9.1.3 Fuel Pool Cooling and Purification System

The Fuel Pool Cooling and Purification System (FPCPS) is designed to maintain the spent fuel pool (SFP) water temperature and water level within prescribed limits by removing decay heat generated by the stored spent fuel assemblies, and to remove impurities from the Fuel Building pool and Reactor Building pool to maintain water clarity and to limit the specific radioactivity in the water.

The FPCPS consists of the following separate and independent subsystems:

- Fuel pool cooling system (FPCS).
- Fuel pool purification system (FPPS).

9.1.3.1 Design Basis

The FPCPS provides the following safety related functions:

- Removes decay heat from the SFP.
- Provides containment isolation of the reactor pool purification supply and return lines and fuel transfer tube.
- Precludes, by design, the drain down of the fuel pool below the required level for shielding of the spent fuel and FPCS operation.
- Provides SFP makeup capability (i.e., Seismic Category I water source, pump, and piping) to compensate for normal SFP evaporation for up to seven days. In addition, provide an independent on-site Seismic Category I back-up water source for SFP makeup.
- Provides isolation capability of non-safety related FPPS piping from the Reactor Building Transfer Compartment and Reactor Cavity and Fuel Building Transfer Compartment and cask loading pit.

The design basis requirements and design criteria are as follows:

1. The FPCPS provides containment isolation for the Reactor Building pool purification supply and return lines and for the fuel transfer tube (GDC 56).
2. The FPCPS components are located inside the FB structure, which is designed to withstand the effects of natural phenomena, such as earthquake, tornados, and hurricanes (GDC 2). The design of the FPCPS meets the guidance of RG 1.13, positions C.1 and C.2.
3. The safety-related portions of the FPCPS are protected from the dynamic effects associated with pipe whip, internal missiles, and discharged fluids, and accommodate the expected environmental conditions such that the system is

capable of performing its intended safety functions (GDC 4). In addition, the design of these FPCPS components conforms with RG 1.13, position C.3.

4. The seismic design of the system components meets the guidance of RG 1.29 (position C.1 for safety-related portion and position C.2 for non-safety-related portion). The quality group classification and Seismic Category of system components meet the requirements of RG 1.26 and 1.29.

5. The FPCS provides adequate cooling to the spent fuel during all heat load conditions, including full-core offloads, by maintaining a maximum SFP temperature of 140°F. In addition, the system design conforms with RG 1.13, position C9.

6. The FPCS provides SFP make-up to maintain continued SFP water level to meet cooling and shielding requirements. In addition, the system design conforms with RG 1.13, position C.8.

7. The FPCS maintains required pool water levels and uniform water temperatures during operating and accident conditions, and conforms to RG 1.13, position C6.

8. The safety functions of the FPCS can be performed assuming a single active failure or failures of non-safety-related components or systems.

9. Monitoring provisions are provided to verify correct system operation, to detect and control system leakage, detect excessive radiation levels, and to isolate portions of the system in case of excessive leakage or component malfunction. Adequate instrumentation is provided for initiating appropriate safety actions (GDC 63). In addition, the system design conforms with RG 1.13, position C.7.

10. The FPCPS design includes the following elements with respect to handling radioactive materials (GDC 61):

    A. The capability for periodic testing of components important to safety.

    B. Provisions for containment.

    C. The capability to prevent the reduction in fuel storage coolant inventory under accident conditions.

    D. The capability and capacity to remove corrosion products, radioactive materials and impurities from the pool water and reduce occupational exposure to radiation.

11. In accordance with the requirements of 10 CFR 20.1101(b), engineering controls are provided to keep radiation doses associated with the FPCPS to as low as reasonably achievable (ALARA) levels. Refer to Section 12.1 for further ALARA design details. A discussion of how the design meets the requirements of RG 8.8, section C.2 with regard to provisions for decontamination is provided in Section 12.3.1.

12. The safety-related components and systems of the FPCPS are not shared among nuclear power units (GDC 5).

9.1.3.2 System Description

9.1.3.2.1 General Description

The FPCPS system is described in following four sections:

- Fuel Building and Reactor Building pools.
- Fuel pool cooling system.
- SFP makeup capability.
- Fuel pool purification system.

9.1.3.2.2 Fuel Building and Reactor Building Pools

The Fuel Building pool (see also the description of the Fuel Building in Section 3.8.4 and the Spent Fuel Storage Facility in Section 9.1.2.2.2) includes the following three compartments:

- The Fuel Building Transfer Compartment is used for transfer of used or new fuel between the Fuel Building and the Reactor Building. This compartment is filled from the in-containment refueling water storage tank (IRWST) before refueling.
- The cask loading pit is filled with water when spent fuel transfer from the pool is required. The water needed to fill this compartment is stored in the Fuel Building Transfer Compartment.
- The SFP is dedicated to the storage and cooling of the spent fuel.

The Reactor Building pool (see also the description of the Reactor Building in Section 1.2 and Section 3.8) includes the following four compartments:

- The Reactor Building transfer compartment is connected to the Fuel Building Transfer Compartment by a transfer tube (see Section 9.1.4), and is used for transfer of used or new fuel between the Fuel Building and the Reactor Building.
- The instrumentation lance compartment is used to store instrumentation (e.g., core outlet thermocouples, in-core detectors, and probes). This compartment remains flooded during all modes of plant operation.
- The internals compartment is filled with water from the IRWST, and is used to store the reactor upper internals during refueling outages.
- The reactor cavity is filled with water from the IRWST during refueling operation.

The initial filling, make-up, and refilling of the Fuel Building and Reactor Building pools is performed by the reactor boron water makeup system. Demineralized water is normally used to compensate for normal evaporation in the pools. The boron concentration of the pool water is maintained the same as the water in the IRWST.

9.1.3.2.3 Fuel Pool Cooling System (FPCS)

The FPCS, shown in Figure 9.1.3-1—Fuel Pool Cooling System, consists of two separate cooling trains located on opposite sides of the SFP for removal of decay heat generated by irradiated fuel stored in the SFP. Each train consists of two pumps in parallel, one heat exchanger, supply and return piping, and associated valves. The pumps can be operated individually or simultaneously, as needed. The heat exchanger is cooled by the component cooling water system (CCWS). The cooling water flow to the heat exchanger can be adjusted from the main control room by CCWS motor operated control valves. Each FPCS train includes a motor-operated isolation valve downstream of the heat exchanger.

The FPCS is designed to maintain the SFP temperature below 120°F during refueling periods to facilitate operations in the SFP area, with a maximum temperature of 140°F if a single failure occurs. A single failure is not considered during infrequent refueling operations that involve a full offload of the fuel to the SFP from the reactor.

9.1.3.2.4 SFP Make-up Capability

Normal make-up water to the SFP is supplied by the demineralized water system. The safety-related and Seismic Category I SFP make-up capability is provided with sufficient inventory and capacity to compensate for normal evaporation losses from the SFP for up to 7 days with the FPCS in operation and maintaining SFP temperature at 140°F. SFP leakage associated with a dropped fuel assembly has not been considered, as an assembly drop will not result in perforation of the SFP liner.

The SFP make-up water, approximately 29,000 gallons, is maintained in the cask loading pit or the transfer compartment (or both) which are both Seismic Category I structures adjacent to the SFP. A Quality Group C and Seismic Category I submersible pump and piping to the SFP is installed in both compartments. The SFP makeup pumps are shown in Figure 9.1.3-2—Fuel Pool Purification System. The SFP make-up pumps are provided with emergency power and are operated from the main control room (MCR).

Other independent on-site Seismic Category I water supplies are available to provide the back-up SFP make-up capability, including the IRWST with at least 500,000 gallons available during plant operation. The piping and pump used to deliver the back-up water to the SFP will not be designed to Seismic Category I.

9.1.3.2.5 Fuel Pool Purification System (FPPS)

The FPPS shown in Figure 9.1.3-2 provides purification of the Fuel Building and Reactor Building pool compartments and is used to transfer water between the pool compartments or the IRWST. The FPPS consists of two pumps installed in parallel. One pump is generally used for Fuel Building pool purification and the second pump is used for Reactor Building pool purification. However, the pumps can be realigned to either pool by using suction and discharge headers. A motor-operated control valve is provided downstream of each purification pump and is used to set the required flow for the desired system configuration. A pressure relief valve installed downstream of the control valve protects downstream piping and purification equipment from overpressure.

The water from the purification pumps is pumped through a pre-filter, mixed bed ion exchanger, resin trap, and post filter before the purified water is returned to the pool. The mixed bed ion exchanger removes the ionic corrosion impurities and fission products and the filters remove particulate matter. Spent resin from the ion exchangers is sent to the resin waste tank of the Coolant Purification System (CPS).

The FPPS supply and return piping that exits the SFP from the top is designed to prevent siphoning water from the pool. The supply piping from the other Fuel Building and Reactor Building pools exits from the bottom of the pool. Valves are provided on each line to allow isolation of any leakage. The valves, and piping from the pools to the isolation valves, are safety related and Seismic Category I. Strainers are also provided to preclude particles from damaging the pumps or creating radioactive hot spots in the piping system. The return piping from all pool compartments enters the pool from the top.

The SFP and reactor cavity include skimming equipment to remove particles from the surface of the pools. The SFP skimming equipment includes a pump and filter that takes suction from a skimmer box mounted on the pool wall and returns the filtered water to the pool. The reactor cavity skimming equipment includes a floating skimmer box that is connected by a hose to the skimmer pump suction pipe. The skimmer pump discharge piping is connected to the Reactor Building purification supply pipe. The water collected in the skimmer is filtered by the FPPS ion exchange and filters.

The purification supply piping from each pool compartment and the purification pumps are also used for transferring water between pool compartments or the IRWST. The water can be passed through the purification ion exchanger and filters as needed, before transfer to the desired pool compartment.

Boron addition to the SFP is normally provided by the reactor boron water and make-up system. Make-up and boron addition operations are performed manually.

Each compartment of the Reactor Building pool and Fuel Building pool includes an overflow pipe to the nuclear island drain and vent system (NIDVS). The purification return line to the SFP includes a piping connection for filling the spent fuel cask with water. Connections are also provided to allow sampling of the water from the Fuel Building and Reactor Building pool compartments.

9.1.3.2.6 Component Description

A general description of the major components of the FPCPS follows. Key component design data for these components is listed in Table 9.1.3-1—Fuel Pool Cooling and Purification System Component Design Data. Refer to Section 3.2 for the seismic and system quality group classification of the FPCPS components.

Fuel Pool Cooling Pumps

The four FPCS pumps are centrifugal type design.

Fuel Pool Cooling Heat Exchangers

The FPC heat exchangers are plate type design and are cooled by the CCWS. The heat exchangers consist of a series of corrugated stainless steel plates. The gasketed plates are compressed together on a rigid frame to create an arrangement of parallel flow channels. FPC will flow in the odd numbered plates and CCW will flow in the even numbered plates with flow in the countercurrent direction. The plate heat exchangers will have flanged piping connections. The CCWS pressure is greater than the FPCS, which precludes radioactive SFP water entering the CCWS in case of leakage.

Fuel Building and Reactor Building Purification Pumps

The Fuel Building and Reactor Building purification pumps are centrifugal canned motor pumps. These pumps are used to circulate Fuel Building and Reactor Building pool water through the filters and mixed bed ion exchange for removal of particulate and ionic impurities.

Fuel Pool Purification Mixed Bed Ion Exchanger

The fuel pool purification mixed bed ion exchanger is a stainless steel pressure vessel. Fresh resin is loaded manually and spent resin is remotely removed to prevent high radiation exposure. This ion exchanger may also be used to purify the Reactor Building pool water.

A cartridge type pre-filter and post filter, and a resin trap, are provided for the mixed bed ion exchanger.

9.1.3.3 System Operation

9.1.3.3.1 Normal Plant Operation

Fuel Pool Cooling System (FPCS)

Operation of the FPCS is required whenever spent fuel assemblies are stored in the SFP. During normal plant operation, one FPC train operates continuously. The second FPC train is maintained in the standby condition as a backup to the train in operation.

During normal refueling operations, the SFP is maintained below 120°F. Both FPC trains are used as necessary. The CCW flow rate to the heat exchanger is adjusted depending on the pool water heat load.

During infrequent refueling operations that include a complete offload of the spent fuel from the reactor to the SFP, the FPCS has the capability to maintain the SFP temperature below 120°F with both trains operating.

Make-up water to the SFP is normally supplied from the demineralized water system. The make-up water supply compensates for normal evaporation losses from the SFP. The make-up water flow rate to the pool is locally controlled by a manually operated valve.

Samples of the SFP water can be taken using the sample line downstream of the heat exchanger.

Fuel Pool Purification System (FPPS)

Normal operation of the FPPS is manual and intermittent. The FPPS maintains water clarity and limits ionic corrosion and fission product concentration in the Fuel Building and Reactor Building pools. The system is generally aligned using Fuel Building purification pump, filters and mixed bed ion exchange. However, both Fuel Building and Reactor Building purification pumps can be operated to obtain maximum system capability. Samples may be taken periodically to determine the quality of the water.

If purification of the Reactor Building instrumentation lance compartment or IRWST is needed during plant operation, the valve alignment can be performed from the MCR to direct the water to either of the purification pumps along with filters and mixed bed ion exchanger.

During an outage, when the Reactor Building pool is filled, it is possible to purify one or several compartments of the Reactor Building pool at the same time. The system is generally aligned using the Reactor Building purification pump and CPS ion exchanger and filters.

During refueling, after the reactor cavity is filled with borated water from the IRWST, the Fuel Building purification pump or Reactor Building purification pump (one or both pumps) takes suction from the reactor cavity and transfers the water through filters and mixed bed ion exchanger, then returns the water to the reactor cavity.

The water transfers can be made between the Reactor Building pool compartments, Fuel Building pool compartments, and IRWST using different supply and return piping and valve alignments. The SFP and instrumentation lance compartments are always filled with water. Water make-up uses non-borated water to maintain the same boron concentration in the pool compartments.

The SFP surface skimmer system is manually aligned and operated, as required, to clean the SFP water surface. The reactor cavity skimmer is generally operated during Reactor Building pool purification.

Filling of the mixed bed ion exchanger is performed manually through resin feed nozzles. Demineralized water is added until the cation and anion exchange resins are covered. The resin is then mixed by injecting nitrogen from the bottom of the ion exchanger. Upon high differential pressure or indication by manual sampling that the ion exchanger resins are spent, the spent resin from the mixed bed ion exchanger is transferred remotely to the resin waste tank.

The cartridge filters and skimming filters are changed remotely with a filter changing machine to limit radiation exposure.

9.1.3.3.2 Abnormal Operating Conditions

Fuel Pool Cooling System or Fuel Pool Purification System Leakage

Fuel pool cooling or purification water leakage can be detected as follows:

- Level increase in the floor drain sump.
- Periodic visual inspection.
- Change in operating point of the FPCS pump.
- Level decrease in the SFP.

In addition to the spent fuel level indication in the MCR, the water level can be checked locally. The affected part of the FPCS or FPPS then can be isolated and repaired.

Failure of FPCS Train

In the case of failure of the operating FPCS pump, the train can be restarted and realigned by starting the parallel FPCS pump. Alternatively, the other FPCS train can be put into operation.

The FPCS has the capability to maintain the SFP temperature below 140°F during normal refueling operations following the complete loss of one train. Complete loss of one train is not considered during an infrequent full core offload refueling.

Instrumentation is available to detect a reduction in FPCS flow or heat exchanger performance that could impact SFP decay heat removal capability.

Loss of Offsite Power (LOOP)

The FPCPS components that perform safety functions are fed from both offsite and onsite power. The power supply to both trains of FPCS components that perform safety functions and FPPS containment isolation valves is backed by the emergency diesel generators (See Section 8.3).

9.1.3.4 Safety Evaluation

1. The FPPS provides containment isolation for the reactor pool purification supply and return piping, and the fuel transfer tube.

   The containment isolation valves are qualified for accident environment conditions (i.e., radiation, temperature, pressure and humidity). The motor-operated isolation valves are provided with Class 1E emergency power to automatically close upon receipt of a containment isolation signal. The fuel transfer tube containment isolation valves are maintained closed during normal plant operation. See Section 6.2.4 for further details on the containment isolation system.

2. The safety-related components of the FPCPS, including the SFP make-up capability components, are located inside the Fuel Building and Reactor Building, which are Seismic Category I structures that are designed to withstand effects of natural phenomena, such as earthquake, tornados, hurricanes, floods, explosion pressure waves, and external missiles.

3. Protection from dynamic effects is provided by locating the pumps and heat exchanger of each FPCS train in separate rooms. In addition, piping for each train to and from the SFP is routed on opposite sides of the SFP. The Fuel Building and plant design protect the SFP from low trajectory turbine missiles.

   The FPCPS components are designed to operate during anticipated Fuel Building environmental conditions associated with normal plant operation and refueling. The FPPS containment isolation valves are designed to operate under design basis accident conditions.

4. The FPCS components are located in the Fuel Building, which is a Seismic Category I structure. The FPCS and the SFP make-up capability, are designed to Quality Group C and Seismic Category I requirements. A Seismic Category I back-up water supply is also available. The FPPS containment isolation boundary is Quality Group B and Seismic Category I.

5. The FPCPS is capable of maintaining acceptable SFP temperatures during all SFP heat load conditions, including full-core offloads. The analyzed SFP heat load conditions consider a minimum of 10 years of storage in the pool. The FPCS has the heat removal capacity to handle the following bounding cases:

   A. Heat load of 0.3 percent of reactor rated thermal power (6.9 Mw), maximum CCWS temperature of 113°F, SFP structural design temperature of 180°F, and assuming a single failure.

   B. Bounding normal refueling heat load (14 Mw), normal CCWS temperature of 100.4°F, SFP temperature of 140°F, and assuming a single failure.

   C. Bounding normal refueling heat load (14 Mw) normal CCWS temperature of 100.4°F, SFP temperature of 120°F, and no single failure.

   D. Bounding full core offload refueling heat load (19.8 Mw), normal CCWS temperature of 100.4°F, SFP temperature of 120°F, and no single failure.

      The analyses performed to determine the heat loads used bounding decay heat values, fuel types, and burnup values. A conservative ORIGEN-2 code model was used which considered bounding offload size, decay times, power history, and the inventory of previously discharged assemblies.

Outage planning will incorporate administrative controls to assure that the actual SFP decay heat load is maintained below the FPCS heat removal design capability, including appropriate heat exchanger margins.

6. The SFP make-up capability and independent back-up water supply each have sufficient inventory and the capacity to compensate for normal SFP leakage and evaporation losses with the FPCS maintaining SFP temperature at 140°F. Postulated fuel handling accidents do not result in SFP liner perforation, so this has not been considered in the SFP make-up capability design. The SFP make-up capability can be initiated from the MCR, as necessary to maintain sufficient SFP water level to meet cooling and shielding requirements.

7. The SFP is normally isolated from the adjacent transfer compartment and cask loading pits by both swivel and slot type gates. The piping penetrations in the SFP are at least 20 feet above the top of the active fuel and this piping is designed to prevent siphoning water from the SFP. These design features prevent inadvertent draining of the SFP to assure that more than 10 feet of water will be maintained above the active fuel. The design will also preclude SFP level falling below the elevation required to support FPC pump operation.

   The arrangement of the FPCPS piping to and from the SFP, and the flow rates provided, are adequate to maintain uniform temperatures within the SFP.

8. The FPCPS has sufficient redundancy to preclude loss of safety function resulting from single active failure or failure of non-safety-related portions of the system. The capability to provide timely isolation of non-safety-related portions of the system is also provided. A single failure is not considered during infrequent full-core offload refueling operations.

9. The FPCPS includes adequate instrumentation, as listed in Section 9.1.3.6.1, to monitor system performance and to detect component malfunction or system leakage. In addition to SFP level instrumentation, SFP leakage detection, Fuel Building sump alarms and radiation monitors will provide timely detection and MCR notification of SFP or system component leakage to allow initiation of appropriate actions.

10. GDC 61 as related to the system design:

    A. The FPCPS is designed to permit appropriate periodic functional testing to confirm component integrity, operability of active components, and operational performance of the system, as described in Section 9.1.3.5.

    B. Safety-related and Seismic Category I piping and valves are provided to allow isolation of the purification piping exiting the bottom of the Fuel Building and Reactor Building pools to provide containment of radioactive water in case of failure of non-safety portions of the system.

    C. The FPCPS decay heat removal capability is addressed by item 5, preceding.

D. The capability to prevent reduction in SFP inventory is addressed by item 7, item 8, and item 9.

E. The FPPS removes corrosion products, radioactive materials and impurities from the pool water and surface. The ion exchangers and filters are designed to maintain safe operating conditions in the area and to reduce occupational exposure to radiation. Strainers are provided in pipes that exit the bottom of a pool to prevent radioactive particles from being spread throughout the piping system. Instrumentation is provided to monitor ion exchanger performance and filter loading to detect conditions that could result in excessive radiation levels.

11. ALARA principles have been incorporated into the FPCPS design with respect to providing adequate shielding, provisions for decontamination, and the use of remote methods for filter replacement.

    – The capability for decontamination and flushing with demineralized water is provided for the FPCPS pumps, heat exchangers, filters, ion exchanger, and resin traps.

12. The components and systems relied on for the performance of FPCPS safety functions are not shared with other nuclear units since this is a single unit plant.

9.1.3.5 Inspection and Testing Requirements

Preoperational testing of the FPCPS and components is performed in accordance with the initial plant test program. Refer to Section 14.2 (test abstract # 001) for initial plant startup test program. The testing includes system pressure test, verification of actuation signals, proper operation of valves, verification of control logic, instrument calibrations and validation of measurements.

9.1.3.6 Instrumentation Requirements

The FPCPS includes the following instrumentation and controls for performance of safety-related functions:

- Class 1E SFP level instruments are provided to alert the operators in the MCR of leakage.
- The FPCS pumps are tripped on low-low SFP level to preclude unacceptable loss of water or damage to the pumps.
- The FPCS isolation motor operated valves are opened or closed automatically.

9.1.3.6.1 Indications and Alarms

The FPCPS includes the following minimum indications and alarms:

- SFP water level and temperature.
- Pump on/off indications.

- Filter differential pressure.
- Mixed bed ion exchanger differential pressure, flow, and temperature.
- FPCS heat exchanger SFP water and CCWS inlet and outlet temperature indication.
- FPCS heat exchanger fuel pool cooling and CCWS flow.
- Containment isolation valve position.
- Fuel Building area radiation monitors (see Section 12.3.4).

Table 9.1.3-1—Fuel Pool Cooling and Purification System Component Design Data
Sheet 1 of 2

Fuel Pool Cooling Pump		
Quantity	4	
Nominal Flow	1.76×10^6 lb/hr (one pump per train) 2.12×10^6 lb/hr (two pumps per train)	
Design Pressure	120 psig	
Design Temperature	230°F	
Material	Austenitic stainless steel	
Fuel Pool Cooling Heat Exchangers		
Quantity	2	
Type	Plate	
Fluid Circulated	SFP Water	CCWS
Nominal Flow – One Pump	1.76×10^6 lb/hr	2.645×10^6 lb/hr
Nominal Flow– Two Pumps	2.12×10^6 lb/hr	
Inlet Temperature (Typical)	120°F or 140°F	100.4°F
Outlet Temperature (Typical)	condition dependent	condition dependent
Design Pressure	120 psig	175 psig
Design Temperature	180°F	180°F
Material	Austenitic stainless steel	
Spent Fuel Pool Make-up Pumps		
Quantity	2	
Nominal Flow	20 gpm	
Design Pressure	25 psig	
Design Temperature	140°F	
Material	Austenitic stainless steel	
Fuel & Reactor Building Purification Pumps		
Quantity	2	
Nominal Flow	400 gpm	
Design Pressure	175 psig	
Design Temperature	140°F	
Material	Austenitic stainless steel	

Table 9.1.3-1—Fuel Pool Cooling and Purification System Component Design Data
Sheet 2 of 2

FPPS Mixed Bed Ion Exchanger	
Resin Volume	106 ft^3
Design Pressure	175 psig
Design Temperature	140°F
Sieve Tray Gap Width	0.008 in
Material	Austenitic stainless steel
Resin Trap for Mixed Bed Ion Exchanger	
Type	Sieve basket
Mesh Size	200 micron
Design Pressure	175 psig
Design Temperature	140°F
Material	Austenitic stainless steel
Cartridge Pre-filter	
Type	Cartridge type filter
Retention Rate	1 micron
Design Pressure	175 psig
Design Temperature	140°F
Material	Austenitic stainless steel
Cartridge Post Filter	
Type	Cartridge type filter
Retention Rate	10 micron
Design Pressure	175 psig
Design Temperature	140°F
Material	Austenitic stainless steel