9.0 AUXILIARY SYSTEMS

9.1 FUEL STORAGE AND HANDLING

9.1.1 NEW FUEL STORAGE

9.1.1.1 Design Bases

The new fuel storage racks are designed for the storage of new fuel assemblies prior to loading them into the core. The new fuel storage racks are designed to:

a) store 80 fuel assemblies (more than 1/3 of a core),

b) store new fuel assemblies with new control element assemblies (CEAs) inserted,

→(EC-18742, R304)

c) provide a geometrically safe configuration, resulting in a k_{eff} of 0.95 or less, assuming flooding with uniform density cold clean water with no credit taken for the steel structure, and

←(EC-18742, R304)

d) maintain a subcritical array, with the assumption in c), under all design loadings, including the safe shutdown earthquake.

The racks and their associated anchorages are designed to maintain the minimum allowable fuel spacing, to support the contained fuel assemblies without damaging them and to allow for subsequent fuel assembly removal for the following conditions (in addition to thermal expansion loads and the dead loads of the fuel assemblies with CEAs):

a) the impact load resulting from a fuel assembly drop, or

b) loads resulting from seismic disturbances (safe shutdown earthquake or operating basis earthquake).

For an operating basis earthquake (OBE) or a safe shutdown earthquake (SSE), racks are designed for simultaneous loads from horizontal and vertical seismic accelerations which are obtained from the floor response spectra curves.

9.1.1.2 Facilities Description

→(DRN 01-692, R11-A)

New fuel assemblies arrive on-site in shipping containers. Upon receiving the shipping containers, personnel use the fuel handling crane to lift each shipping container up to the +46 ft. level of the Fuel Handling Building. On +46 ft., personnel remove the new fuel from each container for an inspection. Once finding that the fuel meets the inspection acceptance criteria, they place the new fuel assemblies into the locations that the Special Nuclear Materials Transfer Report specifies, usually a vertical rack location in the spent fuel pool. New fuel can also be stored in a separate dry fuel storage vault. The remainder of this FSAR section describes the dry storage vault.

←(DRN 01-692, R11-A)

The dry racks are in the 27.5 ft. by 29.25 ft. by 22.0 ft. high new fuel concrete vault located west of the spent fuel storage pool (FSAR Figures 1.2-15 and 1.2-16). The vault side walls restrain dry rack lateral motion.

The vault base slab (at elevation +24.00 ft. MSL) supports the weight of the dry racks. Note the racks actually rest on a two inch redwood floor deck inside the vault, built on top of the base slab.

The fuel storage racks consist of vertical storage cells, grouped in parallel rows, such that fuel assemblies are removed from the top. The storage racks are divided into two units, each consisting of a uniform four by 10 array. Each fuel assembly has a design minimum edge-to-edge spacing of 12 in. or a center-to-center spacing of 21 in.

The rack dimensions are such that no portion of any fuel assembly, with a control element assembly installed, will project out of the rack. The depth of the individual cells is 190 in. The cell openings are 8 15/16 in. x 8 15/16 in. at the lateral support points.

The individual new fuel assemblies are supported axially by the lower end fitting of the assembly. The seating surface is designed to prevent damage of the alignment pins or positioning surfaces.

The fuel assembly lateral restraints are located adjacent to fuel grids and/or fuel end fittings. The length of these restraints provides adequate support and guidance for the new fuel assembly during insertion and removal, to prevent any direct loading or rubbing on the new fuel rods.

Provisions are made to allow lifting of the rack modules for possible removal.

Material stresses determined by combining the dead load and the OBE seismic loading do not exceed the AISC allowable stresses. Material stresses determined by combining the dead load and the SSE seismic loading do not exceed 90 percent of yield stress or 90 percent of critical buckling stress of the materials, as applicable. Shear yield stress is taken as 58 percent of tensile yield stress.

Stress comparisons are as follows:

a) Impact load resulting from a fuel assembly drop on 0.25 in. checkered plate cover,

→(EC-18742, R304)

actual fb = 24.07 KSI < 27 KSI Fb allowable

←(EC-18742, R304)

where fb = bending stress

Fb = allowable bending stress

b) Most critically stressed member due to a seismic occurrence (bottom rack strut C8 x 11.5),

actual fa = 4.6 KSI < 5.3 KSI Fa allowable

where fa = compressive stress

c) Most critically stressed member due to a seismic occurrence (to grid member W8 x 17),

$$\frac{fbx}{Fbx} + \frac{fby}{Fby} = 0.962 < 1.0$$

where:

fbx = bending stress about x-x axis

fby = bending stress about y-y axis

Fbx = allowable beading stress about x-x axis

Fby = allowable bending stress about y-y axis

d) Seismic supports transferring seismic loads from racks to wall:

actual P = 4.9 kips < 16.7 kips allowable (for one in. diameter extra strong pipe)

actual P = 4.9 kips < 17.8 kips allowable (for A325 0.75 in. diameter bolt)

where P = seismic load

9.1.1.3 Safety Evaluation

The racks are designed to provide protection against damage to the new fuel and to prevent new fuel assemblies from being inserted in other than prescribed locations. Above each new fuel storage cell is a one-quarter in. checkered plate hinged cover. In order to place the new fuel in a storage cell, the checkered plate hinged cover of the storage cell must be opened and the new fuel lowered by the cask crane auxiliary hook. By keeping all the other hinged covers closed and having fixed one-quarter in. checkered plate over all areas between these hinged covers, new fuel assemblies are prevented from being inserted in other than prescribed locations.

→(EC-5000082411, R301; EC-18742, R304)

Criticality design calculations have been performed (Reference 5) and consider the effects of manufacturing tolerances in the rack, wear of the racks over their design life and uncertainty of fuel assembly position in the racks.

←(EC-5000082411, R301)

Sufficient margin to criticality is maintained under all conditions for the storage of new fuel assemblies of maximum enrichment (5.0 weight percent U-235 in UO_2). Specifically, analyses have been performed which confirm that a k_{eff} of less than 0.98 would exist for storage of 5.0 weight percent enriched fuel in optimum moderation conditions.

←(EC-18742, R304)

The new fuel storage racks are designed in accordance with the following:

a) AISC - Specification for the Design, Fabrication and Erection of Structural Steel for Building, July 1970

b) American Society of Mechanical Engineers (ASME) 1974 Edition, up to and including the Summer 1976 addenda:
ASME Section II, Material Specifications
ASME Section IX, Welding Qualifications
Fa = allowable compressive stress

c) American Society for Testing Material (ASTM) - ASTM A-167 Type 304 Standard Finish (1974)

d) American Welding Society-AWS Dl.1-1972, Structural Welding Code

→(EC-18742, R304)

The racks are designed to safely withstand all external loads and forces, (including a SSE) and transmit these loads and forces to the surrounding concrete vault structure. Details of seismic designs are discussed in Section 3.7. The most severe force acting in either the east-west direction or the north-south direction are directly combined with the vertical force in the upward or the downward direction.

→(EC-14275, R306)

9.1.2 SPENT FUEL STORAGE IN THE FUEL HANDLING AND CONTAINMENT BUILDINGS

←(EC-14275, R306)

9.1.2.1 Design Basis

→(DRN 99-1097, R11, R11)

Fuel assemblies are stored underwater in high density top entry spent fuel storage racks in the spent fuel pool, the spent fuel cask storage area and, after permanent plant shutdown, in the refueling canal. The function of the spent fuel storage racks is to vertically support, physically separate and facilitate cooling of spent fuel assemblies with control element assemblies inserted. The design of spent fuel storage racks precludes insertion of a fuel assembly in any other region except regions designated for fuel assemblies.

←(DRN 99-1097, R11, R11; EC-18742, R304)

→(EC-14275, R306)

There are four spent fuel storage racks, D, E, F, and G, and their respective storage pedestals, in the Cask Storage Area which must be removed in order for dry cask storage operations to proceed. An option is maintained for the spent fuel storage racks to be available for re-installation as needed.

←(EC-14275, R306)

The spent fuel storage racks are designed to:

→(DRN 99-1097, R11, R11)

a) have storage positions for 2398 fuel assemblies; 1849 spaces in the spent fuel pool; 255 spaces in the spent fuel cask storage area; and 294 spaces in the refueling canal.

←(DRN 99-1097, R11, R11)

→(EC-18742, R304)

b) remain subcritical with a k_{eff} of less than 1.0 assuming spent fuel is flooded with nonborated water, and

←(EC-18742, R304)

c) maintain a subcritical array, with the assumption of b), under all design loadings, including the safe shutdown earthquake.

→(DRN 99-1097, R11, R11)

←(DRN 99-1097, R11, R11)

→(EC-8884, R303)

The spent fuel storage racks are designed as a seismic Category I structure (Reference 6). The racks and their associated anchorages are designed to maintain the minimum allowable fuel spacing, to support the contained fuel assemblies without damaging them (i.e., no fuel cladding rupture), to allow sufficient fuel cooling, and to allow subsequent fuel assembly removal for the following conditions, (in addition to thermal expansion loads of the fuel assemblies with CEAs and the fuel pool water):

a) the impact load resulting from a fuel assembly (with CEA) being dropped in the vertical position from the maximum height it can be lifted above the racks (approximately 18 ft. from the bottom of the fuel assembly to the bottom of pool) (References 6 and 7),

←(EC-8884, R303)

b) loads resulting from seismic disturbances (SSE and OBE), or

c) maximum uplift loads of 5000 lbs. that can be produced by the spent fuel handling machine.

9.1.2.2 Facilities Description

→(DRN 99-1097, R11, R11)

The spent fuel storage racks are located in the spent fuel storage pool, the spent fuel cask storage area and, after permanent plant shutdown, the refueling canal of the Fuel Handling Building. The spent fuel pool is approximately 31’11” wide, 32’6” long, and 41’6” deep. The normal level of the water in the pool is at elevation +44’0”. The bottom of the pool is at elevation +4’6”. The spent fuel cask storage area is located adjacent to (on the West side of) the spent fuel pool. The spent fuel cask storage area is approximately 13’1” wide, 14’9” long and 45’6” deep (the bottom is at elevation +0’6”). The refueling canal is located adjacent (on the West side of) the spent fuel cask storage area. The refueling canal is approximately 5’ wide, 36’6” long, and 41‘6” deep (the bottom is at elevation 4’6”). To the North of the spent fuel cask storage area is the spent fuel cask decontamination area. Stainless steel liners are placed directly against the concrete to form the sides of the three regions (spent fuel pool, spent fuel cask storage area and refueling canal). The stainless steel floor liner plate is supported on a steel beam grillage, which in turn is supported by the concrete base. The entire steel grillage is then completely grouted to the underside of the floor liner plate. The spent fuel pit liner is shown in Figure 9.1-2 and the location of the three regions, within the Fuel Handling Building, is shown in Figures 1.2-15 and 16.

←(DRN 99-1097, R11, R11)

A leak detection system is provided to monitor 100 percent of the pool liner welds. The system consists of a network of stainless steel angles attached to the outside of the pool liner walls and floor by means of seal welds.

These monitor channels do not constitute part of the pool liner boundary but are water tight to the extent necessary to collect and isolate any leakage through the liner plate. In the event that one of the liner plate weld seams develops a leak, the liquid enters the monitor channel system and flows to one of a number of collection points at the base of the pad. In this way, the leakage can be traced to a specific area of the pool. The actual point of leakage can be determined by pressurizing the leaking channel and looking for bubbles inside the pool. Each of the channels can be valved off in order to prevent further leakage from the pool.

→(DRN 99-1097, R11; EC-14275, R306)

The spent fuel pool, spent fuel cask storage area and refueling canal are all designed to be flooded with borated water. The spent fuel cask decontamination area is designed to be a dry area (washdown of the spent fuel transfer cask only). The spent fuel pool can be separated from the spent fuel cask storage area with a removable, watertight gate (Gate #1), the spent fuel cask storage area can be separated from the refueling canal with a removable, watertight gate (Gate #2) and the spent fuel cask storage area can be separated from the cask decontamination area with two removable, watertight gates (Gates #3A and 3B). Gate #3A is presently seal welded closed. The cask decontamination area is separated from the rail bay by a removable non-watertight gate (Gate #4). Administrative controls are in place to ensure that Gate #1 is not installed whenever spent fuel is stored in the spent fuel cask storage area. Administrative controls will be implemented, prior to installing storage racks in the refueling canal, to ensure that Gate #2 is not installed when spent fuel is stored in the refueling canal.

←(DRN 99-1097, R11; EC-14275, R306)

The spent fuel racks are high density poison design shown in Figure 9.1-3. These racks are modular in design with storage positions arranged in a square pattern. This honeycomb structure is inherently strong while providing large surface-to-surface bearing areas that will provide internal friction damping during a seismic incident as an added margin of design conservatism.

Each rack assembly is made by joining a number of parallel rows of square boxes. Each box contains one fuel assembly compartment and two poison assembly compartments. The compartments are arranged so that the fuel assembly compartments in a rack assembly are separated from one another by poison assembly compartments. Each box is fitted with a bottom plate which supports the fuel assembly.

Openings through the bottom plate provide for water circulation through all three compartments. The design permits only one fuel assembly to be inserted into each storage location.

→(DRN 99-1097, R11; EC-18742, R304)

The spent fuel storage racks are free standing and go wall to wall in the spent fuel pool and spent fuel cask storage area. The spent fuel storage racks are grouped into two design styles, designated as Region 1 and Region 2. Both rack styles contain Boral as the active neutron absorbing poison. Boral consists of finely divided particles of boron carbide (B_4C) uniformly distributed in type 1100 aluminum powder, clad in type 1100 aluminum and pressed and sintered in a hot-rolling process. Region 1 racks are located in the spent fuel cask storage area and have the capability to store 255 fuel assemblies in four separate rack modules. Region 2 racks have the capability to store 1849 fuel assemblies in sixteen separate rack modules in the spent fuel pool and 294 fuel assemblies in five separate modules in the refueling canal. Region 1 racks have a center to center spacing of 10.185 inch and Region 2 racks have a center to center spacing of 8.692 inch.

←(EC-18742, R304)

Each poison assembly compartment contains a poison assembly. The neutron poison assembly consists of a sheet of Boral.

←(DRN 99-1097, R11)

The determined seismic response loads consider all degrees of fuel loading of the racks, including racks empty of any fuel, partially loaded with fuel, or filled with fuel with CEAs inserted. The effect of water within the rack cavities is considered. Floor response spectra curves are given in Subsection 3.7.2.

→(DRN 99-1097, R11)

Material stresses determined by combining the dead load and OBE seismic loading do not exceed the ASME allowable stresses.

←(DRN 99-1097, R11)

→(EC-18742, R304)

The spent fuel storage racks are constructed entirely of stainless steel. Thus, material compatibility between components of the spent fuel pool and the Zircaloy-4 clad fuel assemblies is established.

←(EC-18742, R304)

→(DRN 99-1097, R11; EC-28458 R305; EC-30504, R305; EC-14275, R306)

The spent fuel storage pool is so located in the Fuel Handling Building that no equipment, other than the spent fuel handling machine hoist and the cask crane auxiliary hoists will be able to be in both areas. The main hoist on the Fuel Handling Building cask crane is able to access the cask decontamination area and the rail bay; and access the spent fuel cask storage area with administrative controls. The accidental dropping of any heavy object by the spent fuel handling machine will be avoided by the stringent controls as described in Subsection 9.1.4. The auxiliary hoists of the cask crane will only be used to handle the poison assemblies of less than 200 pounds (including the weight of the tool) during the surveillance test. Heavier loads than 200 pounds may be lifted over the spent fuel pool and the spent fuel cask storage area. However, these lifts will be controlled by site procedures and will meet the NUREG-0612 requirements. Regulatory Guide 1.13, Spent Fuel Storage Facility Design Basis, is discussed in Subsections 9.1.3 and 9.1.4.

←(DRN 99-1097, R11; EC-28458 R305; EC-30504, R305; EC-14275, R306)

Radiological considerations are discussed in Subsection 12.3.1.9. Ventilation is provided in this area as discussed in Subsection 9.4-2.

9.1.2.3 Safety Evaluation

→(DRN 99-1097, R11; EC-18742, R304)

The center-to-center spacing between fuel assemblies in the Region 1 racks is such as to maintain the array subcritical with a k_{eff} of less than 1.0 when fully loaded with assemblies (without CEAs) of maximum enrichment of 5.0 w/o U-235 in UO_2, without regard to fuel burnup, when flooded with pure water, and less than 0.95 with 85 ppm soluble boron. The Region 2 racks have a minimum burnup requirement of 34,100 MWD/MTU for unrestricted fuel storage of assemblies at an initial enrichment of 5.0 w/o U-235 (and meeting the same criticality design criteria as the Region 1 racks). Fuel assemblies not meeting the minimum burnup requirements may also be stored in Region 2 utilizing a checkerboard storage pattern of either (1) new fuel and empty cells or (2) fuel of 27 MWD/MTU burnup with fuel of lower reactivity. Region 1 may also be used for storage of fuel assemblies not meeting the minimum burnup requirements established for Region 2. The racks, which comprise Regions 1 and 2, have Boral absorbers which have been sized to fully shadow the active fuel height of all fuel assembly designs stored in the pool. This design condition is maintained during all design loadings described above. The Region 2 racks will

←(DRN 99-1097, R11; EC-18742, R304)

→(DRN 99-1097, R11; EC-5000082411, R301; EC-18742, R304)

maintain a subcritical array with a k_{eff} less than 1.0 when flooded with pure water, and a k_{eff} less than 0.95 with 524 ppm soluble boron. The soluble boron requirement to ensure a k_{eff} less than 0.95 in the Region 1 and Region 2 racks under all accident conditions is 870 ppm.

Criticality analyses were also performed for Region 2 to establish requirements for the interfaces between contiguous sub-regions containing different loading configurations. No restrictions are necessary between a uniform loading pattern and either of the checkerboard loading patterns, fresh or irradiated. For interfaces between the fresh fuel checkerboard and the irradiated fuel checkerboard, the high-reactivity irradiated assembly (e.g., 27 GWD/MTU) may be face-adjacent to no more than one fresh fuel assembly; each fresh fuel assembly may be face-adjacent with up to two high-reactivity irradiated fuel assemblies.

The criticality design calculations were performed (References 1 and 4) using the MCNP and CASMO-4 codes. The calculations considered the effects of manufacturing tolerances in the racks, variation in fuel pool water density and uncertainty of fuel assembly position in the racks. The fuel assembly parameters used in the criticality analysis are described in Table 9.1-8. Since the rack design meets the required seismic criteria, a seismic event will not alter k_{eff}.

←(DRN 99-1097, R11; EC-5000082411, R301; EC-18742, R304)

The governing codes used in the design of the spent fuel storage racks are as follows:

→(DRN 99-1097, R11)

A. Design: The Spent Fuel Storage Racks are designed in accordance with the stress limits of ASME, Section III, Subsection NF for linear type supports (1996 Edition). The ASME Code Stamp is not required. Minimum fillet weld sizes have not been limited by the criteria of ASME Section III, Subsection NF (NF-3324.5d).

B. Fabrication: The Spent Fuel Storage Racks have been fabricated in accordance with ASME, Section III, Subsection NF (1996 Edition). The ASME code stamp is not required. The racks have been fabricated under a 10CFR50 Appendix B program.

C. Materials: All material, including welding filler material, conforms to the requirements of Section II of the ASME Boiler and Pressure Vessel Code (1996 Edition). Requirements of 10CFR50 Appendix B apply.

D. Welding: Welders and welding procedures were qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code (1996 Edition). Welding requirements of ASME Section III, Subsection NF, Subarticles NF-4300 and NF-4400 apply to the fabrication and installation of the Spent Fuel Storage Racks. The ASME code stamp is not required.

E. Visual Examination: All welds were gage checked and visually examined in accordance with ASME Section III, Subsection NF, Subarticle NF-5360. Personnel qualification and certification were in accordance with Subarticle NF5520.

F. Nondestructive Examination: All pedestal to baseplate welds and all fillet welds greater than 3/8" have been subjected to liquid penetrant examination in accordance with the following:

   (1) Liquid penetrant examinations were performed in accordance with ASME Section V, Article 6 (1996 Edition).
   (2) Liquid penetrant examination acceptance standards were in accordance with ASME Section III, Subsection NF, Subarticle NF-5350.
   (3) Personnel qualification and verification were in accordance with ASME Section III, Subsection NF, Subarticle NF-5520.

←(DRN 99-1097, R11)

→(EC-22227, R304)

G. Criticality Accident Requirements: Code of Federal Regulations, 10 CFR 50.68, with credit taken for soluble boron, in compliance with 10 CFR 50.68(b).

←(EC-22227, R304)

The spent fuel storage racks are protected against the design wind loadings and tornado-generated missiles for the design tornado conditions specified in Section 3.3.

→(EC-18742, R304)

A boric acid concentration of greater than or equal to 1900 ppm is maintained in the water. Spent fuel pool radiation dose levels are as discussed in Subsection 12.3.1.9.

←(EC-18742, R304)

The spent fuel cavity and total rack design is such that each fuel assembly and CEA will be kept sufficiently cool by natural convection cooling water flow past the assembly as described in Subsection 9.1.3.

9.1.2.4 Temporary Fuel Storage

9.1.2.4.1 Design Bases

The temporary fuel storage rack consists of one row of five stainless steel boxes which are designed to:

a) Store up to five (5) new or spent fuel assemblies in containment during refueling.

→(DRN 99-1097, R11; EC-18742, R304)

b) Prevent inadvertent criticality by ensuring that k_{eff} is less than 0.95 under all moderation conditions for fuel of maximum expected enrichment of 5.0 weight percent, including conditions of full flooding and low water density spray mist, as might be used for fire fighting.

←(DRN 99-1097, R11; EC-18742, R304)

c) Provide sufficient cooling water to spent fuel as required during refueling.

d) Shield the spent fuel adequately to comply with the zone criteria of Section 12.3.

e) Perform their function and maintain subcriticality during safe shutdown earthquake, tornado, hurricane and flood conditions.

9.1.2.4.2 Facilities Description

The temporary fuel storage rack is located inside containment in the refueling pool.

→(EC-18742, R304)

This rack is a temporary storage location for up to five new or spent fuel assemblies during refueling. New fuel assemblies may be stored wet or dry before being transferred into the core. Fuel may be stored temporarily during fuel shuffling; spent fuel assemblies may be stored temporarily before transfer to the spent fuel pool.

←(EC-18742, R304)

The temporary fuel storage rack consists of five cavities comprised of five square stainless steel cans spaced 18 inches apart center to center in a single row. Each can measures 8.8 inches on all four sides, and the steel is 0.093 inches thick on all sides. The rack is attached to the primary shield wall. Each of the storage cavities has openings to provide cooling for stored spent fuel assemblies.

9.1.2.4.3 Safety Evaluation

→(DRN 99-1097, R11; EC-18742, R304)

The rack is designed to maintain a subcritical array with a k_{eff} of less than 0.95 when fully loaded with five assemblies of maximum enrichment (5.0 w/o U235 in UO_2). This includes moderation by both pure water flooding and by low water density spray mists as might be encountered in fire fighting. The structure of the rack assures that the minimum separation distance between fuel assemblies cannot be violated. No control element assemblies (CEAs) are assumed to be present in the fuel assemblies. Criticality analyses are summarized in Reference 1.

←(DRN 99-1097, R11)

Standoffs prevent a suspended or dropped fuel assembly from coming close enough to fuel stored in the rack to result in a k_{eff} greater than 0.95, even for maximum enrichment fuel. Nonetheless, criticality analyses were performed with a mislocated fuel assembly on the exterior of the temporary fuel storage rack, and showed that the soluble boron requirement for this accident is 359 ppm.

Eight 1-1/2 inch diameter cooling holes (two per face) are located approximately six inches below the bottom plate supporting the fuel assembly. Each spent fuel assembly will be kept sufficiently cool by natural convection cooling water flow.

←(EC-18742, R304)

Structural stresses determined by combining the dead load with OBE seismic loading do not exceed the AISC allowable stresses. Structural stresses determined by combining the dead load and SSE seismic loading do not exceed 90 percent of yield stress or critical buckling stress of materials, as applicable. The rack is designed to maintain its integrity after the impact of a fuel assembly dropped from the maximum height of fuel lift.

9.1.3 FUEL POOL SYSTEM (SPENT FUEL POOL COOLING AND CLEANUP SYSTEM)

9.1.3.1 Design Bases

The Fuel Pool System is designed to:

→(DRN 99-1097, R11; 03-2063, R14; 05-968, R14)

a) remove the decay heat produced in the fuel from 2441 discharged fuel assemblies. The nominal reactor power to determine actual decay heat produced from fuel assemblies discharged into the fuel pool is provided below:

Cycles 1 through 11	3390 MWt.
Cycles 12 and 13	3441 MWt
Cycle 14 and up to 2441 Assemblies	3716 MWt

→(DRN 99-2519, R11; EC-8477, R305)

b) remove the decay heat produced in the fuel from a full core offload placed in the spent fuel pool after reactor shutdown, in addition to the decay heat from 2,224 previously discharged fuel assemblies (approximately 23 previous refueling batches). This is conservative because there will never be more than 2,104 assemblies in storage. With one fuel pool pump operating and administrative controls in place that align the spent fuel pool cooling heat exchangers in parallel and limit the number of assemblies that may be offloaded based on time after shutdown, the maximum spent fuel pool temperature will not exceed 140°F meeting the normal maximum heat load temperature requirement. Refer to Figure 9.1-21. The fuel pool cooling loop is designed to seismic Category 1 requirements. The assumed single failure for a full core discharge is the failure of a divisional electrical bus which renders only one component cooling water pump and one fuel pool cooling pump available.

←(EC-8477, R305)

c) remove the decay heat produced in the spent fuel from approximately 108 assemblies of a core placed in the spent fuel pool after reactor shutdown in addition to the decay heat from 2,332 previously discharged assemblies (approximately 24 previous refueling batches). With one fuel pool pump operating, and administrative controls in place that limit the number of assemblies that may be offloaded based on time after shutdown, the maximum spent fuel pool water temperature will not exceed 140°F. Refer to Figure 9.1-22. The assumed single failure for a partial core discharge is the failure of a divisional electrical bus which takes out a redundant train of cooling water pumps.

←(DRN 99-1097, R11, 99-2519, R11; 05-968, R14)

d) remove soluble and insoluble foreign matter from the spent fuel pool water and dust from the pool surface through use of the purification portion of the Fuel Pool System. This maintains the fuel pool water purity and clarity, permitting visual observation of underwater operations.

e) minimize the continuous radiation dose levels in working areas around the fuel pool to less than 2.5 mrem/hr. by maintaining at least 23 ft of water over the stored spent fuel assemblies. This also ensures that the offsite dose consequences due to a postulated fuel handling accident are acceptable. To ensure the water level is maintained in the spent fuel pool, a seismic category I makeup system is provided from the condensate storage pool. A backup system is also provided with a seismic category I makeup water source, the refueling water storage pool. Also, all connections to the spent fuel storage pool are made so as to preclude the possibility of siphon draining the pool.

→(DRN 99-1097, R11)

←(DRN 03-2063, R14)

The thermal-hydraulic analysis is given in Reference 2.

←(DRN 99-1097, R11)

9.1.3.2 System Description

The piping and instrument diagram of the Fuel Pool System is shown in Drawing G169. The system process flow data is shown in Table 9.1-1.

9.1.3.2.1 Fuel Pool Cooling Loop

→ (DRN 99-1097, R11; 00-691, R11-A; EC-8477, R305)

The cooling portion of the Fuel Pool System is a closed loop system consisting of two half capacity pumps and one full capacity heat exchanger. (The backup fuel pool heat exchanger will be available for use when the fuel pool heat exchanger is out of service and may be used to supplement heat removal during core offloads.) The fuel pool water is drawn from the fuel pool near the surface and is circulated by the fuel pool pumps through the fuel pool heat exchanger, where heat is rejected to the Component Cooling Water System. From the outlet of the fuel pool heat exchanger, (and/or backup fuel pool heat exchanger), the cooled fuel pool water is returned to the fuel pool at elevation +36'6". The cooling system is controlled from the CP-2, Reactor Control Panel. Main control room alarms for high fuel pool temperature, high and low liquid level in the fuel pool, low fuel pool pump discharge header pressure and high radiation in the fuel pool area are provided to alert the operator to abnormal circumstances.

← (DRN 99-1097, R11; 00-691, R11-A; EC-8477, R305)

9.1.3.2.2 Fuel Pool Purification Loop

→ (DRN 99-1097, R11)

The clarity and purity of the water in the fuel pool, refueling cavity, and refueling water storage pool are maintained by the purification portion of the Fuel Pool System. The purification loop consists of the fuel pool purification pump, ion exchanger filter and strainers. The purification flow is drawn from the pool at elevation +40'6". A basket strainer is provided in the purification line to the pump suction to remove any relatively large particulate matter. The screen size is 1/16 in. holes. The fuel pool water is circulated by the pump through a filter which removes particulates twenty microns or smaller in size, then through an ion exchanger to remove ionic material, and finally through a wye type strainer, which prevents resin beads from entering the fuel pool in the unlikely event of ion exchanger retention element failure. A connection to the refueling water storage pool provides makeup to the fuel pool through the purification loop. In addition to purifying the spent fuel pool, the refueling water storage pool and refueling cavity are also provided with connections to the purification loop. Fuel pool water chemistry is given in Table 9.1-2.

← (DRN 99-1097, R11)

9.1.3.2.3 Component Description

The major components of the Fuel Pool System are described in this subsection. The principal component data is summarized in Table 9.1-3.

a) Fuel Pool Heat Exchanger

The fuel pool heat exchanger is a horizontal shell and tube design with a two-pass tube side. A slight pitch, three degrees above the horizontal, is provided for complete draining of the heat exchanger. The component cooling water circulates through the shell side. The internal wetted surface (tube side) is stainless steel.

b) Fuel Pool Purification Filter

The fuel pool purification filter is located upstream of the fuel pool ion exchanger to remove any particulates in the pool water. The nominal filter rating shall be 20 microns or smaller. Filters of reduced nominal rating will be used as required to maintain visual clarity in the fuel pool sufficient to verify fuel inventory. Due to possible buildup of high activity in the filter, the unit is designed and installed to provide for removal of the contaminated element assembly with remotely operated handling equipment. The filter drains to the drain collection header in the Waste Management System. The internal wetted surface is stainless steel.

c) Fuel Pool Ion Exchanger

The fuel pool ion exchanger removes ionic matter from the water. Mixed bed resin is used with the anion resin converted to the borate form and the cation resin in the hydrogen form. The units are provided with all connections required to replace resins by sluicing. The ion exchanger contains a flow distributor on the inlet to prevent channeling of the resin bed and a resin retention element on the discharge to preclude discharge of resin with the effluent. The internal wetted surface is stainless steel.

d) Fuel Pool Purification Pump Suction Strainer

The fuel pool purification pump suction strainer prevents any relatively large particulates (>1/16 in.) from entering the purification pump. The internal wetted surface is stainless steel.

e) Fuel Pool Ion Exchanger Strainer

The wye strainer removes resin fines from the purification flow. Blowdown is directed to the spent resin tank in the Waste Management System. The internal wetted surface is stainless steel.

f) Fuel Pool Pumps

There are two fuel pool pumps installed for parallel operation. Under normal operating conditions one pump is operational. The fuel pool pump(s) may be infrequently secured to allow work to be performed in the spent fuel pool or to allow maintenance to be performed on the Fuel Pool Cooling System. The pumps are provided with mechanical seals. To increase seal life and reduce maintenance, the seals are cooled by circulating a portion of the pump discharge flow to the seals which returns to the pump suction. The seals are provided with leakoff vent and drain connections. The internal wetted surface is stainless steel.

g) Fuel Pool Purification Pump

The fuel pool purification pump is used for purification and skimming operations. Mechanical seals minimize shaft leakage. To increase seal life and reduce maintenance, the seals are cooled by circulating a portion of the pump discharge flow to the seals which returns to the pump suction. The seals are provided with leakoff vent and drain connections. The internal wetted surface of the pump is stainless steel.

h) Refueling Water Pool Purification Pump

The refueling water pool purification pump takes its suction from the refueling water storage pool and discharges into the fuel pool, or back to the refueling water storage pool after passing through the fuel pool ion exchanger. Mechanical seals minimize shaft leakage. The seals are cooled by circulating a portion of the pump discharge flow to the seals which then flows to the pump suction. The internal wetted surface of the pump is stainless steel.

i) Refueling Canal Drain Pump

→ (DRN 99-1097, R11)

The refueling canal drain pump is used for draining the refueling canal, and spent fuel cask decontamination pit. This pump discharges into the fuel pool. Mechanical seals minimize shaft leakage. Seals are cooled by circulating a portion of the pump discharge flow to the seals which then flows to the pump suction. This cooling increases seal life. The internal wetted surface is stainless steel.

← (DRN 99-1097, R11)

j) Refueling Cavity Drain Pump

The refueling cavity drain pump is a non-safety, centrifugal type and horizontally mounted pump. It draws suction from the refueling cavity and discharges water to the refueling water storage pool. This operation is needed during post refueling operation when the water in the refueling cavity has to be completely drained. In case, however, the water chemistry does not permit draining of refueling cavity water directly to the RWSP, the operator has the option to first purify this water via the fuel pool ion exchanger and then discharge to the RWSP. The refueling cavity drain pump is designed to meet these requirements. The internal wetted surface of the pump is stainless steel.

→ (DRN 99-1097, R11)

k) Piping and Valves

All the piping used in the Fuel Pool System is stainless steel with welded connections throughout, except for flanged connections installed at the suction and discharge of the pumps, at strainer housings and at locations required for hydro testing.

All the valves in the Fuel Pool System are stainless steel, 150 lb. class.

l) Backup Fuel Pool Heat Exchanger

This heat exchanger is a horizontal shell and tube design with a two-pass tube side. Component Cooling Water circulates through the shell side. The internal wetted surface (tube side) is stainless steel.

← (DRN 99-1097, R11)

9.1.3.2.4 Instrumentation Requirements

9.1.3.2.4.1 Temperature Instrumentation

a) Fuel Pool Temperature

Fuel pool temperature indication is provided locally and a high temperature alarm is actuated in the main control room to warn the operator of a system malfunction.

b) Fuel Pool Heat Exchanger Inlet Temperature

Local indication of heat exchanger inlet temperature (tube side) is provided. This indication, in conjunction with the heat exchanger outlet temperature, will serve as a measure of heat exchanger performance.

c) Fuel Pool Heat Exchanger Outlet Temperature

Local indication of heat exchanger outlet temperature (tube side) is provided. This indication, in conjunction with the heat exchanger inlet temperature, will serve as a measure of heat exchanger performance.

9.1.3.2.4.2 Pressure Instrumentation

a) Fuel Pool Pump Discharge Pressure

The discharge pressure of each fuel pool pump is indicated locally.

b) Fuel Pool Pumps Discharge Header Pressure

A discharge header pressure switch for the fuel pool pumps serves to actuate a low pressure alarm in the main control room to warn the operator of system malfunction.

c) Fuel Pool Purification Pump Suction Pressure

The suction pressure of the fuel pool purification pump is indicated locally. This indication, in conjunction with the purification pump discharge pressure gage, will serve as a measure of purification pump performance.

d) Fuel Pool Purification Pump Discharge Pressure

The discharge pressure of the fuel pool purification pump is indicated locally. This indication, in conjunction with the purification pump suction pressure gage, will serve as a measure of purification pump performance.

e) Purification Filter and Combined Ion Exchanger Strainer Differential Pressure

The differential pressure of the purification filter and the combined ion exchanger and outlet strainer is indicated locally. Periodic readings of these instruments will indicate any progressive loading of the units.

f) Refueling Canal Drain Pump Discharge Pressure

The discharge pressure of the refueling canal drain pump is indicated locally.

9.1.3.2.4.3 Level Instruments

a) Fuel Pool Level

The fuel pool water level is monitored by a level switch. This switch actuates a high and a low alarm locally and in the main control room to warn the operator of a system malfunction and trips the pumps. This satisfies a requirement of Regulatory Guide 1.13 (3/71) that monitoring equipment be provided to alarm locally and in a continuously manned location if the water level in the fuel pool falls below a predetermined level.

9.1.3.3 Safety Evaluation

All connections to the spent fuel storage pool are made so as to preclude the possibility of siphon draining of the pool. Any leakage from the Fuel Pool System is detected by reduction in pool water inventory. Makeup to the spent fuel storage pool is from the seismic Category I refueling water storage pool and/or the condensate storage pool. The refueling water pool purification pump, which provides makeup from the refueling water storage pool has a capacity of 150 gpm which exceeds normal system leakage and evaporation losses. The component cooling water makeup pumps provide makeup from the condensate storage pool and have a capacity of 600 gpm, also exceeding normal system leakage and evaporation. This design satisfies the requirements of Regulatory Guide 1.13 (3/71) for a seismic Category I makeup system and backup source of makeup water. A sump, with adequate capacity, is provided to collect system leakage. A high level alarm is provided to annunciate in the main control room when a high sump level is reached.

→ (DRN 99-1097, R11; 03-2063, R14)

The failure of portions of the spent fuel pool cooling systems, or of other systems not designed to seismic Category I standards, which are located close to essential portions of the system, will not preclude essential functions. The failure mode and effects analysis is presented in Table 9.1-4. Although it is unlikely that all cooling could be lost to the spent fuel storage pool, it would take approximately 2.89 hours for the bulk pool temperature to rise from 152°F to 212°F. This is based on a full core offload discharged starting three days after reactor shutdown. The corresponding heat load is 51.5×10^6 Btu/hr. This time period allows sufficient time for the operators to intervene and line up an alternate source of replenishing the pool inventory and removing the decay heat.

← (DRN 99-1097, R11; 03-2063, R14)

9.1.3.4 Inspection and Testing Requirements

Each component is inspected and cleaned prior to installation into the system. Demineralized water is then used to flush the entire system. The system is operated and tested initially with regard to flow paths, flow capacity, and mechanical operability. Instruments are calibrated and alarm functions are checked for operability and setpoints during testing.

Data is taken periodically during normal plant operation to confirm heat transfer capabilities, purification efficiency, and component differential pressures.

In-service inspection will be performed during the plant life in accordance with ASME Code Section XI as discussed in Subsection 6.6.2.

9.1.4 FUEL HANDLING SYSTEM

9.1.4.1 Design Bases

9.1.4.1.1 System

The Fuel Handling System is designed for the handling and storage of fuel assemblies and control element assemblies (CEAS) and for the required assembly, disassembly, and storage of reactor internals. As appropriate, the fuel handling equipment includes interlocks, travel limiting features, and other protective devices to minimize the possibility of inadvertent damage to a fuel assembly and potential fission product release, resulting from either mishandling or equipment malfunction.

The refueling water provides the coolant medium during spent fuel transfer. The spent fuel pool is provided with a cooling and cleanup system which is discussed in detail in Subsection 9.1.3.

All spent fuel transfer and storage operations are designed to be conducted underwater to insure adequate shielding during refueling and to permit visual control of the operation at all times. The Fuel Handling System also provides for the disassembly, handling and reassembly of the reactor vessel closure head.

The general arrangement of the Fuel Handling System is shown in Figure 9.1-5.

9.1.4.1.2 Fuel Handling Equipment

The principle design criteria for the fuel and CEA handling equipment (refueling machine, fuel transfer equipment, spent fuel handling machine, and new fuel elevator) are as follows:

a) For nonseismic operating conditions, the bridges, trolleys, hoist units, hoisting cable, grapples and hooks conform to the requirements of Crane Manufacturing Association of America Specification #70 (1975). All other components meet the requirements of "Manual of Steel Construction", American Institute of Steel Construction, 7th Edition (1970) through Supplement 3.

b) For seismic design, the combined dead loads, live loads and seismic loads do not cause any portion of the equipment to disengage from its supports and fall into the pool. The dead weight, live and SSE seismic loadings are combined in calculating material stress.

c) Grapples and mechanical latches which carry fuel assemblies or CEAs are mechanically interlocked against inadvertent opening.

→(EC-35729, R306)

d) External fasteners and parts used in equipment over the refueling or spent fuel pool are provided with a locking mechanism or a restraint, e.g. lockwire, thread sealant, or other suitable restraint.

←(EC-35729, R306)

e) A positive mechanical stop prevents the fuel from being lifted above the minimum safe water cover depth and will not cause damage or distortion to the fuel or the refueling machine when engaged at full operating hoist speed.

f) The fuel hoists are provided with load measuring devices and interlocks to interrupt hoisting if the load increases above the overload setpoint and interrupt lowering if the load decreases below the underload setpoint.

g) In the event of loss of power, the equipment, and its load will remain in a safe condition.

h) Equipment remaining within the containment are capable of withstanding, without damage, the internal building test pressure.

i) Interlocks are provided to ensure the readiness of system components, to simplify the performance of sequential operations, and to limit travel and loads such that design conditions will not be exceeded. In no case are interlocks used to prevent inadvertent criticality or the reduction of the minimum water coverage for personnel protection. No single interlock failure results in a condition which will allow equipment malfunction damage to the fuel or the reduction of shielding water coverage. Where required, redundant switches, mechanical restraints and physical barriers are employed.

j) The fuel handling and CEA machines do not fall within the definition of an overhead or gantry crane as described in OSHA Subpart N, Materials Handling and Storage, of 29CFR1910, Section 1910.179. However, considerable importance has been attached to meeting the standards as well as operator, equipment, and facility safety.

9.1.4.1.3 Containment Polar Crane and Cask Crane

The containment polar crane is designed as a seismic Category I structure with a main hook capacity of 200 tons and an auxiliary hook capacity of 30 tons.

The primary function of the polar crane is to remove the reactor vessel head and place it in its stored position.

→(EC-14275, R306)

The Fuel Handling Building cask crane is designed as a seismic Category I structure with a main hook capacity of 125 tons and two auxiliary hooks, each with a capacity of 15 tons. The primary functions of the cask crane are to place the new fuel into the new fuel storage racks, transfer the new fuel to the new fuel elevator and move the empty or loaded spent fuel transfer casks between the cask storage area and the rail bay.

←(EC-14275, R306)

→(EC-14270, R305)

For the two cask crane auxiliary units and polar crane normal operating conditions, the bridges, trolleys, hoist units, hoisting cable, and hooks conform to the requirements of Crane Manufacturing Association of America Specification #70 (revised 1975 Edition). All other components meet the requirements of "Manual of Steel Construction", American Institute of Steel Construction (July 1970 Edition). Shop welding is in accordance with the requirements of AWS D1.1-1975 edition.

The Fuel Handling Building cask crane main trolley has been upgraded with ASME NOG-1 to meet all qualifications for a single-failure-proof crane. The upgraded crane meets the single-failure-proof criteria of NUREG 0554 and NUREG 0612 as applicable for the modification of an originally non single-failure-proof crane. The crane upgrades included a new replacement single-failure-proof main hoist & trolley designed and qualified in accordance with the appropriate requirements of ASME NOG-1. The retained cask crane bridge conforms to the requirements of Crane Manufacturing Association of America Specification #70 (revised 1975 Edition). Shop welding is in accordance with the requirements of AWS D1.1-1975 edition.

←(EC-14270, R305)

For seismic design, the combined dead loads and seismic loads do not cause any portion of the equipment to disengage from its supports. The dead loads and seismic loadings are combined in calculating material stress.

→(EC-44151, R307)
The crane assemblies and their supports are designed to safely withstand horizontal seismic loads acting simultaneously with vertical seismic loads. Vertical seismic loads are considered to act upward or downward to give the most severe combination. The acceleration coefficients are considered to act at the dead load center of gravity of the cranes and trolleys. Normal loads are defined as the dead load of crane and trolley. The bridge girder limit switch trip plate on the north end of the Fuel Handling Building crane is installed non-seismic.
←(EC-44151, R307)

All parts of both cranes are designed to resist the maximum stresses caused by any of the following conditions of loading:

a) dead load + live load + impact (15 percent of rated hook load)

b) dead load + live load + lateral thrust (10 percent of weight of loaded trolley) or longitudinal thrust (10 percent of max wheel loads)

c) rated breakdown torque of motors (275 percent of rated load)

d) collision with wheel stops

e) dead load (trolley at centerline span) + operating basis earthquake

f) dead load (trolley at centerline span) + design basis earthquake

For conditions a, b, d, and e members shall be designed in accordance with the basic allowable stresses of CMAA Spec. #70 (Revised 1975 edition).

For conditions c and f stresses shall not exceed 90 percent of the elastic limit of the material.

→(EC-14270, R305)
For a detailed description of the Cask and Polar cranes, see Subsections 9.1.4.2.2.14 and 9.1.4.2.2.15 and Tables 9.1-6 and 9.1-7.
←(EC-14270, R305)

9.1.4.2 System Description

9.1.4.2.1 System

→(EC-14275, R306)
The Fuel Handling System is an integrated system of equipment, tools and procedures for refueling the reactor. The system provides for handling and storage of fuel assemblies from receipt of new fuel to transfer of spent fuel to a dry storage cask or from a dry storage cask to the spent fuel pool. The equipment is designed to handle the spent fuel underwater from the time it leaves the reactor until it is placed in a canister for storage at the ISFSI. Underwater transfer of spent fuel provides a visually transparent radiation shield, as well as a cooling medium for removal of decay heat. Boric acid is added to the water in the quantity required to assure subcritical conditions during refueling.
←(EC-14275, R306)

The major components of the system are the dual masted refueling machine with fuel and CEA handling masts, the fuel transfer equipment and the spent fuel handling machine. The refueling machine moves fuel assemblies into and out of the core and between the core and the transfer equipment. The CEA handling mast is used to move CEAs from one fuel assembly to another. The fuel transfer equipment moves the fuel between the Reactor Building to the Fuel Handling Building through the transfer tube. The spent fuel handling machine handles fuel between the transfer equipment, the fuel storage racks in the spent fuel pool, and the spent fuel shipping cask.

Special tools and lifting rigs are also used for disassembly of reactor components and are included in the refueling system. Major tools and servicing equipment required for refueling are listed in Table 9.1-5. The major components of the Fuel Handling System are pictured in Figure 9.1-5. The seismic category and safety class are listed in Table 3.2-1.

Where possible in the design of this equipment, mechanical stops and positive locks have been provided to prevent damage to or dropping of the fuel assemblies. In the design of the refueling machine, positive locking between the grapple and the fuel assembly is provided by the engagement of the actuator arm in vertical channels in the hoist assembly. Relative rotational movement and uncoupling is not possible even with inadvertent initiation of an uncoupling signal to the actuator assembly. Therefore, failure of an electrical interlock will not result in the dropping of a fuel assembly.

➜
For the Refueling Machine, the fuel hoist will stall at a load less than the allowable fuel assembly tensile load. The CEA Hoist will stall at a load less than the combined weights of a fuel assembly, CEA, and intervening Hoist components, such as the CEA hoist box and grapple assemblies.
←

The following list identifies and defines the function of the interlocks contained in the fuel handling equipment. Visual displays are not provided to directly inform the operator that an interlock is inoperative. However, in most cases a redundant device has been provided to perform the same function as the interlock or to present information to the operator allowing him to deduce that an interlock has malfunctioned.

9.1.4.2.1.1 Refueling Machine

The following identifies and describes the functions of the key interlocks in the refueling machine.

a) Refueling Machine Hoist Interlock

➜

Interrupts hoisting of a fuel assembly or a CEA if the load increases above the overload setpoint. The hoisting load is visually displayed so that the operator can manually terminate the withdrawal operation if an overload occurs and the hoist continues to operate.

←

b) Refueling Machine Hoist Interlock

Interrupts hoisting of a fuel assembly or a CEA when the correct vertical position is reached. A mechanical up-stop has also been provided to physically restrain the hoisting of a fuel assembly or a CEA above the elevation which would result in less than the minimum shielding water coverage.

c) Refueling Machine Hoist Interlock

Interrupts insertion of a fuel assembly or CEA if the load decreases below the underload setpoint. The load is visually displayed so that the operator can manually terminate the insertion operation if an underload occurs.

d) Refueling Machine Hoist Interlock

Interrupts lowering of the hoist under a no-load condition when installing a fuel bundle or a CEA. The weighing system interlock is backed up by an independent slack cable switch which terminates lowering under a no-load condition.

e) Refueling Machine Translation Interlock

Denies translation of the bridge and trolley while the fuel or CEA hoist is operating. An additional circuit is provided which, after initiation of a hoisting operation, requires that a separate switch be actuated before normal operation of the translation drives is possible.

f) Refueling Machine Hoist Interlock

Hoisting movement is denied during translation of the bridge and/or trolley. No backup or additional circuitry is provided for this interlock.

g) Refueling Machine Translation Interlock

→(EC-5000082257, R301)

Denies motion of the bridge and trolley with the spreader extended. The underwater TV system can be used by the operator to determine whether the spreader has been raised, and a light on the control console indicates whether it is withdrawn or extended.

←(EC-5000082257, R301)

h) Refueling Machine Mast Anticollision Interlock

Stops translation of the bridge and/or trolley when collision ring on either mast is contacted and deflected.

Redundant switches are provided to minimize the possibility of this interlock becoming inoperative and slow bridge and trolley speeds are mandatory for movement of the refueling machine in areas other than its normal travel route which might contain obstructions. Travel limits also restrict running the mast into the pool wall.

i) Refueling Machine Hoist Speed Interlock

Provides restriction on maximum hoisting speed.

During insertion and withdrawal, the change in hoist speed can be monitored by observation of the hoist vertical position indicator. A change in the sound of the hoist will accompany the change in hoist speed.

→(EC-5000082257, R301)

When a fuel assembly is in a clear water area, the Refuel Machine Hoist can be operated in various speeds including maximum hoist speed.

←(EC-5000082257, R301)

j) Refueling Machine Translation Interlock

Denies translation of the bridge and trolley while they are over the core area and the upender, unless one hoist is at the up limit. Additionally, for operations between the core area and the upender, bridge and trolley translations are denied unless both hoists are at the up limit.

→(EC-5000082257, R301)

←(EC-5000082257, R301)

9.1.4.2.1.2 Transfer System

The following identifies and describes the functions of the interlocks in the transfer system.

a) Transfer System Winch Interlock

Terminates winching of the fuel carriage through the transfer tube if the load increases above the overload setpoint.

The winching load is visually displayed so that the operator can manually terminate the transfer operation if an overload occurs and the interlock fails. An overload is indicated by a light on the control panel and by an audible alarm.

b) Transfer System Winch Interlock

Prevents the winch from actuating with an upender in a vertical position. If this interlock fails and a transfer signal is initiated, winching will be terminated when the load increases above the overload setpoint.

c) Transfer System Upender Interlock

→(EC-5000082257, R301)

Rotation of the upender is denied while the refueling machine is at the upender station, unless the refueling machine hoist is at the up limit with a fuel assembly grappled or at a specified elevation with no fuel assembly grappled.

←(EC-5000082257, R301)

Failure of this interlock while the refueling machine is at the upender station will allow an upending signal by the transfer equipment operator at the station only to initiate rotation of the fuel carrier by the upender. In the event that this signal is erroneously initiated and the interlock fails while the fuel assembly is being lowered from or raised into the refueling machine, the upender will distort the fuel assembly. However, the criterion which prohibits failure of more than one fuel assembly will be met.

d) Transfer System Upender Interlock

Rotation of the upender is denied unless the fuel carrier is correctly located for upending.

Failure of this interlock: (1) with the fuel carrier in the transfer tube, allow the upender to rotate with no effect on the carrier or fuel bundle, and (2) with the fuel carrier partially in the upender, attempt to but not be successful in rotating the carrier since a mechanical lock prevents premature carrier rotation.

e) Transfer Tube Valve Interlock

Contacts are provided in the control system of the transfer system which, when connected to a limit switch on the transfer tube valve, will prevent movement of the fuel carrier unless the valve is fully opened.

If this interlock fails with the valve partially closed, the fuel carrier will contact the valve and winching will be terminated by an overload signal. No damage to the fuel assembly will result since the fuel assembly is enclosed in the carrier.

9.1.4.2.1.3 Spent Fuel Handling Machine

The following identifies and describes the functions of the interlocks in the spent fuel handling machine.

a) Spent Fuel Handling Machine Hoist Interlock

Interrupts hoisting if the load increases above the overload setpoint. Since the spent fuel handling tool is manually controlled by the operator, failure of the tool to move or reduction in tool speed as a result of an overload will be observed by the operator if the interlock becomes inoperative.

b) Spent Fuel Handling Machine Hoist Interlock

Interrupts lowering if the load decreases to cable slack.

Since the tool is manually controlled, a slack cable condition can be visually determined by the operator and lowering terminated.

c) Spent Fuel Handling Machine Translation Interlock

Provides speed restriction on bridge and trolley translation unless the load is in the full up position, at which time fast speed is allowed.

If this interlock fails, the mandatory slow speed restriction is removed. However, since the translation speed controls are infinitely variable, the operator can run at slow speed when the interlock malfunction is recognized.

d) Spent Fuel Handling Machine Translation Interlock

→

With the computer running, zone switches and encoder position feedback protect against running the load into walls or the gate of the storage area. Without the computer, only the zone switches provide the protection,

←

Zone switches protect against running the load into walls or the gate of the storage area.

No backup or additional circuitry is provided for this interlock. However, the operator has direct vision of the tool and the attached load so that translation can be terminated if an interlock fails to operate.

e) Spent Fuel Handling Machine Translation Interlock

Hoisting movement is denied during translation of the bridge and/or trolley. No backup or additional circuitry is provided for this interlock.

9.1.4.2.1.4 New Fuel Elevator

The following identifies and describes the functions of the interlocks in the new fuel elevator.

a) New Fuel Elevator Hoist Interlock

Stops the elevator motor should the cable become slack.

If this interlock fails the operator can stop the elevator motion from the spent fuel handling machine console.

b) New Fuel Elevator Hoist Interlock

Prevents raising of the elevator with a fuel assembly in the elevator box. This interlock is a backup for the administrative control which precludes the placement of a spent fuel assembly in the new fuel elevator.

9.1.4.2.2 Components

9.1.4.2.2.1 Dual Mast Refueling Machine

The refueling machine is shown in Figure 9.1-6. The refueling machine is a traveling bridge and trolley which is located above the refueling pool and rides on rails set in the concrete on each side of the refueling pool.

Motors on the bridge and trolley position the machine over each fuel assembly location within the reactor core or fuel transfer carrier. The hoist assemblies and grappling devices are raised and lowered by cables attached to the hoist winches. After a fuel assembly or CEA has been raised into the refueling machine, the refueling machine transports the fuel assembly or CEA to its designated location.

The controls for the refueling machine are mounted on a console which is located on the refueling machine trolley. Coordinate location of the bridge and trolley is indicated at the console by digital readout devices which are driven by encoders which are coupled to the guide rails through rack and pinion gears.

During withdrawal or insertion of a fuel assembly or a CEA, the load on the hoist cable is monitored at the console to assure that movement is not being restricted. Limits are such that damage to the assembly is prevented.

Locking between the grapple and the fuel assembly or the CEA is provided by the engagement of the grapple actuator arm in axial channels running the length of the fuel or CEA hoist assemblies. Therefore, it is not possible to uncouple even with inadvertent initiation of an uncoupling signal to the actuator assemblies. The drives for both the bridge and the trolley provide close control for accurate positioning, and brakes are provided to maintain the position once achieved. In addition, interlocks are installed so that movement of the refueling machine is not possible when the hoist is withdrawing or inserting a CEA or a fuel assembly. After operation of the hoist a console mounted interlock button must be actuated to allow movement of the bridge or trolley.

→(DRN 00-691)

For operations at the core, the bottom of each hoist assembly is equipped with a spreading device to align the surrounding fuel assemblies or CEAs to their normal core spacing to assure clearance for fuel assemblies being installed or removed. An anticollision device at the bottom of each mast assembly prevents damage should the mast be inadvertently driven into an obstruction, and a positive mechanical up-stop is provided to prevent a fuel assembly or a CEA from being lifted above the minimum safe water cover depth. A system of pointers and scales serves as a backup for the remote positioning readout equipment.

←(DRN 00-691)

Manually operated handwheels are provided for bridge, trolley and winch motions in the event of a power loss. Manual operation of the grappling device is also possible in the event that air pressure is lost.

9.1.4.2.2.2 Transfer Carriage

A transfer carriage as shown on Figure 9.1-5 conveys the fuel assemblies through the transfer tube. Two fuel assembly cavities are provided in the fuel carriage to reduce overall fuel handling time. After the refueling machine deposits a spent fuel bundle in the open cavity, it only has to move approximately one ft. to pick up the new fuel assembly which was brought from the Fuel Handling Building in the other cavity. The handling operation in the Fuel Handling Building is similar. The dual cavity arrangement permits both fuel handling machines to travel fully loaded at all times. Fuel assemblies are placed on the transfer carriage in a vertical position, lowered to the horizontal position, moved through the fuel transfer tube on the transfer carriage, and then restored to the vertical position.

Wheels support the carriage and allow it to roll on tracks within the transfer tube. The track sections at both ends of the transfer tube are mounted on the upending machines to permit the carriage to be properly positioned at the limits of its travel. The carriage is driven by wire rope cables connected to the carriage and through sheaves to its driving winch mounted on the operating floor of the Reactor Building.

The load in the transfer cables is displayed at the master control console. An overload will interrupt the transfer operation. Manual override of the overload cutout allows completion of the transfer. The supports for the replaceable rails on which the transfer carriage rides are welded to the 36 in. diameter transfer tube. The rail assemblies are fabricated to a length which will allow them to be lowered for installation in the transfer tube. No rails need be installed in the valve on the spent fuel pool side of the transfer tube.

9.1.4.2.2.3 Upending Machine

An upending machine as shown on Figure 9.1-5 is provided at each end of the transfer tube. Each consists of a structural support base from which is pivoted an upending straddle frame which engages the two-pocket fuel carrier. When the carriage with its fuel carrier is in position within the upending frame, the pivots for the fuel carrier and the upending frame are coincident. Hydraulic cylinders, attached to both the upending frame and the support base, rotate the fuel carrier between the vertical and horizontal position as required by the fuel transfer procedure. Each hydraulic cylinder can perform the upending operation alone and can be isolated in the event of its failure. A long tool is also provided to allow manual rotation of the fuel carrier in the event that both cylinders fail or hydraulic power is lost.

9.1.4.2.2.4 Fuel Transfer Tube and Valve

A fuel transfer tube extends through the containment wall. During reactor operation, the transfer tube is sealed by means of a blind flange located inside the containment. Prior to filling the refueling pool, the blind flange is removed. After a common water level is reached between the refueling pool and the spent fuel pool, the transfer tube valve is opened.

The procedure is reversed after refueling is completed.

The 36 in. diameter transfer tube is contained in a 48 in. diameter penetration (Figure 3.8-5) which is sealed to the containment. The transfer tube and penetration sleeves are sealed to each other by welding rings and bellows-type expansion joints.

The transfer tube valve is attached to the spent fuel pool end of transfer tube. The manual operator for the valve is designed to allow for movement of the valve due to thermal expansions and still permit operation. The valve stem extends above the spent fuel pool water level and is designed for manipulation from within the Fuel Handling Building.

9.1.4.2.2.5 Fuel Handling Tools

Two fuel handling tools, as shown on Figure 9.1-7, are used to move fuel assemblies in the spent fuel pool area. A short tool is provided for dry transfer of new fuel, and a long tool is provided for underwater handling of both spent and new fuel in the spent fuel pool. The tools are operated manually.

9.1.4.2.2.6 Reactor Vessel Head Lifting Rig

The reactor vessel head lifting rig is shown in Figure 9.1-8.

→(DRN 03-1341, R13)

The lifting rig, used in conjunction with the polar crane, is composed of a removable three-part lifting frame and a three-part column assembly which is attached to the reactor vessel closure head. The column assembly supports the six hoists for handling the hydraulic tensioners, the studs, washers and nuts. It links the lifting frame with the reactor vessel head.

←(DRN 03-1341, R13)

9.1.4.2.2.7 Reactor Internals Handling Equipment

Separate lifting rigs are used to remove either the upper guide structure or the core support barrel from the reactor vessel.

The core support barrel lifting rig, shown in Figure 9.1-9 is provided to withdraw the core support barrel from the vessel for inspection purposes. The upper clevis assembly is a tripod-shaped structure connecting the lifting rig to the polar crane lifting hook. The lifting rig includes a spreader beam providing three attachment points which are threaded to the core support barrel flange. This is accomplished manually from the refueling machine bridge. Correct positioning of the lifting rig is assured by attached guide bushings which mate to the reactor vessel guide pins. The upper guide structure lifting rig is shown in Figure 9.1-10. The lifting rig consists of the core support barrel lifting rig and a structural framework of three column assemblies providing attachment points to the tipper guide structure. Attachment to the upper guide structure is accomplished manually from the working platform. Correct positioning is assured by attached bushings which mate to the reactor vessel guide pins.

The integral in-core instrumentation hoist connects to an adapter that is manually attached to the in-core instrumentation support plate. The incore instrumentation is then lifted by the crane hook. The upper clevis assembly, which is common to this and to the core support barrel lifting rig, is installed prior to lifting of the structure by the crane hook.

9.1.4.2.2.8 Spent Fuel Handling Machine

➜
The spent fuel handling machine as shown on Figure 9.1-11 is a traveling bridge and trolley which rides on rails over the spent fuel pool, refueling canal, and cask storage area. Motors on the bridge and trolley position the machine over the spent fuel assembly storage racks, the new fuel elevator and the upending machine. An auxiliary crane is used to transfer new fuel- from the new fuel storage racks to the new fuel elevator. The spent fuel handling machine hoist assembly contains a grappling device which, when rotated by the actuator mechanism, engages the fuel assembly to be moved. Once the fuel assembly is grappled, a cable and hoist winch raise the fuel assembly. The machine then transports the fuel assembly from the upending machine to the spent fuel storage racks (spent fuel) or from the new fuel elevator to the upending machine (new fuel).
←

The controls for the spent fuel handling machine are mounted on a console which is located on the spent fuel handling machine trolley.

Coordinate location of the bridge and trolley are indicated at the console and by a pointer and target system.

During withdrawal or insertion of a fuel assembly, the load on the hoist cable is monitored to assure that movement is not being restricted. Set points are such that damage to the assembly is prevented.

Positive locking is provided between the grappling device and the fuel assembly to prevent inadvertent uncoupling. The drives for both the bridge and the trolley provide close control for accurate positioning, and brakes are provided to maintain the position once achieved. In addition, interlocks are installed so that movement of the spent fuel handling machine is not possible when the hoist is withdrawing or inserting an assembly.

Manually operated handwheels are provided for bridge, trolley and winch motions in the event of a power loss.

The spent fuel handling machine is designed to seismic Category I requirements.

9.1.4.2.2.9 New Fuel Elevator

A fuel elevator, as shown on Figure 9.1-12, is utilized to lower new fuel from the operating level at the top of the refueling canal to the bottom of the canal where it is grappled by the spent fuel handling tool. The elevator is powered by a cable winch and fuel is contained in a simple support structure whose wheels are captured in two rails. New fuel is loaded into the elevator by means of a crane and the new fuel handling tool.

9.1.4.2.2.10 Underwater Television

A closed circuit television system, as shown on Figure 9.1-13, monitors the fuel and CEA handling operations inside the containment. A camera is mounted on both the fuel and the CEA hoists so that the fuel assembly or CEA can be sighted prior to and during grappling and removal from the core.

The system may also be used to initially align the refueling machine position indication system with the actual core location of the fuel assemblies. A portable monitor is provided at the refueling machine control console. Each camera, if required for remote surveillance or inspection, can be removed from its mount and handled separately.

9.1.4.2.2.11 Fuel Sipping Equipment

A sipping system tests irradiated fuel assemblies for cladding defects. This system consists of both permanently mounted components on the refueling machine and a portable control console that is set onto the refueling machine trolley when a sipping test is to be performed.

9.1.4.2.2.12 Hydraulic Power Unit

The hydraulic power unit, as shown on Figure 9.1-16, provides the motive force for raising and lowering the upender with the fuel carrier. It consists of a stand containing a motor coupled to a hydraulic pump, a pump reservoir, valves and the necessary hoses to connect the power package to the hydraulic cylinders on the upender. The valves can be aligned to actuate either or both upender cylinders. The hydraulic fluid is demineralized water.

9.1.4.2.2.13 Refueling Pool Seal

→(DRN 02-176, R14)

A watertight permanent cavity seal ring (PCSR), as shown on Figure 9.1-17 has been installed between the reactor vessel flange and floor of the refueling pool specifically for the refueling operation. The PCSR has six hatches, which can be opened to provide access for activities within the Reactor cavity.

Double O-ring seals act against the PCSR and the removable hatches. A welded flexure ring is provided on the reactor vessel seal ledge and the refuel pool embedment ring. The flexure ring design permits relative displacement (due to a SSE) between the vessel flange and the pool floor while still maintaining a watertight seal even under a 24 ft. head of water. Provisions are made to test the seals for the removable hatches after installation and before flooding the pool.

←(DRN 02-176, R14)

→(EC-14270, R305)

←(EC-14270, R305)

9.1.4.2.2.14 Cask Crane

→(EC-14275, R306)

A 125 ton capacity cask crane is provided to handle the spent fuel transfer cask in the Fuel Handling Building. The crane transports the spent fuel cask to and from the rail bay.

←(EC-14275, R306)

→(EC-14270, R305)

The crane is provided with two control stations, an 11 button motorized station controlling the main hoist and the east and west monorail hoists, and a radio control system which controls all crane functions. Both systems are arranged so that they may be brought into the cab. The main hoist pushbutton pendant control is suspended from the bridge and supported from a motorized messenger track so that the pendant can be placed at any position along the length of the bridge. The pushbuttons are spring loaded to insure automatic return to "OFF" position when buttons are released. The radio control is such that it can be operated from any point on the operating floor.

←(EC-14270, R305)

The crane is provided with bridge and trolley track type limit switches Both track type limit switches are warning devices designed to give a warning light on the pushbutton station when traveling to within 9 in. of rail stops. The mechanical backups for the track type limit switches are the bridge bumpers and trolley chocks (bumpers).

Bridge spring bumpers are attached to each end of each truck arranged to engage crane bumper stops. The design required that they be capable of stopping the crane, traveling at full speed, with no load and power off, with a peak deceleration of 6.1 ft. per second within the maximum deflection of the springs (2 1/4 in.). The crane is provided with four compression spring chocks, one mounted on each end of each bridge girder to limit the trolley travel. The chocks are welded to the girder top plate on the outside of the rail and strike the trolley side below the wheel bearing retainer. These chocks also function as end stops after maximum spring deflection has been reached. The basis for the no load, power off design for both bridge and trolley is Paragraph 4.14 of CMAA Specification #70. Effects of swinging of the load (pendulum effect) upon sudden stopping of the crane has been evaluated.

Geared upper and lower limit switches are provided for the hoisting and lowering motions. The geared limit switches open the "HOIST" circuit when the bottom block reaches a preset upper limit and open the "LOWER" circuit when the bottom block reaches a preset lower limit. The limit switch assembly is driven by the hoist drum, and is actuated after a predetermined number of drum revolutions. The hoist limit switch automatically resets when the bottom block is lowered below the preset upper limit. In addition, the hoisting motion is restricted by a weight-operated limit switch. When the bottom block approaches its preset upper limit, it contacts the reset counterweight. Continued upper movement of the bottom block lifts the counterweight, rotating a sheave which opens the normally closed contacts of the limit switch. This stops the hoist motor and applies the motor brake.

→(EC-14270, R305)

The main hoist cable consists of 8 parts of redundantly reeved 1 5/8” diameter rope of Python super 8V EEIPS steel rope, with a minimum safety factor of 10 to 1 on the breaking strength, including static and dynamic loads.

←(EC-14270, R305)

The ropes are of sufficient length so that two full laps remain on the 42" diameter main drum at the lowest position of the hook.

→(EC-14270, R305)

←(EC-14270, R305)

A number of other existing crane features are as follows:

a) Crane Controls

→(EC-14270, R305)

The crane panels contain protective disconnect and overload devices, including the main disconnect switch (with provisions for external operation), main contactor, and control circuit fuses. The main disconnect switch is mounted on a panel in a heavy gauge sheet steel enclosure with hinged door interlocked with the main disconnect switch so that the door cannot be opened unless the switch is in the "OFF" position. The same interlock prevents the switch from being closed until the door is closed. The main contactor is reset and opened by the "START-STOP" pushbutton.

The control for the main hoist motion is by an AC Flux Vector Drive (FVD). Control of the hoist motor is accomplished by a microprocessor and feedback system via an encoder. This closed-loop system allows the control to know what the motor is doing at all times, controlling motor speed as well as output voltage and frequency. If the motor changes its operation without input from the crane control, the control can adjust its output. This comparison occurs many times per second to ensure high-precision performance and safe movement of loads.

The control for the bridge and trolley motions is by an AC Variable Frequency Drive (VFD). Control of the traverse motors is accomplished by a microprocessor and the referenced motor parameters. This open-loop system allows the control to monitor and make adjustments to the motor speed, by controlling output voltage and frequency. This comparison occurs many times per second to ensure high-precision performance and safe movement of loads

The FVD and VFD control circuitry is packaged in a cabinet on the bridge which is designed to provide protection against shock, vibration, and severe environments.

←(EC-14270, R305)

All control and resistor wiring and all festoon and pendant cables are capable of passing the flame test as specified in IEEE 383-1974.

b) Crane Drive Assemblies:

→(EC-14270, R305)

Bridge is driven by means of two (2) 7 1/2 HP electric motors mounted on the crane girder and each is connected through shafting and gearing to one of the wheels on the end truck. The driving and control mechanism is so designed and constructed that the crane shall not get out of line and the travel will be steady and free from vibration or rocking in any part of the structure while operating under any specified conditions.

←(EC-14270, R305)

→(EC-14270, R305)

The trolley is driven to two 3 HP electric motors mounted on the trolley frame and each is connected to one drive wheel on each side of the trolley through gearing. Each trolley motor is mounted to a driving wheel.

←(EC-14270, R305)

c) Crane Motion:

The crane is capable of raising, lowering, holding in any position and transporting a proof test load of 125 percent of rated load without damage or distortion to any crane part. The crane and each hoist will operate within the following tolerances:

1) With hook carrying 100 percent of rated load with all hoist brakes properly adjusted and operating normally, it will be possible to control the vertical movement within 1/4 in. When in the inching mode, the auxiliary hooks can be controlled within 3/4 in.

2) Motion of the bridge and trolley will be controllable to within 1/4 in. under all conditions of loading.

The crane motions, have the following maximum speeds at capacity loads:

→(EC-14270, R305)

a) Main hook hoisting – 5.0 ft./min.

b) Auxiliary monorail hook hoisting - 25 ft./min.

c) Bridge travel 50 ft./min.

d) Trolley travel 50 ft./min.

←(EC-14270, R305)

d) Crane Braking System:

1) Bridge Travel: Electrically released, spring-set, friction shoe type brake with capacity at least equal to full operating torque of the bridge drive. The brake will operate when motor controller is in "OFF" position, when main power supply switch is in "OFF" position, or in the event of power failure.

2) Trolley Travel: Electrically released, spring-set, friction shoe type brake with capacity at least equal to full operating torque of the trolley drive. The brake will operate when motor controller is in "OFF" position, when main power supply switch is in "OFF" position, or in the event of power failure.

→(EC-14270, R305)

The main hoist has two electric stopping and holding brakes each of which is capable of holding the load by itself and one electrical hoist control device. Electric stopping and holding brakes will operate automatically and be of the electrically released, spring-set friction shoe type, capable of stopping and holding 1.5 times the full rated load when the power is off. The electric hoist control device is a Magnetorque which is connected to the main hoist cross shaft. It will be capable of controlling the lowering speed under all conditions with up to 1.5 times the rated load on hook. No lowering of load shall occur unless power is applied to the hoist motor in a lowering direction.

←(EC-14270, R305)

Each auxiliary hoist has one electric stopping and holding brake, one mechanical load brake. Electric stopping and holding brake will operate automatically and be of a disc type, capable of stopping and holding 1.5 times the full rated load when the power is off. Mechanical load brake is an automatic control device of a disc type, capable of controlling the lowering speed under all conditions with up to 1.5 times the rated load on hook. No lowering of load shall occur unless power is applied to the hoist motor in a lowering direction.

The dynamic loading effect produced by the deceleration action of the two main hoist brakes is well within the capacity of the load carrying system. This effect represents a small fraction of the impact considered in the girder design.

→(EC-14270, R305)
The trolley has been designed with single failure proof features and has been analyzed to ASME NOG-1 standards for single failure proof cranes. The trolley provides redundant protection against postulated accidents, even during a seismic event. A seismic analysis determined the crane will not drop a Maximum Critical Load on the main hook during an OBE or an SSE. The crane control system is a fail-safe design and safety features are common mode and single failure proof in mitigating postulated accidents.
←(EC-14270, R305)

→(DRN 00-691, R11-A)
9.1.4.2.2.15 Polar Crane

A 200/30 ton reactor circular bridge crane on a 136'-4" diameter (center to center of 171 lb. rails) is used inside containment to facilitate construction, to remove the reactor head during refueling and to remove or replace various equipment during construction. The crane is inactive during normal plant operation and therefore cannot affect the safe shutdown capability of the plant.
←(DRN 00-691, R11-A)
The pushbutton pendant controlling the bridge, trolley and hoist movements is suspended from the bridge to the operating floor and is supported from a motorized messenger track so that the pendant cable can be placed anywhere along the length of the bridge. The pushbuttons are spring loaded to insure an automatic return to the "OFF" position when the buttons are released.

Weight operated limit switches are provided for the hoisting motions. When the bottom block approaches its preset upper limit, it contacts the reset counterweight. Continued upper movement of the bottom block lifts the counterweight, rotating a sheave which opens the normally closed contacts of the limit switch. This stops the hoist motor and applies the motor brake.

The hoist motor has its torque limited to about 275 percent, i.e., a torque corresponding to a design factor of 2.75. When this torque is reached the motor's electrical system is tripped and the brakes engage automatically.

An electronic load indicating device is provided in the bottom block for the main hook. This device is an integral part of the equipment. This device incorporates both high and low load alarms. The load readout is at the pendant control. A hydraulic load indicating and positioning device between the main hook and the reactor head may be used during refueling to provide precise control of linear load movement to within .001 in., and load indication and control up to 250 tons with an accuracy of 0.5 of one percent.

The trolley is provided with track type limit switches which are warning devices designed to give a warning light on the pushbutton station when traveling to within nine inches of rail stops. The mechanical backup for the track type limit switches are the four compression spring chocks, one mounted on each end of each bridge girder to limit the trolley travel. The chocks are welded to the girder top plate on the outside of the rail and strike the trolley side below the wheel bearing retainer. These chocks also function as end stops after maximum spring deflection has been reached.

The main hoist cable consists of 14 parts of 1 3/8" diam. ropes of extra flexible steel rope with a steel center having a minimum of six strands of 37 wires per strand with a factor of safety of 6.8 (breaking strength).

The ropes are of sufficient length so that two full laps remain on the 42" diameter main drum at the lowest position of the hook.

The double reeving arrangement of the hoist ropes is connected to the main drum with clamps having a minimum strength equal to that of the rope.

All trolley components including the drum mounts and sheave housing are designed for angular pulling of the hoist ropes.

A number of other existing crane features are as follows:

a) Crane Controls

The crane panels contain protective disconnect and overload devices, including the main disconnect switch (with provisions for external operation), main contactor, overload relays for each motor circuit, and control circuit fuses. The main disconnect switch is mounted on a panel in a heavy gauge sheet steel enclosure with hinged door interlocked with the main disconnect switch so that the door cannot be opened unless the switch is in the "OFF" position. The same interlock prevents the switch from being closed until the door is closed. The main contactor is reset and opened by the "START-STOP" pushbutton.

The control for the main hoist is AC Static Stepless providing variable speed control over the full range of hoisting and lowering speeds. Control of the motor speed is accomplished by the comparison of a "reference" signal, representing the desired speed, and a "feedback" signal, representing the actual speed. The resultant "error" causes the control system to call for motoring or braking, depending on the polarity of the error, and the motor runs at the desired speed as called for by the operator. Returning the master controller to the "OFF" position reduces the motor reactor current to zero and simultaneously causes the electric load brake to exert maximum torque. Thus, the motor is stopped by the load brake prior to the setting of the motor brake, thereby preventing overheating and excessive motor brake lining wear.

The static control circuitry is packaged in compact functional modules which are designed to provide protection against shock, vibration, and severe environments.

The control for the bridge and trolley motions is AC Static Stepless reversing Plugging providing variable regulated torque control for traverse motions. Control of acceleration is accomplished by the comparison of a variable output induction master reference signal with a torque feedback signal, producing an error signal which controls the supply current to reactors in the motor secondary circuitry. The end result is that the motion rate of acceleration or deceleration is proportionally controlled by the operator.

All control and resistor wiring and all festoon and pendant cables are capable of passing the flame test as specified in IEEE-383.

b) Crane Drive Assemblies:

Bridge is driven by means of two (2) 7 1/2 HP electric motors mounted on the crane girder and connected through shafting and gearing to at least one of the wheels on each truck. The driving and control mechanism is so designed and constructed that the crane shall not get out of line and the travel will be steady and free from vibration or rocking in any part of the structure while operating under any specified conditions.

The trolley is driven by two (2) 3 HP electric motors mounted on the trolley frame and connected to at least one driving wheel on each side of the trolley through gearing and shafting of a driver axle.

c) Crane Motion:

The crane is capable of raising, lowering, holding in any position and transporting a proof test load of 125 percent of rated load without damage or distortion of any crane part. The crane and each hoist will operate within the following tolerances:

1) With hook carrying 100 percent of rated load with all hoist brakes properly adjusted and operating normally, it will be possible to control the vertical movement to within 1/8 in.

2) Motion of the bridge and trolley will be controllable to within 1/4 in. under all conditions of loading.

The crane motions, have the following maximum speeds at capacity loads:

a) Main hook hoisting - 5 ft./min.

b) Auxiliary monorail hook hoisting - 30 ft./min.

c) Bridge travel 55 ft./min. -

→(DRN 06-843, R15)

d) Trolley travel 30 ft./min. -

←(DRN 06-843, R15)

d) Crane Braking System:

1) Bridge Travel: Electrically released, spring-set, friction shoe type break with capacity at least equal to full operating torque of the bridge drive. The brake will operate when motor controller is in "OFF" position, when main power supply switch is in "OFF" position, or in the event of power failure.

2) Trolley Travel: Electrically released, spring-set, friction shoe type brake with capacity at least equal to full operating torque of the trolley drive. The brake will operate when motor controller is in "OFF" position, when main power supply switch is in "OFF" position, or in the event of power failure.

All hoists have two electric stopping and holding brakes each of which is capable of holding the load by itself and one electrical hoist control device. Electric stopping and holding brakes for main and auxiliary hoists will operate automatically and be of the electrically released, spring-set friction-shoe type, capable of stopping and holding 1.5 times the full rated load when the power is off. Electrical hoist control devices are of the eddy current type. They will be capable of controlling the lowering speed under all conditions with up to 1.5 times the rated load on hook. No lowering of load shall occur unless power is applied to the hoist motor in a lowering direction.

The dynamic loading effect produced by the deceleration action of the two main hoist brakes is well within the capacity of the load carrying system. This effect represents a small fraction of the impact considered in the girder design.

Redundant crane controls and safety features are not generally provided. However, diverse safety features do provide redundant protection against postulated accidents. (Even though the crane hoisting system incorporates two brakes, they are subject to common mode failure, e.g., cable failure and are not considered here). For this reason, single active failure analysis cannot be applied to these features. The crane control system is a fail-safe design and safety features are common mode and single failure proof in mitigating postulated accidents.

→(DRN 00-691, R11-A)

9.1.4.2.2.16 Control of Heavy Loads Requirements

←(DRN 00-691, R11-A)

→(EC-11204, R303)

NUREG 0612, "Control of Heavy Loads at Nuclear Power Plants" contains the NRC guidance to ensure that load handling systems are designed and operated such that their probability of failure is low and appropriate for the critical tasks in which they are employed. Waterford 3 has identified the containment polar crane and the fuel handling building cask crane as falling under the guidelines of NUREG 0612, and has implemented the NUREG 0612 Phase I guidance for these systems. In Supplement 6 to the Waterford 3 SER (Section 9.1.4 and Appendix 1) the NRC concluded that the Phase I requirements of NUREG 0612 had been satisfied for Waterford 3 with exceptions as noted in Technical Evaluation Report (TER) attached to Safety Evaluation for Phase 1. In a May 6, 1986 letter the NRC further concluded that, consistent with NUREG 0612 and Generic Letter 85-11, the issue of heavy loads handling was complete.

The safety basis that ensures that the risk associated with load-handling failures is acceptably low is based on: (1) meeting the phase 1 requirements of NUREG 0612, Section 5.1.1 (See TER) and (2) a load drop analysis that demonstrates the fuel remains covered and cooled.

NUREG 0612, Section 5.1.1, commonly known as Phase I, consists of seven elements that must be met for handling heavy loads that could be brought in proximity to or over safe shutdown equipment or irradiated fuel in the spent fuel pool area or containment:

1. Definition of safe load paths
2. Development of load handling procedures
3. Qualifications, training, and specified conduct of crane operators

←(EC-11204, R303)

→(EC-11204, R303)

4. Special lifting devices should satisfy the guidelines of American National Standards Institute (ANSI) N14.6-1978
5. Lifting devices that are not specifically designed should be installed and used in accordance with guidelines of ANSI B30.9
6. Periodic inspection and testing of cranes
7. Design of cranes to ANSI B30.2 or CMAA-70

Safe loads paths are defined and controlled as specified in administrative and refueling procedural guidance. Load handling procedures maintain assumptions from load drop analysis and comply with commitments from NUREG-0612. Crane operators are trained, qualified and conduct themselves in accordance with Chapter 2-3 of American National Standards Institute (ANSI) B30.2-1976, "Overhead and Gantry Cranes." Special lifting devices satisfy the guidelines of ANSI N14.6-1978 with detailed clarification as provided in Technical Evaluation Report attached to NRC Safety Evaluation for Phase I. Non-specifically design lifting devices are installed and used in accordance with the guidelines of ANSI B30.9 with detailed clarification as provided in Technical Evaluation Report attached to NRC Safety Evaluation for Phase I. Cranes for critical lifts are inspected and tested in accordance with Chapter 2-2 of ASME B30.2-1976 with detailed clarification as provided in Technical Evaluation Report attached to NRC Safety Evaluation for Phase I. Cranes used for critical lifts meeting the applicable criteria and guidelines of ASME B30.2-1 and CMAA-70 with detailed clarification as provided in Technical Evaluation Report attached to NRC Safety Evaluation for Phase I.

To control Reactor Pressure Vessel Head lifts, refueling procedural controls are used to control the lift and replacement of the reactor pressure vessel head. These procedural controls establish limits on load height, load weight, and medium present under the load. These procedural controls: (1) use the guidance and acceptance criteria in NEI 08-05 Industry Initiative on Control of Heavy Loads [refer to Engineering Report WF3-CS-08-00001]; and (2) provide additional assurance that the core will remain covered and cooled in the event of a postulated reactor pressure vessel head drop. For reactor Pressure Vessel Head lifts, a load drop analysis assumes a head drop of 17 feet through air onto the reactor vessel with a maximum weight of 387,000 pounds. Refueling procedural controls ensure compliance with load drop analysis assumptions.

←(EC-11204, R303)

9.1.4.2.3 System Operation

9.1.4.2.3.1 New Fuel Transfer

→(DRN 00-691, R11-A)

To transfer new fuel from the shipping container, the container covers are removed. The fuel assembly strongback is then raised and locked in the vertical position. The short handling tool, attached to the overhead crane, is then locked to the fuel assembly, the fuel assembly clamping fixtures removed and the fuel assembly moved from the shipping container. Any protective wrapping is removed and the fuel assembly is moved over to the new fuel elevator (or new fuel storage racks). The tool is unlocked from the assembly and the new fuel elevator lowers the fuel assembly.

←(DRN 00-691, R11-A)

New fuel stored in the new fuel storage racks is transferred to the new fuel elevator using the cask crane and the short fuel handling tool. The cask handling crane clearance is shown in Figures 9.1-18 and 9.1-19.

During reactor refueling operations, new fuel is removed from the storage racks using the spent fuel handling machine to transfer the fuel assembly to the upending mechanism. Interlocks prevent the spent fuel handling machine from lowering the fuel assembly unless the upender is in the vertical position. Once in the upending mechanism, a spent fuel assembly is removed from the other position in the fuel carrier and transferred to a designated position in the spent fuel storage racks.

9.1.4.2.3.2 Spent Fuel Transfer

→(EC-14275, R306)

The spent fuel handling machine transfers the assemblies from the storage racks to the spent fuel transfer cask. The cask loading area is connected to the pool by a gate sized to allow passage of the spent fuel handling machine with a fuel element attached. The spent fuel transfer cask arrives in a specially built low profile transporter at the loading area which is serviced by an overhead cask handling crane. The main hoist of the crane transfers the cask to the cask decontamination area.

The spent fuel transfer cask is only handled using the single-failure-proof main hook on the cask handling crane as part of a single-failure-proof handling system, and thus a drop of a spent fuel transfer cask is not credible.

After the fuel transfer cask is serviced and washed, it is transferred to the spent fuel cask storage area. Positioning the fuel transfer cask into the cask storage area is a two-step hoisting operation. The first hoisting step sets the cask on a variable elevation cask staging pedestal (VECASP). The second hoisting step lowers the fuel transfer cask to the bottom of the VECASP in the cask loading pit.

→(EC-14270, R305)

The spent fuel assemblies are then transferred underwater and loaded into the fuel canister located within the transfer cask using the spent fuel handling machine. Removal of the fuel transfer cask is accomplished by the single-failure-proof main hook on the cask crane.

←(EC-14270, R305)

The loaded cask is moved to the cask decontamination area where radioactive material and residual coolant are removed. The canister containing the spent fuel assemblies is vacuum dried, backfilled with helium and welded shut. After the cask decontamination and canister sealing are complete, the spent fuel transfer cask is moved to the rail bay where the canister containing the spent fuel assemblies is lowered into a fuel storage cask that is transported to a concrete pad for storage.

→(DRN 02-220, R11-A)

←(DRN 02-220, R11-A)

←(EC-14275, R306)

9.1.4.2.3.3 Refueling Procedure

→(DRN 02-176, R14)

During the cooldown, preparations are begun for the refueling operation. Refueling operations are initiated with the removal of the missile shield from over the reactor. The control element drive mechanisms (CEDMS) are disengaged from their drive shaft extensions by deenergizing the electromagnets, and the mechanism cabling is disconnected in preparation for head removal. The stud tensioners are employed to remove the preload on the vessel head studs. The nuts and studs are removed and plugs are installed to prevent refueling water from filling the empty stud holes. Two head alignment pins are inserted to assist in subsequent operations. The CEDM cooling shroud is disconnected from its duct work and the vessel vent line removed. The reactor vessel flange is permanently sealed to the bottom of the pool by means of the refueling pool seal ring with removable hatches. The removable hatches are installed on the seal ring and leak tested to preclude water from entering the lower portion of the reactor vessel cavity. The reactor head lifting rig is then installed on the head assembly, and by means of the polar crane, the head is removed to its storage location. The polar crane clearance is shown in Figure 9.1-20. Equipment laydown areas inside the containment are shown in Figure 1.2-17.

←(DRN 02-176, R14)

During reactor operation, the transfer tube is closed by a manually operated valve in the fuel pool and a double-gasketed blind flange inside the containment. The flange is removed and the pool is filled with borated water. After a common water level is reached, the transfer tube valve is opened preparatory to refueling.

Provision is made in the refueling pool for the temporary storage of the upper guide structure. After this is removed from the vessel, the refueling machine hoist mechanism is positioned to the desired location over the core. Alignment of the hoist to the top of the fuel assembly is accomplished through the use of a digital readout system and is monitored by closed circuit television. After the fuel hoist is lowered, minor adjustments can be made to properly position the hoist if misalignment is indicated on the monitor. The operator then energizes the actuator assembly which rotates the grapple at the bottom of the hoist and locks the fuel assembly to the hoist. The hoist motor is started and the fuel assembly withdrawn into the fuel hoist box assembly so that the fuel is protected during transportation to the fuel upender. The grapple is designed to preclude inadvertent disengagement as the fuel assembly is lifted vertically from the core. When the fuel has been withdrawn from the grapple zone, positive locking between the grapple and the fuel assembly is established so that uncoupling is prevented even in the event of inadvertent initiation of an uncoupling signal to the assembly. After removal from the core, the spent fuel assembly is moved underwater to the transfer area of the pool. The spent fuel assembly is lowered into the transfer carriage in the refueling pool. If the fuel assembly contains a control element assembly, the CEA hoist mast, transfers the control element assembly to a new fuel assembly.

The new fuel assembly is removed from the carriage and moved to the reactor as the upending machine lowers the spent fuel assembly to the horizontal position after which a cable drive transports the carriage on tracks through the transfer tube into the spent fuel pool.

Once received in the spent fuel pool, another upending machine returns the transfer carrier to the vertical position. The spent fuel handling machine transfers a new fuel assembly to the transfer carriage and then removes the spent fuel assembly from the transfer carriage and transports it to the spent fuel rack. The new fuel assembly is carried through the transfer tube to the refueling pool where the refueling machine picks it up and places it in its proper position in the core. The refueling machine is also used to shuffle fuel and CEAs within the core in accordance with the fuel management scheme.

Wet sipping of fuel assemblies can be conducted, if required, during normal fuel handling operations.

→(DRN 02-176, R14)

At the completion of the refueling operation, the transfer valve is manually closed. The upper guide structure is reinserted in the vessel and the incore instrumentation placed in position. The drive shaft extensions are reconnected to the CEAS. The water in the refueling pool is lowered. The head is then lowered until the drive shaft extensions are engaged by the CEDMS. Lowering of the head is continued until it is seated. Then the studs are installed and the head is bolted down, and the transfer tube blind flange installed. The hatches in the permanent refueling pool seal between the reactor vessel flange and the pool are removed. CEDM and in-core instrument cabling is reconnected. The cooling ducts are reconnected to the shroud, the vessel vent piping installed, and the missile shield placed in position.

←(DRN 02-176, R14)

9.1.4.3 Safety Evaluation

The Fuel Pool System and the Fuel Handling System are designed to meet the intent of Regulatory Guide 1.13 (March 1971),with the following clarification:

Regulatory Position	Comment
C.4	During refueling, the normal ventilation system (no filters) in the Fuel Handling Building is operating. Leakage is suitably controlled by automatic actuations of the emergency system should high airborne radiation occur.

9.1.4.3.1 Cask Handling

→(EC-14275, R306)

The leaktight partition wall between the fuel cask handling area and the spent fuel storage area will ensure that the spent fuel racks remain covered with water if the cask handling area empties completely. The portion of the slab in the spent fuel cask storage area is structurally independent of the spent fuel storage pool slab. Therefore, the impact of the transfer cask on the cask storage area slab will have no detrimental structural effect on the independent fuel storage pool slab. To preclude possibility of damage to the spent fuel storage area which could affect its water tightness, an electrical interlock system is provided; the restricted zone limit switch devices and logic will preclude crane entrance to subject zone pending location of trolley, so that the main hoist hook cannot carry a transfer cask such that any part of the cask is over the spent fuel storage area or partition wall. Transfer cask handling will occur only using a single-failure-proof main hook on the cask handling crane, and thus a drop of a transfer cask is not credible.

←(EC-14275, R306)

Safety features of the crane include the following:

→(EC-14270, R305)

a) Main hoist ropes will have a factor of safety of ten and auxiliary hoist ropes will have a factor of safety of six based on rated load and efficiency of lifting tackle but excluding impact load.

←(EC-14270, R305)

b) All parts subject to dynamic strains such as gears, shafts, drums, blocks, and other integral parts will have a factor of safety of five.

c) Bending stress combined with torsional stress in pins and axles shall not exceed 20 percent of the yield stress of material used.

d) Normal torsional deflection in bridge drive shaft will be limited to 0.03 degrees per ft. at two thirds of rated motor torque or a total movement at wheel circumference of 0.5 in., whichever is more restrictive.

9.1.4.3.2 Fuel Handling

A failure mode analysis is not required.

The results of the safety analysis (Chapter 15) demonstrate that applicable dose limits are not exceeded as a result of the design basis fuel handling accident. No credit is taken for components or subsystems of the fuel handling equipment to either prevent or mitigate the consequences of the postulated accident.

Direct communication between the main control room and the refueling machine console is available whenever changes in core geometry are taking place. This provision allows the control room operator to inform the refueling machine operator of any impending unsafe condition detected from the main control board indicators during fuel movement.

Operability of the fuel handling equipment including the bridge and trolley, the lifting mechanisms, the upending machines, the transfer carriage, and the associated instrumentation and controls is assured through the implementation of preoperational tests. Prior to the fuel loading, the equipment is cycled through its operations using dummy fuel. In addition to the interlocks described in Subsection 9.1.4.2.1, the equipment has the following special features:

a) The major components of the Fuel Handling System are electrically interlocked with each other to assist the operator in properly conducting the fuel handling operation. Failure of any of these interlocks in the event of operator error will not result in damage to more than one fuel assembly. The radiological consequences associated with the activity release from an assembly are discussed in Section 15.7.

b) Miscellaneous special design features which facilitate handling operations include: backup hand operation of the refueling machine hoists in the event of power failure; a dual wound transfer system motor to permit applying an increased pull on the transfer carriage in the event it becomes stuck; a viewing port in the refueling machine trolley deck to provide visual access to the reactor for the operator; electronic and visual indication of the refueling machine position over the core; a protective shroud into which a fuel assembly or CEA is drawn by the refueling machine; transfer system upenders manual operation by a special tool in the event that the hydraulic system becomes inoperative.

c) The fuel transfer tube is sufficiently large to provide natural circulation cooling of fuel assembly in the unlikely event that the transfer carriage should be stopped in the tube. The manual operator for the fuel transfer tube valve extends from the valve to the operating deck. Also, the valve operator has enough flexibility to allow for operation of the valve even with thermal expansion of the fuel transfer tube.

d) Travel stops in both the refueling and spent fuel handling machines restrict withdrawal of the spent fuel assemblies. This results in the maintenance of a minimum water cover of nine ft. over the active portion of the fuel assembly. The combined shielding effects of the water and handling tools results in a radiation level of 2.5 mr/hr. or less at the surface of the water. The depth of water surrounding the fuel transfer canal, transfer tube and spent fuel storage pool is sufficient to limit the maximum continuous radiation levels in working areas to 2.5 mr/hr.

9.1.4.4 Testing and Inspection Requirements

During manufacture at the vendor's plant, various in-process inspections and checks are required including certification of materials and heat treating, and liquid-penetrant or magnetic-particle inspection of critical welds. Following completion of manufacture, compliance with design and specification requirements is determined by assembling and testing the equipment in the vendor's shop. Utilizing a dummy fuel assembly having the same weight, center of gravity, exterior size and end geometry as an actual assembly, all equipment is run through several complete operational cycles. In addition, the equipment is checked for its ability to perform under the maximum limits of load, fuel mislocation and misalignment. All traversing mechanisms are tested for speed and positioning accuracy. All hoisting equipment is tested for vertical functions and controls, rotation, and load misalignment.

→(EC-35729, R306)
Hoisting equipment is also tested to 125 percent of specified hoist capacity. Set points are determined and adjusted and the adjustment limits are verified. Equipment interlock function, and backup systems operations are checked. Those functions having manual operation capability are exercised manually. During these tests, the various operating parameters such as motor speed, voltage, and current, hydraulic system pressures, and load measuring accuracy and set points are recorded. At the completion of these tests the equipment is checked for cleanliness and foreign material exclusion issues.
←(EC-35729, R306)

Equipment installation and testing at the plant site is controlled by approved installation procedures and preoperational test procedures designed to verify conformance with specification. Each component is inspected and cleaned prior to installation into the system. Recommended maintenance, including any necessary adjustments and calibrations, is performed prior to equipment operation at each refueling. Preoperational tests also include checks of all control circuits including interlocks and alarm functions.

9.1.4.5 Instrumentation Requirements

The refueling system instrumentation and controls are described in Subsection 9.1.4.2. No credit is taken for instrumentation or interlocks on components of the fuel handling equipment to either prevent or mitigate the consequences of the postulated accident. Therefore, the interlocks described above are not safety related.

→(EC-14275, R306)
9.1.5 SPENT FUEL DRY CASK STORAGE

WF3 has established an Independent Spent Fuel Storage Installation (ISFSI) located directly south of the four water storage tanks and just west of the switchyard area. The ISFSI concrete pad has a capacity for 72 vertical spent fuel storage casks. The PA security fence encompasses the ISFSI site, with 20 ft isolation zones along the inside and outside of the fence. An entrance gate provides for vertical cask transporter (VCT) access to the ISFSI pad, and a man gate is in the fence between the plant and ISFSI areas. The ISFSI is inside the plant protected area.

The Spent Fuel Dry Cask Storage operations at WF3 will be conducted under a general license in accordance with Subpart K of 10 CFR Part 72. The general license issued by 10 CFR 72.210, “General license issued,” authorizes a 10 CFR Part 50 nuclear power plant licensee to store spent fuel at an onsite ISFSI. Subpart K of 10 CFR Part 72 also includes 10 CFR 72.212, “Conditions of general license issued under §72.210,” which requires the use of a dry cask storage system that is pre-approved by the Nuclear Regulatory Commission, as evidenced by its listing in 10 CFR 72.214.
←(EC-14275, R306)

→(EC-14275, R306)

The WF3 ISFSI uses the Holtec HI-STORM 100S Version B vertical cask storage overpack and the Holtec MPC-32 multi-purpose canister (MPC), as described in the HISTORM 100 Cask System FSAR (Reference 8) and approved by the Nuclear Regulatory Commission via the HI-STORM Certificate of Compliance No. 1014 (Reference 9).

The MPC provides the confinement boundary for the stored fuel. The MPC is a welded, cylindrical canister with a honeycombed fuel basket. All MPC confinement boundary components are made entirely of stainless steel. The honeycombed basket, which is equipped with neutron absorbers, provides criticality control.

The HI-STORM 100S Version B storage overpack provides shielding and structural protection of the MPC during storage. The HI-STORM 100S Version B overpack design includes a lid which incorporates the air outlet ducts into the lid. The overpack is a heavy-walled steel and concrete, cylindrical vessel. Its side wall consists of plain (unreinforced) concrete that is enclosed between inner and outer carbon steel shells. The overpack has four air inlets at the bottom and four air outlets at the top to allow air to circulate naturally through the cavity to cool the MPC inside. The inner shell has supports attached to its interior surface to guide the MPC during insertion and removal, and allow cooling air to circulate through the overpack. A loaded MPC is stored within the HI-STORM 100S Version B storage overpack in a vertical orientation.

←(EC-14275, R306)

Section 9.1: REFERENCES

→(DRN 99-1097, R11; 05-1365, R14-A; EC-5000082411, R301; EC-18742, R304)

1. Licensing Report for Waterford Unit 3 Spent Fuel Pool Criticality Analysis by Holtec International, Holtec Report HI-2094376, Rev. 0, June 24, 2009.

←(DRN 05-1365, R14-A; EC-5000082411, R301; EC-18742, R304)

→(EC-8477, R305)

2. Not used.

←(DRN 99-1097, R11; EC-8477, R305)

→(DRN 99-2519, R11)

3. Letter to U.S. Nuclear Regulatory Commission, “Withdrawal of January 22, 1999 Letter Providing Additional Information Regarding License Amendment No. 144”, July 23, 1999, Letter No. W3F1-99-0118.

←(DRN 99-2519, R11)

→(EC-5000082411, R301; EC-18742, R304)

4. Letter to U.S. NRC Document Control Desk, “Response Request for Additional Information RAI #2 …,” W3F1-2009-0022, June 20, 2009.

5. Criticality Safety Evaluation of the Waterford Unit 3 New Fuel Storage Vault by Holtec International, Holtec Report HI-2083974, Rev. 2, June 24, 2009.

←(EC-5000082411, R301; EC-18742, R304)

→(EC-8884, R303)

6. Seismic/Structural Analysis of Waterford 3 Spent Fuel Racks by Holtec International, Holtec Report HI-971606, Calculation EC-C98-009.

7. Fuel Assembly Drop Accident Analysis for Waterford-3 Spent Fuel Pool, Holtec Report HI-961595, Calculation EC-C98-005.

←(EC-8884, R303)

→(EC-8477, R305)

8. Limiting Single Failure Thermal Hydraulic Analysis of Waterford 3 Spent Fuel Pool, Calculation ECM98-067.

←(EC-8477, R305)

→(EC-14275, R306)

9. Holtec International Final Safety Analysis Report for the HI-STORM 100 Cask System, Revision No. 7, USNRC Docket No. 72-1014, Holtec Report No.: HI-2002444, August 6, 2008.

10. USNRC Certificate of Compliance No. 1014, Docket No. 72-1014, Amendment No. 5, for the HI-STORM 100 Cask System, July 14, 2008.

←(EC-14275, R306)

TABLE 9.1-1 Revision 305 (11/11)

FUEL POOL SYSTEM PROCESS FLOW DATA

→(EC-8477, R305)

Fuel Pool Cooling With One Fuel Pool Cooling Pump Running (Parallel Heat Exchangers)

FPS Location*	1	2	3	4	5	6	7
Flow (gpm)	2786	2786	2786	-	-	-	-
Press. (psig)	12	23	16	-	-	-	-
Temp. (F)	130	130	100	-	-	-	-

Fuel Pool Cooling With Two Fuel Pool Cooling Pumps Running (Parallel Heat Exchangers)

FPS Location*	1	2	3	4	5	6	7
Flow (gpm)	4523	4523	4523	-	-	-	-
Press. (psig)	10	35	18	-	-	-	-
Temp. (F)	132	132	109	-	-	-	-

Normal Purification

FPS Location*	1	2	3	4	5	6	7
Flow (gpm)	-	-	-	150	150	150	150
Press. (psig)	-	-	-	11	78	50	3
Temp. (F)	-	-	-	120	120	120	120

←(EC-8477, R305)

* Refer to Drawing G169 for location of process flow points.

TABLE 9.1-2 Revision 304 (06/10)

REFUELING AND SPENT FUEL POOL WATER CHEMISTRY

		Design Parameters
	pH	4.5 - 10.2
	Boron (RWSP)	2050 - 2900 ppm
→(EC-18742, R304)	Boron (SFP)	1900 - 2900 ppm
←(EC-18742, R304)	Chloride	0 - .15 ppm Cl
	Fluoride	0 - .1 ppm F
	Ammonia	0 - 50 ppm NH_3
	Lithium	0 - 2.5 ppm $^7Li^+$
	Hydrazine	0 - 50 ppm N_2H_4
	Optical Clarity	Note (1)

Note (1)

Minimum optical clarity is defined as being able to read fuel bundle lettering which is 3/8" high, 3/16" wide and 1/16" thick at 25 ft. below the surface of the water with the aid of optical instruments.

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Design Parameters

Component	Parameters	Description
Fuel Pool Cooling Pump	Quantity	2
	Type	Centrifugal, horizontal
	Design Pressure, (psig)	150
	Design Temperature (°F)	200
	Design Head, (Ft)	76
	Design Flow, (gpm)	2000
	Normal Operating Temp., (°F)	90 - 150
	Normal Suction Pressure, (psig)	15
	$NPSH_{MIN}$ Available at Design Flow, (Ft)	64
	Motor HP	60
→(DRN 06-843, R15)		
	Fluid, Boric Acid Maximum (Wt. %)	1
←(DRN 06-843, R15)		
	Material in Contact with Liquid	Austenitic Stainless Steel
	Code	ASME Section III, Class 3, 1971/Summer 1972

TABLE 9.1-3 (Sheet 2 of 8) Revision 15 (03/07)

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Design Parameters

Component	Parameters	Description
Fuel Pool Purification Pump	Quantity	1
	Type	Centrifugal, horizontal
	Design Pressure, (psig)	150
	Design Temperature, (°F)	200
	Design Head, (Ft)	165
	Design Flow (gpm)	150
	Normal Operation Temp., (°F) 8	90 - 150
	Normal Suction Pressure, (psig)	15
	NPSH Available at Design Flow, (Ft)	49.2
	Motor HP	20
→(DRN 06-843, R15)		
	Fluid, Boric cid Maximum (Wt. %)	1
←(DRN 06-843, R15)		
	Material in Contact with Liquid	Austenitic Stainless Steel
	Code	ASME Section III, Class 3, 1971/Summer 1972

TABLE 9.1-3 (Sheet 3 of 8) Revision 15 (03/07)

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Design Parameters

Component	Parameters	Description
Refueling Water Pool Purification Pump	Quantity	1
	Type	Centrifugal, horizontal
	Design Pressure, (psig)	100
	Design Temperature (°F)	200
	Design Head, (Ft)	170
→(DRN 06-843, R15)	Design Flow, (gpm)	150
←(DRN 06-843, R15)		
	Normal Operating Temp. (°F)	90 - 150
	Normal Suction Pressure, (psig)	Atmos.
	NPSH Available at Design Flow, (Ft)	31
	Motor HP	15
	Fluid, Boric Acid Maximum (Wt. %)	1.5
	Material in Contact with Liquid	A-296 CF 8M-316 Stainless Steel
	Code	ASME VIII 1973 Winter 1975 addenda

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Design Parameters

Component	Parameters	Description
Refueling Canal Drain Pump	Quantity	1
	Type	Centrifugal, horizontal
	Design Pressure, (psig)	100
	Design Temperature, (°F)	200
	Design Head, (Ft)	100
	Design Flow, (gpm)	200
	Normal Operating Temperature, (°F)	120
	Normal Suction Pressure, (psig)	Atmos.
	NPSH Available at Design Flow, (Ft)	47
	Motor HP	10
	Fluid, Boric Acid Maximum (Wt. %)	1.5
	Material in Contact with Liquid	A-296 CF 8M-316 Stainless Steel
	Code	ASME VIII 1973 Winter 1973 addenda
Fuel Pool Ion Exchanger	Quantity	1
	Type	Flushable
	Design Pressure, (psig)	200
	Design Temperature, (°F)	250
→(DRN 06-843, R15)		
	Normal Operating Temp., (°F)	120
	Normal Operating Pressure, (psig)	80
←(DRN 06-843, R15)		
	Resin Volume, Total (Ft^3)	36.2
	Resin Volume, Useful (Ft^3)	32.0

TABLE 9.1-3 (Sheet 5 of 8) Revision 13-B (01/05)

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Design Parameters

Component	Parameters	Description
Fuel Pool Ion Exchanger (Cont'd)	Normal Flow, (gpm)	150
	Design Flow, (gpm)	300
	Code (Vessel)	ASME VIII, Class 3 1968, Summer 1970 addenda
	Material in Contact with Liquid	Austenitic Stainless Steel
	Retention Screen Size	80 U.S. Mesh
	Resin Type	Anion/Cation Mixed Bed
	Maximum AP @ Design Flow, (Ft)	15
Fuel Pool Purification Filter	Quantity	1
	Type	Resin bonded glass fiber and polyester
	Design Temperature, (°F)	200
	Design Pressure, (psig)	150
	Design Flow, (gpm)	150
	Normal Temperature, (°F)	90 - 130
	Normal Pressure, (psig)	78
→(DRN 04-487, R13-B)	Maximum Operating Temperature (°F)	155
←(DRN 04-487, R13-B)		
	Normal Flow, (gpm)	150
	Clean ΔP @ 150 gpm, (psi)	5
	Loaded ΔP @ 150 gpm, (psi)	25
	Removal Rating Absolute (Beta Method)	≤20 microns

TABLE 9.1-3 (Sheet 6 of 8) Revision 14 (12/05)

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Design Parameters

Component	Parameters	Description
	Shell Materials	Austenitic Stainless Steel
	Code	ASME VIII 1968/Summer 1970
→ (DRN 99-1097, R11)		
Fuel Pool Heat Exchanger*	Quantity	1
← (DRN 99-1097, R11)		
	Type	Shell and Tube (2 Tube Pass)
	Code	ASME III, Class 3, 1971
	Tube Side (Fuel Pool)	
	Fluid	Fuel Pool Water
	Design Pressure (psig)	75
	Design Temperature (°F)	250
	Materials	Austenitic Stainless Steel
	Pressure Drop @ Design Flow (psi)	10
	Normal Flow (gpm)	2000
	Design Flow (gpm)	4000
→ (DRN 99-1097, R11; 03-2063, R14)		
← (DRN 99-1097, R11; 03-2063, R14)		
	Shell Side (Component Cooling Water)	
	Fluid	Component Cooling Water
	Design Pressure 150	
	Design Temperature (°F)	250
	Materials	Carbon Steel
	Pressure Drop @ Design Flow (psi)	15
	Normal Flow, (gpm)	1600
	Design Flow, (gpm)	5000
→ (DRN 99-1097, R11; 03-2063, R14)		
← (DRN 99-1097, R11; 03-2063, R14)		

TABLE 9.1-3 (Sheet 7 of 8) Revision 15 (03/07)

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Operating Parameters

Component	Parameters	Description	
→(DRN 99-1097, R11; 03-2063, R14)			
Fuel Pool Heat Exchanger (Cont'd)	Tube Side (Fuel Pool)	Normal Cooling	Maximum Cooling
	Flow, (gpm)	2440	3650
	Inlet Temp. (°F)	140	155
	Outlet Temp. (°F)	115.7	125.7
	Heat Transferred (Btu/hr)	29.1×10^6	52.5×10^6
	Shell Side Component Cooling Water		
	Flow (gpm)	2768	5000
	Inlet Temp. (°F)	90	90
	Outlet Temp. (°F)	111.2	111.1

Performance data assume that 5% of the Heat Exchanger tubes are plugged

←(DRN 99-1097, R11; 03-2063, R14)

Backup Fuel Pool Heat Exchanger	Quantity	One
	Type	Shell and Tube (2 Tube Pass)
	Code	ASME III, Class 1971 thru Summer 1973
	Tube Side (Fuel Pool) Fluid	Fuel Pool Water
	Design Pressure (psig)	150
	Design Temperature (°F)	200
	Materials	Austenitic Stainless Steel
→(DRN 06-843, R15)	Pressure Drop @ normal flow (psi)	6
←(DRN 06-843, R15)		
	Flow (gpm)	1750
	Inlet temp (°F)	140
→(DRN 99-1097, R11; 03-2063, R14)		
	Outlet temp (°F)	120.6
←(DRN 99-1097, R11)		
	Heat transferred (BTU/HR)	16.7
←(DRN 03-2063, R14)		

PRINCIPAL COMPONENTS DESIGN DATA SUMMARY

Operating Parameters

Component	Parameters	Description
	Shell Side (Component Cooling Water System)	
	Fluid	Component Cooling Water
	Design Pressure (psig)	150
	Design Temperature (°F)	175
	Materials	Carbon Steel
	Pressure Drop @ Normal flow (psi)	5
→(DRN 03-2063, R14)		
	Flow (gpm)	2000
	Inlet temp (°F)	90
	Outlet temp (°F)	106.8
←(DRN 03-2063, R14)		
Refueling Cavity Drain Pump	Quantity	One
	Type	Centrifugal, Horizontally Mounted
	Design Pressure, (psig)	100
	Design Temperature, (°F)	200
	Design Head, (ft.)	100
	Design Flow, (gpm)	500
	Normal Operating Temp. (°F)	120
	Normal Suction Press. (psig)	Atm.
	NPSH Available at Design Flow (ft.)	30
	Motor HP	20
	Fluid, Boric Acid Maximum (wt. %)	1.5
	Material in Contact with Liquid	A296 CF8M, 316 Stainless Steel
	Code	ASME VIII 1973, Winter 1973 Addenda

TABLE 9.1-4 (Sheet 1 of 10) Revision 309 (06/16)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
→(DRN 99-1097, R11, R11)								
1.	Fuel Pool Nozzle Screen	Clogged	Impurities,	Loss of suction for both fuel pool pumps	Pressure Indicator, PI 401, 402 visual	Screen can be cleaned in a short period of time	No Fuel pool cooling when this failure occurs.	Fuel Pool purification system would minimize chance of this failure.
←(DRN 99-1097, R11, R11) →(LBDCR 16-013, R309)								
2.	Fuel Pool pump isolation valve: 3FS-V101A (FP-202), 3FS-V102 B (FP 203)	a) Fails closed	Mechanical failure, blockage	Loss of Suction for one fuel pool pump	Pressure indicator, PI 401, 402	Two redundant Fuel Pool pumps	Equilibrium temperature of fuel pool will be increased	
←(LBDCR 16-013, R309)								
		b) Fails open	Mechanical Failure	No impact on fuel pool cooling, cannot isolate F.P. pump for repair	Periodic Testing	Repair	N/A	
→(DRN 99-1097, R11)								
3.	Fuel Pool pump Temp. Strainer 3FS-S108 A, 3FS-S108 B	Clogged	Impurities, particulate matter	Possible loss of suction of one fuel pool pump	Pressure indicator, PI 401, 402		Equilibrium temperature of fuel pool will be increased	Fuel Pool purification system would minimize this failure. It is a potential common mode failure
←(DRN 99-1097, R11)								
4.	Fuel Pool Pump A,B	Complete Failure	Mechanical, Electrical Failure	Loss of one fuel pool pump	Pressure indicator, PI 401, 402 Possible Low Discharge Pressure Alarm form PS-403	Two fuel pool pumps	Equilibrium temperature of fuel pool will be increased	

TABLE 9.1-4 (Sheet 2 of 10)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
5.	Fuel pool pump dis-charge Pres-sure Indica-tor PI 401, PI 402	Fails to indicate correct pressure	Mechanical, Electrical Failure	Unusual Pressure Indication or erratic pressure indication.	Periodic Testing	Possible Low Discharge Pressure Alarm from PS-403	N/A	
6.	Fuel pool pump Isolation valve: 3FS-V103 A (FP-208) 3FS-V104 B (FP-209)	a) Fails closed	Mechanical Failure, Blockage	Centrifugal pump driving against a dead head; High Pressure indication; loss of one fuel pool pump.	High pressure indication; valve position indicator. (Locally)	Two Redundant fuel pool pumps	Equilibrium temperature of fuel pool will be increased.	
		b) Fails open	Mechanical Failure	No impact on fuel pool cooling; cannot isolate section of pipe for repair.	Periodic Testing	Repair	N/A	
7.	Fuel Pool Pump Dis-charge Header Pressure Switch PS 403	Fails to function properly	Electrical, Mechanical Failure	Erratic Pressure Alarm	Pressure Alarm; Pressure Indicators upstream PI 401, 402; periodic testing.	Pressure Indicators PI 401, 402	N/A	
8.	Fuel Pool Heat exchanger temperature indicator TI 404, TI 405	Fails to indicate correct temper-ature	Electrical Failure	Erroneous indication of Fuel Pool Heat Exchanger Performance	Changes in Fuel Pool Temp. if Operator Changes Coolant Flow in Response To Erroneous Indications.	Fuel Pool Temp. Indicator TI 420 and Alarm	N/A	

TABLE 9.1-4 (Sheet 3 of 10) Revision 309 (06/16)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
9.	Fuel pool Heat Exchanger (or Backup Fuel Pool Heat Exchanger)	a) Cross Leakage	Corrosion or manufacturing defects	Leakage of fuel pool coolant to component cooling system.	Radiation sensors in component cooling	None		
		b) Decrease in ability to transfer heat	i) Excessive fouling ii) Blockage iii) Failure in CCS	High Temperature in fuel pool cooling line. (TI-405)	High Temperature, (TI 405) high temp. alarm if temp. inc. is significant (TI 420)	Two Seismic Category I Makeup sources available to maintain Fuel Pool Level even if Boiling occurs.	Equilibrium temp. of fuel pool will be increased.	

→(DRN 99-1097, R11)
←(DRN 99-1097, R11)

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
10.	Skimmer line diaphragm valve 7FS-V148 (FP-221)	a) Fails closed	Mechanical failure, blockage	Cannot skim the fuel pool. Decrease in clarity of water	Periodic Testing, visual	Repair		
		b) Fails open	Mechanical failure	No impact on fuel pool cooling, or purification cannot isolate skimmer for repair	Periodic Testing	Series Redundant isolation valve (7FS-V109)		

→(LBDCR 15-007, R309)
←(LBDCR 15-007, R309)

TABLE 9.1-4 (Sheet 4 of 10) Revision 11 (05/01)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
12.	Purification pump suction isolation valve	a) Fails closed	Mechanical binding, operator error	Loss of fuel pool purification loop	Low pump suction and discharge pressure	Repair valve		
	7FS-V107, 7FS-V109 (FP-222)	b) Fails open	Mechanical binding	None, valve is normally open during system operation	Handle position	Series redundant isolation valve		
13.	Purification pump suction inline basket strainer 7FS-S151	Clogged	Impurities, particulate matter	Loss of fuel pool purification loop	Low pump suction and discharge pressure	Repair		
14.	Purification pump intake and discharge pressure indicator Pi 411, PI 412	Fails to indicate correct value	Mechanical, Electrical failure	Erroneous indication of pump or purification system performance	Abnormal Indication	Repair		
15.	Fuel pool purification pump	Complete pump failure	Mechanical, Electrical Failure	Loss of fuel pool purification loop	Low pressure indication at PI 411 and PI 412	None Required	Cannot purify fuel pool until repaired	
16.	Fuel pool purification pump discharge Isolation valve 7FS-V118	a) Fails closed	Mechanical Failure, blockage, operator error	Loss of fuel pool purification loop. Purification pump operating at shutoff head pump damage	High Pressure indication at PI 412	Repair		
	(FP-226)	b) Fails open	Mechanical Failure	No impact on fuel pool purification system, valve normally open during operation; cannot isolate section of loop for repair	Handle Position	Series redundant isolation valve		

TABLE 9.1-4 (Sheet 5 of 10) Revision 11 (05/01)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
17.	Fuel pool purification loop sample (7FS-V156), (FP 227), (FP 235), (FP 247)	a) Fails closed	Blockage, corrosion	Cannot sample fuel pool purification system	None, Valve normally closed	None		
		b) Fails open	Seat leakage, operator error	Divert part of fuel pool water to sample outlet	Leakage	Line is capped		
18.	Refueling water pool purification pump isolation valve to fuel pool purification loop 7FS-V126, 7FS-V174	a) Fails closed	Mechanical failure, corrosion	Cannot provide purification for refueling water. Cannot provide makeup to the Fuel Pool from the refueling water storage pool.	Operator	None	Purification and Fuel Pool make up	
		b) Fails open	Mechanical failure, operator error	Divert refueling water to fuel pool	Level alarm in fuel pool	Series redundant isolation valve		
19.	Fuel Pool purification loop filter	Clogged	Impurities, particulate matter	Loss of fuel pool purification loop	High Differential pressure reading in PDI 415	Parallel Redundant flow path through filter bypass valve 7FS-V116		
20.	Fuel Pool purification loop filter by pass valve 7FS-V116 (FP 229)	b) Fails open	Mechanical Failure, contamination, operator error	Purification water by passes filter. Loss of filtration	Very low differen-tial pressure reading on PDI 415	None		

TABLE 9.1-4 (Sheet 6 of 10) Revision 11 (05/01)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
21.	Purification filter isolation valve 7FS-V111 (FP 228), 7FS-V113 (FP 234)	a) Fails closed	Mechanical failure, blockage, operator error	Loss of purification loop, high pressure reading at PI 412 and low differential pressure reading at PDI 415	High pressure reading at PI 412 and low differential pressure reading at PDI 415	Parallel Redundant flow path through filter bypass 7FS-V116		Valve is normally open
		b) Fails open	Mechanical failure	Cannot isolate filter for repair; no impact during normal operation	Leakage during replacement	Series isolation valve	Loss of filtration during repair	Valve is normally open
22.	Fuel pool ion exchanger isolation valve 7FS-V114 (FP 236), 7FS-V117 (FP 248), 7FS-V119 (FP 250), 7FS-V120 (FP 252)	a) Fails closed	Mechanical failure, blockage, operator error	Loss of circulation of either fuel pool or refueling pool water through the purification filters and ion exchanger	Low differential pressure reading at PDI 416	Parallel ion exchanger by pass path for 7FS-V114, 7FS-V117, and 7FS-V119 failure. None for 7FS-V120		
		b) Fails open	Mechanical Failure	None	None	None		
23.	Fuel pool ion exchanger differential pressure indicator PDI 416	Fails to indicate correct value	Mechanical, electrical failure	No impact on fuel pool purification	Periodic testing	None		

TABLE 9.1-4 (Sheet 7 of 10) Revision 11 (05/01)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
24.	Fuel pool ion exchanger	a) Loss of flow	Valve fails closed or strainer clogs, operator error	Loss of circulation of either fuel pool or refueling pool water through the purification filters and ion exchanger	High Pump Discharge pressure at PI 412 and low differential pressure reading at PDI 416	Parallel ion Exchanger bypass path		
		b) Fails to remove contamin-ants	Age and Heavy Load	Buildup of radioactive contaminants in either the fuel pool or the refueling pool	Local Sample	Parallel Filter bypass path		
25.	Ion exchanger Y Strainer 7FS-S153	Loss of function	Impurities, particulate matter	Same as 24 (a)	Same as 24 (a)	Same as 24 (a)		
26.	Ion exchanger By-Pass valve 7FS-V121 (FP 251)	a) Fails closed	Mechanical binding	Inability to by pass ion exchanger during maintenance,	Handle Position	Repair	Valve Normally closed	
		b) Fails open	Operator error	Effective Loss of purifica-tion through the ion exchanger for either the fuel pool or refueling pool, until a repair is made	Local sample Low Differential pressure indication on PDI-416	Purification loop can be safely shut down until a repair is made		

TABLE 9.1-4 (Sheet 8 of 10) Revision 11 (05/01)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
27.	Isolation valve between Refueling Canal Drain Pump and various systems, 7FS-V137, 7FS-V138, 7FS-V139, 7FS-V140, 7FS-V176, 7FS-V177	a) Fails closed	Mechanical failure	Build up of radioactive contaminants in refueling canal, spent fuel cask storage area or spent fuel cask decontamination pit.	Local sample	Repair	N/A	
		b) Fails open	Mechanical binding, seat leakage	Drains part of refueling canal, spent fuel cask decontamination pit inventory to fuel pool.	Fuel pool water level	Series Redundant isolation valve		
28.	Refueling Canal Drain Pump isolation 7FS-V127, 7FS-V152	a) Fails closed	Mechanical failure	Same as 27 (a)	Local Sample	Repair		
		b) Fails open	Mechanical binding, seat leakage	Same as 27 (b)	Fuel pool water level	Same as 27 (b)		
29.	Purification piping	a) Break upstream of pump	Accident	Loss of purification loop until repair is completed. Possibly some loss of water from fuel pool due to siphoning.	Low pool level alarm (LS-420) if there is siphoning. Low pump discharge pressure (PI-412)	Siphon breaker holes at EL 40'-6" this is sufficient.		Purification can be safely suspended while repair is accomplished.
		b) Break downstream of pump	Accident	Purification pump will tend to drain the fuel pool until the pump is shutoff; loses suction. Possibly loss of water from pool due to siphoning from discharge pipe.	Low Pool Level alarm (LS-420)	The discharge leg extends only a short distance below the fuel pool water line. Therefore siphoning will cease before level drops excessively.		

TABLE 9.1-4 (Sheet 9 of 10) Revision 11 (05/01)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
30.	Pool Cooling Piping	a) Break upstream of pumps	Accident	Partial draining of fuel pool, loss of cooling.	Low pump discharge pressure alarm. (PS-403) Low fuel pool level alarm (LS-420)	The pool cooling suction nozzle extends only a short distance below the pool water line, therefore siphoning will cease before serious draining occurs.		
		b) Break downstream of HX	Accident	Cooling pump will tend to drain pool until pump is shut off; loses suction. Possible some loss of water from fuel pool due to siphoning from discharge nozzle.	Low pool level alarm (LS-420)	Same as 29 (a)		
		c) Break between pump and HX	Accident	Cooling pump will tend to drain pool until pump is shut off. Possible some loss of water from fuel pool due to siphoning from discharge nozzle.	Low pump discharge pressure alarm. (PS-403) Low fuel pool level alarm. (LS-420)	Same as 29 (a)		
31.	Refueling canal drain piping	Breakdown stream of pump	Accident	Possibly some loss of water from pool due to siphoning from discharge pipe.	Low Pool Level alarm (LS-420)	Same as 29 (b)		
32.	Component Cooling Makeup pumps to pool isolation valve	a) Fails closed	Mechanical failure, corrosion	Cannot supply fuel pool with cc makeup water when required.	Operator	Repair	Valves are normally closed.	
	7FS-V129 (FP 243), 7FD-V130 (FP 211), 7FS-V131 (FP 201	b) Fails open	Contamination, seat leakage	Same as 31	Low pool level alarm (LS-420)	Series Redundant isolation valve and same as 29 b.		

TABLE 9.1-4 (Sheet 10 of 10) Revision 11 (05/01)

FAILURE MODE AND EFFECTS ANALYSIS

FUEL POOL SYSTEM

No.	Name	Failure Mode	Cause	Symptoms and Local Effects Including Dependent Failures	Method of Detection	Inherent Compensating Provision	Effect Upon	Remarks and Other Effects
33.	Fuel Pool pump check valve 3FS-V10B8 (FP-207), 3FS-V105A (FP-206)	a) Fails closed	Mechanical failure, blockage corrosion	Centrifugal pump driving against a dead head; high pressure indication (PI 401, 402) loss of one fuel pool pump flow supply leg.	High pressure indication; (PI 401, 402) periodic testing	None	Equilibrium temperature of fuel pool will be increased.	
		b) Fails open	Mechanical failure, seat leakage	Reverse Flow: through idle pump	Periodic Testing	None	Equilibrium temperature of fuel pool will be increased.	
34.	Fuel pool purification pump check valve	a) Fails closed	Mechanical failure, blockage, corrosion	Centrifugal pump driving against a dead head; high pressure indication; (PI 402) loss of fuel pool purification loop.	High pressure indication; (PI 402) Periodic Testing	None for 7FS-V110. Bypass IX through 7FS-V121 for 7FS-V115 failure	Cannot purify fuel pool when required	
	7FS-V110 (FP 225), 7FS-V115 (FP 237)	b) Fails open	Mechanical failure, seat leakage	No impact on fuel pool purification system.	Periodic Testing	None		
35.	Refueling Canal Drain Pump line check valve 7FS-V136	a) Fails closed	Same as 34 (a)	Centrifugal pump driving against a dead head.	Periodic Testing	None		
		b) Fails open	Same as 34 (b)	Possible loss of water from pool due to siphoning from discharge pipe.	Periodic Testing	Same as 29 b.		

← (DRN 99-1097)

TABLE 9.1-5 (Sheet 1 of 2) Revision 14 (12/05)

MAJOR TOOLS AND SERVICING EQUIPMENT REQUIRED
FOR REFUELING FUNCTIONS

		Quantity
1.	R.V. Stud Tensioners	3
2.	R.V. Stud Tensioners Pump Unit	1
3.	R.V. Stud Storage Stand (4 hole)	1
4.	Lifting Tools for R.V. Studs and Nuts	3
5.	R.V. Guide Studs	2
6.	Source Handling Tool	1
7.	Head Lift Rig Spreader	1
→(DRN 03-1341, R13)		
8.	Stud Tensioning Hoists	6
←(DRN 03-1341, R13)		
9.	Stud Hold Plugs	54
10.	Surveillance Handling Tool	1
11.	Reactor Coolant Pump Stud Tensioner	2
12.	Reactor Coolant Pump Seal Cartridge Lift Rig	1
13.	UGS Lift Rig	1
14.	CSB Lift Rig	1
15.	Hydraulic Power Unit	2
→(DRN 02-176, R14)		
16.	Pool Seal Hatch Covers	6
←(DRN 02-176, R14)		
17.	CEA Transfer Carrier	4
18.	Refueling Machine	1
19.	Transfer Carriage	1
20.	Upending Machine	2
21.	Underwater TV System (2 cameras)	1
22.	Sipping Console	1

TABLE 9.1-5 (Sheet 2 of 2) Revision 7 (10/94)

MAJOR TOOLS AND SERVICING EQUIPMENT REQUIRED
FOR REFUELING FUNCTIONS

		Quantity
23.	R.V. Stud Support	54
24.	Internals Lift Tie Rod Assembly	1
25.	Containment Polar Crane	1
26.	Cask Handling Crane	1
27.	Transfer System Cable Hook and Wrench	1
28.	Spent Fuel Handling Machine	1
29.	New Fuel Elevator	1
30.	New Fuel Handling Tool	1
31.	Spent Fuel Handling Tool	1
32.	CEA Handling Tool (Short)	1
33.	Reactor Vessel Head Lift Rig	1
→ 34. ←	Hydra-Set Precision Load Pos itioner	1

TABLE 9.1-6 (Sheet 1 of 2) Revision 15 (03/07)

REACTOR BUILDING CRANE DATA

A) BRIDGE

→(DRN 06-843, R15)

Circular Runway length, ft., in.		419 ft.

←(DRN 06-843, R15)

Bridge weight, lbs.		376,400 lbs.
Bridge span, ft., in. (Diameter)		136 ft. - 4 in.
Bridge motor Hp	(2)	7.5 Hp @ 900 RPM
Type of wheels		Straight thread
Number of wheels		8

→(DRN 06-843, R15)

Maximum speed, FPM		60 FPM

←(DRN 06-843, R15)

Type of controls		P&H Static Stepless Control Bulletin 562/563
Type of brake		8 in. CDR
Type of bumpers		None (Circular Crane)

B) TROLLEY

Length of trolley travel, ft., in.		108 ft. - 7 in.
Trolley weight (net) lbs.		127,000 lbs.
Trolley weight (with load), lbs.		527,000 lbs.
Distance between running rails, ft., in.		29 ft. - 0 in.
Trolley drive Hp	(2)	3 Hp @ 600 RPM
Type of wheels		Straight thread
Number of wheels		4
Maximum speed, FPM		30 FPM
Type of controls		P&H Static Stepless Control Bulletin 562/563
Type of brakes		CDR 5 in.
Type of bumpers		Spring (Chocks)

C) HOIST

HOIST	MAIN	AUXILIARY
Lifting capacity, ton	200 ton	30 ton
Drum size (pitch circle diameter) in.	42 1/4 in.	26 1/8 in.
Rope type	I.P.S. 6x46 AAA	I.P.S. 6x37 IWRC
Rope size, in. diameter	1 3/8 in. diameter	3/4 in. diameter
Diameter top block sheaves (pitch circle diameter) in.	33 in.	22 1/2 in.
Diameter hook block (pitch circle diameter) in.	33 in.	22 1/2 in. & 25 in.
Type equalizer	Sheave	Sheave
Type of hook P&H 646	Forged	Forged
Type of hook material	AISI 4320H	AISI 1045

REACTOR BUILDING CRANE DATA

C) HOIST (Cont'd)		MAIN		AUXILIARY
Hook test load, ton		None		None
Maximum travel of hook, Ft., in.		100 ft – 0 in		100 ft – 9 in
→(DRN 06-843, R15)				
Maximum hoist speed, FPM		6 FPM		30 FPM
←(DRN 06-843, R15)				
Number of parts of rope		14		8
c/c sheaves in highest position		64 1/2 in.		84 1/2 in.
Type of control brakes		Eddy Current		Eddy Current
Type of holding brake	(2)	16 in. SBE	(2)	13 in. SBE
Type of control		P&H Static Stepless Control Bulletin 562/563		P&H Static Stepless Control Bulletin 562/563

D) DESIGN LIFE

Number of rated capacity load cycles (structural members)	20,000 minimum
Gearing and shafting fatigue life (cycles of component loading)	10 million minimum

FHB BUILDING CRANE DATA (CASK CRANE)

→(EC-14270, R305)

A) BRIDGE

Runway length, ft., in.		77 ft. - 0 in.
Bridge weight, lbs.		198,575 lbs.
Bridge span, ft., in.		62 ft. - 8 in.
Bridge motor, Hp	(2)	7 1/2 HP @ 1200 RPM
Type of wheels		Straight Thread
Number of wheels		8 (eight)
Maximum speed, FPM		50 FPM
Type of controls		Smartorque G+S3 AFD Bulletin 427S
Type of brake	(2)	Motor-Mounted Disc Brakes @ 50 FT-LB
Type of bumpers		Spring

B) TROLLEY

Length of trolley travel, ft., in.		52 ft. - 6 in.
Trolley weight (net) lbs		60,500 lbs
Trolley weight (with load), lbs		310,500 lbs
Distance between running fails, ft., in.		16 in. 0 in.
Trolley drive, Hp	(2)	3 HP @ 1800 RPM
Type of wheels		Straight Thread
Number of wheels		4 (four)
Maximum speed, FPM		50 FPM
Type of controls		Smartorque G+S3 AFD Bulletin 427S
Type of brakes	(2)	Motor-Mounted Disc Brakes @ 15 FT-LB
Type of bumpers		Spring (Chocks)

C) HOIST

HOIST	MAIN	AUXILIARY (2)
Lifting capacity, ton	125 ton	15 ton
Drum size (pitch circle dia.) in.	42 1/4 in.	20
Rope type	6x37 1 5/8 in. Stainless Steel, Type 304 IWRC	6x37 3/4 in. Stainless Steel, Type 304, IWRC
Rope size, in. diameter	1 5/8 in.	3/4 in.
Diameter Top Block Sheaves (pitch circle diameter) in.	N/A.	9 1/2 in.
Diameter Hook Block (pitch circle diameter) in.	39 in.	15 in.
Type of equalizer	Bar/Hydraulic	Sheave
Type of hook	Forged	Forged
Type of hook material	SAE 4340(34CrNiMo6)	AISI 1045
Hook Test load, ton	250 ton	None
Maximum travel of hook, ft., in.	70 ft. 0 in.	79 ft. 0 in.

←(EC-14270, R305)

FHB BUILDING CRANE DATA (CASK CRANE)

→(EC-14270, R305)

C) HOIST (Cont'd)	MAIN	AUXILIARY
Maximum hoist speed, FPM	5.0 FPM	25 FPM
Number of parts of rope	12	4
c/c sheaves in highest position	N/A	37 7/8 in.
Type of control brakes	Magnetorque	Mechanical Load
Type of holding brakes	(2) 16 in. SBE	Disc
Type of control	Smartorque VG+S3 Bulletin 427V	5 step A.C Magnetic

←(EC-14270, R305)

D) DESIGN LIFE

Number of rated capacity load cycles (structural members)	20,000 minimum
Gearing and shafting fatigue life (cycles of component loading)	10 million minimum

TABLE 9.1-8 (Page 1 of 2) Revision 304 (06/10)

→(DRN 99-1097, R11)

SUMMARY OF REACTIVITY PERTURBATIONS
FOR STANDARD CONFIGURATIONS

→(DRN 05-1365, R14-A; EC-18742, R304)

	Region 1	Region 2
Soluble boron (ppm)	85	448
Design basis burnup at 5.0 wt% initial enrichment	0.0	34.1 GWD/MTU
Reference k_{eff} (MCNP4a)	0.9246	0.9173
MCNP4a calculational bias, Δk	0.0012	0.0012
Temperature bias to 80.33 °F (CASMO-4), Δk	0.0024	0.0029
Burnable absorber depletion bias, Δk	NA	0.0070
Depletion uncertainty, Δk	±0.0000	±0.0125
Rack tolerances uncertainty, Δk	±0.0136	±0.0042
Fuel tolerances uncertainty, Δk	±0.0032	±0.0036
Calculational uncertainty, Δk	±0.0014	±0.0014
MCNP4a code bias uncertainty, Δk	±0.0090	±0.0090
CASMO-4 code bias uncertainty, Δk	±0.0025	±0.0025
Statistical combination of uncertainties, Δk(1)	±0.0169	±0.0166
Maximum k_{eff}	0.9450	0.9450
Regulatory Limit	0.95	0.95

1. Square root of the sum of squares

←(DRN 99-1097, R11; EC-18742, R304)

TABLE 9.1-8 (Page 2 of 2) Revision 304 (06/10)

SUMMARY OF REACTIVITY PERTURBATIONS
FOR REGION 2 CHECKERBOARD CONFIGURATION

→(DRN 99-1097, R11; EC-18742, R304)

	5 wt% U-235 fuel with empty cells	Fuel assemblies at 27 GWD/MTU with lower reactivity fuel
Soluble boron (ppm)	0.0	524
Design basis burnup at 5.0 wt% initial enrichment	0.0	43.2 GWd/MTU
Reference keff (MCNP4a)	0.8256	0.9152
MCNP4a calculational bias, Δk	0.0012	0.0012
Temperature bias to 80.33 °F (CASMO-4), Δk	0.0034	0.0025
Burnable absorber depletion bias, Δk	0.0070	0.0070
Depletion uncertainty, Δk	±0.0000	±0.0157
Rack tolerances uncertainty, Δk	±0.0053	±0.0040
Fuel tolerances uncertainty, Δk	±0.0029	±0.0039
Calculational uncertainty, Δk	±0.0014	±0.0012
MCNP4a code bias uncertainty, Δk	±0.0090	±0.0090
CASMO-4 code bias uncertainty, Δk	±0.0025	±0.0025
Statistical combination of uncertainties, Δk[1]	±0.0112	±0.0191
Maximum k_{eff}	0.8484	0.9450
Regulatory Limit	1.0	0.95

1. Square root of the sum of squares

←(DRN 99-1097, R11; EC-18742, R304)