hoses to connect the system to the vent and drain connections.
Weld Removal System and Port Cover Drill Fixture	Semiautomatic mechanical weld and/or TSC shell cutting system used to remove the closure lid and port cover welds in the unlikely event that a TSC needs to be unloaded. The Port Cover Drill Fixture is used to access the outer and inner vent port covers prior to TSC cavity gas sampling and venting in order to prevent an uncontrolled release of pressurized gas during the vent port cover removal process.
Gas Sampling and Pressure Measurement System	A system connected to the Port Cover Drill Fixture that allows the TSC cavity gas to be sampled and its pressure determined prior to venting of the TSC cavity gas without exposing operations personnel to any high pressure and temperature gas releases.

Table 9.1-2 Threaded Component Torque Values

Threaded Component	Torque Value (ft-lb)
Concrete Cask Lid Bolts	40 ± 5
Concrete Cask Body Extension	100 ± 10
Closure Lid Lifting Hoist Rings • Lid Handling Only • Loaded TSC Handling	 100, + 50, -0 100, + 50, -0
Drain Tube Connector • Viton, EDPM, or Elastomer Seal • Metallic Seal	 200 ± 25 200 ± 25
Vent Port Connector • Viton, EDPM, or Elastomer Seal • Metallic Seal	 200 ± 25 200 ± 25
Cover Plate Bolts	40 ± 5
Concrete Cask Lift Lug Bolts	115 ± 10 ft-lb
Concrete Cask Lid Lifting Hoist Rings	100, + 50, -0
Retaining Ring Bolts (MTC2 only)	30 (+0, -10) ft-lb

9.3 Wet Unloading a TSC

This section provides the basic operational sequence to prepare, open, and unload a TSC in a spent fuel pool. Due to the rugged design and fabrication of the TSC, users are not expected to perform this operational sequence. However, in accordance with the Technical Specifications, each user shall have the procedures and required equipment available, and perform a dry run of the unloading process.

The procedure that follows assumes that the TSC is in a transfer cask in the appropriate workstation.

1. If using MTC1 or MTC2 with retaining blocks, pull the lock pins and retract the retaining blocks in the transfer cask, and reinstall the lock pins. If using MTC2 with retaining ring, detach and remove the retaining ring.
2. Survey the TSC and transfer cask to establish radiation areas.
3. Install and secure by welding the Port Cover Drill Fixture to the outer vent port cover.
4. Install the Gas Sampling and Pressure Measurement System to the Port Cover Drill Fixture access port.
5. Operate the Port Cover Drill Fixture to remotely drill through the outer and inner vent port covers.
6. Measure cavity gas pressure utilizing the Gas Sampling and Pressure Measurement System.
7. Obtain a cavity gas sample from the Port Cover Drill Fixture connection.
8. Determine total gaseous inventory and connect a venting system to the Gas Sampling and Pressure Measurement System and route to the HEPA filters or to the off-gas system.
9. Vent the TSC cavity gas and reduce TSC pressure to atmospheric.
10. Remove the Port Cover Drill Fixture from the outer vent port cover.
11. Install the weld removal system on the closure lid and bolt the system to the closure lid threaded holes.
12. Establish appropriate airborne radiation controls.

    Note: Initial TSC cooling can be provided by an external TSC cooling system prior to port cover removal in order to satisfy the 11-hour maximum transfer time without cooling operations.
13. Using the weld removal system, remove the outer and inner port covers from the vent and drain ports.
14. Remove the weld removal system.
15. Using appropriate radiological controls, remove the vent and drain quick-disconnects and seals.

16. Replace the quick-connects and seals with approved spares, and torque them to the value specified in Table 9.1-2.
17. Attach the cooldown system to the vent and drain connections.

    Note: Cooling of the TSC using the ACWS or equivalent annulus cooling/flush system may be required to assure cavity water boiling will not occur during closure lid weld removal operations per Section 9.1.1.
18. Initiate purge gas flow (nitrogen or helium) through the TSC to flush out residual radioactive gases. Continue nitrogen or helium flow for a minimum of 10 minutes.
19. Initiate the controlled filling (5 +3/-0 gpm) of the TSC with clean water through the drain connector under controlled temperature (minimum 70°F) and pressure conditions (25 +10/-0 psig). Borated water shall be used as required for the PWR fuel contents in accordance with LCO 3.2.1.
20. Monitor steam/water temperature of the discharge from the vent connection.
21. Continue cooldown operations until the discharge water temperature is below 180°F.
22. Terminate cooling water flow and disconnect the cooldown system from the drain and vent ports. Install a vent line to the vent port.

    Note: Cooling of the TSC using the annulus circulating water system may be required to ensure cavity water boiling will not occur during closure lid weld removal operations per Section 9.1.1.
23. Connect a suction pump to the drain connector. Operate the pump and remove approximately 70 gallons of water from the cavity. Disconnect and remove the pump.
24. Remove the drain line from the closure lid.
25. Install the hydrogen detector to the vent line and verify hydrogen gas concentration in the gas volume in the cavity. If the concentration reaches 2.4%, stop all cutting activities and remove cavity gas using a vacuum pump.
26. Install the weld removal system on the closure lid. Operate the weld removal system to remove the closure ring-to-TSC shell and closure ring-to-closure lid welds. Remove the closure ring from the lid area.
27. Operate the weld removal system to remove the closure lid-to-shell weld.
28. Remove shims, if installed, to provide a suitable gap to be able to extract the closure lid under water.
29. Remove the weld removal system. Terminate annulus circulating water flow, if used.
30. Install three swivel hoist rings into the closure lid threaded holes. Attach three-legged sling set to the hoist rings and the lifting system (or, alternately, the transfer cask lifting yoke).
31. Engage the lift yoke to the transfer cask trunnions and bring the transfer cask over the spent fuel pool.

10.1.2.3 Pressure Testing of the TSC

Following completion of the closure lid-to-TSC shell weld during the TSC preparation operations after fuel loading, the TSC shall be hydrostatically pressure tested at not less than 125% of the design pressure of 110 psig in accordance with ASME Code, Section III, Subsection NB, NB-6200 requirements as described and defined in Section 9.1.1. A bounding minimum test pressure of 150 psig shall be applied to the drain port connection for a minimum 10-minute hold period. There shall be no visible water leakage from the closure lid-to-TSC shell weld based on visual examination of the weld after a minimum 10-minute hold period, while maintaining the test pressure. Test pressure shall be maintained until the completion of the visual weld examination. The design pressure and minimum test pressure are identical for both PWR and BWR TSCs. The minimum test pressure conservatively exceeds the hydrostatic test pressure commitment stated in Table 2.1-2 (125% of MNOP).

10.1.2.4 Load Testing of Damaged Fuel Can (DFC)

To qualify the design of the MAGNASTOR DFC, the first DFC to be provided to a user shall be load tested to 150% of the total weight of the DFC plus the heaviest contents to be loaded in the DFC. The test load on the DFC shall be applied and held for a minimum of 10 minutes. Following completion of the load test, all load bearing welds and surfaces shall be visually inspected for permanent deformation, galling or cracking. Load bearing welds shall be inspected using liquid penetrant examination in accordance with ASME Code, Section V, Article 6. Acceptance criteria shall be in accordance with ASME Code, Section III, NG-5350.

Any evidence of permanent deformation, cracking or galling of load bearing surfaces, or unacceptable liquid penetrant examination results shall be cause for rejection, repair, reperformance of the load test and reexamination of the DFC.

10.1.3 Leakage Tests

The confinement boundary is defined as the TSC shell weldment, closure lid assembly, and vent and drain port covers. As described in Section 10.1.1, the confinement boundary is designed, fabricated, examined, and tested in accordance with the requirements of the ASME Code, Section III, Subsection NB, except for the code alternatives listed in Table 2.1-2.

At the completion of the TSC shell weldment confinement boundary welds (e.g., TSC shell seam and shell to bottom plate), the TSC shell weldment shall be leakage tested. The leakage test shall be performed in accordance with the requirements and approved methods of ASME Code, Section V, Article 10, and ANSI N14.5-1997 [20] to confirm the total leakage rate (i.e., leaktight) is less than, or equal to, 1×10^{-7} ref. cm^3/s (air) or approximately 2×10^{-7} cm^3/sec (helium). The sensitivity of the test shall be one-half of the acceptance test criteria as specified in ANSI N14.5-1997.

The TSC shell weldment will be closed using a test lid installed over the top of the shell and the cavity evacuated. A test envelope will be installed around the TSC enclosing all of the TSC shell confinement welds and base metal plates, and filled with 99.995% (minimum) pure helium to an acceptable test concentration. The percentage of helium gas in the test envelope shall be accounted for in the determination of the test sensitivity. A mass spectrometer leak detector (MSLD) will be used to sample the evacuated volume for helium.

If helium leakage is detected, the area of leakage shall be identified, repaired and re-examined in accordance with the ASME Code, Section III, Subsection NB, NB-4450 or NB-4130, as appropriate. Following repair, the complete helium leakage test shall be re-performed to the original test acceptance criteria.

Leakage testing of the TSC shell weldment shall be performed in accordance with written and approved procedures, and the test results documented.

Based on the confinement system materials, welding requirements and inspection methods, shop helium leakage testing of the 9-inch thick closure lid is not required. However, due to the reduced thickness of the stainless steel closure lid (4-inch thick base material) of the composite closure lid assembly, and the presence of extended bolt holes for attachment of the shield plate assembly, a shop helium leakage test of the composite closure lid stainless steel plate shall be performed following fabrication. The leakage test shall be performed in accordance with the requirements and approved methods of ASME Code, Section V, Article 10, and ANSI N14.5-1997 to confirm the total leakage rate is less than, or equal to, 2×10^{-7} cm^3/s (helium). The sensitivity of the test shall be one-half of the acceptance test criteria as specified in ANSI N14.5-1997.

If leakage is detected, the area of leakage shall be identified, repaired and re-examined in accordance with ASME Code, Section III, Subsection NB, NB-4130. Following repair and completion of required NDE, the helium leak test shall be re-performed to the original test acceptance criteria.

Leakage testing of the composite closure lid shall be performed in accordance with written and approved procedures, and the test results documented.

In order to ensure the integrity of the vent and drain inner port cover welds, a helium leakage test of each weld is performed following welding of the inner port covers to the closure lid assembly using the evacuated envelope method, as described in ASME Code, Section V, Article 10, and ANSI N14.5. The leakage test is to confirm that the leakage rate for each port cover is $\leq 2\times10^{-7}$ cm^3/s helium. Following inner port cover welding, a test bell is installed over the top of the port cover and the test bell volume is evacuated to a low pressure by a helium MSLD system. The

12.1.5.1 Cause of Radioactive Particulate Release Event

The most likely cause of a radioactive particulate release event is air passing over the external surfaces of a contaminated TSC. In spite of precautions taken to preclude contamination of the external surface of the TSC, it is possible that a portion of the TSC surface may become contaminated during fuel loading by the spent fuel pool water and that the removable contamination in excess of allowable limits may go undetected. Subsequently, surface contamination could become airborne and be released as a result of the airflow over the TSC surfaces.

12.1.5.2 Detection of Radioactive Particulate Release Event

The release of small amounts of radioactive contamination particulates over time is difficult to detect. Any release is likely to be too low to be detected by any of the normally employed long-term radiation dose monitoring methods (such as TLDs) normally located at the ISFSI perimeter fence. It is possible that a suspected release could be verified by a smear survey of the air outlets.

12.1.5.3 Analysis of Radioactive Particulate Release Event

The analysis presented in Section 5.6.5 calculates a total dose of less than 0.1 mrem at 100 meters from a design basis concrete cask based on removable contamination levels of 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α.

The method for determining the dose is based on the plume dispersion calculations presented in U.S. NRC Regulatory Guides 1.109 [4] and 1.145 [5] and is highly conservative. The analysis demonstrates that the offsite radiological consequences from the release of TSC surface contamination is negligible, and all applicable regulatory criteria are met for an ISFSI array. ISFSI-specific allowable dose rates will be calculated on a site-specific basis to conform to 10 CFR 72.

12.1.5.4 Corrective Actions

No corrective action is required since the radiological consequence is negligible.

12.1.5.5 Radiological Impact

As previously shown, the potential offsite radiological impact due to the release of TSC surface contamination is negligible.

12.1.6 Crane Failure During Loaded Transfer Cask Movements

Before the TSC is placed into the concrete cask, it is handled using the transfer cask. If the crane used to lift and maneuver the transfer cask failed during a lift operation (e.g., moving the transfer cask from the spent fuel pool to the decon pit/work area or from the work area to the VCC), it

would not be possible to submerge the transfer cask and TSC in the spent fuel pool, and it might be difficult to initiate cooling with the ACWS. This off-normal event does not result in the loss of load carrying capability of the crane.

12.1.6.1 Cause of Crane Failure During Loaded Transfer Cask Movements

The transfer cask handling crane may become inoperable due to a mechanical or electrical malfunction of the crane or its supporting equipment.

12.1.6.2 Detection of Crane Failure During Loaded Transfer Cask Movements

Crane failure would be identified immediately by the crane operators.

12.1.6.3 Analysis of Crane Failure During Loaded Transfer Cask Movements

[redacted]

12.1.6.4 Corrective Actions

The required corrective action for this event depends on the heat load of the TSC. Depending on the heat load, cooling flow may be required to be established to maintain fuel temperatures, basket temperatures, and TSC pressure below off-normal allowable limits. Regardless of heat load, the crane would need to be repaired and returned to an operable condition before loading operations could continue.

12.1.6.5 Radiological Impact

The radiological consequences for this event include the additional personnel dose resulting from the need to repair the crane, and to potentially perform additional annulus cooling operations prior to proceeding with the TSC transfer.