CHAPTER 10: RADIATION PROTECTION[†]

This chapter discusses the design considerations and operational features that are incorporated in the HI-STORM 100 Storage System design to protect plant personnel and the public from exposure to radioactive contamination and ionizing radiation during canister loading, closure, transfer, and on-site dry storage. Occupational exposure estimates for typical canister loading, closure, transfer operations, and ISFSI inspections are provided. An off-site dose assessment for a typical ISFSI is also discussed. Since the determination of off-site doses is necessarily site-specific, similar dose assessments are to be prepared by the licensee, as part of implementing the HI-STORM 100 Storage System in accordance with 10CFR72.212 [10.0.1]. The information provided in this chapter meets all requirements of NUREG-1536.

10.1 ENSURING THAT OCCUPATIONAL RADIATION EXPOSURES ARE AS-LOW-AS-REASONABLY-ACHIEVABLE (ALARA)

10.1.1 Policy Considerations

The HI-STORM 100 has been designed in accordance with 10CFR72 [10.0.1] and maintains radiation exposures ALARA consistent with 10CFR20 [10.1.1] and the guidance provided in Regulatory Guides 8.8 [10.1.2] and 8.10 [10.1.3]. Licensees using the HI-STORM 100 System will utilize and apply their existing site ALARA policies, procedures and practices for ISFSI activities to ensure that personnel exposure requirements of 10CFR20 [10.1.1] are met. Personnel performing ISFSI operations shall be trained on the operation of the HI-STORM 100 System, and be familiarized with the expected dose rates around the MPC, HI-STORM and HI-TRAC during all phases of loading, storage, and unloading operations. Chapter 12 provides dose rate limits at the HI-TRAC and HI-STORM surfaces to ensure that the HI-STORM 100 System is operated within design basis conditions and that ALARA goals will be met. Pre-job ALARA briefings should be held with workers and radiological protection personnel prior to work on or around the system. Worker dose rate monitoring, in conjunction with trained personnel and well-planned activities, will significantly reduce the overall dose received by the workers. When preparing or making changes to site-specific procedures for ISFSI activities, users shall ensure that ALARA practices are implemented and the 10CFR20 [10.1.1] standards for radiation protection are met in accordance with the site's written commitments. Users can further reduce dose rates around the HI-STORM 100 System by preferentially loading longer-cooled and lower-burnup spent fuel assemblies in the periphery fuel storage cells of the MPC, and loading assemblies with shorter cooling times and higher burnups in the inner MPC fuel storage cell locations. Users can also further reduce the dose rates around the HI-TRAC by the use of temporary shielding. In some cases, users may opt to upgrade their existing crane to take advantage of the increased shielding capabilities of the 125-Ton HI-TRAC transfer cask (versus the 100-Ton HI-TRAC transfer cask). This decision should be based on a cost-benefit analysis. Temporary shielding *and use of special tools to reduce dose* is discussed in Section 10.1.4. |

[†] This chapter has been prepared in the format and section organization set forth in Regulatory Guide 3.61. However, the material content of this chapter also fulfills the requirements of NUREG 1536. Pagination and numbering of sections, figures, and tables are consistent with the convention set down in Chapter 1, Section 1.0, herein. Finally, all terms-of-art used in this chapter are consistent with the terminology of the glossary (Table 1.0.1) and component nomenclature of the Bill-of-Materials (Section 1.5).

10.1.2 Design Considerations

Consistent with the design criteria defined in Section 2.3.5, the radiological protection criteria that limit exposure to radioactive effluents and direct radiation from an ISFSI using the HI-STORM 100 Storage System are as follows:

1. 10CFR72.104 [10.0.1] requires that for normal operation and anticipated occurrences, the annual dose equivalent to any real individual located beyond the owner-controlled area boundary must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other critical organ. This dose would be a result of planned discharges, direct radiation from the ISFSI, and any other radiation from uranium fuel cycle operations in the area. The licensee is responsible for demonstrating site-specific compliance with these requirements.

2. 10CFR72.106 [10.0.1] requires that any individual located on or beyond the nearest owner-controlled area boundary may not receive from any design basis accident the more limiting of a total effective dose equivalent of 5 rem, or the sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) of 50 rem. The lens dose equivalent shall not exceed 15 rem and the shallow dose equivalent to skin or to any extremity shall not exceed 50 rem. The licensee is responsible for demonstrating site-specific compliance with this requirement.

3. 10CFR20 [10.1.1], Subparts C and D, limit occupational exposure and exposure to individual members of the public. The licensee is responsible for demonstrating site-specific compliance with this requirement.

4. Regulatory Position 2 of Regulatory Guide 8.8 [10.1.2] provides guidance regarding facility and equipment design features. This guidance has been followed in the design of the HI-STORM 100 Storage System as described below:

- Regulatory Position 2a, regarding access control, is met by locating the ISFSI in a Protected Area in accordance with 10CFR72.212(b)(5)(ii) [10.0.1]. Depending on the site-specific ISFSI design, other equivalent measures may be used. Unauthorized access is prevented once a loaded HI-STORM 100 Storage cask is placed in an ISFSI. Due to the nature of the system, only limited monitoring is required, thus reducing occupational exposure and supporting ALARA considerations. The licensee is responsible for site-specific compliance with these criteria.

- Regulatory Position 2b, regarding radiation shielding, is met by the storage cask and transfer cask biological shielding that minimizes personnel exposure, as described in Chapter 5 or later in this chapter. Fundamental design considerations that most directly influence occupational exposures with dry storage systems in general and which have been incorporated into the HI-STORM 100 System design include:
  - system designs that reduce or minimize the number of handling and transfer operations for each spent fuel assembly;

- system designs that reduce or minimize the number of handling and transfer operations for each MPC loading;
- system designs that maximize fuel capacity, thereby taking advantage of the self-shielding characteristics of the fuel and the reduction in the number of MPCs that must be loaded and handled;
- system designs that minimize planned maintenance requirements;
- system designs that minimize decontamination requirements at ISFSI decommissioning;
- system designs that optimize the placement of shielding with respect to anticipated worker locations and fuel placement;
- thick walled overpack that provides gamma and neutron shielding;
- thick MPC lid which provides effective shielding for operators during MPC loading and unloading operations;
- multiple welded barriers to confine radionuclides;
- smooth surfaces to reduce decontamination time;
- minimization of potential crud traps on the handling equipment to reduce decontamination requirements;
- capability of maintaining water in the MPC during welding to reduce dose rates;
- capability of maintaining water in the transfer cask annulus space and water jacket to reduce dose rates during closure operations;
- MPC penetrations located and configured to reduce streaming paths;
- HI-STORM and HI-TRAC designed to reduce streaming paths;
- MPC vent and drain ports with resealable caps to prevent the release of radionuclides during loading and unloading operations and facilitate draining, drying, and backfill operations;
- use of a separate pool lid, annulus seal, and Annulus Overpressure System to prevent contamination of the MPC shell outer surfaces during in-pool activities;
- temporary and auxiliary shielding to reduce dose rates around the HI-TRAC; and
- low-maintenance design to reduce doses during storage operation.

- Regulatory Position 2c, regarding process instrumentation and controls, is met since there are no radioactive systems at an ISFSI.

- Regulatory Position 2d, regarding control of airborne contaminants, is met since the HI-STORM 100 Storage System is designed to withstand all design basis conditions without loss of confinement function, as described in Chapter 7 of this FSAR, and no gaseous releases are anticipated. No significant surface contamination is expected since the exterior of the MPC is kept clean by using clean water in the HI-TRAC transfer cask-MPC annulus and by using an inflatable annulus seal.
- Regulatory Position 2e, regarding crud control, is not applicable to a HI-STORM 100 Storage System ISFSI since there are no radioactive systems at an ISFSI that could transport crud.
- Regulatory Position 2f, regarding decontamination, is met since the exterior of the loaded transfer cask is decontaminated prior to being removed from the plant's fuel building. The exterior surface of the HI-TRAC transfer cask is designed for ease of decontamination. In addition, an inflatable annulus seal is used to prevent fuel pool water from contacting and contaminating the exterior surface of the MPC.
- Regulatory Position 2g, regarding monitoring of airborne radioactivity, is met since the MPC provides confinement for all design basis conditions. There is no need for monitoring since no airborne radioactivity is anticipated to be released from the casks at an ISFSI.
- Regulatory Position 2h, regarding resin treatment systems, is not applicable to an ISFSI since there are no treatment systems containing radioactive resins.
- Regulatory Position 2i, regarding other miscellaneous ALARA items, is met since stainless steel is used in the MPC shell, the primary confinement boundary. This material is resistant to the damaging effects of radiation and is well proven in the SNF cask service. Use of this material quantitatively reduces or eliminates the need to perform maintenance (or replacement) on the primary confinement system.

10.1.3 Operational Considerations

Operational considerations that most directly influence occupational exposures with dry storage systems in general and that have been incorporated into the design of the HI-STORM 100 System include:

- totally-passive design requiring minimal maintenance and monitoring (other than security monitoring) during storage;
- remotely operated welding system, lift yoke, transfer slide and ~~Vacuum Drying System (VDS)~~*moisture removal systems* to reduce time operators spend in the vicinity of the loaded MPC;
- maintaining water in the MPC and the annulus region during MPC closure activities to reduce dose rates;

- low fuel assembly lift-over height of the HI-TRAC maximizes water coverage over assemblies during fuel assembly loading;
- a water-filled neutron shield jacket allows filling after removal of the HI-TRAC from the spent fuel pool. This maximizes the shielding on the HI-TRAC without exceeding the crane capacity;
- descriptive operating procedures that provide guidance to reduce equipment contamination, obtain survey information, minimize dose and alert workers to possible changing radiological conditions;
- preparation and inspection of the HI-STORM and HI-TRAC in low-dose areas;
- MPC lid fit tests and inspections prior to actual loading to ensure smooth operation during loading;
- gas sampling of the MPC and HI-STAR 100 annulus (receiving from transport) to assess the condition of the cladding and MPC confinement boundary;
- fuel cool-down operations developed for fuel unloading operations which minimize thermal shock to the fuel and therefore reduce the potential for fuel cladding rupture;
- HI-STORM vent ~~thermocouples~~ *temperature elements* (See Chapter 12) allow remote monitoring of the vent operability surveillance;
- wetting of component surfaces prior to placement in the spent fuel pool to reduce the need for decontamination;
- decontamination practices which consider the effects of weeping during HI-TRAC transfer cask heat up and surveying of HI-TRAC prior to removal from the fuel handling building;
- a sequence of operations based on ALARA considerations; and
- use of mock-ups and dry run training to prepare personnel for actual work situations.

10.1.4 Auxiliary/Temporary Shielding

To minimize occupational dose during loading and unloading operations, a specially-designed set of auxiliary shielding is available. The HI-STORM 100 auxiliary shielding consists of the Automated Welding System Baseplate, the HI-TRAC Temporary Shield Ring, the annulus shield, HI-STORM vent shield insert, the HI-TRAC transfer step, and the shield panel trim plates. *Additional supplemental shielding such as lead blankets and bricks or other such shielding may also be used to help reduce dose rates.* Each auxiliary shield is described in Table 10.1.1, shown on Figure 10.1.1 and the procedures for utilization are provided in Chapter 8. *Other embodiments of the temporary shielding may also be used.* Table 10.1.2 provides the minimum requirements for use of the temporary shielding indicating optional and required shielding. Users shall evaluate the need for ~~additional~~ auxiliary and temporary shielding *and use* *of special tooling to reduce the overall exposure* based on an ALARA review of cask loading operations *and the MPC contents.*

Table 10.1.1
HI-STORM 100 AUXILIARY AND TEMPORARY SHIELDS

Temporary Shield	Description	Utilization
Automated Welding System Baseplate	Thick gamma and neutron shield circular plate that sits on the MPC lid. Plate is set directly on the MPC lid and has alignment pins for centering. Threaded lift holes are provided to assist in rigging.	Used during MPC closure and unloading operations in the cask preparation area to reduce the dose rates around the MPC lid. The design of the closure ring allows the baseplate shield to remain in place during the entire closure operation.
HI-TRAC Temporary Shield Ring	A series of eight custom-fit water-filled tanks that are placed atop of the HI-STAR or HI-TRAC neutron shield. The tanks, when secured together, form a complete shielding ring around the top flange.	Used during MPC and HI-TRAC closure operations and MPC transfers into HI-STAR to reduce dose rates to the operators around the top flange of the HI-TRAC.
Annulus Shield	A solid ring that is seated between the MPC shell and the HI-TRAC.	Used during MPC closure operations to reduce streaming from the annulus.
HI-TRAC Transfer Step	A stepped block used to position the pool lid and transfer lid at the same elevation. The transfer step creates a tight seam between the two lids to eliminate streaming during bottom lid replacement.	Used during HI-TRAC bottom lid replacement.
Shield Panel Trim Plates	Four steel plates approximately 0.25 inch by 3 inch by 80 inch that are placed at the ends of the transfer lid top and bottom plate and secured by clamps or other method deemed suitable by the user.	Used during MPC transfer to and from HI-TRAC to shield the small gap above and below the sliding doors on the transfer lid.
HI-STORM Vent Shield Inserts	Custom-fit concrete blocks shaped to fit into the HI-STORM exit vents.	Used during MPC transfer to and from HI-STORM to eliminate the streaming path from the exit vents during MPC transfer operations.

Table 10.1.2
HI-STORM 100 AUXILIARY AND TEMPORARY SHIELD REQUIREMENTS

Auxiliary Shielding	**Required for the 100-Ton HI-TRAC**	**Required for the 125-ton HI-TRAC**
Temporary Shield Ring	~~Yes~~*Note 1*	No
Automated Welding System Baseplate Shield	No	No
Annulus Shield	*Note 1*~~Yes~~	*Note 1*~~Yes~~
Vent Duct Shield Inserts	*Note 2*~~Yes~~	*Note 2*~~Yes~~
Transfer Step	Yes	Yes
Trim Plates	No	No

Notes:

1. *Users shall determine the need for this temporary shielding based on the specific operations and the MPC contents.*
2. *NOT REQUIRED FOR THE HI-STORM 100S OVERPACK.*

10.2 RADIATION PROTECTION DESIGN FEATURES

The development of the HI-STORM 100 System has focused on design provisions to address the considerations summarized in Sections 10.1.2 and 10.1.3. The intent has been to improve on past concrete-based dry storage system designs by developing HI-STORM 100 as a hybrid of current metal and concrete storage system technologies. The design is, therefore, an evolution in storage systems, which incorporates preferred features from concrete storage, canister-based systems while retaining several of the advantages of metal casks as well. This approach results in a reduction in the need for maintenance, in overall radiation levels, and in the time spent on maintenance, when compared with current concrete-based dry storage systems. The following specific design features ensure a high degree of confinement integrity and radiation protection:

- HI-STORM 100 has been designed to meet storage condition dose rates required by 10CFR72 [10.0.1] for five-year cooled fuel;
- HI-STORM 100 has been designed to accommodate a maximum number of PWR or BWR fuel assemblies to minimize the number of cask systems that must be handled and stored at the storage facility and later transported off-site;
- HI-STORM 100 overpack structure is virtually maintenance free, especially over the years following its initial loading, because of the outer metal shell. The metal shell and its protective coating provide a high level of resistance to corrosion and other forms of degradation (e.g., erosion);
- HI-STORM 100 has been designed for redundant, multi-pass welded closures on the MPC; consequently, no monitoring of the confinement boundary is necessary and no gaseous or particulate releases occur for normal, off-normal or credible accident conditions;
- HI-TRAC transfer cask has a transfer step and other auxiliary shielding devices which eliminates streaming paths and simplify operations;
- The pool lid maximizes available fuel assembly water coverage in the spent fuel pool.
- The transfer lid is designed for quick alignment with HI-STORM; and
- HI-STORM 100 has been designed to allow close positioning (pitch) on the ISFSI storage pad, thereby increasing the ISFSI self-shielding by decreasing the view factors and reducing exposures to on-site and off-site personnel.

10.3 ESTIMATED ON-SITE COLLECTIVE DOSE ASSESSMENT

This section provides the estimates of the cumulative exposure to personnel performing loading, unloading and transfer operations using the HI-STORM system. This section uses the shielding analysis provided in Chapter 5 and the operations procedures provided in Chapter 8 to develop a dose assessment. The dose assessment is provided in Tables 10.3.1, 10.3.2, and 10.3.3.

The dose rates from the HI-STORM 100 overpack, MPC lid, HI-TRAC transfer cask, and HI-STAR 100 overpack are calculated to determine the dose to personnel during the various loading and unloading operations. The dose rates are also calculated for the various conditions of the cask that may affect the dose rates to the operators (e.g., MPC water level, HI-TRAC annulus water level, neutron shield water level, presence of temporary shielding). The dose rates around the 100-Ton HI-TRAC transfer cask are based on 24 PWR fuel assemblies with a burnup of 42,500 MWD/MTU and cooling of 5 years including BPRAs. The dose rates around the 125-Ton HI-TRAC transfer cask are based on 24 PWR fuel assemblies with a burnup of 57,500 MWD/MTU and cooling of 12 years including BPRAs. The dose rates around the HI-STORM 100 overpack are based on 24 PWR fuel assemblies with a burnup of 52,500 MWD/MTU and cooling of 5 years. The selection of these fuel assembly types in all fuel cell locations bound all possible PWR and BWR loading scenarios for the HI-STORM System from a dose-rate perspective. No assessment is made with respect to background radiation since background radiation can vary significantly by site. In addition, exposures are based on work being performed with the temporary shielding described in Table 10.1.2.

The choice of burnup and cooling times used in this chapter is extremely conservative. The bounding burnup and cooling time that resulted in the highest dose rates around the 100-ton and 125-ton HI-TRACs were used in conjunction with the very conservative burnup and cooling time for the HI-STORM 100 overpack (as discussed in Section 5.1). In addition, including the source term from BPRAs increases the level of conservatism. The maximum dose rate due to BPRAs was used in this analysis. As stated in Chapter 5, using the maximum source for the BPRAs in conjunction with the bounding burnup and cooling time for fuel assemblies is very conservative as it is not expected that burnup and cooling times of the BPRAs and fuel assemblies would be such that they are both at the maximum design basis values. This combined with the already conservative dose rates for the HI-TRACs and HI-STORMs results in an upper bound estimate of the occupational exposure. Users' radiation protection programs will assure appropriate temporary shielding is used based on actual fuel to be loaded and resulting dose rates in the field.

For each step in Tables 10.3.1 through 10.3.3, the operator work location is identified. These correspond to the locations identified in Figure 10.3.1. The relative locations refer to both the HI-STORM 100 Overpack and the HI-STORM 100s Overpack. The dose rate location points around the transfer cask and overpack were selected to model actual worker locations and cask conditions during the operation. Cask operators typically work at an arms-reach distance from the cask. To account for this, an 18-inch distance was used to estimate the dose rate for the worker. This assessment addresses only the operators that perform work on or immediately adjacent to the cask.

Justification for the duration of operations along with the corresponding procedure steps from Chapter 8 are also provided in the tables. The assumptions used in developing time durations are based on mockups of the MPC, review of design drawings, walk-downs using other equipment to represent the HI-TRAC transfer cask and HI-STORM 100 overpack the HI-STAR 100 overpack and MPC-68 prototype, consultation with UST&D (weld examination) and consultation with cask operations personnel from Calvert Cliffs Nuclear Power Plant (for items such as lid installation and decontamination). In addition, for the shielding calculations, only the Temporary Shield Ring was assumed to be in place for applicable portions of the operations.

Tables 10.3.1a and 10.3.1b provide a summary of the dose assessment for a HI-STORM 100 System loading operation using the 125-ton HI-TRAC and the 100-ton HI-TRAC, respectively. Tables 10.3.2a and 10.3.2b provide a summary of the dose assessment for HI-STORM 100 System unloading operations operation using the 125-ton HI-TRAC transfer cask and the 100-ton HI-TRAC transfer cask, respectively. Tables 10.3.3a and 10.3.3.b provide a summary of the dose assessment for transferring the MPC to a HI-STAR 100 overpack as described in Section 8.5 of the operating procedures using the 125-ton HI-TRAC and the 100-ton HI-TRAC transfer cask, respectively.

10.3.1 Estimated Exposures for Loading and Unloading Operations

The assumptions used to estimate personnel exposures are conservative by design. The main factors attributed to actual personnel exposures are the age and burnup of the spent fuel assemblies and good ALARA practices. To estimate the dose received by a single worker, it should be understood that a canister-based system requires a diverse range of disciplines to perform all the necessary functions. The high visibility and often critical path nature of fuel movement activities have prompted utilities to load canister systems in a round-the-clock mode in most cases. This results in the exposure being spread out over several shifts of operators and technicians with no single shift receiving a majority of the exposure.

The total person-rem exposure from operation of the HI-STORM 100 System is proportional to the number of systems loaded. A typical utility will load approximately four MPCs per reactor cycle to maintain the current available spent fuel pool capacity. Utilities requiring dry storage of spent fuel assemblies typically have a large inventory of spent fuel assemblies that date back to the reactor's first cycle. The older fuel assemblies will have a significantly lower dose rate than the design basis fuel assemblies due to the extended cooling time (i.e., much greater than the values used to compute the dose rates). Users shall assess the cask loading for their particular fuel types (burnup, cooling time) to satisfy the requirements of 10CFR20 [10.1.1].

For licensees using the 100-Ton HI-TRAC transfer cask, design basis dose rates will be higher (than a corresponding 125-Ton HI-TRAC) due to the decreased mass of shielding. Due to the higher expected dose rates from the 100-Ton HI-TRAC, users may need to use the auxiliary shielding (See Table 10.1.2), and should consider preferential loading, and increased precautions (e.g., additional temporary or auxiliary shielding, remotely operated equipment, additional contamination prevention measures). Actual use of optional dose reduction measures must be decided by each user based on the fuel to be loaded.

10.3.2 Estimated Exposures for Surveillance and Maintenance

Table 10.3.4 provides the maximum occupational exposure required for security surveillance and maintenance of an ISFSI. Although the HI-STORM 100 System requires only minimal maintenance during storage, maintenance will be required around the ISFSI for items such as security equipment maintenance, grass cutting, snow removal, vent system surveillance, drainage system maintenance, and lighting, telephone, and intercom repair. Security surveillance time is based on a daily security patrol around the perimeter of the ISFSI security fence. The estimated dose rates described below are based on a sample array of HI-STORM 100 overpacks fully loaded with design basis fuel assemblies, placed at their minimum required pitch, in a 2 x 6 HI-STORM array. The maintenance worker is assumed to be at a distance of 5 meters from the center of the long edge of the array. The security worker is assumed to be at a distance of 15 meters from the center of the long edge of the array. Users may opt to utilize electronic temperature monitoring of the HI-STORM modules or remote viewing methods instead of performing direct visual observation of the modules. Since security surveillances can be performed from outside the ISFSI, a dose rate of 3 mrem/hour is estimated. For maintenance of the casks and the ISFSI, a dose rate of 10 mrem/hour is estimated

Table 10.3.1a
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
Section 8.1.4								
LOAD PRE-SELECTED FUEL ASSEMBLIES INTO MPC	2	1020	1	2	1	17.0	34.0	15 MINUTES PER ASSEMBLY/68 ASSY
PERFORM POST-LOADING VISUAL VERIFICATION OF ASSEMBLY IDENTIFICATION	3	68	1	2	1	1.1	2.3	1 MINUTES PER ASSY/68 ASSY
Section 8.1.5								
INSTALL MPC LID AND ATTACH LIFT YOKE	1.g	45	2	2	2	1.5	3.0	CONSULTATION WITH CALVERT CLIFFS
RAISE HI-TRAC TO SURFACE OF SPENT FUEL POOL	1.i	20	2	2	2	0.7	1.3	40 FEET @ 2 FT/MINUTE (CRANE SPEED)
SURVEY MPC LID FOR HOT PARTICLES	1.i	3	3A	1	18.35	0.9	0.9	TELESCOPING DETECTOR USED
VERIFY MPC LID IS SEATED	1.j	0.5	3A	1	18.35	0.2	0.2	VISUAL VERIFICATION FROM 3 METERS
INSTALL LID RETENTION SYSTEM BOLTS	1.k	6	3B	2	19.45	1.9	3.9	24 BOLTS @ 1/PERSON-MINUTE
REMOVE HI-TRAC FROM SPENT FUEL POOL	1.m	8.5	3C	1	38.9	5.5	5.5	17 FEET @ 2 FT/MIN (CRANE SPEED)
DECONTAMINATE HI-TRAC BOTTOM	1.n	10	3D	1	51.45	8.6	8.6	LONG HANDLED TOOLS, PRELIMINARY DECON
TAKE SMEARS OF HI-TRAC EXTERIOR SURFACES	1.n	5	5B	1	59.31	4.9	4.9	50 SMEARS @ 10 SMEARS/MINUTE
DISCONNECT ANNULUS OVERPRESSURE SYSTEM	1.o	0.5	5C	1	31.89	0.3	0.3	QUICK DISCONNECT COUPLING
SET HI-TRAC IN CASK PREPARATION AREA	1.p	10	4A	1	19.45	3.2	3.2	100 FT @ 10 FT/MIN (CRANE SPEED)
REMOVE NEUTRON SHIELD JACKET FILL PLUG	1.q	2	4A	1	19.45	0.6	0.6	SINGLE PLUG, NO SPECIAL TOOLS
INSTALL NEUTRON SHIELD JACKET FILL PLUG	1.q	2	5B	1	59.31	2.0	2.0	SINGLE PLUG, NO SPECIAL TOOLS
DISCONNECT LID RETENTION SYSTEM	1.r	6	5A	2	21.35	2.1	4.3	24 BOLTS @ 1 BOLT/PERSON MINUTES
MEASURE DOSE RATES AT MPC LID	1.t	3	5A	1	21.35	1.1	1.1	TELESCOPING DETECTOR USED

[†] See notes at bottom of Table 10.3.4.

Table 10.3.1a
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
DECONTAMINATE AND SURVEY HI-TRAC	1.t	103	5B	1	59.31	101.8	101.8	490 SQ-FT@5 SQ-FT/PRERSON-MINUTE+50 SMEARS@10 SMEARS/MINUTE
INSTALL TEMPORARY SHIELD	1.v	16	6A	2	11.05	2.9	5.9	8 SEGMENTS @ 1 SEGMENT/PERSON MIN
FILL TEMPORARY SHIELD RING	1.v	25	6A	1	11.05	4.6	4.6	230 GAL @10GPM, LONG HANDLED SPRAY WAND
ATTACH DRAIN LINE TO HI-TRAC DRAIN PORT	1.w	0.5	5C	1	31.89	0.3	0.3	QUICK DISCONNECT COUPLING
INSTALL RVOAs	2.a	2	6A	1	11.05	0.4	0.4	SINGLE THREADED CONNECTION X 2 RVOAs
ATTACH WATER PUMP TO DRAIN PORT	2.b	2	6A	1	11.05	0.4	0.4	POSITION PUMP SELF PRIMING
DISCONNECT WATER PUMP	2.c	5	6A	1	11.05	0.9	0.9	DRAIN HOSES MOVE PUMP
DECONTAMINATE MPC LID TOP SURFACE AND SHELL AREA ABOVE INFLATABLE ANNULUS SEAL	2.d	6	6A	1	11.05	1.1	1.1	30 SQ-FT @5 SQ-FT/MINUTE+10 SMEARS@10 SMEARS/MINUTE
REMOVE INFLATABLE ANNULUS SEAL	2.e	3	6A	1	11.05	0.6	0.6	SEAL PULLS OUT DIRECTLY
SURVEY MPC LID TOP SURFACES AND ACCESSIBLE AREAS OF TOP THREE INCHES OF MPC SHELL	2.f	1	6A	1	11.05	0.2	0.2	10 SMEARS@10 SMEARS/MINUTE
INSTALL ANNULUS SHIELD	2.g	2	6A	1	11.05	0.4	0.4	SHIELD PLACED BY HAND
CENTER LID IN MPC SHELL	3.a	20	6A	3	11.05	3.7	11.1	CONSULTATION WITH CALVERT CLIFFS
INSTALL MPC LID SHIMS	3.b	12	6A	2	11.05	2.2	4.4	MEASURED DURING WELD MOCKUP TESTING
POSITION AWS BASEPLATE SHIELD ON MPC LID	3.c	20	7A	2	11.05	3.7	7.4	ALIGN AND REMOVE 4 SHACKLES
INSTALL AUTOMATED WELDING SYSTEM ROBOT	3.c	8	7A	2	11.05	1.5	2.9	ALIGN AND REMOVE 4 SHACKLES/4 QUICK CONNECTS@1/MIN
VISUALLY INSPECT TACK WELD	3.e	5	7A	1	11.05	0.9	0.9	MEASURED DURING WELD MOCKUP TESTING
PERFORM LIQUID PENETRANT EXAMINATION OF WELD ROOT	3.g	45	7A	1	11.05	8.3	8.3	MEASURED DURING WELD MOCKUP TESTING

Table 10.3.1a
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK
ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
PERFORM INTERMEDIATE LIQUID PENETRANT EXAMINATION (3 SETS)	3.h	135	7A	1	11.05	24.9	24.9	MEASURED DURING WELD MOCKUP TESTING
PERFORM LIQUID PENETRANT EXAMINATION ON MPC LID FINAL PASS	3.i	45	7A	1	11.05	8.3	8.3	MEASURED DURING WELD MOCKUP TESTING
ATTACH DRAIN LINE TO VENT PORT	4.a	1	7A	1	11.05	0.2	0.2	1" THREADED FITTING NO TOOLS
VISUALLY EXAMINE MPC LID-TO-SHELL WELD FOR LEAKAGE OF WATER	4.c	10	7A	1	11.05	1.8	1.8	10 MIN TEST DURATION
DISCONNECT WATER FILL LINE AND DRAIN LINE	4.c	2	7A	1	11.05	0.4	0.4	1" THREADED FITTING NO TOOLS X 2
REPEAT LIQUID PENETRANT EXAMINATION ON MPC LID FINAL PASS	4.d	45	7A	1	11.05	8.3	8.3	5 MIN TO APPLY, 7 MIN TO WIPE, 5 APPLY DEV, INSP (24 IN/MIN)
ATTACH GAS SUPPLY TO VENT PORT	4.e	1	7A	1	11.05	0.2	0.2	1" THREADED FITTING NO TOOLS
ATTACH DRAIN LINE TO DRAIN PORT	4.c	1	7A	1	11.05	0.2	0.2	1" THREADED FITTING NO TOOLS
CONNECT MSLD SNIFFER TO AUTOMATED WELDING SYSTEM	4.i	4	8A	1	15.4	1.0	1.0	SIMPLE ATTACHMENT NO TOOLS
DISCONNECT MSLD SNIFFER FROM AUTOMATED WELDING SYSTEM	4.i	4	8A	1	15.4	1.0	1.0	SIMPLE ATTACHMENT NO TOOLS
ATTACH DRAIN LINE TO VENT PORT	5.a	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
ATTACH WATER FILL LINE TO DRAIN PORT	5.a	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
DISCONNECT WATER FILL DRAIN LINES FROM MPC	5.b	2	8A	1	15.4	0.5	0.5	1" THREADED FITTING NO TOOLS X 2
ATTACH HELIUM OR NITROGEN SUPPLY TO VENT PORT	5.c	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
ATTACH DRAIN LINE TO DRAIN PORT	5.d	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
DISCONNECT GAS SUPPLY LINE FROM MPC	5.i	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
DISCONNECT DRAIN LINE FROM MPC	5.j	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS

Table 10.3.1a
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK
ESTIMATED OPERATIONAL EXPOSURES† (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
ATTACH ~~VACUUM DRYING~~*M MOISTURE REMOVAL* SYSTEM ~~(VDS)~~ TO VENT AND DRAIN PORT RVOAs	6.a	2	8A	1	15.4	0.5	0.5	1" THREADED FITTING NO TOOLS
DISCONNECT ~~VDS~~ *MOISTURE REMOVAL SYSTEM* FROM MPC	6.j	2	8A	1	15.4	0.5	0.5	1" THREADED FITTING NO TOOLS X 2
CLOSE DRAIN PORT RVOA CAP AND REMOVE DRAIN PORT RVOA	6.l	1.5	8A	1	15.4	0.4	0.4	SINGLE THREADED CONNECTION (1 RVOA)
ATTACH HELIUM BACKFILL SYSTEM TO VENT PORT	7.c	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
DISCONNECT HBS FROM MPC	7.f	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
CLOSE VENT PORT RVOA AND DISCONNECT VENT PORT RVOA	7.g	1.5	8A	1	15.4	0.4	0.4	SINGLE THREADED CONNECTION (1 RVOA)
WIPE INSIDE AREA OF VENT AND DRAIN PORT RECESSES	8.a	2	8A	1	15.4	0.5	0.5	2 PORTS, 1 MIN/PORT
PLACE COVER PLATE OVER VENT PORT RECESS	8.b	1	8A	1	15.4	0.3	0.3	INSTALLED BY HAND NO TOOLS (2/MIN)
VISUALLY INSPECT TACK WELDS	8.d	10	8A	1	15.4	2.6	2.6	MEASURED DURING WELD MOCKUP TESTING
PERFORM LIQUID PENETRANT EXAMINATION ON VENT AND DRAIN COVER PLATE ROOT WELD	8.f	45	8A	1	15.4	11.6	11.6	MEASURED DURING WELD MOCKUP TESTING
PERFORM A LIQUID PENETRANT EXAMINATION ON VENT AND DRAIN PORT COVER WELD	8.h	45	8A	1	15.4	11.6	11.6	CONSULTATION WITH UST&D ON PROTOTYPE
FLUSH CAVITY WITH HELIUM AND INSTALL SET SCREWS	9.b	2	8A	1	15.4	6.7	6.7	4 SET SCREWS @2/MINUTE
PLUG WELD OVER ET SCREWS	9.b	8	8A	1	15.4	6.7	6.7	FOUR SINGLE SPOT WELDS @ 1 PER 2 MINTES
INSTALL MSLD OVER VENT PORT COVER PLATE	9.f	2	8A	1	15.4	0.5	0.5	INSTALLED BY HAND NO TOOLS
INSTALL MSLD OVER DRAIN PORT COVER PLATE	9.f	2	8A	1	15.4	0.5	0.5	INSTALLED BY HAND NO TOOLS
INSTALL AND ALIGN CLOSURE RING	10.a	5	8A	1	15.4	1.3	1.3	INSTALLED BY HAND NO TOOLS
VISUALLY INSPECT TACK WELDS	10.c	5	8A	1	15.4	1.3	1.3	10 TACKS @ 2/MIN

Table 10.3.1a
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
PERFORM A LIQUID PENETRANT EXAMINATION ON CLOSURE RING ROOT WELDS	10.g	90	8A	1	15.4	23.1	23.1	MEASURED DURING WELD MOCKUP TESTING
PERFORM A LIQUID PENETRANT EXAMINATION ON CLOSURE RING FINAL WELD	10.g	90	8A	1	15.4	23.1	23.1	MEASURED DURING WELD MOCKUP TESTING
RIG AWS TO CRANE	10.j	12	8A	1	15.4	3.1	3.1	10 MIN TO DISCONNECT LINES, 4 SHACKLES@2/MIN
Section 8.1.6								
REMOVE ANNULUS SHIELD	1	1	8A	1	15.4	0.3	0.3	SHIELD PLACED BY HAND
ATTACH DRAIN LINE TO HI-TRAC	2	1	9D	1	135.28	2.3	2.3	1" THREADED FITTING NO TOOLS
POSITION HI-TRAC TOP LID	3	10	9B	2	15.4	2.6	5.1	VERTICAL FLANGED CONNECTION
TORQUE TOP LID BOLTS	4	12	9B	1	15.4	3.1	3.1	24 BOLTS AT 2/MIN (INSTALL AND TORQUE,1 PASS)
INSTALL MPC LIFT CLEATS AND MPC SUPPORT STAYS	5	25	9A	2	67.84	28.3	56.5	INSTALL CLEATS AND HYDRO TORQUE 4 BOLTS
REMOVE TEMPORARY SHIELD RING DRAIN PLUGS	6	1	9B	1	15.4	0.3	0.3	8 PLUGS @ 8/MIN
REMOVE TEMPORARY SHIELD RING SEGMENTS	6	4	9A	1	67.84	4.5	4.5	REMOVED BY HAND NO TOOLS (8 SEGS@2/MIN)
ATTACH MPC SUPPORT STAYS TO LIFT YOKE	7.a	4	9A	2	67.84	4.5	9.0	INSTALLED BY HAND NO TOOLS
POSITION HI-TRAC ABOVE TRANSFER STEP	7.c	15	9C	1	38.9	9.7	9.7	100 FT @ 10 FT/MIN (CRANE SPEED)+ 5MIN TO ALIGN
REMOVE BOTTOM LID BOLTS	7.f	6	10A	1	135.28	13.5	13.5	36 BOLTS@6 BOLTS/MIN IMPACT TOOLS USED
INSTALL TRANSFER LID BOLTS	7.j	18	11B	1	135.28	40.6	40.6	36 BOLTS @ 2/MIN IMPACT TOOLS USED 1 PASS
DISCONNECT MPC SUPPORT STAYS	7.l	4	9A	2	67.84	4.5	9.0	INSTALLED BY HAND NO TOOLS
Section 8.1.7								
POSITION HI-TRAC ON TRANSPORT DEVICE	1	20	11A	2	38.9	13.0	25.9	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
TRANSPORT HI-TRAC TO OUTSIDE TRANSFER LOCATION	1.b	90	12A	3	18.64	28.0	83.9	DRIVER AND 2 SPOTTERS
ATTACH OUTSIDE LIFTING DEVICE LIFT LINKS	5	2	12A	2	18.64	0.6	1.2	2 LINKS@1/MIN

Table 10.3.1a
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK
ESTIMATED OPERATIONAL EXPOSURES† (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
MATE OVERPACKS	6	10	13B	2	41.91	7.0	14.0	ALIGNMENT GUIDES USED
ATTACH MPC LIFT SLINGS TO MPC LIFT CLEATS	7	10	13A	2	67.84	11.3	22.6	2 SLINGS@5MIN/SLING NO TOOLS
REMOVE TRANSFER LID DOOR LOCKING PINS AND OPEN DOORS	10	4	13B	2	41.91	2.8	5.6	2 PINS@2MIN/PIN
INSTALL TRIM PLATES	11	4	13B	2	41.91	2.8	5.6	INSTALLED BY HAND
DISCONNECT SLINGS FROM MPC LIFTING DEVICE	13	10	13A	2	67.84	11.3	22.6	2 SLINGS@5MIN/SLING
REMOVE MPC LIFT CLEATS AND MPC LIFT SLINGS	15	10	14A	1	200.07	33.3	33.3	4 BOLTS,NO TORQUING
INSTALL HOLE PLUGS IN EMPTY MPC BOLT HOLES	15	2	14A	1	200.07	6.7	6.7	4 PLUGS AT 2/MIN NO TORQUING
REMOVE HI-STORM VENT DUCT SHIELD INSERTS	16.a	2	15A	1	7.85	0.3	0.3	4 SHACKLES@2/MIN
REMOVE ALIGNMENT DEVICE	16.c	4	15A	1	7.85	0.5	0.5	REMOVED BY HAND NO TOOLS (4 PCS@1/MIN)
INSTALL HI-STORM LID AND INSTALL LID STUDS/NUTS	16.c	25	16A	2	2.96	1.2	2.5	INSTALL LID AND HYDRO TORQUE 4 BOLTS
INSTALL HI-STORM EXIT VENT GAMMA SHIELD CROSS PLATES	16.e	4	16B	1	22.88	1.5	1.5	4 PCS @ 1/MIN INSTALL BY HAND NO TOOLS
INSTALL ~~THERMOCOUPLE~~*TEMPERATURE ELEMENTS*	16.e	20	16B	1	22.88	7.6	7.6	4@5MIN/~~THERMOCOUPLE~~*TEMPERATURE ELEMENT*
INSTALL EXIT VENT SCREENS	16.e	20	16B	1	22.88	7.6	7.6	4 SCREENS@5MIN/SCREEN
REMOVE HI-STORM LID LIFTING DEVICE	16.f	2	16A	1	2.96	0.1	0.1	4 SHACKLES@2/MIN
INSTALL HOLE PLUGS IN EMPTY HOLES	16.f	2	16A	1	2.96	0.1	0.1	4 PLUGS AT 2/MIN NO TORQUING
PERFORM SHIELDING EFFECTIVENESS TESTING	16.g	16	16D	2	9.96	2.7	5.3	16 POINTS@1 MIN
SECURE HI-STORM TO TRANSPORT DEVICE	16.h	10	16A	2	2.96	0.5	1.0	ASSUMES AIR PAD
TRANSFER HI-STORM TO ITS DESIGNATED STORAGE LOCATION	17.a	40	16C	1	7.89	5.3	5.3	200 FEET @ 4FT/MIN
INSERT HI-STORM LIFTING JACKS	17.b	4	16D	1	9.96	0.7	0.7	4 JACKS@1/MIN

Table 10.3.1a
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK
ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
REMOVE AIR PAD	17.b	5	16D	2	9.96	0.8	1.7	1 PAD MOVED BY HAND
REMOVE HI-STORM LIFTING JACKS	17.c	4	16D	1	9.96	0.7	0.7	4 JACKS@1/MIN
INSTALL INLET VENT SCREENS/CROSS PLATES	18	20	16D	1	9.96	3.3	3.3	4 SCREENS@5MIN/SCREEN
PERFORM AIR TEMPERATURE RISE TEST	19	8	16B	1	22.88	3.1	3.1	8 MEASUREMENTS@1/MIN
TOTAL							**787.4 PERSON-MREM**	

Table 10.3.1b
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
Section 8.1.4								
LOAD PRE-SELECTED FUEL ASSEMBLIES INTO MPC	2	1020	1	2	3	51.0	102.0	15 MINUTES PER ASSEMBLY/68 ASSY
PERFORM POST-LOADING VISUAL VERIFICATION OF ASSEMBLY IDENTIFICATION	3	68	1	2	3	3.4	6.8	1 MINUTES PER ASSY/68 ASSY
Section 8.1.5								
INSTALL MPC LID AND ATTACH LIFT YOKE	1.g	45	2	2	3	2.3	4.5	CONSULTATION WITH CALVERT CLIFFS
RAISE HI-TRAC TO SURFACE OF SPENT FUEL POOL	1.i	20	2	2	3	1.0	2.0	40 FEET @ 2 FT/MINUTE (CRANE SPEED)
SURVEY MPC LID FOR HOT PARTICLES	1.i	3	3A	1	18.35	0.9	0.9	TELESCOPING DETECTOR USED
VERIFY MPC LID IS SEATED	1.j	0.5	3A	1	18.35	0.2	0.2	VISUAL VERIFICATION FROM 3 METERS
INSTALL LID RETENTION SYSTEM BOLTS	1.k	6	3B	2	64.04	6.4	12.8	24 BOLTS @ 1/PERSON-MINUTE
REMOVE HI-TRAC FROM SPENT FUEL POOL	1.m	8.5	3C	1	295.96	41.9	41.9	17 FEET @ 2 FT/MIN (CRANE SPEED)
DECONTAMINATE HI-TRAC BOTTOM	1.n	10	3D	1	234.04	39.0	39.0	LONG HANDLED TOOLS, PRELIMINARY DECON
TAKE SMEARS OF HI-TRAC EXTERIOR SURFACES	1.n	5	5B	1	376.05	31.3	31.3	50 SMEARS @ 10 SMEARS/MINUTE
DISCONNECT ANNULUS OVERPRESSURE SYSTEM	1.o	0.5	5C	1	125.48	1.0	1.0	QUICK DISCONNECT COUPLING
SET HI-TRAC IN CASK PREPARATION AREA	1.p	10	4A	1	64.04	10.7	10.7	100 FT @ 10 FT/MIN (CRANE SPEED)
REMOVE NEUTRON SHIELD JACKET FILL PLUG	1.q	2	4A	1	64.04	2.1	2.1	SINGLE PLUG, NO SPECIAL TOOLS
INSTALL NEUTRON SHIELD JACKET FILL PLUG	1.q	2	5B	1	376.05	12.5	12.5	SINGLE PLUG, NO SPECIAL TOOLS

[†] See notes at bottom of Table 10.3.4.

Table 10.3.1b
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES† (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
DISCONNECT LID RETENTION SYSTEM	1.r	6	5A	2	55.41	5.5	11.1	24 BOLTS @ 1 BOLT/PERSON MINUTES
MEASURE DOSE RATES AT MPC LID	1.t	3	5A	1	55.41	2.8	2.8	TELESCOPING DETECTOR USED
DECONTAMINATE AND SURVEY HI-TRAC	1.t	103	5B	1	376.05	645.6	645.6	490 SQ-FT@5 SQ-FT/PRERSON-MINUTE+50 SMEARS@10 SMEARS/MINUTE
INSTALL TEMPORARY SHIELD	1.v	16	6A	2	30.91	8.2	16.5	8 SEGMENTS @ 1 SEGMENT/PERSON MIN
FILL TEMPORARY SHIELD RING	1.v	25	6A	1	30.91	12.9	12.9	230 GAL @10GPM, LONG HANDLED SPRAY WAND
ATTACH DRAIN LINE TO HI-TRAC DRAIN PORT	1.w	0.5	5C	1	125.48	1.0	1.0	QUICK DISCONNECT COUPLING
INSTALL RVOAs	2.a	2	6A	1	30.91	1.0	1.0	SINGLE THREADED CONNECTION X 2 RVOAs
ATTACH WATER PUMP TO DRAIN PORT	2.b	2	6A	1	30.91	1.0	1.0	POSITION PUMP SELF PRIMING
DISCONNECT WATER PUMP	2.c	5	6A	1	30.91	2.6	2.6	DRAIN HOSES MOVE PUMP
DECONTAMINATE MPC LID TOP SURFACE AND SHELL AREA ABOVE INFLATABLE ANNULUS SEAL	2.d	6	6A	1	30.91	3.1	3.1	30 SQ-FT @5 SQ-FT/MINUTE+10 SMEARS@10 SMEARS/MINUTE
REMOVE INFLATABLE ANNULUS SEAL	2.e	3	6A	1	30.91	1.5	1.5	SEAL PULLS OUT DIRECTLY
SURVEY MPC LID TOP SURFACES AND ACCESSIBLE AREAS OF TOP THREE INCHES OF MPC SHELL	2.f	1	6A	1	30.91	0.5	0.5	10 SMEARS@10 SMEARS/MINUTE
INSTALL ANNULUS SHIELD	2.g	2	6A	1	30.91	1.0	1.0	SHIELD PLACED BY HAND
CENTER LID IN MPC SHELL	3.a	20	6A	3	30.91	10.3	30.9	CONSULTATION WITH CALVERT CLIFFS
INSTALL MPC LID SHIMS	3.b	12	6A	2	30.91	6.2	12.4	MEASURED DURING WELD MOCKUP TESTING
POSITION AWS BASEPLATE SHIELD ON MPC LID	3.c	20	7A	2	30.91	10.3	20.6	ALIGN AND REMOVE 4 SHACKLES

Table 10.3.1b
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
INSTALL AUTOMATED WELDING SYSTEM ROBOT	3.c	8	7A	2	30.91	4.1	8.2	ALIGN AND REMOVE 4 SHACKLES/4 QUICK CONNECTS@1/MIN
VISUALLY INSPECT TACK WELD	3.e	5	7A	1	30.91	2.6	2.6	MEASURED DURING WELD MOCKUP TESTING
PERFORM LIQUID PENETRANT EXAMINATION OF WELD ROOT	3.g	45	7A	1	30.91	23.2	23.2	MEASURED DURING WELD MOCKUP TESTING
PERFORM INTERMEDIATE LIQUID PENETRANT EXAMINATION (3 SETS)	3.h	135	7A	1	30.91	69.5	69.5	MEASURED DURING WELD MOCKUP TESTING
PERFORM LIQUID PENETRANT EXAMINATION ON MPC LID FINAL PASS	3.i	45	7A	1	30.91	23.2	23.2	MEASURED DURING WELD MOCKUP TESTING
ATTACH DRAIN LINE TO VENT PORT	4.a	1	7A	1	30.91	0.5	0.5	1" THREADED FITTING NO TOOLS
VISUALLY EXAMINE MPC LID-TO-SHELL WELD FOR LEAKAGE OF WATER	4.c	10	7A	1	30.91	5.2	5.2	10 MIN TEST DURATION
DISCONNECT WATER FILL LINE AND DRAIN LINE	4.c	2	7A	1	30.91	1.0	1.0	1" THREADED FITTING NO TOOLS X 2
REPEAT LIQUID PENETRANT EXAMINATION ON MPC LID FINAL PASS	4.d	45	7A	1	30.91	23.2	23.2	5 MIN TO APPLY, 7 MIN TO WIPE, 5 APPLY DEV, INSP (24 IN/MIN)
ATTACH GAS SUPPLY TO VENT PORT	4.e	1	7A	1	30.91	0.5	0.5	1" THREADED FITTING NO TOOLS
ATTACH DRAIN LINE TO DRAIN PORT	4.e	1	7A	1	30.91	0.5	0.5	1" THREADED FITTING NO TOOLS
CONNECT MSLD SNIFFER TO AUTOMATED WELDING SYSTEM	4.i	4	8A	1	52.84	3.5	3.5	SIMPLE ATTACHMENT NO TOOLS
DISCONNECT MSLD SNIFFER FROM AUTOMATED WELDING SYSTEM	4.i	4	8A	1	52.84	3.5	3.5	SIMPLE ATTACHMENT NO TOOLS
ATTACH DRAIN LINE TO VENT PORT	5.a	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
ATTACH WATER FILL LINE TO DRAIN PORT	5.a	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS

Table 10.3.1b
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES† (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
DISCONNECT WATER FILL DRAIN LINES FROM MPC	5.b	2	8A	1	52.84	1.8	1.8	1" THREADED FITTING NO TOOLS X 2
ATTACH HELIUM OR NITROGEN SUPPLY TO VENT PORT	5.c	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
ATTACH DRAIN LINE TO DRAIN PORT	5.d	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
DISCONNECT GAS SUPPLY LINE FROM MPC	5.i	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
DISCONNECT DRAIN LINE FROM MPC	5.j	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
ATTACH ~~VACUUM DRYING~~*MOISTURE REMOVAL* SYSTEM ~~(VDS)~~ TO VENT AND DRAIN PORT RVOAs	6.a	2	8A	1	52.84	1.8	1.8	1" THREADED FITTING NO TOOLS
DISCONNECT ~~VDS~~ *MOISTURE REMOVAL SYSTEM* FROM MPC	6.j	2	8A	1	52.84	1.8	1.8	1" THREADED FITTING NO TOOLS X 2
CLOSE DRAIN PORT RVOA CAP AND REMOVE DRAIN PORT RVOA	6.l	1.5	8A	1	52.84	1.3	1.3	SINGLE THREADED CONNECTION (1 RVOA)
ATTACH HELIUM BACKFILL SYSTEM TO VENT PORT	7.c	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
DISCONNECT HBS FROM MPC	7.f	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
CLOSE VENT PORT RVOA AND DISCONNECT VENT PORT RVOA	7.g	1.5	8A	1	52.84	1.3	1.3	SINGLE THREADED CONNECTION (1 RVOA)
WIPE INSIDE AREA OF VENT AND DRAIN PORT RECESSES	8.a	2	8A	1	52.84	1.8	1.8	2 PORTS, 1 MIN/PORT
PLACE COVER PLATE OVER VENT PORT RECESS	8.b	1	8A	1	52.84	0.9	0.9	INSTALLED BY HAND NO TOOLS (2/MIN)
VISUALLY INSPECT TACK WELDS	8.d	10	8A	1	52.84	8.8	8.8	MEASURED DURING WELD MOCKUP TESTING
PERFORM LIQUID PENETRANT EXAMINATION ON VENT AND DRAIN COVER PLATE ROOT	8.f	45	8A	1	52.84	39.6	39.6	MEASURED DURING WELD MOCKUP TESTING

Table 10.3.1b
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
WELD								
PERFORM A LIQUID PENETRANT EXAMINATION ON VENT AND DRAIN PORT COVER WELD	8.h	45	8A	1	52.84	39.6	39.6	CONSULTATION WITH UST&D ON PROTOTYPE
FLUSH CAVITY WITH HELIUM AND INSTALL SET SCREWS	9.b	2	8A	1	52.84	1.8	23.9	4 SET SCREWS @2/MINUTE
PLUG WELD OVER ET SCREWS	9.b	8	8A	1	52.84	7.0	23.9	FOUR SINGLE SPOT WELDS @ 1 PER 2 MINTES
INSTALL MSLD OVER VENT PORT COVER PLATE	9.f	2	8A	1	52.84	1.8	1.8	INSTALLED BY HAND NO TOOLS
INSTALL MSLD OVER DRAIN PORT COVER PLATE	9.f	2	8A	1	52.84	1.8	1.8	INSTALLED BY HAND NO TOOLS
INSTALL AND ALIGN CLOSURE RING	10.a	5	8A	1	52.84	4.4	4.4	INSTALLED BY HAND NO TOOLS
VISUALLY INSPECT TACK WELDS	10.c	5	8A	1	52.84	4.4	4.4	10 TACKS @ 2/MIN
PERFORM A LIQUID PENETRANT EXAMINATION ON CLOSURE RING ROOT WELDS	10.g	90	8A	1	52.84	79.3	79.3	MEASURED DURING WELD MOCKUP TESTING
PERFORM A LIQUID PENETRANT EXAMINATION ON CLOSURE RING FINAL WELD	10.g	90	8A	1	52.84	79.3	79.3	MEASURED DURING WELD MOCKUP TESTING
RIG AWS TO CRANE	10.j	12	8A	1	52.84	10.6	10.6	10 MIN TO DISCONNECT LINES, 4 SHACKLES@2/MIN
Section 8.1.6								
REMOVE ANNULUS SHIELD	1	1	8A	1	52.84	0.9	0.9	SHIELD PLACED BY HAND
ATTACH DRAIN LINE TO HI-TRAC	2	1	9D	1	804.79	13.4	13.4	1" THREADED FITTING NO TOOLS
POSITION HI-TRAC TOP LID	3	10	9B	2	52.84	8.8	17.6	VERTICAL FLANGED CONNECTION
TORQUE TOP LID BOLTS	4	12	9B	1	52.84	10.6	10.6	24 BOLTS AT 2/MIN (INSTALL AND TORQUE,1 PASS)
INSTALL MPC LIFT CLEATS AND MPC SUPPORT STAYS	5	25	9A	2	177.55	74.0	148.0	INSTALL CLEATS AND HYDRO TORQUE 4 BOLTS

Table 10.3.1b
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
REMOVE TEMPORARY SHIELD RING DRAIN PLUGS	6	1	9B	1	52.84	0.9	0.9	8 PLUGS @ 8/MIN
REMOVE TEMPORARY SHIELD RING SEGMENTS	6	4	9A	1	177.55	11.8	11.8	REMOVED BY HAND NO TOOLS (8 SEGS@2/MIN)
ATTACH MPC SUPPORT STAYS TO LIFT YOKE	7.a	4	9A	2	177.55	11.8	23.7	INSTALLED BY HAND NO TOOLS
POSITION HI-TRAC ABOVE TRANSFER STEP	7.c	15	9C	1	316.83	79.2	79.2	100 FT @ 10 FT/MIN (CRANE SPEED)+ 5MIN TO ALIGN
REMOVE BOTTOM LID BOLTS	7.f	6	10A	1	804.79	80.5	80.5	36 BOLTS@6 BOLTS/MIN IMPACT TOOLS USED
INSTALL TRANSFER LID BOLTS	7.j	18	11B	1	804.79	241.4	241.4	36 BOLTS @ 2/MIN IMPACT TOOLS USED 1 PASS
DISCONNECT MPC SUPPORT STAYS	7.l	4	9A	2	177.55	11.8	23.7	INSTALLED BY HAND NO TOOLS
Section 8.1.7								
POSITION HI-TRAC ON TRANSPORT DEVICE	1	20	11A	2	316.83	105.6	211.2	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
TRANSPORT HI-TRAC TO OUTSIDE TRANSFER LOCATION	1.b	90	12A	3	18.64	28.0	83.9	DRIVER AND 2 SPOTTERS
ATTACH OUTSIDE LIFTING DEVICE LIFT LINKS	5	2	12A	2	18.64	0.6	1.2	2 LINKS@1/MIN
MATE OVERPACKS	6	10	13B	2	284.51	47.4	94.8	ALIGNMENT GUIDES USED
ATTACH MPC LIFT SLINGS TO MPC LIFT CLEATS	7	10	13A	2	177.55	29.6	59.2	2 SLINGS@5MIN/SLING NO TOOLS
REMOVE TRANSFER LID DOOR LOCKING PINS AND OPEN DOORS	10	4	13B	2	284.51	19.0	37.9	2 PINS@2MIN/PIN
INSTALL TRIM PLATES	11	4	13B	2	284.51	19.0	37.9	INSTALLED BY HAND
DISCONNECT SLINGS FROM MPC LIFTING DEVICE	13	10	13A	2	177.55	29.6	59.2	2 SLINGS@5MIN/SLING
REMOVE MPC LIFT CLEATS AND MPC LIFT SLINGS	15	10	14A	1	255.57	42.6	42.6	4 BOLTS,NO TORQUING
INSTALL HOLE PLUGS IN EMPTY MPC BOLT HOLES	15	2	14A	1	255.57	8.5	8.5	4 PLUGS AT 2/MIN NO TORQUING

Table 10.3.1b
HI-STORM 100 SYSTEM LOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
REMOVE HI-STORM VENT DUCT SHIELD INSERTS	16.a	2	15A	1	27.85	0.9	0.9	4 SHACKLES@2/MIN
REMOVE ALIGNMENT DEVICE	16.c	4	15A	1	27.85	1.9	1.9	REMOVED BY HAND NO TOOLS (4 PCS@1/MIN)
INSTALL HI-STORM LID AND INSTALL LID STUDS/NUTS	16.c	25	16A	2	4.26	1.8	3.6	INSTALL LID AND HYDRO TORQUE 4 BOLTS
INSTALL HI-STORM EXIT VENT GAMMA SHIELD CROSS PLATES	16.e	4	16B	1	34.58	2.3	2.3	4 PCS @ 1/MIN INSTALL BY HAND NO TOOLS
INSTALL ~~THERMOCOUPLE~~*TEMPERATURE ELEMENTS*	16.e	20	16B	1	34.58	11.5	11.5	4@5MIN/~~THERMOCOUPLE~~*TEMPERATURE ELEMENT*
INSTALL EXIT VENT SCREENS	16.e	20	16B	1	34.58	11.5	11.5	4 SCREENS@5MIN/SCREEN
REMOVE HI-STORM LID LIFTING DEVICE	16.f	2	16A	1	4.26	0.1	0.1	4 SHACKLES@2/MIN
INSTALL HOLE PLUGS IN EMPTY HOLES	16.f	2	16A	1	4.26	0.1	0.1	4 PLUGS AT 2/MIN NO TORQUING
PERFORM SHIELDING EFFECTIVENESS TESTING	16.g	16	16D	2	34.76	9.3	18.5	16 POINTS@1 MIN
SECURE HI-STORM TO TRANSPORT DEVICE	16.h	10	16A	2	4.26	0.7	1.4	ASSUMES AIR PAD
TRANSFER HI-STORM TO ITS DESIGNATED STORAGE LOCATION	17.a	40	16C	1	11.79	7.9	7.9	200 FEET @ 4FT/MIN
INSERT HI-STORM LIFTING JACKS	17.b	4	16D	1	34.76	2.3	2.3	4 JACKS@1/MIN
REMOVE AIR PAD	17.b	5	16D	2	34.76	2.9	5.8	1 PAD MOVED BY HAND
REMOVE HI-STORM LIFTING JACKS	17.c	4	16D	1	34.76	2.3	2.3	4 JACKS@1/MIN
INSTALL INLET VENT SCREENS/CROSS PLATES	18	20	16D	1	34.76	11.6	11.6	4 SCREENS@5MIN/SCREEN
PERFORM AIR TEMPERATURE RISE TEST	19	8	16B	1	34.58	4.6	4.6	8 MEASUREMENTS@1/MIN
TOTAL							2906.5 PERSON- MREM	

Table 10.3.2a
HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
Section 8.3.2 (Step Sequence Varies By Site and Mode of Transport)								
REMOVE INLET VENT SCREENS	1	20	16D	1	9.96	3.3	3.3	4 SCREENS@5MIN/SCREEN
INSERT HI-STORM LIFTING JACKS	1	4	16D	1	9.96	0.7	0.7	4 JACKS@1/MIN
INSERT AIR PAD	1	5	16D	2	9.96	0.8	1.7	1 PAD MOVED BY HAND
REMOVE HI-STORM LIFTING JACKS	1	4	16D	1	9.96	0.7	0.7	4 JACKS@1/MIN
TRANSFER HI-STORM TO MPC TRANSFER LOCATION	1	40	16C	1	7.89	5.3	5.3	200 FEET @ 4FT/MIN
REMOVE HI-STORM LID STUDS/NUTS	1	10	16A	1	2.96	0.5	0.5	4 BOLTS NO TORQUE
REMOVE HI-STORM LID LIFTING HOLE PLUGS AND INSTALL LID LIFTING SLING	1	2	16A	1	2.96	0.1	0.1	4 PLUGS AT 2/MIN NO TORQUING
REMOVE GAMMA SHIELD CROSS PLATES	1	4	16B	1	22.88	1.5	1.5	4 PLATES@1/MIN
REMOVE ~~THERMOCOUPLE~~*TEMPERATURE ELEMENTS*	1	8	16B	1	22.88	3.1	3.1	4 ~~THERMCPL~~*TEMP. ELEMENTS* @ 2MIN/~~THERMCPL~~*TEMP. ELEMENT* NO TORQUE
REMOVE HI-STORM LID	1	2	16A	1	2.96	0.1	0.1	4 SHACKLES@2/MIN
INSTALL HI-STORM VENT DUCT SHIELD INSERTS	1	2	15A	1	7.85	0.3	0.3	4 SHACKLES@2/MIN
INSTALL ALIGNMENT DEVICE	1	4	15A	1	7.85	0.5	0.5	REMOVED BY HAND NO TOOLS (4 PCS@1/MIN)
REMOVE MPC LIFT CLEAT HOLE PLUGS	1	2	14A	1	200.07	6.7	6.7	4 PLUGS AT 2/MIN NO TORQUING
INSTALL MPC LIFT CLEATS AND MPC LIFT SLINGS	1	2	14A	1	200.07	6.7	6.7	4 PLUGS AT 2/MIN NO TORQUING
ALIGN HI-TRAC OVER HI-STORM AND MATE OVERPACKS	7	10	13B	2	41.91	7.0	14.0	ALIGNMENT GUIDES USED

[†] See notes at bottom of Table 10.3.4.

Table 10.3.2a

HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
PULL MPC LIFT SLINGS THROUGH TOP LID HOLE	9	10	13A	2	67.84	11.3	22.6	2 SLINGS@5MIN/SLING
INSTALL TRIM PLATES	10	4	13B	2	41.91	2.8	5.6	INSTALLED BY HAND NO FASTENERS
ATTACH MPC LIFT SLING TO LIFTING DEVICE	11	10	13A	1	67.84	11.3	11.3	2 SLINGS@5MIN/SLING NO BOLTING
CLOSE HI-TRAC DOORS AND INSTALL DOOR LOCKING PINS	14	4	13B	2	41.91	2.8	5.6	2 PINS@2MIN/PIN
DISCONNECT SLINGS FROM MPC LIFT CLEATS	16	10	13A	2	67.84	11.3	22.6	2 SLINGS@5MIN/SLING
DOWNEND HI-TRAC ON TRANSPORT FRAME	1	20	12A	2	18.64	6.2	12.4	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
TRANSPORT HI-TRAC TO FUEL BUILDING	1	90	12A	1	18.64	28.0	28.0	DRIVER RECEIVES MOST DOSE
UPEND HI-TRAC	1	20	12A	2	18.64	6.2	12.4	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
Section 8.3.3								
MOVE HI-TRAC TO TRANSFER SLIDE	1.a	20	11A	2	38.9	13.0	25.9	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
ATTACH MPC SUPPORT STAYS	1.a	4	9A	2	67.84	4.5	9.0	INSTALLED BY HAND NO TOOLS
REMOVE TRANSFER LID BOLTS	1.e	6	11B	1	135.28	13.5	13.5	36 BOLTS@6 BOLTS/MIN IMPACT TOOLS USED
INSTALL POOL LID BOLTS	1.i	18	10A	1	135.28	40.6	40.6	36 BOLTS @ 2/MIN IMPACT TOOLS USED 1 PASS
DISCONNECT MPC SUPPORT STAYS AND LIFT CLEATS	1.k	10	9A	1	67.84	11.3	11.3	4 BOLTS,NO TORQUING
PLACE HI-TRAC IN PREPARATION AREA	1.m	15	9C	1	38.9	9.7	9.7	100 FT @ 10 FT/MIN (CRANE SPEED)+ 5MIN TO ALIGN
REMOVE TOP LID BOLTS	2.a	6	9B	1	15.4	1.5	1.5	24 BOLTS AT 4/MIN (NO TORQUE IMPACT TOOLS)
REMOVE HI-TRAC TOP LID	2.a	2	6A	1	11.05	0.4	0.4	4 SHACKLES@2/MIN
ATTACH WATER FILL LINE TO HI-TRAC DRAIN PORT	2.b	0.5	9D	1	135.28	1.1	1.1	QUICK DISCONNECT NO TOOLS

Table 10.3.2a
HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
INSTALL BOLT PLUGS OR WATERPROOF TAPE FROM HI-TRAC TOP BOLT HOLES	3.a	9	8A	1	15.4	2.3	2.3	18 HOLES@2/MIN
CORE DRILL CLOSURE RING AND VENT AND DRAIN PORT COVER PLATES	3.b	40	7A	2	11.05	7.4	14.7	20 MINUTES TO INSTALL/ALIGN +10 MIN/COVER
REMOVE CLOSURE RING SECTION AND VENT AND DRAIN PORT COVER PLATES	3.c	1	8A	1	15.4	0.3	0.3	2 COVERS@2/MIN NO TOOLS
ATTACH RVOAS	4.a	2	8A	1	15.4	0.5	0.5	SINGLE THREADED CONNECTION (1 RVOA)
ATTACH A SAMPLE BOTTLE TO VENT PORT RVOA	4.b	0.5	8A	1	15.4	0.1	0.1	1" THREADED FITTING NO TOOLS
GATHER A GAS SAMPLE FROM MPC	4.d	0.5	8A	1	15.4	0.1	0.1	SMALL BALL VALVE
CLOSE VENT PORT CAP AND DISCONNECT SAMPLE BOTTLE	4.e	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
ATTACH COOL-DOWN SYSTEM TO RVOAs	5.a	2	8A	1	15.4	0.5	0.5	1" THREADED FITTING NO TOOLS X 2
DISCONNECT GAS LINES TO VENT AND DRAIN PORT RVOAs	5.k	1	8A	1	15.4	0.3	0.3	1" THREADED FITTING NO TOOLS
VACUUM TOP SURFACES OF MPC AND HI-TRAC	5.m	10	6A	1	11.05	1.8	1.8	SHOP VACUUM WITH WAND + HAND WIPE
REMOVE ANNULUS SHIELD	6.a	1	8A	1	15.4	0.3	0.3	SHIELD PLACED BY HAND
MANUALLY INSTALL INFLATABLE SEAL	6.b	10	6A	2	11.05	1.8	3.7	CONSULTATION WITH CALVERT CLIFFS
OPEN NEUTRON SHIELD JACKET DRAIN VALVE	7.a	2	5C	1	31.89	1.1	1.1	SINGLE THREADED CONNECTION
CLOSE NEUTRON SHIELD JACKET DRAIN VALVE	7.a	2	5C	1	31.89	1.1	1.1	SINGLE THREADED CONNECTION
REMOVE MPC LID LIFTING HOLE PLUGS	7.b	2	5A	1	21.35	0.7	0.7	4 PLUGS AT 2/MIN NO TORQUING
ATTACH LID RETENTION SYSTEM	7.d	12	5A	1	21.35	4.3	4.3	24 BOLTS @ 2 MINUTES/BOLT
ATTACH ANNULUS	7.e	0.5	5C	1	31.89	0.3	0.3	QUICK DISCONNECT NO TOOLS

Table 10.3.2a
HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 125-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES† (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
OVERPRESSURE SYSTEM								
POSITION HI-TRAC OVER CASK LOADING AREA	7.f	10	5C	1	31.89	5.3	5.3	100 FT @ 10 FT/MIN (CRANE SPEED)
LOWER HI-TRAC INTO SPENT FUEL POOL	7.g	8.5	3C	1	38.9	5.5	5.5	17 FEET @ 2 FT/MIN (CRANE SPEED)
REMOVE LID RETENTION BOLTS	7.i	12	3B	1	19.45	3.9	3.9	24 BOLTS @ 2/MINUTE
PLACE HI-TRAC ON FLOOR	7.j	20	2	2	2	0.7	1.3	40 FEET @ 2 FT/MINUTE (CRANE SPEED)
REMOVE MPC LID	7.l	20	2	2	2	0.7	1.3	CONSULTATION WITH CALVERT CLIFFS
Section 8.3.4								
REMOVE SPENT FUEL ASSEMBLIES FROM MPC	1	1020	1	2	1	17.0	34.0	15 MINUTES PER ASSEMBLY/68 ASSY
TOTAL							**362.2 PERSON-MREM**	

Table 10.3.2b
HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
Section 8.3.2 (Step Sequence Varies By Site and Mode of Transport)								
REMOVE INLET VENT SCREENS	1	20	16D	1	34.76	11.6	11.6	4 SCREENS@5MIN/SCREEN
INSERT HI-STORM LIFTING JACKS	1	4	16D	1	34.76	2.3	2.3	4 JACKS@1/MIN
INSERT AIR PAD	1	5	16D	2	34.76	2.9	5.8	1 PAD MOVED BY HAND
REMOVE HI-STORM LIFTING JACKS	1	4	16D	1	34.76	2.3	2.3	4 JACKS@1/MIN
TRANSFER HI-STORM TO MPC TRANSFER LOCATION	1	40	16C	1	11.79	7.9	7.9	200 FEET @ 4FT/MIN
REMOVE HI-STORM LID STUDS/NUTS	1	10	16A	1	4.26	0.7	0.7	4 BOLTS NO TORQUE
REMOVE HI-STORM LID LIFTING HOLE PLUGS AND INSTALL LID LIFTING SLING	1	2	16A	1	4.26	0.1	0.1	4 PLUGS AT 2/MIN NO TORQUING
REMOVE GAMMA SHIELD CROSS PLATES	1	4	16B	1	34.58	2.3	2.3	4 PLATES@1/MIN
REMOVE ~~THERMOCOUPLE~~*TEMPERATURE ELEMENTS*	1	8	16B	1	34.58	4.6	4.6	4 ~~THERMCPL~~*TEMP. ELEMENTS* @ 2MIN/~~THERMCPL~~*TEMP. ELEMENT* NO TORQUE
REMOVE HI-STORM LID	1	2	16A	1	4.26	0.1	0.1	4 SHACKLES@2/MIN
INSTALL HI-STORM VENT DUCT SHIELD INSERTS	1	2	15A	1	27.85	0.9	0.9	4 SHACKLES@2/MIN
INSTALL ALIGNMENT DEVICE	1	4	15A	1	27.85	1.9	1.9	REMOVED BY HAND NO TOOLS (4 PCS@1/MIN)
REMOVE MPC LIFT CLEAT HOLE PLUGS	1	2	14A	1	255.57	8.5	8.5	4 PLUGS AT 2/MIN NO TORQUING
INSTALL MPC LIFT CLEATS AND MPC LIFT SLINGS	1	2	14A	1	255.57	8.5	8.5	4 PLUGS AT 2/MIN NO TORQUING
ALIGN HI-TRAC OVER HI-STORM AND MATE OVERPACKS	7	10	13B	2	284.51	47.4	94.8	ALIGNMENT GUIDES USED

[†] See notes at bottom of Table 10.3.4.

Table 10.3.2b
HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
PULL MPC LIFT SLINGS THROUGH TOP LID HOLE	9	10	13A	2	177.55	29.6	59.2	2 SLINGS@5MIN/SLING
INSTALL TRIM PLATES	10	4	13B	2	284.51	19.0	37.9	INSTALLED BY HAND NO FASTENERS
ATTACH MPC LIFT SLING TO LIFTING DEVICE	11	10	13A	1	177.55	29.6	29.6	2 SLINGS@5MIN/SLING NO BOLTING
CLOSE HI-TRAC DOORS AND INSTALL DOOR LOCKING PINS	14	4	13B	2	284.51	19.0	37.9	2 PINS@2MIN/PIN
DISCONNECT SLINGS FROM MPC LIFT CLEATS	16	10	13A	2	177.55	29.6	59.2	2 SLINGS@5MIN/SLING
DOWNEND HI-TRAC ON TRANSPORT FRAME	1	20	12A	2	18.64	6.2	12.4	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
TRANSPORT HI-TRAC TO FUEL BUILDING	1	90	12A	1	18.64	28.0	28.0	DRIVER RECEIVES MOST DOSE
UPEND HI-TRAC	1	20	12A	2	18.64	6.2	12.4	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
Section 8.3.3								
MOVE HI-TRAC TO TRANSFER SLIDE	1.a	20	11A	2	316.83	105.6	211.2	ALIGN TRUNNIONS, DISCONNECT LIFT YOKE
ATTACH MPC SUPPORT STAYS	1.a	4	9A	2	177.55	11.8	23.7	INSTALLED BY HAND NO TOOLS
REMOVE TRANSFER LID BOLTS	1.e	6	11B	1	804.79	80.5	80.5	36 BOLTS@6 BOLTS/MIN IMPACT TOOLS USED
INSTALL POOL LID BOLTS	1.i	18	10A	1	804.79	241.4	241.4	36 BOLTS @ 2/MIN IMPACT TOOLS USED 1 PASS
DISCONNECT MPC SUPPORT STAYS AND LIFT CLEATS	1.k	10	9A	1	177.55	29.6	29.6	4 BOLTS,NO TORQUING
PLACE HI-TRAC IN PREPARATION AREA	1.m	15	9C	1	316.83	79.2	79.2	100 FT @ 10 FT/MIN (CRANE SPEED)+ 5MIN TO ALIGN
REMOVE TOP LID BOLTS	2.a	6	9B	1	52.84	5.3	5.3	24 BOLTS AT 4/MIN (NO TORQUE IMPACT TOOLS)
REMOVE HI-TRAC TOP LID	2.a	2	6A	1	30.91	1.0	1.0	4 SHACKLES@2/MIN
ATTACH WATER FILL LINE TO HI-TRAC DRAIN PORT	2.b	0.5	9D	1	804.79	6.7	6.7	QUICK DISCONNECT NO TOOLS

Table 10.3.2b
HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
INSTALL BOLT PLUGS OR WATERPROOF TAPE FROM HI-TRAC TOP BOLT HOLES	3.a	9	8A	1	52.84	7.9	7.9	18 HOLES@2/MIN
CORE DRILL CLOSURE RING AND VENT AND DRAIN PORT COVER PLATES	3.b	40	7A	2	30.91	20.6	41.2	20 MINUTES TO INSTALL/ALIGN +10 MIN/COVER
REMOVE CLOSURE RING SECTION AND VENT AND DRAIN PORT COVER PLATES	3.c	1	8A	1	52.84	0.9	0.9	2 COVERS@2/MIN NO TOOLS
ATTACH RVOAS	4.a	2	8A	1	52.84	1.8	1.8	SINGLE THREADED CONNECTION (1 RVOA)
ATTACH A SAMPLE BOTTLE TO VENT PORT RVOA	4.b	0.5	8A	1	52.84	0.4	0.4	1" THREADED FITTING NO TOOLS
GATHER A GAS SAMPLE FROM MPC	4.d	0.5	8A	1	52.84	0.4	0.4	SMALL BALL VALVE
CLOSE VENT PORT CAP AND DISCONNECT SAMPLE BOTTLE	4.e	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
ATTACH COOL-DOWN SYSTEM TO RVOAs	5.a	2	8A	1	52.84	1.8	1.8	1" THREADED FITTING NO TOOLS X 2
DISCONNECT GAS LINES TO VENT AND DRAIN PORT RVOAs	5.k	1	8A	1	52.84	0.9	0.9	1" THREADED FITTING NO TOOLS
VACUUM TOP SURFACES OF MPC AND HI-TRAC	5.m	10	6A	1	30.91	5.2	5.2	SHOP VACUUM WITH WAND + HAND WIPE
REMOVE ANNULUS SHIELD	6.a	1	8A	1	52.84	0.9	0.9	SHIELD PLACED BY HAND
MANUALLY INSTALL INFLATABLE SEAL	6.b	10	6A	2	30.91	5.2	10.3	CONSULTATION WITH CALVERT CLIFFS
OPEN NEUTRON SHIELD JACKET DRAIN VALVE	7.a	2	5C	1	125.48	4.2	4.2	SINGLE THREADED CONNECTION
CLOSE NEUTRON SHIELD JACKET DRAIN VALVE	7.a	2	5C	1	125.48	4.2	4.2	SINGLE THREADED CONNECTION
REMOVE MPC LID LIFTING HOLE PLUGS	7.b	2	5A	1	55.41	1.8	1.8	4 PLUGS AT 2/MIN NO TORQUING
ATTACH LID RETENTION SYSTEM	7.d	12	5A	1	55.41	11.1	11.1	24 BOLTS @ 2 MINUTES/BOLT
ATTACH ANNULUS	7.e	0.5	5C	1	125.48	1.0	1.0	QUICK DISCONNECT NO TOOLS

Table 10.3.2b
HI-STORM 100 SYSTEM UNLOADING OPERATIONS USING THE 100-TON HI-TRAC TRANSFER CASK ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
OVERPRESSURE SYSTEM								
POSITION HI-TRAC OVER CASK LOADING AREA	7.f	10	5C	1	125.48	20.9	20.9	100 FT @ 10 FT/MIN (CRANE SPEED)
LOWER HI-TRAC INTO SPENT FUEL POOL	7.g	8.5	3C	1	295.96	41.9	41.9	17 FEET @ 2 FT/MIN (CRANE SPEED)
REMOVE LID RETENTION BOLTS	7.i	12	3B	1	64.04	12.8	12.8	24 BOLTS @ 2/MINUTE
PLACE HI-TRAC ON FLOOR	7.j	20	2	2	3	1.0	2.0	40 FEET @ 2 FT/MINUTE (CRANE SPEED)
REMOVE MPC LID	7.l	20	2	2	3	1.0	2.0	CONSULTATION WITH CALVERT CLIFFS
Section 8.3.4								
REMOVE SPENT FUEL ASSEMBLIES FROM MPC	1	1020	1	2	3	51.0	102.0	15 MINUTES PER ASSEMBLY/68 ASSY
TOTAL							**1384.2 PERSON-MREM**	

Table 10.3.3a
MPC TRANSFER INTO THE HI-STORM 100 SYSTEM DIRECTLY FROM TRANSPORT USING THE 125-TON HI-TRAC TRANSFER CASK
ESTIMATED OPERATIONAL EXPOSURES† (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
Section 8.5.2								
MEASURE HI-STAR DOSE RATES	2	16	17A	2	14.1	3.8	7.5	16 POINTS@1 POINT/MIN
REMOVE PERSONNEL BARRIER	3	10	17C	2	21.5	3.6	7.2	ATTACH SLING REMOVE 8 LOCKS
PERFORM REMOVABLE CONTAMINATION SURVEYS	4	1	17C	1	21.5	0.4	0.4	10 SMEARS@10 SMEARS/MINUTE
REMOVE IMPACT LIMITERS	5	16	17A	2	14.1	3.8	7.5	ATTACH FRAME REMOVE 22 BOLTS IMPACT TOOLS
REMOVE TIE-DOWN	6	6	17A	2	14.1	1.4	2.8	ATTACH 2-LEGGED SLING REMOVE 4 BOLTS
PERFORM A VISUAL INSPECTION OF OVERPACK	7	10	17B	1	9	1.5	1.5	CHECKSHEET USED
REMOVE REMOVABLE SHEAR RING SEGMENTS	8	4	17A	1	14.1	0.9	0.9	4 BOLTS EACH @2/MIN X 2 SEGMENTS
UPEND HI-STAR OVERPACK	9	20	17B	2	9	3.0	6.0	DISCONNECT LIFT YOKE
INSTALL TEMPORARY SHIELD RING SEGMENTS	10	16	18A	1	7.9	2.1	2.1	8 SEGMENTS @ 2 MIN/SEGMENT
FILL TEMPORARY SHIELD RING SEGMENTS	11	25	18A	1	7.9	3.3	3.3	230 GAL @10GPM, LONG HANDLED SPRAYER
REMOVE OVERPACK VENT PORT COVER PLATE	11.a	2	18A	1	7.9	0.3	0.3	4 BOLTS @2/MIN
ATTACH BACKFILL TOOL	11.a	2	18A	1	7.9	0.3	0.3	4 BOLTS @2/MIN
OPEN/CLOSE VENT PORT PLUG	11.c	0.5	18A	1	7.9	0.1	0.1	SINGLE TURN BY HAND NO TOOLS
REMOVE CLOSURE PLATE BOLTS	14	39	18A	2	7.9	5.1	10.3	52 BOLTS@4/MIN X 3 PASSES
REMOVE OVERPACK CLOSURE PLATE	14	2	18A	1	7.9	0.3	0.3	4 SHACKLES@2/MIN
INSTALL HI-STAR SEAL SURFACE PROTECTOR	15	2	19B	1	7.9	0.3	0.3	PLACED BY HAND NO TOOLS

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† See notes at bottom of Table 10.3.4.

Table 10.3.3a

MPC TRANSFER INTO THE HI-STORM 100 SYSTEM DIRECTLY FROM TRANSPORT USING THE 125-TON HI-TRAC TRANSFER CASK

ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
INSTALL TRANSFER COLLAR ON HI-STAR	16	10	19B	2	7.9	1.3	2.6	ALIGN AND POSITION REMOVE 4 SHACKLES
REMOVE MPC LIFT CLEAT HOLE PLUGS	17	2	19A	1	200.07	6.7	6.7	4 PLUGS AT 2/MIN NO TORQUING
INSTALL MPC LIFT CLEATS AND LIFT SLING	18	25	19A	2	200.07	83.4	166.7	INSTALL CLEATS AND HYDRO TORQUE 4 BOLTS
MATE OVERPACKS	27	10	20B	2	41.91	7.0	14.0	ALIGNMENT GUIDES USED
REMOVE DOOR LOCKING PINS AND OPEN DOORS	28	4	20B	2	41.91	2.8	5.6	2 PINS@2/MIN
INSTALL TRIM PLATES	29	4	20B	2	41.91	2.8	5.6	INSTALLED BY HAND NO FASTENERS
Section 8.5.3								
REMOVE TRIM PLATES	3	4	20B	2	41.91	2.8	5.6	INSTALLED BY HAND NO FASTENERS
DISCONNECT SLINGS FROM MPC LIFTING DEVICE	6	10	20A	2	67.84	11.3	22.6	2 SLINGS@5/MIN
REMOVE TRIM PLATES	6	4	13B	2	41.91	2.8	5.6	INSTALLED BY HAND NO FASTENERS
REMOVE MPC LIFT CLEATS AND MPC LIFT SLINGS	6	10	14A	1	200.07	33.3	33.3	4 BOLTS,NO TORQUING
INSTALL HOLE PLUGS IN EMPTY MPC BOLT HOLES	6	2	14A	1	200.07	6.7	6.7	4 PLUGS AT 2/MIN NO TORQUING
REMOVE HI-STORM VENT DUCT SHIELD INSERTS	6	2	15A	1	7.85	0.3	0.3	4 SHACKLES@2/MIN
REMOVE ALIGNMENT DEVICE	6	4	15A	1	7.85	0.5	0.5	REMOVED BY HAND NO TOOLS (4 PCS@1/MIN)
INSTALL HI-STORM LID AND INSTALL LID STUDS/NUTS	6	25	16A	2	2.96	1.2	2.5	INSTALL LID AND HYDRO TORQUE 4 BOLTS
INSTALL HI-STORM EXIT VENT GAMMA SHIELD CROSS PLATES	6	4	16B	1	22.88	1.5	1.5	4 PCS @ 1/MIN INSTALL BY HAND NO TOOLS
INSTALL ~~THERMOCOUPLE~~*TEMPERATURE*	6	20	16B	1	22.88	7.6	7.6	4@5MIN/~~THERMOCOUPLE~~*TEMPERATURE ELEMENT*

Table 10.3.3a
MPC TRANSFER INTO THE HI-STORM 100 SYSTEM DIRECTLY FROM TRANSPORT USING THE 125-TON HI-TRAC TRANSFER CASK
ESTIMATED OPERATIONAL EXPOSURES[†] (57,500 MWD/MTU, 12-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
ELEMENTS								
INSTALL EXIT VENT SCREENS	6	20	16B	1	22.88	7.6	7.6	4 SCREENS@5MIN/SCREEN
REMOVE HI-STORM LID LIFTING DEVICE	6	2	16A	1	2.96	0.1	0.1	4 SHACKLES@2/MIN
INSTALL HOLE PLUGS IN EMPTY HOLES	6	2	16A	1	2.96	0.1	0.1	4 PLUGS AT 2/MIN NO TORQUING
PERFORM SHIELDING EFFECTIVENESS TESTING	8	16	16D	1	9.96	2.7	2.7	16POINTS@1 MIN
SECURE HI-STORM TO TRANSPORT DEVICE	6	10	16A	1	2.96	0.5	0.5	ASSUMES AIR PAD
TRANSFER HI-STORM TO ITS DESIGNATED STORAGE LOCATION	6	40	16C	1	7.89	5.3	5.3	200 FEET @ 4FT/MIN
INSERT HI-STORM LIFTING JACKS	6	4	16D	1	9.96	0.7	0.7	4 JACKS@1/MIN
REMOVE AIR PAD	6	5	16D	1	9.96	0.8	0.8	1 PAD MOVED BY HAND
REMOVE HI-STORM LIFTING JACKS	6	4	16D	1	9.96	0.7	0.7	4 JACKS@1/MIN
INSTALL INLET VENT SCREENS	6	20	16D	1	9.96	3.3	3.3	4 SCREENS@5MIN/SCREEN
PERFORM AIR TEMPERATURE RISE TEST	9	8	16B	1	22.88	3.1	3.1	8 MEASMT@1/MIN
TOTAL							**362.8 PERSON–MREM**	

Table 10.3.3b

MPC TRANSFER INTO THE HI-STORM 100 SYSTEM DIRECTLY FROM TRANSPORT USING THE 100-TON HI-TRAC TRANSFER CASK

ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
Section 8.5.2								
MEASURE HI-STAR DOSE RATES	2	16	17A	2	14.1	3.8	7.5	16 POINTS@1 POINT/MIN
REMOVE PERSONNEL BARRIER	3	10	17C	2	21.5	3.6	7.2	ATTACH SLING REMOVE 8 LOCKS
PERFORM REMOVABLE CONTAMINATION SURVEYS	4	1	17C	1	21.5	0.4	0.4	10 SMEARS@10 SMEARS/MINUTE
REMOVE IMPACT LIMITERS	5	16	17A	2	14.1	3.8	7.5	ATTACH FRAME REMOVE 22 BOLTS IMPACT TOOLS
REMOVE TIE-DOWN	6	6	17A	2	14.1	1.4	2.8	ATTACH 2-LEGGED SLING REMOVE 4 BOLTS
PERFORM A VISUAL INSPECTION OF OVERPACK	7	10	17B	1	9	1.5	1.5	CHECKSHEET USED
REMOVE REMOVABLE SHEAR RING SEGMENTS	8	4	17A	1	14.1	0.9	0.9	4 BOLTS EACH @2/MIN X 2 SEGMENTS
UPEND HI-STAR OVERPACK	9	20	17B	2	9	3.0	6.0	DISCONNECT LIFT YOKE
INSTALL TEMPORARY SHIELD RING SEGMENTS	10	16	18A	1	7.9	2.1	2.1	8 SEGMENTS @ 2 MIN/SEGMENT
FILL TEMPORARY SHIELD RING SEGMENTS	11	25	18A	1	7.9	3.3	3.3	230 GAL @10GPM, LONG HANDLED SPRAYER
REMOVE OVERPACK VENT PORT COVER PLATE	11.a	2	18A	1	7.9	0.3	0.3	4 BOLTS @2/MIN
ATTACH BACKFILL TOOL	11.a	2	18A	1	7.9	0.3	0.3	4 BOLTS @2/MIN
OPEN/CLOSE VENT PORT PLUG	11.c	0.5	18A	1	7.9	0.1	0.1	SINGLE TURN BY HAND NO TOOLS
REMOVE CLOSURE PLATE BOLTS	14	39	18A	2	7.9	5.1	10.3	52 BOLTS@4/MIN X 3 PASSES
REMOVE OVERPACK CLOSURE PLATE	14	2	18A	1	7.9	0.3	0.3	4 SHACKLES@2/MIN
INSTALL HI-STAR SEAL	15	2	19B	1	7.9	0.3	0.3	PLACED BY HAND NO TOOLS

[†] See notes at bottom of Table 10.3.4.

Table 10.3.3b

MPC TRANSFER INTO THE HI-STORM 100 SYSTEM DIRECTLY FROM TRANSPORT USING THE 100-TON HI-TRAC TRANSFER CASK

ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
SURFACE PROTECTOR								
INSTALL TRANSFER COLLAR ON HI-STAR	16	10	19B	2	7.9	1.3	2.6	ALIGN AND POSITION REMOVE 4 SHACKLES
REMOVE MPC LIFT CLEAT HOLE PLUGS	17	2	19A	1	255.57	8.5	8.5	4 PLUGS AT 2/MIN NO TORQUING
INSTALL MPC LIFT CLEATS AND LIFT SLING	18	25	19A	2	255.57	106.5	213.0	INSTALL CLEATS AND HYDRO TORQUE 4 BOLTS
MATE OVERPACKS	27	10	20B	2	284.51	47.4	94.8	ALIGNMENT GUIDES USED
REMOVE DOOR LOCKING PINS AND OPEN DOORS	28	4	20B	2	284.51	19.0	37.9	2 PINS@2/MIN
INSTALL TRIM PLATES	29	4	20B	2	284.51	19.0	37.9	INSTALLED BY HAND NO FASTENERS
Section 8.5.3								
REMOVE TRIM PLATES	3	4	20B	2	284.51	19.0	37.9	INSTALLED BY HAND NO FASTENERS
DISCONNECT SLINGS FROM MPC LIFTING DEVICE	6	10	20A	2	177.55	179.1	358.3	2 SLINGS@5/MIN
REMOVE TRIM PLATES	6	4	13B	2	284.51	19.0	37.9	INSTALLED BY HAND NO FASTENERS
REMOVE MPC LIFT CLEATS AND MPC LIFT SLINGS	6	10	14A	1	255.57	42.6	42.6	4 BOLTS,NO TORQUING
INSTALL HOLE PLUGS IN EMPTY MPC BOLT HOLES	6	2	14A	1	255.57	8.5	8.5	4 PLUGS AT 2/MIN NO TORQUING
REMOVE HI-STORM VENT DUCT SHIELD INSERTS	6	2	15A	1	27.85	0.9	0.9	4 SHACKLES@2/MIN
REMOVE ALIGNMENT DEVICE	6	4	15A	1	27.85	1.9	1.9	REMOVED BY HAND NO TOOLS (4 PCS@1/MIN)
INSTALL HI-STORM LID AND INSTALL LID STUDS/NUTS	6	25	16A	2	4.26	1.8	3.6	INSTALL LID AND HYDRO TORQUE 4 BOLTS
INSTALL HI-STORM EXIT VENT GAMMA SHIELD CROSS PLATES	6	4	16B	1	34.58	2.3	2.3	4 PCS @ 1/MIN INSTALL BY HAND NO TOOLS

Table 10.3.3b
MPC TRANSFER INTO THE HI-STORM 100 SYSTEM DIRECTLY FROM TRANSPORT USING THE 100-TON HI-TRAC TRANSFER CASK
ESTIMATED OPERATIONAL EXPOSURES[†] (42,500 MWD/MTU, 5-YEAR COOLED PWR FUEL)

ACTION	CHAPTER 8 STEP	DURATION (MINUTES)	OPERATOR LOCATION (FIGURE 10.3.1)	NUMBER OF OPERATORS	DOSE RATE AT OPERATOR LOCATION (MREM/HR)	DOSE TO INDIVIDUAL (MREM/HR)	TOTAL DOSE (PERSON-MREM)	ASSUMPTIONS
INSTALL ~~THERMOCOUPLE~~*TEMPERATURE ELEMENTS*	6	20	16B	1	34.58	11.5	11.5	4@5MIN/~~THERMOCOUPLE~~*TEMPERATURE ELEMENT*
INSTALL EXIT VENT SCREENS	6	20	16B	1	34.58	11.5	11.5	4 SCREENS@5MIN/SCREEN
REMOVE HI-STORM LID LIFTING DEVICE	6	2	16A	1	4.26	0.1	0.1	4 SHACKLES@2/MIN
INSTALL HOLE PLUGS IN EMPTY HOLES	6	2	16A	1	4.26	0.1	0.1	4 PLUGS AT 2/MIN NO TORQUING
PERFORM SHIELDING EFFECTIVENESS TESTING	8	16	16D	1	34.76	9.3	9.3	16POINTS@1 MIN
SECURE HI-STORM TO TRANSPORT DEVICE	6	10	16A	1	4.26	0.7	0.7	ASSUMES AIR PAD
TRANSFER HI-STORM TO ITS DESIGNATED STORAGE LOCATION	6	40	16C	1	11.79	7.9	7.9	200 FEET @ 4FT/MIN
INSERT HI-STORM LIFTING JACKS	6	4	16D	1	34.76	2.3	2.3	4 JACKS@1/MIN
REMOVE AIR PAD	6	5	16D	1	34.76	2.9	2.9	1 PAD MOVED BY HAND
REMOVE HI-STORM LIFTING JACKS	6	4	16D	1	34.76	2.3	2.3	4 JACKS@1/MIN
INSTALL INLET VENT SCREENS	6	20	16D	1	34.76	11.6	11.6	4 SCREENS@5MIN/SCREEN
PERFORM AIR TEMPERATURE RISE TEST	9	8	16B	1	34.58	4.6	4.6	8 MEASMT@1/MIN
TOTAL							**1004.3 PERSON-MREM**	

Table 10.3.4
ESTIMATED EXPOSURES FOR HI-STORM 100 SURVEILLANCE AND MAINTENANCE

ACTIVITY	ESTIMATED PERSONNEL	ESTIMATED HOURS PER YEAR	ESTIMATED DOSE RATE (MREM/HR)	OCCUPATIONAL DOSE TO INDIVIDUAL (PERSON-MREM)
SECURITY SURVEILLANCE	1	30	3	90
ANNUAL MAINTENANCE	2	15	10	300

Notes for Tables 10.3.1a, 10.3.1b, 10.3.2a, 10.3.2b, 10.3.3a, 10.3.3b and 10..3.4:

1. Refer to Chapter 8 for detailed description of activities.
2 Number of operators may be set to 1 to simplify calculations where the duration is indirectly proportional to the number of operators. The total dose is equivalent in both respects.
3 HI-STAR 100 Operations assume that the cooling time is at least 10 years.

10.4 ESTIMATED COLLECTIVE DOSE ASSESSMENT

10.4.1 Controlled Area Boundary Dose for Normal Operations

10CFR72.104 [10.0.1] limits the annual dose *equivalent* to any real individual at the controlled area boundary to a maximum of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem for any other critical organ. This includes contributions from all uranium fuel cycle operations in the region.

It is not feasible to predict bounding controlled area boundary dose rates on a generic basis since radiation from plant and other sources; the location and the layout of an ISFSI; and the number and configuration of casks are necessarily site-specific. In order to compare the performance of the HI-STORM 100 System with the regulatory requirements, sample ISFSI arrays were analyzed in Chapter 5. These represent a full array of design basis fuel assemblies. Users are required to perform a site specific dose analysis for their particular situation in accordance with 10CFR72.212 [10.0.1]. The analysis must account for the ISFSI (size, configuration, fuel assembly specifics) and any other radiation from uranium fuel cycle operations within the region.

Table 5.1.9 presents dose rates at various distances from sample ISFSI arrays for the design basis burnup and cooling time which results in the highest off-site dose for the combination of maximum burnup and minimum cooling times analyzed in Chapter 5. 10CFR72.106 [10.0.1] specifies that the minimum distance from the ISFSI to the controlled area boundary is 100 meters. Therefore this was the minimum distance analyzed in Chapter 5. As a summary of Chapter 5, Table 10.4.1 presents the annual dose results for a single overpack at 100 and 200 meters and a 2x5 array of HI-STORM 100 systems at 350 meters. These annual doses are based on a full array of design basis fuel with a burnup of ~~45,000~~*52,500* MWD/MTU and 5-year cooling. This burnup and cooling time combination conservatively bounds the allowable burnup and cooling times listed in the Technical Specifications. In addition, 100% occupancy (8760 hours) is conservatively assumed. In the calculation of the annual dose, the casks were positioned on an infinite slab of soil to account for earth-shine effects. These results indicate that the calculated annual dose is less than the regulatory limit of 25 mrem/year at a distance of 200 meters for a single cask and at 350 meters for a 2x5 array of HI-STORM 100 Systems containing design basis fuel. These results are presented only as an illustration to demonstrate that the HI-STORM 100 System is in compliance with 10CFR72.104[10.0.1]. Neither the distances nor the array configurations become part of the Technical Specifications. Rather, users are required to perform a site specific analyses to demonstrate compliance with 10CFR72.104[10.0.1] contributors and 10CFR20[10.1.1].

An additional contributor to the controlled area boundary dose is the loaded HI-TRAC transfer cask, if the HI-TRAC is to be used at the ISFSI outside of the fuel building. Table 10.4.2

provides dose rates at 100, 200, and 300 meters for a 100-ton HI-TRAC transfer cask loaded with design basis fuel. The 100-ton HI-TRAC dose rates bound the 125-ton HI-TRAC by large margins. Based on the short duration that the loaded HI-TRAC is used outside at the ISFSI, the HI-STORM 100 System is in compliance with 10CFR72.104[10.0.1] when worst-case design basis fuel is loaded in all fuel cell locations. However, users are required to perform a site specific analysis to demonstrate compliance with 10CFR72.104[10.0.1] and 10CFR20[10.1.1] taking into account the actual site boundary distance and fuel characteristics.

A minor contributor to the minimum controlled area boundary is the normal storage condition leakage from the welded MPC. Although leakage is not expected, Section 7.2 provides an analysis for the annual dose *equivalent* based on a continuous leak from the MPC. ~~equal to the tested leakage rate plus the minimum test sensitivity.~~ The ~~total effective~~*annual* dose equivalent to an individual at the minimum controlled area boundary based on the assumed leakage rate and continuous occupancy ~~was computed to be less than 0.1 mrem for the worst case MPC~~*is presented in Table 7.3.8*. The site licensee is required to perform a site-specific dose evaluation of all dose contributors as part of the ISFSI design. This evaluation will account for the location of the controlled area boundary, the total number of casks on the ISFSI and the effects of the radiation from uranium fuel cycle operations within the region.

10.4.2 Controlled Area Boundary Dose for Off-Normal Conditions

As demonstrated in Section 11.1, the postulated off-normal conditions (off-normal pressure, off-normal environmental temperatures, leakage of one MPC ~~seal~~weld, partial blockage of air inlets, and off-normal handling of HI-TRAC) do not result in the degradation of the HI-STORM 100 System shielding effectiveness. Therefore, the dose at the controlled area boundary from direct radiation for off-normal conditions is equal to that of normal conditions.

However, the annual dose at the controlled area boundary as a result of an assumed effluent release under off-normal conditions is different than that under normal conditions. Under off-normal conditions, 10% of the fuel rods are assumed to have been breached, in lieu of 1% of the fuel rods for normal conditions. The resulting ~~total effective~~*annual* dose equivalent to an individual at the minimum controlled area boundary, based on the assumed leakage rate and continuous occupancy, ~~was computed to be less than 1.0 mrem for the worst case MPC.~~*is presented in Table 7.3.8*. The analysis to determine the off-normal dose at the controlled area boundary is described in Section 7.2.

10.4.3 Controlled Area Boundary Dose for Accident Conditions

10CFR72.106 [10.0.1] specifies that the maximum doses allowed to any individual at the controlled area boundary from any design basis accident (See Subsection 10.1.2). In addition, it is specified that the minimum distance from the ISFSI to the controlled area boundary be at least 100 meters.

Subsection 7.3 demonstrates that the resultant ~~effective~~ doses for a non-mechanistic postulated breach of the MPC confinement boundary at the regulatory minimum site boundary distance of 100 meters ~~are less than 45 mrem for continuous 30 day occupancy~~*is presented in Table 7.3.8*~~.~~ ~~Specific organ doses are also~~ within the regulatory limits specified in 10CFR72.106 [10.0.1].

Chapter 11 presents the results of the evaluations performed to demonstrate that the HI-STORM 100 System can withstand the effects of all accident conditions and natural phenomena without the corresponding radiation doses exceeding the requirements of 10CFR72.106 [10.0.1]. The accident events addressed in Chapter 11 include: handling accidents, tip-over, fire, tornado, flood, earthquake, 100 percent fuel rod rupture, confinement boundary leakage, explosion, lightning, burial under debris, extreme environmental temperature, partial blockage of MPC basket air inlets, and 100% blockage of air inlets.

The worst-case shielding consequence of the accidents evaluated in Section 11.2 for the loaded HI-STORM overpack assumes that as a result of a fire, the outer-most one inch of the concrete experiences temperatures above the concrete's design temperature. Therefore, the shielding effectiveness of this outer-most one inch of concrete is degraded. However, with over 25 inches of concrete providing shielding, the loss of one inch will have a negligible effect on the dose at the controlled area boundary.

The worst case shielding consequence of the accidents evaluated in Section 11.2 for the loaded HI-TRAC transfer cask assumes that as a result of a fire, tornado missile, or handling accident, the all the water in the water jacket is lost. The shielding analysis of the 100-ton HI-TRAC transfer cask with complete loss of the water from the water jacket is discussed in Section 5.1.2. These results bound those for the 125-Ton HI-TRAC transfer cask by a large margin. The results in that section show that the resultant dose rate at the 100-meter controlled area boundary would be approximately ~~0.8~~*1.47* mrem/hour for the loaded HI-TRAC transfer cask during the accident condition. At the calculated dose rate, it would take approximately ~~260~~ *141* days for the dose at the controlled area boundary to reach 5 rem. This length of time is sufficient to implement and complete the corrective actions outlined in Chapter 11. Therefore, the dose requirement of 10CFR72.106 [10.0.1] is satisfied. Once again, this dose is calculated assuming design basis fuel in all fuel cell locations. Users will need to perform site-specific analysis considering the actual site boundary distance and fuel characteristics.

Table 10.4.1

ANNUAL DOSE FOR ARRAYS OF HI-STORM 100 OVERPACKS
WITH DESIGN BASIS ZIRCALOY CLAD FUEL
~~45,000~~*52,500* MWD/MTU AND 5-YEAR COOLING

Array Configuration	**1 Cask**	**1 Cask**	**2x5 Array**
Annual Dose (mrem/year)[†]	~~109.6~~*130.0*	~~17.0~~*20.19*	~~15.6~~*18.64*
Distance to Controlled Area Boundary (meters)[††, †††]	100	200	350

[†] 100% occupancy is assumed.

[††] Dose location is at the center of the long side of the array.

[†††] Actual controlled area boundary dose rates will be lower because the maximum permissible burnup for 5-year cooling as specified in the Technical Specifications is lower than the burnup analyzed for the design basis fuel used in this table.

Table 10.4.2
DOSE RATE FOR THE 100-TON HI-TRAC TRANSFER CASK WITH DESIGN BASIS ZIRCALOY CLAD FUEL

Fuel Burnup & Cooling Time	**100 Meters**	**200 Meters**	**300 Meters**
~~35,000~~*42,500* MWD/MTU & 5 Years	~~0.27~~*0.42* mrem/hr	~~0.04~~ *0.06* mrem/hr	~~0.01~~*0.02* mrem/hr
~~45,000~~*52,500* MWD/MTU & ~~9~~*10* Years	~~0.16~~*0.26* mrem/hr	~~0.026~~*0.04* mrem/hr	~~0.007~~*0.01* mrem/hr

CHAPTER 11[†]: ACCIDENT ANALYSIS

This chapter presents the evaluation of the HI-STORM 100 System for the effects of off-normal and postulated accident conditions. The design basis off-normal and postulated accident events, including those resulting from mechanistic and non-mechanistic causes as well as those caused by natural phenomena, are identified in Sections 2.2.2 and 2.2.3. For each postulated event, the event cause, means of detection, consequences, and corrective action are discussed and evaluated. As applicable, the evaluation of consequences includes structural, thermal, shielding, criticality, confinement, and radiation protection evaluations for the effects of each design event.

The structural, thermal, shielding, criticality, and confinement features and performance of the HI-STORM 100 System are discussed in Chapters 3, 4, 5, 6, and 7. The evaluations provided in this chapter are based on the design features and evaluations described therein.

Chapter 11 is in full compliance with NUREG-1536; no exceptions are taken.

11.1 OFF-NORMAL CONDITIONS

During normal storage operations of the HI-STORM 100 System it is possible that an off-normal situation could occur. Off-normal operations, as defined in accordance with ANSI/ANS-57.9, are those conditions which, although not occurring regularly, are expected to occur no more than once a year. In this section, design events pertaining to off-normal operation for expected operational occurrences are considered. The off-normal conditions are listed in Subsection 2.2.2.

The following off-normal operation events have been considered in the design of the HI-STORM 100:

Off-Normal Pressures
Off-Normal Environmental Temperatures
Leakage of One MPC Seal Weld
Partial Blockage of Air Inlets
Off-Normal Handling of HI-TRAC Transfer Cask

For each event, the postulated cause of the event, detection of the event, analysis of the event effects and consequences, corrective actions, and radiological impact from the event are presented.

[†] This chapter has been prepared in the format and section organization set forth in Regulatory Guide 3.61. However, the material content of this chapter also fulfills the requirements of NUREG-1536. Pagination and numbering of sections, figures, and tables are consistent with the convention set down in Chapter 1, Section 1.0, herein. Finally, all terms-of-art used in this chapter are consistent with the terminology of the glossary (Table 1.0.1) and component nomenclature of the Bill-of-Materials (Section 1.5).

The results of the evaluations performed herein demonstrate that the HI-STORM 100 System can withstand the effects of off-normal events without affecting function, and are in compliance with the applicable acceptance criteria. The following sections present the evaluation of the HI-STORM 100 System for the design basis off-normal conditions that demonstrate that the requirements of 10CFR72.122 are satisfied, and that the corresponding radiation doses satisfy the requirements of 10CFR72.106(b) and 10CFR20.

The load combinations evaluated for off-normal conditions are defined in Table 2.2.14. The load combinations include both normal and off-normal loads. The off-normal load combination evaluations are discussed in Section 11.1.5.

11.1.1 Off-Normal Pressures

The sole pressure boundary in the HI-STORM 100 System is the MPC internal pressure boundary. The off-normal pressure condition is specified in Section 2.2.2.1. The off-normal pressure for the MPC internal cavity is a function of the initial helium fill pressure and the temperature obtained with maximum decay heat load design basis fuel. The maximum off-normal environmental temperature is 100°F with full solar insolation. The MPC internal pressure is further increased by the conservative assumption that 10% of the fuel rods rupture and 100% of the fill gas, and 30% of the fission gases are released to the cavity.

11.1.1.1 Postulated Cause of Off-Normal Pressure

After fuel assembly loading, the MPC is drained, dried, and backfilled with an inert gas (helium) to assure long-term fuel cladding integrity during dry storage. Therefore, the probability of failure of intact fuel rods in dry storage is low. Nonetheless, the event is postulated and evaluated.

11.1.1.2 Detection of Off-Normal Pressure

The HI-STORM 100 System is designed to withstand the MPC off-normal internal pressure without any effects on its ability to meet its safety requirements. There is no requirement for detection of off-normal pressure and, therefore, no monitoring is required.

11.1.1.3 Analysis of Effects and Consequences of Off-Normal Pressure

Chapter 4 calculates the MPC internal pressure with an ambient temperature of 80°F, 10% fuel rods ruptured, full insolation, and maximum decay heat, and reports the maximum value of *75.0*~~62.8~~ psig in Table 4.4.14 at an average temperature of *513.6*~~503.5~~°K. Using this pressure, the off-normal temperature of 100°F (ΔT of 20°F or 11.1°K), and the ideal gas law, the off-normal resultant pressure is calculated to be below the normal condition MPC internal design pressure.

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

$$P_2 = \frac{P_1 T_2}{T_1}$$

$$P_2 = \frac{(75.0\,\text{psig} + 14.7)\,(513.6^\circ\text{K} + 11.1^\circ\text{K})}{513.6^\circ\text{K}}$$

$$P_2 = 91.6\,\text{psia or } 76.9\,\text{psig}$$

The off-normal MPC internal design pressure of 100 psig (Table 2.2.1) has been established to bound the off-normal condition. Therefore, no additional analysis is required.

Structural

The structural evaluation of the MPC enclosure vessel for off-normal internal pressure conditions is equivalent to the evaluation at normal internal pressures, since the normal design pressure was set at a value which would encompass the off-normal pressure. Therefore, the resulting stresses from the off-normal condition are equivalent to that of the normal condition and are well within the short-term allowable values, as discussed in Section 3.4.

Thermal

The MPC internal pressure for off-normal conditions is calculated as presented above. As can be seen from the value above, the 100 psig design basis internal pressure for off-normal conditions used in the structural evaluation bounds the calculated value above.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the off-normal pressure does not affect the safe operation of the HI-STORM 100 System.

11.1.1.4 Corrective Action for Off-Normal Pressure

The HI-STORM 100 System is designed to withstand the off-normal pressure without any effects on its ability to maintain safe storage conditions. There is no corrective action requirement for off-normal pressure.

11.1.1.5 Radiological Impact of Off-Normal Pressure

The event of off-normal pressure has no radiological impact because the confinement barrier and shielding integrity are not affected.

11.1.2 Off-Normal Environmental Temperatures

The HI-STORM 100 System is designed for use at any site in the United States. Off-normal environmental temperatures of -40 to 100°F (HI-STORM overpack) and 0 to 100°F (HI-TRAC transfer cask) have been conservatively selected to bound off-normal temperatures at these sites. The off-normal temperature range affects the entire HI-STORM 100 System and must be evaluated against the allowable component design temperatures. This off-normal event is of a short duration, therefore the resultant temperatures are evaluated against the accident condition temperature limits as listed in Table 2.2.3.

11.1.2.1 Postulated Cause of Off-Normal Environmental Temperatures

The off-normal environmental temperature is postulated as a constant ambient temperature caused by extreme weather conditions. To determine the effects of the off-normal temperatures, it is conservatively assumed that these temperatures persist for a sufficient duration to allow the HI-STORM 100 System to achieve thermal equilibrium. Because of the large mass of the HI-STORM 100 System with its corresponding large thermal inertia and the limited duration for the off-normal temperatures, this assumption is conservative.

11.1.2.2 Detection of Off-Normal Environmental Temperatures

The HI-STORM 100 System is designed to withstand the off-normal environmental temperatures without any effects on its ability to maintain safe storage conditions. There is no requirement for detection of off-normal environmental temperatures for the HI-STORM overpack and MPC. Chapter

2 provides operational limitations to the use of the HI-TRAC transfer cask at temperatures of ≤32°F and prohibits use of the HI-TRAC transfer cask below 0°F.

11.1.2.3 Analysis of Effects and Consequences of Off-Normal Environmental Temperatures

The off-normal event considering an environmental temperature of 100°F for a duration sufficient to reach thermal equilibrium is evaluated with respect to design temperatures listed in Table 2.2.3. The evaluation is performed with design basis fuel with the maximum decay heat and the most restrictive thermal resistance. The 100°F environmental temperature is applied with full solar insolation.

The HI-STORM 100 System maximum temperatures for components close to the design basis temperatures are listed in Subsection 4.4. These temperatures are conservatively calculated at an environmental temperature of 80°F. The maximum off-normal environmental temperature is 100°F, which is an increase of 20°F. ~~Including the effect of a hypothetical 10% rod rupture condition on the MPC cavity gas conductivity, c~~*C*onservatively bounding temperatures *for all MPC designs (Table 1.2.1)* ~~of the MPC-68 and MPC-24~~ are calculated to be as listed in Table 11.1.1. As illustrated by the table, all the maximum off-normal temperatures are below the short-term condition design basis temperatures. The maximum temperatures are the peak values and are based on the conservative assumptions applied in this analysis. The component temperatures for the HI-TRAC listed in Table 4.5.2 are all based on the maximum off-normal environmental temperature. The off-normal environmental temperature is of a short duration (several consecutive days would be highly unlikely) and the resultant temperatures are evaluated against short-term temperature limits. Therefore, all the HI-STORM 100 System maximum off-normal temperatures meet the design requirements.

Additionally, the off-normal environmental temperature generates a pressure that is evaluated in Subsection 11.1.1. The off-normal MPC cavity pressure is less than the design basis pressure listed in Table 2.2.1.

The off-normal event considering an environmental temperature of -40°F and no solar insolation for a duration sufficient to reach thermal equilibrium is evaluated with respect to material design temperatures of the HI-STORM overpack. The HI-STORM overpack and MPC are conservatively assumed to reach -40°F throughout the structure. The minimum off-normal environmental temperature specified for the HI-TRAC transfer cask is 0°F and the HI-TRAC is conservatively assumed to reach 0°F throughout the structure. For ambient temperatures from 0° to 32°F, a 25% ethylene glycol solution is added to the demineralized water in the water jacket to prevent freezing. Chapter 3, Subsection 3.1.2.3, details the structural analysis and testing performed to assure prevention of brittle fracture failure of the HI-STORM 100 System.

Structural

The effect on the MPC for the upper off-normal thermal conditions (i.e., 100°F) is an increase in the internal pressure. As shown in Subsection 11.1.1.3, the resultant pressure is well below the design pressure of 100 psig used in the structural analysis. The effect of the lower off-normal thermal conditions (i.e., -40°F) results in an evaluation of the potential for brittle fracture that is discussed in Section 3.1.2.3.

Thermal

The resulting off-normal system and fuel assembly cladding temperatures for the hot conditions are provided in Table 11.1.1 for the HI-STORM overpack and MPC. As can be seen from this table, all temperatures for off-normal conditions are within the short-term allowable values described in Table 2.2.3.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the specified off-normal environmental temperatures do not affect the safe operation of the HI-STORM 100 System.

11.1.2.4 Corrective Action for Off-Normal Environmental Temperatures

The HI-STORM 100 System is designed to withstand the off-normal environmental temperatures without any effects on its ability to maintain safe storage conditions. There are no corrective actions required for off-normal environmental temperatures.

11.1.2.5 Radiological Impact of Off-Normal Environmental Temperatures

Off-normal environmental temperatures have no radiological impact, as the confinement barrier and shielding integrity are not affected.

11.1.3 Leakage of One Seal

The HI-STORM 100 System has a reliable welded boundary to contain radioactive fission products within the confinement boundary. The radioactivity confinement boundary is defined by the MPC shell, baseplate, MPC lid, and vent and drain port cover plates. The closure ring provides a redundant welded closure to the release of radioactive material from the MPC cavity through the field-welded MPC lid closures. Confinement boundary welds are inspected by radiography or ultrasonic examination except for field welds that are examined by the liquid penetrant method on the root *(for multi-pass welds)* and final pass, at a minimum. Field welds are performed on the MPC lid, the MPC vent and drain port covers, and the MPC closure ring. The welds on the MPC lid, and vent and drain port covers are leakage tested. Additionally, the MPC lid weld is subjected to a hydrostatic test to verify its integrity.

The MPC lid-to-MPC shell weld is postulated to fail to confirm the safety of the HI-STORM 100 confinement boundary. The failure of the MPC lid weld is equivalent to the MPC drain or vent port cover weld failing. The MPC lid-to-shell weld has been selected because it is the main closure weld performed in the field for the MPC. It is extremely unlikely that the weld examination, helium leakage testing and hydrostatic testing would fail to detect a poorly welded closure plate. The MPC lid weld failure affects the MPC confinement boundary; however, no leakage will occur.

11.1.3.1 Postulated Cause of Leakage of One Seal in the Confinement Boundary

Failure of the MPC confinement boundary is highly unlikely. The MPC confinement boundary is shown to withstand all normal, off-normal, and accident conditions. There are no credible conditions that could damage the integrity of the MPC confinement boundary. The MPC lid-to-MPC shell weld is liquid penetrant inspected on the root and final pass, volumetrically inspected or liquid penetrant inspected on multiple passes, hydrostatically tested, and helium leak tested. The initial integrity of the closure welds will be maintained throughout the design life because the MPC is stored within the HI-STORM overpack which provides physical protection and a weather shield. Failure of the MPC lid-to-MPC shell weld would require all of the following:

1. Improper weld by a qualified welding machine or welder using approved welding procedures.
2. Failure to detect the unacceptable indication during the liquid penetrant or volumetric inspections performed by a qualified inspector in accordance with approved procedures.

3. Failure of the qualified leakage test equipment to detect the leak in accordance with approved procedures.

4. Failure to detect the unacceptable leak during the hydrostatic test performed by qualified personnel in accordance with approved procedures.

The evaluation of the failure of the MPC lid-to-MPC shell weld has been postulated to demonstrate the safety of the HI-STORM 100 confinement system and cannot be derived from a credible loading condition.

11.1.3.2 Detection of Leakage of One Seal in the Confinement Boundary

The HI-STORM 100 System is designed to withstand the leakage of one field weld in the confinement boundary without any effects on its ability to meet its safety requirements. As the HI-STORM 100 System can withstand the failure of one field weld with no leakage, there is no requirement to detect leakage from one seal.

11.1.3.3 Analysis of Effects and Consequences of Leakage of One Seal in the Confinement Boundary

If the MPC lid-to-MPC shell weld were to fail, the MPC closure ring will retain the design pressure. The analysis of the MPC closure ring's ability to retain the design pressure is provided in Appendix 3.E of the HI-STAR TSAR Docket Number 72-1008. The consequences of the MPC lid-to-MPC shell weld failure are that the MPC closure ring maintains the integrity of the confinement boundary.

Structural

The stress evaluation of the closure ring is discussed in Appendix 3.E. All stresses are within the allowable values.

Thermal

There is no effect on the thermal performance of the system as a result of this off-normal event.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the specified off-normal leakage of one seal event does not affect the safe operation of the HI-STORM 100 System.

11.1.3.4 Corrective Action for Leakage of One Seal in the Confinement Boundary

There is no corrective action required for the failure of one weld in the closure system of the confinement boundary. Leakage of one weld in the confinement boundary closure system does not affect the HI-STORM 100 System's ability to operate safely.

11.1.3.5 Radiological Impact of Leakage of One Seal in the Confinement Boundary

The off-normal event of the failure of one weld in the confinement boundary closure system has no radiological impact because the confinement barrier is not breached and shielding is not affected.

11.1.4 Partial Blockage of Air Inlets

The HI-STORM 100 System is designed with fine mesh screens on the inlet and outlet air ducts. These screens ensure the air ducts are protected from the incursion of foreign objects. There are four air inlet ducts 90° apart and it is highly unlikely that blowing debris during normal or off-normal operation could block all air inlet ducts. As required by the design criteria presented in Chapter 2, it is conservatively assumed that two of the four air inlet ducts are blocked. The blocked air inlet ducts are assumed to be completely blocked with an ambient temperature of 80°F (Table 2.2.2), full solar insolation, and maximum SNF decay heat values. This condition is analyzed to demonstrate the inherent thermal stability of the HI-STORM 100 System.

An additional evaluation is performed with three of the four air inlet ducts. While not required by the HI-STORM System design criteria, this additional evaluation is performed as a parametric study of the effects of incremental duct blockage. The purpose of the parametric study is to demonstrate the robustness of the HI-STORM System design beyond the design basis.

11.1.4.1 Postulated Cause of Partial Blockage of Air Inlets

It is conservatively assumed that the blocked air inlet ducts are completely blocked, although mesh screens prevent foreign objects from entering the ducts. The mesh screens are either inspected periodically or the outlet duct air temperature is monitored as specified by Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~. It is, however, possible that blowing debris may block two air inlet ducts of the overpack. As already stated, the blockage of three inlet ducts is evaluated only to demonstrate the limited effects of additional incremental duct blockage.

11.1.4.2 Detection of Partial Blockage of Air Inlets

The detection of the partial blockage of air inlet ducts will occur during the routine visual inspection of the mesh screens or temperature monitoring of the outlet duct air as required and specified by Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~. The frequency of inspection is based on an assumed complete blockage of all four air inlet ducts. There is no inspection requirement as a result of the postulated two inlet duct blockage, because the complete blockage of all four air inlet ducts is bounding.

11.1.4.3 Analysis of Effects and Consequences of Partial Blockage of Air Inlets

Evaluations for two inlet ducts and three inlet ducts blocked are evaluated for the MPC-32 at its maximum decay heat load. Only the MPC-32 is evaluated because it has the highest decay heat load of all MPC designs (Table 1.2.1). The largest temperature rise of the MPC or its contents as a result of the blockage of two air inlet ducts is 25 °F, for the MPC shell. The largest temperature rise of the MPC or its contents as a result of the blockage of three air inlet ducts (performed as a parametric study of incremental duct blockage only) is 81 °F, also for the MPC shell. ~~T~~*Conservatively adding the largest component temperature rise to all cask system component temperatures, t*he resultant *bounding* temperatures for the complete blockage of two air inlet ducts are provided in Table 11.1.2. ~~for the highest component temperatures from the MPC-68 or MPC-24, each with the maximum decay heat load.~~ ~~T~~*Following this same procedure of adding the largest component temperature rise to all cask system component temperatures, t*he resultant *bounding* temperatures for the complete blockage of three air inlet ducts~~, performed as a parametric study of incremental duct blockage only,~~ are included in the same table for comparison purposes. These values are based on full insolation and an ambient temperature of 80°F. The analysis method for the blockage of two and three of the air inlet ducts is ~~identical~~*conservative with respect* to the analysis method for the normal condition. As a result of the air inlet duct blockages, the head loss is increased and the airflow is decreased thereby increasing component temperatures.

~~T~~*As stated above, t*he largest temperature rise of the MPC or its contents as a result of the blockage of two air inlet ducts is ~~16~~*25*°F, for the MPC shell. A bounding MPC internal pressure as a result of this calculated temperature increase is computed, based on initial conditions presented previously in Subsection 11.1.1.3, as follows:

$$P_2 = P_1 \frac{T_1 + \Delta T}{T_1}$$

where:

P_2 = Bounding MPC Cavity Pressure (psia)

P_1 = Initial MPC Cavity Pressure (*89.7*~~77.5~~*4* psia)
T_1 = Initial MPC Cavity Average Temperature (*513.6*~~503.5~~°K)
ΔT = Bounding MPC Temperature Rise (~~16~~*25*°F or ~~8.9~~*19.9*°K)

Substituting these values into the equation above, the bounding MPC internal pressure is obtained as:

$$P_2 = 89.7 \times \frac{513.6 + 13.9}{513.6} = 92.1 psia = 77.4 psig$$

The off-normal MPC internal design pressure of 100 psig (Table 2.2.1) has been established to bound this partial inlet duct blockage condition.

Although it is a beyond the design basis condition, the bounding pressure rise for the three blocked air inlet ducts condition can be determine in the same manner. ~~T~~*As stated above, t*he bounding temperature rise for this condition is ~~60~~*81*°F (~~33.3~~*44.9*°K), and the corresponding bounding MPC internal pressure is ~~82.6~~*97.5* psia (~~67.9~~*82.8* psig). This parametric evaluation demonstrates the insensitivity of the MPC internal pressure to incremental duct blockage, as the relatively large incremental flow area reduction increases the pressure by only ~~3.7~~*5.4* psi.

Structural

There are no structural consequences as a result of this off-normal event.

Thermal

Using the methodology and model discussed in Section 4.4, the thermal analysis for the two air inlet ducts blocked off-normal condition is performed. The analysis demonstrates that under steady-state conditions, no system components exceed the short-term allowable temperatures in Table 2.2.3.

The parametric study of incremental duct blockage, performed by evaluating a three air inlet ducts blocked condition, demonstrates the insensitivity of the system to relatively large incremental flow area reductions. This beyond the design basis condition results in relatively small temperature increases and temperatures well below the short-term allowable temperatures in Table 2.2.3, even though no such requirement exists.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the specified off-normal partial blockage of air inlet ducts event does not affect the safe operation of the HI-STORM 100 System.

11.1.4.4 Corrective Action for Partial Blockage of Air Inlets

The corrective action for the partial blockage of air inlet ducts is the removal, cleaning, and replacement of the affected mesh screens. After clearing of the blockage, the storage module temperatures will return to the normal temperatures reported in Chapter 4. Partial blockage of air inlet ducts does not affect the HI-STORM 100 System's ability to operate safely.

Inspection of the HI-STORM overpack air duct screen covers is required with the frequency specified by Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~ or, alternatively, the outlet duct air temperature is monitored. The frequency of inspection is based on an assumed blockage of all four air inlet ducts analyzed in Subsection 11.2.

11.1.4.5 Radiological Impact of Partial Blockage of Air Inlets

The off-normal event of partial blockage of the air inlet ducts has no radiological impact because the confinement barrier is not breached and shielding is not affected.

11.1.5 Off-Normal Handling of HI-TRAC

During upending and/or downending of the HI-TRAC transfer cask, the total lifted weight is distributed among both the upper lifting trunnions and the lower pocket trunnions. Each of the four trunnions on the HI-TRAC therefore supports approximately one-quarter of the total weight. This even distribution of the load would continue during the entire rotation operation.

If the lifting device is allowed to "go slack", the total weight would be applied to the lower pocket trunnions only. Under this off-normal condition, the pocket trunnions would each be required to support one-half of the total weight, doubling the load per trunnion. This condition is analyzed to demonstrate that the pocket trunnions possess sufficient strength to support the increased load under this off-normal condition.

11.1.5.1 Postulated Cause of Off-Normal Handling of HI-TRAC

If the cable of the crane handling the HI-TRAC is inclined from the vertical, it would possible to unload the upper lifting trunnions such that the lower pocket trunnions are supporting the total cask weight and the lifting trunnions are only preventing cask rotation.

11.1.5.2 Detection of Off-Normal Handling of HI-TRAC

Handling procedures and standard rigging practice call for maintaining the crane cable in a vertical position by keeping the crane trolley centered over the lifting trunnions. In such an orientation it is not possible to completely unload the lifting trunnions without inducing rotation. If the crane cable were inclined from the vertical, however, the possibility of unloading the lifting trunnions would exist. It is therefore possible to detect the potential for this off-normal condition by monitoring the incline of the crane cable with respect to the vertical.

11.1.5.3 Analysis of Effects and Consequences of Off-Normal Handling of HI-TRAC

If the upper lifting trunnions are unloaded, the lower pocket trunnions will support the total weight of the loaded HI-TRAC. The analysis of the pocket trunnions to support the applied load of one-half of the total weight is provided in Appendices 3.AA and 3.AI of this FSAR. The consequence of off-normal handling of the HI-TRAC is that the pocket trunnions safely support the applied load.

Structural

The stress evaluations of the lower pocket trunnions are discussed in Appendices 3.AA and 3.AI. All stresses are within the allowable values.

Thermal

There is no effect on the thermal performance of the system as a result of this off-normal event.

Shielding

There is no effect on the shielding performance of the system as a result of this off-normal event.

Criticality

There is no effect on the criticality control features of the system as a result of this off-normal event.

Confinement

There is no effect on the confinement function of the MPC as a result of this off-normal event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this off-normal event.

Based on this evaluation, it is concluded that the specified off-normal handling of the HI-TRAC does not affect the safe operation of the system.

11.1.5.4 Corrective Action for Off-Normal Handling of HI-TRAC

The HI-TRAC transfer casks are designed to withstand the off-normal handling condition without any adverse effects. There are no corrective actions required for off-normal handling of HI-TRAC other than to attempt to maintain the crane cable vertical during HI-TRAC upending or downending.

11.1.5.5 Radiological Consequences of Off-Normal Handling of HI-TRAC

The off-normal event of off-normal handling of HI-TRAC has no radiological impact because the confinement barrier is not breached and shielding is not affected.

11.1.6 Off-Normal Load Combinations

Load combinations for off-normal conditions are provided in Table 2.2.14. The load combinations include normal loads with the off-normal loads. The load combination results are shown in Section 3.4 to meet all allowable values.

Table 11.1.1

MAXIMUM TEMPERATURES CAUSED BY OFF-NORMAL ENVIRONMENTAL TEMPERATURES[‡]

Location	**Temperature [°F]**	**Design Basis Limits [°F]**
Fuel Cladding	*711*~~749~~ (PWR) *760*~~765~~ (BWR)	1058 short-term
MPC Basket	*740*~~745~~	950 short-term
MPC ~~Outer~~ Shell ~~Surface~~	*371*~~327~~	775 short-term
Overpack Air Outlet	*226*~~206~~	N/A
Overpack Inner Shell	*219*~~192~~	350 short-term (overpack concrete)
Overpack Outer Shell	*165*~~151~~	350 short-term (overpack concrete)

~~[†] Conservatively bounding temperatures reported in this table include a hypothetical rupture of 10% of the stored fuel rods.~~

Table 11.1.2

~~MAXIMUM~~*BOUNDING*[†] TEMPERATURES[‡] CAUSED BY PARTIAL BLOCKAGE OF AIR INLET DUCTS [°F]

Temperature Location	**No Blockage of Inlet Ducts**	**Partial Blockage of Inlet Ducts**		**Off-Normal Design Basis**
		2 Ducts Blocked	**3 Ducts Blocked**	
Fuel Cladding	~~729 (MPC-24)~~ ~~745 (MPC-68)~~*740*	~~738 (MPC-24)~~ ~~754 (MPC-68)~~*765*	~~760 (MPC-24)~~ ~~778 (MPC-68)~~*821*	1058 short-term
MPC Basket	~~689 (MPC-24)~~ ~~725 (MPC-68)~~*720*	~~698 (MPC-24)~~ ~~734 (MPC-68)~~*745*	~~720 (MPC-24)~~ ~~758 (MPC-68)~~*801*	950 short-term
MPC ~~Outer~~ Shell ~~Surface~~	~~306 (MPC-24)~~ ~~302 (MPC-68)~~*351*	~~322 (MPC-24)~~ ~~318 (MPC-68)~~*376*	~~366 (MPC-24)~~ ~~361 (MPC-68)~~*432*	775 short-term
Overpack Air Outlet	~~184 (MPC-24)~~ ~~186 (MPC-68)~~*206*	~~200 (MPC-24)~~ ~~202 (MPC-68)~~*231*	~~243 (MPC-24)~~ ~~242 (MPC-68)~~*287*	N/A
Overpack Inner Shell	~~170 (MPC-24)~~ ~~172 (MPC-68)~~*199*	~~186 (MPC-24)~~ ~~186 (MPC-68)~~*224*	~~232 (MPC-24)~~ ~~231 (MPC-68)~~*280*	350 short-term (overpack concrete)
Overpack Outer Shell	~~131 (MPC-24)~~ ~~130 (MPC-68)~~*145*	~~133 (MPC-24)~~ ~~135 (MPC-68)~~*170*	~~149 (MPC-24)~~ ~~149 (MPC-68)~~*226*	350 short-term (overpack concrete)

[†] *The bounding temperatures presented in this table are obtained by adding the maximum temperature rise of any cask component to the normal condition temperatures of every cask component.*

~~[‡] Conservatively bounding temperatures reported in this table include a hypothetical rupture of 10% of the stored fuel rods.~~

11.2 ACCIDENTS

Accidents, in accordance with ANSI/ANS-57.9, are either infrequent events that could reasonably be expected to occur during the lifetime of the HI-STORM 100 System or events postulated because their consequences may affect the public health and safety. Section 2.2.3 defines the design basis accidents considered. By analyzing for these design basis events, safety margins inherently provided in the HI-STORM 100 System design can be quantified.

The results of the evaluations performed herein demonstrate that the HI-STORM 100 System can withstand the effects of all credible and hypothetical accident conditions and natural phenomena without affecting safety function, and are in compliance with the acceptable criteria. The following sections present the evaluation of the design basis postulated accident conditions and natural phenomena which demonstrate that the requirements of 10CFR72.122 are satisfied, and that the corresponding radiation doses satisfy the requirements of 10CFR72.106(b) and 10CFR20.

The load combinations evaluated for postulated accident conditions are defined in Table 2.2.14. The load combinations include normal loads with the accident loads. The accident load combination evaluations are provided in Section 3.4.

11.2.1 HI-TRAC Transfer Cask Handling Accident

11.2.1.1 Cause of HI-TRAC Transfer Cask Handling Accident

During the operation of the HI-STORM 100 System, the loaded HI-TRAC transfer cask can be transported to the ISFSI in the vertical or horizontal position. The loaded HI-TRAC transfer cask is typically transported by a heavy-haul vehicle that cradles the HI-TRAC horizontally or by a device with redundant drop protection that holds the HI-TRAC vertically. The height of the loaded overpack above the ground shall be limited to below the horizontal handling height limit determined in Chapter 3 and specified by the Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~ to limit the inertia loading on the cask in a horizontal drop to less than 45g's. Although a handling accident is remote, a cask drop from the horizontal handling height limit is a credible accident. A vertical drop of the loaded HI-TRAC transfer cask is not a credible accident as the loaded HI-TRAC shall be transported and handled in the vertical orientation by devices designed in accordance with the criteria specified in Subsection 2.3.3.1 as required by the Technical Specification.

11.2.1.2 HI-TRAC Transfer Cask Handling Accident Analysis

The handling accident analysis evaluates the effects of dropping the loaded HI-TRAC in the horizontal position. The analysis of the handling accident is provided in Chapter 3. The analysis shows that the HI-STORM 100 System meets all structural requirements and there is no adverse effect on the confinement, thermal or subcriticality performance of the contained MPC. Limited localized damage to the HI-TRAC water jacket shell and loss of the water in the water jacket may occur as a result of the handling accident. The HI-TRAC top lid and transfer lid housing are demonstrated to remain attached by withstanding the maximum deceleration. The transfer lid doors are also shown to remain closed during the drop. Limiting the inertia loading to 60g's or less ensures the fuel cladding remains intact based on dynamic impact effects on spent fuel assemblies in the literature [11.2.1]. Therefore, demonstrating that the 45g limit for the HI-TRAC transfer cask is met ensures that the fuel cladding remains intact.

Structural

The structural evaluation of the MPC for 45g's is provided in Section 3.4. As discussed in Section 3.4, the MPC stresses as a result of the HI-TRAC side drop, 45g loading, are all within allowable values.

As discussed above, the water jacket enclosure shell could be punctured which results in a loss of the water within the water jacket. Additionally, the HI-TRAC top lid, transfer lid, and transfer lid doors are shown to remain in position under the 45g loading. Analysis of the lead in the HI-TRAC is performed in Appendix 3.F and it is shown that there is no appreciable change in the lead shielding.

Thermal

The loss of the water in the water jacket causes the temperatures to increase slightly due to a reduction in the thermal conductivity through the HI-TRAC water jacket. The temperatures of the MPC in the HI-TRAC transfer cask as a result of the loss of water in the water jacket are presented in Table 11.2.8. As can be seen from the values in the table, the temperatures are well below the short-term allowable fuel cladding and material temperatures provided in Table 2.2.3 for accident conditions.

Shielding

The loss of the water in the water jacket results in an increase in the radiation dose rates at locations adjacent to the water jacket. The shielding analysis results presented in Section 5.1.2 demonstrate that the requirements of 10CFR72.106 are not exceeded. As the structural analysis demonstrates that the HI-TRAC top lid, transfer lid, and transfer lid doors remain in place, there is no change in the dose rates at the top and bottom of the HI-TRAC.

Criticality

There is no effect on the criticality control features of the system as a result of this accident event.

Confinement

There is no effect on the confinement function of the MPC as a result of this accident event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

There is no degradation in the confinement capabilities of the MPC, as discussed above. There are increases in the local dose rates adjacent *to the* water jacket. The dose rate at 1 meter from the water jacket after the water is lost is calculated *in* ~~to be less than 1 R/hr (~~Table 5.1.10~~)~~. Immediately after the drop accident a radiological inspection of the HI-TRAC will be performed and temporary shielding shall be installed to limit the exposure to the public. Based on a minimum distance to the controlled area boundary of 100 meters, the dose rate at the controlled area boundary will be approximately ~~0.8~~ *1.47* mrem/hr *(Section 5.1.2)*. Therefore, it is evident, based on the short duration of the accident, that the requirements of 10CFR72.106 (5 Rem) will not be exceeded.

11.2.1.3 HI-TRAC Transfer Cask Handling Accident Dose Calculations

The handling accident could cause localized damage to the HI-TRAC water jacket shell and loss of the water in the water jacket as the neutron shield impacts the ground.

When the water jacket is impacted, the HI-TRAC transfer cask surface dose rate could increase. The HI-TRAC's post-accident shielding analysis presented in Section 5.1.2 assumes complete loss of the water in the water jacket and bounds the dose rates anticipated for the handling accident.

If the water jacket of the loaded HI-TRAC is damaged beyond immediate repair and the MPC is not damaged, the loaded HI-TRAC may be unloaded into a HI-STORM overpack, a HI-STAR overpack, or simply unloaded in the fuel pool. If the MPC is damaged, the loaded HI-TRAC must be returned to the fuel pool for unloading. Depending on the damage to the HI-TRAC and the current location in the loading or unloading sequence, less personnel exposure may be received by continuing to load the MPC into a HI-STORM or HI-STAR overpack. Once the MPC is placed in the HI-STORM or HI-STAR overpack, the dose rates are greatly reduced. The highest personnel exposure will result from returning the loaded HI-TRAC to the fuel pool to unload the MPC.

As a result of the loss of water from the water jacket, the dose rates at 1 meter adjacent to the water jacket mid-height increase~~d from 42 mrem/hr to 736 mrem/hr (125-ton HI-TRAC, Table 5.1.10) and 380 mrem/hr to 1090 mrem/hr~~ (~~100-ton HI-TRAC,~~ Table 5.1.10). Increasing the personnel exposure for each task ~~e~~*a*ffected by the increased dose rate adjacent to the water jacket by the ratio of the one meter dose rate increase results in a ~~cummulative~~ *cumulative* dose of less than ~~2.0~~ *5.0* person-rem, for the 125-ton HI-TRAC or 100-ton HI-TRAC. Using the ratio of the water jacket mid-height dose rates at one meter is very conservative. Dose rate at the top and bottom of the HI-TRAC water jacket would not increase as much as the peak mid-height dose rates. In the determination of the personnel exposure, dose rates at the top and bottom of the loaded HI-TRAC are assumed to remain constant.

The analysis of the handling accident presented in Section 3.4 shows that the MPC confinement barrier will not be compromised and, therefore, there will be no release of radioactive material from the confinement vessel. Any possible rupture of the fuel cladding will have no effect on the site boundary dose rates because the magnitude of the radiation source has not changed.

11.2.1.4 HI-TRAC Transfer Cask Handling Accident Corrective Action

Following a handling accident, the ISFSI operator shall first perform a radiological and visual inspection to determine the extent of the damage to the HI-TRAC transfer cask and MPC to the maximum practical extent. As appropriate, place temporary shielding around the HI-TRAC to reduce radiation dose rates. Special handling procedures will be developed and approved by the ISFSI operator to lift and upright the HI-TRAC. Upon uprighting, the portion of the overpack not previously accessible shall be radiologically and visually inspected. If damage to the water jacket is limited to a local penetration or crushing, local repairs can be performed to the shell and the water replaced. If damage to the water jacket is extensive, the damage shall be repaired and re-tested in accordance with Chapter 9, following removal of the MPC.

If upon inspection of the damaged HI-TRAC transfer cask and MPC, damage of the MPC is observed, the loaded HI-TRAC transfer cask will be returned to the facility for fuel unloading in accordance with Chapter 8. The handling accident will not affect the ability to unload the MPC using normal means as the structural analysis of the 60g loading (HI-STAR Docket Numbers 71-9261 and 72-1008) shows that there will be no gross deformation of the MPC basket. After unloading, the structural damage of the HI-TRAC and MPC shall be assessed and a determination shall be made if repairs will enable the equipment to return to service. Subsequent to the repairs, the equipment shall be inspected and appropriate tests shall be performed to certify the equipment for service. If the equipment cannot be repaired and returned to service, the equipment shall be disposed of in accordance with the appropriate regulations.

11.2.2 HI-STORM Overpack Handling Accident

11.2.2.1 Cause of HI-STORM Overpack Handling Accident

During the operation of the HI-STORM 100 System, the loaded HI-STORM overpack is lifted in the vertical orientation. The height of the loaded overpack above the ground shall be limited to below the vertical handling height limit determined in Chapter 3 and specified by the ~~t~~*T*echnical Specifications in *Appendix A to the CoC*~~Chapter 12~~. This vertical handling height limit will maintain the inertial loading on the cask in a vertical drop to 45g's or less. Although a handling accident is remote, a drop from the vertical handling height limit is a credible accident.

11.2.2.2 HI-STORM Overpack Handling Accident Analysis

The handling accident analysis evaluates the effects of dropping the loaded overpack in the vertical orientation. The analysis of the handling accident is provided in Chapter 3. The analysis shows that the HI-STORM 100 System meets all structural requirements and there are no adverse effects on the structural, confinement, thermal or subcriticality performance of the HI-STORM 100 System.

Limiting the inertia loading to 60g's or less ensures the fuel cladding remains intact based on dynamic impact effects on spent fuel assemblies in the literature [11.2.1].

Structural

The structural evaluation of the MPC under a 60g vertical load is presented in the HI-STAR TSAR and SAR [11.2.6 and 11.2.7] and it is demonstrated therein that the stresses are within allowable limits. The structural analysis of the HI-STORM overpack is presented in Section 3.4. The structural analysis of the overpack shows that the concrete shield attached to the underside of the overpack lid remains attached and air inlet ducts do not collapse.

Thermal

As the structural analysis demonstrates that there is no change in the MPC or overpack, there is no effect on the thermal performance of the system as a result of this event.

Shielding

As the structural analysis demonstrates that there is no change in the MPC or overpack, there is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the vertical drop of the HI-STORM Overpack with the MPC inside does not affect the safe operation of the HI-STORM 100 System.

11.2.2.3 HI-STORM Overpack Handling Accident Dose Calculations

The vertical drop handling accident of the loaded HI-STORM overpack will not cause any change of the shielding or breach of the MPC confinement boundary. Any possible rupture of the fuel cladding will have no affect on the site boundary dose rates because the magnitude of the radiation source has not changed. Therefore, the dose calculations are equivalent to the normal condition dose rates.

11.2.2.4 HI-STORM Overpack Handling Accident Corrective Action

Following a handling accident, the ISFSI operator shall first perform a radiological and visual inspection to determine the extent of the damage to the overpack. Special handling procedures, as required, will be developed and approved by the ISFSI operator.

If upon inspection of the MPC, structural damage of the MPC is observed, the MPC is to be returned to the facility for fuel unloading in accordance with Chapter 8. After unloading, the structural damage of the MPC shall be assessed and a determination shall be made if repairs will enable the MPC to return to service. Likewise, the HI-STORM overpack shall be thoroughly inspected and a determination shall be made if repairs will enable the HI-STORM overpack to return to service. Subsequent to the repairs, the equipment shall be inspected and appropriate tests shall be performed to certify the HI-STORM 100 System for service. If the equipment cannot be repaired and returned to service, the equipment shall be disposed of in accordance with the appropriate regulations.

11.2.3 Tip-Over

11.2.3.1 Cause of Tip-Over

The analysis of the HI-STORM 100 System has shown that the overpack does not tip over as a result of the accidents (i.e., tornado missiles, flood water velocity, and seismic activity) analyzed in this section. It is highly unlikely that the overpack will tip-over during on-site movement because of the low handling height limit. The tip-over accident is stipulated as a non-mechanistic accident.

For the anchored HI-STORM designs (HI-STORM 100A and 100SA), a tip-over accident is not possible. As described in Chapter 2 of this FSAR, *these system designs are not evaluated for the hypothetical tip-over. As such, the remainder of this accident discussion applies only to the non-anchored designs (i.e., the 100 and 100S designs only).*

11.2.3.2 Tip-Over Analysis

The tip-over accident analysis evaluates the effects of the loaded overpack tipping-over onto a reinforced concrete pad. The tip-over analysis is provided in Section 3.4. The structural analysis provided in Appendix 3.A demonstrates that the resultant deceleration loading on the MPC as a result of the tip-over accident is less than the design basis 45g's. The analysis shows that the HI-STORM 100 System meets all structural requirements and there is no adverse effect on the structural, confinement, thermal, or subcriticality performance of the MPC. However, the side impact will cause some localized damage to the concrete and outer shell of the overpack in the radial area of impact.

Structural

The structural evaluation of the MPC presented in Section 3.4 demonstrates that under a 45g loading the stresses are well within the allowable values. Analysis presented in Chapter 3 shows that the concrete shields attached to the underside and top of the overpack lid remains attached. As a result of the tip-over accident there will be localized crushing of the concrete in the area of impact.

Thermal

The thermal analysis of the overpack and MPC is based on vertical storage. The thermal consequences of this accident while the overpack is in the horizontal orientation are bounded by the burial under debris accident evaluated in Subsection 11.2.14. Damage to the overpack will be limited as discussed above. As the structural analysis demonstrates that there is no significant change in the MPC or overpack, once the overpack and MPC are returned to their vertical orientation there is no effect on the thermal performance of the system.

Shielding

The effect on the shielding performance of the system as a result of this event is limited to a localized decrease in the shielding thickness of the concrete.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is a very localized reduction in shielding and no effect on the confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this accident event.

Based on this evaluation, it is concluded that the accident pressure does not affect the safe operation of the HI-STORM 100 System.

11.2.3.3 Tip-Over Dose Calculations

The tip-over accident could cause localized damage to the radial concrete shield and outer steel shell where the overpack impacts the surface. The overpack surface dose rate in the affected area could increase due to the damage. However, there should be no noticeable increase in the ISFSI site or boundary dose rate, because the affected areas will be small and localized. The analysis of the tip-over accident has shown that the MPC confinement barrier will not be compromised and, therefore, there will be no release of radioactivity or increase in site-boundary dose rates.

11.2.3.4 Tip-Over Accident Corrective Action

Following a tip-over accident, the ISFSI operator shall first perform a radiological and visual inspection to determine the extent of the damage to the overpack. Special handling procedures will be developed and approved by the ISFSI operator.

If upon inspection of the MPC, structural damage of the MPC is observed, the MPC shall be returned to the facility for fuel unloading in accordance with Chapter 8. After unloading, the structural damage of the MPC shall be assessed and a determination shall be made if repairs will enable the MPC to return to service. Likewise, the HI-STORM overpack shall be thoroughly inspected and a determination shall be made if repairs are required and will enable the HI-STORM overpack to return to service. Subsequent to the repairs, the equipment shall be inspected and appropriate tests shall be performed to certify the HI-STORM 100 System for service. If the equipment cannot be repaired and returned to service, the equipment shall be disposed of in accordance with the appropriate regulations.

11.2.4 Fire Accident

11.2.4.1 Cause of Fire

Although the probability of a fire accident affecting a HI-STORM 100 System during storage operations is low due to the lack of combustible materials at the ISFSI, a conservative fire has been assumed and analyzed. The analysis shows that the HI-STORM 100 System continues to perform its structural, confinement, thermal, and subcriticality functions.

11.2.4.2 Fire Analysis

11.2.4.2.1 Fire Analysis for HI-STORM Overpack

The possibility of a fire accident near an ISFSI is considered to be extremely remote due to an absence of combustible materials within the ISFSI and adjacent to the overpacks. The only credible concern is related to a transport vehicle fuel tank fire, causing the outer layers of the storage overpack to be heated by the incident thermal radiation and forced convection heat fluxes. The amount of combustible fuel in the on-site transporter is limited to a volume of 50 gallons based on a Technical Specification in *Appendix A to the CoC*~~Chapter 12~~.

With respect to fire accident thermal analysis, NUREG-1536 (4.0,V,5.b) states:

> "Fire parameters included in 10 CFR 71.73 have been accepted for characterizing the heat transfer during the in-storage fire. However, a bounding analysis that limits the fuel source thus limits the length of the fire (e.g., by limiting the source of the fuel in the transporter) has also been accepted."

Based on this NUREG-1536 guidance, the fire accident thermal analysis is performed using the 10 CFR 71.73 parameters and the fire duration is determined from the limited fuel volume of 50 gallons. The entire transient evaluation of the storage fire accident consists of three parts: (1) a bounding steady-state initial condition, (2) the short-duration fire event, and (3) the post-fire temperature relaxation period.

As stated above, the fire parameters from 10 CFR 71.73 are applied to the HI-STORM fire accident evaluation. 10 CFR 71 requirements for thermal evaluation of hypothetical accident conditions specifically define pre- and post-fire ambient conditions, specifically:

> "the ambient air temperature before and after the test must remain constant at that value between -29°C (-20°F) and +38°C (100°F) which is most unfavorable for the feature under consideration."

The ambient air temperature is therefore set to 100°F both before (bounding steady state) and after (post-fire temperature relaxation period) the short-duration fire event.

During the short-duration fire event, the following parameters from 10CFR71.71(c)(4) are applied:

1. Except for a simple support system, the cask must be fully engulfed. The ISFSI pad is a simple support system, so the fire environment is not applied to the overpack baseplate. By fully engulfing the overpack, additional heat transfer surface area is conservatively exposed to the elevated fire temperatures.

2. The average emissivity coefficient must be at least 0.9. During the entire duration of the fire, the painted outer surfaces of the overpack are assumed to remain intact, with an emissivity of 0.85. It is conservative to assume that the flame emissivity is 1.0, the limiting maximum value corresponding to a perfect blackbody emitter. With a flame emissivity conservatively assumed to be 1.0 and a painted surface emissivity of 0.85, the effective emissivity coefficient is 0.85. Because the minimum required value of 0.9 is greater than the actual value of 0.85, use of an average emissivity coefficient of 0.9 is conservative.

3. The average flame temperature must be at least 800°C (1475°F). Open pool fires typically involve the entrainment of large amounts of air, resulting in lower average flame temperatures. Additionally, the same temperature is applied to all exposed cask surfaces,

which is very conservative considering the size of the HI-STORM cask. It is therefore conservative to use the 1475°F temperature.

4. The fuel source must extend horizontally at least 1 m (40 in), but may not extend more than 3 m (10 ft), beyond the external surface of the cask. Use of the minimum ring width of 1 meter yields a deeper pool for a fixed quantity of combustible fuel, thereby conservatively maximizing the fire duration.

5. The convection coefficient must be that value which may be demonstrated to exist if the cask were exposed to the fire specified. Based upon results of large pool fire thermal measurements [11.2.2], a conservative forced convection heat transfer coefficient of 4.5 Btu/(hr×ft^2×°F) is applied to exposed overpack surfaces during the short-duration fire.

Due to the severity of the fire condition radiative heat flux, heat flux from incident solar radiation is negligible and is not included. Furthermore, the smoke plume from the fire would block most of the solar radiation.

Based on the 50 gallon fuel volume, the overpack outer diameter and the 1 m fuel ring width, the fuel ring surrounding the overpack covers 147.6 ft^2 and has a depth of 0.54 in. From this depth and a linear fuel consumption rate of 0.15 in/min, the fire duration is calculated to be 3.622 minutes (217 seconds). The linear fuel consumption rate of 0.15 in/min is the smallest value given in a Sandia Report on large pool fire thermal testing [11.2.2]. Use of the minimum linear consumption rate conservatively maximizes the duration of the fire.

It is recognized that the ventilation air in contact with the inner surface of the HI-STORM overpack with design-basis decay heat under maximum normal ambient temperature conditions varies between 80°F at the bottom and *206*~~186~~°F at the top of the overpack. It is further recognized that the inlet and outlet ducts occupy only 1.25% of area of the cylindrical surface of the massive HI-STORM overpack. Due to the short duration of the fire event and the relative isolation of the ventilation passages from the outside environment, the ventilation air is expected to experience little intrusion of the fire combustion products. As a result of these considerations, it is conservative to assume that the air in the HI-STORM overpack ventilation passages is held constant at a substantially elevated temperature of 300°F during the entire duration of the fire event.

The thermal transient response of the storage overpack is determined using the ANSYS finite element program. Time-histories for points in the storage overpack are monitored for the duration of the fire and the subsequent post-fire equilibrium phase.

Heat input to the HI-STORM overpack while it is subjected to the fire is from a combination of an incident radiation and convective heat fluxes to all external surfaces. This can be expressed by the following equation:

$$q_F = h_{fc}(T_A - T_S) + 0.1714\times10^{8}\,\varepsilon\,[(T_A + 460)^4 - (T_S + 460)^4]$$

where:

q_F =Surface Heat Input Flux (Btu/ft^2-hr)
h_{fc} = Forced Convection Heat Transfer Coefficient (4.5 Btu/ft^2-hr-$^\circ$F)
T_A = Fire Condition Temperature (1475°F)
T_S = Transient Surface Temperature ($^\circ$F)
ε = Average Emissivity (0.90 per 10 CFR 71.73)

The forced convection heat transfer coefficient is based on the results of large pool fire thermal measurements [11.2.2].

After the fire event, the ambient temperature is restored to 100°F and the storage overpack cools down (post-fire temperature relaxation). Heat loss from the outer surfaces of the storage overpack is determined by the following equation:

$$q_S = h_S (T_S - T_A) + 0.1714\times 10^8 \varepsilon [(T_S + 460)^4 - (T_A + 460)^4]$$

where:

q_S =Surface Heat Loss Flux (Btu/ft^2-hr)
h_S = Natural Convection Heat Transfer Coefficient (Btu/ft^2-hr-$^\circ$F)
T_S = Transient Surface Temperature ($^\circ$F)
T_A = Ambient Temperature ($^\circ$F)
ε = Surface Emissivity

In the post-fire temperature relaxation phase, the surface heat transfer coefficient (h_S) is determined by the following equation:

$$h_S = 0.19 \times (T_A - T_S)^{1/3}$$

where:

h_S = Natural Convection Heat Transfer Coefficient (Btu/ft^2-hr-$^\circ$F)
T_A = External Air Temperature ($^\circ$F)
T_S = Transient Surface Temperature ($^\circ$F)

As discussed in Subsection 4.5.1.1.2, this equation is appropriate for turbulent natural convection from vertical surfaces. For the same conservative value of the Z parameter assumed earlier (2.6×10^5) and the HI-STORM overpack height of approximately 19 feet, the surface-to-ambient temperature difference required to ensure turbulence is 0.56 °F.

A two-dimensional, axisymmetric model was developed for this analysis. Material thermal properties used were taken from Section 4.2. An element plot of the 2-D axisymmetric ANSYS model is shown in Figure 11.2.1. The outer surface and top surface of the overpack are exposed to the ambient conditions (fire and post-fire), and the base of the overpack is insulated. The transient study is conducted for a period of 5 hours, which is sufficient to allow temperatures in the overpack to reach their maximum values and begin to recede.

Based on the results of the analysis, the maximum temperature increases at several points near the overpack mid-height are summarized in Table 11.2.2 along with the corresponding peak temperatures. Temperature profiles through the storage overpack wall thickness near the mid-height of the cask are included in Figures 11.2.2 through 11.2.4. A plot of temperature versus time is shown in Figure 11.2.5 for several points through the overpack wall, near the mid-height of the cask. The temperature profile plots (Figures 11.2.2 through 11.2.4) each contain profiles corresponding to time "snapshots". Profiles are presented at the following times: 1 minute (60 seconds), 2 minutes (120 seconds), 3.622 minutes (217 seconds – end of fire), 10 minutes (600 seconds), 20 minutes (1200 seconds), 40 minutes and 90 minutes.

The primary shielding material in the storage overpack is concrete, which can suffer a reduction in neutron shielding capability at sustained high temperatures due to a loss of water. As shown in Figure 11.2.5, less than 1 inch of the concrete near the outer overpack surface exceeds the material short-term temperature limit. This condition is addressed specifically in NUREG-1536 (4.0,V,5.b), which states:

> "The NRC accepts that concrete temperatures may exceed the temperature criteria of ACI 349 for accidents if the temperatures result from a fire."

These results demonstrate that the fire accident event does not substantially affect the HI-STORM overpack. Only localized regions of concrete are exposed to temperatures in excess of the allowable short-term temperature limit. No portions of the steel structure exceed the allowable temperature limits.

Having evaluated the effects of the fire on the overpack, we must now evaluate the effects on the MPC and contained fuel assemblies. Guidance for the evaluation of the MPC and its internals during a fire event is provided by NUREG-1536 (4.0,V,5.b), which states:

> "For a fire of very short duration (i.e., less than 10 percent of the thermal time constant of the cask body), the NRC finds it acceptable to calculate the fuel temperature increase by assuming that the cask inner wall is adiabatic. The fuel temperature increase should then be determined by dividing the decay energy released during the fire by the thermal capacity of the basket-fuel assembly combination."

The time constant of the cask body (i.e., the overpack) can be determined using the formula:

$$\tau = \frac{c_p \times \rho \times L_c^2}{k}$$

where:

c_p = Overpack Specific Heat Capacity (Btu/lb-°F)
ρ = Overpack Density (lb/ft^3)
L_c = Overpack Characteristic Length (ft)
k = Overpack Thermal Conductivity (Btu/ft-hr-°F)

The concrete contributes the majority of the overpack mass and volume, so we will use the specific heat capacity (0.156 Btu/lb-°F), density (142 lb/ft^3) and thermal conductivity (1.05 Btu/ft-hr-°F) of concrete for the time constant calculation. The characteristic length of a hollow cylinder is its wall thickness. The characteristic length for the HI-STORM overpack is therefore 29.5 in, or approximately 2.46 ft. Substituting into the equation, the overpack time constant is determined as:

$$\tau = \frac{0.156 \times 142 \times 2.46^2}{1.05} = 127.7\,hrs$$

One-tenth of this time constant is approximately 12.8 hours (766 minutes), substantially longer than the fire duration of 3.622 minutes, so the MPC is evaluated by considering the MPC canister as an adiabatic boundary. The temperature of the MPC is therefore increased by the contained decay heat only.

Table 4.5.5 lists lower-bound thermal inertia values for the MPC and the contained fuel assemblies of *4680*~~4200~~ Btu/°F and 2240 Btu/°F, respectively. Applying an upper-bound decay heat load of *28.74*~~22.25~~ kW (*98,090*~~76,028~~ Btu/hr) for the 3.622 minute (0.0604 hours) fire duration results in the contained fuel assemblies heating up by only:

$$\Delta T_{fuel} = \frac{98090 \times 0.0604}{4680 + 2240} = 0.86°F$$

This is a negligible increase in the fuel temperature. Consequently, the impact on the MPC internal helium pressure will be negligible as well. Based on a conservative analysis of the HI-STORM 100 System response to a hypothetical fire event, it is concluded that the fire event does not significantly affect the temperature of the MPC or contained fuel. Furthermore, the ability of the HI-STORM 100 System to cool the spent nuclear fuel within design temperature limits during post-fire temperature relaxation is not compromised.

Structural

As discussed above, there are no structural consequences as a result of the fire accident condition.

Thermal

As discussed above, the MPC internal pressure increases a negligible amount and is bounded by the 100% fuel rod rupture accident in Section 11.2.9. As shown in Table 11.2.2, the peak fuel cladding and material temperatures are well below short-term accident condition allowable temperatures of Table 2.2.3.

Shielding

With respect to concrete damage from a fire, NUREG-1536 (4.0,V,5.b) states: "the loss of a small amount of shielding material is not expected to cause a storage system to exceed the regulatory requirements in 10 CFR 72.106 and, therefore, need not be estimated or evaluated in the SAR." Less than one-inch of the concrete (less than 4% of the total overpack radial concrete section) exceeds the short-term temperature limit.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is a very localized reduction in shielding and no effect on the confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this accident event.

Based on this evaluation, it is concluded that the overpack fire accident does not affect the safe operation of the HI-STORM 100 System.

11.2.4.2.2 Fire Analysis for HI-TRAC Transfer Cask

To demonstrate the fuel cladding and MPC pressure boundary integrity under an exposure to a hypothetical short duration fire event during on-site handling operations, a fire accident analysis of the loaded 100-ton HI-TRAC is performed. This analysis, because of the lower mass of the 100-ton HI-TRAC, bounds the effects for the 125-ton HI-TRAC. In this analysis, the contents of the HI-TRAC are conservatively postulated to undergo a transient heat-up as a lumped mass from the decay heat input and heat input from the short duration fire. The rate of temperature rise of the HI-TRAC depends on the thermal inertia of the cask, the cask initial conditions, the spent nuclear fuel decay heat generation, and the fire heat flux. All of these parameters are conservatively bounded by the values in Table 11.2.3, which are used for the fire transient analysis.

Using the values stated in Table 11.2.3, a bounding cask temperature rise of ~~9.332~~*5.509*°F per minute is determined from the combined radiant and forced convection fire and decay heat inputs to the cask. During the handling of the HI-TRAC transfer cask, the transporter is limited to a maximum of 50 gallons, in accordance with a Technical Specification in *Appendix A to the CoC*~~Chapter 12~~. The duration of the 50-gallon fire is 4.775 minutes. Therefore, the fuel cladding will not exceed the short-term fuel cladding temperature limit (see Table 11.2.5).

The elevated temperatures as a result of the fire accident will cause the pressure in the water jacket to increase and cause the overpressure relief valve to vent steam to the atmosphere. Based on the fire heat input to the water jacket, less than *1*~~20~~% of the water in the water jacket can be boiled off. However, it is conservatively assumed, for dose calculations, that all the water in the water jacket is lost. In the 125-ton HI-TRAC, which uses Holtite in the lids for neutron shielding, the elevated fire temperatures would cause the Holtite to exceed its design accident temperature limits. It is conservatively assumed, for dose calculations, that all the Holtite in the 125-ton HI-TRAC is lost.

Due to the increased temperatures the MPC experiences as a result of the fire accident in the HI-TRAC transfer cask, the MPC internal pressure increases. Table 11.2.4 provides the MPC maximum internal pressures as a result of the HI-TRAC fire accident. *The values presented in Table 11.2.4 are determined using a bounding temperature rise of 43.2°F, instead of the calculated 26.3°F temperature rise, and are therefore conservative.* Table 11.2.5 provides a summary of the loaded HI-TRAC bounding maximum temperatures for the hypothetical fire accident condition.

Structural

As discussed above, there are no structural consequences as a result of the fire accident condition.

Thermal

As discussed above, the MPC internal pressure increases as a result of the fire accident, but the internal pressure, conservatively including a non-mechanistic 100% fuel rod rupture, is shown in Table 11.2.4 to be less than the accident condition MPC internal design pressure of *200*~~125~~ psig (Table 2.2.1). As shown in Table 11.2.5, the peak fuel cladding and material temperatures are well below short-term accident condition allowable temperatures of Table 2.2.3.

The loss of the water in the water jacket causes the temperatures to increase slightly due to a reduction in the thermal conductivity through the HI-TRAC water jacket. The temperatures of the MPC in the HI-TRAC transfer cask as a result of the loss of water in the water jacket are presented in Table 11.2.8 based on an assumed start at normal on-site transport conditions. As can be seen from the values in the table, the temperatures increase by less than 20°F. Therefore, if the temperatures presented in Table 11.2.5 were increased by 20°F to account for the decrease in conductivity of the water jacket, the resultant temperatures will still be well below the short-term allowable fuel cladding and material temperatures provided in Table 2.2.3 for accident conditions.

Shielding

The assumed loss of all the water in the water jacket results in an increase in the radiation dose rates at locations adjacent to the water jacket. The assumed loss of all the Holtite in the 125-ton HI-TRAC lids results in an increase in the radiation dose rates at locations adjacent to the lids. The shielding analysis results presented in Section 5.1.2 demonstrate that the requirements of 10CFR72.106 are not exceeded.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event, since the internal pressure does not exceed the accident condition design pressure and the MPC confinement boundary temperatures do not exceed the short-term allowable temperature limits.

Radiation Protection

There is no degradation in confinement capabilities of the MPC, as discussed above. There are increases in the local dose rates adjacent water jacket. HI-TRAC dose rates at 1 meter and 100 meters from the water jacket, after the water is lost, have already been reported in Subsection 11.2.1.2. Immediately after the fire accident a radiological inspection of the HI-TRAC will be performed and temporary shielding shall be installed to limit the exposure to the public.

11.2.4.3 Fire Dose Calculations

The complete loss of the HI-TRAC neutron shield along with the water jacket shell is assumed in the shielding analysis for the post-accident analysis of the loaded HI-TRAC in Chapter 5 and bounds the determined fire accident consequences. The loaded HI-TRAC following a fire accident meets the accident dose rate requirement of 10CFR72.106.

The elevated temperatures experienced by the HI-STORM overpack concrete shield is limited to the outermost layer. Therefore, any corresponding reduction in neutron shielding capabilities is limited to the outermost layer. The slight increase in the neutron dose rate as a result of the concrete in the outer inch reaching elevated temperatures will not significantly increase the site boundary dose rate, due to the limited amount of the concrete shielding with reduced effectiveness and the negligible neutron dose rate calculated for normal conditions at the site boundary. The loaded HI-STORM overpack following a fire accident meets the accident dose rate requirement of 10CFR72.106.

The analysis of the fire accident shows that the MPC confinement boundary is not compromised and therefore, there is no release of airborne radioactive materials.

11.2.4.4 Fire Accident Corrective Actions

Upon detection of a fire adjacent to a loaded HI-TRAC or HI-STORM overpack, the ISFSI operator shall take the appropriate immediate actions necessary to extinguish the fire. Fire fighting personnel should take appropriate radiological precautions, particularly with the HI-TRAC as the pressure relief valves may have opened and water loss from the water jacket may have occurred resulting in an increase in radiation doses. Following the termination of the fire, a visual and radiological inspection of the equipment shall be performed.

As appropriate, install temporary shielding around the HI-TRAC. Specific attention shall be taken during the inspection of the water jacket of the HI-TRAC. If damage to the HI-TRAC is limited to the loss of water in the water jacket due to the pressure increase, the water may be replaced by adding water at pressure. If damage to the HI-TRAC water jacket or HI-TRAC body is widespread and/or radiological conditions require, the HI-TRAC shall be unloaded in accordance with Chapter 8, prior to repair.

If damage to the HI-STORM storage overpack as the result of a fire event is widespread and/or as radiological conditions require, the MPC shall be removed from the HI-STORM overpack in accordance with Chapter 8. However, the thermal analysis described herein demonstrates that only the outermost layer of the radial concrete exceeds its design temperature. The HI-STORM overpack may be returned to service if there is no increase in the measured dose rates (i.e., the overpack's shielding effectiveness is confirmed) and if the visual inspection is satisfactory.

11.2.5 Partial Blockage of MPC Basket Vent Holes

Each MPC basket fuel cell wall has elongated vent holes at the bottom and top. The partial blockage of the MPC basket vent holes analyzes the effects on the HI-STORM 100 System due to the restriction of the vent openings.

11.2.5.1 Cause of Partial Blockage of MPC Basket Vent Holes

After the MPC is loaded with spent nuclear fuel, the MPC cavity is drained, vacuum dried, and backfilled with helium. There are only two possible sources of material that could block the MPC basket vent holes. These are the fuel cladding/fuel pellets and crud. Due to the maintenance of relatively low cladding temperatures during storage, it is not credible that the fuel cladding would rupture, and that fuel cladding and fuel pellets would fall to block the basket vent holes. It is conceivable that a percentage of the crud deposited on the fuel rods may fall off of the fuel assembly and deposit at the bottom of the MPC.

Helium in the MPC cavity provides an inert atmosphere for storage of the fuel. The HI-STORM 100 System maintains the peak fuel cladding temperature below the required long-term storage limits. All credible accidents do not cause the fuel assembly to experience an inertia loading greater than 60g's. Therefore, there is no mechanism for the extensive rupture of spent fuel rod cladding.

Crud can be made up of two types of layers, loosely adherent and tightly adherent. The SNF assembly movement from the fuel racks to the MPC may cause a portion of the loosely adherent crud to fall away. The tightly adherent crud is not removed during ordinary fuel handling operations. *The MPC vent holes that act as the bottom plenum for the MPC internal thermosiphon are of an elongated, semi-circular design to ensure that the flow passages will remain open under a hypothetical shedding of the crud on the fuel rods. For conservatism, only the minimum semi-circular hole area is credited in the thermal models (i.e., the elongated portion of the hole is completely neglected).*

The amount of crud on fuel assemblies varies greatly from plant to plant. Typically, BWR plants have more crud than PWR plants. Based on the maximum expected crud volume per fuel assembly provided in reference [11.2.5], and the area at the base of the MPC basket fuel storage cell, the maximum depth of crud at the bottom of the MPC-68 was determined. For the *PWR-style MPC designs (see Table 1.2.~~/MPC-24~~)*, 90% of the maximum crud volume was used to determine the crud depth. The maximum crud depths calculated for each of the MPCs is listed in Table 2.2.8. The maximum amount of crud was assumed to be present on all fuel assemblies within the MPC. Both the tightly and loosely adherent crud was conservatively assumed to fall off of the fuel assembly. As can be seen by the values listed in the table, the maximum amount of crud depth does not totally block any of the MPC basket vent holes *as the crud accumulation depth is less than the elongation of the vent holes. Therefore, the available vent holes area is greater than that used in the thermal models.*

11.2.5.2 Partial Blockage of MPC Basket Vent Hole Analysis

The partial blockage of the MPC basket vent holes has no affect on the structural, confinement and thermal analysis of the MPC. There is no affect on the shielding analysis other than a slight increase of the gamma radiation dose rate at the base of the MPC due to the accumulation of crud. As the MPC basket vent holes are not completely blocked, preferential flooding of the MPC fuel basket is not possible, and, therefore, the criticality analyses are not affected.

Structural

There are no structural consequences as a result of this event.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this accident event.

Criticality

There is no effect on the criticality control features of the system as a result of this accident event.

Confinement

There is no effect on the confinement function of the MPC as a result of this accident event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this accident event.

Based on this evaluation, it is concluded that the partial blockage of MPC vent holes does not affect the safe operation of the HI-STORM 100 System.

11.2.5.3 Partial Blockage of MPC Basket Vent Holes Dose Calculations

Partial blockage of basket vent holes will not result in a compromise of the confinement boundary. Therefore, there will be no effect on the site boundary dose rates because the magnitude of the radiation source has not changed. There will be no radioactive material release.

11.2.5.4 Partial Blockage of MPC Basket Vent Holes Corrective Action

There are no consequences that exceed normal storage conditions. No corrective action is required for the partial blockage of the MPC basket vent holes.

11.2.6 Tornado

11.2.6.1 Cause of Tornado

The HI-STORM 100 System will be stored on an unsheltered ISFSI concrete pad and subject to environmental conditions. Additionally, the transfer of the MPC from the HI-TRAC transfer cask to the overpack may be performed at the unsheltered ISFSI concrete pad. It is possible that the HI-STORM System (storage overpack and HI-TRAC transfer cask) may experience the extreme environmental conditions of a tornado.

11.2.6.2 Tornado Analysis

The tornado accident has two effects on the HI-STORM 100 System. The tornado winds and/or tornado missile attempt to tip-over the loaded overpack or HI-TRAC transfer cask. The pressure loading of the high velocity winds and/or the impact of the large tornado missiles act to apply an overturning moment. The second effect is tornado missiles propelled by high velocity winds which attempt to penetrate the storage overpack or HI-TRAC transfer cask.

During handling operations at the ISFSI pad, the loaded HI-TRAC transfer cask, while in the vertical orientation, shall be attached to a lifting device designed in accordance with the requirements specified in Subsection 2.3.3.1. Therefore, it is not credible that the tornado missile and/or wind could tip-over the loaded HI-TRAC while being handled in the vertical orientation. During handling of the loaded HI-TRAC in the horizontal orientation, it is possible that the tornado missile and/or wind may cause the rollover of the loaded HI-TRAC on the transport vehicle. The horizontal drop handling accident for the loaded HI-TRAC, Subsection 11.2.1, evaluates the consequences of the loaded HI-TRAC falling from the horizontal handling height limit and consequently this bounds the effect of the roll-over of the loaded HI-TRAC on the transport vehicle.

Structural

Section 3.4 provides the analysis of the pressure loading which attempts to tip-over the storage overpack and the analysis of the effects of the different types of tornado missiles. These analyses show that the loaded storage overpack does not tip-over as a result of the tornado winds and/or tornado missiles.

Analyses provided in Section 3.4 also shows that the tornado missiles do not penetrate the storage overpack or HI-TRAC transfer cask to impact the MPC. The result of the tornado missile impact on the storage overpack or HI-TRAC transfer cask is limited to damage of the shielding.

Thermal

The loss of the water in the water jacket causes the temperatures to increase slightly due to a reduction in the thermal conductivity through the HI-TRAC water jacket. The temperatures of the MPC in the HI-TRAC transfer cask as a result of the loss of water in the water jacket are presented in Table 11.2.8. As can be seen from the values in the table, the temperatures are well below the short-term allowable fuel cladding and material temperatures provided in Table 2.2.3 for accident conditions.

Shielding

The loss of the water in the water jacket results in an increase in the radiation dose rates at locations adjacent to the water jacket. The shielding analysis results presented in Section 5.1.2 demonstrate that the requirements of 10CFR72.106 are not exceeded.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

There is no degradation in confinement capabilities of the MPC, since the tornado missiles do not impact the MPC, as discussed above. There are increases in the local dose rates adjacent water jacket as a result of the loss of water in the HI-TRAC water jacket. HI-TRAC dose rates at 1 meter and 100 meters from the water jacket, after the water is lost, have already been reported in Subsection 11.2.1.2. Immediately after the tornado accident a radiological inspection of the HI-TRAC will be performed and temporary shielding shall be installed to limit the exposure to the public.

11.2.6.3 Tornado Dose Calculations

The tornado winds do not tip-over the loaded storage overpack; damage the shielding materials of the overpack or HI-TRAC; or damage the MPC confinement boundary. There is no affect on the radiation dose as a result of the tornado winds. A tornado missile may cause localized damage in the concrete radial shielding of the storage overpack. However, the damage will have a negligible effect on the site boundary dose. A tornado missile may penetrate the HI-TRAC water jacket shell causing the loss of the neutron shielding (water). The effects of the tornado missile damage on the loaded HI-TRAC transfer cask is bounded by the post-accident dose assessment performed in Chapter 5, which conservatively assumes complete loss of the water in the water jacket and the water jacket shell.

11.2.6.4 Tornado Accident Corrective Action

Following exposure of the HI-STORM 100 System to a tornado, the ISFSI operator shall perform a visual and radiological inspection of the overpack and/or HI-TRAC transfer cask. Damage sustained by the overpack outer shell, concrete, or vent screens shall be inspected and repaired. Damage sustained by the HI-TRAC shall be inspected and repaired.

11.2.7 Flood

11.2.7.1 Cause of Flood

The HI-STORM 100 System will be located on an unsheltered ISFSI concrete pad. Therefore, it is possible for the storage area to be flooded. The potential sources for the flood water could be unusually high water from a river or stream, a dam break, a seismic event, or a hurricane.

11.2.7.2 Flood Analysis

The flood accident affects the HI-STORM 100 overpack structural analysis in two ways. The flood water velocity acts to apply an overturning moment, which attempts to tip-over the loaded overpack. The flood affects the MPC by applying an external pressure.

Structural

Section 3.4 provides the analysis of the flood water applying an overturning moment. The results of the analysis show that the loaded overpack does not tip over if the flood velocity does not exceed the value stated in Table 2.2.8.

The structural evaluation of the MPC for the accident condition external pressure (Table 2.2.1) is presented in Section 3.4 and the resulting stresses from this event are shown to be well within the allowable values.

Thermal

For a flood of sufficient magnitude to allow the water to come into contact with the MPC, there is no adverse effect on the thermal performance of the system. The thermal consequence of such a flood is an increase in the rejection of the decay heat. Because the storage overpack is ventilated, water from a large flood will enter the annulus between the MPC and the overpack. The water would actually provide cooling that exceeds that available in the air filled annulus, due to water's higher thermal conductivity, density and heat capacity, and the forced convection coefficient associated with flowing water. Since the flood water temperature will be within the off-normal temperature range specified in Table 2.2.2, the thermal transient associated with the initial contact of the floodwater will be bounded by the off-normal operation conditions.

For a smaller flood that blocks the air inlet ducts but is not sufficient to allow water to come into contact with the MPC, a thermal analysis is included in Subsection 11.2.13 of this FSAR.

Shielding

There is no effect on the shielding performance of the system as a result of this event. The flood water acts as a radiation shield and will reduce the radiation doses.

Criticality

There is no effect on the criticality control features of the system as a result of this event. The criticality analysis is unaffected because under the flooding condition water does not enter the MPC cavity and therefore the reactivity would be less than the loading condition in the fuel pool which is presented in Section 6.1.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the flood accident does not affect the safe operation of the HI-STORM 100 System.

11.2.7.3 Flood Dose Calculations

Since the flood accident produces no leakage of radioactive material and no reduction in shielding effectiveness, there are no adverse radiological consequences.

11.2.7.4 Flood Accident Corrective Action

As shown in the analysis of the flood accident, the HI-STORM 100 System sustains no damage as a result of the flood. At the completion of the flood, the exterior and interior of the overpack, and the exterior of the MPC shall be cleaned to maintain the proper air flow and emissivity.

11.2.8 Earthquake

11.2.8.1 Cause of Earthquake

The HI-STORM 100 System may be employed at any reactor or ISFSI facility in the United States. It is possible that during the use of the HI-STORM 100 System, the ISFSI may experience an earthquake.

11.2.8.2 Earthquake Analysis

The earthquake accident analysis evaluates the effects of a seismic event on the loaded HI-STORM 100 System. The objective is to determine the stability limits of the HI-STORM 100 System. Based on a static stability criteria, it is shown in Chapter 3 that the HI-STORM 100 System is qualified to seismic activity less than or equal to the values specified in Table 2.2.8. The analyses in Chapter 3 show that the HI-STORM 100 System will not tip over under the conditions evaluated. The seismic activity has no adverse thermal, criticality, confinement, or shielding consequences.

Some ISFSI sites will have earthquakes that exceed the seismic activity specified in Table 2.2.8. For these high-seismic sites, anchored HI-STORM designs (the HI-STORM 100A and 100SA) have been developed. The design of these anchored systems is such that seismic loads cannot result in tip-over or lateral displacement. Chapter 3 provides a detailed discussion of the anchored systems design.

Structural

The sole structural effect of the earthquake is an inertial loading of less than 1g. This loading is bounded by the tip-over analysis presented in Section 11.2.3, which analyzes a deceleration of 45g's and demonstrates that the MPC allowable stress criteria are met.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the earthquake does not affect the safe operation of the HI-STORM 100 System.

11.2.8.3 Earthquake Dose Calculations

Structural analysis of the earthquake accident shows that the loaded overpack will not tip over as a result of the specified seismic activity. If the overpack were to tip over, the resultant damage would be equal to that experienced by the tip-over accident analyzed in Subsection 11.2.3. Since the loaded overpack does not tip-over, there is no increase in radiation dose rates or release of radioactivity.

11.2.8.4 Earthquake Accident Corrective Action

Following the earthquake accident, the ISFSI operator shall perform a visual and radiological inspection of the overpacks in storage to determine if any of the overpacks have tipped-over. In the unlikely event of a tip-over, the corrective actions shall be in accordance with Subsection 11.2.3.4.

11.2.9 100% Fuel Rod Rupture

This accident event postulates that all the fuel rods rupture and that the appropriate quantities of fission product gases and fill gas are released from the fuel rods into the MPC cavity.

11.2.9.1 Cause of 100% Fuel Rod Rupture

Through all credible accident conditions, the HI-STORM 100 System maintains the spent nuclear fuel in an inert environment while maintaining the peak fuel cladding temperature below the required short-term temperature limits, thereby providing assurance of fuel cladding integrity. There is no credible cause for 100% fuel rod rupture. This accident is postulated to evaluate the MPC confinement barrier for the maximum possible internal pressure based on the non-mechanistic failure of 100% of the fuel rods.

11.2.9.2 100% Fuel Rod Rupture Analysis

The 100% fuel rod rupture accident has no thermal, structural, criticality or shielding consequences. The event does not change the reactivity of the stored fuel, the magnitude of the radiation source which is being shielded, the shielding capability, or the criticality control features of the HI-STORM 100 System. The determination of the maximum accident pressure is provided in Chapter 4. The MPC design basis internal pressure bounds the pressure developed assuming 100% fuel rod rupture. The structural analysis provided in Chapter 3 evaluates the MPC confinement boundary under the accident condition internal pressure.

Structural

The structural evaluation of the MPC for the accident condition internal pressure presented in Section 3.4 demonstrates that the MPC stresses are well within the allowable values.

Thermal

The MPC internal pressure for the 100% fuel rod rupture condition is presented in Table 4.4.14. As can be seen from the values, the *200*~~125~~ psig design basis accident condition MPC internal pressure used in the structural evaluation bounds the calculated value.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the non-mechanistic 100% fuel rod rupture accident does not affect the safe operation of the HI-STORM 100 System.

11.2.9.3 100% Fuel Rod Rupture Dose Calculations

The MPC confinement boundary maintains its integrity. There is no effect on the shielding effectiveness, and the magnitude of the radiation source is unchanged. However, the radiation source could redistribute within the sealed MPC cavity causing a slight change in the radiation dose rates at certain locations. Therefore, there is no release of radioactive material or significant increase in radiation dose rates.

11.2.9.4 100% Fuel Rod Rupture Accident Corrective Action

As shown in the analysis of the 100% fuel rod rupture accident, the MPC confinement boundary is not damaged. The HI-STORM 100 System is designed to withstand this accident and continue performing the safe storage of spent nuclear fuel under normal storage conditions. No corrective actions are required.

11.2.10 Confinement Boundary Leakage

The confinement boundary leakage accident assumes simultaneous rupture of 100% of the fuel rods and the release of the available radioactive gas inventory to the environment at a rate ~~equal to the maximum leak test rate of the MPC confinement boundary plus the test sensitivity~~ *based on 150% of the maximum leak rate under reference conditions.*

11.2.10.1 Cause of Confinement Boundary Leakage

There is no credible cause for confinement boundary leakage. The accidents analyzed in this chapter show that the MPC confinement boundary withstands all credible accidents. There are no man-made or natural phenomena that could cause failure of the confinement boundary restricting radioactive material release. The release is analyzed to demonstrate the safety of the HI-STORM 100 System.

11.2.10.2 Confinement Boundary Leakage Analysis

The following is the basis for the conservative analysis of the confinement boundary leakage accident.

1. All the fuel stored in the MPC has been cooled for 5 years~~ and has a burnup of 40,000 MWD/MTU~~. The PWR fuel type is the B&W 15×15 ~~with 3.4%~~*at 4.8%* enrichment *with a burnup of 70,000 MWD/MTU.* The BWR fuel type is the GE 7×7 ~~with 3.0%~~*at 4.4%* enrichment *with a burnup of 60,000 MWD/MTU.* These fuel characteristics bound the design basis fuel for the HI-STORM 100 System.

2. One hundred percent of all the fuel rods are assumed to rupture.

3. The releasable source term and release fractions are in accordance with NUREG-~~6487, Section 7.0.~~*1536, ISG-5 and ISG-11.*

4. The maximum possible leakage rate of radionuclides to the environment is ~~equal to the maximum allowable leakage plus the measurement sensitivity from the~~*based on the helium leak rate under reference test conditions from the* ~~t~~*T*echnical Specification in *Appendix A to the CoC*~~Chapter 12~~.

Chapter 7 presents an evaluation of the consequences of a non-mechanistic postulated ground-level breach of the MPC confinement boundary under hypothetical accident conditions of storage. The resulting Total Effective Dose Equivalent (TEDE) and ~~thyroid~~*other* dose *equivalents* at a downstream distance of 100 meters are evaluated for each MPC type~~ (MPC-24, MPC-68 and MPC-68F)~~.

Structural

There are no structural consequences of the loss of confinement accident.

Thermal

Since this event is a non-mechanistic assumption, there are no realistic thermal consequences. As discussed in the Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~, the leak test rate would result in a negligible loss of helium fill gas over the design life of the MPC, which would have an inconsequential effect on thermal performance.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

This event is based upon an assumed instantaneous breach of the confinement.

Radiation Protection

The postulated release will result in an increase in dose to the public. The analysis of this event is provided in Section 7.3. As shown therein, the postulated breach results in dose rates to the public less than the limit established by 10CFR72.106(b) for the site boundary.

11.2.10.3 Confinement Boundary Leakage Dose Calculations

10CFR72.106 requires that any individual located at or beyond the nearest controlled area boundary must not receive a dose greater than 5 Rem to the whole body or any organ from any design basis accident. The maximum whole body dose contribution as a result of the instantaneous leak accident is calculated in Chapter 7 (Table 7.3.~~2~~*8*~~) to be 54.4 mRem~~. The maximum ~~thyroid~~ dose*s* as a result of the ~~instantaneous~~*confinement boundary* leak accident is calculated in Chapter 7 *(Table 7.3.8)*~~to be 0.016 mRem~~. Both values are well below the regulatory limit of 5 Rem.

11.2.10.4 Confinement Boundary Leakage Accident Corrective Action

A detected breached MPC will need to be repaired or the fuel removed and placed into a new MPC. First, the breached MPC must be returned to the facility in accordance with the procedures provided in Chapter 8. If the leak can be detected and repaired, and testing can be performed to verify the integrity of the confinement boundary, the MPC may be placed back into service. Otherwise, the MPC should be unloaded in accordance with the procedures provided in Chapter 8.

11.2.11 Explosion

11.2.11.1 Cause of Explosion

An explosion within the bounds of an ISFSI is improbable since there are no explosive materials within the site boundary. An explosion as a result of combustion of the fuel contained in cask transport vehicle is possible. The fuel available for the explosion would be limited and therefore, any explosion would be limited in size. Any explosion stipulated to occur beyond the site boundary would have a minimal effect on the HI-STORM 100 System.

11.2.11.2 Explosion Analysis

Any credible explosion accident is bounded by the accident external pressure of 60 psig (Table 2.2.1) analyzed as a result of the flood accident water depth in Subsection 11.2.7 and the tornado missile accident of Subsection 11.2.6, because explosive materials will not be stored within close proximity to the casks. The HI-STORM Overpack does not experience the 60 psi external pressure since it is not a sealed vessel. However, a pressure differential of 10.0 psi (Table 2.2.1) is applied to the overpack. Section 3.4 provides the analysis of the accident external pressure on the MPC and overpack. The analysis shows that the MPC can withstand the effects of the accident condition external pressure, while conservatively neglecting the MPC internal pressure.

Structural

The structural evaluations for the MPC accident condition external pressure and overpack pressure differential are presented in Section 3.4 and demonstrate that all stresses are within allowable values.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the explosion accident does not affect the safe operation of the HI-STORM 100 System.

11.2.11.3 Explosion Dose Calculations

The bounding external pressure load has no effect on the HI-STORM 100 overpack and MPC. Therefore, no effect on the shielding, criticality, thermal or confinement capabilities of the HI-STORM 100 System is experienced as a result of the explosion pressure load. The effects of explosion generated missiles on the HI-STORM 100 System structure is bounded by the analysis of tornado generated missiles.

11.2.11.4 Explosion Accident Corrective Action

The explosive overpressure caused by the explosion is bounded by the external pressure exerted by the flood accident. The external pressure from the flood is shown not to damage the HI-STORM 100 System. Following an explosion, the ISFSI operator shall perform a visual and radiological inspection of the overpack. If the outer shell or concrete is damaged as a result of explosion generated missiles, the concrete material may be replaced and the outer shell repaired.

11.2.12 Lightning

11.2.12.1 Cause of Lightning

The HI-STORM 100 System will be stored on an unsheltered ISFSI concrete pad. There is the potential for lightning to strike the overpack. This analysis evaluates the effects of lightning striking the overpack.

11.2.12.2 Lightning Analysis

The HI-STORM 100 System is a large metal/concrete cask stored in an unsheltered ISFSI. As such, it may be subject to lightning strikes. When the HI-STORM 100 System is hit with lightning, the lightning will discharge through the steel shell of the overpack to the ground. Lightning strikes have high currents, but their duration is short (i.e., less than a second). The overpack outer shell is composed of conductive carbon steel and, as such, will provide a direct path to ground.

The MPC provides the confinement boundary for the spent nuclear fuel. The effects of a lightning strike will be limited to the overpack. The lightning current will discharge into the overpack and directly into the ground. Therefore, the MPC will be unaffected.

The lightning accident shall have no adverse consequences on thermal, criticality, confinement, shielding, or structural performance of the HI-STORM 100 System.

Structural

There is no structural consequence as a result of this event.

Thermal

There is no effect on the thermal performance of the system as a result of this event.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the lightning accident does not affect the safe operation of the HI-STORM 100 System.

11.2.12.3 Lightning Dose Calculations

An evaluation of lightning strikes demonstrates that the effect of a lightning strike has no effect on the confinement boundary or shielding materials. Therefore, no further analysis is necessary.

11.2.12.4 Lightning Accident Corrective Action

The HI-STORM 100 System will not sustain any damage from the lightning accident. There is no surveillance or corrective action required.

11.2.13 100% Blockage of Air Inlets

11.2.13.1 Cause of 100% Blockage of Air Inlets

This event is defined as a complete blockage of all four bottom inlets. Such blockage of the inlets may be postulated to occur as a result of a flood, blizzard snow accumulation, tornado debris, or volcanic activity.

11.2.13.2 100% Blockage of Air Inlets Analysis

The immediate consequence of a complete blockage of the air inlet ducts is that the normal circulation of air for cooling the MPC is stopped. A*n* ~~small~~ amount of heat will continue to be removed by localized air circulation patterns in the overpack annulus and outlet ducts, and the MPC will continue to radiate heat to the relatively cooler storage overpack. *As the temperatures of the MPC and its contents rise, the rate of heat rejection will increase correspondingly.* Under this condition, the temperatures of the overpack, the MPC and the stored fuel assemblies will rise as a function of time.

As a result of the large mass, and correspondingly large thermal capacity, of the storage overpack (in excess of 170,000 lbs), it is expected that a significant temperature rise is only possible if the completely blocked condition is allowed to persist for a number of days. This accident condition is, however, a short duration event that will be identified and corrected by scheduled periodic surveillance at the ISFSI site. Thus, the worst possible scenario is a complete loss of ventilation air during the scheduled surveillance time interval in effect at the ISFSI site.

It is noted that there is a large thermal margin, between the maximum calculated fuel cladding temperature with design-basis fuel decay heat (Tables 4.4.9*,* ~~and~~ 4.4.10*, 4.4.46 and 4.4.27*) and the short-term fuel cladding temperature limit (1058°F), to meet the transient short-term fuel cladding temperature excursion. In other words, the fuel stored in a HI-STORM system can heat up by over 300°F before the short-term peak temperature limit is reached. The concrete in the overpack *and the MPC and overpack structural members also have* ~~has a smaller, but nevertheless~~ significant, margin*s* between ~~its~~ *their* calculated maximum long-term temperature*s* and ~~its~~ *their* short-term temperature limit*s*, with which to withstand such extreme hypothetical events.

To rigorously evaluate the minimum time available before the short-term temperature limits of either the concrete*, structural members* or fuel cladding are exceeded, a transient thermal model of the HI-STORM System is developed. The HI-STORM system transient model with all four air inlet ducts completely blocked is created as an axisymmetric finite-volume (FLUENT) model. With the exceptions of the inlet air duct blockage and the specification of thermal inertia properties (i.e., density and heat capacity), the model is identical to the steady-state models discussed in Chapter 4 of this FSAR. The model includes the lowest MPC thermal inertia of any MPC design ~~and conservatively bounding fuel decay heat load is applied~~.

In the first step of the transient solution, the decay heat load is set equal to 22.25 kW and the MPC internal convection (i.e., thermosiphon) is suppressed. This evaluation provides the peak temperatures of the fuel cladding, the MPC confinement boundary and the concrete overpack shield wall, all as a function of time. Because the MPC with the lowest thermal inertia is used in the analysis, the ~~The~~ temperature rise results obtained from evaluation of this *transient* model, therefore, bound the temperature rises for *all MPC* ~~the MPC-24 or MPC-68~~ designs *(Table 1.2.1)* under this postulated event.

The results of the blocked duct thermal transient evaluation are presented in Figures 11.2.7 ~~and 11.2.8,~~ and Table 11.2.9. Figure 11.2.7 presents the temperature rise as a function of time after complete air inlet duct blockage for the following:

i. Fuel Cladding at the Location of Initial Maximum Temperature
ii. MPC Shell at the Location of Initial Maximum Temperature
iii. Overpack Inner Concrete at the Active Fuel Axial Mid-Height
iv. Overpack Inner Concrete at the Location of Initial Maximum Temperature
v. Overpack Outer Concrete at the Active Fuel Axial Mid-Height
vi. Overpack Outer Concrete at the Location of Initial Maximum Temperature

~~Figure 11.2.8 presents temperature contour plots at several instants in time to illustrate the transient heatup of the HI-STORM System. The concrete reaches its short-term temperature limit in approximately 33 hours.~~ *The concrete section average (i.e., through thickness) temperature remains below the short-term temperature limit through 72 hours of blockage.* Both the fuel cladding and the MPC confinement boundary temperatures remain ~~substantially~~ below their respective short-term temperature limits at 72 hours, *the fuel cladding by over 150°F and the confinement boundary by almost 175°F.* Table 11.2.9 summarizes the temperatures at several points in the HI-STORM System at 33 hours and 72 hours after complete inlet air duct blockage. These results establish the design-basis minimum surveillance interval (i.e., 24 hours per Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~) for the duct screens.

Incorporation of the MPC thermosiphon internal natural convection, as described in Chapter 4, enables the maximum design basis decay heat load to rise to about 29 kW. The thermosiphon effect also shifts the highest temperatures in the MPC enclosure vessel toward the top of the MPC. The peak MPC closure plate outer surface temperature, for example, is computed to be about 450°F in the thermosiphon-enabled solution compared to about 210°F in the thermosiphon-suppressed solution, with both solutions computing approximately the same peak clad temperature. In the 100% inlet duct blockage condition, the heated MPC closure plate and MPC shell become effective heat dissipaters because of their proximity to the overpack outlet ducts and by virtue of the fact that thermal radiation heat transfer rises at the fourth power of absolute temperature. As a result of this increased heat rejection from the upper region of the MPC, the time limit~~s~~ for reaching the short-term ~~concrete and~~ peak fuel cladding temperature limit~~s~~ ~~(33 hours and~~ 72 hours~~, respectively)~~ remains applicable.

It should be noted that the rupture of 100% of the fuel rods and the subsequent release of the contained rod gases has a significant positive impact on the MPC internal thermosiphon heat transport mechanism. The increase in the MPC internal pressure accelerates the thermosiphon, as does the introduction of higher molecular weight gaseous fission products. The values reported in Table 11.2.9 do not reflect this improved heat transfer and will actually be lower than reported. Crediting the increased MPC internal pressure only and neglecting the higher molecular weights of the gaseous fission products, the MPC bulk average gas temperature will be reduced by approximately 34.5°C (62.1°F).

Under the complete air inlet ducts blockage accident condition, it must be demonstrated that the MPC internal pressure does not exceed its design-basis accident limit during this event. Chapter 4 presented the MPC internal pressure calculated at an ambient temperature of 80°F, 100% fuel rods ruptured, full insolation, and maximum decay heat. This calculated pressure is *174.8*~~97.6~~ psi*a*~~g~~, as reported in Table 4.4.14, at an average temperature of *513.6*~~503.5~~°K. Using this pressure, a bounding increase in the MPC cavity temperature of 184°F (*102.2°K,* maximum of MPC shell or fuel cladding temperature rise 33 hours after blockage of all four ducts, see Table 11.2.9), *the reduction in the bulk average gas temperature of 34.5°C,* and the ideal gas law, the resultant MPC internal pressure is calculated below.

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

$$P_2 = \frac{P_1 T_2}{T_1}$$

$$P_2 = \frac{(174.8\,\text{psi}\,a)(513.6^\circ\text{K} + 102.2^\circ\text{K} - 34.5^\circ\text{K})}{513.6^\circ\text{K}}$$

$$P_2 = 197.8\,\text{psia or } 183.1\,\text{psig}$$

The accident MPC internal design pressure of ~~125~~*200* psig (Table 2.2.1) bounds the resultant pressure calculated above. Therefore, no additional analysis is required.

Structural

There are no structural consequences as a result of this event.

Thermal

Thermal analysis is performed to determine the time until the ~~local maximum~~ concrete *section average and peak fuel cladding* temperature*s* approach~~es~~ ~~its~~ *their* short-term temperature limit*s*. At the specified time limit, *both the concrete section average and* ~~the~~ peak fuel cladding temperature*s* remains below ~~its~~ *their* short-term temperature limits. The MPC internal pressure for this event is calculated as presented above. As can be seen from the value above, the ~~125~~*200* psig design basis internal pressure for accident conditions used in the structural evaluation bounds the calculated value above.

To demonstrate the robustness of the HI-STORM System design, the results of the parametric study of incremental duct blockage performed in Subsection 11.1.4 are examined again. Even with three air inlet ducts completely blocked, as shown in Table 11.1.2, large steady-state margins against the short-term temperature limits exist for all system components and the fuel cladding of the stored assemblies. *Both the peak fuel cladding and overpack concrete section average temperatures*~~The temperature of the inner radial concrete surface~~, *which approach* the*ir* limiting temperature*s* under the 100% blockage condition, with a single open duct ~~is~~*are* ~~over~~ *approximately* ~~100~~ ~~*70*~~*240*°F *and 100°F, respectively,* less than the*ir respective* short-term temperature limit*s*. These results show that only a relatively small amount of the total air inlet duct area, on the order of 25% or less, must remain open to prevent exceeding system short-term temperature limits under steady-state conditions.

Shielding

There is no effect on the shielding performance of the system as a result of this event, since the concrete temperatures do not exceed the short-term condition design temperature provided in Table 2.2.3.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the 100% blockage of air inlets accident does not affect the safe operation of the HI-STORM 100 System, if the blockage is removed in the specified time period. The Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~ specify the time interval to ensure that the blockage duration cannot exceed the time limit calculated herein.

11.2.13.3 100% Blockage of Air Inlets Dose Calculations

As shown in the analysis of the 100% blockage of air inlets accident, the shielding capabilities of the HI-STORM 100 System are unchanged because the peak concrete temperature does not exceed its short-term condition design temperature. The elevated temperatures will not cause the breach of the confinement system and the short term fuel cladding temperature limit is not exceeded. Therefore, there is no radiological impact.

11.2.13.4 100% Blockage of Air Inlets Accident Corrective Action

Analysis of the 100% blockage of air inlet ducts accident shows that the *overpack concrete section average and* fuel cladding peak temperatures remain substantially below the*ir* short-term temperature limits if the blockage is cleared within 72 hours. ~~Overpack localized concrete temperatures will not~~

~~exceed the short-term temperature limit if the blockage is cleared within 33 hours.~~ Upon detection of the complete blockage of the air inlet ducts, the ISFSI operator shall assign personnel to clear the blockage with mechanical and manual means as necessary. After clearing the overpack ducts, the overpack shall be visually and radiologically inspected for any damage. Per the Technical Specifications in *Appendix A to the CoC*~~Chapter 12~~, visual inspection of the duct screens is specified on a frequency of 24 hours, or air outlet temperature monitoring is required. Therefore, an undetected blockage event could not exceed 24 hours.

If exit air temperature monitoring is performed in lieu of direct visual inspections, the difference between the ambient air temperature and the exit air temperature will be the basis for assurance that the temperature limits are not exceeded. A measured temperature difference between the ambient air and the exit air that exceeds the design-basis maximum air temperature rise, calculated in Section 4.4.2, will indicate blockage of the overpack air ducts.

For ~~a flood~~ *an accident event* that *completely* blocks the ~~air~~ inlet *or outlet air* ducts*, a site-specific evaluation or analysis may be performed to demonstrate that adequate heat removal is available for the duration of the event. Adequate heat removal is defined as overpack concrete section average and fuel cladding temperatures remaining below their short term temperature limits. For those events where an evaluation or analysis is not performed or is not successful is showing that fuel cladding temperatures remain below the short term temperature limit ,* ~~but does not immerse the MPC~~, the site's emergency plan shall include provisions to ~~either~~ *address* remove*al of* the ~~water~~ *material* blocking the air inlet ducts ~~or~~ *and to* provide ~~supplemental~~ *alternate means of* cooling prior to exceeding the time when the ~~local concrete~~ *fuel cladding* temperature reaches its short-term temperature limit. ~~*Supplemental*~~*Alternate means of cooling could include, for example, spraying water into the air outlet ducts using pumps or fire-hoses or blowing air into the air outlet ducts using fans, to directly cool the MPC. Another example of supplemental cooling, for sufficiently low decay heat loads, would be to remove the overpack lid to increase free-surface natural convection.*

~~*For those design basis events resulting in blockage of all inlet or outlet ducts and lasting more than 33 hours, the users' corrective actions shall include verification of the effectiveness of the shielding of the HI-STORM 100 overpack after the event is over. This is required to ensure that any local temperature excursions in the overpack concrete, as described earlier in this section, do not significantly reduce the effectiveness of the shielding provided by the overpack. Appropriate actions, commensurate with the safety significance of the findings, shall be taken in accordance with the user's corrective action program.*~~

11.2.14 Burial Under Debris

11.2.14.1 Cause of Burial Under Debris

Burial of the HI-STORM System under debris is not a credible accident. During storage at the ISFSI, there are no structures over the casks. The minimum regulatory distance of 100 meters from the

ISFSI to the nearest site boundary and the controlled area around the ISFSI concrete pad precludes the close proximity of substantial amounts of vegetation.

There is no credible mechanism for the HI-STORM System to become completely buried under debris. However, for conservatism, complete burial under debris is considered. Blockage of the HI-STORM overpack air inlet ducts has already been considered in Subsection 11.2.13.

11.2.14.2 Burial Under Debris Analysis

Burial of the HI-STORM System does not impose a condition that would have more severe consequences for criticality, confinement, shielding, and structural analyses than that performed for the other accidents analyzed. The debris would provide additional shielding to reduce radiation doses. The accident external pressure encountered during the flood bounds any credible pressure loading caused by the burial under debris.

Burial under debris can affect thermal performance because the debris acts as an insulator and heat sink. This will cause the HI-STORM System and fuel cladding temperatures to increase. A thermal analysis has been performed to determine the time for the fuel cladding temperatures to reach the short term accident condition temperature limit during a burial under debris accident.

To demonstrate the inherent safety of the HI-STORM System, a bounding analysis that considers the debris to act as a perfect insulator is considered. Under this scenario, the contents of the HI-STORM System will undergo a transient heat up under adiabatic conditions. The minimum time required for the fuel cladding to reach the short term design fuel cladding temperature limit depends on the amount of thermal inertia of the cask, the cask initial conditions, and the spent nuclear fuel decay heat generation.

As stated in Subsection 11.2.13.2, there is a margin of over 300°F between the maximum calculated fuel cladding temperature and the short-term fuel cladding temperature limit. If *a highly conservative* *150*~~300~~°F is postulated as the permissible fuel cladding temperature rise for the burial under debris scenario, then a curve representing the relationship between the time required and decay heat load can be constructed. This curve is shown in Figure 11.2.6. In this figure, plots of the burial period at different levels of heat generation in the MPC are shown based on a *150*~~300~~°F rise in fuel cladding temperature resulting from transient heating of the HI-STORM System. Using the values stated in Table 11.2.6, the allowable time before the cladding temperatures meet the short-term fuel cladding temperature limit can be determined using:

$$\Delta t = \frac{m \times c_p \times \Delta T}{Q}$$

where:

Δt = Allowable Burial Time (hrs)
m = Mass of HI-STORM System (lb)
c_p = Specific Heat Capacity (Btu/lb×°F)
ΔT = Permissible Fuel Cladding Temperature Rise (*150*~~300~~°F)

Q = Total Decay Heat Load (Btu/hr)

The allowable burial time as a function of total decay heat load (Q) is presented in Figure 11.2.6.

The MPC cavity internal pressure under this accident scenario is bounded by the calculated internal pressure for the hypothetical 100% air inlets blockage previously evaluated in Subsection 11.2.13.2.~~Conservatively including a hypothetical 10% rods rupture condition, a bounding MPC internal gas pressure (P_2) resulting from a 300°F ($\Delta T = 166.7$°K) temperature rise is computed below:~~

$$\cancel{P_2} = \frac{P_1(T_1 + \Delta T)}{T_1}$$

~~where:~~

~~P_1 = Initial cavity pressure (62.8 psig, [Table 4.4.14])~~
~~T_1 = Initial MPC cavity average gas temperature (503.5°K) at normal storage condition~~

~~Thus:~~

~~This pressure is below the accident condition MPC design pressure (125 psig). Thus confinement boundary structural integrity is maintained.~~

Structural

The structural evaluation of the MPC enclosure vessel for accident internal pressure conditions bounds the pressure calculated herein. Therefore, the resulting stresses from this event are well within the allowable values, as demonstrated in Section 3.4.

Thermal

With the cladding temperature rise limited to *150*~~300~~°F, the corresponding pressure rise*, bounded by the calculations in Subsection 11.2.13.2,* ~~calculation performed herein~~ demonstrates large margins of safety for the MPC vessel structural integrity. Consequently, cladding integrity and confinement function of the MPC are not compromised.

Shielding

There is no effect on the shielding performance of the system as a result of this event.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the burial under debris accident does not affect the safe operation of the HI-STORM 100 System, if the debris is removed within the specified time (Figure 11.2.6). The 24-hour minimum duct inspection interval specified in the Technical Specification in *Appendix A to the CoC*~~Subsection 12.3.18~~ ensures that a burial under debris condition will be detected long before the allowable burial time is reached.

11.2.14.3 Burial Under Debris Dose Calculations

As discussed in burial under debris analysis, the shielding is enhanced while the HI-STORM System is covered.

The elevated temperatures will not cause the breach of the confinement system and the short term fuel cladding temperature limit is not exceeded. Therefore, there is no radiological impact.

11.2.14.4 Burial Under Debris Accident Corrective Action

Analysis of the burial under debris accident shows that the fuel cladding peak temperatures will not exceed the short term limit if the debris is removed within *45*~~100~~ hours. Upon detection of the burial under debris accident, the ISFSI operator shall assign personnel to remove the debris with mechanical and manual means as necessary. After uncovering the storage overpack, the storage overpack shall be visually and radiologically inspected for any damage. The loaded MPC shall be removed from the storage overpack with the HI-TRAC transfer cask to allow complete inspection of the overpack air inlets and outlets, and annulus. Removal of obstructions to the air flow path shall be performed prior to the re-insertion of the MPC. The site's emergency action plan shall include provisions for the performance of this corrective action.

11.2.15 Extreme Environmental Temperature

11.2.15.1 Cause of Extreme Environmental Temperature

The extreme environmental temperature is postulated as a constant ambient temperature caused by extreme weather conditions. To determine the effects of the extreme temperature, it is conservatively assumed that the temperature persists for a sufficient duration to allow the HI-STORM 100 System to achieve thermal equilibrium. Because of the large mass of the HI-STORM 100 System, with its corresponding large thermal inertia and the limited duration for the extreme temperature, this assumption is conservative.

11.2.15.2 Extreme Environmental Temperature Analysis

The accident condition considering an environmental temperature of 125°F for a duration sufficient to reach thermal equilibrium is evaluated with respect to accident condition design temperatures listed in Table 2.2.3. The evaluation is performed with design basis fuel with the maximum decay heat and the most restrictive thermal resistance. The 125°F environmental temperature is applied with full solar insolation.

The HI-STORM 100 System maximum temperatures for components close to the design basis temperatures are listed in Section 4.4. These temperatures are conservatively calculated at an environmental temperature of 80°F. The extreme environmental temperature is 125°F, which is an increase of 45°F. ~~Including the effect of a hypothetical 10% rods rupture condition on the MPC cavity gas conductivity, c~~ *C*onservatively bounding temperatures ~~of~~ *for all* the *MPC designs* ~~MPC-24 and MPC-68~~ are obtained and reported in Table 11.2.7. As illustrated by the table, all the temperatures are well below the accident condition design basis temperatures. The extreme environmental temperature is of a short duration (several consecutive days would be highly unlikely) and the resultant temperatures are evaluated against short-term accident condition temperature limits. Therefore, the HI-STORM 100 System extreme environmental temperatures meet the design requirements.

Additionally, the extreme environmental temperature generates a pressure that is bounded by the pressure calculated for the complete inlet duct blockage condition because the duct blockage condition temperatures are much higher than the temperatures that result from the extreme environmental temperature. As shown in Subsection 11.2.13.2, the accident condition pressures are below the accident limit specified in Table 2.2.1.

Structural

The structural evaluation of the MPC enclosure vessel for accident condition internal pressure bounds the pressure resulting from this event. Therefore, the resulting stresses from this event are bounded by that of the accident condition and are well within the allowable values, as discussed in Section 3.4.

Thermal

The resulting temperatures for the system and fuel assembly cladding are provided in Table 11.2.7. As can be seen from this table, all temperatures are within the short-term accident condition allowable values specified in Table 2.2.3.

Shielding

There is no effect on the shielding performance of the system as a result of this event, since the concrete temperature does not exceed the short-term temperature limit specified in Table 2.2.3.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is no degradation in shielding or confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this event.

Based on this evaluation, it is concluded that the extreme environment temperature accident does not affect the safe operation of the HI-STORM 100 System.

11.2.15.3 Extreme Environmental Temperature Dose Calculations

The extreme environmental temperature will not cause the concrete to exceed its normal design temperature. Therefore, there will be no degradation of the concrete's shielding effectiveness. The elevated temperatures will not cause a breach of the confinement system and the short-term fuel cladding temperature is not exceeded. Therefore, there is no radiological impact on the HI-STORM 100 System for the extreme environmental temperature and the dose calculations are equivalent to the normal condition dose rates.

11.2.15.4 Extreme Environmental Temperature Corrective Action

There are no consequences of this accident that require corrective action.

Table 11.2.1

INTENTIONALLY DELETED

Table 11.2.2

HI-STORM 100 OVERPACK ~~MID-HEIGHT~~*MAXIMUM* TEMPERATURES AS A RESULT OF THE HYPOTHETICAL FIRE CONDITION

Material/Component	**Initial[†] Condition (°F)**	**During Fire (°F)**	**Post-Fire[††] Cooldown (°F)**
Fuel Cladding	*691*~~729~~ (MPC-24) *691 (MPC-24E)* *691 (MPC-32)* *740*~~745~~ (MPC-68)	*692*~~730~~ (MPC-24) *692 (MPC-24E)* *692 (MPC-32)* *741*~~746~~ (MPC-68)	*692*~~730~~ (MPC-24) *692 (MPC-24E)* *692 (MPC-32)* *741*~~746~~ (MPC-68)
MPC Fuel Basket	*650*~~689~~ (MPC-24) *650 (MPC-24E)* *660 (MPC-32)* *720*~~725~~ (MPC-*68*~~24~~)	*651*~~690~~ (MPC-24) *651 (MPC-24E)* *661 (MPC-32)* *721*~~726~~ (MPC-*68*~~24~~)	*651*~~690~~ (MPC-24) *651 (MPC-24E)* *661 (MPC-32)* *721*~~726~~ (MPC-*68*~~24~~)
Overpack Inner Shell	195	300	195
Overpack Radial Concrete Inner Surface	195	281	282
Overpack Radial Concrete Mid-Surface	173	173	184
Overpack Radial Concrete Outer Surface	157	529	530
Overpack Outer Shell	157	570	570

[†] Bounding 195°F uniform inner surface and 157°F uniform outer surface temperatures assumed.

[††] Maximum temperature during post-fire cooldown.

Table 11.2.3

SUMMARY OF INPUTS FOR HI-TRAC FIRE ACCIDENT HEAT-UP

Minimum Weight of Loaded HI-TRAC with Pool Lid (lb)	~~180,574~~*180,436*
Lower Heat Capacity of Carbon Steel (Btu/lbm·°R)	0.1
Heat Capacity UO_2 (Btu/lbm·°R)	0.056
Heat Capacity Lead (Btu/lbm·°R)	0.031
Maximum Decay Heat (kW)	*28.74*~~22.25~~
Total Fuel Assembly Weight (lb)	40,320
Lead Weight (lb)	52,*478*~~525~~
Water Weight (lb)	7,5*9*~~58~~

Table 11.2.4

BOUNDING HI-TRAC HYPOTHETICAL FIRE CONDITION PRESSURES[†]

Condition	**Pressure (psig)**			
	MPC-24	***MPC-24E***	***MPC-32***	**MPC-68**
Without Fuel Rod Rupture	*79.8*~~70.3~~	*79.8*	*79.8*	*79.8*~~70.7~~
With 100% Fuel Rod Rupture	*158.9*~~114.9~~	*159.3*	*191.1*	*126.4*~~106.3~~

[†] The reported pressures are based on temperatures that exceed the calculated maximum temperatures and are therefore slightly conservative.

Table 11.2.5

SUMMARY OF BOUNDING MPC PEAK TEMPERATURES DURING A HYPOTHETICAL HI-TRAC FIRE ACCIDENT CONDITION

Location	**Initial Steady State Temperature [°F]**	**Bounding Temperature Rise [°F]**	**Hottest MPC Cross Section Peak Temperature [°F]**
Fuel Cladding	*872*~~902~~	*26.3*~~45~~	*898.3*~~947~~
Basket Periphery	*600*~~527~~	*26.3*~~45~~	*626.3*~~572~~
MPC Shell	*455*~~459~~	*26.3*~~45~~	*481.3*~~504~~

Table 11.2.6

SUMMARY OF INPUTS FOR ADIABATIC CASK HEAT-UP

Minimum Weight of HI-STORM 100 System (lb) (overpack and MPC)	300,000
Lower Heat Capacity of Carbon Steel (BTU/lb/°F)	0.1
Initial Uniform Temperature of Cask (°F)	*740*~~745~~[†]
Bounding Decay Heat (kW)	*28.74*~~22.25~~

[†] The cask is conservatively assumed to be at a uniform temperature equal to the maximum fuel cladding temperature.

Table 11.2.7

MAXIMUM TEMPERATURES CAUSED BY EXTREME ENVIRONMENTAL TEMPERATURES[†] [°F]

Location	**Temperature**	**Accident Temperature Limit**
Fuel Cladding	*736*~~774~~ (PWR) *785*~~790~~ (BWR)	1058
MPC Basket	*765*~~770~~	950
MPC ~~Outer~~ Shell ~~Surface~~	*396*~~352~~	775
Overpack Air Exit	*251*~~231~~	N/A
Overpack Inner Shell	*244*~~217~~	350 (overpack concrete)
Overpack Outer Shell	*190*~~176~~	350 (overpack concrete)

[†] Conservatively bounding temperatures reported include a hypothetical rupture of 10% of the fuel rods.

Table 11.2.8

MAXIMUM TEMPERATURES CAUSED BY LOSS OF WATER FROM THE HI-TRAC WATER JACKET [°F]

Temperature Location	**Normal**	**Calculated Without Water in Water Jacket**	**Accident Condition Design Temperature**
Fuel Cladding	~~902~~*872*	~~914~~*888*	1058 short-term
MPC Basket	~~884~~*852*	~~896~~*868*	950 short-term
MPC Basket Periphery	~~527~~*600*	~~541~~*612*	950 short-term
MPC ~~Outer~~ Shell ~~Surface~~	~~459~~*455*	~~476~~*466*	775 short-term
HI-TRAC Inner Shell	~~323~~*322*	~~345~~*342*	400 long-term 600 short-term
HI-TRAC Water Jacket Inner Surface	~~315~~*314*	~~329~~*334*	350 long-term
HI-TRAC Enclosure Shell Outer Surface	~~223~~*224*	~~221~~*222*	350 long-term
Axial Neutron Shield†	~~175~~*258*	~~177~~*261*	300 long-term

Note: Where it can be shown that the temperatures are below the normal long-term condition limits, the calculated temperatures are compared to the normal long-term temperature limits for conservatism. The corresponding short-term temperature limits are higher temperatures as presented in Table 2.2.3.

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† *Local maximum section temperature.*

Table 11.2.9

SUMMARY OF BLOCKED AIR INLET DUCT EVALUATION RESULTS

	Max. Initial Steady-State Temp.[†] (°F)	**Temperature Rise (°F)**		**Transient Temperature (°F)**		**Short-Term Temperature Limit (°F)**
		at 33 hrs	at 72 hrs	at 33 hrs	at 72 hrs	
Fuel Cladding	~~745~~*740*	101	160	~~846~~*841*	~~905~~*900*	1058
MPC Shell	~~306~~*351*	184	250	~~490~~*535*	~~556~~*601*	775
Overpack Inner Shell #1[††]	~~172~~*199*	113	174	~~285~~*312*	~~346~~*373*	*600*~~350~~ ~~(overpack concrete)~~
Overpack Inner Shell #2[†††]	155	193	286	348	441	*600*~~350~~ ~~(overpack concrete)~~
Overpack Outer Shell	~~131~~*145*	14	40	~~145~~*159*	~~171~~*185*	*600*~~350~~
Concrete Section Average	*172*	*79*	*141*	*251*	*313*	*350*

[†] Conservatively bounding temperatures reported includes a hypothetical rupture of 10% of the fuel rods.

[††] Coincident with location of initial maximum.

[†††] Coincident with active fuel axial mid-height.

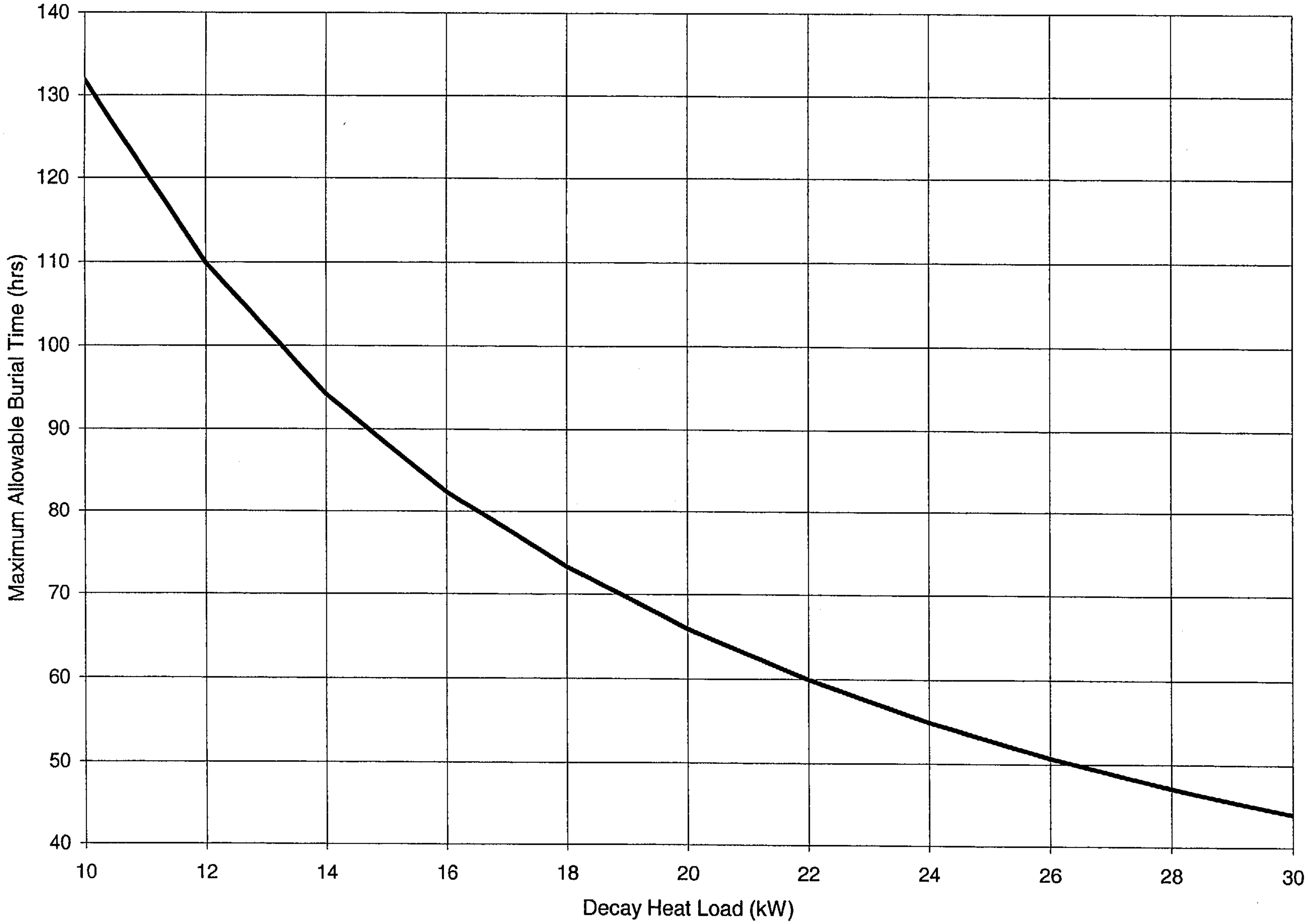

FIGURE 11.2.6; ALLOWABLE BURIAL UNDER DEBRIS TIME VERSUS DECAY HEAT LOAD

FIGURE 11.2.8; INTENTIONALLY DELETED

12.1 PROPOSED OPERATING CONTROLS AND LIMITS

12.1.1 NUREG-1536 (Standard Review Plan) Acceptance Criteria

12.1.1.1 This portion of the FSAR establishes the commitments regarding the HI-STORM 100 System and its use. Other 10CFR72 [12.1.2] and 10CFR20 [12.1.3] requirements in addition to the Technical Specifications may apply. The conditions for a general license holder found in 10CFR72.212 [12.1.2] shall be met by the licensee prior to loading spent fuel into the HI-STORM 100 System. The general license conditions governed by 10CFR72 [12.1.2] are not repeated with these Technical Specifications. Licensees are required to comply with all commitments and requirements.

12.1.1.2 The Technical Specifications provided in Appendix A to CoC 72-1014 and the authorized contents and design features provided in Appendix B to CoC 72-1014 are primarily established to maintain subcriticality, confinement boundary *and intact fuel cladding* integrity, shielding and radiological protection, heat removal capability, and structural integrity under normal, off-normal and accident conditions. Table 12.1.1 addresses each of these conditions respectively and identifies the appropriate Technical Specification(s) designed to control the condition. Table 12.1.2 provides the list of Technical Specifications for the HI-STORM 100 System.

Table 12.1.1

HI-STORM 100 SYSTEM CONTROLS

Condition to be Controlled	Applicable Technical Specifications[1]
Criticality Control	Refer to Appendix B to Certificate of Compliance 72-1014 for fuel specifications and design features *3.3.1 Boron Concentration*
Confinement Boundary *and Intact Fuel Cladding* Integrity	3.1.1 Multi-Purpose Canister (MPC) *5.6 Fuel Cladding Oxide Thickness Evaluation Program*
Shielding and Radiological Protection	Refer to Appendix B to Certificate of Compliance 72-1014 for fuel specifications and design features 3.1.1 Multi-Purpose Canister (MPC) 3.1.3 Fuel Cool-Down 3.2.1 TRANSFER CASK Average Surface Dose Rates 3.2.2 TRANSFER CASK Surface Contamination 3.2.3 OVERPACK Average Surface Dose Rates
Heat Removal Capability	Refer to Appendix B to Certificate of Compliance 72-1014 for fuel specifications and design features 3.1.1 Multi-Purpose Canister (MPC) 3.1.2 SFSC Heat Removal System
Structural Integrity	3.5 Cask Transfer Facility (CTF) (CoC 72-1014, Appendix B – Design Features) 5.5 Cask Transport Evaluation Program

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[1] Technical Specifications are located in Appendix A to CoC 72-1014

Table 12.1.2

HI-STORM 100 SYSTEM TECHNICAL SPECIFICATIONS

NUMBER	TECHNICAL SPECIFICATION
1.0	USE AND APPLICATION 1.1 Definitions 1.2 Logical Connectors 1.3 Completion Times 1.4 Frequency
2.0	Not Used. Refer to Appendix B to CoC 72-1014 for fuel specifications.
3.0	LIMITING CONDITION FOR OPERATION (LCO) APPLICABILITY SURVEILLANCE REQUIREMENT (SR) APPLICABILITY
3.1.1	Multi-Purpose Canister (MPC)
3.1.2	SFSC Heat Removal System
3.1.3	Fuel Cool-Down
3.2.1	TRANSFER CASK Average Surface Dose Rates
3.2.2	TRANSFER CASK Surface Contamination
3.2.3	OVERPACK Average Surface Dose Rates
3.3.1	*Boron Concentration*
Table 3-1	MPC Model-Dependent Limits
4.0	Not Used. Refer to Appendix B to CoC 72-1014 for design features.
5.0	ADMINSTRATIVE CONTROLS AND PROGRAMS
5.1	~~Training Program~~*Deleted*
5.2	~~Pre-Operational testing and Training Exercise~~*Deleted*
5.3	~~Special Requirements For First System In Place~~*Deleted*
5.4	Radioactive Effluent Control Program
5.5	Cask Transport Evaluation Program
5.6	*Fuel Cladding Oxide Thickness Evaluation Program*
Table 5-1	TRANSFER CASK and OVERPACK Lifting Requirements

12.2 DEVELOPMENT OF OPERATING CONTROLS AND LIMITS

This section provides a discussion of the operating controls and limits for the HI-STORM 100 System to assure long-term performance consistent with the conditions analyzed in this FSAR. In addition to the controls and limits provided in the Technical Specifications contained in Appendix A to Certificate of Compliance 72-1014 and the Approved Contents and Design Features in Appendix B to Certificate of Compliance 72-1014, the licensee shall ensure that the following training and dry run activities are performed.

12.2.1 Training Modules

Training modules are to be developed under the licensee's training program to require a comprehensive, site-specific training, assessment, and qualification (including periodic re-qualification) program for the operation and maintenance of the HI-STORM 100 Spent Fuel Storage Cask (SFSC) System and the Independent Spent Fuel Storage Installation (IFSI). The training modules shall include the following elements, at a minimum:

1. HI-STORM 100 System Design (overview);
2. ISFSI Facility Design (overview);
3. Systems, Structures, and Components Important to Safety (overview)
4. HI-STORM 100 System ~~Topical~~ *Final* Safety Analysis Report (overview);
5. NRC Safety Evaluation Report (overview);
6. Certificate of Compliance conditions;
7. HI-STORM 100 Technical Specifications, Approved Contents, Design Features and other Conditions for Use;
8. HI-STORM 100 Regulatory Requirements (e.g., 10CFR72.48, 10CFR72, Subpart K, 10CFR20, 10CFR73);
9. Required instrumentation and use;
10. Operating Experience Reviews

11. HI-STORM 100 System and ISFSI Procedures, including

- Procedural overview
- Fuel qualification and loading
- MPC /HI-TRAC/overpack rigging and handling, including safe load pathways
- MPC welding operations
- HI-TRAC/overpack closure
- Auxiliary equipment operation and maintenance (e.g., draining, ~~vacuum drying~~*moisture removal*, helium backfilling, and cooldown)
- MPC/HI-TRAC/overpack pre-operational and in-service inspections and tests
- Transfer and securing of the loaded HI-TRAC/overpack onto the transport vehicle
- Transfer and offloading of the HI-TRAC/overpack
- Preparation of MPC/HI-TRAC/overpack for fuel unloading
- Unloading fuel from the MPC/HI-TRAC/overpack
- Surveillance
- Radiation protection
- Maintenance
- Security
- Off-normal and accident conditions, responses, and corrective actions

12.2.2 Dry Run Training

A dry run training exercise of the loading, closure, handling, and transfer of the HI-STORM 100 System shall be conducted by the licensee prior to the first use the system to load spent fuel assemblies. The dry run shall include, but is not limited to the following:

1. Receipt inspection of HI-STORM 100 System components.

2. Moving the HI-STORM 100 MPC/HI-TRAC into the spent fuel pool.

3. Preparation of the HI-STORM 100 System for fuel loading.

4. Selection and verification of specific fuel assemblies to ensure type conformance.

5. Locating specific assemblies and placing assemblies into the MPC (using a dummy fuel assembly), including appropriate independent verification.

6. Remote installation of the MPC lid and removal of the MPC/HI-TRAC from the spent fuel pool.

7. Replacing the HI-TRAC pool lid with the transfer lid.

8. MPC welding, NDE inspections, hydrostatic testing, draining, ~~vacuum drying~~*moisture removal*, helium backfilling and leakage testing (for which a mockup may be used).

9. HI-TRAC upending/downending on the horizontal transfer trailer or other transfer device, as applicable to the site's cask handling arrangement.

10. Placement of the HI-STORM 100 System at the ISFSI.

11. HI-STORM 100 System unloading, including cooling fuel assemblies, flooding the MPC cavity, and removing MPC welds (for which a mock-up may be used).

12.2.3 Functional and Operating Limits, Monitoring Instruments, and Limiting Control Settings

The controls and limits apply to operating parameters and conditions which are observable, detectable, and/or measurable. The HI-STORM 100 System is completely passive during storage and requires no monitoring instruments. The user may choose to implement a temperature monitoring system to verify operability of the overpack heat removal system in accordance with Technical Specification Limiting Condition for Operation (LCO) 3.1.2.

12.2.4 Limiting Conditions for Operation

Limiting Conditions for Operation specify the minimum capability or level of performance that is required to assure that the HI-STORM 100 System can fulfill its safety functions.

12.2.5 Equipment

The HI-STORM 100 System and its components have been analyzed for specified normal, off-normal, and accident conditions, including extreme environmental conditions. Analysis has shown in this FSAR that no credible condition or event prevents the HI-STORM 100 System from meeting its safety function. As a result, there is no threat to public health and safety from any postulated accident condition or analyzed event. When all equipment is loaded, tested, and placed into storage in accordance with procedures developed for the ISFSI, no failure of the system to perform its safety function is expected to occur.

12.2.6 Surveillance Requirements

The analyses provided in this FSAR show that the HI-STORM 100 System fulfills its safety functions, provided that the Technical Specifications in Appendix A to CoC 72-1014 and the Authorized Contents and Design Features in Appendix B to CoC 72-1014 are met. Surveillance requirements during loading, unloading, and storage operations are provided in the Technical Specifications.

12.2.7 Design Features

This section describes HI-STORM 100 System design features that are Important to Safety. These features require design controls and fabrication controls. The design features, detailed in this FSAR and in Appendix B to CoC 72-1014, are established in specifications and drawings which are controlled through the quality assurance program. ~~presented in Chapter 13.~~ Fabrication controls and inspections to assure that the HI-STORM 100 System is fabricated in accordance with the design drawings and the requirements of this FSAR are described in Chapter 9.

12.2.8 MPC

a. Basket material composition, properties, dimensions, and tolerances for criticality control.

b. Canister material mechanical properties for structural integrity of the confinement boundary.

c. Canister and basket material thermal properties and dimensions for heat transfer control.

d. Canister and basket material composition and dimensions for dose rate control.

12.2.9 HI-STORM 100 Overpack

a HI-STORM 100 overpack material mechanical properties and dimensions for structural integrity to provide protection of the MPC and shielding of the spent nuclear fuel assemblies during loading, unloading and handling operations.

b. HI-STORM 100 overpack material thermal properties and dimensions for heat transfer control.

c. HI-STORM 100 overpack material composition and dimensions for dose rate control

HI-STORM 100 SYSTEM FSAR

APPENDIX 12.A

TECHNICAL SPECIFICATION BASES

FOR THE HOLTEC HI-STORM 100 SPENT FUEL STORAGE CASK SYSTEM

(*42* PAGES, INCLUDING THIS PAGE)

BASES TABLE OF CONTENTS

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.

A.1

If the cavity vacuum drying pressure *or MPC gas exit 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 ~~is~~ *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 temperature reaches the acceptance limit.* A low vacuum pressure *or a temperature less than or equal to the saturation pressure of water at 3 torr* is an indication that the cavity is dry. *For high burnup fuel, the gas recirculation method of moisture removal must be used to provide necessary cooling of the fuel during drying operations.*

(continued)

BASES

SURVEILLANCE REQUIREMENTS

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

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 4.4, 7.2, 7.3 and 8.1

B 3.1 SFSC Integrity

B 3.1.2 SFSC Heat Removal System

BASES

BACKGROUND

The SFSC Heat Removal System is a passive, air-cooled, convective heat transfer system which ensures heat from the MPC canister is transferred to the environs by the chimney effect. Relatively cool air is drawn into the annulus between the OVERPACK and the MPC through the four inlet air ducts at the bottom of the OVERPACK. The MPC transfers its heat from the canister surface to the air via natural convection. The buoyancy created by the heating of the air creates a chimney effect and the air is forced back into the environs through the four outlet air ducts at the top of the OVERPACK.

APPLICABLE SAFETY ANALYSIS

The thermal analyses of the SFSC take credit for the decay heat from the spent fuel assemblies being ultimately transferred to the ambient environment surrounding the OVERPACK. Transfer of heat away from the fuel assemblies ensures that the fuel cladding and other SFSC component temperatures do not exceed applicable limits. Under normal storage conditions, the four inlet and four outlet air ducts are unobstructed and full air flow (i.e., maximum heat transfer for the given ambient temperature) occurs.

Analyses have been performed for the complete obstruction of two, three, and four inlet air ducts. Blockage of two inlet air ducts reduces air flow through the OVERPACK annulus and decreases heat transfer from the MPC. Under this off-normal condition, no SFSC components exceed the short term temperature limits.

Blockage of three inlet air ducts further reduces air flow through the OVERPACK annulus and decreases heat transfer from the MPC. Under this accident condition, no SFSC components exceed the short term temperature limits.

(continued)

BASES

APPLICABLE SAFETY ANALYSIS (continued)

The complete blockage of all four inlet air ducts stops *normal* air cooling of the MPC. The MPC will continue to radiate heat to the relatively cooler inner shell of the OVERPACK. With the loss of normal air cooling, the SFSC component temperatures will increase toward their respective short-term temperature limits. *None of the components reach their temperature limits over the 72-hour duration of the analyzed event. Therefore, the*~~The~~ limiting component is *assumed to be the fuel cladding.* ~~OVERPACK concrete temperature, which, by analysis, approaches its temperature limit in 33 hours if no action is taken to restore air flow to the heat removal system. The analysis assumed a 72 hour duration. At 72 hours, the fuel cladding temperature remains below the short term temperature limit.~~

LCO

The SFSC Heat Removal System must be verified to be ~~OPERABLE~~ *operable* to preserve the assumptions of the thermal analyses. Operability of the heat removal system ensures that the decay heat generated by the stored fuel assemblies is transferred to the environs at a sufficient rate to maintain fuel cladding and other SFSC component temperatures within design limits.

The intent of this LCO is to address those occurrences of air duct blockage that can be reasonably anticipated to occur from time to time at the ISFSI (i.e., Design Event I and II class events per ANSI/ANS-57.9). These events are of the type where corrective actions can usually be accomplished within one 8-hour operating shift to restore the heat removal system to operable status (e.g., removal of loose debris).

(continued)

BASES (continued)

LCO
(continued)

This LCO is not intended to address low frequency, unexpected Design Event III and IV class events such as design basis accidents and extreme environmental phenomena that could potentially block one or more of the air ducts for an extended period of time (i.e., longer than the total Completion Time of the LCO). This class of events is addressed site-specifically as required by Section 3.4.9 of Appendix B to the CoC.

APPLICABILITY

The LCO is applicable during STORAGE OPERATIONS. Once an OVERPACK containing an MPC loaded with spent fuel has been placed in storage, the heat removal system must be ~~OPERABLE~~ *operable* to ensure adequate heat transfer of the decay heat away from the fuel assemblies.

ACTIONS

A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each SFSC. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each SFSC not meeting the LCO. Subsequent SFSCs that don't meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the heat removal system has been determined to be inoperable, it must be restored to ~~OPERABLE~~ *operable* status within eight hours. Eight hours is *a* reasonable *period of time* ~~based on the accident analysis which shows that the limiting SFSC component temperature will not reach its temperature limit for 33 hours after a complete blockage of all inlet air ducts. This time frame allows for the 24 hour surveillance interval (assuming complete blockage immediately after successful performance of the previous surveillance) plus eight hours~~ (typically, one operating shift) to take action to remove the obstructions in the air flow path.

(continued)

BASES

ACTIONS (continued)

B.1

If the heat removal system cannot be restored to ~~OPERABLE~~ *operable* status within eight hours, the innermost portion of the OVERPACK concrete may *experience elevated temperatures* ~~be affected~~. Therefore, Surveillance Requirement (SR) 3.2.3.1 is required to be performed to determine the effectiveness of the radiation shielding provided by the concrete. This SR must be performed immediately and repeated every twelve hours thereafter to provide timely and continued evaluation of whether the concrete is providing adequate shielding. As necessary, the cask user shall provide additional radiation protection measures such as temporary shielding. The Completion Time is reasonable considering the expected slow rate of deterioration, if any, of the concrete under elevated temperatures.

B.2.1

In addition to Required Action B.1, efforts must continue to restore cooling to the SFSC. Efforts must continue to restore the heat removal system to ~~OPERABLE~~ *operable* status by removing the air flow obstruction(s) unless optional Required Action B.2.2 is being implemented.

This Required Action must be complete in 48 hours. The Completion Time reflects a conservative total time period without any cooling of 80 hours, assuming all of the inlet air ducts become blocked immediately after the last previous successful Surveillance. The results of the thermal analysis of this accident show that the fuel cladding temperature does not reach its short term temperature limit for more than 72 hours. It is also unlikely that an unforseen event could cause complete blockage of all four air inlet ducts immediately after the last successful Surveillance.

(continued)

BASES

ACTIONS
(continued)

B.2.2

~~Since the thermal analyses show that the concrete approaches its short term temperature limit at 33 hours, action must be taken to ensure the fuel in the MPC does not exceed its short term temperature limit.~~ In lieu of implementing Required Action B.2.1, transfer of the MPC into a TRANSFER CASK will place the MPC in an analyzed condition and ensure adequate fuel cooling until actions to correct the heat removal system inoperability can be completed. Transfer of the MPC into a TRANSFER CASK removes the SFSC from the LCO Applicability since STORAGE OPERATIONS does not include times when the MPC resides in the TRANSFER CASK.

An engineering evaluation must be performed to determine if any concrete deterioration has occurred which prevents it from performing its design function. If the evaluation is successful and the air flow obstructions have been cleared, the OVERPACK heat removal system may be considered ~~OPERABLE~~ *operable* and the MPC transferred back into the OVERPACK. Compliance with LCO 3.1.2 is then restored. If the evaluation is unsuccessful, the user must transfer the MPC into a different, fully qualified OVERPACK to resume STORAGE OPERATIONS and restore compliance with LCO 3.1.2

(continued)

BASES

ACTIONS

B.2.2 (continued)

In lieu of performing the engineering evaluation, the user may opt to proceed directly to transferring the MPC into a different, fully qualified OVERPACK or place the TRANSFER CASK in the spent fuel pool and unload the MPC.

The Completion Time of 48 hours reflects a conservative total time period without any cooling of 80 hours, assuming all of the inlet air ducts become blocked immediately after the last previous successful Surveillance. The results of the thermal analysis of this accident show that the fuel cladding temperature does not reach its short term temperature limit for more than 72 hours. It is also unlikely that an unforseen event could cause complete blockage of all four air inlet ducts immediately after the last successful Surveillance.

SURVEILLANCE REQUIREMENTS

SR 3.1.2.1

The long-term integrity of the stored fuel is dependent on the ability of the SFSC to reject heat from the MPC to the environment. There are two options for implementing SR 3.1.2.1, either of which is acceptable for demonstrating that the heat removal system is OPERABLE.

Visual observation that all four inlet and outlet air ducts are unobstructed ensures that air flow past the MPC is occurring and heat transfer is taking place. Complete blockage of any one or more inlet or outlet air ducts renders the heat removal system inoperable and this LCO not met. Partial blockage of one or more inlet or outlet air ducts does not constitute inoperability of the heat removal system. However, corrective actions should be taken promptly to remove the obstruction and restore full flow through the affected duct(s).

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.1.2.1 (continued)

As an alternative, for OVERPACKs with air temperature monitoring instrumentation installed in the outlet air ducts, the temperature rise between ambient and the OVERPACK air outlet may be monitored to verify operability of the heat removal system. Blocked inlet or outlet air ducts will reduce air flow and increase the temperature rise experienced by the air as it removes heat from the MPC. Based on the analyses, provided the air temperature rise is less than the ~~limits~~ stated in the SR, adequate air flow and, therefore, adequate heat transfer is occurring to provide assurance of long term fuel cladding integrity. The reference ambient temperature used to perform this Surveillance shall be measured at the ISFSI facility.

The Frequency of 24 hours is reasonable based on the time necessary for SFSC components to heat up to unacceptable temperatures assuming design basis heat loads, and allowing for corrective actions to take place upon discovery of blockage of air ducts.

REFERENCES

1. FSAR Chapter 4
2. FSAR Sections 11.2.13 and 11.2.14
3. *ANSI/ANS 57.9-1992*

B 3.1 SFSC INTEGRITY

B 3.1.3 Fuel Cool-Down

BASES

BACKGROUND

In the event that an MPC must be unloaded, the TRANSFER CASK with its enclosed MPC is returned to the cask preparation area to begin the process of fuel unloading. The MPC closure ring, and vent and drain port cover plates are removed. The MPC gas is sampled to determine the integrity of the spent fuel cladding. The MPC is attached to the Cool-Down System. The Cool-Down System is a closed-loop forced ventilation gas cooling system that cools the fuel assemblies by cooling the surrounding helium gas.

Following fuel cool-down, the MPC is then re-flooded with water and the MPC lid weld is removed leaving the MPC lid in place. The transfer cask and MPC are placed in the spent fuel pool and the MPC lid is removed. The fuel assemblies are removed from the MPC and the MPC and transfer cask are removed from the spent fuel pool and decontaminated.

Reducing the fuel cladding temperatures significantly reduces the temperature gradients across the cladding thus minimizing thermally-induced stresses on the cladding during MPC re-flooding. Reducing the MPC internal temperatures eliminates the risk of high MPC pressure due to sudden generation of steam during re-flooding.

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 minimizing thermally-induced stresses to the cladding.

(continued)

BASES

APPLICABLE SAFETY ANALYSIS (continued)	This is accomplished during the unloading operations by lowering the MPC internal temperatures prior to MPC re-flooding. The Integrity of the MPC depends on maintaining the internal cavity pressures within design limits. This is accomplished by reducing the MPC internal temperatures such that there is no sudden formation of steam during MPC re-flooding. (Ref. 1).
LCO	Monitoring the circulating MPC gas exit temperature ensures that there will be no large thermal gradient across the fuel assembly cladding during re-flooding which could be potentially harmful to the cladding. The temperature limit specified in the LCO was selected to ensure that the MPC gas exit temperature will closely match the desired fuel cladding temperature prior to re-flooding the MPC. The temperature was selected to be lower than the boiling temperature of water with an additional margin.
APPLICABILITY	The MPC helium gas exit temperature is measured during UNLOADING OPERATIONS after the transfer cask and integral MPC are back in the FUEL BUILDING and are no longer suspended from, or secured in, the transporter. Therefore, the Fuel Cool-Down LCO does not apply during TRANSPORT OPERATIONS and STORAGE OPERATIONS. A note has been added to the APPLICABILITY for LCO 3.1.3 which states that the Applicability is only applicable during wet UNLOADING OPERATIONS. This is acceptable since the intent of the LCO is to avoid uncontrolled MPC pressurization due to water flashing during re-flooding operations. This is not a concerning for dry UNLOADING OPERATIONS.
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

(continued)

BASES

ACTIONS (continued)

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.

A.1

If the MPC helium gas exit temperature limit is not met, actions must be taken to restore the parameters to within the limits before re-flooding the MPC. Failure to successfully complete fuel cool-down could have several causes, such as failure of the cool down system, inadequate cool down, or clogging of the piping lines. The Completion Time is sufficient to determine and correct most failure mechanisms and proceeding with activities to flood the MPC cavity with water are prohibited.

A.2

If the LCO is not met, in addition to performing Required Action A.1 to restore the gas temperature to within the limit, the user must ensure that the proper conditions exist for the transfer of heat from the MPC to the surrounding environs to ensure the fuel cladding remains below the short term temperature limit. If the TRANSFER CASK is located in a relatively open area such as a typical refuel floor, no additional actions are necessary. However, if the TRANSFER CASK is located in a structure such as a decontamination pit or fuel vault, additional actions may be necessary depending on the heat load of the stored fuel.

Three acceptable options for ensuring adequate heat transfer for a TRANSFER CASK located in a pit or vault are provided below, based on an MPC loaded with fuel assemblies with design basis heat load in every storage location. Users may develop other alternatives on a site-specific basis, considering actual fuel loading and decay heat generation.

(continued)

BASES

ACTIONS

A.2 (continued)

1. Ensure the annulus between the MPC and the TRANSFER CASK is filled with water. This places the system in a heat removal configuration which is bounded by the FSAR thermal evaluation of the system considering a vacuum in the MPC. The system is open to the ambient environment which limits the temperature of the ultimate heat sink (the water in the annulus) and, therefore, the MPC shell to 212° F.

2. Remove the TRANSFER CASK from the pit or vault and place it in an open area such as the refuel floor with a reasonable amount of clearance around the cask and not near a significant source of heat.

3. Supply nominally 1000 SCFM of ambient (or cooler) air to the space inside the vault at the bottom of the TRANSFER CASK to aid the convection heat transfer process. This quantity of air is sufficient to limit the temperature rise of the air in the cask-to-vault annulus to approximately 60° F at design basis maximum heat load while providing enhanced cooling of the cask by the forced flow.

Twenty-~~four~~ *two (22)* hours is an acceptable time frame to allow for completion of Required Action A.2 based on a thermal evaluation of a TRANSFER CASK located in a pit or vault. *In such a configuration, passive cooling mechanisms will be largely diminished.* Eliminating ~~all credit for~~ *90% of the* passive cooling mechanisms with the cask emplaced in the vault, the thermal inertia of the cask (approximately 20,000 Btu/° F) will limit the rate of ~~*adiabatic*~~ temperature rise with design basis maximum heat load to ~~*less than four*~~ *approximately 4.5* degrees F per hour. Thus, the fuel cladding temperature rise in ~~*24*~~ *22* hours will be less than 100° F. Large short term temperature margins exist to preclude any cladding integrity concerns under this temperature rise.

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.1.3.1

The long-term integrity of the stored fuel is dependent on the material condition of the fuel assembly cladding. By minimizing thermally-induced stresses across the cladding the integrity of the fuel assembly cladding is maintained. The integrity of the MPC is dependent on controlling the internal MPC pressure. By controlling the MPC internal temperature prior to re-flooding the MPC there is no formation of steam during MPC re-flooding.

The MPC helium exit gas temperature limit ensures that there will be no large thermal gradients across the fuel assembly cladding during MPC re-flooding and no formation of steam which could potentially overpressurize the MPC.

Fuel cool down must be performed successfully on each SFSC before the initiation of MPC re-flooding operations to ensure the design and analysis basis are preserved.

REFERENCES

1. FSAR, Sections 4.4.1, 4.5.1.1.4, and 8.3.2.

B 3.2 SFSC Radiation Protection

B 3.2.1 TRANSFER CASK Average Surface Dose Rates

BASES

BACKGROUND	The regulations governing the operation of an ISFSI set limits on the control of occupational radiation exposure and radiation doses to the general public (Ref. 1). Occupational radiation exposure should be kept as low as reasonably achievable (ALARA) and within the limits of 10CFR Part 20. Radiation doses to the public are limited for both normal and accident conditions.
APPLICABLE SAFETY ANALYSIS	The TRANSFER CASK average surface dose rates are not an assumption in any accident analysis, but are used to ensure compliance with regulatory limits on occupational dose and dose to the public.
LCO	The limits on TRANSFER CASK average surface dose rates are based on the shielding analysis of the HI-STORM 100 System (Ref. 2). The limits were selected to minimize radiation exposure to the general public and maintain occupational dose ALARA to personnel working in the vicinity of the TRANSFER CASKs. The LCO requires specific locations for taking dose rate measurements to ensure the dose rates measured are indicative of the neutron shielding material's effectiveness and not the steel channel members.
APPLICABILITY	The average TRANSFER CASK surface dose rates apply during TRANSPORT OPERATIONS. These limits ensure that the transfer cask average surface dose rates during TRANSPORT OPERATIONS, AND UNLOADING OPERATIONS are within the estimates contained in the HI-STORM 100 Topical Safety Analysis Report. Radiation doses during STORAGE OPERATIONS are verified for the OVERPACK under LCO 3.2.3 and monitored thereafter by the SFSC user in accordance with the plant-specific radiation protection program required by 10CFR72.212(b)(6).

(continued)

BASES (continued)

ACTIONS

A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each TRANSFER CASK. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each TRANSFER CASK not meeting the LCO. Subsequent TRANSFER CASKs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the TRANSFER CASK average surface dose rates are not within limits, it could be an indication that a fuel assembly was inadvertently loaded into the MPC that did not meet the Functional and Operating Limits in Section 2.0. Administrative verification of the MPC fuel loading, by means such as review of video recordings and records of the loaded fuel assembly serial numbers, can establish whether a mis-loaded fuel assembly is the cause of the out of limit condition. The Completion Time is based on the time required to perform such a verification.

A.2

If the TRANSFER CASK average surface dose rates are not within limits, and it is determined that the MPC was loaded with the correct fuel assemblies, an analysis may be performed. This analysis will determine if the OVERPACK, once located at the ISFSI, would result in the ISFSI offsite or occupational doses exceeding regulatory limits in 10 CFR Part 20 or 10 CFR Part 72. If it is determined that the out of limit average surface dose rates do not result in the regulatory limits being exceeded, TRANSPORT OPERATIONS may proceed.

B.1

If it is verified that unauthorized fuel was loaded or that the ISFSI offsite radiation protection requirements of 10 CFR Part 20 or 10 CFR Part 72 will not be met with the transfer cask average surface dose rates above the LCO limit, the fuel

(continued)

BASES

ACTIONS

B.1 (continued)

assemblies 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 3.2.1.1

This SR ensures that the TRANSFER CASK average surface dose rates are within the LCO limits prior to TRANSPORT OPERATIONS. The surface dose rates are measured *on the sides and the top of the TRANSFER CASK at locations described in the SR* ~~approximately at the locations indicated on Figure 3.2.1-1~~ following standard industry practices for determining average dose rates for large containers. The SR requires specific locations for taking dose rate measurements to ensure the dose rates measured are indicative of the average value around the cask.

REFERENCES

1. 10 CFR Parts 20 and 72.
2. FSAR Sections 5.1 and 8.1.6.

B 3.2 SFSC Radiation Protection

B 3.2.2 TRANSFER CASK Surface Contamination

BASES

BACKGROUND

A TRANSFER CASK is immersed in the spent fuel pool in order to load the spent fuel assemblies. As a result, the surface of the TRANSFER CASK may become contaminated with the radioactive material in the spent fuel pool water. This contamination is removed prior to moving the TRANSFER CASK to the ISFSI, or prior to transferring the MPC into the OVERPACK, whichever occurs first, in order to minimize the radioactive contamination to personnel or the environment. This allows dry fuel storage activities to proceed without additional radiological controls to prevent the spread of contamination and reduces personnel dose due to the spread of loose contamination or airborne contamination. This is consistent with ALARA practices.

APPLICABLE SAFETY ANALYSIS

The radiation protection measures implemented during MPC transfer and transportation using the TRANSFER CASK are based on the assumption that the exterior surfaces of the TRANSFER CASKs have been decontaminated. Failure to decontaminate the surfaces of the TRANSFER CASKs could lead to higher-than-projected occupational doses.

LCO

Removable surface contamination on the TRANSFER CASK exterior surfaces and accessible surfaces of the MPC is limited to 1000 dpm/100 cm^2 from beta and gamma sources and 20 dpm/100 cm^2 from alpha sources. These limits are taken from the guidance in IE Circular 81-07 (Ref. 2) and are based on the minimum level of activity that can be routinely detected under a surface contamination control program using direct survey methods. Only loose contamination is controlled, as fixed contamination will not result from the TRANSFER CASK loading process. Experience has shown that these limits are low enough to prevent the spread of contamination to clean areas and are significantly less than the levels which would cause significant personnel skin dose.

(continued)

BASES

LCO
(continued)

LCO 3.2.2 requires removable contamination to be within the specified limits for the exterior surfaces of the TRANSFER CASK and accessible portions of the MPC. The location and number of surface swipes used to determine compliance with this LCO are determined based on standard industry practice and the user's plant-specific contamination measurement program for objects of this size. Accessible portions of the MPC means the upper portion of the MPC external shell wall accessible after the inflatable annulus seal is removed and before the annulus shield ring is installed. The user shall determine a reasonable number and location of swipes for the accessible portion of the MPC. The objective is to determine a removable contamination value representative of the entire upper circumference of the MPC, while implementing sound ALARA practices.

APPLICABILITY

The applicability is modified by a note that states that the LCO is not applicable to the TRANSFER CASK if MPC transfer operations occur inside the FUEL BUILDING. This is consistent with the intent of this LCO, which is to ensure loose contamination on the loaded TRANSFER CASK and MPC outside the FUEL BUILDING is within limits. If the MPC transfer is performed inside the FUEL BUILDING the empty TRANSFER CASK remains behind and is treated like any other contaminated hardware under the user's Part 50 contamination control program.

Verification that the ~~TRANSFER CASK and MPC~~ surface contamination is less than the LCO limit is performed during LOADING OPERATIONS. This occurs before TRANSPORT OPERATIONS, when the LCO is applicable. Measurement of ~~the TRANSFER CASK and MPC~~ surface contamination is unnecessary during UNLOADING OPERATIONS as surface contamination would have been measured prior to moving the subject TRANSFER CASK to the ISFSI.

(continued)

BASES (continued0

ACTIONS

A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each TRANSFER CASK. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each TRANSFER CASK not meeting the LCO. Subsequent TRANSFER CASKs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the removable surface contamination of a TRANSFER CASK or MPC, *as applicable,* that has been loaded with spent fuel is not within the LCO limits, action must be initiated to decontaminate the TRANSFER CASK or MPC and bring the removable surface contamination within limits. The Completion Time of 72 hours is appropriate given that sufficient time is needed to prepare for, and complete the decontamination once the LCO is determined not to be met.

SURVEILLANCE REQUIREMENTS

SR 3.2.2.1

This SR verifies that the removable surface contamination on the TRANSFER CASK and/*or* accessible portions of the MPC is less than the limits in the LCO. The Surveillance is performed using smear surveys to detect removable surface contamination. The Frequency requires performing the verification during LOADING OPERATIONS in order to confirm that the TRANSFER CASK or OVERPACK can be moved to the ISFSI without spreading loose contamination.

REFERENCES

1. FSAR Sections 8.1.5 and 8.1.6.
2. NRC IE Circular 81-07.

B 3.2 SFSC Radiation Protection

B 3.2.3 OVERPACK Average Surface Dose Rates

BASES

BACKGROUND

The regulations governing the operation of an ISFSI set limits on the control of occupational radiation exposure and radiation doses to the general public (Ref. 1). Occupational radiation exposure should be kept as low as reasonably achievable (ALARA) and within the limits of 10CFR Part 20. Radiation doses to the public are limited for both normal and accident conditions.

APPLICABLE SAFETY ANALYSIS

The OVERPACK average surface dose rates are not an assumption in any accident analysis, but are used to ensure compliance with regulatory limits on occupational dose and dose to the public.

LCO

The limits on OVERPACK average surface dose rates are based on the shielding analysis of the HI-STORM 100 System (Ref. 2). The limits were selected to minimize radiation exposure to the general public and maintain occupational dose ALARA to personnel working in the vicinity of the SFSCs.

APPLICABILITY

The average OVERPACK surface dose rates apply during TRANSPORT OPERATIONS and STORAGE OPERATIONS. These limits ensure that the OVERPACK average surface dose rates are within the estimates contained in the HI-STORM 100 Topical Safety Analysis Report. Radiation doses during STORAGE OPERATIONS are monitored for the OVERPACK by the SFSC user in accordance with the plant-specific radiation protection program required by 10CFR72.212(b)(6).

(continued)

BASES (continued)

ACTIONS

A note has been added to the ACTIONS which states that, for this LCO, separate Condition entry is allowed for each SFSC. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each SFSC not meeting the LCO. Subsequent SFSCs that don't meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the OVERPACK average surface dose rates are not within limits, it could be an indication that a fuel assembly was inadvertently loaded into the MPC that did not meet the Functional and Operating Limits in Section 2.0. Administrative verification of the MPC fuel loading, by means such as review of video recordings and records of the loaded fuel assembly serial numbers, can establish whether a mis-loaded fuel assembly is the cause of the out of limit condition. The Completion Time is based on the time required to perform such a verification.

A.2

If the OVERPACK average surface dose rates are not within limits, and it is determined that the MPC was loaded with the correct fuel assemblies, an analysis may be performed. This analysis will determine if the OVERPACK, once located at the ISFSI, would result in the ISFSI offsite or occupational doses exceeding regulatory limits in 10 CFR Part 20 or 10 CFR Part 72. If it is determined that the out of limit average surface dose rates do not result in the regulatory limits being exceeded, STORAGE OPERATIONS may proceed.

B.1

If it is verified that the correct fuel was not loaded or that the ISFSI offsite radiation protection requirements of 10 CFR Part 20 or 10 CFR Part 72 will not be met with the OVERPACK average surface dose rates above the LCO limit, the fuel

(continued)

ACTIONS
(continued)

assemblies must be placed in a safe condition in the spent fuel pool. The Completion Time is reasonable based on the time required to transfer the MPC back into the TRANSFER CASK, replace the transfer lid with the pool lid, perform fuel cooldown operations, re-flood the MPC, cut the MPC lid welds, move the SFSC 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 3.2.3.1

This SR ensures that the OVERPACK average surface dose rates are within the LCO limits within 24 hours of placing the OVERPACK in its designated storage location on the ISFSI. Surface dose rates are measured *at the locations described in the SR* ~~approximately at the locations indicated on Figure 3.2.3-1~~ following standard industry practices for determining average dose rates for large containers. ~~Measurements at approximate locations to those shown on Figure 3.2.3-1 are acceptable.~~

REFERENCES

1. 10 CFR Parts 20 and 72.
2. FSAR Sections 5.1 and 8.1.6.

B 3.3 SFSC Criticality Control

B 3.3.1 Boron Concentration

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 Certificate of Compliance. 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 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. The TRANSFER CASK bottom pool lid is replaced with the transfer lid to allow eventual transfer of the MPC into the OVERPACK.

For those MPCs containing PWR fuel assemblies of relatively high initial enrichment, credit is taken in the criticality analyses for boron in the water within the MPC. To preserve the analysis basis, users must verify that the boron concentration of the water in the MPC meets specified limits when there is fuel and water in the MPC. This may occur during LOADING OPERATIONS and UNLOADING OPERATIONS.

APPLICABLE SAFETY ANALYSIS

The spent nuclear fuel stored in the SFSC is required to remain subcritical ($k_{eff} < 0.95$) under all conditions of storage. The HI-STORM 100 SFSC is analyzed to stored a wide variety of spent nuclear fuel assembly types with differing initial enrichments. For all PWR fuel loaded in the MPC-32, and for relatively high enrichment PWR fuel loaded in the MPC-24, -24E, and -24EF, credit was taken in the criticality analyses for neutron poison in the form of soluble boron in the water within the MPC. Compliance with this LCO preserves the assumptions made in the criticality analyses regarding credit for soluble boron.

(continued)

BASES (continued)

LCO

Compliance with this LCO ensures that the stored fuel will remain subcritical with a $k_{eff} \leq 0.95$ while water is in the MPC. LCOs 3.3.1.a and 3.3.1.b provide the minimum concentration of soluble boron required in the MPC water for the MPC-24, and MPC-24E/24EF, respectively. The limits are applicable to the respective MPCs if one or more fuel assemblies to be loaded in the MPC had an initial enrichment of U-235 greater than the value in Table 2.1-2 for loading with no soluble boron credit.

LCO 3.3.1.c provides the minimum boron concentration required in the MPC water for the MPC-32 if one or more to fuel assemblies to be loaded had an initial enrichment less than or equal to 4.1 wt.% U-235. LCO 3.3.1.d provides the minimum boron concentration required in the MPC water for the MPC-32 if one or more to fuel assemblies to be loaded had an initial enrichment greater than 4.1 wt.% U-235.

All fuel assemblies loaded into the MPC-24, MPC-24E, MPC-24EF, and MPC-32 are limited by analysis to maximum enrichments of 5.0 wt.% U-235.

APPLICABILITY

The boron concentration LCO is applicable whenever an MPC-24, -24E, -24EF, or -32 has at least one PWR fuel assembly in a storage location and water in the MPC, For the MPC-24 and MPC-24E/24EF, when all fuel assemblies to be loaded have initial enrichments less than the limit for no soluble boron credit as provided in CoC Appendix B, Table 2.1-2, the boron concentration requirement is implicitly understood to be zero.

During LOADING OPERATIONS, the LCO is applicable immediately upon the loading of the first fuel assembly in the MPC. It remains applicable until the MPC is drained of water

(continued)

BASES

LCO (continued)

During UNLOADING OPERATIONS, the LCO is applicable when the MPC is re-flooded with water after helium cooldown operations. Note that compliance with SR 3.0.4 assures that the water to be used to flood the MPC is of the correct boron concentration to ensure the LCO is upon entering the Applicability.

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.

A.1 and A.2

Continuation of LOADING OPERATIONS, UNLOADING OPERATIONS or positive reactivity additions (including actions to reduce boron concentration) is contingent upon maintaining the SFSC in compliance with the LCO. If the boron concentration of water in the MPC is less than its limit, all activities LOADING OPERATIONS, UNLOADING OPERATIONS or positive reactivity additions must be suspended immediately.

A.3

In addition to immediately suspending LOADING OPERATIONS, UNLOADING OPERATIONS and positive reactivity additions, action to restore the concentration to within the limit specified in the LCO must be initiated immediately.

(continued)

BASES

ACTIONS (continued)

A.3 (cont'd)

One means of complying with this action is to initiate boration of the affected MPC. In determining the required combination of boration flow rate and concentration, there is no unique design basis event that must be satisfied; only that boration be initiated without delay. In order to raise the boron concentration as quickly as possible, the operator should begin boration with the best source available for existing plant conditions.

Once boration is initiated, it must be continued until the boron concentration is restored. The restoration time depends on the amount of boron that must be injected to reach the required concentration.

B.1

If the helium backfill density 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 cavity 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

SURVEILLANCE REQUIREMENTS (continued)

SR 3.3.1.1

The boron concentration in the MPC water must be verified to be within the applicable limit within four hours of entering the Applicability of the LCO. For LOADING OPERATIONS, this means within four hours of loading the first fuel assembly into the cask.

For UNLOADING OPERATIONS, this means verifying the source of borated water to be used to re-flood the MPC within four hours of commencing re-flooding operations. This ensures that when the LCO is applicable (upon introducing water into the MPC), the LCO will be met.

Surveillance Requirement 3.3.1.1 is modified by a note which states that SR 3.3.1.1 is only required to be performed if the MPC is submerged in water or if water is to be added to, or recirculated through the MPC. This reflects the underlying premise of this SR which is to ensure, once the correct boron concentration is established, it need only be verified thereafter if the MPC is in a state where the concentration could be changed.

There is no need to re-verify the boron concentration of the water in the MPC after it is removed from the spent fuel pool unless water is to be added to, or recirculated through the MPC., because these are the only credible activities that could potentially change the boron concentration during this time. This note also prevents the interference of unnecessary sampling activities while lid closure welding and other MPC storage preparation activities are taking place in an elevated radiation area atop the MPC. Plant procedures should ensure that any water to be added to, or recirculated through the MPC is at a boron concentration greater than or equal to the minimum boron concentration specified in the LCO

REFERENCES

1. *FSAR Chapter 6.*