HOLTEC INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797-0900
Fax (856) 797-0909

BY OVERNIGHT MAIL

October 12, 2001

United States Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: USNRC Docket No. 72-1014, TAC L23344
HI-STORM 100 Certificate of Compliance 1014
HI-STORM License Amendment Request 1014-1, Revision 2, Supplement 3

References: Holtec Project 5014

Dear Sir:

Pursuant to our communication of October 10, 2001, attached herewith is Supplement 3 to License Amendment Request (LAR) 1014-1, Revision 2. Supplement 3 contains the required information on the Forced Helium Dehydration (FHD) system to be used to reduce the moisture in the MPCs to trace levels, when vacuum drying is not permitted or is otherwise an undesirable method of drying the MPC. Enclosed are the following documents:

1. Instructions for updating the two-volume LAR package

2. Replacement pages for the marked-up CoC, revised CoC, proposed Revision 1 of the FSAR, and the FSAR Table of Contents and List of Effective Pages. Modified FSAR pages are noted with "Proposed Rev. 1E" in the footer for configuration control.

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The specific changes in each section that comprise this supplement are listed in the attached table. Please contact us if you have any questions regarding the enclosed material.

Sincerely,

Brian Gutherman, P.E.
Licensing Manager

Approved:

K.P. Singh, Ph.D., P.E.
President and CEO

Technical Concurrence:

Dr. Indresh Rampall (Thermal Evaluation)

Document I.D.: 5014438

Enclosures:
1. Instructions for inserting pages into the LAR package
2. Replacement pages for LAR 1014-1, Revision 2, Supplement 3

Distribution: Mr. Tim Kobetz, USNRC (w/10 copies of enclosures)
HUG Group N (w/o encl.)
Holtec Group 1 (w/o encl.)

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Attachment

CHANGE	AFFECTED LAR SECTION	DESCRIPTION OF CHANGE
1	CoC, Appendix A, LCO 3.1.1, Condition A and SR 3.1.1.1	Replaced "MPC exit gas temperature" with "demoisturizer exit gas temperature."
2	CoC, Appendix B, New Section 3.6	New section added to Design Features to establish design and performance criteria, and acceptance testing requirements for the Forced Helium Dehydration FHD system
3	FSAR, Section 1.2.2.2, 6th paragraph	This paragraph has been revised to summarize the use of the FHD system for MPCs with high burnup fuel.
4	FSAR, New Appendix 2.B	Appendix 2.B has been created to describe the FHD system and define its design, performance, analysis, and test requirements.
5	FSAR, Section 4.5.1.1.4	This section has been re-titled "MPC Temperatures During Moisture Removal Operations" and two subsections have been created. Subsection 4.5.1.1.4.1 addresses vacuum drying as in previous versions of the FSAR, with a cross-reference added to direct readers to discussion of the FHD system. Subsection 4.5.1.1.4.2 has been created to address MPC drying by forced helium recirculation.
6	FSAR, Appendix 12.A	The Bases for LCO 3.1.1, Action A.1 and SR 3.1.1.1 have been revised to match the changes in Condition A of the LCO and SR 3.1.1.1.

INSTRUCTIONS FOR LAR 1014-1, REV. 2, SUPPLEMENT 3

The following instructions apply to LAR 1014-1, Revision 2, Supplement 3, contained in a two-volume set of blue three-ring binders dated July, 2001. Insertion pages are enclosed with Holtec letter to the NRC number 5014438.

1. CoC Markup (Tab # 3):

   a. Remove pages 3.1.1-1 through.3.1.1-3 of CoC Appendix A and replace with the three enclosed replacement pages.

   b. Remove page 3-15 of CoC Appendix B and replace with the enclosed pages 3-15 through 3-17.

2. Revised CoC (Tab # 4)

   a. Remove pages 3.1.1-1 through.3.1.1-3 of CoC Appendix A and replace with the three enclosed replacement pages.

   b. Insert new page 3-15/16 at the end of CoC Appendix B.

3. Proposed FSAR Changes (Tab # 6)

   a. TOC Tab: Replace the existing TOC in its entirety with the enclosed version.

   b. LOEP Tab: Replace the existing LOEP in its entirety with the enclosed version. Do not remove the pages prior to the LOEP.

   c. Remove pages 1.2-19 through 1.2-34, Proposed Rev. 1D and replace with enclosed pages 1.2-19 through 1.2-34, Proposed Rev. 1E.

   d. Insert new Appendix 2.B, Proposed Rev. 1E behind existing Appendix 2.A.

   e. Remove pages 4.5-1 through 4.5-25, Proposed Rev. 1B and replace with enclosed pages 4.5-1 through 4.5-26, Proposed Rev. 1E.

   f. Remove Appendix 12.A, Bases B 3.1.1, Proposed Revision 1B in its entirety and replace with enclosed Bases B 3.1.1, Proposed Revision 1E.

3.1 SFSC INTEGRITY

3.1.1 Multi-Purpose Canister (MPC)

LCO 3.1.1 The MPC shall be dry and helium filled.

APPLICABILITY: During TRANSPORT OPERATIONS and STORAGE OPERATIONS.

ACTIONS

---NOTE---
Separate Condition entry is allowed for each MPC.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. MPC cavity vacuum drying pressure *or demoisturizer exit gas temperature* limit not met.	A.1 Perform an engineering evaluation to determine the quantity of moisture left in the MPC.	7 days
	<u>AND</u>	
	A.2 Develop and initiate corrective actions necessary to return the MPC to an analyzed condition.	30 days
B. MPC helium backfill ~~density~~ limit not met.	B.1 Perform an engineering evaluation to determine the impact of helium differential.	72 hours
	<u>AND</u>	
	B.2 Develop and initiate corrective actions necessary to return the MPC to an analyzed condition.	14 days

ACTIONS
(continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
C. MPC helium leak rate limit not met.	C.1 Perform an engineering evaluation to determine the impact of increased helium leak rate on heat removal capability and offsite dose.	24 hours
	AND	
	C.2 Develop and initiate corrective actions necessary to return the MPC to an analyzed condition.	7 days
D. Required Actions and associated Completion Times not met.	D.1 Remove all fuel assemblies from the SFSC.	30 days

SURVEILLANCE REQUIREMENTS

	SURVEILLANCE	FREQUENCY
SR 3.1.1.1	*For those MPCs containing all moderate burnup (≤ 45,000 MWD/MTU) fuel assemblies, ~~V~~verify* MPC cavity vacuum drying pressure is within the limit specified in Table 3-1 for the applicable MPC model. *OR* *For those MPCs containing fuel assemblies of any authorized burnup, while using the recirculating helium method to dehydrate the MPC cavity, verify that the gas temperature exiting the demoisturizer is ≤ 21°F for ≥ 30 minutes.*	Once, prior to TRANSPORT OPERATIONS
SR 3.1.1.2	Verify MPC helium backfill density *or pressure* is within the limit specified in Table 3-1 for the applicable MPC model.	Once, prior to TRANSPORT OPERATIONS
SR 3.1.1.3	Verify that the total helium leak rate through the MPC lid confinement weld and the drain and vent port confinement welds is within the limit specified in Table 3-1 for the applicable MPC model.	Once, prior to TRANSPORT OPERATIONS

DESIGN FEATURES

Table 3-3

Load Combinations and Service Condition Definitions for the CTF Structure (Note 1)

Load Combination	ASME III Service Condition for Definition of Allowable Stress	Comment
D* D + S	Level A	All primary load bearing members must satisfy Level A stress limits
D + M + W' (Note 2) D + F D + E D + Y	Level D	Factor of safety against overturning shall be ≥ 1.1

D = Dead load
D* = Apparent dead load
S = Snow and ice load for the CTF site
M = Tornado missile load for the CTF site
W' = Tornado wind load for the CTF site
F = Flood load for the CTF site
E = Seismic load for the CTF site
Y = Tsunami load for the CTF site

Notes:
1. The reinforced concrete portion of the CTF structure shall also meet the factored combinations of loads set forth in ACI-318(89).
2. Tornado missile load may be reduced or eliminated based on a PRA for the CTF site.

DESIGN FEATURES

3.6 Forced Helium Dehydration System

3.6.1 System Description

Use of the Forced Helium Dehydration (FHD) system, (a closed-loop system) is an alternative to vacuum drying the MPC for moderate burnup fuel (≤ 45,000 MWD/MTU) and mandatory for drying MPCs containing one or more high burnup fuel assemblies. The FHD system shall be designed for normal operation (i.e., excluding startup and shutdown ramps) in accordance with the criteria in Section 3.6.2.

3.6.2 Design Criteria

3.6.2.1 The temperature of the helium gas in the MPC shall be at least 15°F higher than the saturation temperature at coincident pressure.

3.6.2.2 The pressure in the MPC cavity space shall be ≤ 60.3 psig (75 psia).

3.6.2.3 The fuel cladding temperature shall be ≤ 650°F.

3.6.2.4 The hourly recirculation rate of helium shall be ≥ 10 times the nominal helium mass backfilled into the MPC for fuel storage operations.

3.6.2.5 The partial pressure of the water vapor in the MPC cavity will not exceed 3 torr if the helium temperature at the demoisturer outlet is ≤ 21°F for a period of 30 minutes.

3.6.2.6 The condensing module shall be designed to de-vaporize the recirculating helium gas to a dew point ≤ 120°F.

3.6.2.7 The demoisturizing module shall be configured to be introduced into its helium conditioning function after the condensing module has been operated for the required length of time to assure that the bulk moisture vaporization in the MPC (defined as Phase 1 in FSAR Appendix 2.B) has been completed.

3.6.2.8 The helium circulator shall be sized to effect the minimum flow rate of circulation required by these design criteria.

3.6.2.9 The pre-heater module shall be engineered to ensure that the temperature of the helium gas in the MPC meets these design criteria.

(continued)

DESIGN FEATURES

3.6 Forced Helium Dehydration System (continued)

3.6.3 Acceptance Testing

A one-time acceptance test of the FHD system shall be performed by the CoC holder to confirm that the system operates as designed and ensures that meeting the acceptance criterion in SR 3.1.1.1 is indicative of a vapor pressure ≤ 3 torr in the MPC. A written evaluation of the test results shall be submitted to the NRC.

3.1 SFSC INTEGRITY

3.1.1 Multi-Purpose Canister (MPC)

LCO 3.1.1 The MPC shall be dry and helium filled.

APPLICABILITY: During TRANSPORT OPERATIONS and STORAGE OPERATIONS.

ACTIONS

-----NOTE-----
Separate Condition entry is allowed for each MPC.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. MPC cavity vacuum drying pressure or demoisturizer exit gas temperature limit not met.	A.1 Perform an engineering evaluation to determine the quantity of moisture left in the MPC.	7 days
	<u>AND</u>	
	A.2 Develop and initiate corrective actions necessary to return the MPC to an analyzed condition.	30 days
B. MPC helium backfill limit not met.	B.1 Perform an engineering evaluation to determine the impact of helium differential.	72 hours
	<u>AND</u>	
	B.2 Develop and initiate corrective actions necessary to return the MPC to an analyzed condition.	14 days

ACTIONS
(continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
C. MPC helium leak rate limit not met.	C.1 Perform an engineering evaluation to determine the impact of increased helium leak rate on heat removal capability and offsite dose.	24 hours
	<u>AND</u>	
	C.2 Develop and initiate corrective actions necessary to return the MPC to an analyzed condition.	7 days
D. Required Actions and associated Completion Times not met.	D.1 Remove all fuel assemblies from the SFSC.	30 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.1.1	For those MPCs containing all moderate burnup ($\leq$ 45,000 MWD/MTU) fuel assemblies, verify MPC cavity vacuum drying pressure is within the limit specified in Table 3-1 for the applicable MPC model. OR For those MPCs containing fuel assemblies of any authorized burnup, while using the recirculating helium method to dehydrate the MPC cavity, verify that the gas temperature exiting the demoisturizer is $\leq$ 21°F for $\geq$ 30 minutes.	Once, prior to TRANSPORT OPERATIONS
SR 3.1.1.2	Verify MPC helium backfill density or pressure is within the limit specified in Table 3-1 for the applicable MPC model.	Once, prior to TRANSPORT OPERATIONS
SR 3.1.1.3	Verify that the total helium leak rate through the MPC lid confinement weld and the drain and vent port confinement welds is within the limit specified in Table 3-1 for the applicable MPC model.	Once, prior to TRANSPORT OPERATIONS

DESIGN FEATURES

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3.6.1 System Description

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3.6.2.6 The condensing module shall be designed to de-vaporize the recirculating helium gas to a dew point $\leq$ 120°F.

3.6.2.7 The demoisturizing module shall be configured to be introduced into its helium conditioning function after the condensing module has been operated for the required length of time to assure that the bulk moisture vaporization in the MPC (defined as Phase 1 in FSAR Appendix 2.B) has been completed.

3.6.2.8 The helium circulator shall be sized to effect the minimum flow rate of circulation required by these design criteria.

3.6.2.9 The pre-heater module shall be engineered to ensure that the temperature of the helium gas in the MPC meets these design criteria.

(continued)

DESIGN FEATURES

3.6 Forced Helium Dehydration System (continued)

3.6.3 Acceptance Testing

A one-time acceptance test of the FHD system shall be performed by the CoC holder to confirm that the system operates as designed and ensures that meeting the acceptance criterion in SR 3.1.1.1 is indicative of a vapor pressure $\leq$ 3 torr in the MPC. A written evaluation of the test results shall be submitted to the NRC.

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3.0-4	1B		Fig. 3.1.3	1B
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3.0-6	1B		3.2-2	1
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Fig. 3.A.28	Deleted		3.B-50	0
Fig. 3.A.29	Deleted		3.B-51	0
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3.B-5	0		3.B-57	0
3.B-6	0		3.B-58	0
3.B-7	0		3.B-59	0
3.B-8	0		3.B-60	0
3.B-9	0		3.B-61	0
3.B-10	0		3.B-62	0
3.B-11	0		3.C-1	0
3.B-12	0		3.C-2	0
3.B-13	0		3.C-3	0
3.B-14	0		3.C-4	0
3.B-15	0		3.C-5	0
3.B-16	0		3.C-6	0
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3.D-3	1C		3.G-10	0
3.D-4	1C		3.G-11	0
3.D-5	1C		3.G-12	0
3.D-6	1C		3.G-13	0
3.D-7	1C		Fig. 3.G.1	0
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3.E-3	0		3.I-8	1
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3.E-7	0		3.K-1	0
3.E-8	0		3.K-2	0
3.E-9	0		3.K-3	0
3.E-10	0		3.K-4	0
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Fig. 3.E.2	0		3.K-6	0
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3.F-4	0		3.L-4	0
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Fig. 3.F.2	0		3.L-6	0
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3.M-12	1		3.X-5	0
3.M-13	1		3.X-6	0
3.M-14	1		3.X-7	0
3.M-15	1		3.X-8	0
3.M-16	1		3.X-9	0
3.M-17	1		3.X-10	0
3.M-18	1		Fig. 3.X.1	0
3.M-19	1		Fig. 3.X.2	0
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3.S-1	1B		3.Y-4	1
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3.U-1	1		3.Y-6	1
3.U-2	1		3.Y-7	1
3.U-3	1		3.Y-8	1
3.U-4	1		3.Y-9	1
3.U-5	1		3.Y-10	1
3.U-6	1		3.Y-11	1
3.U-7	1		3.Y-12	1
3.U-8	1		3.Y-13	1
3.U-9	1		3.Y-14	1
3.U-10	1		3.Y-15	1
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3.V-1	1		3.Y-17	1
3.V-2	1		3.Y-18	1
3.V-3	1		3.Y-19	1
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3.V-5	1		3.Y-21	1
3.V-6	1		Fig. 3.Y.1	0
3.V-7	1		Fig. 3.Y.2	0
3.V-8	1		3.Z-1	0
3.V-9	1		3.Z-2	0
3.V-10	1		3.Z-3	0
3.W-1	1		3.Z-4	0
3.W-2	1		3.Z-5	0
3.W-3	1		3.Z-6	0
3.W-4	1		3.Z-7	0
3.W-5	1		3.Z-8	0
3.W-6	1		3.Z-10	0
3.W-7	1		3.Z-11	0
3.W-8	1		3.Z-12	0
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3.AA-4	0		3.AD-14	1
3.AA-5	0		3.AD-15	1
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Fig. 3.AA.1	0		Fig. 3.AD.1	0
Fig. 3.AA.2	0		Fig. 3.AD.2	0
Fig. 3.AA.3	0		Fig. 3.AD.3	0
Fig. 3.AA.4	0		3.AE-1	0
Fig. 3.AA.5	0		3.AE-2	0
Fig. 3.AA.6	0		3.AE-3	0
Fig. 3.AA.7	0		3.AE-4	0
Fig. 3.AA.8	0		3.AE-5	0
3.AB-1	0		3.AE-6	0
3.AB-2	0		Fig. 3.AE.1a	0
3.AB-3	0		Fig. 3.AE.1b	0
3.AB-4	0		Fig. 3.AE.1c	0
3.AB-5	0		Fig. 3.AE.2	0
3.AB-6	0		Fig. 3.AE.3	0
3.AB-7	0		Fig. 3.AE.4	0
3.AB-8	0		3.AF-1	1
3.AB-9	0		3.AF-2	1
3.AB-10	0		3.AF-3	1
3.AB-11	0		3.AF-4	1
3.AB-12	0		3.AF-5	1
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3.AB-14	0		3.AF-7	1
3.AC-1	1		3.AF-8	1
3.AC-2	1		3.AG-1	0
3.AC-3	1		3.AG-2	0
3.AC-4	1		3.AG-3	0
3.AC-5	1		3.AG-4	0
3.AC-6	1		3.AG-5	0
3.AC-7	1		3.AG-6	0
3.AC-8	1		3.AG-7	0
3.AC-9	1		3.AG-8	0
3.AC-10	1		3.AG-9	0
3.AC-11	1		3.AG-10	0
3.AC-12	1		3.AH-1	0
3.AD-1	1		3.AH-2	0
3.AD-2	1		3.AH-3	0
3.AD-3	1		3.AH-4	0
3.AD-4	1		3.AH-5	0
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3.AI-5	0		3.AK-13	0
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3.AI-13	0		3.AL-3	0
3.AI-14	0		3.AL-4	0
3.AI-15	0		3.AL-5	0
3.AI-16	0		3.AL-6	0
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3.AJ-2	0		3.AM-7	0
3.AJ-3	0		3.AM-8	0
3.AJ-4	0		3.AM-9	0
3.AJ-5	0		3.AM-10	0
3.AJ-6	0		3.AM-11	0
3.AJ-7	0		3.AM-12	0
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3.AJ-9	0		3.AM-14	0
3.AJ-10	0		3.AM-15	0
3.AJ-11	0		3.AM-16	0
3.AJ-12	0		3.AM-17	0
3.AJ-13	0		3.AM-18	0
3.AJ-14	0		3.AM-19	0
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3.AJ-16	0		3.AM-21	0
Fig. 3.AJ.1	0		3.AM-22	0
Fig. 3.AJ.2	0		3.AM-23	0
Fig. 3.AJ.3	0		3.AM-24	0
3.AK-1	0		3.AM-25	0
3.AK-2	0		3.AM-26	0
3.AK-3	0		3.AM-27	0
3.AK-4	0		3.AM-28	0
3.AK-5	0		3.AM-29	0
3.AK-6	0		3.AM-30	0
3.AK-7	0		3.AN-1	0
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3.AN-6	0		3.AR-2	1
3.AN-7	0		3.AR-3	1
3.AN-8	0		3.AR-4	1
3.AN-9	0		3.AR-5	1
3.AN-10	0		3.AR-6	1
3.AN-11	0		3.AR-7	1
3.AN-12	0		3.AR-8	1
3.AN-13	0		3.AR-9	1
3.AN-14	0		3.AR-10	1
Fig. 3.AN.1	0		3.AR-11	1
Fig. 3.AN.2	0		3.AS-1	1
Fig. 3.AN.3	0		3.AS-2	1
Fig. 3.AN.4	0		3.AS-3	1
Fig. 3.AN.5	0		3.AS-4	1
Fig. 3.AN.6	0		3.AS-5	1
Fig. 3.AN.7	0		3.AS-6	1
Fig. 3.AN.8	0		3.AS-7	1
Fig. 3.AN.9	0		3.AS-8	1
Fig. 3.AN.10	0		3.AS-9	1
Fig. 3.AN.11	0		3.AS-10	1
Fig. 3.AN.12	0		3.AS-11	1
Fig. 3.AN.13	0		3.AS-12	1
Fig. 3.AN.14	0		3.AS-13	1
Fig. 3.AN.15	0			
Fig. 3.AN.16	0			
Fig. 3.AN.17	0			
Fig. 3.AN.18	0			
Fig. 3.AN.19	0			
Fig. 3.AN.20	0			
Fig. 3.AN.21	0			
Fig. 3.AN.22	0			
Fig. 3.AN.23	0			
Fig. 3.AN.24	0			
Fig. 3.AN.25	0			
Fig. 3.AN.26	0			
Fig. 3.AN.28	0			
Fig. 3.AN.29	0			
Fig. 3.AN.20	0			
3.AO-1	1B			
3.AP-1	1B			
3.AQ-1	1			
3.AQ-2	1			
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3.AQ-4	1			
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Fig. 4.2.1	0		4.4-24	1B
Fig. 4.2.2	0		4.4-25	1B
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4.3-2	1B		4.4-27	1B
4.3-3	1B		4.4-28	1B
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4.3-6	1B		4.4-31	1B
4.3-7	1B		4.4-32	1B
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4.3-19	1B		4.4-44	1B
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4.3-21	1B		4.4-46	1B
4.3-22	1B		4.4-47	1B
4.3-23	1B		4.4-48	1B
Fig. 4.3.1	0		4.4-49	1B
Fig. 4.3.2	0		4.4-50	1B
Fig. 4.3.3	0		4.4-51	1B
Fig. 4.3.4	0		4.4-52	1B
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4.4-70	1B		4.5-26	1E
Fig. 4.4.1	0		Fig. 4.5.1	0
Fig. 4.4.2	0		Fig. 4.5.2	1
Fig. 4.4.3	0		Fig. 4.5.3	1B
Fig. 4.4.4	0		4.6-1	1
Fig. 4.4.5	0		4.6-2	1
Fig. 4.4.6	0		4.7-1	1
Fig. 4.4.7	0		4.7-2	1
Fig. 4.4.8	0		4.7-3	1
Fig. 4.4.9	0		4.A-1	1B
Fig. 4.4.10	0		4.A-2	1D
Fig. 4.4.11	0		4.A-3	1B
Fig. 4.4.12	0		4.A-4	1B
Fig. 4.4.13	0		4.A-5	1B
Fig. 4.4.14	Deleted in Rev. 1		4.A-6	1B
Fig. 4.4.15	0		4.A-7	1B
Fig. 4.4.16	1		4.A-8	1B
Fig. 4.4.17	1		4.A-9	1B
Fig. 4.4.18	0		4.A-10	1B
Fig. 4.4.19	1		4.A-11	1B
Fig. 4.4.20	1		4.A-12	1B
Fig. 4.4.21	0		4.A-13	1B
Fig. 4.4.22	Deleted in Rev. 1		4.A-14	1B
Fig. 4.4.23	Deleted in Rev. 1		4.A-15	1B
Fig. 4.4.24	0		4.A-16	1B
Fig. 4.4.25	1		4.A-17	1B
Fig. 4.4.26	1		4.A-18	1B
4.5-1	1E		4.A-19	1B
4.5-2	1E		4.A-20	1B
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4.5-4	1E		4.A-22	1B
4.5-5	1E		4.A-23	1B
4.5-6	1E		4.A-24	1B
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4.5-9	1E		Fig. 4.A.2	1B
4.5-10	1E		Fig. 4.A.3	1B
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Fig. 4.A.11	1B			
Fig. 4.A.12	1B			
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Fig. 4.B.4	1A			
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5.1-12	1B		5.2-32	1B
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5.1-15	1B		5.2-35	1B
5.1-16	1C		5.2-36	1B
5.1-17	1B		5.2-37	1B
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5.1-19	1B		5.2-39	1B
5.1-20	1B		5.2-40	1B
Fig. 5.1.1	1		5.2-41	1B
Fig. 5.1.2	0		5.2-42	1B
Fig. 5.1.3	1		5.2-43	1B
Fig. 5.1.4	0		5.2-44	1B
Fig. 5.1.5	0		5.2-45	1B
Fig. 5.1.6	0		5.2-46	1B
Fig. 5.1.7	0		5.2-47	1B
Fig. 5.1.8	0		5.2-48	1B
Fig. 5.1.9	0		5.2-49	1B
Fig. 5.1.10	0		5.2-50	1B
Fig. 5.1.11	0		5.2-51	1B
Fig. 5.1.12	1B		5.2-52	1B
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5.2-12	1B		5.3-10	1B
5.2-13	1B		5.3-11	1B
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Fig. 5.3.7	0		5.A-2	0
Fig. 5.3.8	0		5.A-3	0
Fig. 5.3.9	0		5.B-1	0
Fig. 5.3.10	1B		5.B-2	0
Fig. 5.3.11	0		5.B-3	0
Fig. 5.3.12	0		5.B-4	0
Fig. 5.3.13	0		5.B-5	0
Fig. 5.3.14	0		5.B-6	0
Fig. 5.3.15	0		5.B-7	0
Fig. 5.3.16	0		5.C-1	0
Fig. 5.3.17	0		5.C-2	0
Fig. 5.3.18	1B		5.C-3	0
Fig. 5.3.19	1B		5.C-4	0
5.4-1	1		5.C-5	0
5.4-2	1		5.C-6	0
5.4-3	1		5.C-7	0
5.4-4	1		5.C-8	0
5.4-5	1		5.C-9	0
5.4-6	1		5.C-10	0
5.4-7	1		5.C-11	0
5.4-8	1		5.C-12	0
5.4-9	1		5.C-13	0
5.4-10	1		5.C-14	0
5.4-11	1		5.C-15	0
5.4-12	1		5.C-16	0
5.4-13	1		5.C-17	0
5.4-14	1		5.C-18	0
5.4-15	1		5.C-19	0
5.4-16	1		5.C-20	0
5.4-17	1		5.C-21	0
5.4-18	1		5.C-22	0
5.4-19	1		5.C-23	0
5.4-20	1		5.C-24	0
5.4-21	1		5.C-25	0
5.4-22	1		5.C-26	0
5.4-23	1		5.C-27	0
5.4-24	1		5.C-28	0
5.4-25	1		5.C-29	0
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5.4-27	1		5.C-31	0
5.4-28	1		5.C-32	0
5.4-29	1		5.C-33	0
5.4-30	1		5.C-34	0
5.4-31	1		5.C-35	0
5.4-32	1		5.C-36	0
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5.C-54	0			
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6.1-7	1B		6.2-41	1
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6.1-9	1B		6.2-43	1
6.1-10	1B		6.2-44	1
6.1-11	1B		6.2-45	1
6.1-12	1B		6.2-46	1
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6.1-14	1B		6.2-48	1
6.1-15	1B		6.2-49	1
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6.1-18	1B		6.2-52	1
6.2-1	1		6.2-53	1
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6.2-9	1		6.2-61	1
6.2-10	1		6.2-62	1
6.2-11	1		6.2-63	1
6.2-12	1		Fig. 6.2.1	0
6.2-13	1		6.3-1	1B
6.2-14	1		6.3-2	1B
6.2-15	1		6.3-3	1B
6.2-16	1		6.3-4	1B
6.2-17	1		6.3-5	1B
6.2-18	1		6.3-6	1B
6.2-19	1		6.3-7	1B
6.2-20	1		6.3-8	1B
6.2-21	1		6.3-9	1B
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6.4-3	1B		6.A-11	1
6.4-4	1B		6.A-12	1
6.4-5	1B		6.A-13	1
6.4-6	1B		6.A-14	1
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6.4-13	1D		Fig. 6.A.1	0
6.4-14	1D		Fig. 6.A.2	0
6.4-15	1D		Fig. 6.A.3	0
6.4-16	1B		Fig. 6.A.4	0
6.4-17	1B		Fig. 6.A.5	0
6.4-18	1B		Fig. 6.A.6	0
6.4-19	1B		6.B-1	0
6.4-20	1B		6.B-2	0
6.4-21	1B		6.C-1	1
6.4-22	1B		6.C-2	1
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Fig. 6.4.1	0		6.C-6	1
Fig. 6.4.2	1		6.C-7	1
Fig. 6.4.3	1		6.C-8	1
Fig. 6.4.4	1		6.C-9	1
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Fig. 6.4.7	1		6.C-12	1
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Fig. 6.4.11	1		6.C-16	1
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Fig. 6.4.15	1		6.D-3	0
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Fig. 10.3.1a	0			
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Fig. 10.3.1c	0			
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Automated Welding System baseplate shield *(if used)* is installed to reduce dose rates around the top of the cask. The MPC water level is lowered slightly and the MPC lid is seal-welded using the Automated Welding System (AWS) *or other approved welding process*. Liquid penetrant examinations are performed on the root and final passes. A *multi-layer liquid penetrant or* volumetric examination is also performed on the MPC lid-to-shell weld. The water level is raised to the top of the MPC and the weld is hydrostatically tested. Then a small volume of the water is displaced with helium gas. The helium gas is used for leakage testing. A helium leakage rate test is performed on the MPC lid confinement weld (lid-to-shell) to verify weld integrity and to ensure that ~~*required*~~ leakage rates are within acceptance criteria. ~~*The water level is raised to the top of the MPC again and then the*~~ *The* MPC water is displaced from the MPC by blowing pressurized helium or nitrogen gas into the vent port of the MPC, thus displacing the water through the drain line. ~~*The volume of water displaced from the MPC is measured to determine the free volume inside the MPC. This information is used to determine the helium backfill requirements for the MPC.*~~

For storage of moderate burnup fuel, ~~the~~ *a* Vacuum Drying System (VDS) *may be used to remove moisture from the MPC cavity. The VDS* is connected to the MPC and is used to remove ~~all~~ liquid water from the MPC in a stepped evacuation process. The stepped evacuation process is used to preclude the formation of ice in the MPC and Vacuum Drying System lines. The internal pressure is reduced and held for a duration to ensure that all liquid water has evaporated. *This process is continued until the pressure in the MPC meets the technical specification limit and can be held there for the required amount of time.*

For storage of high burnup fuel and as an option for storage of moderate burnup fuel, the reduction of residual moisture in the MPC to trace amounts is accomplished using a Forced Helium Dehydration (FHD) system, as described in Appendix 2.B. Relatively warm and dry helium is recirculated through the MPC cavity, which helps maintain the SNF in a cooled condition while moisture is being removed. The warm, dry gas is supplied to the MPC drain port and circulated through the MPC cavity where it absorbs moisture. The humidified gas travels out of the MPC and through appropriate equipment to cool and remove the absorbed water from the gas. The dry gas may be heated prior to its return to the MPC in a closed loop system to accelerate the rate of moisture removal in the MPC. This process is continued until the temperature of the gas exiting the demoisturizing module described in Appendix 2.B meets the limit specified in the technical specifications.

Following *moisture removal,* ~~this dryness test,~~ the VDS *or FHD system* is disconnected and the Helium Backfill System (HBS) is attached and the MPC is backfilled with a predetermined amount of helium gas. The helium backfill ensures adequate heat transfer during storage, provides an inert atmosphere for long-term fuel integrity, and provides the means of future leakage rate testing of the MPC confinement boundary welds. Cover plates are installed and seal-welded over the MPC vent and drain ports with liquid penetrant examinations performed on the root and final passes. The cover plates are helium leakage tested to confirm that they meet the established leakage rate criteria.

The MPC closure ring is then placed on the MPC, aligned, tacked in place, and seal welded, providing redundant closure of the MPC lid and cover plates confinement closure welds. Tack welds are visually examined, and the root and final welds are inspected using the liquid penetrant examination technique to ensure weld integrity. The annulus shield is removed and the remaining water in the annulus is drained. The AWS Baseplate shield is removed. The MPC lid and accessible areas of the top of the MPC shell are smeared for removable contamination and HI-TRAC dose rates are measured. The HI-TRAC top lid is installed and the bolts are torqued. The MPC lift cleats are installed on the MPC lid. The MPC lift cleats are the primary lifting point of the MPC. Two cleats provide redundant support of the MPC when it is lifted or supported.

Two or four stays (depending on the site crane hook configuration) are installed between the MPC lift cleats and the lift yoke main pins. The stays secure the MPC within HI-TRAC while the pool lid is replaced with the transfer lid. The HI-TRAC is manipulated to replace the pool lid with the transfer lid. The MPC lift cleats and stays support the MPC during the transfer operations.

MPC transfer from the HI-TRAC transfer cask into the overpack may be performed inside or outside the fuel building. Similarly, HI-TRAC and HI-STORM may be transferred to the ISFSI in several different ways. The loaded HI-TRAC may be handled in the vertical or horizontal orientation. The loaded HI-STORM can only be handled vertically.

For MPC transfers inside the fuel building, the empty HI-STORM overpack is inspected and positioned in the truck bay with the lid removed and, *for the HI-STORM 100 overpack,* the vent duct shield inserts installed. The loaded HI-TRAC is placed using the fuel building crane on top of HI-STORM. Alignment pins help guide HI-TRAC during this operation.

After the HI-TRAC is positioned atop the HI-STORM, the MPC is raised slightly. The transfer lid door locking pins are removed and the doors are opened. The MPC is lowered into HI-STORM. Following verification that the MPC is fully lowered, slings are disconnected and lowered onto the MPC lid. *For the HI-STORM 100*, the doors are closed and the locking pins are installed. HI-TRAC is removed from on top of HI-STORM along with the vent shield inserts. *For the HI-STORM 100S, the HI-TRAC may need to be lifted above the overpack to a height sufficient to allow closure of the transfer lid doors without interfering with the MPC lift cleats. The HI-TRAC is then removed and placed in its designated storage location.* The MPC lift cleats and slings are removed from atop the MPC. *The HI-STORM lid is installed, and the upper vent screens and gamma shield cross plates are installed. The HI-STORM lid studs are installed and torqued.*

For MPC transfers outside of the fuel building, the empty HI-STORM overpack is inspected and positioned in the cask transfer facility with the lid removed and, *for the HI-STORM 100,* the vent duct shield inserts installed. The loaded HI-TRAC is transported to the cask transfer facility in the vertical or horizontal orientation. A number of methods may be utilized as long as the handling limitations prescribed in the technical specifications are not exceeded.

To place the loaded HI-TRAC in a horizontal orientation, a transport frame or "cradle" is utilized. The cradle is equipped with rotation trunnions which engage the HI-TRAC pocket trunnions. While the loaded HI-TRAC is lifted by the lifting trunnions, the HI-TRAC is lowered onto the cradle rotation trunnions. Then, the crane lowers and the HI-TRAC pivots around the pocket trunnions and is placed in the horizontal position in the cradle.

If the loaded HI-TRAC is transferred to the cask transfer facility in the horizontal orientation, the HI-TRAC and cradle are placed on a transport vehicle. The transport vehicle may be an air pad, railcar, heavy-haul trailer, dolly, etc. If the loaded HI-TRAC is transferred to the cask transfer facility in the vertical orientation, the HI-TRAC may be lifted by the lifting trunnions or seated on the transport vehicle. During the transport of the loaded HI-TRAC, standard plant heavy load handling practices shall be applied including administrative controls for the travel path and tie-down mechanisms.

After the loaded HI-TRAC arrives at the cask transfer facility, the HI-TRAC is upended by a crane if the HI-TRAC is in a horizontal orientation. The loaded HI-TRAC is then placed, using the crane located in the transfer area, on top of HI-STORM. Alignment pins help guide HI-TRAC during this operation.

After the HI-TRAC is positioned atop the HI-STORM, the MPC is raised slightly. The transfer lid door locking pins are removed and the doors are opened. The MPC is lowered into HI-STORM. Following verification that the MPC is fully lowered, slings are disconnected and lowered onto the MPC lid. *For the HI-STORM 100,* the doors are closed and the locking pins are installed. HI-TRAC is removed from on top of HI-STORM along with the vent duct shield inserts. *For the HI-STORM 100S, the HI-TRAC may need to be lifted above the overpack to a height sufficient to allow closure of the transfer lid doors without interfering with the MPC lift cleats. The HI-TRAC is then removed and placed in its designated storage location.* The MPC lift cleats and slings are removed from atop the MPC. The HI-STORM lid is installed, and the upper vent screens and gamma shield cross plates are installed. The HI-STORM lid studs *and nuts* are installed and torqued.

After the HI-STORM has been loaded either within the fuel building or at a dedicated cask transfer facility, the HI-STORM is then moved to its designated position on the ISFSI pad. The HI-STORM overpack may be moved using a number of methods as long as the handling limitations listed in the technical specifications are not exceeded. The loaded HI-STORM must be handled in the vertical orientation. However, the loaded overpack may be lifted from the top through the lid studs or from the bottom by the inlet vents. After the loaded HI-STORM is lifted, it may be placed on a transport mechanism or continue to be lifted by the lid studs and transported to the storage location. The transport mechanism may be an air pad, crawler, railcar, heavy-haul trailer, dolly, etc. During the transport of the loaded HI-STORM, standard plant heavy load handling practices shall be applied including administrative controls for the travel path and tie-down mechanisms. Once in position at the storage pad, vent operability testing is performed to ensure that the system is functioning within its design parameters.

In the case of HI-STORM 100A, the anchor studs are installed and fastened into the anchor receptacles in the ISFSI pad in accordance with the design requirements.

Unloading Operations

The HI-STORM 100 System unloading procedures describe the general actions necessary to prepare the MPC for unloading, cool the stored fuel assemblies in the MPC, flood the MPC cavity, remove the lid welds, unload the spent fuel assemblies, and recover HI-TRAC and empty the MPC. Special precautions are outlined to ensure personnel safety during the unloading operations, and to prevent the risk of MPC overpressurization and thermal shock to the stored spent fuel assemblies.

The MPC is recovered from HI-STORM either at the cask transfer facility or the fuel building using any of the methodologies described in Section 8.1. ~~*If it hasn't already been removed prior to entering the Part 50 facility,*~~ ~~t~~*T*he HI-STORM lid is removed *and, for the HI-STORM 100,* the vent duct shield inserts are installed. The MPC lift cleats are attached to the MPC and the MPC lift slings are attached to the MPC lift cleats. *For the HI-STORM 100S, the transfer doors may need to be opened to avoid interfering with the MPC lift cleats.* HI-TRAC is raised and positioned on top of HI-STORM. The MPC is raised into HI-TRAC. Once the MPC is raised into HI-TRAC, the HI-TRAC transfer lid doors are closed and the locking pins are installed. HI-TRAC is removed from on top of HI-STORM.

The HI-TRAC is brought into the fuel building and manipulated for bottom lid replacement. The transfer lid is replaced with the pool lid. The MPC lift cleats and stays support the MPC during the transfer operations.

HI-TRAC and its enclosed MPC are returned to the designated preparation area and the MPC stays, MPC lift cleats, and HI-TRAC top lid are removed. The annulus is filled with plant demineralized water*(borated, if necessary)*. The annulus shield is installed *and pressurized* to protect the annulus from debris produced from the lid removal process. Similarly, HI-TRAC top surfaces are covered with a protective fire-retarding blanket.

The MPC closure ring and vent and drain port cover plates are core drilled. Local ventilation is established around the MPC ports. The RVOAs are attached to the vent and drain port. The RVOAs allow access to the inner cavity of the MPC, while providing a hermetic seal. The MPC is cooled using a closed-loop heat exchanger to reduce the MPC internal temperature to allow water flooding. Following the fuel cool-down, the MPC is flooded with *borated or unborated* water *in accordance with the CoC*. The -MPC lid-to-MPC shell weld is removed. Then, all weld removal equipment is removed with the MPC lid left in place.

~~*The inflatable annulus seal is installed and pressurized.*~~ The MPC lid is rigged to the lift yoke and the lift yoke is engaged to HI-TRAC lifting trunnions. If weight limitations require, the neutron shield jacket is drained. HI-TRAC is placed in the spent fuel pool and the MPC lid is removed. All fuel assemblies are returned to the spent fuel storage racks and the MPC fuel cells are vacuumed to remove any assembly debris. HI-TRAC and MPC are returned to the designated preparation area where the MPC water is *removed* ~~*pumped back into the spent fuel pool*~~. The annulus water is drained and the MPC and HI-TRAC are decontaminated in preparation for re-utilization.

1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

1.2.2.3.1 Criticality Prevention

Criticality is controlled by geometry and neutron absorbing materials in the fuel basket. The MPC-24, *MPC-24E, and 24EF(all with lower enriched fuel)* and *the* MPC-68 do not rely on soluble boron credit during loading or the assurance that water cannot enter the MPC during storage to meet the stipulated criticality limits.

Each MPC model is equipped with Boral neutron absorber plates affixed to the fuel cell walls as shown on the design drawings. The minimum ^{10}B areal density specified for the Boral in each MPC model is shown in Table 1.2.2. These values are chosen to be consistent with the assumptions made in the criticality analyses.

~~The MPC-68, *MPC-68FF, MPC-24E, and MPC-32* baskets *are is* equipped with Boral with a minimum ^{10}B areal density of 0.0372 g/cm^2. The MPC-24 basket is equipped with Boral with a minimum ^{10}B areal density of 0.0267 g/cm^2. Due to the lower reactivity of the fuel to be stored in the MPC-68F as specified by the *Technical Specifications in Chapter 12 Appendix B to the CoC*, the MPC-68F is equipped with Boral with a minimum ^{10}B areal density of 0.01 g/cm^2.~~

The MPC-24, MPC-24E and 24EF(all with higher enriched fuel) and the MPC-32 take credit for soluble boron in the MPC water for criticality prevention during wet loading and unloading operations. Boron credit is only necessary for these PWR MPCs during loading and unloading operations that take place under water. During storage, with the MPC cavity dry and sealed from the environment, criticality control measures beyond the fixed neutron poisons affixed to the storage cell walls are not necessary because of the low reactivity of the fuel in the dry, helium filled canister and the design features that prevent water from intruding into the canister during storage.

1.2.2.3.2 Chemical Safety

There are no chemical safety hazards associated with operations of the HI-STORM 100 dry storage system. A detailed evaluation is provided in Section 3.4.

1.2.2.3.3 Operation Shutdown Modes

The HI-STORM 100 System is totally passive and consequently, operation shutdown modes are unnecessary. Guidance is provided in Chapter 8, which outlines the HI-STORM 100 unloading procedures, and Chapter 11, which outlines the corrective course of action in the wake of postulated accidents.

1.2.2.3.4 Instrumentation

As stated earlier, the HI-STORM 100 confinement boundary is the MPC, which is seal welded and leak tested. The HI-STORM 100 is a completely passive system with appropriate margins of safety; therefore, it is not necessary to deploy any instrumentation to monitor the cask in the storage mode. At the option of the user, ~~a thermocouple~~ *temperature elements* may be utilized to monitor the air temperature of the HI-STORM overpack exit vent*s* in lieu of routinely inspecting the ducts for blockage. See Subsection 2.3.3.2 and the Technical Specifications in ~~Chapter 12~~ *Appendix A to the CoC* for additional details.

1.2.2.3.5 Maintenance Technique

Because of their passive nature, the HI-STORM 100 System requires minimal maintenance over its lifetime. No special maintenance program is required. Chapter 9 describes the acceptance criteria and maintenance program set forth for the HI-STORM 100.

1.2.3 Cask Contents

The HI-STORM 100 System is designed to house different types of MPCs. The MPCs are designed to store both BWR and PWR spent nuclear fuel assemblies. Tables 1.2.1 and 1.2.2 provide key design parameters for the MPCs. A description of acceptable fuel assemblies for storage in the MPCs is provided in Section 2.1 and the ~~Technical Specifications~~ *Approved Contents section of Appendix B to the CoC. This includes fuel assemblies classified as damaged fuel assemblies and fuel debris in accordance with the definitions of these terms in the CoC. A summary of the types of fuel authorized for storage in each MPC model is provided below. All fuel assemblies must meet the fuel specifications provided in Appendix B to the CoC. All fuel assemblies classified as damaged fuel or fuel debris must be stored in damaged fuel containers.* The quantity of damaged fuel containers with fuel debris is limited to meet the off-site transportation requirements of 10CFR71, specifically, 10CFR71.63(b).

~~*At this time, failed fuel assemblies discharged from Dresden Unit 1 and Humboldt Bay reactors have been evaluated and this application requests approval of these two types of damaged fuel assemblies and fuel debris as contents for storage in the MPC-68. Damaged fuel assemblies and fuel debris shall be placed in damaged fuel containers prior to loading into the MPC to facilitate handling and contain loose components. Any combination of damaged fuel assemblies in damaged fuel containers and intact fuel assemblies, up to a total of 68, may be stored in the standard MPC-68. The MPC-68 design to store fuel debris is almost identical to the MPC-68*~~

~~*design to store intact or damaged fuel, the sole difference being the former requires a lower minimum B^{10} areal density in the Boral. Therefore, an MPC-68 which is to store damaged fuel containers with fuel assemblies classified as fuel debris must be designated during fabrication to ensure the proper minimum B^{10} areal density criteria is applied. To distinguish an MPC-68 which is fabricated to store damaged fuel containers with fuel assemblies classified as fuel debris, the MPC shall be designated as an "MPC-68F".*~~

~~*Up to 4 damaged fuel containers with fuel assemblies classified as fuel debris and meeting the requirements in the Technical Specifications may be stored within an MPC-68F.*~~

MPC-24

The MPC-24 is designed to accommodate up to twenty-four (24) PWR fuel assemblies classified as intact fuel assemblies, with or without non-fuel hardware.

MPC-24E

The MPC-24E is designed to accommodate up to twenty-four (24) PWR fuel assemblies, with or without non-fuel hardware. Up to four (4) fuel assemblies may be classified as damaged fuel assemblies, with the balance being classified as intact fuel assemblies. Damaged fuel assemblies must be stored in fuel storage locations 3, 6, 19, and/or 22 (see Figure 1.2.4A).

MPC-24EF

The MPC-24EF is designed to accommodate up to twenty-four (24) PWR fuel assemblies, with or without non-fuel hardware. Up to four (4) fuel assemblies may be classified as damaged fuel assemblies or fuel debris, with the balance being classified as intact fuel assemblies. Damaged fuel assemblies and fuel debris must be stored in fuel storage locations 3, 6, 19, and/or 22 (see Figure 1.2.4A).

MPC-32

The MPC-32 is designed to accommodate up to thirty-two (32) PWR fuel assemblies classified as intact fuel assemblies, with or without non-fuel hardware.

MPC-68

The MPC-68 is designed to accommodate up to sixty-eight (68) BWR intact and/or damaged fuel assemblies, with or without channels. For the Dresden Unit 1 or Humboldt Bay plants, the number of damaged fuel assemblies may be up to a total of 68. For damaged fuel assemblies from plants other than Dresden Unit 1 and Humboldt Bay, the number of damaged fuel assemblies is limited to sixteen (16) and must be stored in fuel storage locations 1, 2, 3, 8, 9, 16, 25, 34, 35, 44, 53, 60, 61, 66, 67, and/or 68 (see Figure 1.2.2).

MPC-68F

The MPC-68F is designed to accommodate up to sixty-eight (68) Dresden Unit 1 or Humboldt Bay BWR fuel assemblies (with or without channels) made up of any combination of fuel assemblies classified as intact fuel assemblies, damaged fuel assemblies, and up to four (4) fuel assemblies classified as fuel debris.

MPC-68FF

The MPC-68FF is designed to accommodate up to sixty-eight (68) BWR fuel assemblies with or without channels. Any number of these fuel assemblies may be Dresden Unit 1 or Humboldt Bay BWR fuel assemblies classified as intact fuel or damaged fuel. Dresden Unit 1 and Humboldt Bay fuel debris is limited to eight(8) DFCs. DFCs containing Dresden Unit 1 or Humboldt Bay fuel debris may be stored in any fuel storage location For BWR fuel assemblies from plants other than Dresden Unit 1 and Humboldt Bay, the total number of fuel assemblies classified as damaged fuel assemblies or fuel debris is limited to sixteen (16), with up to eight (8) of the 16 fuel assemblies classified as fuel debris. These fuel assemblies must be stored in fuel storage locations 1, 2, 3, 8, 9, 16, 25, 34, 35, 44, 53, 60, 61, 66, 67, and/or 68 (see Figure 1.2.2). The balance of the fuel storage locations may be filled with intact BWR fuel assemblies, up to a total of 68.

Table 1.2.1

KEY SYSTEM DATA FOR HI-STORM 100 SYSTEM

ITEM	QUANTITY	NOTES
Types of MPCs included in this revision of the submittal	~~3~~ *7*	~~1~~ *4* for PWR ~~2~~ *3* for BWR
MPC storage capacity†:	MPC-24 *MPC-24E* *MPC-24EF* *MPC-32*	Up to 24 intact zircaloy or stainless steel clad PWR fuel assemblies *with or without non-fuel hardware. Up to four damaged fuel assemblies may be stored in the MPC-24E and up to four (4)damaged fuel assemblies and/or fuel assemblies classified as fuel debris may be stored in the MPC-24EF* ~~Control components and non-fuel hardware are not authorized for loading.~~ *OR* *Up to 32 intact zircaloy or stainless steel clad PWR fuel assemblies.*
	MPC-68	Any combination of *Dresden Unit 1 or Humboldt Bay* damaged fuel assemblies in damaged fuel containers and intact fuel assemblies, up to a total of 68. ~~in the MPC-68~~ *. For damaged fuel other than Dresden Unit 1 and Humboldt Bay, the number of fuel assemblies is limited to 16, with the balance being intact fuel assemblies.* OR

† *See Section 1.2.3 and Appendix B to the CoC for a complete description of cask contents and fuel specifications, respectively.*

Table 1.2.1 (continued)
KEY SYSTEM DATA FOR HI-STORM 100 SYSTEM

ITEM	QUANTITY	NOTES
MPC storage capacity:	MPC-68F	Up to 4 damaged fuel containers with zircaloy clad *Dresden Unit 1 (D-1) or Humboldt Bay (HB)* BWR fuel debris and the complement damaged zircaloy clad *Dresden Unit 1 or Humboldt Bay* BWR fuel assemblies in damaged fuel containers or intact *Dresden Unit 1 or Humboldt Bay* BWR intact fuel assemblies ~~within an MPC-68F~~. *OR*
	MPC-68FF	*Up to 68 Dresden Unit 1 or Humboldt Bay intact fuel or damaged fuel and up to 8 damaged fuel containers containing D-1 or HB fuel debris. For other BWR plants, up to 16 damaged fuel containers containing BWR damaged fuel and/or fuel debris with the complement intact fuel assemblies, up to a total of 68. The number of damaged fuel containers containing BWR fuel debris is limited to eight (8) for all BWR plants.*

Table 1.2.2

KEY PARAMETERS FOR HI-STORM 100 MULTI-PURPOSE CANISTERS

	PWR	BWR
Pre-disposal service life (years)	40	40
Design temperature, max./min. (°F)	725°†/-40°††	725°†/-40°††
Design internal pressure (psig) Normal conditions Off-normal conditions Accident Conditions	 100 100 ~~125~~ *200*	 100 100 ~~125~~ *200*
Total heat load, max. (kW)	~~20.88~~ *27.77* (MPC-24) *28.17 (MPC-24E & MPC-24EF)* *28.74 (MPC-32)*	~~21.4~~ *28.19* (MPC-68, *MPC-68F, & MPC-68FF*)
Maximum permissible peak fuel cladding temperature: Normal (°F) Short Term & Accident (°F)	 See Table 2.2.3 1058°	 See Table 2.2.3 1058°
MPC internal environment Helium fill ~~(g-moles/l of free space)~~	~~0.1212~~ *29.3 – 33.3 psig* *OR* 0.1212 gm-moles/l *of free space*	~~0.1218.~~ *29.3 – 33.3psig* *OR* 0.1218 gm-moles/l *of free space*
Maximum permissible multiplication factor (k_{eff}) including all uncertainties and biases	< 0.95	< 0.95
Boral ^{10}B Areal Density (g/cm^2)	0.0267 (MPC-24, *MPC-24E & MPC-24EF*) *0.0372 (MPC-32)*	0.0372 (MPC-68 *& MPC-68FF*) 0.01 (MPC-68F)
End closure(s)	Welded	Welded
Fuel handling	Opening compatible with standard grapples	Opening compatible with standard grapples
Heat dissipation	Passive	Passive

† Maximum normal condition design temperatures for the MPC fuel basket. A complete listing of design temperatures for all components is provided in Table 2.2.3.

†† Temperature based on off-normal minimum environmental temperatures specified in Section 2.2.2.2 and no fuel decay heat load.

Table 1.2.3

BORAL EXPERIENCE LIST
DOMESTIC PRESSURIZED WATER REACTORS

Plant	Utility
Donald C. Cook	American Electric Power
Indian Point 3	New York Power Authority
Maine Yankee	Maine Yankee Atomic Power
Salem 1,2	Public Service Electric and Gas
Sequoyah 1,2	Tennessee Valley Authority
Yankee Rowe	Yankee Atomic Power
Zion 1,2	Commonwealth Edison Company
Byron 1,2	Commonwealth Edison Company
Braidwood 1,2	Commonwealth Edison Company
Three Mile Island I	GPU Nuclear
Sequoyah (rerack)	Tennessee Valley Authority
D.C. Cook (rerack)	American Electric Power
Maine Yankee	Maine Yankee Atomic Power Company
Connecticut Yankee	Northeast Utilities Service Company
Salem Units 1 & 2 (rerack)	Public Service Electric & Gas Company

Table 1.2.4

BORAL EXPERIENCE LIST
DOMESTIC BOILING WATER REACTORS

Browns Ferry 1,2,3	Tennessee Valley Authority
Brunswick 1,2	Carolina Power & Light
Clinton	Illinois Power
Dresden 2,3	Commonwealth Edison Company
Duane Arnold Energy Center	Iowa Electric Light and Power
J.A. FitzPatrick	New York Power Authority
E.I. Hatch 1,2	Georgia Power Company
Hope Creek	Public Service Electric and Gas
Humboldt Bay	Pacific Gas and Electric Company
LaCrosse	Dairyland Power
Limerick 1,2	Philadelphia Electric Company
Monticello	Northern States Power
Peachbottom 2,3	Philadelphia Electric Company
Perry 1,2	Cleveland Electric Illuminating
Pilgrim	Boston Edison Company
Susquehanna 1,2	Pennsylvania Power & Light
Vermont Yankee	Vermont Yankee Atomic Power
Hope Creek	Public Service Electric and Gas Company
Shearon Harris Pool B	Carolina Power & Light Company
Duane Arnold	Iowa Electric Light and Power
Pilgrim	Boston Edison Company
LaSalle Unit 1	Commonwealth Edison Company
Millstone Point Unit One	Northeast Utilities Service Company

Table 1.2.5

BORAL EXPERIENCE LIST
FOREIGN PLANTS

INTERNATIONAL INSTALLATIONS USING BORAL	
COUNTRY	PLANT(S)
France	12 PWR Plants
South Africa	Koeberg 1,2
Switzerland	Beznau 1,2 Gosgen
Taiwan	Chin-Shan 1,2 Kuosheng 1,2
Mexico	Laguna Verde Units 1,2
Korea	Ulchin Units 1, 2
Brazil	Angra 1
United Kingdom	Sizewell B

Table 1.2.6

HI-STORM 100 OPERATIONS SEQUENCE

Site-specific handling and operations procedures will be prepared, reviewed, and approved by each owner/user.	
1	HI-TRAC and MPC lowered into the fuel pool without lids
2	Fuel assemblies transferred into the MPC fuel basket
3	MPC lid lowered onto the MPC
4	HI-TRAC/MPC assembly moved to the decon pit and MPC lid welded in place, volumetrically or multi-layer PT examined, hydrostatically tested, and leak tested
5	MPC dewatered, ~~vacuum dried~~*moisture removed*, backfilled with helium, and the closure ring welded
6	HI-TRAC annulus drained and external surfaces decontaminated
7	MPC lifting cleats installed and MPC weight supported by rigging
8	HI-TRAC pool lid removed and transfer lid attached
9	MPC lowered and seated on HI-TRAC transfer lid
10	HI-TRAC/MPC assembly transferred to atop HI-STORM overpack
11	MPC weight supported by rigging and transfer lid doors opened
12	MPC lowered into HI-STORM overpack, ~~*HI-TRAC transfer lid doors closed,*~~ and HI-TRAC removed from atop HI-STORM overpack
13	HI-STORM overpack lid installed and bolted in place
14	HI-STORM overpack placed in storage at the ISFSI pad
15	*For HI-STORM 100A (or 100SA) users, the overpack is anchored to the ISFSI pad by installation of nuts onto studs and torquing to the minimum required torque.*

Table 1.2.7

REPRESENTATIVE ASME BOLTING AND THREADED ROD MATERIALS ACCEPTABLE FOR THE HI-STORM 100A ANCHORAGE SYSTEM

ASME MATERIALS FOR BOLTING

Composition	I.D.	Type Grade or UNC No.	Ultimate Strength (ksi)	Yield Strength (ksi)	Code Permitted Size Range†
C	SA-354	BC K04100	125	109	$t \leq 2.5"$
¾ Cr	SA-574	51B37M	170	135	$t \geq 5/8"$
1 Cr – 1/5 Mo	SA-574	4142	170	135	$t \geq 5/8"$
1 Cr-1/2 Mo-V	SA-540	B21 (K 14073)	165	150	$t \leq 4"$
5 Cr – ½ Mo	SA-193	B7	125	105	$t \leq 2.5"$
$2N_i$ – ¾ Cr – ¼ Mo	SA-540	B23 (H-43400)	135	120	
$2N_i$ – ¾ Cr – 1/3 Mo	SA-540	B-24 (K-24064)	135	120	
17Cr-4Ni-4Cu	SA-564	630(H-1100)	140	115	
17Cr-4Ni-4Cu	SA-564	630(H-1075)	145	125	
25Ni-15Cr-2Ti	SA-638	660	130	85	
22CR-13Ni-5Mn	SA-479	XM-19(S20910)	135	105	

Note: The materials listed in this table are representative of acceptable materials and have been abstracted from the ASME Code, Section II, Part D, Table 3. Other materials listed in the Code are also acceptable as long as they meet the size requirements, the minimum requirements on yield and ultimate strength (see Table 2.0.4), and are suitable for the environment. The family of acceptable materials is denoted as "Alloy Z."

† *Nominal diameter of the bolt (or rod) as listed in the Code tables. Two-inch diameter studs/rods are specified for the HI-STORM 100A.*

Appendix 2.B The Forced Helium Dehydration (FHD) System

2.B.1 System Overview

The Forced Helium Dehydration (FHD) system is used to remove the remaining moisture in the MPC cavity after all of the water that can practically be removed through the drain line using a hydraulic pump has been expelled in the water blowdown operation. The FHD system is required to be used for MPCs containing at least one high burnup fuel assembly and is optional for MPCs containing all moderate burnup fuel assemblies.

Expelling the water from the MPC using a conventional pump would remove practically all of the contained water except for the small quantity remaining on the MPC baseplate below the bottom of the drain line and an even smaller adherent amount wetting the internal surfaces. A skid-mounted, closed loop dehydration system will be used to remove the residual water from the MPC such that the partial pressure of the trace quantity of water vapor in the MPC cavity gas is brought down to ≤ 3 torr. The FHD system, engineered for this purpose, shall utilize helium gas as the working substance.

The FHD system, schematically illustrated in Figure 2.B.1, can be viewed as an assemblage of four thermal modules, namely, (i) the condensing module, (ii) the demoisturizer module, (iii) the helium circulator module and (iv) the pre-heater module. The condensing module serves to cool the helium/vapor mixture exiting the MPC to a temperature well below its dew point such that water may be extracted from the helium stream. The condensing module is equipped with suitable instrumentation to provide a direct assessment of the extent of condensation that takes place in the module during the operation of the FHD system. The demoisturizer module, engineered to receive partially cooled helium exiting the condensing module, progressively chills the recirculating helium gas to a temperature that is well below the temperature corresponding to the partial pressure of water vapor at 3 torr.

The motive energy to circulate helium is provided by the helium circulator module, which is sized to provide the pressure rise necessary to circulate helium at the requisite rate. The last item, labeled the pre-heater module, serves to pre-heat the flowing helium to the desired temperature such that it is sufficiently warm to boil off any water present in the MPC cavity.

The pre-heater module, in essence, serves to add supplemental heat energy to the helium gas (in addition to the heat generated by the stored SNF in the MPC) so as to facilitate rapid conversion of water into vapor form. The heat input from the pre-heater module can be adjusted in the manner of a conventional electric heater so that the recirculating helium entering the MPC is sufficiently dry and hot to evaporate water, but not unduly hot to place unnecessary thermal burden on the condensing module.

The FHD system described in the foregoing performs its intended function by continuously removing water entrained in the MPC through successive cooling, moisture removal and reheating of the working substance in a closed loop. In a classical system of the FHD genre, the moisture removal operation occurs in two discrete phases. In the beginning of the FHD system's operation (Phase 1), the helium exiting the MPC is laden with water vapor produced by boiling of the entrained bulk water. The condensing module serves as the principal device to condense out the water vapor from the helium stream in Phase 1. Phase 1 ends when all of the bulk water in the MPC cavity is vaporized. At this point, the operation of the FHD system moves on to steadily lowering the relative humidity and bulk temperature of the circulating helium gas (Phase 2). The demoisturizer module, equipped with the facility to chill flowing helium, plays the principal role in the dehydration process in Phase 2.

2.B.2 Design Criteria

The design criteria set forth below are intended to ensure that design and operation of the FHD system will drive the partial pressure of the residual vapor in the MPC cavity to ≤ 3 torr if the temperature of helium exiting the demoisturizer has met the value and duration criteria provided in the HI-STORM technical specifications. The FHD system shall be designed to ensure that during normal operation (i.e., excluding startup and shutdown ramps) the following criteria are met:

i. The temperature of helium gas in the MPC shall be at least 15ºF higher than the saturation temperature at coincident pressure.

ii. The pressure in the MPC cavity space shall be less than or equal to 60.3 psig (75 psia).

iii. The fuel cladding temperature shall be less than or equal to 650°F..

iv. The recirculation rate of helium shall be sufficiently high (minimum hourly throughput equal to ten times the nominal helium mass backfilled into the MPC for fuel storage operations) so as to produce a turbulated flow regime in the MPC cavity.

v. The partial pressure of the water vapor in the MPC cavity will not exceed 3 torr if the helium temperature at the demoisturer outlet is ≤ 21ºF for a period of 30 minutes.

In addition to the above system design criteria, the individual modules shall be designed in accordance with the following critereia:

i. The condensing module shall be designed to de-vaporize the recirculating helium gas to a dew point of 120ºF or less.

ii. The demoisturizer module shall be configured to be introduced into its helium conditioning function *after* the condensing module has been operated for the required length of time to assure that the bulk moisture vaporization in the MPC (defined as Phase 1 in Section 2.B.1) has been completed.

iii. The helium circulator shall be sized to effect the minimum flow rate of circulation required by the system design criteria described above.

iv. The pre-heater module shall be engineered to ensure that the temperature of the helium gas in the MPC meets the system design criteria described above.

2.B.3 Analysis Requirements

The design of the FHD system shall be subject to the confirmatory analyses listed below to ensure that the system will accomplish the performance objectives set forth in this FSAR.

i. System thermal analysis in Phase 1: Characterize the rate of condensation in the condensing module and helium temperature variation under Phase 1 operation (i.e., the scenario where there is some unevaporated water in the MPC) using a classical thermal-hydraulic model wherein the incoming helium is assumed to fully mix with the moist helium inside the MPC.

ii. System thermal analysis in Phase 2: Characterize the thermal performance of the closed loop system in Phase 2 (no unvaporized moisture in the MPC) to predict the rate of condensation and temperature of the helium gas exiting the condensing and the demoisturizer modules. Establish that the system design is capable to ensure that partial pressure of water vapor in the MPC will reach ≤ 3 torr if the temperature of the helium gas exiting the demoisturizer is predicted to be at a maximum of 21ºF for 30 minutes.

iii. Thermodynamic state of the MPC cavity: A steady-state thermal analysis of the MPC under the forced helium flow scenario shall be performed to ensure that the peak temperature of the fuel cladding under the most adverse condition of FHD system operation (design basis heat emission rate from the stored SNF, a complete absence of moisture in the MPC cavity and maximum helium inlet temperature predicted by the system thermal analysis in (i) above) is below the peak cladding temperature limit for normal conditions of storage specified in the FSAR.

2.B.4 Acceptance Testing

The first FHD system designed and built for the MPC drying function required by HI-STORM's technical specifications shall be subject to confirmatory testing as follows:

a. A representative quantity of water shall be placed in a manufactured MPC (or equivalent mock-up) and the closure lid and RVOAs installed and secured to create a hermetically sealed container.

b. The MPC cavity drying test shall be conducted for the worst case scenario (no heat generation within the MPC available to vaporize water).

c. The drain and vent line RVOAs on the MPC lid shall be connected to the terminals located in the pre-heater and condensing modules of the FHD system, respectively.

d. The FHD system shall be operated through the moisture vaporization (Phase 1) and subsequent dehydration (Phase 2). The FHD system operation will be stopped after the temperature of helium exiting the demoisturizer module has been at or below 21ºF for thirty minutes (nominal). Thereafter, a sample of the helium gas from the MPC will be extracted and tested to determine the partial pressure of the residual water vapor in it. The FHD system will be deemed to have passed the acceptance testing if the partial pressure in the extracted helium sample is less than or equal to 3 torr.

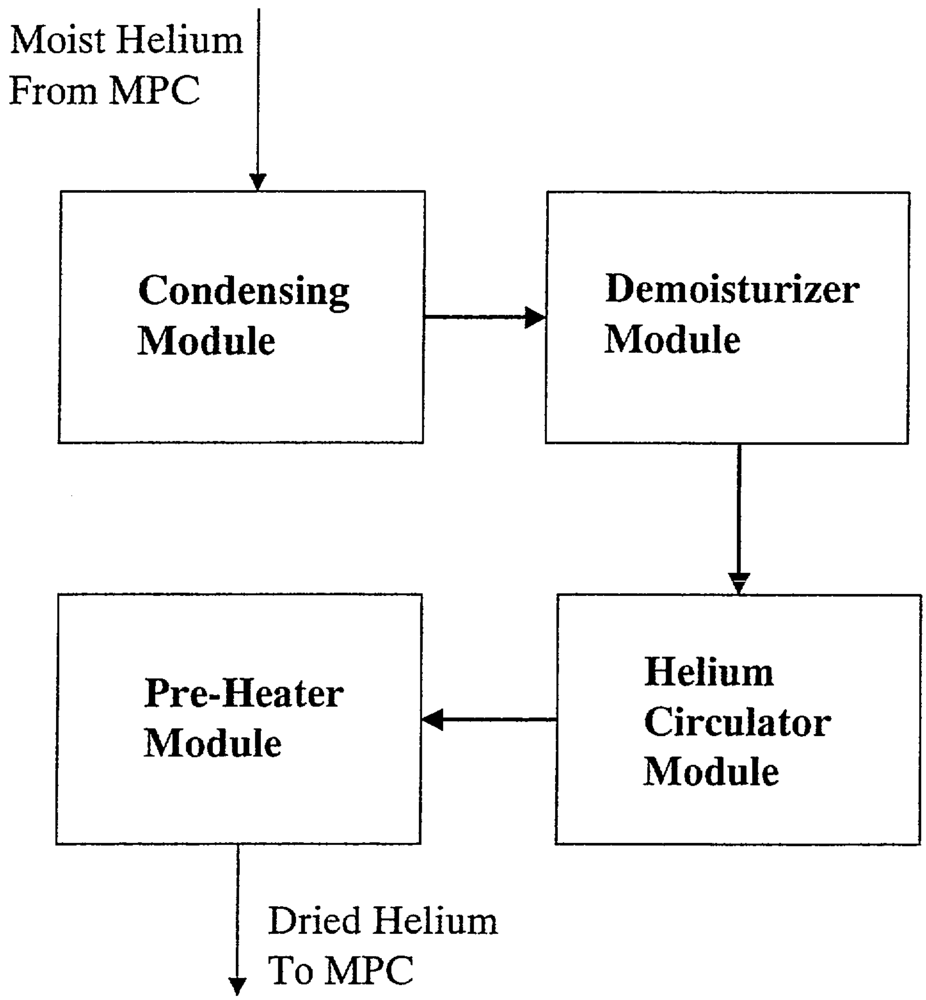

FIGURE 2.B.1: SCHEMATIC OF THE FORCED HELIUM DEHYDRATION SYSTEM

4.5 THERMAL EVALUATION FOR NORMAL HANDLING AND ONSITE TRANSPORT

Prior to placement in a HI-STORM overpack, an MPC must be loaded with fuel, outfitted with closures, dewatered, vacuum dried, backfilled with helium and transported to the HI-STORM module. In the unlikely event that the fuel needs to be returned to the spent fuel pool, these steps must be performed in reverse. Finally, if required, transfer of a loaded MPC between HI-STORM overpacks or between a HI-STAR transport overpack and a HI-STORM storage overpack must be carried out in an assuredly safe manner. All of the above operations are short duration events that would likely occur no more than once or twice for an individual MPC.

The device central to all of the above operations is the HI-TRAC transfer cask that, as stated in Chapter 1, is available in two anatomically identical weight ratings (100- and 125-ton). The HI-TRAC transfer cask is a short-term host for the MPC; therefore it is necessary to establish that, during all thermally challenging operation events involving either the 100-ton or 125-ton HI-TRAC, the permissible temperature limits presented in Section 4.3 are not exceeded. The following discrete thermal scenarios, all of short duration, involving the HI-TRAC transfer cask have been identified as warranting thermal analysis.

i. Normal Onsite Transport
ii. MPC Cavity Vacuum Drying
iii. Post-Loading Wet Transfer Operations
iv. MPC Cooldown and Reflood for Unloading Operations

The above listed conditions are described and evaluated in the following subsections. Subsection 4.5.1 describes the individual analytical models used to evaluate these conditions. Due to the simplicity of the conservative evaluation of wet transfer operations, Subsection 4.5.1.1.5 includes both the analysis model and analysis results discussions. The maximum temperature analyses for onsite transport and vacuum drying are discussed in Subsection 4.5.2. Subsections 4.5.3, 4.5.4 and 4.5.5, respectively, discuss minimum temperature, MPC maximum internal pressure and thermal data for stress analyses during onsite transport.

4.5.1 Thermal Model

The HI-TRAC transfer cask is used to load and unload the HI-STORM concrete storage overpack, including onsite transport of the MPCs from the loading facility to an ISFSI pad. Section views of the HI-TRAC have been presented in Chapter 1. Within a loaded HI-TRAC, heat generated in the MPC is transported from the contained fuel assemblies to the MPC shell in the manner described in Section 4.4. From the outer surface of the MPC to the ambient air, heat is transported by a combination of conduction, thermal radiation and natural convection. It has been demonstrated in Section 4.3 that from a thermal standpoint, storage of stainless steel clad fuel assemblies is bounded by storage of zircaloy clad fuel assemblies. Thus, only zircaloy clad fuel assemblies shall be considered in the HI-TRAC thermal performance evaluations. Analytical modeling details of all the various thermal transport mechanisms are provided in the following subsection.

Two HI-TRAC transfer cask designs, namely, the 125-ton and the 100-ton versions, are developed for onsite handling and transport, as discussed in Chapter 1. The two designs are principally different in terms of lead thickness and the thickness of radial connectors in the water jacket region. The analytical model developed for HI-TRAC thermal characterization conservatively accounts for these differences by applying the higher shell thickness and thinner radial connectors' thickness to the model. In this manner, the HI-TRAC overpack resistance to heat transfer is overestimated, resulting in higher predicted MPC internals and fuel cladding temperature levels.

4.5.1.1 Analytical Model

From the outer surface of the MPC to the ambient atmosphere, heat is transported within HI-TRAC through multiple concentric layers of air, steel and shielding materials. Heat must be transported across a total of six concentric layers, representing the air gap, the HI-TRAC inner shell, the lead shielding, the HI-TRAC outer shell, the water jacket and the enclosure shell. From the surface of the enclosure shell heat is rejected to the atmosphere by natural convection and radiation.

A small diametral air gap exists between the outer surface of the MPC and the inner surface of the HI-TRAC overpack. Heat is transported across this gap by the parallel mechanisms of conduction and thermal radiation. Assuming that the MPC is centered and does not contact the transfer overpack walls conservatively minimizes heat transport across this gap. Additionally, thermal expansion that would minimize the gap is conservatively neglected. Heat is transported through the cylindrical wall of the HI-TRAC transfer overpack by conduction through successive layers of steel, lead and steel. A water jacket, which provides neutron shielding for the HI-TRAC overpack, surrounds the cylindrical steel wall. The water jacket is composed of carbon steel channels with welded, connecting enclosure plates. Conduction heat transfer occurs through both the water cavities and the channels. While the water jacket channels are sufficiently large for natural convection loops to form, this mechanism is conservatively neglected. Heat is passively rejected to the ambient from the outer surface of the HI-TRAC transfer overpack by natural convection and thermal radiation.

In the vertical position, the bottom face of the HI-TRAC is in contact with a supporting surface. This face is conservatively modeled as an insulated surface. Because the HI-TRAC is not used for long-term storage in an array, radiative blocking does not need to be considered. The HI-TRAC top lid is modeled as a surface with convection, radiative heat exchange with air and a constant maximum incident solar heat flux load. Insolation on cylindrical surfaces is conservatively based on 12-hour levels prescribed in 10CFR71 averaged on a 24-hour basis. Concise descriptions of these models are given below.

4.5.1.1.1 Effective Thermal Conductivity of Water Jacket

The 125-ton HI-TRAC water jacket is composed of fourteen formed channels equispaced along the circumference of the HI-TRAC and welded along their length to the HI-TRAC outer shell. Enclosure plates are welded to these channels, creating twenty-eight water compartments. The 100-ton HI-TRAC water jacket has 15 formed channels and enclosure plates creating thirty compartments. Holes in the channel legs connect all the individual compartments in the water jacket. Thus, the annular region between the HI-TRAC outer shell and the enclosure shell can be considered as an array of steel ribs and water spaces.

The effective radial thermal conductivity of this array of steel ribs and water spaces is determined by combining the heat transfer resistance of individual components in a parallel network. A bounding calculation is assured by using the minimum number of channels and channel thickness as input values. The thermal conductivity of the parallel steel ribs and water spaces is given by the following formula:

$$K_{ne} = \frac{K_r N_r t_r \ln\left(\frac{r_o}{r_i}\right)}{2\pi L_R} + \frac{K_w N_r t_w \ln\left(\frac{r_o}{r_i}\right)}{2\pi L_R}$$

where:

- K_{ne} = effective radial thermal conductivity of water jacket
- r_i = inner radius of water spaces
- r_o = outer radius of water spaces
- K_r = thermal conductivity of carbon steel ribs
- N_r = minimum number of channel legs (equal to number of water spaces)
- t_r = minimum (nominal) rib thickness (lower of 125-ton and 100-ton designs)
- L_R = effective radial heat transport length through water spaces
- K_w = thermal conductivity of water
- t_w = water space width (between two carbon steel ribs)

Figure 4.5.1 depicts the resistance network to combine the resistances to determine an effective conductivity of the water jacket. The effective thermal conductivity is computed in the manner of the foregoing, and is provided in Table 4.5.1.

4.5.1.1.2 Heat Rejection from Overpack Exterior Surfaces

The following relationship for the surface heat flux from the outer surface of an isolated cask to the environment applied to the thermal model:

$$q_s = 0.19(T_s - T_A)^{4/3} + 0.1714\varepsilon\left[\left(\frac{T_s+460}{100}\right)^4 - \left(\frac{T_A+460}{100}\right)^4\right]$$

where:

T_S = cask surface temperatures (°F)
T_A = ambient atmospheric temperature (°F)
q_s = surface heat flux ($Btu/ft^2 \times hr$)
ε = surface emissivity

The second term in this equation the Stefan-Boltzmann formula for thermal radiation from an exposed surface to ambient. The first term is the natural convection heat transfer correlation recommended by Jacob and Hawkins [4.2.9]. This correlation is appropriate for turbulent natural convection from vertical surfaces, such as the vertical overpack wall. Although the ambient air is conservatively assumed to be quiescent, the natural convection is nevertheless turbulent.

Turbulent natural convection correlations are suitable for use when the product of the Grashof and Prandtl (Gr×Pr) numbers exceeds 10^9. This product can be expressed as $L^3 \times \Delta T \times Z$, where L is the characteristic length, ΔT is the surface-to-ambient temperature difference, and Z is a function of the surface temperature. The characteristic length of a vertically oriented HI-TRAC is its height of approximately 17 feet. The value of Z, conservatively taken at a surface temperature of 340°F, is 2.6×10^5. Solving for the value of ΔT that satisfies the equivalence $L^3 \times \Delta T \times Z = 10^9$ yields ΔT = 0.78°F. For a horizontally oriented HI-TRAC the characteristic length is the diameter of approximately 7.6 feet (minimum of 100- and 125-ton designs), yielding ΔT = 8.76°F. The natural convection will be turbulent, therefore, provided the surface to air temperature difference is greater than or equal to 0.78°F for a vertical orientation and 8.76°F for a horizontal orientation.

4.5.1.1.3 Determination of Solar Heat Input

As discussed in Section 4.4.1.1.8, the intensity of solar radiation incident on an exposed surface depends on a number of time varying terms. A twelve-hour averaged insolation level is prescribed in 10CFR71 for curved surfaces. The HI-TRAC cask, however, possesses a considerable thermal inertia. This large thermal inertia precludes the HI-TRAC from reaching a steady-state thermal condition during a twelve-hour period. Thus, it is considered appropriate to use the 24-hour averaged insolation level.

4.5.1.1.4 MPC Temperatures During *Moisture Removal*~~Vacuum Drying~~ Operations

4.5.1.1.4.1 Vacuum Drying

The initial loading of SNF in the MPC requires that the water within the MPC be drained and replaced with helium. *For MPCs containing moderate burnup fuel assemblies only, this*~~This~~ operation ~~on the MPCs will~~*may* be carried out using the conventional vacuum drying approach. In this method, removal of the last traces of residual moisture from the MPC cavity is accomplished by evacuating the MPC for a short time after draining the MPC. *As stipulated in the Technical Specifications, vacuum drying may not be performed on MPCs containing high burnup fuel* *assemblies. High burnup fuel drying is performed by a forced flow helium drying process as described in Section 4.5.1.1.4.2 and Appendix 2.B.*

Prior to the start of the MPC draining operation, both the HI-TRAC annulus and the MPC are full of water. The presence of water in the MPC ensures that the fuel cladding temperatures are lower than design basis limits by large margins. As the heat generating active fuel length is uncovered during the draining operation, the fuel and basket mass will undergo a gradual heat up from the initially cold conditions when the heated surfaces were submerged under water.

The vacuum condition effective fuel assembly conductivity is determined by procedures discussed earlier (Subsection 4.4.1.1.2) after setting the thermal conductivity of the gaseous medium to a small fraction (one part in one thousand) of helium conductivity. The MPC basket cross sectional effective conductivity is determined for vacuum conditions according to the procedure discussed in 4.4.1.1.4. Basket periphery-to-MPC shell heat transfer occurs through conduction and radiation.

As described in Chapter 8 (Operating Procedures) vacuum drying of the MPC is performed with the annular gap between the MPC and the HI-TRAC ~~filled~~ *continuously flushed* with water. The ~~presence of~~ water *movement* in this annular gap will maintain the MPC shell temperature ~~approximately equal to the saturation temperature of the annulus water~~ *at about the temperature of flowing water.* Thus, the thermal analysis of the MPC during vacuum drying is performed with cooling of the MPC shell with water *at a bounding maximum temperature of 125°F.*

An axisymmetric FLUENT thermal model of the MPC is constructed, *employing the MPC in-plane conductivity as an isotropic fuel basket conductivity (i.e. conductivity in the the basket radial and axial directions is equal),* to determine peak cladding temperature at design basis heat loads. *To avoid excessive conservatism in the computed FLUENT solution, partial recognition for higher axial heat dissipation is adopted in the peak cladding calculations.* The boundary conditions applied to this evaluation are:

i. A bounding steady-state analysis is performed with the MPC decay heat load set equal to the largest design-basis decay heat load.

ii. The entire outer surface of the MPC shell is postulated to be at a bounding maximum temperature of *125*~~232~~°F~~, equal to the saturation temperature of water at the bottom of the annular gap. This elevated temperature is the result of the hydrostatic pressure of the water column.~~

iii. The top and bottom surfaces of the MPC are adiabatic.

Results of vacuum condition analyses are provided in Subsection 4.5.2.2.

4.5.1.1.4.2 Forced Helium Recirculation

To reduce moisture to trace levelsin the MPC using a Forced Helium Dehydration (FHD) system, a conventional, closed loop dehumidification system consisting of a condenser, a demoisturizer, a compressor, and a pre-heater is utilized to extract moisture from the MPC cavity through repeated displacement of its contained helium, accompanied by vigorous flow turbulation. A vapor pressure of 3 torr or less is assured by verifying that the helium temperature exiting the demoisturizer is maintained at or below the psychrometric threshold of 21°F for a minimum of 30 minutes. See Appendix 2.B for detailed discussionof the design criteria and operation of the FHD system.

The FHD system provides concurrent fuel cooling during the moisture removal process through forced convective heat transfer. The attendant forced convection-aided heat transfer occurring during operation of the FHD system ensures that the fuel cladding temperature will remain below the applicable peak cladding temperature limit for normal conditions of storage, which is well below the high burnup cladding temperature limit 752°F (400°C) for all combinations of SNF type, burnup, decay heat, and cooling time. Because the FHD operation induces a state of forced convection heat transfer in the MPC, (in contrast to the quiescent mode of natural convection in long term storage), it is readily concluded that the peak fuel cladding temperature under the latter condition will be greater than that during the FHD operation phase. In the event that the FHD system malfunctions, the forced convection state will degenerate to natural convection, which corresponds to the conditions of normal storage. As a result, the peak fuel cladding temperatures will approximate the values reached during normal storage as described elsewhere in this chapter.

4.5.1.1.5 <u>Maximum Time Limit During Wet Transfer Operations</u>

In accordance with NUREG-1536, water inside the MPC cavity during wet transfer operations is not permitted to boil. Consequently, uncontrolled pressures in the de-watering, purging, and recharging system that may result from two-phase conditions are completely avoided. This requirement is accomplished by imposing a limit on the maximum allowable time duration for fuel to be submerged in water after a loaded HI-TRAC cask is removed from the pool and prior to the start of vacuum drying operations.

When the HI-TRAC transfer cask and the loaded MPC under water-flooded conditions are removed from the pool, the combined water, fuel mass, MPC, and HI-TRAC metal will absorb the decay heat emitted by the fuel assemblies. This results in a slow temperature rise of the entire system with time, starting from an initial temperature of the contents. The rate of temperature rise is limited by the thermal inertia of the HI-TRAC system. To enable a bounding heat-up rate determination for the HI-TRAC system, the following conservative assumptions are imposed:

i. Heat loss by natural convection and radiation from the exposed HI-TRAC surfaces to the pool building ambient air is neglected (i.e., an adiabatic temperature rise calculation is performed).

ii. Design-basis maximum decay heat input from the loaded fuel assemblies is imposed on the HI-TRAC transfer cask.

iii. The smaller of the two (i.e., 100-ton and 125-ton) HI-TRAC transfer cask designs is credited in the analysis. The 100-ton design has a significantly smaller quantity of metal mass, which will result in a higher rate of temperature rise.

iv. The smallest of the *minimum* MPC cavity-free volumes among the two MPC types is considered for flooded water mass determination.

v. Only fifty percent of the water mass in the MPC cavity is credited towards water thermal inertia evaluation.

Table 4.5.5 summarizes the weights and thermal inertias of several components in the loaded HI-TRAC transfer cask. The rate of temperature rise of the HI-TRAC transfer cask and contents during an adiabatic heat-up is governed by the following equation:

$$\frac{dT}{dt} = \frac{Q}{C_h}$$

where:

Q = decay heat load (Btu/hr) [Design Basis maximum *28.74* ~~22.25~~ kW = *98,205* ~~75,940~~ Btu/hr]

C_h = combined thermal inertia of the loaded HI-TRAC transfer cask (Btu/°F)

T = temperature of the contents (°F)

t = time after HI-TRAC transfer cask is removed from the pool (hr)

A bounding heat-up rate for the HI-TRAC transfer cask contents is determined to be equal to 3.77 ~~2.76~~°F/hr. From this adiabatic rate of temperature rise estimate, the maximum allowable time duration (t_{max}) for fuel to be submerged in water is determined as follows:

$$t_{max} = \frac{T_{boil} - T_{initial}}{(dT/dt)}$$

where:

T_{boil} = boiling temperature of water (equal to 212°F at the water surface in the MPC cavity)

$T_{initial}$ = initial temperature of the HI-TRAC contents when the transfer cask is removed from the pool

Table 4.5.6 provides a summary of t_{max} at several representative HI-TRAC contents starting temperature.

As set forth in the HI-STORM operating procedures, in the unlikely event that the maximum allowable time provided in Table 4.5.6 is found to be insufficient to complete all wet transfer operations, a forced water circulation shall be initiated and maintained to remove the decay heat from the MPC cavity. In this case, relatively cooler water will enter via the MPC lid drain port connection and heated water will exit from the vent port. The minimum water flow rate required to maintain the MPC cavity water temperature below boiling with an adequate subcooling margin is determined as follows:

$$M_W = \frac{Q}{C_{pW}\,(T_{max} - T_{in})}$$

where:

M_W = minimum water flow rate (lb/hr)
C_{pw} = water heat capacity (Btu/lb-°F)
T_{max} = maximum MPC cavity water mass temperature
T_{in} = temperature of pool water supply to MPC

With the MPC cavity water temperature limited to 150°F, MPC inlet water maximum temperature equal to 125°F and at the design basis maximum heat load, the water flow rate is determined to be *3928* ~~3044~~ lb/hr (*7.9* ~~6.1~~ gpm).

4.5.1.1.6 Cask Cooldown and Reflood Analysis During Fuel Unloading Operation

NUREG-1536 requires an evaluation of cask cooldown and reflood procedures to support fuel unloading from a dry condition. Past industry experience generally supports cooldown of cask internals and fuel from hot storage conditions by direct water quenching. The extremely rapid cooldown rates to which the hot MPC internals and the fuel cladding are subjected during water injection may, however, result in uncontrolled thermal stresses and failure in the structural members. Moreover, water injection results in large amounts of steam generation and unpredictable transient two-phase flow conditions inside the MPC cavity, which may result in overpressurization of the confinement boundary. To avoid potential safety concerns related to rapid cask cooldown by direct water quenching, the HI-STORM MPCs will be cooled in a gradual manner, thereby eliminating thermal shock loads on the MPC internals and fuel cladding.

In the unlikely event that a HI-STORM storage system is required to be unloaded, the MPC will be transported on-site via the HI-TRAC transfer cask back to the fuel handling building. Prior to reflooding the MPC cavity with water†, a forced flow helium recirculation system with adequate flow capacity shall be operated to remove the decay heat and initiate a slow cask cooldown lasting for several days. The operating procedures in Chapter 8 (Section 8.3) provide a detailed description of the steps involved in the cask unloading. An analytical method that provides a basis for determining

† *Prior to helium circulation, the HI-TRAC annulus is flooded with water to substantially lower the MPC shell temperature (approximately 100°F). For low decay heat MPCs (~10 kW or less) the annulus cooling is adequate to lower the MPC cavity temperature below the boiling temperature of water.*

the required helium flow rate as a function of the desired cooldown time is presented below, to meet the objective of eliminating thermal shock when the MPC cavity is eventually flooded with water.

Under a closed-loop forced helium circulation condition, the helium gas is cooled, via an external chiller, down to 100°F. The chilled helium is then introduced into the MPC cavity, near the MPC baseplate, through the drain line. The helium gas enters the MPC basket from the bottom oversized flow holes and moves upward through the hot fuel assemblies, removing heat and cooling the MPC internals. The heated helium gas exits from the top of the basket and collects in the top plenum, from where it is expelled through the MPC lid vent connection to the helium recirculation and cooling system. The MPC contents bulk average temperature reduction as a function of time is principally dependent upon the rate of helium circulation. The temperature transient is governed by the following heat balance equation:

$$C_h \frac{dT}{dt} = Q_D - m\,C_p\,(T - T_i) - Q_c$$

Initial Condition: $T = T_o$ at $t = 0$

where:

- $T =$ MPC bulk average temperature (°F)
- $T_o =$ initial MPC bulk average temperature in the HI-TRAC transfer cask (equal to *586°F* ~~541.8°F~~)
- $t =$ time after start of forced circulation *(hrs)* ~~°F)~~
- $Q_D =$ decay heat load (Btu/hr) (equal to Design Basis maximum *28.74kW* ~~22.25 kW~~ (i.e., *98,205 Btu/hr* ~~75,940 Btu/hr)~~)
- $m =$ helium circulation rate (lb/hr)
- $C_p =$ helium heat capacity (Btu/lb-°F) (equal to 1.24 Btu/lb-°F)
- $Q_c =$ heat rejection from cask exposed surfaces to ambient (Btu/hr) (conservatively neglected)
- $C_h =$ thermal capacity of the loaded MPC (Btu/°F) (For a bounding upper bound 100,000 lb loaded MPC weight and heat capacity of Alloy X equal to 0.12 Btu/lb-°F, the heat capacity is equal to 12,000 Btu/°F.)
- $T_i =$ MPC helium inlet temperature (°F)

The differential equation is analytically solved, yielding the following expression for time-dependent MPC bulk temperature:

$$T(t) = \left(T_i + \frac{Q_D}{m\,C_p}\right)\left(1 - e^{-\frac{m C_p}{C_h} t}\right) + T_o\, e^{-\frac{m C_p}{C_h} t}$$

This equation is used to determine the minimum helium mass flow rate that would cool the MPC cavity down from initially hot conditions to less than 200°F *(i.e., with a subcooling margin for* *normal boiling temperature of water*[†] *(212 °F)).* For example, to cool the MPC to less than 200°F in 72 hours using 0°F helium would require a helium mass flow rate of *432 lb/hr* ~~354 lb/hr~~ (i.e., *647 SCFM* ~~530 SCFM~~).

Once the helium gas circulation has cooled the MPC internals to less than 200°F, water can be injected to the MPC without risk of boiling and the associated thermal stress concerns. Because of the relatively long cooldown period, the thermal stress contribution to the total cladding stress would be negligible, and the total stress would therefore be bounded by the normal (dry) condition. The elimination of boiling eliminates any concern of overpressurization due to steam production.

4.5.1.1.7 Study of Lead-to-Steel Gaps on Predicted Temperatures

Lead, poured between the inner and outer shells, is utilized as a gamma shield material in the HI-TRAC on-site transfer cask designs. Lead shrinks during solidification requiring the specification and implementation of appropriate steps in the lead installation process so that the annular space is free of gaps. Fortunately, the lead pouring process is a mature technology and proven methods to insure that radial gaps do not develop are widely available. This subsection outlines such a method to achieve a zero-gap lead installation in the annular cavity of the HI-TRAC casks.

The 100-ton and 125-ton HI-TRAC designs incorporate 2.5 inch and 4.5 inch annular spaces, respectively, formed between a 3/4-inch thick steel inner shell and a 1-inch thick steel outer shell. The interior steel surfaces are cleaned, sandblasted and fluxed in preparation for the molten lead that will be poured in the annular cavity. The appropriate surface preparation technique is essential to ensure that molten lead sticks to the steel surfaces, which will form a metal to lead bond upon solidification. The molten lead is poured to fill the annular cavity. The molten lead in the immediate vicinity of the steel surfaces, upon cooling by the inner and outer shells, solidifies forming a melt-solid interface. The initial formation of a gap-free interfacial bond between the solidified lead and steel surfaces initiates a process of lead crystallization from the molten pool onto the solid surfaces. Static pressure from the column of molten lead further aids in retaining the solidified lead layer to the steel surfaces. The melt-solid interface growth occurs by freezing of successive layers of molten lead as the heat of fusion is dissipated by the solidified metal and steel structure enclosing it. This growth stops when all the molten lead is used up and the annulus is filled with a solid lead plug. The shop fabrication procedures, being developed in conjunction with the designated manufacturer of the HI-TRAC transfer casks, shall contain detailed step-by-step instructions devised to eliminate the incidence of annular gaps in the lead space of the HI-TRAC.

In the spirit of a defense-in-depth approach, however, a conservatively bounding lead-to-steel gap is assumed herein and the resultant peak cladding temperature under design basis heat load is computed. It is noted that in a non-bonding lead pour scenario, the lead shrinkage resulting from phase transformation related density changes introduces a tendency to form small gaps. This tendency is counteracted by gravity induced slump, which tends to push the heavy mass of lead

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† *Certain fuel configurations in PWR MPCs are required to be flooded with borated water, which has a higher boiling temperature. Thus, greater subcooling margins are present in this case.*

against the steel surfaces. If the annular molten mass of lead is assumed to contract as a solid, in the absence of gravity, then a bounding lead-to-steel gap is readily computed from density changes. This calculation is performed for the 125-ton HI-TRAC transfer cask, which has a larger volume of lead and is thus subject to larger volume shrinkage relative to the 100-ton design, and is presented below.

The densities of molten (ρ_l) and solid (ρ_s) lead are given on page 3-96 of Perry's Handbook (6th Edition) as 10,430 kg/m^3 and 11,010 kg/m^3, respectively. The fractional volume contraction during solidification (δv/v) is calculated as:

$$\frac{\delta v}{v} = \frac{(\rho_s - \rho_l)}{\rho_l} = \frac{(11{,}010 - 10{,}430)}{10{,}430} = 0.0556$$

and the corresponding fractional linear contraction during solidification is calculated as:

$$\frac{\delta L}{L} = \left[1 + \frac{\delta v}{v}\right]^{1/3} - 1 = 1.0556^{1/3} - 1 = 0.0182$$

The bounding lead-to-steel gap, which is assumed filled with air, is calculated by multiplying the nominal annulus radial dimension (4.5 inches in the 125-ton HI-TRAC) by the fractional linear contraction as:

$$\delta = 4.5 \times \frac{\delta L}{L} = 4.5 \times 0.0182 = 0.082 \cdot inches$$

In this hypothetical lead shrinkage process, the annular lead cylinder will contract towards the inner steel shell, eliminating gaps and tightly compressing the two surfaces together. Near the outer steel cylinder, a steel-to-lead air gap will develop as a result of volume reduction in the liquid to solid phase transformation. The air gap is conservatively postulated to occur between the inner steel shell and the lead, where the heat *flux* is higher relative to the outer steel shell, and hence the *computed* temperature gradient is greater. The combined resistance of an annular lead cylinder with an air gap (R_{cyl}) is computed by the following formula:

$$R_{cyl} = \frac{\ln(R_o / R_i)}{2\pi K_{pb}} + \frac{\delta}{2\pi R_i [K_{air} + K_r]}$$

where:

- R_i = inner radius (equal to 35.125 inches)
- R_o = outer radius (equal to 39.625 inches)
- K_{pb} = bounding minimum lead conductivity (equal to 16.9 Btu/ft-hr-°F, from Table 4.2.2)
- δ = lead-to-steel air gap, computed above
- K_{air} = temperature dependent air conductivity (see Table 4.2.2)
- K_r = effective thermal conductivity contribution from radiation heat transfer across air gap

The effective thermal conductivity contribution from radiation heat transfer (K_r) is defined by the following equation:

$$K_r = 4 \times \sigma \times F_\varepsilon \times T^3 \times \delta$$

where:

- σ = Stefan-Boltzmann constant
- F_ε = $(1/\varepsilon_{cs} + 1/\varepsilon_{pb} - 1)^{-1}$
- ε_{cs} = carbon steel emissivity (equal to 0.66, HI-STORM FSAR Table 4.2.4)
- ε_{pb} = lead emissivity (equal to 0.63 for oxidized surfaces at 300°F from McAdams, Heat Transmission, 3rd Ed.)
- T = absolute temperature

Based on the total annular region resistance (R_{cyl}) computed above, an equivalent annulus conductivity is readily computed. This effective temperature-dependent conductivity results are tabulated below:

Temperature (°F)	**Effective Annulus Conductivity (Btu/ft-hr-°F)**
200	1.142
450	1.809

The results tabulated above confirm that the assumption of a bounding annular air gap grossly penalizes the heat dissipation characteristics of lead filled regions. Indeed, the effective conductivity computed above is an order of magnitude lower than that of the base lead material. To confirm the heat dissipation adequacy of HI-TRAC casks under the assumed overly pessimistic annular gaps, the HI-TRAC thermal model described earlier is altered to include the effective annulus conductivity computed above for the annular lead region. The peak cladding temperature results are tabulated below:

Annular Gap Assumption	**Peak Cladding Temperature (°F)**	**Cladding Temperature Limit (°F)**
None	*872* ~~902~~	1058
Bounding Maximum	*924* ~~947~~	1058

From these results, it is readily apparent that the stored fuel shall be maintained within safe temperature limits by a substantial margin of safety (in excess of 100°F).

4.5.1.2 Test Model

A detailed analytical model for thermal design of the HI-TRAC transfer cask was developed using the FLUENT CFD code, the industry standard ANSYS modeling package and conservative adiabatic calculations, as discussed in Subsection 4.5.1.1. Furthermore, the analyses incorporate many conservative assumptions in order to demonstrate compliance to the specified short-term limits with adequate margins. In view of these considerations, the HI-TRAC transfer cask thermal design complies with the thermal criteria established for short-term handling and onsite transport. Additional experimental verification of the thermal design is therefore not required.

4.5.2 Maximum Temperatures

4.5.2.1 Maximum Temperatures Under Onsite Transport Conditions

An axisymmetric FLUENT thermal model of an MPC inside a HI-TRAC transfer cask was developed to evaluate temperature distributions for onsite transport conditions. A bounding steady-state analysis of the HI-TRAC transfer cask has been performed using the *hottest MPC,* ~~least favorable MPC basket thermal conductivity (MPC-68)~~, the highest design-basis decay heat load (Table 2.1.6), and design-basis insolation levels. While the duration of onsite transport may be short enough to preclude the MPC and HI-TRAC from obtaining a steady-state, a steady-state analysis is conservative. Information listing all other thermal analyses pertaining to the HI-TRAC cask and associated subsection of the FSAR summarizing obtained results is provided in Table 4.5.8.

A converged temperature contour plot is provided in Figure 4.5.2. Maximum fuel clad temperatures are listed in Table 4.5.2, which also summarizes maximum calculated temperatures in different parts of the HI-TRAC transfer cask and MPC. As described in Subsection 4.4.2, the FLUENT calculated peak temperature in Table 4.5.2 is actually the peak pellet centerline temperature, which bounds the peak cladding temperature. We conservatively assume that the peak clad temperature is equal to the peak pellet centerline temperature.

The maximum computed temperatures listed in Table 4.5.2 are based on the HI-TRAC cask at Design Basis Maximum heat load, passively rejecting heat by natural convection and radiation to a hot ambient environment at 100°F in still air *in a vertical orientation. In this orientation, there is apt to be a less of metal-to-metal contact between the physically distinct entitities, viz., fuel, fuel basket, MPC shell and HI-TRAC cask. For this reason, the gaps resistance between these parts is higher than in a horizontally oriented HI-TRAC. To bound gaps resistance, the various parts are postulated to be in a centered configuration. MPC internal convection at a postulated low cavity pressure of 5 atm is included in the thermal model.* The peak cladding temperature computed under these adverse Ultimate Heat Sink (UHS) assumptions is *872°F* ~~902°~~*which* is substantially lower than the ~~short term~~*short-term* temperature limit of 1058°F. Consequently, cladding integrity assurance is provided by large safety margins (in excess of 100°F) during onsite transfer of an MPC emplaced in a HI-TRAC cask.

As a defense-in-depth measure, cladding integrity is demonstrated for a theoretical bounding scenario. For this scenario, all means of convective heat dissipation within the canister are neglected in addition to the bounding relative configuration for the fuel, basket, MPC shell and HI-TRAC overpack assumption stated earlier for the vertical orientation. This means that the fuel is centered in the basket cells, the basket is centered in the MPC shell and the MPC shell is centered in the HI-TRAC overpack to maximize gaps thermal resistance. The peak cladding temperature computed for this scenario (1025°F) is below the short-term limit of 1058°F.

As discussed in Sub-section 4.5.1.1.6, MPC fuel unloading operations are performed with the MPC inside the HI-TRAC cask. For this operation, a helium cooldown system is engaged to the MPC via lid access ports and a forced helium cooling of the fuel and MPC is initiated. With the HI-TRAC cask external surfaces dissipating heat to a UHS in a manner in which the ambient air access is not restricted by bounding surfaces or large objects in the immediate vicinity of the cask, the temperatures reported in Table 4.5.2 will remain bounding during fuel unloading operations. Under a scenario in which the cask is emplaced in a area with ambient air access restrictions (for example in a cask pit area), additional means shall be devised to limit the cladding temperature rise arising from such restrictions to less than 100°F. These means are discussed next.

The time duration allowed for the cask to be emplaced in a ambient air restricted area with the helium cooling system non-operational shall be limited to 22 hours. *Conservatively postulating that the rate of passive cooling is substantially degraded by 90% (i.e., 10% of* decay heat *is dissipated to ambient),* ~~Eliminating all credit for passive cooling mechanisms during this 24 hour time limit,~~ cladding integrity is demonstrated based on ~~adiabatic~~ cask heating considerations *from the undissipated heat.* At a bounding heat load of *28.74kW,* ~~22.25 kW,~~ the HI-TRAC cask system thermal inertia (*19,532 Btu/°F,* ~~20,000 Btu/°F~~, Table 4.5.5), limits the ~~adiabatic~~ temperature rise to *4.52°F/hr.* ~~less than 4°F/hr~~. Thus, the *computed* cladding temperature rise during this time period will be less than 100°F.

A forced supply of ambient air near the bottom of the cask pit to aid heat dissipation by the natural convection process is another adequate means to maintain the fuel cladding within safe operating limits. Conservatively assuming this column of moving air as the UHS (i.e. to which all heat dissipation occurs) with no credit for enhanced cooling as a result of forced convection heat transfer, a nominal air supply of 1000 SCFM (4850 lbs/hr) adequately meets the cooling requirement. At this flow rate, the temperature rise of the UHS resulting from cask decay heat input to the ~~air flow~~*airflow* will be less than 100°F. The cladding temperature elevation will consequently be bounded by this temperature rise.

4.5.2.2 Maximum MPC Basket Temperature Under Vacuum Conditions

As stated in Subsection 4.5.1.1.4, above, an axisymmetric FLUENT thermal model-of the MPC is *developed with an isotropic fuel basket thermal conductivity for the vacuum condition.*~~used to evaluate the vacuum drying condition temperature distributions~~. *Each MPC is analyzed at its respective design maximum heat load. The steady-state peak cladding results, with partial recognition for higher axial heat dissipation, are summarized in Table 4.5.9.* ~~Representative steady-state temperature contours under vacuum conditions are shown in Figure 4.5.3.~~ The peak fuel clad temperatures during short-term vacuum drying operations with design-basis maximum heat loads are calculated to be less than *1058°F* ~~950°F~~ for *all* ~~both~~ MPC baskets by a significant margin. ~~The 950°F temperature limit imposed during the vacuum drying condition is lower than the maximum fuel cladding temperature limits for short-term conditions (see Table 4.3.1) by a large margin~~.

4.5.3 Minimum Temperatures

In Table 2.2.2 and Chapter 12, the minimum ambient temperature condition required to be considered for the HI-TRAC design is specified as 0°F. If, conservatively, a zero decay heat load (with no solar input) is applied to the stored fuel assemblies then every component of the system at steady state would be at this outside minimum temperature. Provided an antifreeze is added to the water jacket (required by Technical Specification for ambient temperatures below 32°F), all HI-TRAC materials will satisfactorily perform their intended functions at this minimum postulated temperature condition. Fuel transfer operations are controlled by Technical Specifications in Chapter 12 to ensure that onsite transport operations are not performed at an ambient temperature less than 0°F.

4.5.4 Maximum Internal Pressure

After fuel loading and vacuum drying, but prior to installing the MPC closure ring, the MPC is initially filled with helium. During handling in the HI-TRAC transfer cask, the gas temperature within the MPC rises to its maximum operating temperature as determined based on the thermal analysis methodology described previously. The gas pressure inside the MPC will also increase with rising temperature. The pressure rise is determined based on the ideal gas law, which states that the absolute pressure of a fixed volume of gas is proportional to its absolute temperature. The net free volumes of the *four* ~~two~~ MPC designs are determined in Section 4.4.

The maximum MPC internal pressure is determined for normal onsite transport conditions, as well as off-normal conditions of a postulated accidental release of fission product gases caused by fuel rod rupture. Based on NUREG-1536 [4.4.10] recommended fission gases release fraction data, net free volume and initial fill gas pressure, the bounding maximum gas pressures with 1% and 10% rod rupture are given in Table 4.5.3. The MPC maximum gas pressures listed in Table 4.5.3 are all below the MPC design internal pressure listed in Table 2.2.1.

4.5.5 Maximum Thermal Stresses

Thermal expansion induced mechanical stresses due to non-uniform temperature distributions are reported in Chapter 3. Tables 4.5.2 and 4.5.4 provide a summary of MPC and HI-TRAC transfer cask component temperatures for structural evaluation.

4.5.6 Evaluation of System Performance for Normal Conditions of Handling and Onsite Transport

The HI-TRAC transfer cask thermal analysis is based on a detailed heat transfer model that conservatively accounts for all modes of heat transfer in various portions of the MPC and HI-TRAC. The thermal model incorporates several conservative features, which are listed below:

i. The most severe levels of environmental factors - bounding ambient temperature (100°F) and constant solar flux - were coincidentally imposed on the thermal design. A bounding solar absorbtivity of 1.0 is applied to all insolation surfaces.

ii. The HI-TRAC cask-to-MPC annular gap is analyzed based on the nominal design dimensions. No credit is considered for the significant reduction in this radial gap that would occur as a result of differential thermal expansion with design basis fuel at hot conditions. The MPC is considered to be concentrically aligned with the cask cavity. This is a worst-case scenario since any eccentricity will improve conductive heat transport in this region.

iii. No credit is considered for cooling of the HI-TRAC baseplate while in contact with a supporting surface. An insulated boundary condition is applied in the thermal model on the bottom baseplate face.

Temperature distribution results (Tables 4.5.2 and 4.5.4, and Figure 4.5.2) obtained from this highly conservative thermal model show that the short-term fuel cladding and cask component temperature limits are met with adequate margins. Expected margins during normal HI-TRAC use will be larger due to the many conservative assumptions incorporated in the analysis. Corresponding MPC internal pressure results (Table 4.5.3) show that the MPC confinement boundary remains well below the short-term condition design pressure. Stresses induced due to imposed temperature gradients are within ASME Code limits (Chapter 3). The maximum local axial neutron shield temperature is lower than design limits. Therefore, it is concluded that the HI-TRAC transfer cask thermal design is adequate to maintain fuel cladding integrity for short-term onsite handling and transfer operations.

The water in the water jacket of the HI-TRAC provides necessary neutron shielding. During normal handling and onsite transfer operations this shielding water is contained within the water jacket, which is designed for an elevated internal pressure. It is recalled that the water jacket is equipped with pressure relief valves set at 60 psig. This set pressure elevates the saturation pressure and temperature inside the water jacket, thereby precluding boiling in the water jacket under normal conditions. Under normal handling and onsite transfer operations, the bulk temperature inside the water jacket reported in Table 4.5.2 is less than the coincident saturation temperature at 60 psig (307°F), so the shielding water remains in its liquid state. The bulk temperature is determined via a conservative analysis, presented earlier, with design-basis maximum decay heat load. One of the assumptions that render the computed temperatures extremely conservative is the stipulation of a 100°F steady-state ambient temperature. In view of the large thermal inertia of the HI-TRAC, an appropriate ambient temperature is the "time-averaged" temperature, formally referred to in this FSAR as the normal temperature.

Note that during hypothetical fire accident conditions (see Section 11.2) these relief valves allow venting of any steam generated by the extreme fire flux, to prevent overpressurizing the water jacket. In this manner, a portion of the fire heat flux input to the HI-TRAC outer surfaces is expended in vaporizing a portion of the water in the water jacket, thereby mitigating the magnitude of the heat input to the MPC during the fire.

During vacuum drying operations, the annular gap between the MPC and the HI-TRAC is filled with water. The saturation temperature of the annulus water bounds the maximum temperatures of all HI-TRAC components, which are located radially outside the water-filled annulus. As previously stated (see Subsection 4.5.1.1.4) the maximum annulus water ~~saturation~~ temperature is only *125*~~232~~°F, so the HI-TRAC water jacket temperature will be less than the 307°F saturation temperature.

Table 4.5.1

EFFECTIVE RADIAL THERMAL CONDUCTIVITY OF THE WATER JACKET

Temperature (°F)	**Thermal Conductivity (Btu/ft-hr-°F)**
200	1.376
450	1.408
700	1.411

Table 4.5.2

HI-TRAC TRANSFER CASK STEADY-STATE
MAXIMUM TEMPERATURES

Component	Temperature [°F]
Fuel Cladding	*872* ~~902~~
MPC Basket	*852* ~~884~~
Basket Periphery	*600* ~~527~~
MPC Outer Shell Surface	*455* ~~459~~
HI-TRAC Overpack Inner Surface	*322* ~~323~~
Water Jacket Inner Surface	*314* ~~315~~
Enclosure Shell Outer Surface	*224* ~~223~~
Water Jacket Bulk Water	*258* ~~269~~
Axial Neutron Shield†	*258* ~~175~~

† Local neutron shield section temperature.

Table 4.5.3

SUMMARY OF MPC CONFINEMENT BOUNDARY PRESSURES† FOR NORMAL HANDLING AND ONSITE TRANSPORT

Condition	**Pressure (psig)**
MPC-24:	
Initial backfill (at 70°F)	31.3 28.3
Normal condition	*76.0* ~~66.6~~
With 1% rod rupture	*76.8* ~~67.0~~
With 10% rod rupture	*83.7* ~~70.0~~
MPC-68:	
Initial backfill (at 70°F)	*31.3* ~~28.5~~
Normal condition	*76.0* ~~67.0~~
With 1% rods rupture	*76.5* ~~67.3~~
With 10% rod rupture	*80.5* ~~70.8~~
MPC-32:	
Initial backfill (at 70°F)	*31.3*
Normal condition	*76.0*
With 1% rods rupture	*77.1*
With 10% rod rupture	*86.7*
MPC-24E:	
Initial backfill (at 70°F)	*31.3*
Normal condition	*76.0*
With 1% rods rupture	*76.8*
With 10% rod rupture	*83.7*

† *Includes gas from BPRA rods for PWR MPCs*

Table 4.5.4

SUMMARY OF HI-TRAC TRANSFER CASK AND MPC COMPONENTS
NORMAL HANDLING AND ONSITE TRANSPORT TEMPERATURES

Location	Temperature (°F)
MPC Basket Top:	
Basket periphery	*590* ~~222~~
MPC shell	*445* ~~215~~
O/P† inner shell	*280* ~~186~~
O/P enclosure shell	*196* ~~155~~
MPC Basket Bottom:	
Basket periphery	*334* ~~279~~
MPC shell	*302* ~~270~~
O/P inner shell	*244* ~~245~~
O/P enclosure shell	*199* ~~201~~

† O/P is an abbreviation for HI-TRAC overpack.

Table 4.5.5

SUMMARY OF LOADED 100-TON HI-TRAC TRANSFER CASK
BOUNDING COMPONENT
WEIGHTS AND THERMAL INERTIAS

Component	**Weight (lbs)**	**Heat Capacity (Btu/lb-°F)**	**Thermal Inertia (Btu/°F)**
Water Jacket	7,000	1.0	7,000
Lead	52,000	0.031	1,612
Carbon Steel	40,000	0.1	4,000
Alloy-X MPC (empty)	39,000	0.12	4,680
Fuel	40,000	0.056	2,240
MPC Cavity Water†	*6,500* ~~8,000~~	1.0	*6,500* ~~8,000~~
			26,032 (Total) ~~27,532 (Total)~~

† *Conservative lower bound water mass.* ~~Based on smallest MPC-68 cavity net free volume with 50% credit for flooded water mass.~~

Table 4.5.6

MAXIMUM ALLOWABLE TIME DURATION FOR WET TRANSFER OPERATIONS

Initial Temperature (°F)	Time Duration (hr)
115	*25.7* ~~35.2~~
120	*24.4* ~~33.4~~
125	*23.1* ~~31.5~~
130	*21.7* ~~29.7~~
135	*20.4* ~~27.9~~
140	*19.1* ~~26.1~~
145	*17.8* ~~24.3~~
150	*16.4* ~~22.5~~

Table 4.5.7

INTENTIONALLY DELETED

~~Component~~	~~MPC-24 (°F)~~	~~MPC-68 (°F)~~
~~Fuel Cladding~~	~~827~~	~~822~~
~~MPC Basket~~	~~759~~	~~786~~
~~MPC Basket Periphery~~	~~442~~	~~315~~
~~MPC Outer Shell Surface~~	~~232~~	~~232~~

Table 4.5.8
MATRIX OF HI-TRAC TRANSFER CASK THERMAL EVALUATIONS

Scenario	Description	Ultimate Heat Sink	Analysis Type	Principal Input Parameters	Results in FSAR Subsection
1	Onsite ~~Vertical†~~ Transport	Ambient	SS(B)	O_T, Q_D, ST, SC	4.5.2.1
2	Lead Gaps	Ambient	SS(B)	O_T, Q_D, ST, SC	4.5.1.1.7
3	Vacuum	HI-TRAC annulus water	SS(B)	Q_D	4.5.2.2
4	Wet Transfer Operation	Cavity water and Cask Internals	AH	Q_D	4.5.1.1.5
5	Fuel Unloading	Helium Circulation	TA	Q_D	4.5.1.1.6
6	Fire Accident	Jacket Water, Cask Internals	TA	Q_D, F	11.2.4
7	Jacket Water Loss Accident	Ambient	SS(B)	O_T, Q_D, ST, SC	11.2.1

Legend:

O_T - Off-Normal Temperature (100°F)
Q_D - Design Basis Maximum Heat Load

ST - Insolation Heating (Top)
SC - Insolation Heating (Curved)
F - Fire Heating (1475°F)

SS(B) - Bounding Steady State
TA - Transient Analysis
AH - Adiabatic Heating

† ~~Cask heat transport is enhanced by basket-to-MPC shell and MPC-to-overpack contact in a horizontal orientation. Consequently, the vertical orientation results are conservative for the horizontal condition.~~

Table 4.5.9

PEAK CLADDING TEMPERATURE IN VACUUM†

MPC	*Temperature (°F)*
MPC-24	*960*
MPC-68	*1014*
MPC-32	*1040*
MPC-24E	*942*

† *Steady state temperatures at the MPC design maximum heat load reported.*

B 3.1 SFSC Integrity

B 3.1.1 Multi-Purpose Canister (MPC)

BASES

BACKGROUND

A TRANSFER CASK with an empty MPC is placed in the spent fuel pool and loaded with fuel assemblies meeting the requirements of the ~~Functional and Operating Limits~~ *CoC*. A lid is then placed on the MPC. The TRANSFER CASK and MPC are raised to the top of the spent fuel pool surface. The TRANSFER CASK and MPC are then moved into the cask preparation area where dose rates are measured and the MPC lid is welded to the MPC shell and the welds are inspected and tested. The water is drained from the MPC cavity and ~~vacuum drying~~ *moisture removal* is performed. The MPC cavity is backfilled with helium. Additional dose rates are measured and the MPC vent and drain cover plates and closure ring are installed and welded. Inspections are performed on the welds. TRANSFER CASK bottom pool lid is replaced with the transfer lid to allow eventual transfer of the MPC into the OVERPACK.

MPC cavity *moisture removal using* vacuum drying *or forced helium recirculation* is ~~utilized~~ *performed* to remove residual moisture from the MPC fuel cavity after the MPC has been drained of water. *If vacuum drying is used,* ~~A~~*a*ny water that has not drained from the fuel cavity evaporates from the fuel cavity due to the vacuum. This is aided by the temperature increase due to the ~~temperature~~ *decay heat* of the fuel and by the heat added to the MPC from the optional warming pad, if used.

If helium recirculation is used, the dry gas introduced to the MPC cavity through the vent or drain port absorbs the residual moisture in the MPC. This humidified gas exits the MPC via the other port and the absorbed water is removed through condensation and/or mechanical drying. The dried helium is then forced back to the MPC until the temperature acceptance limit is met.

(continued)

BASES

BACKGROUND (continued)

After the completion of moisture removal, the MPC cavity is backfilled with helium meeting the ~~pressure~~ requirements of the CoC.

Backfilling of the MPC fuel cavity with helium promotes *gaseous* heat *dissipation* ~~*transfer from the fuel*~~ and the inert atmosphere protects the fuel cladding. Providing a helium pressure *in the required range* ~~greater than atmospheric pressure~~ ~~*ensures that there will be no in-leakage of air over the life of the MPC*~~ *at room temperature (70°F), eliminates air inleakage over the life of the MPC because the cavity pressure rises due to heat up of the confined gas by the fuel decay heat during storage. Providing helium in the required density range accomplishes the same function.*

In-leakage of air could be harmful to the fuel. Prior to moving the SFSC to the storage pad, the MPC helium leak rate is determined to ensure that the fuel is confined.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity during the storage of spent fuel in the MPC is ensured by the multiple confinement boundaries and systems. The barriers relied on are the fuel pellet matrix, the metallic fuel cladding tubes in which the fuel pellets are contained, and the MPC in which the fuel assemblies are stored. Long-term integrity of the fuel and cladding depend on storage in an inert atmosphere. This is accomplished by removing water from the MPC and backfilling the cavity with an inert gas. The thermal analyses of the MPC assume that the MPC cavity is filled with dry helium *of a minimum quantity to ensure the assumptions used for convection heat transfer are preserved. Keeping the backfill pressure below the maximum value preserves the initial condition assumptions made in the MPC overpressurization evaluation.*

(continued)

BASES (continued)

LCO	A dry, helium filled and sealed MPC establishes an inert heat removal environment necessary to ensure the integrity of the multiple confinement boundaries. Moreover, it also ensures that there will be no air in-leakage into the MPC cavity that could damage the fuel cladding over the storage period.
APPLICABILITY	The dry, sealed and inert atmosphere is required to be in place during TRANSPORT OPERATIONS and STORAGE OPERATIONS to ensure both the confinement barriers and heat removal mechanisms are in place during these operating periods. These conditions are not required during LOADING OPERATIONS or UNLOADING OPERATIONS as these conditions are being established or removed, respectively during these periods in support of other activities being performed with the stored fuel.
ACTIONS	A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each MPC. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each MPC not meeting the LCO. Subsequent MPCs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions. <u>A.1</u> If the cavity vacuum drying pressure *or demoisturizer exit gas temperature* limit has been determined not to be met during TRANSPORT OPERATIONS or STORAGE OPERATIONS, an engineering evaluation is necessary to determine the potential quantity of moisture left within the MPC cavity. Since moisture remaining in the cavity during these modes of operation may represent a long-term degradation concern, immediate action is not necessary. The Completion Time is sufficient to complete the engineering evaluation commensurate with the safety significance of the CONDITION.

(continued)

BASES

ACTIONS (continued)

A.2

Once the quantity of moisture potentially left in the MPC cavity is determined, a corrective action plan shall be developed and actions initiated to the extent necessary to return the MPC to an analyzed condition. Since the quantity of moisture estimated under Required Action A.1 can range over a broad scale, different recovery strategies may be necessary. Since moisture remaining in the cavity during these modes of operation may represent a long-term degradation concern, immediate action is not necessary. The Completion Time is sufficient to develop and initiate the corrective actions commensurate with the safety significance of the CONDITION.

B.1

If the helium backfill density *or pressure* limit has been determined not to be met during TRANSPORT OPERATIONS or STORAGE OPERATIONS, an engineering evaluation is necessary to determine the quantity of helium within the MPC cavity. Since too much or too little helium in the MPC during these modes represents a potential overpressure or heat removal degradation concern, an engineering evaluation shall be performed in a timely manner. The Completion Time is sufficient to complete the engineering evaluation commensurate with the safety significance of the CONDITION.

(continued)

BASES

ACTIONS (continued)

B.2

Once the quantity of helium in the MPC cavity is determined, a corrective action plan shall be developed and initiated to the extent necessary to return the MPC to an analyzed condition. Since the quantity of helium estimated under Required Action B.1 can range over a broad scale, different recovery strategies may be necessary. Since elevated or reduced helium quantities existing in the MPC cavity represent a potential overpressure or heat removal degradation concern, corrective actions should be developed and implemented in a timely manner. The Completion Time is sufficient to develop and initiate the corrective actions commensurate with the safety significance of the CONDITION.

C.1

If the helium leak rate limit has been determined not to be met during TRANSPORT OPERATIONS or STORAGE OPERATIONS, an engineering evaluation is necessary to determine the impact of increased helium leak rate on heat removal and off-site dose. Since the HI-STORM OVERPACK is a ventilated system, any leakage from the MPC is transported directly to the environment. Since an increased helium leak rate represents a potential challenge to MPC heat removal and the off-site doses calculated in the FSAR confinement analyses, reasonably rapid action is warranted. The Completion Time is sufficient to complete the engineering evaluation commensurate with the safety significance of the CONDITION.

(continued)

BASES

ACTIONS (continued)

C.2

Once the cause and consequences of the elevated leak rate from the MPC are determined, a corrective action plan shall be developed and initiated to the extent necessary to return the MPC to an analyzed condition. Since the recovery mechanisms can range over a broad scale based on the evaluation performed under Required Action C.1, different recovery strategies may be necessary. Since an elevated helium leak rate represents a challenge to heat removal rates and off-site doses, reasonably rapid action is required. The Completion Time is sufficient to develop and initiate the corrective actions commensurate with the safety significance of the CONDITION.

D.1

If the MPC fuel cavity cannot be successfully returned to a safe, analyzed condition, the fuel must be placed in a safe condition in the spent fuel pool. The Completion Time is reasonable based on the time required to replace the transfer lid with the pool lid, perform fuel cooldown operations, re-flood the MPC, cut the MPC lid welds, move the TRANSFER CASK into the spent fuel pool, remove the MPC lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.

SURVEILLANCE REQUIREMENTS

SR 3.1.1.1, SR 3.1.1.2, and SR 3.1.1.3

The long-term integrity of the stored fuel is dependent on storage in a dry, inert environment. *For moderate burnup fuel* ~~C~~cavity dryness ~~s~~ *may be* demonstrated *either* by evacuating the cavity to a very low absolute pressure and verifying that the pressure is held over a specified period of time *or by recirculating dry helium through the MPC cavity to absorb moisture until the demoisturizer exit temperature reaches and remains below the acceptance limit for the specified time period.* A low vacuum pressure *or a demoisturizer exit temperature meeting the acceptance limit* is an indication that the cavity is dry. *For high burnup fuel, the forced helium*

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.1.1.1, SR 3.1.1.2, and SR 3.1.1.3 (continued)

recirculation method of moisture removal must be used to provide necessary cooling of the fuel during drying operations. Cooling provided by normal operation of the forced helium dehydration system ensures that the fuel cladding temperature remains below the applicable limits since forced recirculation of helium provides more effective heat transfer than that which occurs during normal storage operations.

Having the proper helium backfill density *or pressure* ensures adequate heat transfer from the fuel to the fuel basket and surrounding structure of the MPC. Meeting the helium leak rate limit ensures there is adequate helium in the MPC for long term storage and the leak rate assumed in the confinement analyses remains bounding for off-site dose.

The leakage rate acceptance limit is specified in units of atm-cc/sec. This is a mass-like leakage rate as specified in ANSI N14.5 (1997). This is defined as the rate of change of the pressure-volume product of the leaking fluid at test conditions. This allows the leakage rate as measured by a mass spectrometer leak detector (MSLD) to be compared directly to the acceptance limit without the need for unit conversion from test conditions to standard, or reference conditions.

All three of these surveillances must be successfully performed once, prior to TRANSPORT OPERATIONS to ensure that the conditions are established for SFSC storage which preserve the analysis basis supporting the cask design.

REFERENCES

1. FSAR Sections *1.2,* 4.4, *4.5* 7.2, 7.3 and 8.1