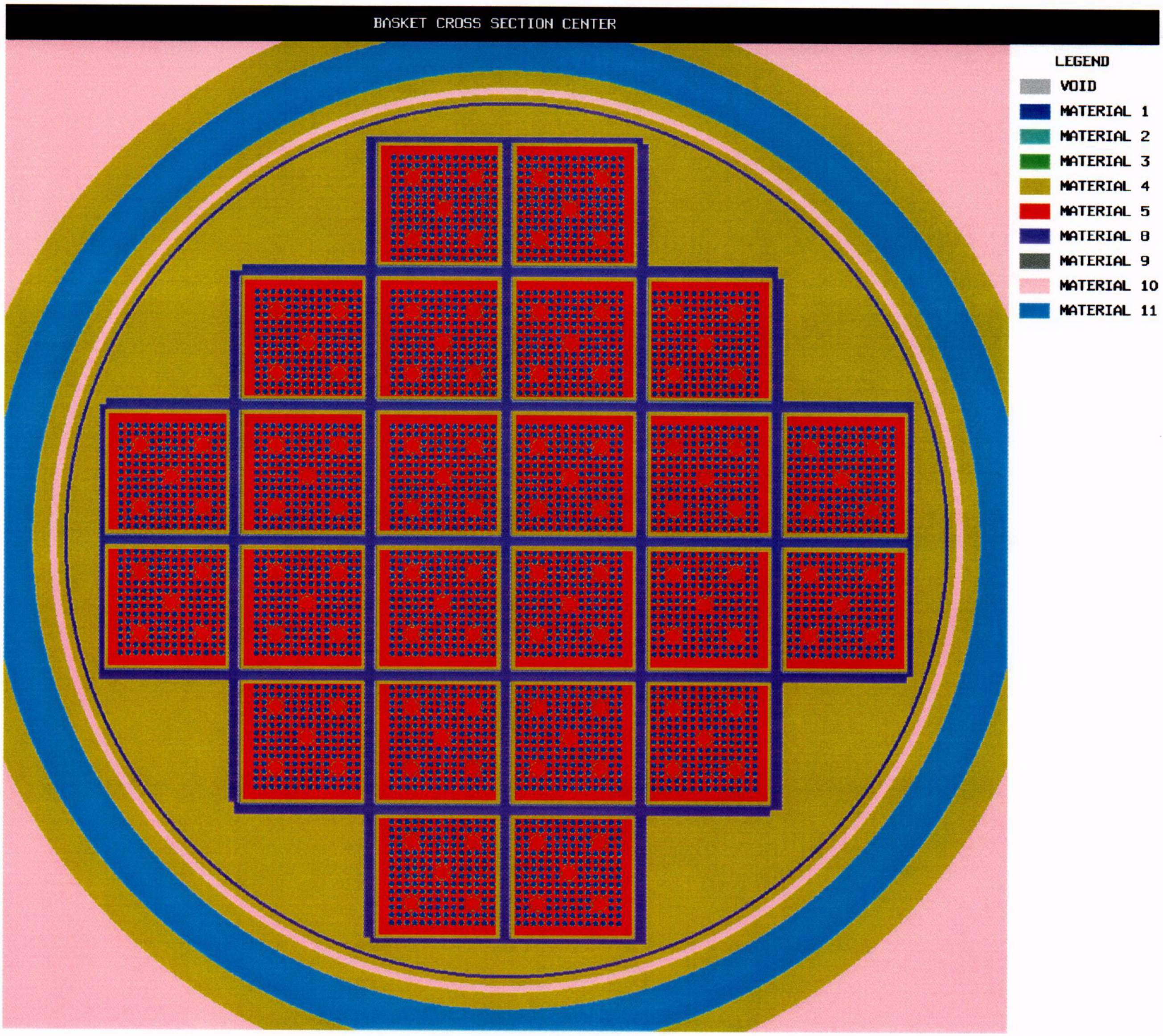


Figure P.6-14
CE 14x14 Class Assembly KENO Model

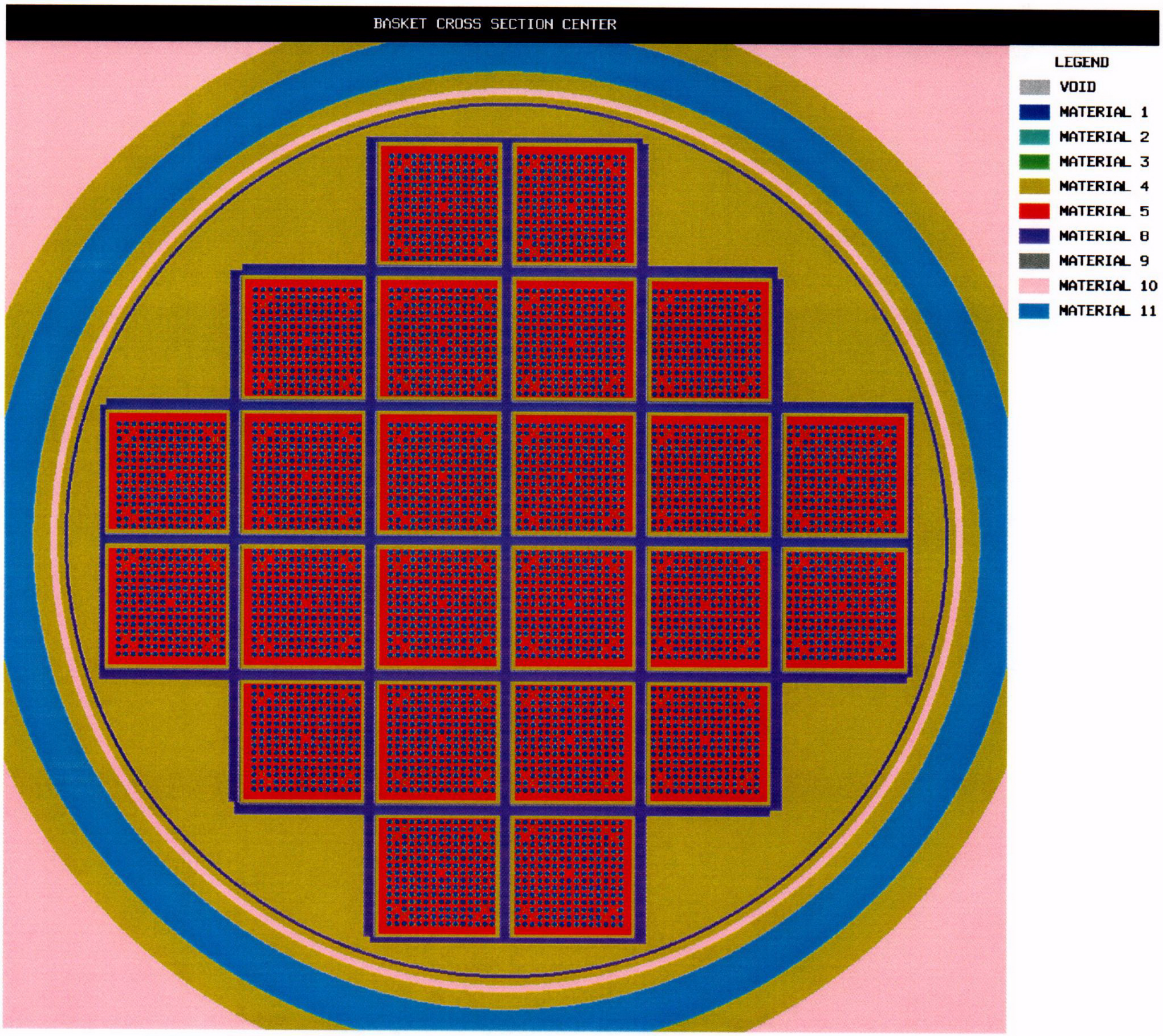


Figure P.6-15
CE 15x15 Class Assembly KENO Model

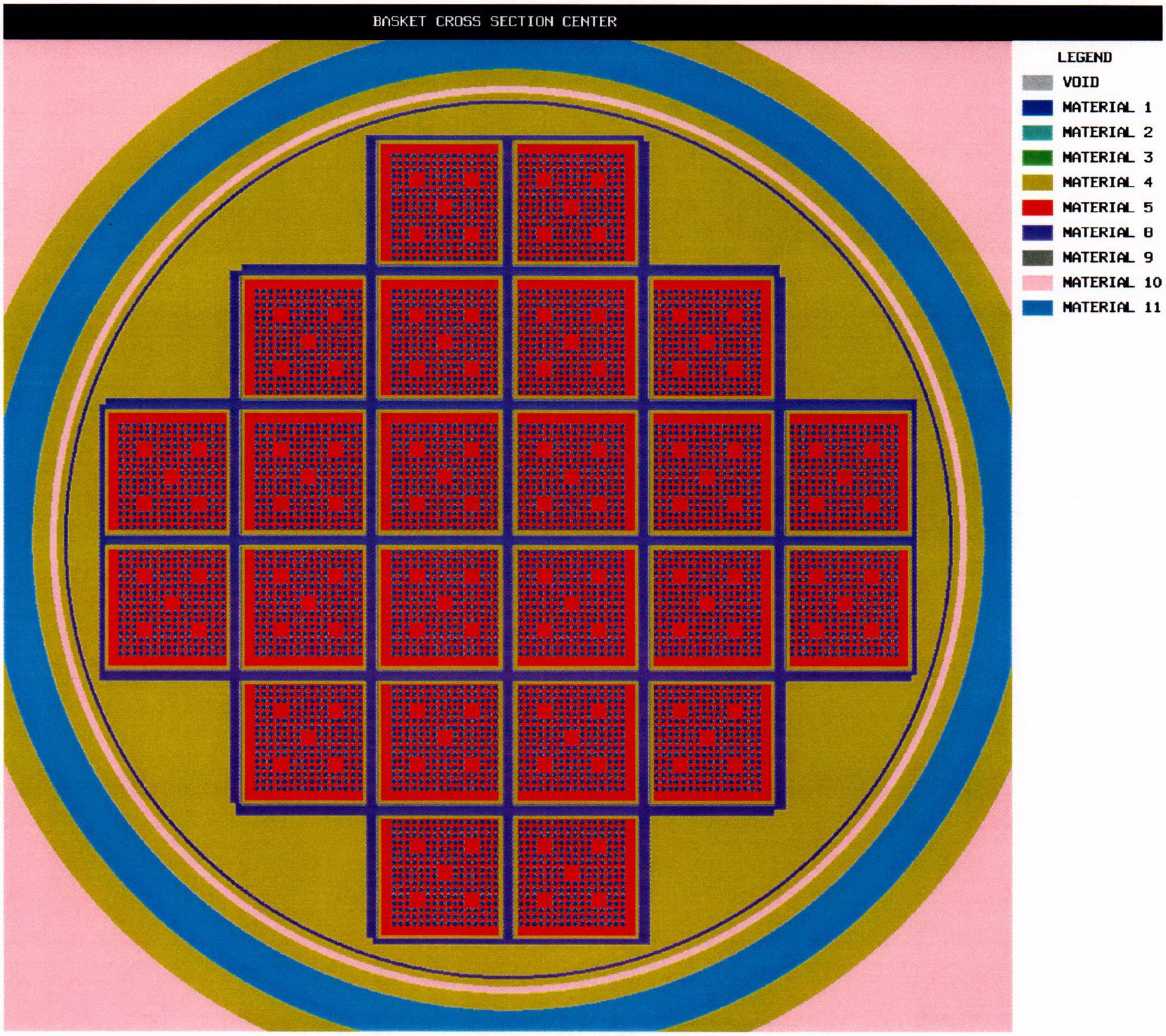


Figure P.6-16
CE 16x16 Class Assembly KENO Model

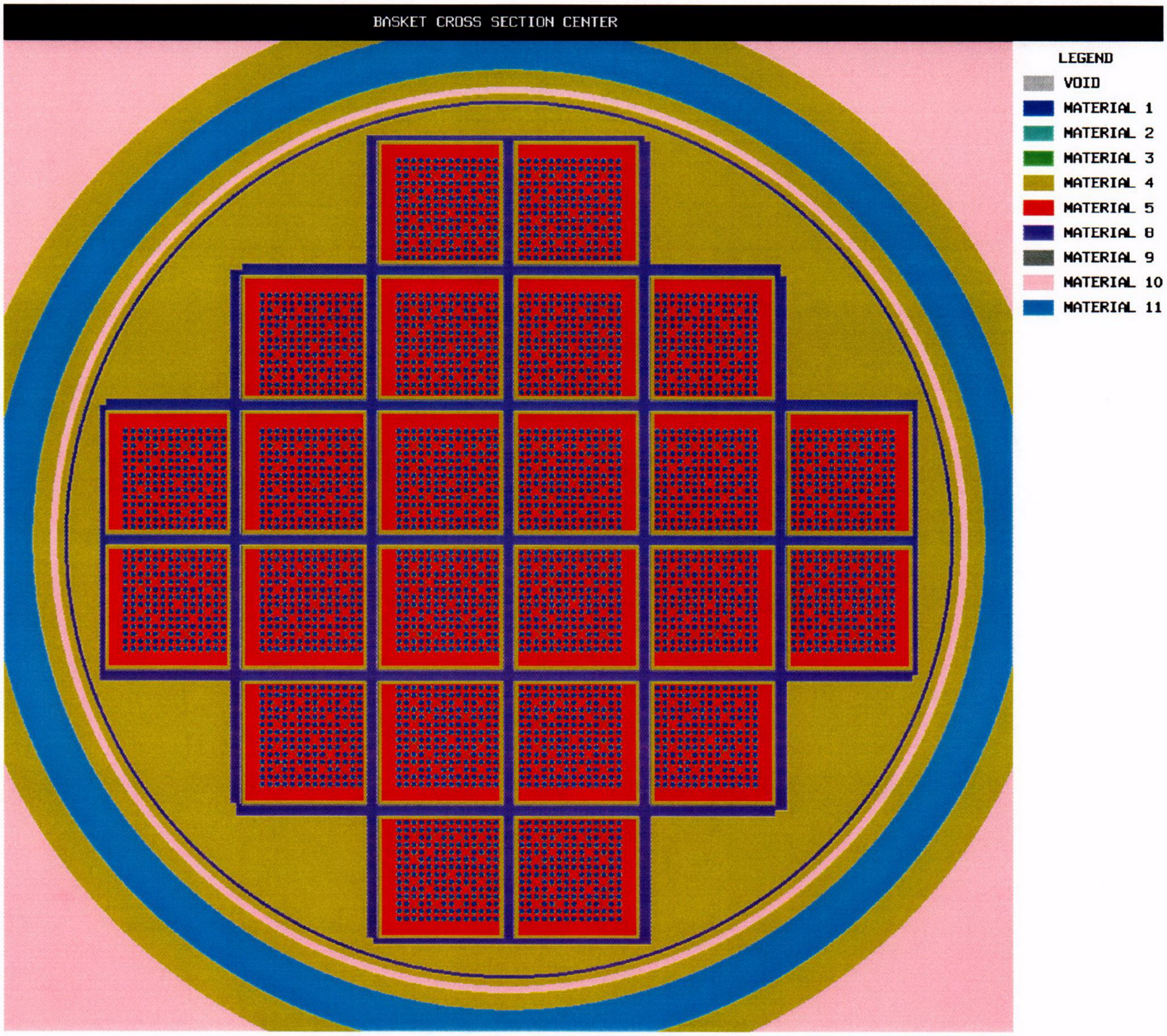


Figure P.6-17
WE 14x14 Class Assembly KENO Model

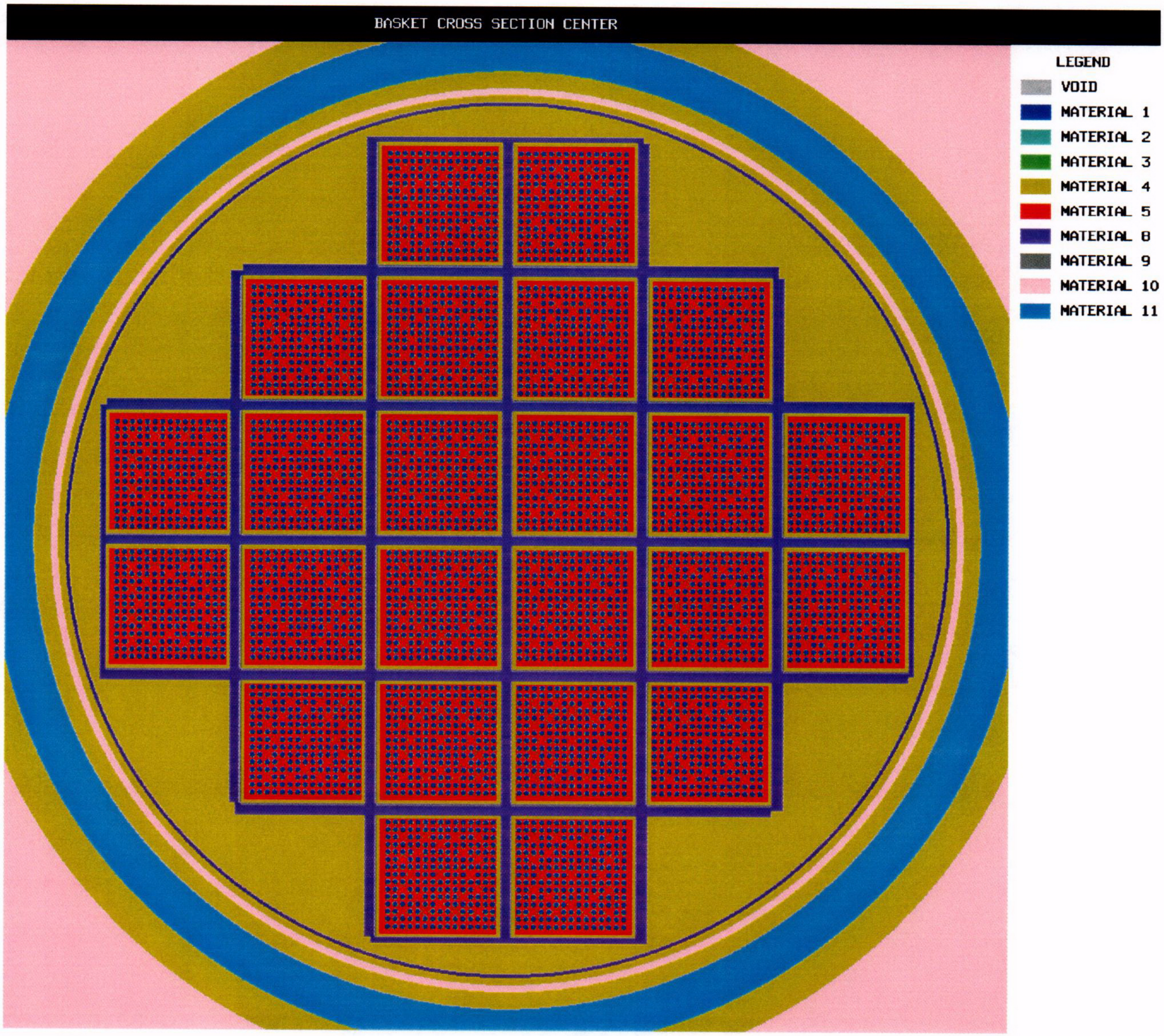


Figure P.6-18
WE 15x15 Class Assembly KENO Model

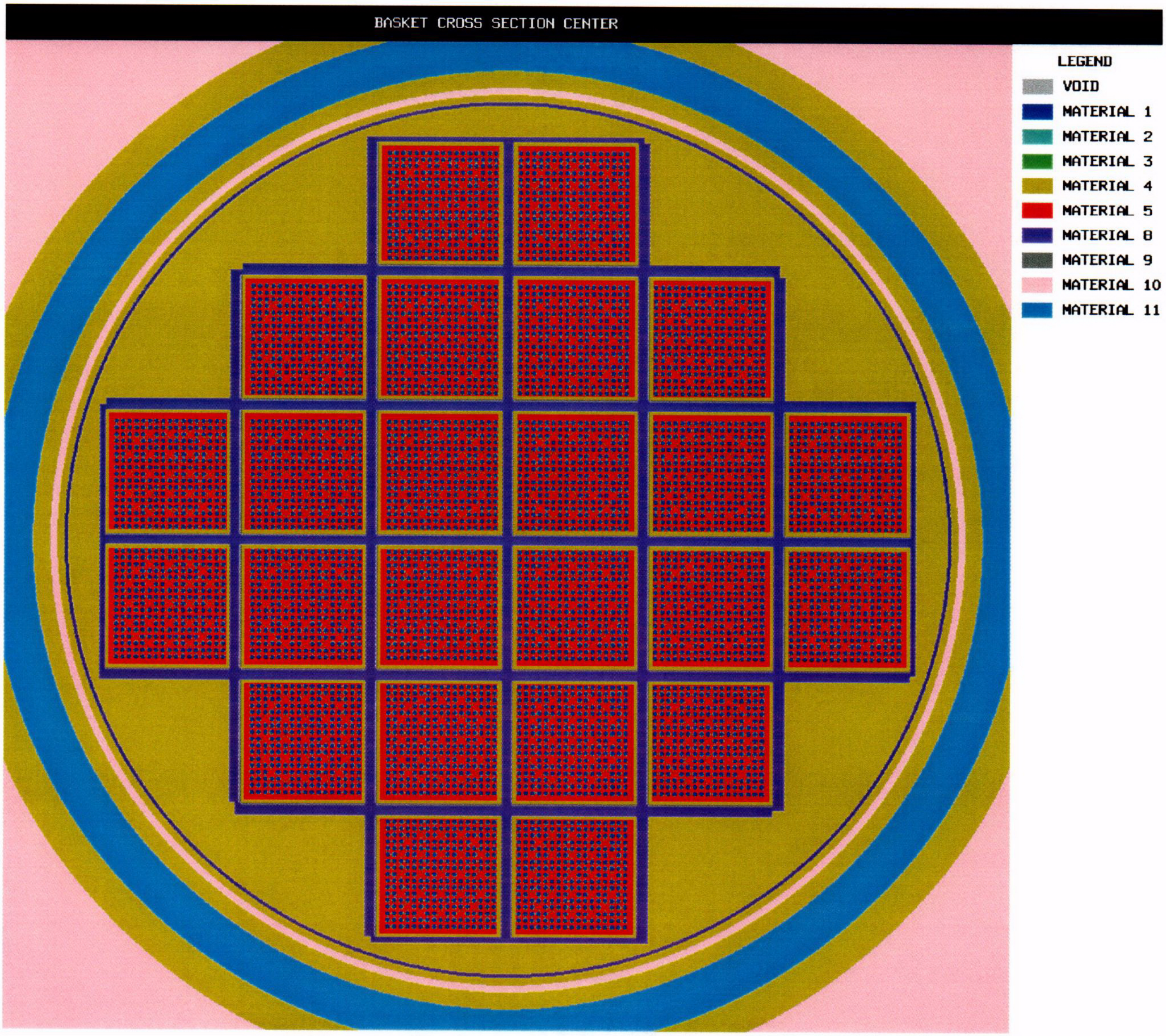


Figure P.6-19
WE 17x17 Class Assembly KENO Model

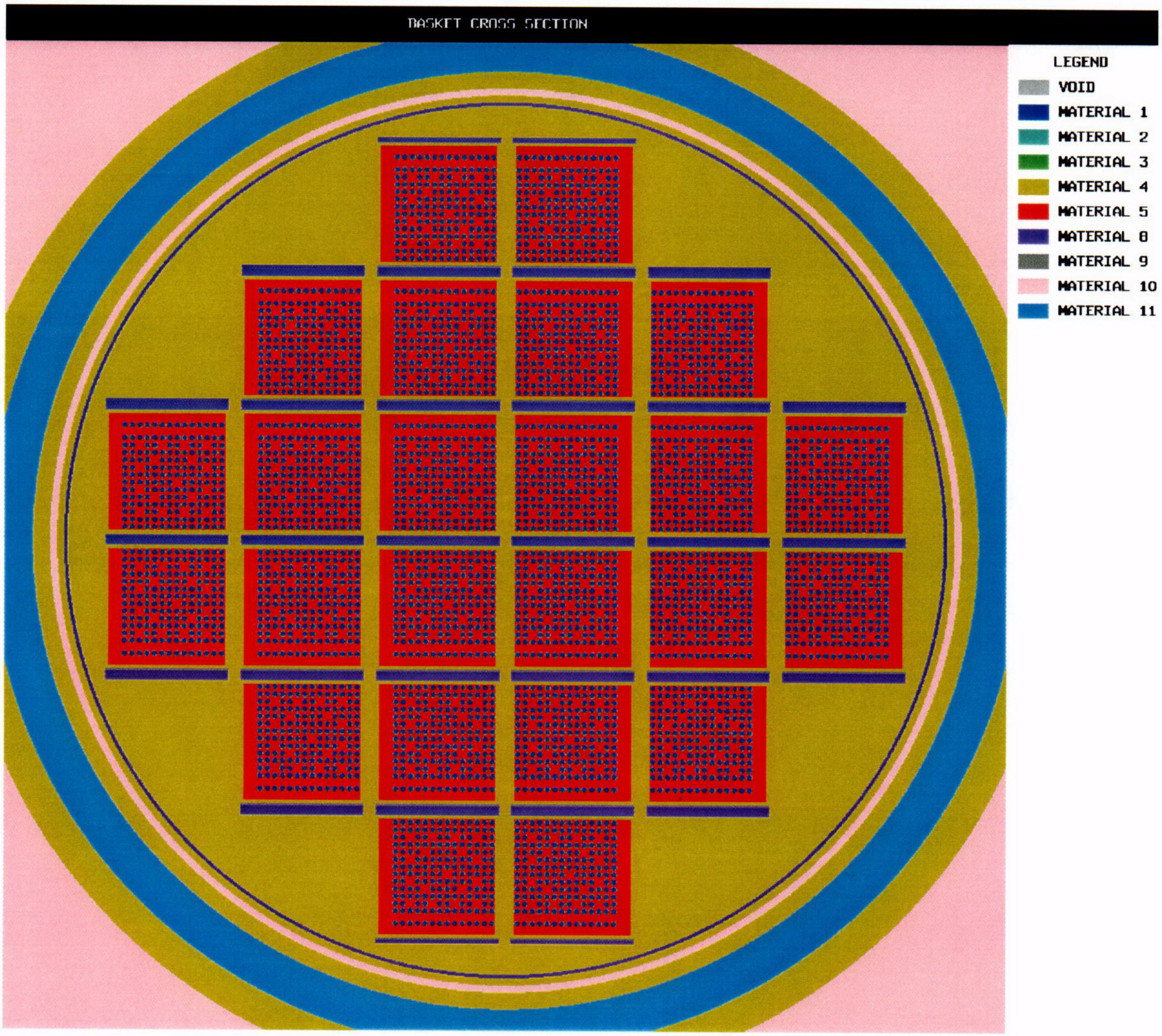


Figure P.6-20
WE 14x14 Class Assembly, Single Shear Study Model

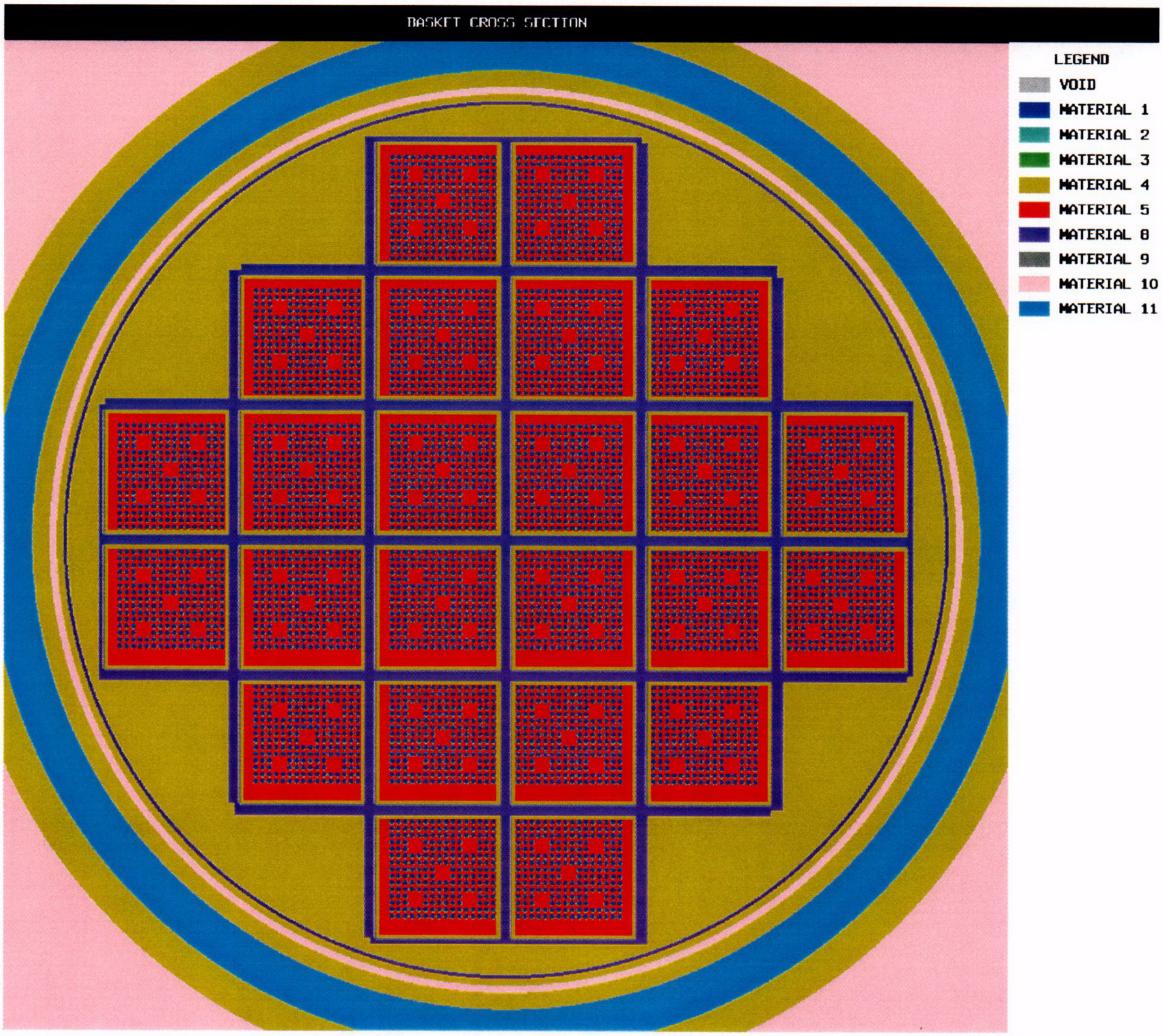


Figure P.6-21
CE 16x16 Class Assembly, Double Shear Study Model

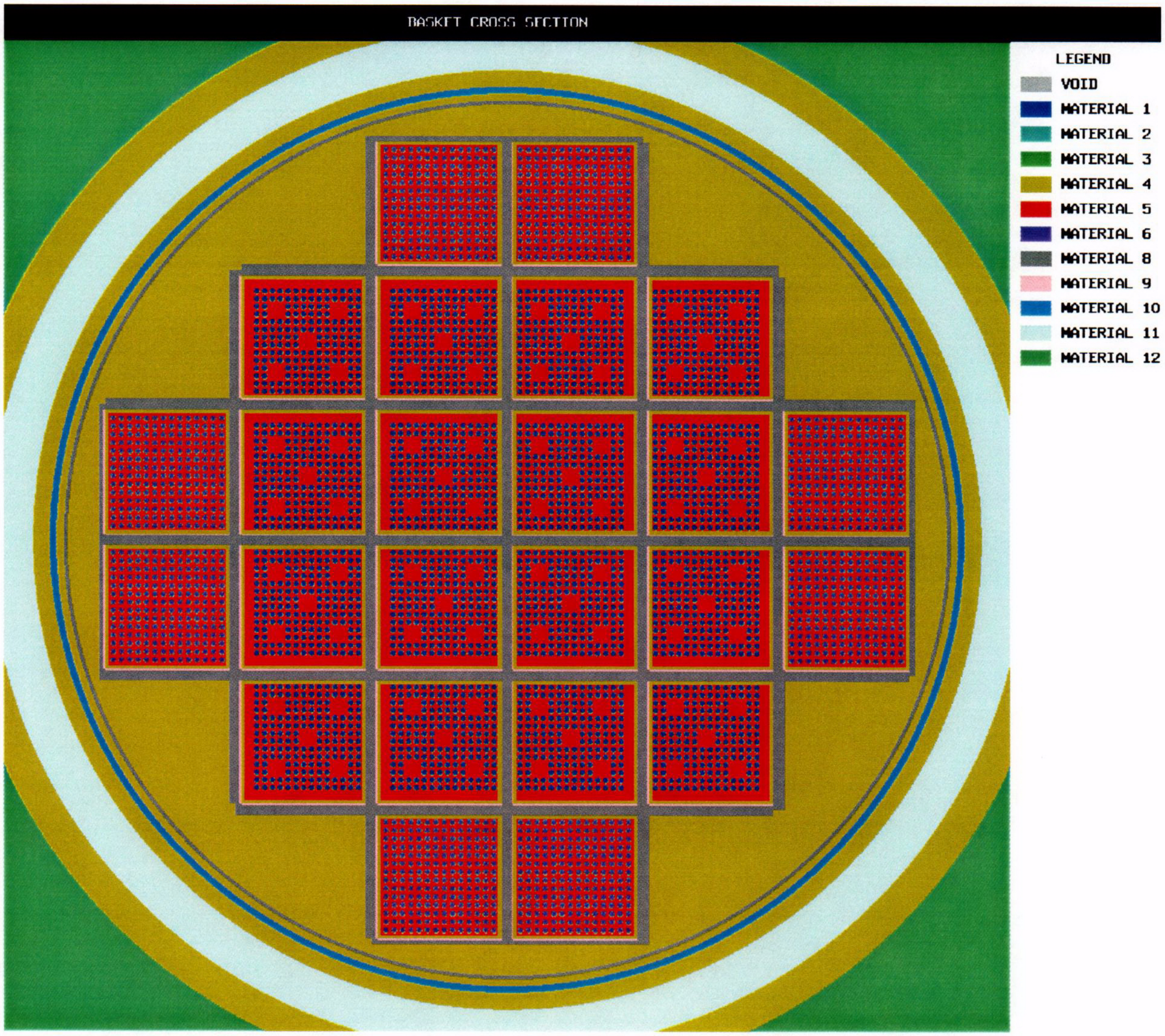


Figure P.6-22
CE 14x14 Class Assembly, 8 Damaged / 16 Intact Fuel Assemblies

C20

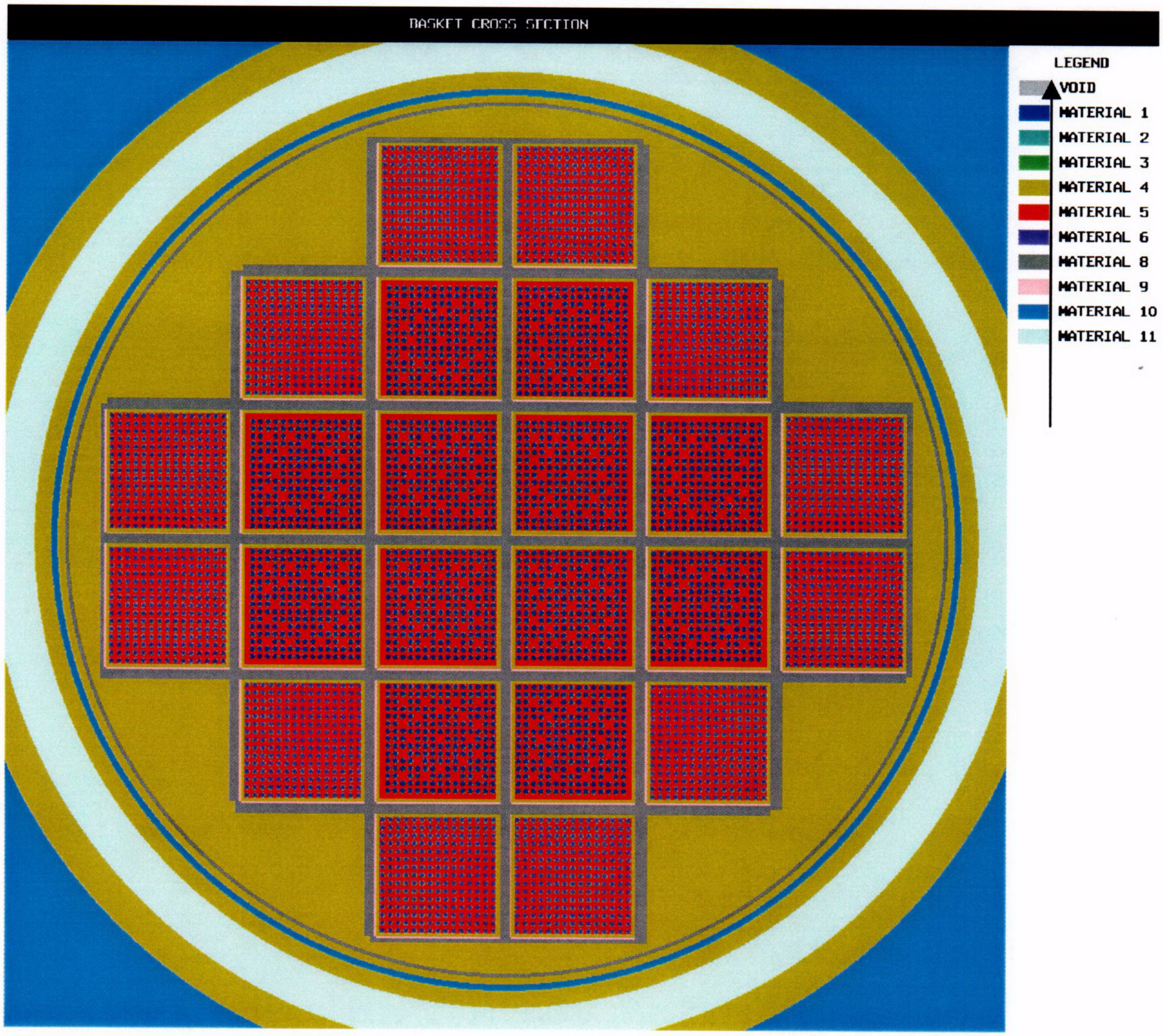
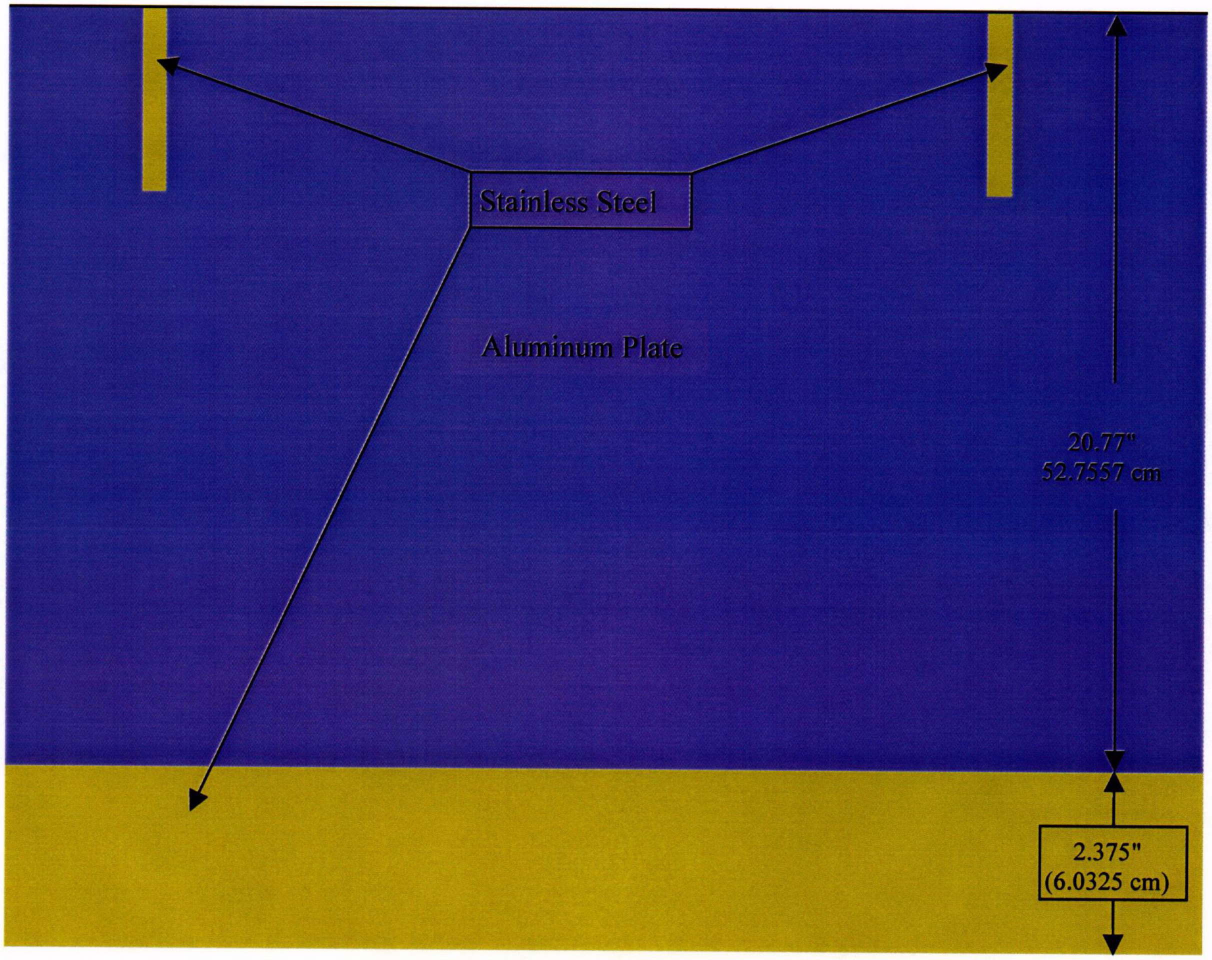


Figure P.6-23
WE 15x15 Class Assembly, 12 Damaged / 12 Intact Fuel Assemblies



Periodic Boundary at the Bottom of Model

Figure P.6-24 Basket Model Compartment Wall (View G)

(Not to Scale)

C22

Periodic Boundary at the Top

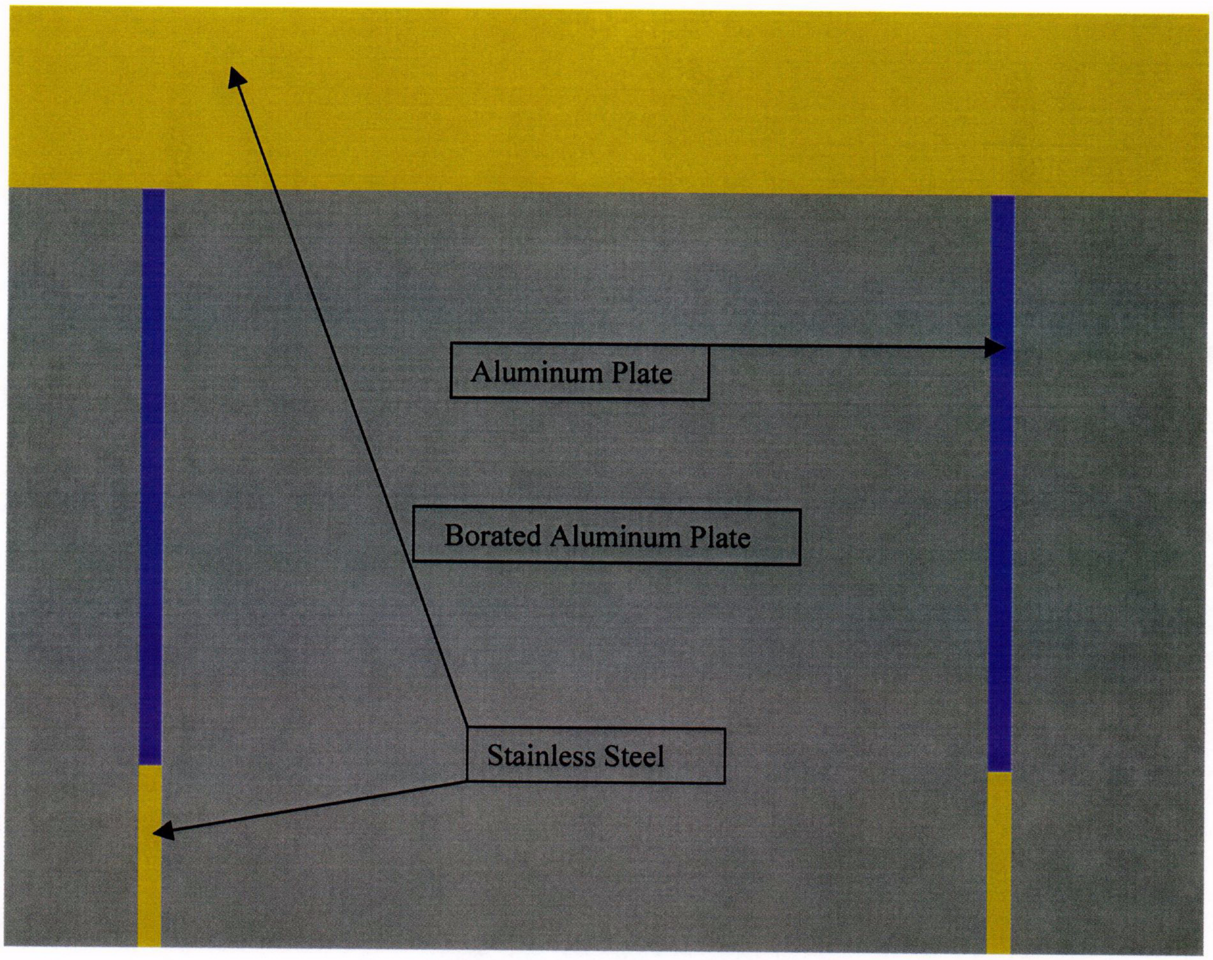


Figure P.6-25 Basket Model Compartment Wall (View F)

(Not to Scale)

P.7 Confinement

Confinement of all radioactive materials in the NUHOMS®-24PTH system is provided by the NUHOMS®-24PTH DSC which is designed and tested to meet the leak tight criteria of ANSI N14.5 [7.1].

As discussed in Section 7.2.2, the release of airborne radioactive material is addressed for three phases of system operation: fuel handling in the spent fuel pool, drying and sealing of the DSC, and DSC transfer and storage. Potential airborne releases from irradiated fuel assemblies in the spent fuel pool are discussed in the plant's existing 10CFR50 license.

DSC drying and sealing operations are performed using procedures which prohibit airborne leakage. During these operations, all vent lines are routed to the existing radwaste systems of the plant. Once the DSC is dried and sealed, there are no design basis accidents, which could result in a breach of the DSC and the airborne release of radioactivity. Design provisions to preclude the release of gaseous fission products as a result of accident conditions are discussed in Section 8.2.9.

During transfer of the sealed DSC and subsequent storage in the HSM, the only postulated mechanism for the release of airborne radioactive material is the dispersion of non-fixed surface contamination on the DSC exterior. By filling the cask/DSC annulus with clean demineralized water, placing an inflatable seal over the annulus, and utilizing procedures which require examination of the DSC exterior surfaces for smearable contamination, the contamination limits on the DSC can be kept below the permissible level for off-site shipments of fuel. Therefore, there is no possibility of significant radionuclide release from the DSC exterior surface during transfer or storage.

P.7.1 Confinement Boundary

Once inside the DSC, the spent fuel assemblies (SFAs) are confined by the DSC shell and by multiple barriers at each end of the DSC. For intact fuel, the fuel cladding is the first barrier for confinement of radioactive materials. The fuel cladding is protected by maintaining the cladding temperatures during storage below those levels which may cause degradation of the cladding. In addition, the SFAs are stored in an inert atmosphere to prevent degradation of the fuel, specifically cladding rupture due to oxidation and its resulting volumetric expansion of the fuel. Thus, a helium atmosphere for the DSC is incorporated in the design to protect the fuel cladding integrity by inhibiting the ingress of oxygen into the DSC cavity.

Helium is known to leak through valves, mechanical seals, and escape through very small passages because of its small atomic diameter and because it is an inert element and exists in a monatomic species. Negligible leakage rates can be achieved with careful design of vessel closures. Helium will not, to any practical extent, diffuse through stainless steel. For this reason, the DSC has been designed as a multi-pass weld-sealed containment pressure vessel with no mechanical or electrical penetrations.

P.7.1.1 Confinement Vessel

The confinement vessel is provided by the NUHOMS®-24PTH DSC. The DSC is designed to provide confinement of all radionuclides under normal and accident conditions. The DSC is designed, fabricated and tested in accordance with the applicable requirements of the ASME Boiler and Pressure Vessel Code, Division 1, Section III, Subsection NB [7.2] with alternatives as listed in Table P.3.1-1. The shell and inner bottom cover plates are delivered to the site as an assembly. The shell and the inner bottom cover plate, which provide the confinement boundary as shown in Figure P.3.1-1 and Figure P.3.1-2, are tested to meet the leak tight criteria as defined in ANSI N14.5 [7.1] at the fabricator. The pneumatic pressure test and leak test are performed on the finished shell and the inner bottom cover plate during fabrication.

Once the fuel assemblies are loaded in the DSC, the heavy shield plug is installed to provide radiation shielding to minimize radiation exposure to workers during DSC closure operations. The inner top cover plate or inner top closure is welded into place along with the vent and siphon port cover plates. These welds represent the first level of closure for the DSC. Finally, the outer top cover plate is welded into place to form the redundant confinement boundary of the DSC. The inner plate is tested using the test port in the outer top cover plate or by using a test hood to meet the leak tight criteria [7.1]. The test port plug is then placed into the outer top cover plate and seal welded in place. The root and final layer closure welds for this redundant boundary are inspected using dye penetrant inspection methods in accordance with requirements of the ASME code [7.2].

P.7.1.2 Confinement Penetrations

The DSC pressure boundary contains two penetrations (vent and siphon ports) for draining, vacuum drying and backfilling the DSC cavity. The vent and siphon ports are closed with welded cover plates and the outer top cover plate provides the redundant closure. The outer cover plate has a single penetration used for leak testing the closure welds. This test port plug is placed into the outer top cover plate and seal welded in place after testing to complete the redundant closure. The DSC has no bolted closures or mechanical seals. The final confinement boundary contains no external penetrations.

P.7.1.3 Seals and Welds

The DSC cylindrical shell is fabricated from rolled ASME stainless steel plate that is joined with full penetration 100% radiographed welds. The DSC shell weldments at the inner bottom confinement boundary are also 100% volumetrically inspected welds. All top and bottom end closure welds are multiple-layer welds. This effectively eliminates a pinhole leak which might occur in a single pass weld, since the chance of pinholes being in alignment on successive weld passes is not credible. Furthermore, specific closure welds (top inner cover plate, siphon and vent block, and siphon and vent cover plate) of the pressure boundary are per ASME Code Case N-595-2. This closure is in accordance with the alternatives to the ASME Code (Reference Table P.3.1-1). These criteria insure that the weld filler metal is as sound as the parent metal of the pressure vessel. There are no bolted closures or mechanical seals.

P.7.1.4 Closure

All top end closure welds are multiple-layer welds. This effectively eliminates a pinhole leak which might occur in a single pass weld, since the chance of pinholes being in alignment on successive weld passes is not credible. Furthermore, specific closure welds (top inner cover plate, siphon and vent block, and siphon and vent cover plate) of the pressure boundary are per ASME Code Case N-595-2. This closure is in accordance with the alternative to the ASME Code (Reference Table P.3.1-1). Finally, the inner closure welds are tested to the leak tight criteria [7.1]. There are no bolted closures or mechanical seals.

P.7.2 Requirements for Normal Conditions of Storage

P.7.2.1 Release of Radioactive Material

The NUHOMS®-24PTH DSC is designed, fabricated and tested to meet the leak tight criteria of ANSI N14.5 [7.1]. Therefore, there is no release of radioactive material under normal conditions of storage. As noted in acceptance criteria IV-4 of [7.3], a closure monitoring system is not required. The confinement boundary ensures that the inert fill gas does not leak or diffuse through the weld or parent material of the DSC. The continued effectiveness of the confinement boundary is demonstrated by (a) daily visual inspections of the HSM inlets and outlets OR daily monitoring of the HSM thermal performance (b) and the use of radiation monitors (typically TLDs) on the ISFSI boundary fence. A release following a breach of the confinement boundary would result in an increase in the measured dose at the ISFSI fence. If an increase were detected, steps would be initiated to enable the licensee to take corrective actions to maintain safe storage conditions.

P.7.2.2 Pressurization of Confinement Vessel

The maximum internal pressures in the NUHOMS®-24PTH DSC during transfer and storage for normal and off-normal conditions are calculated in Section P.4.6. These pressures are below the design pressures of the DSC as shown in Section P.4.6.

P.7.3 Confinement Requirements for Hypothetical Accident Conditions

P.7.3.1 Fission Gas Products

The analysis presented in Section P.3 demonstrates that the confinement boundary (pressure boundary) is not compromised following hypothetical accident conditions. Therefore, there is no need to calculate the fission gas products available for release.

P.7.3.2 Release of Contents

The NUHOMS®-24PTH DSC is designed and tested to meet the leak tight criteria of ANSI N14.5 [7.1]. The analysis presented in Chapter P.11 demonstrates that the confinement boundary (pressure boundary) is not compromised following hypothetical accident conditions. Therefore, there is no release of radioactive material under hypothetical accident conditions of storage.

P.7.4 References

7.1 "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment," ANSI N14.5-1997, American National Standards Institute, Inc., New York, New York, 1997.

7.2 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 1998 Edition, including 2000 addenda.

7.3 Interim Staff Guidance (ISG)-5, Revision 1: Confinement Evaluation.

P.8 Operating Systems

This Chapter presents the operating procedures for the standardized NUHOMS®-24PTH system described in previous chapters and shown on the drawings in Section P.1.5. The procedures include preparation of the DSC and fuel loading, closure of the DSC, transfer to the ISFSI using the TC, DSC transfer into the HSM, monitoring operations, and DSC retrieval from the HSM. The standardized NUHOMS® transfer equipment, and the existing plant systems and equipment are used to accomplish these operations. Procedures are delineated here to describe how these operations are to be performed and are not intended to be limiting. Standard fuel and cask handling operations performed under the plant's 10CFR50 operating license are described in less detail. Existing operational procedures may be revised by the licensee and new ones may be developed according to the requirements of the plant, provided that the limiting conditions of operation specified in Technical Specifications, Functional and Operating Limits of NUHOMS® CoC are not exceeded.

The following sections outline the typical operating procedures for the standardized NUHOMS® System. These generic NUHOMS® procedures have been developed to minimize the amount of time required to complete the subject operations, to minimize personnel exposure, and to assure that all operations required for DSC loading, closure, transfer, and storage are performed safely. Plant specific ISFSI procedures are to be developed by each licensee in accordance with the requirements of 10CFR72.212 (b) and the guidance of Regulatory Guide 3.61 [8.1]. The generic procedures presented here are provided as a guide for the preparation of plant specific procedures and serve to point out how the NUHOMS® System operations are to be accomplished.

Note: The generic terms used throughout this Section are as follows. See Chapter P.1 for description of components.

- TC may be either a NUHOMS® OS197/OS197H or OS197FC (with a liquid neutron shield) or standardized NUHOMS® TC (with a solid neutron shield),

- DSC may be 24PTH-S or 24PTH-L or 24PTH-S-LC type DSC, and

- HSM may be a NUHOMS® HSM-H or standardized NUHOMS® HSM Model 102.

P.8.1 Procedures for Loading the Cask

Process flow diagrams for the NUHOMS® System operations are presented Figure P.8-1 and Figure P.8-2. The location of the various operations may vary with individual plant requirements. The following steps describe the recommended generic operating procedures for the standardized NUHOMS® System.

P.8.1.1 Preparation of the TC and DSC

1. Prior to placement in dry storage, the candidate intact and damaged fuel assemblies shall be evaluated (by plant records or other means) to verify that they meet the physical, thermal and radiological criteria specified in Technical Specification 1.2.1.

2. Prior to being placed in service, the TC is to be cleaned or decontaminated as necessary to insure a surface contamination level of less than those specified in Technical Specification 1.2.12.

3. Place the TC in the vertical position in the cask decon area using the cask handling crane and the TC lifting yoke.

4. Place scaffolding around the cask so that the top cover plate and surface of the cask are easily accessible to personnel.

5. Remove the TC top cover plate and examine the cask cavity for any physical damage and ready the cask for service. If required by the plant lifting crane capacity limit, drain the TC neutron shield water to an acceptable location.

6. Examine the DSC for any physical damage which might have occurred since the receipt inspection was performed. The DSC is to be cleaned and any loose debris removed.

7. Verify that the DSC basket type (1A, 2A etc.) is appropriate for the specific fuel loading campaign.

8. Using a crane, lower the DSC into the cask cavity by the internal lifting lugs and rotate the DSC to match the cask and DSC alignment marks.

9. Fill the cask-DSC annulus with clean, demineralized water. Place the inflatable seal into the upper cask liner recess and seal the cask-DSC annulus by pressurizing the seal with compressed air.

10. If damaged fuel assemblies are included in a specific loading campaign, place the required number of bottom end caps provided (up to a maximum of 12) into the cell locations per Technical Specification 1.2.1. Optionally, this step may be performed at any prior time.

11. Fill the DSC cavity with water from the fuel pool or an equivalent source which meets the requirements of Technical Specification 1.2.15c.

NOTE: A TC/DSC annulus pressurization tank filled with demineralized water as described above is connected to the top vent port of the TC via a hose to provide a positive head above the level of water in the TC/DSC annulus. This is an optional arrangement, which provides additional assurance that contaminated water from the fuel pool will not enter the TC/DSC annulus, provided a positive head is maintained at all times.

12. Place the top shield plug onto the DSC. Examine the top shield plug to ensure a proper fit. Optionally, the top shield plug once fitted, may be removed and disconnected from the yoke. It may be installed later once the DSC is loaded and prior to removing it from the pool.

13. Position the cask lifting yoke and engage the cask lifting trunnions and the rigging cables to the DSC top shield plug. Adjust the rigging cables as necessary to obtain even cable tension.

14. Visually inspect the yoke lifting hooks to insure that they are properly positioned and engaged on the cask lifting trunnions.

15. Provide for later connection to the vacuum drying system (VDS) or optional liquid pump to the siphon port of the DSC and position any connecting hose such that the hose will not interfere with loading (yoke, fuel, shield plug, rigging, etc.). A flowmeter or other suitable means for measuring the amount of water removed must be installed at a suitable location as part of this connection.

16. Move the scaffolding away from the cask as necessary.

17. Lift the cask just far enough to allow the weight of the cask to be distributed onto the yoke lifting hooks. Reinspect the lifting hooks to insure that they are properly positioned on the cask trunnions.

18. Optionally, secure a sheet of suitable material to the bottom of the TC to minimize the potential for ground-in contamination. This may also be done prior to initial placement of the cask in the decon area.

19. Prior to the cask being lifted into the fuel pool, the water level in the pool should be adjusted as necessary to accommodate the cask/DSC volume. If the water placed in the DSC cavity was obtained from the fuel pool, a level adjustment may not be necessary.

P.8.1.2 <u>DSC Fuel Loading</u>

1. Lift the cask/DSC and position it over the cask loading area of the spent fuel pool in accordance with the plant's 10CFR50 cask handling procedures.

2. Lower the cask into the fuel pool until the bottom of the cask is at the height of the fuel pool surface. As the cask is lowered into the pool, spray the exterior surface of the cask with demineralized water.

3. Place the cask in the location of the fuel pool designated as the cask loading area.

4. Disengage the lifting yoke from the cask lifting trunnions and move the yoke and the top shield plug clear of the cask. Spray the lifting yoke and top shield plug with clean demineralized water if it is raised out of the fuel pool.

5. The potential for fuel misloading is essentially eliminated through the implementation of procedural and administrative controls. The controls instituted to ensure that damaged and/or intact fuel assemblies and control components (CCs), if applicable, are placed into a known cell location within a DSC, will typically consist of the following:

   - A cask/DSC loading plan is developed to verify that the damaged and/or intact fuel assemblies, and CCs, if applicable, meet the burnup, enrichment and cooling time parameters of Technical Specification 1.2.1.

   - The loading plan is independently verified and approved before the fuel load.

   - A fuel movement schedule is then written, verified and approved based upon the loading plan. All fuel movements from any rack location are performed under strict compliance of the fuel movement schedule.

   - If loading damaged fuel assemblies, verify that the required number of bottom end caps are installed in appropriate fuel compartment tube locations.

6. Prior to loading of a spent fuel assembly (and CCs, if applicable) into the DSC, the identity of the assembly (and CCs, if applicable) is to be verified by two individuals using an underwater video camera or other means. Verification of CC identification is optional if the CC has not been moved from the host fuel assembly since it's last verification. Read and record the identification number from the fuel assembly (and CCs, if applicable) and check this identification number against the DSC loading plan which indicates which fuel assemblies (and CCs, if applicable) are acceptable for dry storage.

7. Position the fuel assembly for insertion into the selected DSC storage cell and load the fuel assembly. Repeat Step 6 for each SFA loaded into the DSC. If loading damaged fuel assemblies, place top end caps over each damaged fuel assembly placed into the basket. A maximum of 12 damaged fuel assemblies may be loaded into the basket per Technical Specification 1.2.1. After the DSC has been fully loaded, check and record the identity and location of each fuel assembly and CCs, if applicable, in the DSC.

8. After all the SFAs and CCs, if applicable, have been placed into the DSC and their identities verified, position the lifting yoke and the top shield plug and lower the shield plug onto the DSC.

   CAUTION: Verify that all the lifting height restrictions as a function of temperature specified in Technical Specification 1.2.13 can be met in the following steps which involve lifting of the TC.

9. Visually verify that the top shield plug is properly seated onto the DSC.

10. Position the lifting yoke with the TC trunnions and verify that it is properly engaged.

11. Raise the TC to the pool surface. Prior to raising the top of the cask above the water surface, stop vertical movement.

12. Inspect the top shield plug to verify that it is properly seated onto the DSC. If not, lower the cask and reposition the top shield plug. Repeat Steps 11 and 12 as necessary.

13. Continue to raise the TC from the pool and spray the exposed portion of the cask with demineralized water until the top region of the cask is accessible.

14. Drain any excess water from the top of the DSC shield plug back to the fuel pool.

15. Check the radiation levels at the center of the top shield plug and around the perimeter of the cask.

16. If loading 24PTH-S DSC or 24PTH-L DSC, drain water from the DSC as necessary to meet the plant lifting crane capacity limits.

17. Lift the TC from the fuel pool. As the cask is raised from the pool, continue to spray the cask with demineralized water.

18. Move the TC with loaded DSC to the cask decon area.

19. If applicable to keep the occupational exposure ALARA, replace the water removed from the DSC in Step 16 with spent fuel pool water of the proper boron concentration. Fill the neutron shield with demineralized water if it was drained in Step P.8.1.1.5. Temporary shielding may be installed as necessary to minimize personnel exposure.

20. Verify that the transfer cask dose rates are compliant with limits specified in Technical Specification 1.2.11b or 1.2.11.c as applicable.

P.8.1.3 DSC Drying and Backfilling

CAUTION: During performance of steps listed in Section 8.1.3, monitor the Cask/DSC annulus water level and replenish if necessary.

1. Check the radiation levels along the perimeter of the cask. The cask exterior surface should be decontaminated as necessary in accordance with the limits specified in Technical Specification 1.2.12 for the DSC surfaces. Temporary shielding may be installed as necessary to minimize personnel exposure.

2. Place scaffolding around the cask so that any point on the surface of the cask is easily accessible to personnel.

3. Disengage the rigging cables from the top shield plug and remove the eyebolts. Disengage the lifting yoke from the trunnions and position it clear of the cask.

4. Decontaminate the exposed surfaces of the DSC shell perimeter and remove the inflatable cask/DSC annulus seal.

5. Connect the cask drain line to the cask, open the cask cavity drain port and allow water from the annulus to drain out until the water level is approximately twelve inches below the top edge of the DSC shell. Take swipes around the outer surface of the DSC shell and check for smearable contamination in accordance with the Technical Specification 1.2.12 limits.

6. Prior to the start of welding operations, drain a minimum of 750 gallons of water from the DSC back into the fuel pool or other suitable location using the VDS or an optional liquid pump. Alternatively, all the water from the DSC may be drained if precautions are taken to keep the occupational exposure ALARA.

7. Disconnect hose from the DSC siphon port.

8. Install the automatic welding machine onto the inner top cover plate and place the inner top cover plate with the automatic welding machine onto the DSC. Verify proper fit-up of the inner top cover plate with the DSC shell.

9. Check radiation levels along surface of the inner top cover plate. Temporary shielding may be installed as necessary to minimize personnel exposure.

   CAUTION: Insert a 1/4-inch flexible tubing of sufficient length and adequate temperature resistance through the vent port such that it terminates just below the DSC shield plug. Connect the flexible tubing to a hydrogen monitor to allow continuous monitoring of the hydrogen atmosphere in the DSC cavity during welding of the inner cover plate. Optionally, other methods may be used for continuous monitoring of the hydrogen atmosphere in the DSC cavity during welding of the inner top cover plate.

10. Cover the cask/DSC annulus to prevent debris and weld splatter from entering the annulus.

11. Ready the automatic welding machine and tack weld the inner top cover plate to the DSC shell. Install the inner top cover plate weldment and remove the automatic welding machine.

    CAUTION: Continuously monitor the hydrogen concentration in the DSC cavity using the flexible tube arrangement or other alternate methods described in Step 9 during the inner top cover plate cutting/welding operations. Verify that the measured hydrogen concentration does not exceed a safety limit of 2.4% [8.2 and 8.3]. If this limit is exceeded, stop all welding operations and purge the DSC cavity with approximately 2-3 psig helium (or any other inert medium) via the 1/4 inch flexible tubing to reduce the hydrogen concentration safely below the 2.4% limit.

12. Perform dye penetrant weld examination of the inner top cover plate weld in accordance with the Technical specification 1.2.5 requirements.

13. Connect the VDS to the DSC siphon and vent ports.

14. Install temporary shielding to minimize personnel exposure throughout the subsequent welding operations as required.

15. Engage the compressed air, nitrogen or helium supply and open the valve on the vent port and allow compressed gas to force the water from the DSC cavity through the siphon port.

16. Once the water stops flowing from the DSC, close the DSC siphon port and disengage the gas source.

17. Connect the hose from the vent port and the siphon port to the intake of the vacuum pump. Connect a hose from the discharge side of the VDS to the plant's radioactive waste system or spent fuel pool. Connect the VDS to a helium source.

18. Open the valve on the suction side of the pump, start the VDS and draw a vacuum on the DSC cavity. The cavity pressure should be reduced in steps of approximately 100 mm Hg, 50 mm Hg, 25 mm Hg, 15 mm Hg, 10 mm Hg, 5 mm Hg, and 3 mm Hg. After pumping down to each level, the pump is valved off and the cavity pressure monitored. The cavity pressure will rise as water and other volatiles in the cavity evaporate. When the cavity pressure stabilizes, the pump is valved in to complete the vacuum drying process. It may be necessary to repeat some steps, depending on the rate and extent of the pressure increase. Vacuum drying is complete when the pressure stabilizes for a minimum of 30 minutes at 3 mm Hg or less as specified in Technical Specification 1.2.2.

    CAUTION: The vacuum drying Step 18 for 24PTH DSC must meet the time duration limits of Technical Specification 1.2.17c. No time limits apply for this step if helium is used for blowdown in Step 15.

19. Open the valve to the vent port and allow the helium to flow into the DSC cavity.

20. Pressurize the DSC with helium to about 24 psia not to exceed 34 psia.

21. Helium leak test the inner top cover plate weld for a leak rate of 1 x 10-4 atm cm3 /sec.

22. If a leak is found, repair the weld, repressurize the DSC and repeat the helium leak test.

23. Once no leaks are detected, depressurize the DSC cavity by releasing the helium through the VDS to the plant's spent fuel pool or radioactive waste system.

24. Re-evacuate the DSC cavity using the VDS. The cavity pressure should be reduced in steps of approximately 10 mm Hg, 5 mm Hg, and 3 mm Hg. After pumping down to each level, the pump is valved off and the cavity pressure is monitored. When the cavity pressure stabilizes, the pump is valved in to continue the vacuum drying process. Vacuum drying is complete when the pressure stabilizes for a minimum of 30 minutes at 3 mm Hg or less in accordance with Technical Specification 1.2.2 limits.

25. Open the valve on the vent port and allow helium to flow into the DSC cavity to pressurize the DSC to about 17.2 psia in accordance with Technical Specification 1.2.3a limits.

26. Close the valves on the helium source.

27. Decontaminate as necessary, and store.

P.8.1.4 DSC Sealing Operations

CAUTION: During performance of steps listed in Section P.8.1.4, monitor the Cask/DSC annulus water level and replenish as necessary to maintain cooling.

1. Disconnect the VDS from the DSC. Seal weld the prefabricated plugs over the vent and siphon ports, inject helium into blind space just prior to completing welding, and perform a dye penetrant weld examination in accordance with the Technical Specification 1.2.5 requirements.

2. Temporary shielding may be installed as necessary to minimize personnel exposure. Install the automatic welding machine onto the outer top cover plate and place the outer top cover plate with the automatic welding system onto the DSC. Verify proper fit up of the outer top cover plate with the DSC shell.

3. Tack weld the outer top cover plate to the DSC shell. Place the outer top cover plate weld root pass.

4. Helium leak test the inner top cover plate and vent/siphon port plate welds using the leak test port in the outer top cover plate in accordance with Technical Specification 1.2.4a limits. Verify that the personnel performing the leak test are qualified in accordance with SNT-TC-1A [8.4]. Alternatively this can be done with a test head in step P.8.1.4.1.

5. If a leak is found, remove the outer cover plate root pass, the vent and siphon port plugs and repair the inner cover plate welds. Repeat procedure steps from P.8.1.3 Step 18.

6. Perform dye penetrant examination of the root pass weld. Weld out the outer top cover plate to the DSC shell and perform dye penetrant examination on the weld surface in accordance with the Technical Specification 1.2.5 requirements.

7. Seal weld the prefabricated plug over the outer cover plate test port and perform dye penetrant weld examinations in accordance with Technical Specification 1.2.5 requirement.

8. Remove the automatic welding machine from the DSC.

9. Open the cask drain port valve and drain the water from the cask/DSC annulus.

10. Rig the cask top cover plate and lower the cover plate onto the TC.

11. Bolt the cask cover plate into place, tightening the bolts to the required torque in a star pattern.

    CAUTION: Monitor the applicable time limits of Technical Specification 1.2.18 until the completion of DSC transfer Step 6 of Section P.8.1.6.

12. Verify that the transfer cask dose rates are compliant with limits specified in Technical Specification 1.2.11b or 1.2.11c, as appropriate.

P.8.1.5 TC Downending and Transfer to ISFSI

1. If loading with OS197/OS197H/OS197FC TC, drain the TC neutron shield to an acceptable location as required to meet the plant lifting crane capacity limit.

2. Re-attach the TC lifting yoke to the crane hook, as necessary. Ready the transport trailer and cask support skid for service.

3. Move the scaffolding away from the cask as necessary. Engage the lifting yoke and lift the cask over the cask support skid on the transport trailer.

4. The transport trailer should be positioned so that cask support skid is accessible to the crane with the trailer supported on the vertical jacks.

5. Position the cask lower trunnions onto the transfer trailer support skid pillow blocks.

6. Move the crane forward while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks.

7. Inspect the positioning of the cask to insure that the cask and trunnion pillow blocks are properly aligned.

8. Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.

9. Inspect the trunnions to ensure that they are properly seated onto the skid and install the trunnion tower closure plates.

10. Fill the neutron shield, if it was drained in step P.8.1.5.1.

11. Remove the bottom ram access cover plate from the cask. Install the two-piece temporary neutron/gamma shield plug to cover the bottom ram access. Install the ram trunnion support frame on the bottom of the TC. (The temporary shield plug and ram trunnion support frame are not required with integral ram/trailer).

P.8.1.6 DSC Transfer to the HSM

1. Prior to transporting the cask to the ISFSI, remove the HSM door using a porta-crane, inspect the cavity of the HSM, removing any debris and ready the HSM to receive a DSC. The doors on adjacent HSMs should remain in place.

2. Inspect the HSM air inlet and outlets to ensure that they are clear of debris. Inspect the screens on the air inlet and outlets for damage.

   CAUTION: Verify that the requirements of Technical Specification 1.2.14, "TC/DSC Transfer Operations at High Ambient Temperatures" are met prior to next step.

3. Using a suitable vehicle, transport the cask from the plant's fuel/reactor building to the ISFSI along the designated transfer route.

4. Once at the ISFSI, position the transport trailer to within a few feet of the HSM.

5. Check the position of the trailer to ensure the centerline of the HSM and cask approximately coincide. If the trailer is not properly oriented, reposition the trailer, as necessary.

6. Using a porta-crane, unbolt and remove the cask top cover plate.

   CAUTION: Verify that the applicable time limits of Technical Specification 1.2.18 are met.

7. Back the cask to within a few inches of the HSM, set the trailer brakes and disengage the tractor. Extend the transfer trailer vertical jacks.

8. Connect the skid positioning system hydraulic power unit to the positioning system via the hose connector panel on the trailer, and power it up. Remove the skid tie-down bracket fasteners and use the skid positioning system to bring the cask into approximate vertical and horizontal alignment with the HSM. Using optical survey equipment and the alignment marks on the cask and the HSM, adjust the position of the cask until it is properly aligned with the HSM.

9. Using the skid positioning system, fully insert the cask into the HSM access opening docking collar.

10. Secure the cask trunnions to the front wall embedments of the HSM using the cask restraints.

11. After the cask is docked with the HSM, verify the alignment of the TC using the optical survey equipment.

12. Position the hydraulic ram behind the cask in approximate horizontal alignment with the cask and level the ram. Remove either the bottom ram access cover plate or the outer plug of the two-piece temporary shield plug. Power up the ram hydraulic power supply and extend the ram through the bottom cask opening into the DSC grapple ring.

13. Activate the hydraulic cylinder on the ram grapple and engage the grapple arms with the DSC grapple ring.

14. Recheck all alignment marks in accordance with the Technical Specification 1.2.9 limits and ready all systems for DSC transfer.

15. Activate the hydraulic ram to initiate insertion of the DSC into the HSM. Stop the ram when the DSC reaches the support rail stops at the back of the module.

16. Disengage the ram grapple mechanism so that the grapple is retracted away from the DSC grapple ring.

17. Retract and disengage the hydraulic ram system from the cask and move it clear of the cask. Remove the cask restraints from the HSM.
18. Using the skid positioning system, disengage the cask from the HSM access opening.
19. Install the DSC drop-in retainer through the HSM door opening.
20. Install the HSM door using a portable crane and secure it in place. Door may be welded for security. Verify that the HSM dose rates are compliant with the limits specified in Technical Specification 1.2.7c or 1.2.7d as appropriate.
21. Replace the TC top cover plate. Secure the skid to the trailer, retract the vertical jacks and disconnect the skid positioning system.
22. Tow the trailer and cask to the designated equipment storage area. Return the remaining transfer equipment to the storage area.
23. Close and lock the ISFSI access gate and activate the ISFSI security measures.

P.8.1.7 Monitoring Operations

1. Perform routine security surveillance in accordance with the licensee's ISFSI security plan.
2. Perform a daily visual surveillance of the HSM air inlets and outlets to insure that no debris is obstructing the HSM vents in accordance with Technical Specification 1.3.1 requirements OR perform a temperature measurement of the thermal performance, for each HSM, on a daily basis in accordance with Technical Specification 1.3.2 requirements.

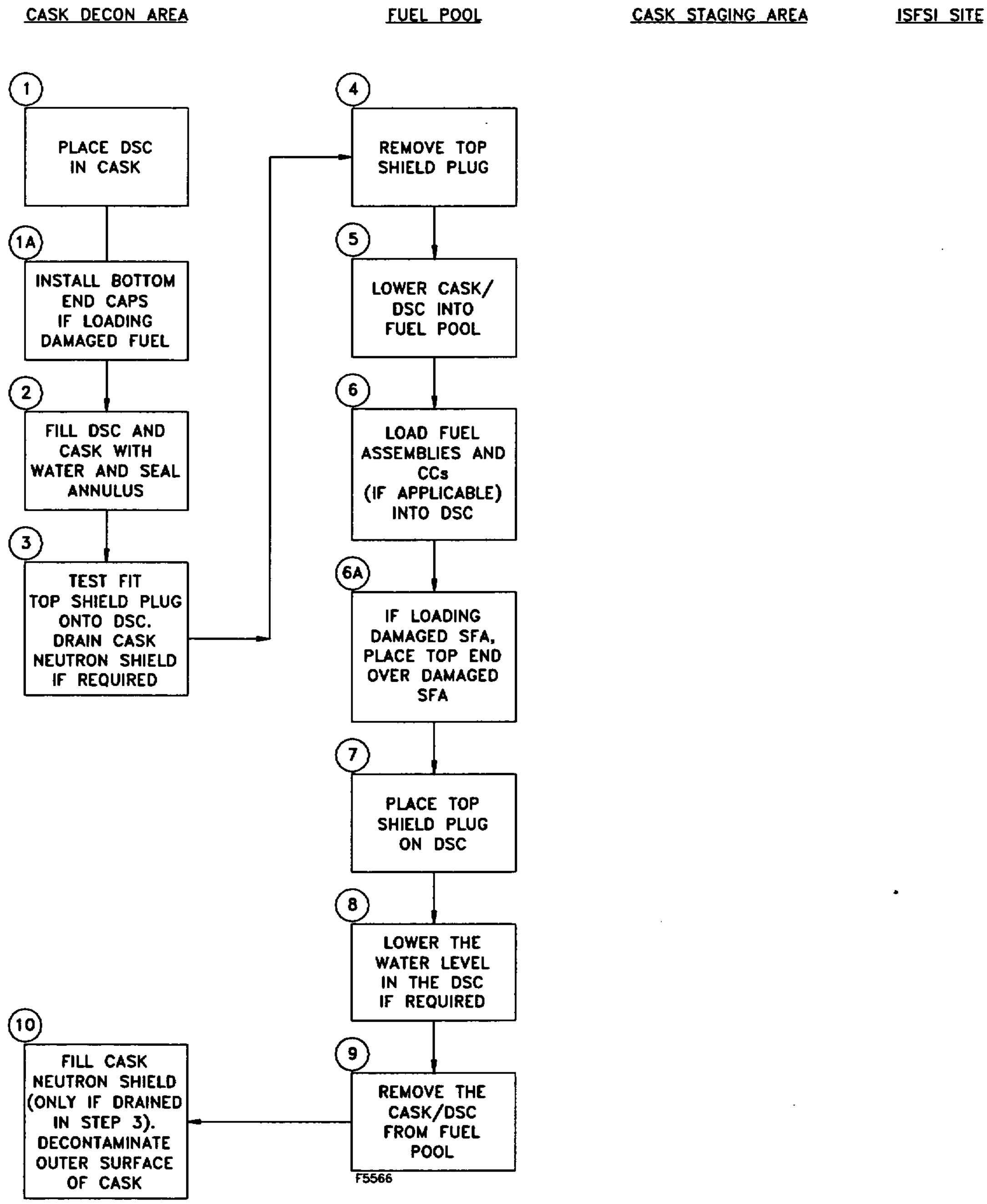


Figure P.8-1
NUHOMS® System Loading Operations Flow Chart

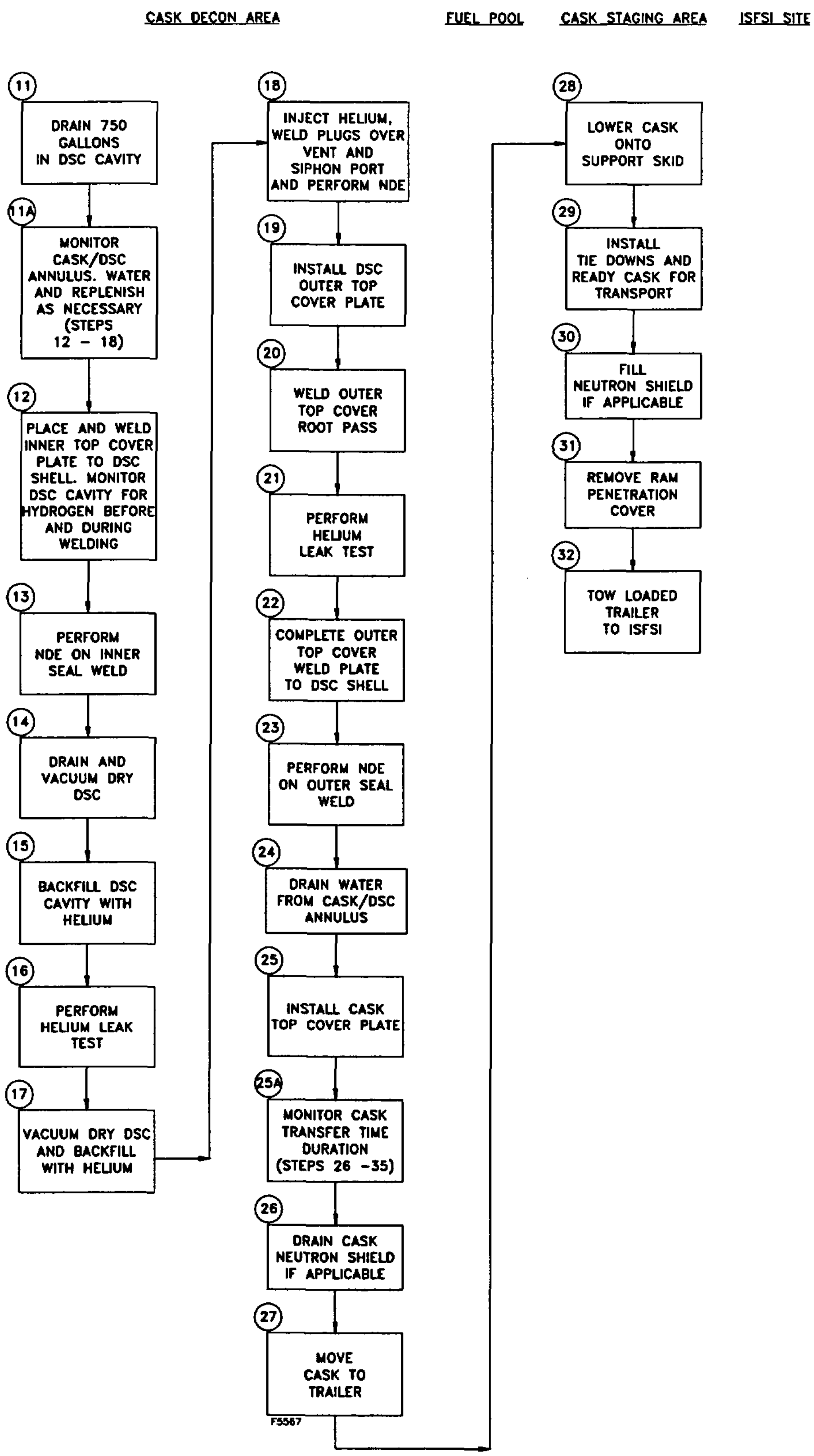


Figure P.8-1 NUHOMS® System Loading Operations Flow Chart (continued)

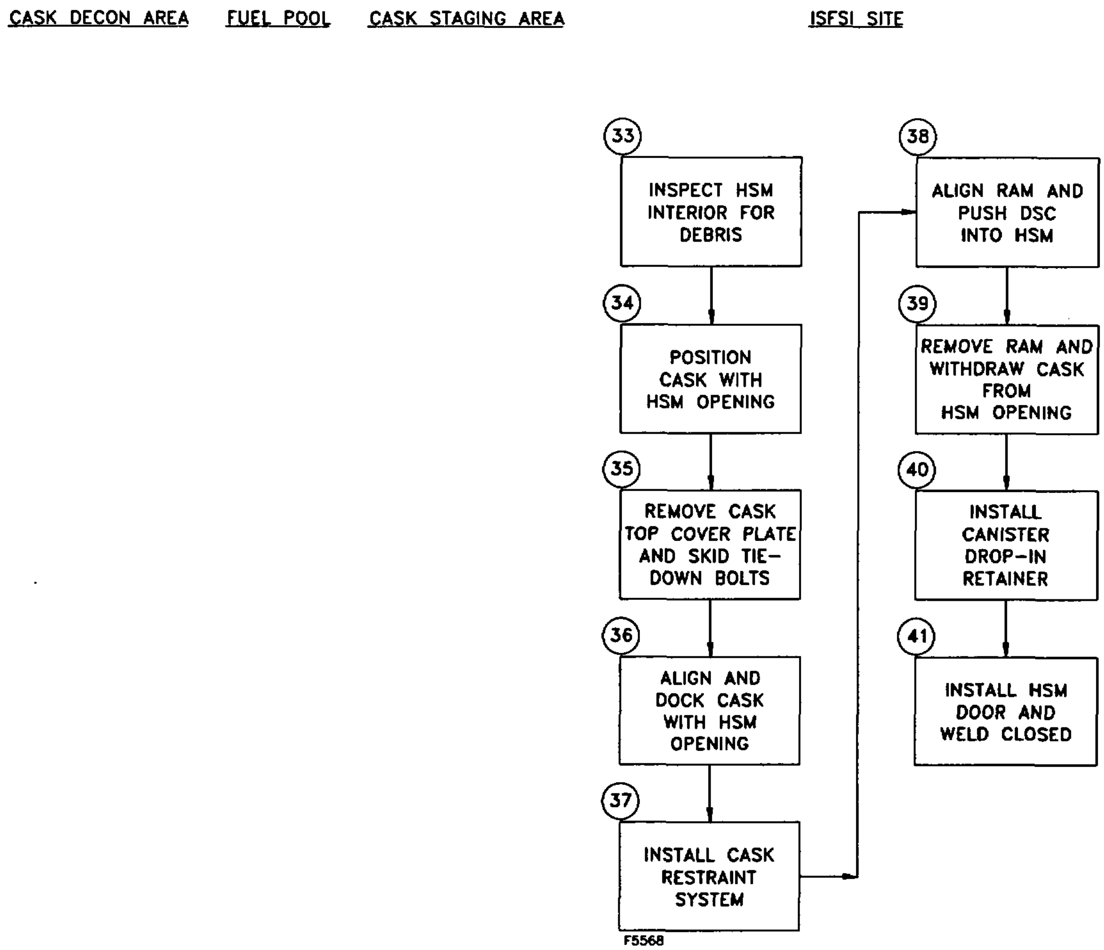


Figure P.8-1 NUHOMS® System Loading Operations Flow Chart (concluded)

P.8.2 Procedures for Unloading the Cask

P.8.2.1 DSC Retrieval from the HSM

1. Ready the TC, transport trailer, and support skid for service and tow the trailer to the HSM.
2. Back the trailer to within a few inches of the HSM and remove the cask top cover plate.
3. Cut any welds from the door and remove the HSM door using a porta-crane. Remove the DSC drop-in retainer.
4. Using the skid positioning system align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.
5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. Install the cask restraints.
6. Install and align the hydraulic ram with the cask.
7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.
8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.
9. Retract ram and pull the DSC into the cask.
10. Retract the ram grapple arms.
11. Disengage the ram from the cask.
12. Remove the cask restraints.
13. Using the skid positioning system, disengage the cask from the HSM.
14. Install the cask top cover plate and ready the trailer for transport.
15. Replace the door on the HSM.

P.8.2.2 Removal of Fuel from the DSC

When the DSC has been removed from the HSM, there are several potential options for off-site shipment of the fuel. It is preferred to ship the DSC intact to a reprocessing facility, monitored retrievable storage facility or permanent geologic repository in a compatible shipping cask licensed under 10CFR71.

If it becomes necessary to remove fuel from the DSC prior to off-site shipment, there are two basic options available at the ISFSI or reactor site. The fuel assemblies could be removed and reloaded into a shipping cask using dry transfer techniques, or if the applicant so desires, the initial fuel loading sequence could be reversed and the plant's spent fuel pool utilized. Procedures for unloading the DSC in a fuel pool are presented here. However, wet or dry unloading procedures are essentially identical to those of DSC loading through the DSC weld removal (beginning of preparation to placement of the cask in the fuel pool). Prior to opening the DSC, the following operations are to be performed.

CAUTION: Verify that the applicable time limits of Technical Specification 1.2.18 are met until the completion of Step P.8.2.2.14.

1. The TC may now be transported to the cask handling area inside the plant's fuel/reactor building.
2. Position and ready the trailer for access by the crane and install the ram access penetration cover plate.
3. Attach the lifting yoke to the crane hook.
4. Engage the lifting yoke with the trunnions of the TC.
5. Visually inspect the yoke lifting hooks to insure that they are properly aligned and engaged onto the TC trunnions.
6. If unloading with OS197/OS197H/OS197FC TC, drain the TC water from the neutron shield to an acceptable location as required to meet the plant lifting crane capacity limit.
7. Lift the TC approximately one inch off the trunnion supports. Visually inspect the yoke lifting hooks to insure that they are properly positioned on the trunnions.
8. Move the crane backward in a horizontal motion while simultaneously raising the crane hook vertically and lift the TC off the trailer. Move the TC to the cask decon area.
9. Lower the TC into the cask decon area in the vertical position. Fill the neutron shield with water if it was drained in Step P.8.2.2.6.
10. Wash the TC to remove any dirt which may have accumulated on the TC during the DSC loading and transfer operations.
11. Place scaffolding around the TC so that any point on the surface of the TC is easily accessible to handling personnel.
12. Unbolt the TC top cover plate.
13. Connect the rigging cables to the TC top cover plate and lift the cover plate from the TC. Set the TC cover plate aside and disconnect the lid lifting cables.
14. Install temporary shielding to reduce personnel exposure as required. Fill the TC/DSC annulus with clean demineralized water and seal the annulus.

The process of DSC unloading is similar to that used for DSC loading. DSC opening operations described below are to be carefully controlled in accordance with plant procedures. This operation is to be performed under the site's standard health physics guidelines for welding, grinding, and handling of potentially highly contaminated equipment. These are to include the use of prudent housekeeping measures and monitoring of airborne particulates. Procedures may require personnel to perform the work using respirators or supplied air.

If fuel needs to be removed from the DSC, either at the end of service life or for inspection after an accident, precautions must be taken against the potential for the presence of damaged or oxidized fuel and to prevent radiological exposure to personnel during this operation. A sampling of the atmosphere within the DSC will be taken prior to inspection or removal of fuel.

If the work is performed outside the fuel/reactor building, a tent may be constructed over the work area, which may be kept under a negative pressure to control airborne particulates. Any radioactive gas release will be Kr-85, which is not readily captured. Whether the krypton is vented through the plant stack or allowed to be released directly depends on the plant operating requirements.

Following opening of the DSC, the cask and DSC are filled with water prior to lowering the top of cask below the surface of the fuel pool to prevent a sudden inrush of pool water. Cask placement into the pool is performed in the usual manner. Fuel unloading procedures will be governed by the plant operating license under 10CFR50. The generic procedures for these operations are as follows:

15. Locate the DSC siphon and vent port using the indications on the top cover plate. Place a portable drill press on the top of the DSC. Position the drill with the siphon port.

16. Place an exhaust hood or tent over the DSC, if necessary. The exhaust should be filtered or routed to the site radwaste system.

17. Drill a hole through the DSC top cover plate to expose the siphon port quick connect.

18. Drill a second hole through the top cover plate to expose the vent port quick connect.

19. Obtain a sample of the DSC atmosphere, if necessary (e.g., at the end of service life). Fill the DSC with water from the fuel pool through the siphon port with the vent port open and routed to the plant's off-gas system.

    CAUTION:

    (a) The water fill rate must be regulated during this reflooding operation to ensure that the DSC vent pressure does not exceed 20.0 psig.

    (b) Provide for continuous hydrogen monitoring of the DSC cavity atmosphere during all subsequent cutting operations to ensure that a safety limit of 2.4% is not exceeded [8.2 and 8.3]. Drain appropriate amount of water from the DSC cavity before cutting operations to ensure that sufficient free volume exists in the DSC cavity for H_2 concentration limit. Purge with 2-3 psig helium (or any other inert medium) as necessary to maintain the hydrogen concentration safely below this limit.

20. Place welding blankets around the cask and scaffolding.

21. Using plasma arc-gouging, a mechanical cutting system or other suitable means, remove the seal weld from the outer top cover plate and DSC shell. A fire watch should be placed on the scaffolding with the welder, as appropriate. The exhaust system should be operating at all times.

22. The material or waste from the cutting or grinding process should be treated and handled in accordance with the plant's low level waste procedures unless determined otherwise.

23. Remove the top of the tent, if necessary.

24. Remove the exhaust hood, if necessary.

25. Remove the DSC outer top cover plate.

26. Reinstall tent and temporary shielding, as required. Remove the seal weld from the inner top cover plate to the DSC shell in the same manner as the top cover plate. Remove the inner top cover plate. Remove any remaining excess material on the inside shell surface by grinding.

27. Clean the cask surface of dirt and any debris which may be on the cask surface as a result of the weld removal operation. Any other procedures which are required for the operation of the cask should take place at this point as necessary.

28. Engage the yoke onto the trunnions, install eyebolts into the top shield plug and connect the rigging cables to the eyebolts.

29. Visually inspect the lifting hooks or the yoke to insure that they are properly positioned on the trunnions.

30. If unloading 24PTH-S DSC or 24PTH-L DSC, drain a minimum of 750 gallons of water from the DSC. The neutron shield water from the TC may also need to be drained as required, to meet plant crane limits.

31. The cask should be lifted just far enough to allow the weight of the TC to be distributed onto the yoke lifting hooks. Inspect the lifting hooks to insure that they are properly positioned on the trunnions.

32. Install suitable protective material onto the bottom of the TC to minimize cask contamination. Move the cask to the fuel pool.

33. Prior to lowering the cask into the pool, adjust the pool water level, if necessary, to accommodate the volume of water which will be displaced by the cask during the operation.

34. Lower the cask into the fuel pool leaving the top surface of the cask approximately one foot above the surface of the pool water.

35. Fill the DSC with appropriate amount pool water.

36. Position the cask over the cask loading area in the fuel pool
37. Lower the cask into the pool. As the cask is being lowered, the exterior surface of the cask should be sprayed with clean demineralized water.
38. Disengage the lifting yoke from the cask and lift the top shield plug from the DSC.
39. Remove the fuel from the DSC and place the fuel into the spent fuel racks.
40. Lower the top shield plug onto the DSC.
41. Visually verify that the top shield plug is properly positioned onto the DSC.
42. Engage the lifting yoke onto the cask trunnions.
43. Visually verify that the yoke lifting hooks are properly engaged with the cask trunnions.
44. Lift the cask by a small amount and verify that the lifting hooks are properly engaged with the trunnions.
45. Lift the cask to the pool surface. Prior to raising the top of the cask to the water surface, stop vertical movement and inspect the top shield plug to ensure that it is properly positioned.
46. Spray the exposed portion of the cask with demineralized water.
47. Visually inspect the top shield plug of the DSC to insure that it is properly seated onto the cask. If the top shield plug is not properly seated, lower the cask back to the fuel pool and reposition the plug.
48. Drain any excess water from the top of the top shield plug into the fuel pool.
49. Lift the cask from the pool. As the cask is rising out of the pool, spray the cask with demineralized water.
50. Move the cask to the cask decon area.
51. Check radiation levels around the perimeter of the cask. The cask exterior surface should be decontaminated if necessary.
52. Place scaffolding around the cask so that any point along the surface of the cask is easily accessible to personnel.
53. Ready the DSC vacuum drying system (VDS).
54. Connect the VDS to the vent port with the system open to atmosphere. Also connect the VDS to the siphon port and connect the other end of the system to the liquid pump. The pump discharge should be routed to the plant radwaste system or the spent fuel pool.

55. Open the valves on the vent port and siphon port of the VDS.

56. Activate the liquid pump.

57. Once the water stops flowing out of the DSC, deactivate the pump.

58. Close the valves on the VDS.

59. Disconnect the VDS from the vent and siphon ports.

60. The top cover plates may be welded into place as required.

61. Decontaminate the DSC, as necessary, and handle in accordance with low-level waste procedures. Alternatively, the DSC may be repaired for reuse.

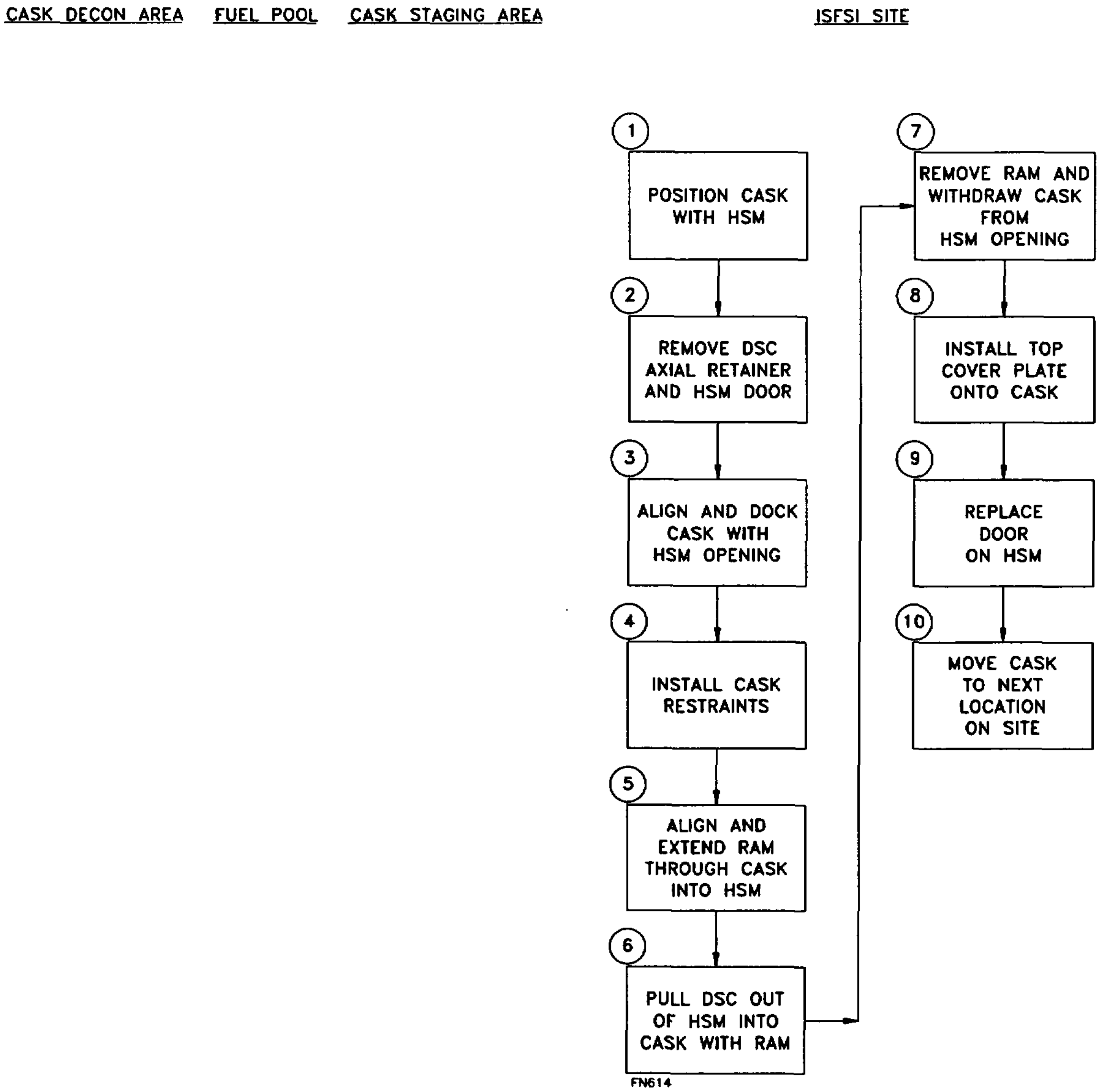


Figure P.8-2
NUHOMS® System Retrieval Operations Flow Chart

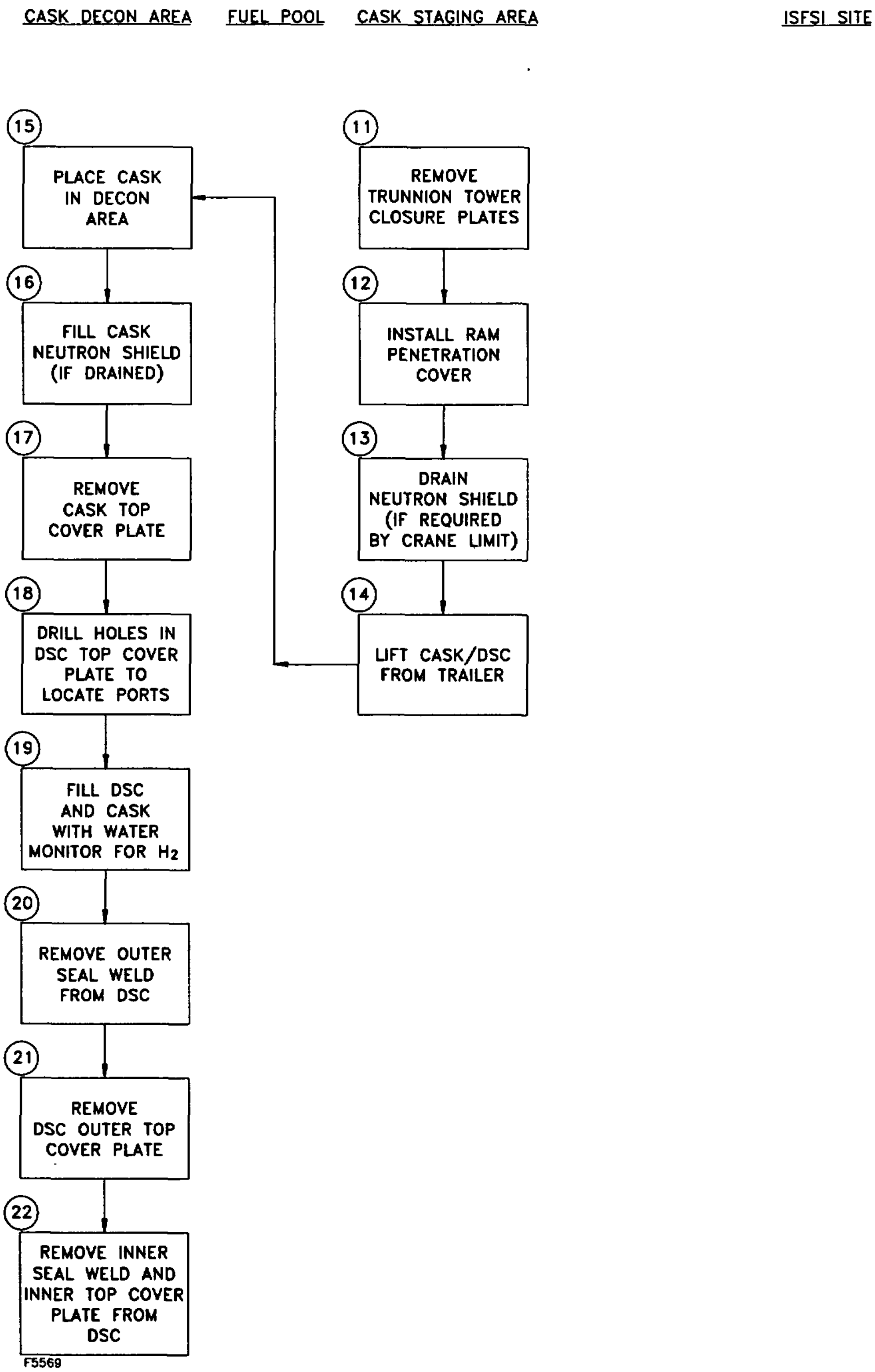


Figure P.8-2
NUHOMS® System Retrieval Operations Flow Chart
(Continued)

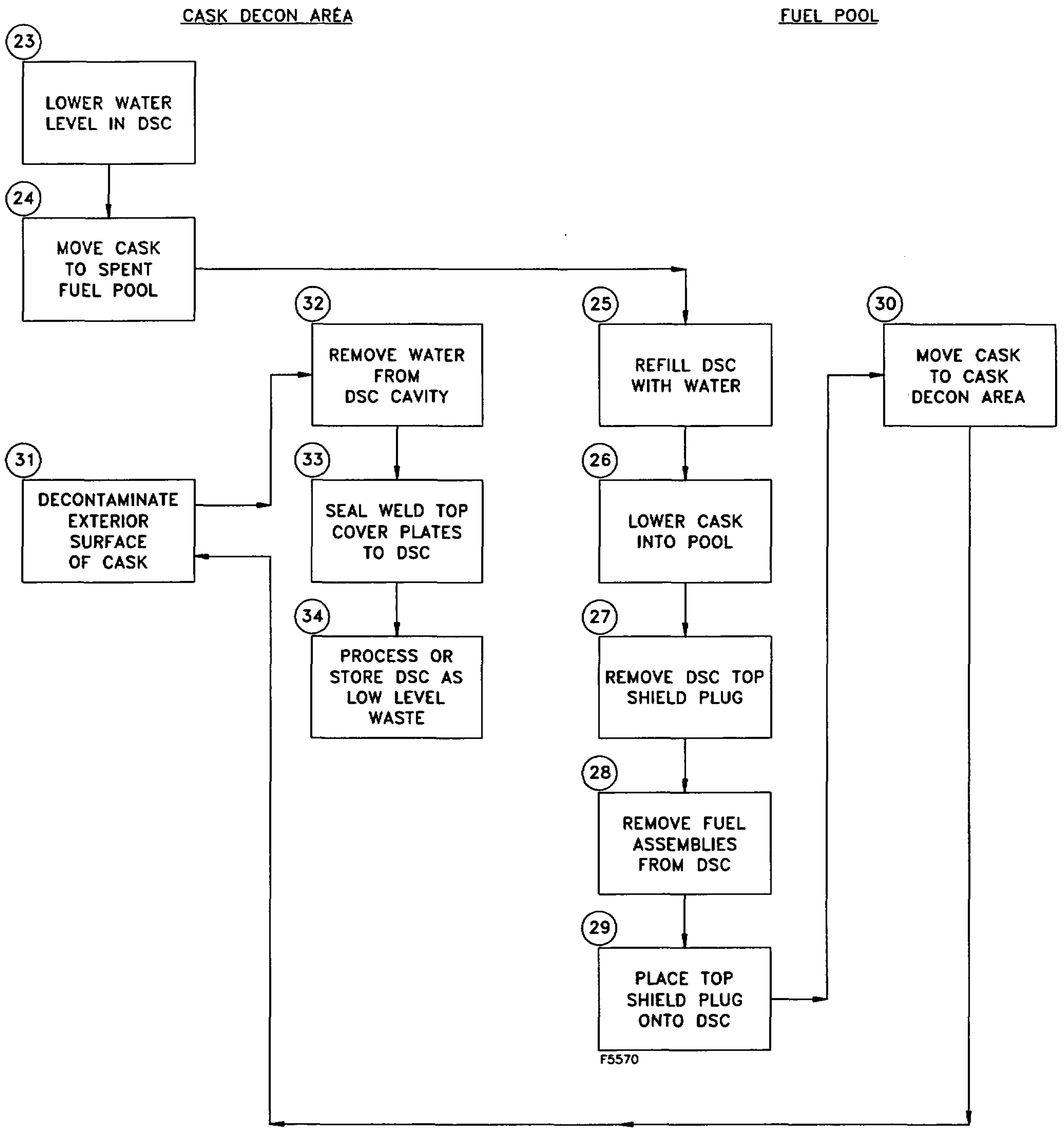


Figure P.8-2
NUHOMS® System Retrieval Operations Flow Chart
(Concluded)

P.8.3 Identification of Subjects for Safety Analysis

No Change.

P.8.4 Fuel Handling Systems

No Change.

P.8.5 Other Operating Systems

No Change.

P.8.6 Operation Support System

No Change.

P.8.7 Control Room and/or Control Areas

No Change.

P.8.8 Analytical Sampling

No Change.

P.8.9 References

8.1 U.S. Nuclear Regulatory Commission, "Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Container," Regulatory Guide 3.61 (February 1989).

8.2 U.S. Nuclear Regulatory Commission, Office of the Nuclear Material Safety and Safeguards, "Safety Evaluation of VECTRA Technologies' Response to Nuclear Regulatory Commission Bulletin 96-04 For the NUHOMS®-24P and NUHOMS®–7P.

8.3 U.S. Nuclear Regulatory Commission Bulletin 96-04, "Chemical, Galvanic or Other Reactions in Spent Fuel Storage and Transportation Casks," July 5, 1996.

8.4 SNT-TC-1A, "American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing," 1992.

P.9 Acceptance Tests and Maintenance Program

P.9.1 Acceptance Tests

The acceptance requirements for the NUHOMS®-24PTH system are given in the FSAR except as described in the following sections. The NUHOMS®-24PTH DSC has been enhanced to provide leaktight confinement and the basket includes an updated poison plate design. The requirements for the poison plate material acceptance tests for the 24PTH system are the same as the NUHOMS® 32PT system described in Appendix M.9 [9.11] except Boral® which is described in Appendix K.9. These are repeated here for completion of this section on the 24PTH system

P.9.1.1 Visual Inspection

Visual examinations are performed at the fabricator's facility to ensure that the NUHOMS®-24PTH system components conform to the fabrication specifications and drawings.

Visual examination of all finished neutron absorber plates are done to ensure that they are free of cracks, porosity, blisters, or foreign substances. Dimensional inspections of the plates is done to verify that the dimensions of the poison plates shown on drawings in Section P.1.5 are met. The minimum thickness, length and width of the poison plate material should also be verified to ensure that their functional requirements listed in P.9.1.7 are met.

P.9.1.2 Structural Tests

The NUHOMS®-24PTH DSC confinement welds are designed, fabricated, tested and inspected in accordance with ASME B&PV Code Section III, Subsection NB [9.1] with exceptions as listed in Section P.3.1. The following requirements are unique to the NUHOMS®-24PTH DSC:

- The inner bottom cover weld is inspected in accordance with Article NB-5231,
- The outer bottom cover weld root and cover are penetrant tested, and
- The outer top cover plate weld root and cover are penetrant tested.

The NUHOMS®-24PTH DSC basket is designed, fabricated, and inspected in accordance with ASME B&PV Code Section III, Subsection NG [9.1] with exceptions as listed in Section P.3.1.

P.9.1.3 Leak Tests

The NUHOMS®-24PTH DSC confinement boundary is leak tested to verify that it is leaktight in accordance with the criteria of ANSI N14.5 [9.2]. The personnel performing the leak test are qualified in accordance with SNT-TC-1A [9.8].

The leak tests are typically performed using the helium mass spectrometer method. Alternative methods are acceptable, provided that the required sensitivity is achieved.

P.9.1.4 Component Tests

No change.

P.9.1.5 Shielding Integrity Tests

No change.

P.9.1.6 Thermal Acceptance Tests

The analyses to ensure that the NUHOMS®-24PTH system is capable of performing their heat transfer function are presented in Section P.4.

P.9.1.7 Poison Plate Acceptance Tests

The poison plates only serve as a neutron absorber for criticality control and as a heat conduction path. The NUHOMS®-24PTH DSC safety analyses do not rely upon their mechanical strength except in through-thickness compression. The radiation and temperature environment in the cask is not sufficiently severe to damage the aluminum matrix that retains the boron-containing particles. To assure performance of the plates' Important-to-Safety function, the only critical variables that need to be verified are thermal conductivity and B10 areal density as discussed in the following paragraphs.

P.9.1.7.1 Thermal Conductivity Testing of Poison Plates

The poison plate material shall be qualification tested to verify that the thermal conductivity equals or exceeds the values listed in Section P.4.3. Acceptance testing of the material in production may be done at only one temperature in that range to verify that the conductivity equals or exceeds the corresponding value in Section P.4.3.

Testing may be by ASTM E1225 [9.3], ASTM E1461 [9.4], or equivalent method, performed on coupons as defined in Section P.9.1.7.2.1.

P.9.1.7.2 B10 Areal Density Testing of Poison Plates

There are three poison materials qualified for the NUHOMS®-24PTH DSC basket:

- Borated aluminum,
- Boron carbide/aluminum metal matrix composites (MMCs), such as Boralyn®, or Metamic®, or equivalent, and
- Boral®.

For each poison material, the NUHOMS®-24PTH DSC basket is configured with three alternate basket configurations, depending on the boron loadings analyzed (designated as Type A basket for low B10 loading, Type B basket for moderate B10 loading, and Type C basket for high B10 loading). A summary of the minimum poison loadings considered and the corresponding credit taken in the criticality analysis for each poison material as a function of 24PTH DSC basket type is summarized in Table P.9-1.

The B10 areal density and uniformity of the poison plates shall be verified, based on type, using approved procedures, as follows.

P.9.1.7.2.1 Borated Aluminum Using Natural or Enriched Boron, 90% B10 Credit

Borated Aluminum Material Description

The poison plate consists of wrought aluminum containing isotopically enriched B10. Alternately, a thicker aluminum plate containing natural B10 or a blend of enriched boron and natural boron is also acceptable provided it meets the specified minimum areal B10 density. Because of the negligibly low solubility of boron in solid aluminum, the boron appears entirely as discrete second phase particles of AlB_2 in the aluminum matrix. The matrix is limited to any 1000 series aluminum, aluminum alloy 6063, or aluminum alloy 6351 so that no boron-containing phases other than AlB_2 are formed. Titanium may also be added to form TiB_2 particles, which are finer. The effect on the properties of the matrix aluminum alloy are those typically associated with a uniform fine (1-10 micron) dispersion of an inert equiaxed second phase.

The cast ingot may be rolled, extruded, or both to the final plate dimensions.

Borated Aluminum Test Coupon and Lot Definitions

A sample taken from the plate material is a test coupon. Test coupons will be removed so that there is at least one coupon contiguous with each plate. These coupons will be used for neutron transmission and thermal conductivity testing. The minimum dimension of the coupon shall be as required for the acceptance test procedures.

A lot is defined as all the plates produced from a single cast ingot, or all the plates produced from a single heat.

Borated Aluminum Acceptance Testing, Neutronic

Effective B10 content is verified by neutron transmission testing of these coupons. The transmission through the coupons is compared with transmission through calibrated standards composed of a homogeneous boron compound without other significant poisons, for example zirconium diboride or titanium diboride. These standards are paired with aluminum shims sized to match the scattering by aluminum in the poison plates. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to be equivalent to a homogeneous standard.

The neutron transmission testing measurements are taken using a collimated neutron beam size of approximately 1 cm^2. The neutron transmission test procedure shall include provisions to vary the selected measurement location along the coupon length.

The acceptance criterion for neutron transmission testing is that the B10 areal density, minus 3s based on the number of neutrons counted for that measurement, must be greater than or equal to the minimum value specified for a specific basket type as listed in Table P.9-1.

In the event that a coupon fails the single neutron transmission measurement, the associated plate is rejected. As an alternate basis for accepting that plate, four additional measurements may be made at separate random locations on the plate itself, or on coupons cut from four random locations of the plate. For each of the additional measurements, the value of areal density less 3s based on the number of neutrons counted must be greater than or equal to the specified minimum in order to accept the plate.

If any of those four fails, the plate associated with the measurements will be rejected. However, the average of the five measurements made is to be used as a datum in the subsequent statistical analysis conducted on the lot (see below).

Initial sampling of coupons for neutron transmission measurements and radioscopy/radiography shall be 100%. Reduced sampling (50%) may be introduced based upon acceptance of all coupons in the first 25% of the lot. A rejection during reduced inspection will require a return to 100% inspection of the lot.

To verify macroscopic uniformity of B10 distribution, a statistical analysis of the neutron transmission results for all plates in a lot shall be performed. This analysis shall demonstrate, using a one-sided tolerance limit factor for a normal distribution with at least 95% probability, the areal density is greater than or equal to the specified minimum value with 95% confidence level.

This statistical analysis shall be based on full data set for the lot, except that any data from materials which are rejected based on physical examination of the materials may be eliminated from the statistical analysis. For example, a rejection based on dimensional or surface finish inspection is ground for excluding the datum associated with that plate. Failure to meet the acceptance criterion of this statistical analysis shall result in rejection of the entire lot. Individual pieces in that lot may be accepted based on the determination of an alternate minimum thickness as follows:

All areal densities determined by neutron transmission for that lot may be converted to volume density by dividing by the thickness of the corresponding coupon. The thickness shall be measured at the same location as the neutron transmission test, or shall be an equal or larger value. The one sided lower tolerance limit of volume density with 95% probability and 95% confidence may then be determined. Finally, the minimum specified value of B10 areal density may be divided by the 95/95 lower tolerance limit of B10 volume density to arrive at a minimum plate thickness. Then, all plates which have any location (other than local pits) thinner than this minimum shall be rejected, and those equal to or thicker may be accepted.

Justification for Acceptance Test Requirements, Borated Aluminum

For a specific basket type, the criticality calculations in Section P.6 use boron areal densities that are 90% of the minimum value listed in Table P.9-1. This is justified base on the information provided in Reference [9.7].

P.9.1.7.2.2 Boron carbide/aluminum metal matrix composites (MMCs), such as Boralyn®, or Metamic®, or Equivalent

MMC Material Description

The MMC poison plates (Boralyn®, Metamic®, or equivalent) consist of a composite of aluminum with boron carbide particulate reinforcement. The material is formed into a billet by powder metallurgical processes and either extruded, rolled, or both to final dimensions. The finished product has near-theoretical density and metallurgical bonding of the aluminum matrix particles. It is a "uniform" blend of powder particles from face to face, i.e.; it is not a "sandwich" panel.

Typical MMC processing steps consist of:

- blending of boron carbide powder with aluminum alloy powder,
- billet formed by vacuum hot pressing (Boralyn®) or cold isostatic pressing followed by vacuum sintering (Metamic®),
- billet extruded to intermediate or to final size,
- hot roll, cold roll and flatten as required, and
- anneal (optional).

MMC Qualification Test Program

The process specifications for the Boralyn® or Metamic® have been subjected to qualification testing to demonstrate that the process results in a material that:

- has a uniform distribution of boron carbide particles in an aluminum alloy with few or none of the following: voids, oxide-coated aluminum particles, B_4C fracturing, or B_4C/aluminum reaction products,
- meets the requirements for B10 areal density and thermal conductivity, and
- will be capable of performing its Important-to-Safety functions under the thermal and radiological environment of the NUHOMS®-24PTH DSC over its 40-year lifetime.

These qualification programs consisted of:

1. Fast neutron irradiation of the material to a fluence of about $8x10^{15}$ n/cm^2 or more, with dimensional measurements, transmission electron microscopic (TEM) examination, and /or mechanical testing to evaluate differences in the as-produced and irradiated conditions.

2. Exposure to temperatures in the range of 700°F or greater for periods of 30 days or more, again with dimensional measurements, transmission electron microscopic (TEM) examination, and /or mechanical testing to evaluate differences in the as-produced and irradiated conditions.

3. Evaluation of corrosion or hydrogen generation rates.

4. Verification of uniformity of B10 distribution by neutron radioscopy or by statistical analysis of neutron transmission measurements together with quantitative metallography.

The results of these qualification test programs have been previously presented to the NRC in the license applications for the TN-68 dry storage cask [9.6], the NUHOMS® 61BT DSC (Appendix K), and the NUHOMS® MP-197 transport packaging [9.7].

The qualification testing described above demonstrated, as would be expected from the properties of aluminum and boron carbide alone, that the materials suffer insignificant damage from the levels of radiation and temperature experienced in dry storage or transport of irradiated fuel. These materials also demonstrate corrosion characteristics very similar to the aluminum matrix.

Boralyn® qualification testing was performed on a 15 volume % boron carbide / 1000 series aluminum composite, and Metamic® qualification testing was performed on 15, 31 and 40 volume % boron carbide / 6000 series aluminum composites. The boron carbide content of material produced for the NUHOMS®-24PTH DSC will not exceed the volume percent subjected to qualification testing for that material, unless it is subjected to additional testing as described in the following sections.

The production of MMC plates for use in the NUHOMS®-24PTH DSC is consistent with the process used to produce the qualification test material. Processing changes may be incorporated into the production process, only if they are reviewed and approved by the holder of an NRC-approved QA plan who is supervising fabrication, in accordance with the following criteria:

Major processing changes, such as billet formation by processes other than hot vacuum pressing or CIP/vacuum sintering, or direct rolling of the billet (elimination of extrusion) shall be subject to a complete program of qualification testing including the four areas of radiation exposure, thermal exposure, hydrogen generation / corrosion, and B10 uniformity described above for the original Boralyn® and Metamic® qualification programs. Other examples of major changes which require qualification testing are:

- B_4C content of > 15 volume % for Boralyn® or equivalent, or
- B_4C content of > 40 volume % for Metamic® or equivalent, or

- Product theoretical density < 98%, or
- More than 5 % of B_4C powder ≥ 40 microns, and more than 20 % of B_4C powder ≥ 25 microns.

Minor processing changes that do not have an adverse effect on the particle bonding, microstructure or uniformity of the B_4C particle distribution may be accepted by engineering review without testing. Examples of such changes include reduction of B_4C content in the MMC, increased billet forming pressure, and changes in mechanical processing variables such as extrusion speed. Changes that have an uncertain or a small adverse effect on the microstructure shall be subjected to limited additional testing such as microscopic metallurgical examination in the as-built condition of the plates. Examples of such changes are increased billet forming temperature and small increases in the B_4C content (within the maximum limits listed above).

The basis for acceptance shall be that the changes do not have an adverse effect on either the durability or neutron absorption effectiveness of the material. These characteristics are determined by the bonding and uniformity of the B_4C particle distribution. The evaluation may consist of an engineering review, or it may consist of additional testing.

MMC Test Coupon and Lot Definitions

Coupon removal for MMC's is the same as for borated aluminum. A lot shall be defined as all plates made from a single billet, or from a group of billets, all processed from the same batch of blended powder, and compacted into billets during a single production campaign.

MMC Acceptance Testing, Neutronic

The acceptance criteria for neutron transmission testing of MMC plates and the alternate acceptance criteria in the event that a MMC coupon fails an acceptance criteria are the same as those discussed in Section P.9.1.7.2.1.

Justification for Acceptance Test Requirements, MMCs

The justification for the test requirements and 90% B10 credit for MMCs is the same as those for borated aluminum discussed in Section P.9.1.7.2.1, except that the boron carbide particles in a MMC are typically in the range of 1-25 microns.

P.9.1.7.2.3 Boral®, 75 % B10 Credit

Material Description, Boral®

Boral® consists of a core of mechanically bonded aluminum and boron carbide powders sandwiched between two outer layers of aluminum 1100, which is mechanically bonded to the core. The boron carbide particles average approximately 85 microns in diameter. The sheet is formed by filling an aluminum 1100 box with the boron carbide/aluminum powder mixture, and then hot-rolling the box. The walls of the box form the cladding, while the powder mixture forms the core of the Boral®. Additional information on the fabrication, specification, and performance of Boral® may be found in References [9.9] and [9.10].

Acceptance Testing, Neutronic

Boral® will be procured using AAR Advance Structures' standard specification for guidance [9.9]. In accordance with Section 7.3 of that specification, B10 areal density will be verified by chemical analysis or by neutron attenuation testing, using a sampling plan that will verify that the coupon meets the specified minimum values of Table P.9-1 with 95% probability at the 95% confidence level. Both neutron absorption and chemical samples are taken from roughly one square centimeter sample through the thickness of the plate.

P.9.2 Maintenance Program

NUHOMS®-24PTH system is a totally passive system and therefore requires little, if any, maintenance over the lifetime of the ISFSI. Typical NUHOMS®-24PTH system maintenance tasks are performed in accordance with the FSAR.

P.9.3 References

9.1 ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition including 2000 addenda.

9.2 ANSI N14.5-1997, "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials," February 1998.

9.3 ASTM E1225, "Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique."

9.4 ASTM E1461, "Thermal Diffusivity of Solids by the Flash Method."

9.5 NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," 1997.

9.6 Transnuclear Inc., TN-68 Dry Storage Cask, Final Safety Analysis Report, Revision 0, Hawthorne, NY, 2000 (Docket No. 72-1027).

9.7 Transnuclear Inc., NUHOMS® - MP197 Transportation Packaging, Safety Analysis Report (Docket No. 71-9302).

9.8 SNT-TC-1A, "American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing," 1992.

9.9 AAR Advanced Structures, "Boral®, The Proven Neutron Absorber."

9.10 AAR Advanced Structures, Boral® Product Performance Report 624.

9.11 Section M.9 of Appendix M, Revision 6 of Application for Amendment No. 5 to the NUHOMS® Certificate of Compliance No. 1004 (TAC No. L23343).

Table P.9-1
B10 Specification for the NUHOMS®-24PTH Poison Plates

Poison Type	24PTH Basket Type	Minimum Poison Loading (B10 mg/cm^2)	% Credit Used in Criticality Analysis
Borated Aluminum Alloy/MMC	1A or 2A	7	90
	1B or 2B	15	
	1C or 2C	32	
Boral®	1A or 2A	9	75
	1B or 2B	19	
	1C or 2C	40	

P.10 Radiation Protection

Section 7.4.1 discusses the anticipated cumulative dose exposure to site personnel during the fuel handling and transfer activities associated with utilizing one NUHOMS® HSM for storage of one DSC. Chapter 5 describes in detail the NUHOMS® operational procedures, several of which involve potential exposure to personnel. This section of the Appendix provides occupational exposure and off-site dose rates from NUHOMS®-24PTH-L/S DSC to be stored in NUHOMS® HSM-H and from NUHOMS®-24PTH-S-LC DSC to be stored in NUHOMS® HSM-Model 102.

Note that while the 24PTH-S-LC DSC may be stored in the HSM-H, only the HSM-Model 102 is evaluated with the 24PTH-S-LC DSC for the off-site dose rate calculation because this configuration results in limiting dose rates.

P.10.1 Occupational Exposure

The expected occupational dose for placing a canister of spent fuel into dry storage is based on the operational steps outlined in Table 7.4-1. The total exposure for the occupational dose due to placing a single NUHOMS®-24PTH-L DSC into storage is conservatively estimated to be 4.4 person-rem. This value bounds the exposure for loading either a 24PTH-S or 24PTH-S-LC DSC into storage. This is a very conservative estimate because the dose rates on and around the 24PTH DSC's used in these calculations are based on very conservative assumptions for the design-basis source terms and analyses models (Configuration 2 from Section P.2). The calculated exposures are due mainly to the expected gamma dose rate during preparation for welding.

The NUHOMS®-24PTH System loading operations, the number of workers required for each operation, and the amount of time required for each operation are presented in Table P.10-1. This information is used as the basis for estimating the total occupational exposure associated with one fuel load. This evaluation is performed for the storage of one design-basis NUHOMS®-24PTH-L DSC in an HSM-H. The loading operations are identical for the 24PTH-S and 24PTH-S-LC DSC. The dose rates applicable for each operation are based on the results presented in Section P.5.4 for loading operations. Engineering judgment and operational experience are used to estimate dose rates that were not explicitly evaluated. This evaluation assumes that a transfer trailer/skid with an integral ram is used for the DSC transfer operations. Licensees may elect to use different equipment and/or different procedures. Each Licensee must evaluate any such changes in accordance with its ALARA program.

Unique steps are sometimes necessary at the individual site to load the canister, complete closure operations and place the canister in the HSM. Specifically, the licensee may choose to modify the sequence of operations in order to achieve reduced dose rates for a larger number of steps, with the end result of reduced total exposure. The only requirement is that the licensee practice ALARA with respect to the total exposure received for a loading campaign. These estimated durations, manloading and dose rates are not limits.

The amount of time required to complete some operations as identified in Table P.10-1 may be greater than the actual amount of time spent in a radiation field. The process of vacuum drying the DSC includes setting up the vacuum drying system (VDS), verifying that the VDS is operating correctly, evacuating the DSC cavity, monitoring the DSC pressure, and disconnecting the VDS from the DSC. Of these tasks, only setup and removal of the VDS require a worker to spend time near the DSC. The most time consuming task, evacuating the DSC, does not require anyone to be present near DSC at all. The total exposure calculated for each task is therefore not necessarily equal to the number of workers multiplied by the total time required, multiplied by a dose rate. The exposure estimation for each task correctly accounts for cases such as vacuum drying assumes that good ALARA practices are followed.

The results of the evaluations of the 24PTH-L are presented in Table P.10-1.

P.10.2 Off-Site Dose Calculations

Calculated dose rates in the immediate vicinity of the NUHOMS®-24PTH System are presented in Section P.5, which provides a detailed description of source term configuration, analysis models and bounding dose rates. Off-site dose rates and doses are presented in this section. This evaluation determines the neutron and gamma-ray off-site dose rates including skyshine in the vicinity of the two generic ISFSI layouts containing design-basis fuel in the NUHOMS®-24PTH DSCs.

The first generic ISFSI evaluated is a 2x10 back-to-back array of HSM-Hs loaded with design-basis fuel, including CCs, in NUHOMS®-24PTH-L DSCs (Configuration 2 from Section P.2). The second generic layout evaluated is two 1x10 front-to-front arrays of HSM-Hs loaded with design-basis fuel, including CCs, in NUHOMS®-24PTH-L DSCs (Configuration 2 from Section P.2). This evaluation provides results for distances ranging from 6.1 to 600 meters from each face of the two arrays of HSMs. The 2x10 and two 1x10 analyses are also performed for the NUHOMS®-24PTH-S-LC DSCs within HSM-Model 102s filled with 24 design basis fuel assemblies.

The total annual exposure for each ISFSI layout as a function of distance from each face is given in Table P.10-2 and Table P.10-3 for the HSM-H and HSM-Model 102, respectively. These data are also plotted in Figure P.10-1 and Figure P.10-2 for the HSM-H and HSM-Model 102, respectively. The total annual exposure estimates assume 100% occupancy for 365 days.

The Monte Carlo computer code MCNP [10.1] calculates the dose rates at the specified locations around the arrays of HSMs. The results of this calculation provide an example of how to demonstrate compliance with the relevant radiological requirements of 10CFR20 [10.2], 10CFR72 [10.3], and 40CFR190 [10.4] for a specific site. Each site must perform specific site calculations to account for the actual layout of the HSMs and fuel source.

The assumptions used to generate the geometry of the ISFSIs for the MCNP analyses are summarized below.

- The 20 HSM-Hs in the 2x10 back-to-back array are modeled as a box enveloping the 2x10 array of HSM-Hs including the 3-foot shield walls on the two sides of the array. The 20 HSM-Model 102s in the 2x10 back-to-back array are modeled as a box enveloping the 2x10 array of HSM-Model 102s including the six inch gaps between modules and the 2-foot shield walls on the two sides of the array. MCNP starts the source particles on the surfaces of the box.

- The 20 HSM-Hs in the two 1x10 front-to-front arrays are modeled as two boxes which envelope each 1x10 array of HSM-Hs including the 3-foot shield walls on the two sides and back of each array. The 20 HSM-Model 102s in the two 1x10 front-to-front arrays are modeled as two boxes which envelope each 1x10 array of HSM-Model 102s including the six inch gaps between modules and the 2-foot shield walls on the two sides and back of each array. MCNP starts the source particles on the surfaces of one of the boxes.

The following assumptions are applicable to both the HSM-H and HSM-Model 102 analyses.

- The ISFSI approach slab is modeled as concrete. Because the ground composition has, at best, only a secondary impact on the dose rates at the detectors, any differences between this assumed layout and the actual layout would not have a significant affect on the site dose rates.

- For the 2x10 array, the interiors of the HSMs and shield walls are modeled as air. Most particles that enter the interiors of the HSMs and shield walls will therefore pass through unhindered.

- For the two 1x10 arrays, the interiors of one array of HSMs and shield walls are modeled as air. Most particles that enter the interiors of these HSMs and shield walls will therefore pass through unhindered. The other 1x10 array is modeled as concrete to simulate the shielding provided by the second array of HSMs for the direct radiation from the front of the opposing 1x10 array.

- The "universe" is a sphere surrounding the ISFSI. To account for skyshine radius of this sphere (r=500,000 cm) is more than 10 mean free paths for neutrons and 50 mean free paths for gammas greater than that of the outermost surface, thus ensuring that the model is of a sufficient size to include all interactions, including skyshine, affecting the dose rate at the detectors.

The assumption used to generate the HSM surface sources for the MCNP analysis is summarized below.

- The HSM-H and HSM-Model 102 surface sources are bootstrapped (input to provide an equivalent boundary condition) using the HSM-H and HSM-Model 102 surface average dose rates calculated in Section P.5.4. The HSM-H analysis uses average dose rates from Table P.5-1, while the HSM-Model 102 analysis used average dose rates from Table P.5-2.

The assumptions used for the MCNP analyses are summarized below. These assumptions are applicable to both the HSM-H and HSM-Model 102 analyses.

- MCNP starts the source particles on the ISFSI array surface with initial directions following a cosine distribution. Radiation fluxes outside thick shields such as the HSM walls and roof tend to have forward peaked angular distributions; therefore, a cosine function is a reasonable approximation for the starting direction distribution. Vents through shielding regions such as the HSM vents tend to collimate particles such that a semi-isotropic assumption would not be appropriate.

- Point detectors determine the dose rates on the four sides of the ISFSI as a function of distance from the ISFSI. All detectors represent the dose rate at three feet above ground level.

- Source information required by MCNP includes gamma-ray and neutron spectra for the HSM array surfaces, total gamma-ray and neutron activities for each HSM array face and total gamma-ray and neutron activities for the entire ISFSI. The neutron and gamma-ray spectra are determined using a 1-D ANISN [10.6] run through the HSM-H roof using the design-basis in-core neutron and gamma fuel sources. Use of the roof is conservative because it represents the thickest cross section of the HSM-H shield. As the HSM-H roof is thicker than the HSM-Model 102 roof, this spectrum is also used for the HSM-Model 102 site dose analysis. The thicker shield increases the dose rate importance of the higher energy neutrons and gamma-rays from the fuel because the thicker shield filters out the lower energy particles. Therefore, use of the thickest part of the shield results in a harder spectrum for all of the other surfaces. The HSM-H spectra as determined from ANISN are normalized to a one mrem/hour source using the flux-to-dose-factors from Reference [10.5]. These normalized spectra are then input in the MCNP ERG source variable.

- The probability of a particle being born on a given surface is proportional to the total activity of that surface. The activity of each surface is determined by multiplying the sum of the normalized group fluxes, calculated above, by the average surface dose rate and by the area of the surface. This calculation is performed for the roof, sides, back and front of the HSM. The sum of the surface activities is then input as the tally multiplier for each of the MCNP tallies to convert the tally results to fluxes (particles per second per square centimeter).
- Gamma-ray spectrum calculations for the HSM-H are shown in Table P.10-4. The group fluxes on the HSM-H roof are taken from the ANISN run. The dose rate contribution from each group is the product of the flux and the flux-to-dose factor. The "Input Current" column in Table P.10-4 is simply the roof flux in each group, divided by half the total dose rate and represents the roof current normalized to one mrem per hour. Similar calculations for neutrons are shown in Table P.10-5. These spectra are also used in the HSM-Model 102 calculations.

P.10.2.1 Activity Calculations

2x10 Back-to-Back Array

A box that envelops the HSM array and shield walls, as modeled in MCNP, approximates the 2x10 back-to-back array of HSMs. The dimensions of the box also include the width of the HSM end shield walls. As discussed above, the total activity of each face of the box is calculated by multiplying the current per mrem/hr by the average dose rate of the face and by the area of the face.

Two 1x10 Front-to-Front Arrays

A box that envelops the HSM array and shield walls, as modeled in MCNP, approximates the two 1x10 arrays of HSMs. The dimensions of the box also include the width of the HSM end and back shield walls. As discussed above, the total activity of each face of the box is calculated by multiplying the current per mrem/hr by the average dose rate of the face and by the area of the face.

The HSM-H and HSM-Model 102 surface activities are summarized in Table P.10-6 and Table P.10-7, respectively.

P.10.2.2 Dose Rates

Dose rates are calculated for distances of 6.1 meters (20 feet) to 600 meters from the edges of the two ISFSI designs. The HSM is modeled in MCNP as a box, representing the HSM arrays.

Neutron and gamma-ray sources are placed on each HSM, with shield walls, surface using the spectra and activities determined above. The angular distribution of source particles is modeled as a cosine distribution. The contribution of capture gamma-rays has been neglected, as has the contribution of bremsstrahlung electrons. The inclusion of coherent scattering greatly increases the variance in a problem with point detector tallies without improving the accuracy of the calculation. Thus, coherent scattering of photons is ignored.

The MCNP models of the ISFSI layouts are described herein. For the 2x10 back-to-back array of HSM-Hs with end shield walls, the "box" dimensions are as follows. The total width is 1260 cm. The length of the "box" is 3129 cm and the height of the "box" is 564 cm.

For the two 1x10 front-to-front arrays of HSM-Hs with end and back shield walls, the "box" dimensions for each array are as follows. The total width is 721 cm. The length of the "box" is 3129 cm and the height of the "box" is 564 cm. The two 1x10 arrays are 1026 cm (34 feet) apart.

For the 2x10 back-to-back array of HSM-Model 102s with end shield walls, the "box" dimensions are as follows. The total width is 1158 cm. The length of the "box" is 3220 cm and the height of the "box" is 457 cm.

For the two 1x10 front-to-front arrays of HSM-Model 102s with end and back shield walls, the "box" dimensions for each array are as follows. The total width is 640 cm. The length of the "box" is 3220 cm and the height of the "box" is 457 cm. The two 1x10 arrays are 1066 cm (35 feet) apart.

Point detectors are placed at the following locations as measured from each face of the "box": 6.095 m (20 feet), 10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 70 m, 80 m, 90 m, 100 m, 200 m, 300 m, 400 m, 500 m, and 600 m. Each point detector is placed 91.4 cm (3 feet) above the ground.

The MCNP results for each detector from the front of 2x10 back-to-back array are summarized in Table P.10-8 and Table P.10-11 for the HSM-H and HSM-Model 102, respectively. The MCNP results as a function of distance from the back of the two 1x10 front-to-front arrays are summarized in Table P.10-9 and Table P.10-12 for the HSM-H and HSM-Model 102, respectively. The MCNP results as a function of distance from the side of the 2x10 back-to-back array and the two 1x10 front-to-front arrays are summarized in Table P.10-10 and Table P.10-13 for the HSM-H and HSM-Model 102, respectively. The results from Table P.10-8, Table P.10-9 and Table P.10-10 are plotted in Figure P.10-1 for the HSM-H. The results from Table P.10-11, Table P.10-12, and Table P.10-13 are plotted in Figure P.10-2 for the HSM-Model 102.

The preceding analyses and the results provided in Figure P.10-1 and Figure P.10-2 are intended to provide typical dose rates for the generic ISFSI layouts described in Section P.10.2. They may not be applicable to an actual ISFSI. The written evaluations performed by a licensee for an actual ISFSI must consider the type and number of storage units, layout, characteristics of the irradiated fuel to be stored, site characteristics (e.g., berms, distance to the controlled area boundary, etc.), and reactor operations at the site in order to demonstrate compliance with 10CFR72.104.

P.10.3 References

10.1 "MCNP 4C2 - Monte Carlo N-Particle Transport Code System," CCC-701, Oak Ridge National Laboratory, RSICC Computer Code Collection, June 2001.

10.2 Title 10, "Energy," Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation."

10.3 Title 10, "Energy," Code of Federal Regulations, Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."

10.4 Title 40, "Protection of Environment," Code of Federal Regulations, Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."

10.5 "American National Standard Neutron and Gamma-Ray Fluence-to-Dose Factors," ANSI/ANS-6.1.1-1977, American Nuclear Society, La Grange Park, Illinois, March 1977.

10.6 "ANISN-ORNL - One-Dimensional Discrete Ordinates Transport Code System with Anisotropic Scattering," CCC-254, Oak Ridge National Laboratory, RSIC Computer Code Collection, April 1991.

Table P.10-1
Occupational Exposure Summary, 24PTH System

Location	Task Description	# of workers	Duration (hr)	Area Dose Rate (mrem/hr)	Total Exposure (person-mrem)
Auxiliary Building and Fuel Pool	Ready the DSC and TC for Service	2	4	0	0
	Place the DSC into the Transfer Cask	3	1	2	6
	Fill the Cask/DSC Annulus with Clean Water and Install the Inflatable Seal	2	2	2	8
	Fill the DSC Cavity with Water (borated for PWRs)	1	6	2	12
	Place the Cask Containing the DSC in the Fuel Pool	5	0.5	2	5
	Verify and Load the Candidate Fuel Assemblies into the DSC	3	5	2	30
	Place the Top Shield Plug on the DSC	2	1	2	4
	Remove the Cask/DSC from the Fuel Pool and Place them in the Decon Area	5	0.5	2	5
		1	0.033	371	12
		1	1	238	238
Cask Decontamination Area	Decontaminate the Outer Surface of the Cask	1	1.75	238	416
		1	1	2	2
	Decontaminate the Top Region of the Cask and DSC	2	0.5	466	466
		1	1	2	2
	Drain Water from the DSC	1	0.083	371	31
	Remove Cask/DSC Annulus Seal and Set-Up Welding Machine	1	0.25	557	139
		1	1.25	362	453
		1	1.5	2	3
	Weld the Inner Top Cover to the DSC Shell and Perform NDE (PT)	2	6	2	24
		1	0.5	362	181
	Drain the Cask/DSC Annulus and the DSC Cavity	1	0.25	362	91
		1	0.017	557	9
		1	0.5	2	1
	Vacuum Dry and Backfill the DSC with Helium	Same as Draining			101
	Helium Leak Test the Shield Plug Weld	2	1	2	4
	Seal Weld the Prefabricated Plugs to the Vent and Siphon Port and Perform NDE (PT)	1	0.5	362	181
	Fit-Up the DSC Top Cover Plate	1	0.5	2	1
		1	0.5	362	181
	Weld the Outer Top Cover Plate to DSC Shell and Perform NDE (PT)	1	1.25	362	453
		1	1.5	2	3
		2	14	2	56
		1	0.5	362	181
	Install The Cask Lid	2	1	36	72
Reactor/ Fuel Building Bay	Ready the Cask Support Skid and Transport Trailer for the Service	2	2	2	8
	Place the Cask onto the Skid and Trailer	2	0.5	304	304
	Secure the Cask to the Skid	1	0.25	304	76
ISFSI Site	Ready The Cask Support Skid and Transport Trailer for the Service	2	2	negligible	0
	Transport the Cask to ISFSI	6	1	negligible	0
	Position the Cask in Close Proximity with the HSM	3	1	negligible	0
	Remove the Cask Lid	2	1	46	93
	Align and Dock the Cask with the HSM	2	0.25	314	157
	Position and Align Ram with Cask	2	0.5	314	314
	Remove Ram Access Cover Plate	1	0.25	361	90
	Transfer the DSC from the Cask to the HSM	3	0.5	negligible	0
	Lift the Ram Back onto the Trailer and Un-Dock the Cask from the	2	0.083	314	52
	Install HSM Access Door	2	0.5	10	10
Totals		N/A	66	N/A	4475

Total estimated dose is 4.4 person-rem per 24PTH-L canister load.
This dose bounds the expected dose for the 24PTH-S and 24PTH-S-LC canister loads.
Total estimated completion time is approximately 66 hrs.

Table P.10-2
Total Annual Exposure, 24PTH-L Within HSM-H

Two 1x10 Front To Front Array

Distance (meters)	Back Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	2469	8	0.003
10	1816	9	0.005
20	1056	11	0.010
30	722	17	0.024
40	515	6	0.012
50	394	6	0.016
60	319	6	0.018
70	249	3	0.013
80	206	3	0.013
90	171	2	0.013
100	141	2	0.014
200	36	1	0.041
300	10	0.3	0.026
400	4	0.1	0.029
500	1	0.1	0.069
600	1	0.05	0.076

Distance (meters)	Side Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	9266	42	0.005
10	4944	18	0.004
20	1775	9	0.005
30	959	8	0.008
40	628	10	0.016
50	437	4	0.010
60	337	5	0.015
70	271	11	0.041
80	210	4	0.021
90	182	7	0.037
100	144	7	0.050
200	33	1	0.036
300	11	1	0.087
400	4	0.3	0.086
500	1	0.04	0.033
600	0.5	0.02	0.045

2x10 Back To Back Array

Distance (meters)	Front Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	25076	44	0.002
10	15202	24	0.002
20	5910	13	0.002
30	2996	13	0.004
40	1807	10	0.006
50	1193	12	0.010
60	823	4	0.005
70	613	5	0.008
80	470	4	0.009
90	366	3	0.008
100	292	3	0.011
200	54	1	0.017
300	17	1	0.046
400	5	0.4	0.076
500	2	0.2	0.077
600	1	0.03	0.041

Distance (meters)	Side Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	3057	9	0.003
10	1934	16	0.008
20	937	6	0.007
30	604	5	0.008
40	439	4	0.009
50	328	3	0.009
60	261	3	0.013
70	211	3	0.013
80	174	6	0.035
90	143	2	0.014
100	118	2	0.014
200	29	1	0.037
300	10	1	0.078
400	3	0.1	0.042
500	1	0.1	0.049
600	0.4	0.01	0.028

Table P.10-3
Total Annual Exposure, 24PTH-S-LC Within HSM-Model 102

Two 1x10 Front To Front Array

Distance (meters)	Back Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	4807	19	0.004
10	3810	30	0.008
20	2376	24	0.010
30	1655	13	0.008
40	1251	12	0.009
50	996	22	0.022
60	767	9	0.012
70	625	7	0.012
80	528	7	0.014
90	435	6	0.014
100	365	5	0.014
200	89	3	0.031
300	30	4	0.119
400	10	0.7	0.072
500	3	0.2	0.053
600	2	0.1	0.065

Distance (meters)	Side Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	46850	101	0.002
10	27836	66	0.002
20	10106	45	0.004
30	5079	32	0.006
40	2981	16	0.006
50	1984	14	0.007
60	1437	16	0.011
70	1055	11	0.011
80	797	7	0.009
90	641	7	0.011
100	534	14	0.026
200	106	5	0.046
300	31	1	0.047
400	13	1	0.096
500	5	0.9	0.166
600	2	0.2	0.116

2x10 Back To Back Array

Distance (meters)	Front Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	94706	139	0.001
10	55813	87	0.002
20	21087	45	0.002
30	10656	76	0.007
40	6173	18	0.003
50	4053	25	0.006
60	2776	14	0.005
70	2025	11	0.006
80	1552	18	0.012
90	1188	9	0.008
100	958	15	0.015
200	169	3	0.019
300	49	2	0.036
400	16	0.6	0.039
500	7	0.3	0.053
600	3	0.1	0.054

Distance (meters)	Side Total Dose (mrem)	1σ Uncertainty (mrem)	1σ Relative Uncertainty
6.1	48780	87	0.002
10	24096	57	0.002
20	7643	29	0.004
30	3864	32	0.008
40	2345	16	0.007
50	1618	14	0.009
60	1172	9	0.008
70	892	9	0.010
80	694	6	0.009
90	553	5	0.009
100	454	5	0.012
200	100	3	0.028
300	27	1	0.030
400	9	0.3	0.031
500	4	0.2	0.046
600	1	0.1	0.053

Table P.10-4
HSM-H/HSM-Model 102 Gamma-Ray Spectrum Calculation Results

Group Number	E_{upper} (MeV)	E_{mean} (MeV)	Flux-Dose Conversion Factors (mR/hr)/(γ/cm^2-sec)	Roof Flux (γ/cm^2-sec)	Dose Rate (mR/hr)	Input Current (γ/cm^2-sec per mrem/hr)
23	10	9	8.77E-03	1.04E-01	9.12E-04	6.188E-03
24	8	7.25	7.48E-03	6.01E-01	4.49E-03	3.575E-02
25	6.5	5.75	6.37E-03	9.40E-01	5.99E-03	5.592E-02
26	5	4.5	5.41E-03	1.04E+00	5.60E-03	6.160E-02
27	4	3.5	4.62E-03	6.89E+00	3.19E-02	4.102E-01
28	3	2.75	3.96E-03	1.49E+01	5.90E-02	8.864E-01
29	2.5	2.25	3.47E-03	1.99E+02	6.89E-01	1.183E+01
30	2	1.83	3.02E-03	1.69E+02	5.11E-01	1.007E+01
31	1.66	1.495	2.63E-03	3.39E+02	8.91E-01	2.017E+01
32	1.33	1.165	2.21E-03	5.68E+02	1.25E+00	3.381E+01
33	1	0.9	1.83E-03	4.82E+02	8.84E-01	2.871E+01
34	0.8	0.7	1.52E-03	6.62E+02	1.01E+00	3.943E+01
35	0.6	0.5	1.17E-03	9.47E+02	1.11E+00	5.635E+01
36	0.4	0.35	8.76E-04	6.16E+02	5.40E-01	3.669E+01
37	0.3	0.25	6.31E-04	8.51E+02	5.37E-01	5.068E+01
38	0.2	0.15	3.83E-04	1.90E+03	7.28E-01	1.130E+02
39	0.1	0.08	2.67E-04	5.23E+02	1.40E-01	3.114E+01
40	0.05	0.03	9.35E-04	2.15E+00	2.01E-03	1.282E-01
			Totals	7.28E+03	8.40E+00	433.5

Table P.10-5
HSM-H/HSM-Model 102 Neutron Spectrum Calculation Results

Group Number	E_{upper} (MeV)	E_{mean} (MeV)	Flux-Dose Conversion Factors (mR/hr)/(n/cm^2-sec)	Roof Flux (n/cm^2-sec)	Dose Rate (mR/hr)	Input Current (n/cm^2-sec per mrem/hr)
1	1.49E+01	1.36E+01	1.94E-01	8.29E-06	1.61E-06	1.911E-04
2	1.22E+01	1.11E+01	1.60E-01	5.69E-05	9.08E-06	1.310E-03
3	1.00E+01	9.09E+00	1.47E-01	2.11E-04	3.11E-05	4.872E-03
4	8.18E+00	7.27E+00	1.48E-01	1.86E-03	2.74E-04	4.279E-02
5	6.36E+00	5.66E+00	1.53E-01	4.93E-03	7.56E-04	1.135E-01
6	4.96E+00	4.51E+00	1.51E-01	4.34E-03	6.54E-04	1.001E-01
7	4.06E+00	3.54E+00	1.39E-01	4.91E-03	6.82E-04	1.131E-01
8	3.01E+00	2.74E+00	1.28E-01	1.09E-02	1.40E-03	2.507E-01
9	2.46E+00	2.41E+00	1.25E-01	1.05E-02	1.32E-03	2.427E-01
10	2.35E+00	2.09E+00	1.26E-01	1.69E-02	2.13E-03	3.894E-01
11	1.83E+00	1.47E+00	1.29E-01	2.63E-02	3.39E-03	6.060E-01
12	1.11E+00	8.30E-01	1.17E-01	2.73E-02	3.19E-03	6.298E-01
13	5.50E-01	3.31E-01	6.52E-02	4.00E-02	2.61E-03	9.227E-01
14	1.11E-01	5.72E-02	9.19E-03	6.29E-02	5.78E-04	1.449E+00
15	3.35E-03	1.97E-03	3.71E-03	2.89E-02	1.07E-04	6.654E-01
16	5.83E-04	3.42E-04	4.01E-03	3.64E-02	1.46E-04	8.381E-01
17	1.01E-04	6.50E-05	4.29E-03	3.04E-02	1.31E-04	7.017E-01
18	2.90E-05	1.96E-05	4.48E-03	2.20E-02	9.84E-05	5.065E-01
19	1.01E-05	6.58E-06	4.57E-03	2.96E-02	1.35E-04	6.818E-01
20	3.06E-06	2.09E-06	4.54E-03	2.63E-02	1.19E-04	6.062E-01
21	1.12E-06	7.67E-07	4.37E-03	2.77E-02	1.21E-04	6.381E-01
22	4.14E-07	2.12E-07	3.71E-03	1.03E+00	3.81E-03	2.362E+01
			Totals	1.44E+00	2.17E-02	33.1

Table P.10-6
Summary of ISFSI Surface Activities, 24PTH-L DSC Within HSM-H

2x10 Back-To-Back Array

Source	Area (cm^2)	Gamma-Ray Activity (γ/sec)	Neutron Activity (neutrons/sec)
Roof	3,942,392.1	6.044E+07	3.397E+10
Front 1	1,764,538.4	6.418E+06	7.878E+09
Front 2	1,764,538.4	6.418E+06	7.878E+09
Side 1	710,398.6	1.075E+06	3.107E+08
Side 2	710,398.6	1.075E+06	3.107E+08
Total	8,892,266.1	7.542E+07	5.035E+10

Two 1x10 Front-To-Front Arrays

Source	Area (cm^2)	Gamma-Ray Activity (γ/sec)	Neutron Activity (neutrons/sec)
Roof	2,257,337.4	3.461E+07	1.945E+10
Front	1,764,538.4	6.418E+06	7.878E+09
Back	1,764,538.4	4.817E+05	4.305E+08
Side 1	406,760.5	6.156E+05	1.779E+08
Side 2	406,760.5	6.156E+05	1.779E+08
Total	6,599,935.2	4.274E+07	2.812E+10

Table P.10-7
Summary of ISFSI Surface Activities, 24PTH-S-LC DSC Within HSM-Model 102

2x10 Back-To-Back Array

Source	Area (cm^2)	Gamma-Ray Activity (γ/sec)	Neutron Activity (neutrons/sec)
Roof	3,730,366.7	1.977E+07	7.648E+10
Front 1	1,472,513.2	4.341E+07	2.911E+10
Front 2	1,472,513.2	4.341E+07	2.911E+10
Side 1	529,547.3	1.579E+06	7.277E+09
Side 2	529,547.3	1.579E+06	7.277E+09
Total	7,734,487.8	1.098E+08	1.492E+11

Two 1x10 Front-To-Front Arrays

Source	Area (cm^2)	Gamma-Ray Activity (γ/sec)	Neutron Activity (neutrons/sec)
Roof	2,061,518.5	1.093E+07	4.227E+10
Front	1,472,513.2	4.341E+07	2.911E+10
Back	1,472,513.2	4.390E+05	4.979E+08
Side 1	292,644.6	8.725E+05	4.021E+09
Side 2	292,644.6	8.725E+05	4.021E+09
Total	5,591,834.0	5.652E+07	7.991E+10

Table P.10-8
MCNP Front Detector Dose Rates for 2x10 Array, 24PTH-L DSC Within HSM-H

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	2.81E+00	1.80E-03	5.21E-02	5.50E-03	2.86E+00	0.0018
10	1.70E+00	1.60E-03	3.41E-02	7.60E-03	1.74E+00	0.0016
20	6.59E-01	2.30E-03	1.56E-02	1.20E-02	6.75E-01	0.0023
30	3.33E-01	4.50E-03	9.06E-03	1.71E-02	3.42E-01	0.0044
40	2.00E-01	5.70E-03	5.81E-03	1.55E-02	2.06E-01	0.0056
50	1.32E-01	1.00E-02	4.30E-03	3.65E-02	1.36E-01	0.0098
60	9.10E-02	4.90E-03	2.94E-03	2.05E-02	9.40E-02	0.0048
70	6.78E-02	7.80E-03	2.15E-03	2.02E-02	7.00E-02	0.0076
80	5.20E-02	9.20E-03	1.68E-03	3.24E-02	5.37E-02	0.0090
90	4.05E-02	8.70E-03	1.31E-03	2.89E-02	4.18E-02	0.0085
100	3.23E-02	1.11E-02	1.07E-03	2.84E-02	3.34E-02	0.0108
200	5.92E-03	1.71E-02	2.26E-04	5.32E-02	6.15E-03	0.0166
300	1.83E-03	4.81E-02	7.00E-05	4.45E-02	1.90E-03	0.0464
400	5.98E-04	7.95E-02	2.68E-05	5.66E-02	6.25E-04	0.0761
500	2.43E-04	8.04E-02	1.24E-05	5.68E-02	2.55E-04	0.0765
600	8.91E-05	4.31E-02	6.41E-06	1.18E-01	9.55E-05	0.0410

Table P.10-9
MCNP Back Detector Dose Rates for the Two 1x10 Arrays, 24PTH-L DSC Within HSM-H

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	2.64E-01	0.0032	1.74E-02	0.0104	2.82E-01	0.0031
10	1.93E-01	0.0052	1.39E-02	0.0121	2.07E-01	0.0049
20	1.12E-01	0.0107	8.68E-03	0.0152	1.21E-01	0.0100
30	7.66E-02	0.0260	5.86E-03	0.0213	8.25E-02	0.0242
40	5.48E-02	0.0124	4.04E-03	0.0179	5.88E-02	0.0116
50	4.18E-02	0.0176	3.16E-03	0.0237	4.50E-02	0.0164
60	3.41E-02	0.0188	2.34E-03	0.0255	3.64E-02	0.0177
70	2.67E-02	0.0137	1.76E-03	0.0244	2.84E-02	0.0129
80	2.21E-02	0.0138	1.46E-03	0.0332	2.35E-02	0.0131
90	1.83E-02	0.0137	1.17E-03	0.0280	1.95E-02	0.0129
100	1.51E-02	0.0145	9.07E-04	0.0275	1.61E-02	0.0138
200	3.81E-03	0.0421	2.53E-04	0.1507	4.07E-03	0.0406
300	1.06E-03	0.0272	8.16E-05	0.0697	1.14E-03	0.0257
400	3.76E-04	0.0305	3.10E-05	0.0734	4.07E-04	0.0288
500	1.52E-04	0.0751	1.32E-05	0.0865	1.66E-04	0.0694
600	6.50E-05	0.0814	7.29E-06	0.2079	7.23E-05	0.0761

Table P.10-10
MCNP Side Detector Dose Rates, 24PTH-L DSC Within HSM-H

2x10 Back-to-Back Array

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	3.24E-01	3.10E-03	2.46E-02	9.80E-03	3.49E-01	0.0030
10	2.04E-01	8.80E-03	1.65E-02	1.17E-02	2.21E-01	0.0082
20	9.85E-02	7.10E-03	8.46E-03	2.26E-02	1.07E-01	0.0068
30	6.37E-02	8.30E-03	5.33E-03	2.60E-02	6.90E-02	0.0079
40	4.64E-02	9.90E-03	3.72E-03	2.60E-02	5.01E-02	0.0094
50	3.49E-02	9.50E-03	2.61E-03	2.43E-02	3.75E-02	0.0090
60	2.77E-02	1.23E-02	2.18E-03	8.36E-02	2.98E-02	0.0129
70	2.25E-02	1.39E-02	1.58E-03	3.02E-02	2.40E-02	0.0131
80	1.86E-02	3.69E-02	1.23E-03	2.71E-02	1.99E-02	0.0347
90	1.54E-02	1.44E-02	9.96E-04	3.06E-02	1.64E-02	0.0137
100	1.27E-02	1.45E-02	8.04E-04	3.96E-02	1.35E-02	0.0138
200	3.19E-03	3.88E-02	1.79E-04	5.12E-02	3.37E-03	0.0368
300	1.03E-03	8.16E-02	5.34E-05	2.44E-02	1.09E-03	0.0776
400	3.02E-04	4.50E-02	2.28E-05	3.64E-02	3.25E-04	0.0419
500	1.19E-04	5.25E-02	1.05E-05	6.80E-02	1.30E-04	0.0486
600	4.18E-05	2.99E-02	4.83E-06	7.33E-02	4.66E-05	0.0279

Two 1x10 Front-To-Front Arrays

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	1.03E+00	4.70E-03	2.99E-02	1.43E-02	1.06E+00	0.0046
10	5.45E-01	3.80E-03	1.97E-02	1.30E-02	5.64E-01	0.0037
20	1.93E-01	5.40E-03	9.86E-03	2.29E-02	2.03E-01	0.0053
30	1.04E-01	8.20E-03	5.91E-03	2.06E-02	1.09E-01	0.0078
40	6.73E-02	1.65E-02	4.37E-03	4.18E-02	7.17E-02	0.0157
50	4.68E-02	1.04E-02	3.09E-03	3.50E-02	4.99E-02	0.0100
60	3.59E-02	1.52E-02	2.56E-03	7.40E-02	3.85E-02	0.0150
70	2.92E-02	4.36E-02	1.79E-03	3.69E-02	3.10E-02	0.0411
80	2.26E-02	2.19E-02	1.36E-03	3.96E-02	2.40E-02	0.0208
90	1.96E-02	3.95E-02	1.15E-03	4.37E-02	2.07E-02	0.0374
100	1.56E-02	5.27E-02	8.60E-04	2.54E-02	1.65E-02	0.0500
200	3.52E-03	3.74E-02	2.07E-04	6.44E-02	3.73E-03	0.0355
300	1.15E-03	9.22E-02	7.16E-05	6.72E-02	1.23E-03	0.0869
400	3.99E-04	9.23E-02	2.73E-05	5.16E-02	4.26E-04	0.0864
500	1.24E-04	3.57E-02	9.99E-06	3.25E-02	1.34E-04	0.0331
600	4.95E-05	4.97E-02	5.63E-06	7.12E-02	5.51E-05	0.0452

Table P.10-11
MCNP Front Detector Dose Rates for 2x10 Array, 24PTH-S-LC DSC Within HSM-Model 102

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	1.05E+01	1.50E-03	2.62E-01	3.90E-03	1.08E+01	0.0015
10	6.22E+00	1.60E-03	1.52E-01	5.20E-03	6.37E+00	0.0016
20	2.35E+00	2.20E-03	5.61E-02	6.90E-03	2.41E+00	0.0022
30	1.19E+00	7.30E-03	2.78E-02	9.60E-03	1.22E+00	0.0071
40	6.88E-01	3.00E-03	1.62E-02	1.12E-02	7.05E-01	0.0029
50	4.52E-01	6.40E-03	1.07E-02	1.87E-02	4.63E-01	0.0063
60	3.10E-01	5.00E-03	7.20E-03	1.89E-02	3.17E-01	0.0049
70	2.26E-01	5.70E-03	5.12E-03	2.12E-02	2.31E-01	0.0056
80	1.73E-01	1.19E-02	3.80E-03	1.94E-02	1.77E-01	0.0117
90	1.33E-01	7.70E-03	2.91E-03	2.07E-02	1.36E-01	0.0075
100	1.07E-01	1.55E-02	2.27E-03	2.71E-02	1.09E-01	0.0152
200	1.89E-02	1.89E-02	4.16E-04	5.71E-02	1.93E-02	0.0185
300	5.50E-03	3.72E-02	1.23E-04	8.05E-02	5.62E-03	0.0364
400	1.79E-03	3.97E-02	4.58E-05	4.99E-02	1.84E-03	0.0387
500	7.25E-04	5.45E-02	1.84E-05	4.32E-02	7.43E-04	0.0532
600	2.99E-04	5.50E-02	1.10E-05	2.49E-01	3.10E-04	0.0538

Table P.10-12
MCNP Back Detector Dose Rates for the Two 1x10 Arrays, 24PTH-S-LC DSC Within HSM-Model 102

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	5.27E-01	0.0041	2.17E-02	0.0087	5.49E-01	0.0039
10	4.18E-01	0.0083	1.73E-02	0.0094	4.35E-01	0.0080
20	2.61E-01	0.0105	1.05E-02	0.0127	2.71E-01	0.0101
30	1.82E-01	0.0078	6.85E-03	0.0143	1.89E-01	0.0076
40	1.38E-01	0.0096	4.80E-03	0.0149	1.43E-01	0.0093
50	1.10E-01	0.0229	3.63E-03	0.0226	1.14E-01	0.0222
60	8.49E-02	0.0124	2.69E-03	0.0192	8.75E-02	0.0120
70	6.92E-02	0.0121	2.13E-03	0.0375	7.14E-02	0.0118
80	5.87E-02	0.0144	1.61E-03	0.0206	6.03E-02	0.0140
90	4.84E-02	0.0149	1.35E-03	0.0246	4.97E-02	0.0145
100	4.06E-02	0.0144	1.09E-03	0.0252	4.17E-02	0.0141
200	9.94E-03	0.0318	2.32E-04	0.0336	1.02E-02	0.0310
300	3.36E-03	0.1218	7.88E-05	0.0420	3.44E-03	0.1191
400	1.15E-03	0.0738	3.44E-05	0.0756	1.18E-03	0.0717
500	3.83E-04	0.0552	1.31E-05	0.0557	3.96E-04	0.0534
600	1.70E-04	0.0681	7.27E-06	0.1160	1.77E-04	0.0655

Table P.10-13
MCNP Side Detector Dose Rates, 24PTH-S-LC DSC Within HSM-Model 102

2x10 Back-to-Back Array

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	5.53E+00	1.80E-03	3.67E-02	1.06E-02	5.57E+00	0.0018
10	2.73E+00	2.40E-03	2.33E-02	1.50E-02	2.75E+00	0.0024
20	8.61E-01	3.80E-03	1.13E-02	2.19E-02	8.73E-01	0.0038
30	4.34E-01	8.50E-03	7.18E-03	2.60E-02	4.41E-01	0.0084
40	2.63E-01	6.80E-03	4.63E-03	3.17E-02	2.68E-01	0.0067
50	1.81E-01	8.90E-03	3.37E-03	5.25E-02	1.85E-01	0.0088
60	1.31E-01	8.00E-03	2.54E-03	3.51E-02	1.34E-01	0.0079
70	9.99E-02	9.70E-03	1.95E-03	3.62E-02	1.02E-01	0.0095
80	7.76E-02	8.70E-03	1.62E-03	6.12E-02	7.92E-02	0.0086
90	6.20E-02	8.90E-03	1.14E-03	2.58E-02	6.32E-02	0.0088
100	5.10E-02	1.18E-02	9.28E-04	3.29E-02	5.19E-02	0.0116
200	1.11E-02	2.61E-02	3.46E-04	3.78E-01	1.15E-02	0.0278
300	3.02E-03	3.02E-02	7.37E-05	9.67E-02	3.09E-03	0.0296
400	1.05E-03	3.19E-02	2.73E-05	7.60E-02	1.08E-03	0.0312
500	4.04E-04	4.78E-02	1.18E-05	7.52E-02	4.16E-04	0.0465
600	1.62E-04	5.33E-02	8.29E-06	2.90E-01	1.70E-04	0.0526

Two 1x10 Front-To-Front Arrays

Distance (meters)	Gamma Dose Rate (mrem/hr)	Gamma MCNP 1σ Uncertainty	Neutron Dose Rate (mrem/hr)	Neutron MCNP 1σ Uncertainty	Total Dose Rate (mrem/hr)	Combined MCNP 1σ Uncertainty
6.1	5.25E+00	2.20E-03	9.70E-02	5.60E-03	5.35E+00	0.0022
10	3.13E+00	2.40E-03	5.12E-02	6.50E-03	3.18E+00	0.0024
20	1.14E+00	4.50E-03	1.86E-02	1.34E-02	1.15E+00	0.0044
30	5.70E-01	6.40E-03	9.71E-03	1.66E-02	5.80E-01	0.0063
40	3.34E-01	5.60E-03	5.89E-03	1.83E-02	3.40E-01	0.0055
50	2.23E-01	7.00E-03	3.89E-03	2.04E-02	2.27E-01	0.0069
60	1.61E-01	1.12E-02	3.05E-03	6.58E-02	1.64E-01	0.0111
70	1.18E-01	1.08E-02	2.11E-03	2.57E-02	1.20E-01	0.0106
80	8.93E-02	9.10E-03	1.67E-03	3.53E-02	9.10E-02	0.0090
90	7.19E-02	1.09E-02	1.31E-03	2.73E-02	7.32E-02	0.0107
100	6.00E-02	2.60E-02	1.01E-03	2.61E-02	6.10E-02	0.0256
200	1.19E-02	4.71E-02	2.08E-04	4.74E-02	1.21E-02	0.0463
300	3.42E-03	4.78E-02	7.40E-05	6.56E-02	3.49E-03	0.0468
400	1.48E-03	9.85E-02	4.21E-05	2.45E-01	1.53E-03	0.0960
500	5.93E-04	1.69E-01	1.08E-05	5.34E-02	6.03E-04	0.1658
600	1.86E-04	1.19E-01	5.63E-06	8.37E-02	1.91E-04	0.1156

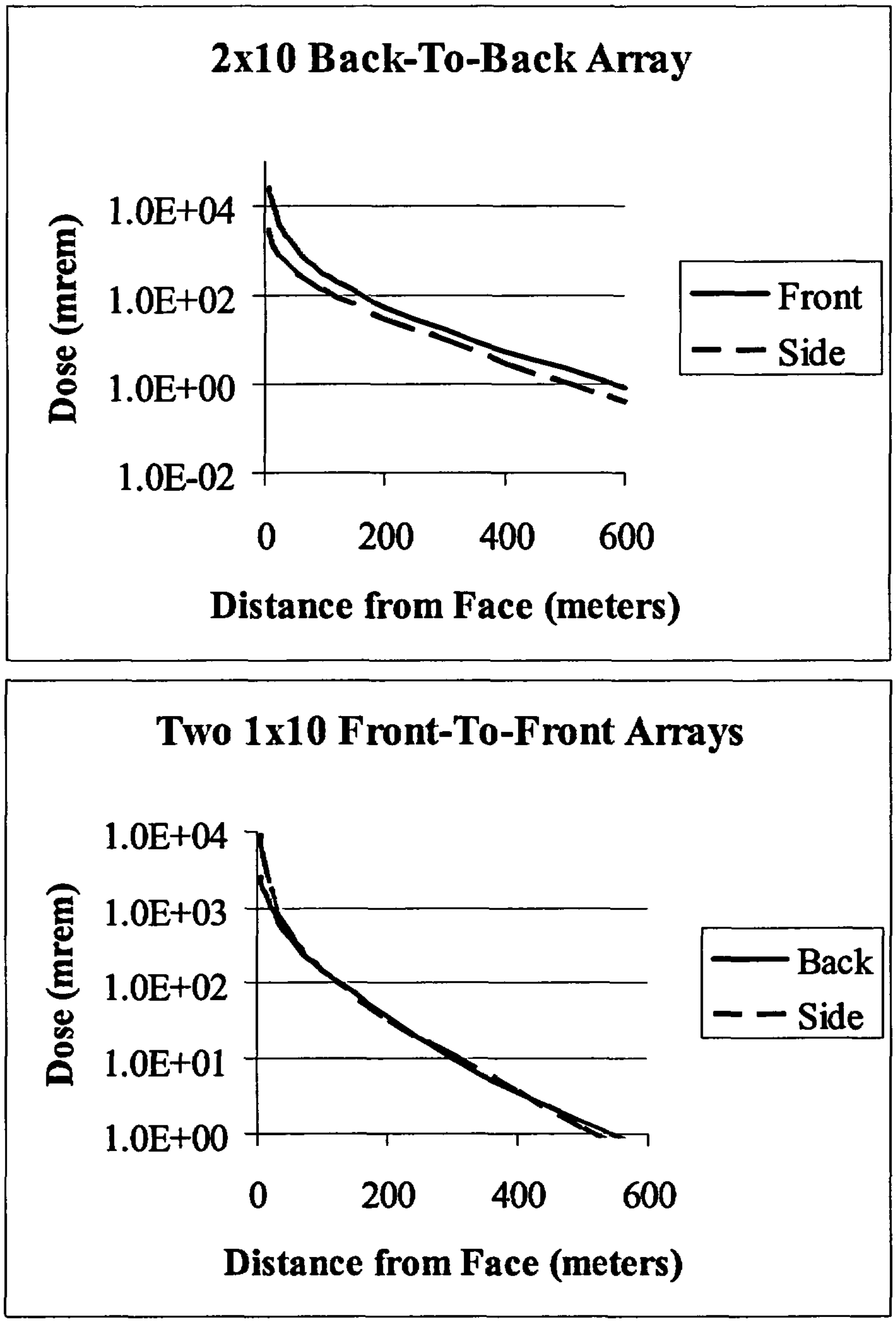
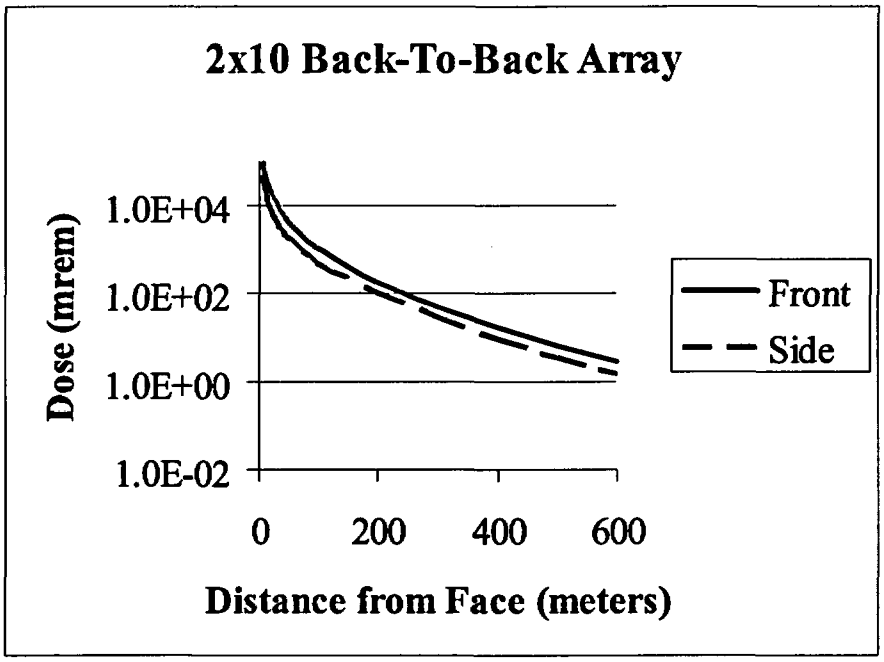


Figure P.10-1
Annual Exposure from the ISFSI as a Function of Distance, 24PTH-L DSC Within HSM-H



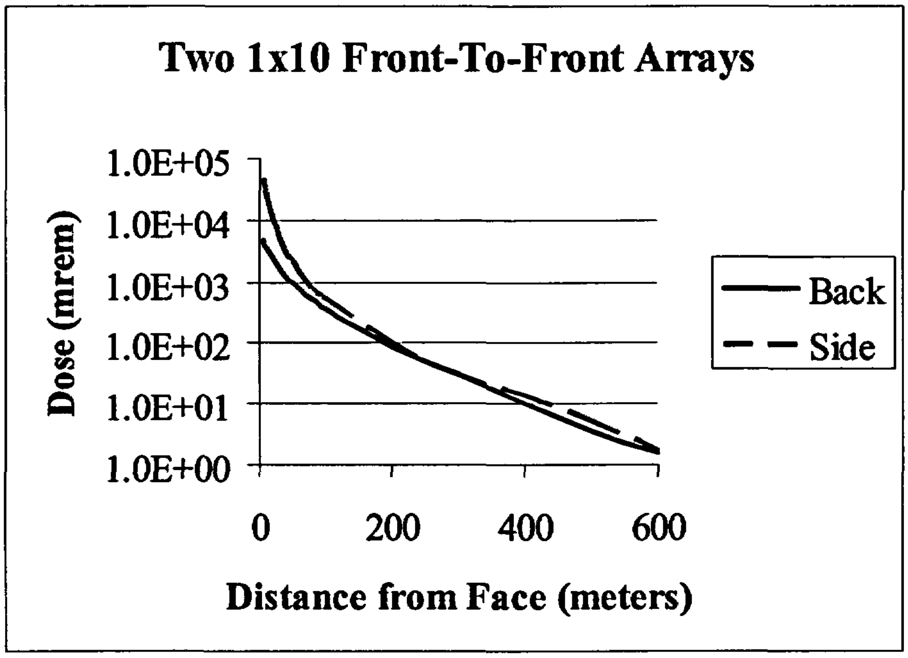


Figure P.10-2
Annual Exposure from the ISFSI as a Function of Distance, 24PTH-S-LC DSC Within HSM-Model 102

P.11 Accident Analyses

This section describes the postulated off-normal and accident events that could occur during transfer and storage of the NUHOMS®-24PTH DSC. Sections which do not affect the evaluation presented in Chapter 8 are identified as "No change." Detailed analysis of the events are provided in other sections and referenced herein.

P.11.1 Off-Normal Operations

Off-normal operations are design events of the second type (Design Event II) as defined in ANSI/ANS 57.9 [11.1]. Off-normal conditions consist of that set of events that, although not occurring regularly, can be expected to occur with moderate frequency or on the order of once during a calendar year of ISFSI operation.

The off-normal conditions considered for the NUHOMS®-24PTH DSC are off-normal transfer loads, extreme temperatures and a postulated release of radionuclides.

P.11.1.1 Off-Normal Transfer Loads

No change. The limiting off-normal event is the jammed DSC during loading or unloading from the HSM. This event is described in Section 8.1.2. Other off-normal events are bounded by the jammed DSC event.

P.11.1.1.1 Postulated Cause of Event

See Section 8.1.2. The probability of a jammed DSC does not increase with the NUHOMS®-24PTH DSC, since the outside diameter of the DSC is the same as the NUHOMS®-24P and 52B DSCs and the length is bounded by the 24P and 52B.

P.11.1.1.2 Detection of Event

No change. See Section 8.1.2.

P.11.1.1.3 Analysis of Effects and Consequences

A detailed evaluation of this event is presented in Section P.3.6.2 for the 24PTH DSC and is summarized below. The NUHOMS®-24PTH DSC has a 0.5 inch shell wall thickness, while the NUHOMS®-24P and -52B have 0.62 inch thick shells. Therefore, the stresses in the canister shell are increased. The DSC shell stress due to the 2,690 in-kip moment due to axial sticking of the DSC is S_{mx} = 1.55 ksi. This magnitude of stress is negligible when compared to the allowable membrane stress of 17.5 ksi.

The DSC shell stress due to the 1,400-pound axial load during the binding of the DSC is 15.7 ksi. As stated in Section P.3.6.2.1, this stress is considered secondary and is enveloped by other handling stresses.

The evaluation of the basket due to normal and off-normal handling and transfer loads is presented in Section P.3.6.1.3.

P.11.1.1.4 Corrective Actions

No change. See Section 8.1.2.

P.11.1.2 Extreme Temperatures

No change. The off-normal maximum ambient temperature of 125°F is used in Section 8.1.2.2. For the NUHOMS®-24PTH system, a maximum ambient temperature of 117°F is used. Therefore, the analyses in Section 8.1.2.2 bound TCs and HSM Model 102 used in the NUHOMS®-24PTH system.

P.11.1.2.1 Postulated Cause of Event

No change. See Section 8.1.2.2.

P.11.1.2.2 Detection of Event

No change. See Section 8.1.2.2.

P.11.1.2.3 Analysis of Effects and Consequences

The thermal evaluation of the NUHOMS®-24PTH system for off-normal conditions is presented in Section P.4. The 100°F normal condition with insolation bounds the 117°F case without insolation for the DSC in the TC. Therefore the normal condition maximum temperatures are bounding. The 117°F case with the DSC in the HSM-H is not bounded by the normal conditions and therefore evaluated in Section P.4.

The NUHOMS® standardized TC and HSM Model 102 were evaluated for a maximum heat load of 24 kW and maximum off-normal ambient temperature of 125°F. The maximum heat load of the 24PTH-S-LC DSC in standardized TC or HSM Model 102 is limited to 24 kW. Therefore the evaluation presented in Section 8.1.2.2 is bounding for these components.

The structural evaluation of the 24PTH DSC for off-normal temperature conditions is presented in Section P.3.6.2.2. The structural evaluation of the basket due to off-normal thermal conditions is presented in Section P.3.6.1.3. The structural evaluation of HSM-H and OS197FC Transfer Cask for off-normal conditions with 24PTH DSC are presented in Section P.3.6.

P.11.1.2.4 Corrective Actions

Restrictions for onsite handling of the TC with a loaded DSC under extreme temperature conditions are presented in Technical Specifications 1.2.13 and 1.2.14. There is no change to this requirement as a result of addition of the NUHOMS®-24PTH DSC.

P.11.1.3 Off-Normal Releases of Radionuclides

The NUHOMS®-24PTH DSC is designed and tested to the leak tight criteria of ANSI N14.5 [11.2]. Therefore the estimated quantity of radionuclides expected to be released annually to the environment due to normal or off-normal events is zero.

P.11.1.3.1 Postulated Cause of Event

In accordance with the Standard Review Plan, NUREG-1536 [11.3] and ISG-5 Rev. 1 [11.4] for off-normal conditions, it is conservatively assumed that 10% of the fuel rods fail.

P.11.1.3.2 Detection of Event

Failed fuel rods would go undetected, but are not a safety concern since the canister is designed and tested to the leak tight criteria of ANSI N14.5.

P.11.1.3.3 Analysis of Effects and Consequences

The bounding off-normal pressure for the NUHOMS®-24PTH DSC is calculated with the DSC in either the HSM-H or HSM Model 102 or in the TCs in Section P.4.6 as 13.7 psig. The NUHOMS®-24PTH DSC stresses were evaluated in Section P.3.6 assuming conservatively a 20 psig off-normal internal DSC pressure. The results show that the stresses due to these pressures are below the allowable stresses for off-normal conditions, as shown in P.3.6.

The NUHOMS®-24PTH DSC is designed and tested to the leak tight criteria of ANSI N14.5. Therefore the estimated quantity of radionuclides expected to be released annually to the environment due to normal or off-normal events is zero.

P.11.1.3.4 Corrective Actions

None required.

P.11.1.4 Radiological Impact from Off-Normal Operations

The NUHOMS®-24PTH DSC is designed and tested to the leak tight criteria of ANSI N14.5. The off-normal conditions have been evaluated in accordance with the ASME B&PV code [11.5]. The resulting stresses are below the allowable stresses. There will be no breach of the confinement boundary due to the off-normal conditions. Therefore, the estimated quantity of radionuclides expected to be released annually to the environment due to off-normal events is zero.

P.11.2 Postulated Accidents

P.11.2.1 Reduced HSM Air Inlet and Outlet Shielding

P.11.2.1.1 Cause of Accident

No change to the cause for HSM Model 102 described in Section 8.2.1.1.

For HSM-H, this accident is not credible since the array of HSM-Hs is designed with the elimination of 6-inch gaps between the adjacent HSM-Hs. The HSM-Hs are placed next to each other and even in the unlikely event of large settlement of the ISFSI foundation, shifting of adjacent HSM-Hs occurring and causing the HSM-Hs to separate is not credible.

P.11.2.1.2 Accident Analysis

There are no structural consequences that affect the safe operation of the NUHOMS®-24PTH system resulting from the separation of the HSM Model 102. The thermal effects of this accident result from the blockage of HSM Model 102 air inlet and outlet openings. However, the effect on the NUHOMS®-24PTH-S-LC DSC, HSM Model 102 and fuel temperatures is bounded by the complete blockage of air inlet and outlet openings described in Section P.11.2.7. The radiological consequences of this accident are described in the paragraph below.

P.11.2.1.3 Accident Dose Calculations

The off-site radiological effects that result from a partial loss of adjacent HSM Model 102 shielding is an increase in the air scattered (skyshine) and direct doses from the assumed 12 inch gap between the separated HSMs. The air scattered (skyshine) and direct doses are reduced from the gap between the HSM Model 102s that are in contact with each other. On-site radiological effects result from an increase in the direct radiation during recovery operations and increased skyshine radiation. Table 8.2-2 shows the comparisons of the increased dose rate as a function of distance due to the reduced shielding effects of the adjacent HSMs for the 24P DSC with 5-year cooled design basis fuel. Table P.11-1 provides a similar table for 24PTH-S-LC DSC of the NUHOMS®-24PTH System. For the NUHOMS®-24PTH System, the dose received by a person located 100 meters away from the NUHOMS® installation for eight hours a day for five days (estimated recovery time) would be 8 mrem. The increased dose to an off-site person for 24 hours a day for five days located 600 meters away would be about 0.07 mrem. Thus, the 10CFR72 requirements for this postulated event are met.

P.11.2.1.4 Corrective Actions

No change. See Section 8.2.1.4.

P.11.2.2 Earthquake

P.11.2.2.1 Cause of Accident

No change. See Section 8.2.3.1.

P.11.2.2.2 Accident Analysis

Section 8.2.3.2 describes the analyses performed to demonstrate that the NUHOMS® System withstands the design basis seismic event. Section P.3.7.2 presents the changes to this analysis resulting from the addition of NUHOMS®-24PTH DSC. The results of this analysis show that seismic stresses are well below allowables and, thus, the leak-tight integrity of the canister is not compromised. The basket stresses are also low and do not result in deformations that would prevent fuel from being unloaded from the canister.

P.11.2.2.3 Accident Dose Calculations

The NUHOMS® 24PTH system is designed and analyzed to withstand the design basis earthquake accident. Hence, no radioactivity is released and there is no associated dose increase due to this event.

P.11.2.2.4 Corrective Actions

After a seismic event, the NUHOMS® HSMs (HSM-H and HSM Model 102) and TC would be inspected for damage. Any debris would be removed. An evaluation would be performed to determine if the system components were still within the licensed design basis.

P.11.2.3 Extreme Winds and Tornado Missiles

P.11.2.3.1 Cause of Accident

No change to the determination of the tornado wind and tornado missile loads acting on the HSM Model 102 as detailed in Section P.2.

These same loads are also evaluated for HSM-H.

P.11.2.3.2 Accident Analysis

An evaluation of the HSM Model 102 and TC with respect to tornado winds is presented in Section 8.2.2. Changes to this analysis, as a result of the addition of the NUHOMS®-24PTH DSC, are presented in Section P.3.7.1. Evaluation of the HSM Model 102 and TC with respect to tornado missile is also presented in Section 8.2.2. The tornado missile impact evaluation of the HSM-H is presented in the following Sections.

The evaluation of the HSM-H for the effect of DBT wind pressure loads is addressed in Section P.3.7.1.1.

P.11.2.3.2.1 HSM-H Missile Impact Analysis

P.11.2.3.2.1.1 Local Damage Evaluation

Local missile impact effects consist of (a) missile penetration into the target, (b) missile perforation through the target and (c) spalling and scabbing of the target. This also includes punching shear in the region of the target. As per the ACI code [11.6] if the concrete thickness is at least 20% greater than that required to prevent perforation, the punching shear requirement of the code need not be checked. Several empirical formulas are available which are used to predict local damage effects.

The following enveloping missiles (based on the mass of the missile) are considered for local damage:

- Utility pole
- Armor piercing artillery shell
- 12" diameter steel pipe missile

Large deformable missiles such as automobiles do not penetrate the structure. Therefore, the local effects from an automobile are evaluated using punching shear criteria of the ACI Code [11.6].

The following empirical formulas are used to determine the local damage effects:

Reinforced Concrete Target

(a) Modified National Defense Research Committee (NDRC) formulas for penetration depth [11.7]:

$$x = [4KNWd^{-0.8}(v_o/1000d)^{1.8}]^{0.5} \quad \text{for } x/d \leq 2.0$$

$$x = \{[KNW(v_o/1000d)^{1.8}] + d\} \quad \text{for } x/d > 2.0$$

where, x = Missile penetration depth, inches

K = concrete penetrability factor = $180/\sqrt{fc'}$

N = projectile shape factor

= 0.72 flat nosed

= 0.84 blunt nosed

= 1.0 bullet nosed (spherical end)

= 1.14 very sharp nose

W = weight of missile, lbs

v_o = striking velocity of missile, fps

d = effective projectile diameter, inches.

for a solid cylinder, d = diameter of projectile and

for a non-solid cylinder, $d = (4A_c/\pi)^{1/2}$

A_c = projectile impact area, in^2

(b) Modified NDRC formula for perforation thickness [11.7]:

$(e/d) = 3.19(x/d)-0.718(x/d)^2$ for $x/d \leq 1.35$

$(e/d) = 1.32 + 1.24\,(x/d)$ for $1.35 \leq x/d \leq 13.5$

where e = perforation thickness, in.

In order to provide an adequate margin of safety the design thickness $t_d = 1.2\,e$ [11.6]

(c) Modified NDRC formula for scabbing thickness [11.7]:

$(s/d) = 7.91(x/d)-5.06(x/d)^2$ for $x/d \leq 0.65$

$(s/d) = 2.12 + 1.36\,(x/d)$ for $0.65 \leq x/d \leq 11.75$

where s = scabbing thickness, in.

In order to provide an adequate margin of safety the design thickness $t_d = 1.2\,s$ [11.6]

The concrete targets of the HSM-H which may be subjected to local damage due to missile impact are:

- 44" thick roof
- 42" thick (minimum) front wall
- 36" thick end shield wall with 12" thick side wall (No gap between shield wall and side wall)
- 36" thick rear shield wall with 12" thick (minimum) rear wall
- 36" thick end shield wall at the side of the roof (with vent opening) and at the bottom with 6" gap between the shield wall and the side wall.
- 30.375" thick composite shielding door (7.875" steel in front, 22.5" concrete at rear)

Steel Targets

The steel barriers subjected to missile impact are designed to preclude perforation. The steel plate thickness for threshold of perforation is [11.8]:

$$T_p = (E_k)^{2/3} / 672D$$

Where:

$E_k = M_m v_o^2/2$

T_p = steel plate thickness for threshold of perforation (in)

E_k = missile kinetic energy (ft-lbs)

M_m = mass of the missile (lb-sec^2 /ft)

v_o = missile striking velocity (fps)

D = missile diameter (in), for pipe missiles, D is the outside diameter of the pipe

The design thickness to prevent perforation is $t_p = 1.25\ T_p$ [11.8].

The steel target of the HSM-H which may be subjected to local damage due to missile impact is the composite steel door (7.875" steel in front).

(A) Local Missile Impact Effects of Utility Pole Missile

The wood missiles (utility pole missile) do not have sufficient strength to penetrate a concrete target and the scabbing thickness required for wood missiles is substantially less than that required for a steel missile with the same mass and velocity. Practical wooden pole missiles are not capable of causing local damage to walls 12 inches thick, or greater for the missile velocities considered. Because none of the concrete targets are less than 12 inch thick, the postulated wood missiles will not cause any local damage to the HSM-H concrete structure. Steel targets are also resistant to penetration which implies that only nondeformable missiles can perforate a steel target.

(B) Local Missile Impact Effects of Armor Piercing Artillery Shell

Concrete Wall Evaluation:

d = diameter of missile = 8"

W = 280 lbs (conservatively assumed)

V_o = 185 fps

f_c' = 5000 psi

K = $180/\sqrt{5000} = 2.55$

N = 0.84 blunt nosed

Penetration thickness = x = 4.67 in for $x/d = 0.584 \leq 2$

Perforation thickness e = 12.95"

Required Perforation thickness = 1.2*12.95 = 15.5"

Scabbing thickness s = 23.1" inches

Required scabbing thickness = 1.2*23.2 = 27.7"

Shielded Door Evaluation:

Required perforation thickness of steel is 0.66" which is less than 7.875". Therefore, the missile will not perforate the steel in the shielded door.

(C) Local Missile Impact Effects of 12 Inch Diameter Steel Pipe Missile

Concrete Wall Evaluation:

Diameter of missile = 12.75" (Outer diameter of 12" dia Sch 40 pipe)

Contact surface area = A_c = 15.7 in^2 (cross section metal area of 12" dia Sch 40 pipe)

Effective diameter = d = $(4*15.7/\pi)^{1/2}$ = 4.47 inches

W = 1500 lbs

v_o = 205 fps

f_c' = 5000 psi

K = $180/\sqrt{5000} = 2.55$

N = 0.72 flat nosed

Perforation thickness x = 15.2 in for $x/d > 2$

Perforation thickness e = 24.75 in

Required perforation thickness 1.2*24.75 = 29.7"

Scabbing thickness = s = 30.15 inches

Required scabbing thickness = 1.2*30.15 = 36.2 inches

The roof (44" thick), font wall (42" thick) and the shield walls (36" thick) will not be perforated. However, the missile may produce scabbing in the end shield wall above the side walls and lower 40" of the end shield wall. Assuming some scabbed concrete from the end shield will fall into the vent openings, it will not cause any problem in the safe retrieval of the DSC from the module.

Composite Shield Door Evaluation

M_m = 1500/32.2 = 46.6 lb-sec²/ft

v_s = 205 fps

E_k = 46.6 * 205*205/2=979182

D = 12.75 in

Tp = $(979182)^{2/3}$ /(672*12.75) = 1.16 inches

The required thickness = 1.25 Tp = 1.25*1.16 = 1.45 inches

The composite shield door will not be perforated by this missile.

P.11.2.3.2.1.2 Massive Missile Impact Analysis

The HSM-H stability and potential damage due to impact of the postulated DBT massive missile consisting of a 4000 lb. automobile, 20 sq. ft. frontal area traveling at 195 ft./sec., is evaluated. The massive missile is assumed to impact the shield wall of an end module in an array. Using the principles of conservation of momentum with a coefficient of restitution of zero, the analysis presented below demonstrates that the end module remains stable and the missile energy is dissipated by sliding or slight tipping of the module.

Using conservation of momentum, the missile impact force equals the change in linear (sliding) or angular (overturning) momentum of the HSM-H. The HSM-H velocities immediately after impact are:

Sliding: $V = (m*v_i) / (M+m)$ (Eq. 11.2-1)

Overturning: $\omega_b = (m*d_m*v_i)/(m*d_m^2 + I_B)$ (Eq. 11.2-2)

Where, V = initial linear velocity of module after impact

v_i = 195 ft/sec = initial velocity of missile (conservative)

ω_B = initial rotational velocity about bottom right corner of the module and end shield walls (Figure P.11-2)

d_m = Vertical distance of the CG of the missile from B (Figure P.11-1) = 198 inches

m = 4000/386.4 = 10.35 lb-sec²/in = mass of the missile

M = (290.0+110+2*172.0)*1000/386.4 = 1925.5 lb-sec^2 /in = Mass of loaded HSM-H + End Shield walls

d = = 118.77, Elevation of the CG of the loaded HSM-H

I_B = Mass moment of inertia of loaded HSM-H about point B (Figure P.11-1)

= 3.85×10^7 lb-sec^2-in (conservatively used)

Sliding:

From Eq. 11.2-1: V = 12.51 in/sec = 1.043 ft/sec

For an impact at the bottom of the HSM-H wall, the kinetic energy imparted to the HSM-H is absorbed by sliding friction between the concrete of the HSM-H and the basemat. Coefficient of friction is 0.6 [11.6].

Assuming that the missile impact load results in sliding of the HSM-H and equating the kinetic energy generated by the moving module to the work done by sliding friction force gives:

$$\mu * g * (M+m) * \Delta = (M+m)*V^2/2$$

$$\Delta = 0.0281 \text{ ft} = 0.34 \text{ inch}$$

Therefore, a massive missile impact on a single HSM-H will slide the complete module approximately 0.34 inches sideways. The sliding distance will be significantly reduced due to presence of more than one module side by side.

Therefore, the sliding displacement of the modules due to a massive missile impact is insignificant and will not cause any structural damage.

Overturning:

When the massive missile impacts at the top of the HSM-H, the missile energy is absorbed by plastic deformation of the missile and in rotation of the HSM-H. Therefore, equating the loss of kinetic energy to increase in the potential energy:

$$I_B\, \omega_B^2 /2 = M *g*d\,[\cos(\beta+\alpha-90)-\cos\beta] \quad \text{(Figure P.11-1)}$$

From Eq. 11.2-2: ω_B = 0.12372 rad/sec

β = $\tan^{-1}\{(52)/ 118.77) = 24.65°$

M = 1480 lb-sec^2/in

$$\cos(24.65+\alpha-90) - \cos(24.65) = 0.00433$$

$\cos(24.65+\alpha-90) = 0.00433 + 0.907411 = 0.911741$

$90-\alpha = 24.85-24.25 = 0.60$

Therefore, a loaded HSM-H rotates a maximum of 0.60° from vertical. The loaded HSM-H is stable against overturning as tip-over does not occur until the CG rotates past the edge point (point B, Figure P.11-1) to an angle of more than 24.65° [= $\tan^{-1}(52.0/118.77)$].

P.11.2.3.3 Accident Dose Calculations

The NUHOMS®-24PTH DSC is designed and tested as a leak-tight containment boundary according to the criteria of ANSI N14.5. As shown in Section P.11.2.3.2, the tornado wind and tornado missiles do not breach the containment boundary. Therefore, there is no increase in site boundary dose due to this accident event.

P.11.2.3.4 Corrective Actions

After excessive high winds or a tornado, the HSM's and TCs would be inspected for damage. Any debris would be removed. Any damage resulting from impact with a missile would be evaluated to determine if the system was still within the licensed design basis.

P.11.2.4 Flood

P.11.2.4.1 Cause of Accident

No change. See Section 8.2.4.1.

P.11.2.4.2 Accident Analysis

No change to the HSM Model 102 analysis presented in Section 8.2.4.2.

The HSM-H and DSCs are evaluated for flooding in Section P.3.7.3. The DSC is designed and tested to be leak tight to the criteria of ANSI N14.5. The stresses in the DSC due to the design basis flood are well below the allowable stresses for Service Level C of the ASME Code Subsection NB [11.5]. Therefore, the NUHOMS®-24PTH DSC will withstand the design basis flood without breach of the confinement boundary.

P.11.2.4.3 Accident Dose Calculations

The radiation dose due to flooding of the HSMs (HSM-H or HSM Model 102) is negligible. The NUHOMS®-24PTH DSC is designed and tested as a leak-tight containment boundary. Flooding does not breach the containment boundary. Therefore radioactive material inside the DSC will remain sealed in the DSC and, therefore, will not contaminate the encroaching flood water. See also Section 8.2.4.3.

P.11.2.4.4 Corrective Actions

No change. See Section 8.2.4.4.

P.11.2.5 Accidental TC Drop

P.11.2.5.1 Cause of Accident

See Section P.3.7.4.

P.11.2.5.2 Accident Analysis

The evaluation of the NUHOMS®-24PTH DSC shell and basket assemblies due to an accidental drop is presented in Section P.3.7.4. As documented in Chapter P.3.7, the TCs have been evaluated for a payload that bounds the 24PTH DSC payload, and therefore is not affected by the 24PTH DSC. As shown in Section P.3.7.4, the DSC shell and basket stress intensities are within the appropriate ASME Code Service Level D allowable limits and maintains their structural integrity.

For the standardized TC with solid neutron shield, complete loss of neutron shield during cask drop events is not credible. For the case of a liquid neutron shield, a complete loss of neutron shield was evaluated at the 100°F ambient condition with full solar load in Section P.4. It is conservatively assumed that the neutron shield jacket is still present but all the liquid is lost. The maximum DSC shell temperature is 685°F. The maximum cask inner liner, cask outer shell, and cask neutron shield jacket temperatures are 530°F, 488°F and 325°F respectively for 24PTH DSC with 40.8 kW decay heat load as shown in Table P.4-12. The fuel cladding temperatures are below their limit as shown in Table P.4-25. Accident thermal conditions, such as loss of the liquid neutron shield, need not be considered in the load combination evaluation. Rather the peak stresses resulting from the accident thermal conditions must be less than the allowable fatigue stress limit for 10 cycles from the appropriate fatigue design curves in Appendix I of the ASME Code. Similar analyses of other NUHOMS® TCs have shown that fatigue is not a concern. Therefore, these thermal stresses in a TC with a liquid neutron shield need not be evaluated for the accident condition.

P.11.2.5.3 Accident Dose Calculations for Loss of Neutron Shield

The postulated accident condition for the on-site TC assumes that after a drop event, the water in the neutron shield is lost. The loss of neutron shield is modeled using the normal operation models described in Section P.5.4 by replacing the neutron shield with air. The accident condition dose rates from Chapter P.5, are summarized in Table P.11-2 for the bounding 24PTH-DSC loaded with design basis fuel plus control components.

Table P.11-2 shows the accident condition dose rates at 1, 100 and 500 meters from the OS197FC TC and standardized TC. The dose received by a person located 100 meters away from the NUHOMS® 24PTH system installation for an assumed 8 hour duration would be 8 mrem with the OS197FC TC and 2.4 mrem with the standardized TC. The increased dose to an off-site person located 600 meters away for the assumed 8 hour duration would be less than 0.01

mrem with both the OS197FC TC and the standardized TC with NUHOMS® 24PTH DSC. These exposures are well within the limits of 10CFR72 for an accident condition.

P.11.2.5.4 Corrective Action

No change. See Section 8.2.5.4.

P.11.2.6 Lightning

No change. The evaluation presented in Section 8.2.6 is not affected by the addition of the NUHOMS®-24PTH DSC to the NUHOMS® System.

P.11.2.7 Blockage of Air Inlet and Outlet Openings

This accident conservatively postulates the complete blockage of the ventilation air inlet and outlet openings of the HSM-H.

P.11.2.7.1 Cause of Accident

No change. See Section 8.2.7.1.

P.11.2.7.2 Accident Analysis

This event is evaluated in Section 8.2.7.2 for HSM Model 102 and a 24P DSC with 24 kW heat load. The maximum heat load in the 24PTH-S-LC DSC in HSM Model 102 is also 24kW. Therefore, the evaluation presented in Section 8.2.7.2 is also applicable to the HSM Model 102 with 24PTH-S-LC DSC.

The thermal evaluation of this event is presented in Section P.4 for HSM-H and a 24PTH-S and –L DSCs. The temperatures determined in Section P.4 are used in the structural evaluation of this event, which is presented in Sections P.3.7.6 and P.3.4.4.3 for HSM-H and 24PTH-S and –L DSCs.

The section below describes the additional analyses performed to demonstrate the acceptability of the system with the NUHOMS®-24PTH DSC.

P.11.2.7.3 Accident Dose Calculations

There are no off-site dose consequences as a result of this accident. The only significant dose increase is that related to the recovery operation. Based on the results presented in Section P.5, Table P.5-1 and Table P.5-2, the bounding average dose on HSM front or roof is 20.3 mrem/hr and 47.5 mrem/hr for the 24PTH-S or –L DSC in HSM-H and 24PTH-S-LC DSC in HSM Model 102 respectively.

It is conservatively estimated that the on-site workers will receive an additional dose of no more than 380 mrem during the eight hour period it is estimated may be required for removal of debris from the inlet and outlet vent openings.

P.11.2.7.4 Corrective Action

No change. See Section 8.2.7.4.

P.11.2.8 DSC Leakage

The NUHOMS®-24PTH DSC is designed as a pressure retaining containment boundary to prevent leakage of contaminated materials. The analyses of normal, off-normal, and accident conditions have shown that no credible conditions can breach the DSC shell or fail the double seal welds at each end of the DSC. The NUHOMS®-24PTH DSC is designed and tested to be leak tight. Therefore DSC leakage is not considered a credible accident scenario. See Section P.7 for additional details on the confinement evaluation.

P.11.2.9 Accident Pressurization of DSC

P.11.2.9.1 Cause of Accident

The bounding internal pressurization of the NUHOMS®-24PTH DSC is postulated to result from cladding failure of the spent fuel in combination with the transfer accident case with the loss of sunshield and liquid neutron shield in the transfer cask under extreme ambient temperature conditions of 117°F and maximum insolation, and the consequent release of spent fuel rod fill gas and free fission gas. The evaluation conservatively assumes that 100% of the fuel rods have failed.

P.11.2.9.2 Accident Analysis

The pressure due to this case is evaluated in Section P.4.6. The maximum accident condition pressure calculated is 97.2 psig for the 24PTH-S or –L DSCs and 80.4 psig for the 24PTH-S-LC DSC. The accident design pressure is conservatively assumed to be 120 psig and 90 psig in the structural load combinations presented in Table P.2-15 for 24PTH-S or –L DSC and 24PTH-S-LC DSC respectively.

P.11.2.9.3 Accident Dose Calculations

There is no increase in dose rates as a result of this event.

P.11.2.9.4 Corrective Actions

This is a hypothetical event. Therefore no corrective actions are required. The canister is designed to withstand the pressure as a Level D condition. There will be no structural damage to the canister or leakage of radioactive material as a result of this event.

P.11.2.10 Fire and Explosion

P.11.2.10.1 Cause of the Accident

Combustible materials will not normally be stored at an ISFSI. Therefore, a credible fire would be very small and of short duration such as that due to a fire or explosion from a vehicle or portable crane.

However, a hypothetical fire accident is evaluated for the NUHOMS®-24PTH System based on a fuel fire. The source of fuel is postulated to be from a ruptured fuel tank of the TC transporter tow vehicle. The bounding capacity of the fuel tank is 300 gallons and the bounding hypothetical fire is an engulfing fire around the TC. Direct engulfment of the HSM is highly unlikely. Any fire within the ISFSI boundary while the DSC is in the HSM would be bounded by the fire during TC movement. The HSM concrete acts as a significant insulating fire wall to protect the 24PTH-DSC from the high temperatures of the fire.

P.11.2.10.2 Accident Analysis

The evaluation of the hypothetical fire event is presented in Section P.4.6.7.3. The fire thermal evaluation is performed primarily to demonstrate the confinement integrity and fuel retrievability of the 24PTH-DSC. This is assured by demonstrating that the DSC temperatures and internal pressures will not exceed those of the transfer cask drop accidents (see Section P.11.2.5) during the fire scenario. Peak temperatures for the NUHOMS®-24PTH System components are summarized in Table P.4-13.

P.11.2.10.3 Accident Dose Calculations

The 24PTH-DSC confinement boundary will not be breached as a result of the postulated fire/explosion scenario. Accordingly, no 24PTH-DSC damage or release of radioactivity is postulated. Because no radioactivity is released, no resultant dose increase is associated with this event.

The fire scenario may result in the loss of TC neutron shielding should the fire occur while the 24PTH-DSC is in the cask. The effect of loss of the neutron shielding due to a fire is bounded by that resulting from a cask drop scenario. See Section P.11.2.5.3 for evaluation of the dose consequences of a cask drop.

P.11.2.10.4 Corrective Actions

Evaluation of HSM or TC neutron shield damage as a result of a fire is to be performed to assess the need for temporary shielding (for HSM-H or cask, if fire occurs during transfer operations) and repairs to restore the TC and HSM-H to pre-fire design conditions.

P.11.3 References

11.1 American Nuclear Society, ANSI/ANS-57.9, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type), 1992.

11.2 ANSI N14.5-1997, "Leakage Tests on Packages for Shipment," February 1998.

11.3 NUREG-1536, "Standard Review Plan for dry Storage Casks, Final Report," US Nuclear Regulatory Commission, January 1997.

11.4 ISG-5, Rev. 1, Confinement Evaluation.

11.5 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, 1998 including 2000 addenda.

11.6 American Concrete Institute, Code Requirements for Nuclear Safety Related Concrete Structures and Commentary, ACI 349-97 and ACI 349R-97, American Concrete Institute, Detroit, MI.

11.7 American Society of Civil Engineers, ASCE Manual No. 58, Structural Analysis and Design of Nuclear Plant Facilities, 1980.

11.8 "Design of Structures for Missile Impact", BC-TOP-9A, Revision 2, September 1974, Bechtel Power Corporation.

Table P.11-1
Comparison of Total Dose Rates for HSM-H Loaded with 24PTH-S-LC, with and without Adjacent HSM Shielding Effects

Distance from Nearest HSM Wall, 2x10 Array (meters)	Normal Case Dose Rate[1] (mrem/hr)	Accident Case Dose Rate[1] (mrem/hr)
10	6.4	12.7
100	0.1	0.2
500	7.4×10^{-4}	1.5×10^{-3}
600	3.1×10^{-4}	6.2×10^{-4}

[1] Air scattered plus direct radiation

Table P.11-2
Calculated Accident Dose Rates on the Side of the OS197FC TC and Standardized TC

Distance	Neutron		Total Gamma		Total	
	mRem/hr	1σ error	mRem/hr	1σ error	mRem/hr	1σ error
OS197FC TC						
1 meter	3.19E+03	0.0124	3.10E+02	0.0011	3.505E+03	0.0128
100 meter	5.10E-01	0.0134	1.50E-01	0.0366	6.61E-01	0.0124
500 meter	4.10E-04	0.0305	4.95E-04	0.8299	9.05E-04	0.0194
Standardized TC						
1 meter	4.18E+02	0.0219	3.44E+02	0.0018	7.62E+02	0.0258
100 meter	6.76E-02	0.0232	1.67E-01	0.0872	2.35E-01	0.0308
500 meter	5.34E-05	0.0341	6.20E-04	1.1638	6.74E-04	0.0279

Figure Withheld Under 10 CFR 2.390

[illegible]

Figure P.11-1
HSM-H Dimensions for Missile Impact Stability Analysis

P.12 Conditions for Cask Use - Operating Controls and Limits or Technical Specifications

Attachment B of this application provides the suggested changes to the Technical Specifications due to the addition of 24PTH DSC to the NUHOMS® System.

P.13 Quality Assurance

Chapter 11.0 provides a description of the Quality Assurance Program to be applied to the safety related and important to safety activities associated with the standardized NUHOMS® System. For the 24PTH DSC system, the following is added to clarify the contents of Section 11.2:

> "In lieu of the requirements listed in paragraphs A through H, Category A items may also be procured as commercial grade items and dedicated by in accordance with the guidelines of EPRI NP-5652."

P.14 Decommissioning

There is no change from the decommissioning evaluation presented in Section 9.6 due to the addition of 24PTH DSC to the NUHOMS® System.