GE Hitachi Nuclear Energy

Richard E. Kingston
Vice President, ESBWR Licensing

P.O. Box 780 M/C A-65
Wilmington, NC 28402-0780
USA

T 910.675.6192
F 910.362.6192
rick.kingston@ge.com

MFN 09-761 Docket No. 52-010

December 4, 2009

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6 – Fuel and Auxiliary Pool Cooling System - RAI Number 9.1-20 S05**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) 9.1-20 S05 sent by NRC Letter 391, Reference 1. The response to RAI Number 9.1-20 S04 was previously submitted to the NRC via Reference 2 in response to Reference 3.

GEH response to RAI Number 9.1-20 S05 is addressed in Enclosure 1. Enclosure 2 contains the DCD markups associated with this response.

If you have any questions or require additional information, please contact me.

Sincerely,

Charles W. Bagwell for

Richard E. Kingston
Vice President, ESBWR Licensing

References:

1. MFN 09-725, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6*, November 9, 2009
2. MFN 09-546, Response to Portion of NRC Request for Additional Information Letter Number No. 340 Related to ESBWR Design Certification Application – Fuel and Auxiliary Pool Cooling System - RAI Numbers 9.1-20 S04, August 14, 2009
3. MFN 09-397, Letter from U.S. Nuclear Regulatory Commission to Jerald G. Head, *Request for Additional Information Letter No. 340 Related to ESBWR Design Certification Application*, June 9, 2009

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6 – Fuel and Auxiliary Pool Cooling System - RAI Number 9.1-20 S05
2. Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6 – Fuel and Auxiliary Pool Cooling System - RAI Number 9.1-20 S05 – DCD Markups

cc:	AE Cubbage	USNRC (with enclosures)
	JG Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	TL Enfinger	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0110-3877

Enclosure 1

MFN 09-761

Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6

Fuel and Auxiliary Pool Cooling System

RAI Number 9.1-20 S05

NRC RAI 9.1-20 S05

The design specifications provided in the ESBWR DCD, Tier 1 Table 2.6.2 and Tier 2 Table 9.1-8 appear to only pertain to the fuel and auxiliary pool cooling system (FAPCS) heat exchangers being able to remove 8.3 MW of heat from the suppression pool, while the probabilistic risk assessment (PRA) credits FAPCS with being able to remove approximately 34 MW of heat under accident conditions. In previous RAI responses, the applicant has indicated that MAAP runs have shown that if the differential temperature were high enough across the heat exchanger primary to secondary boundary and if the flow was sufficiently high on the secondary side, then 34 MW could be removed by a heat exchanger. While this is true mathematically, it does not assure that the heat exchanger physically can withstand the effects of such high temperatures (e.g., voiding, seal failure, water hammer, thermal expansion) or that the associated FAPCS pumps can handle the thermal effects (e.g., net positive suction head (NPSH) issues).

Provide a write up in the DCD (Chapter 9.1 and Chapter 19, Tier 2) that provides reasonable assurance that the FAPCS heat exchangers and pumps will be capable of removing the assumed heat load credited in the ESBWR PRA, NEDO-33201, Rev. 4. The writeup should address the 34 MW (and its associated MAAP runs) and the maximum temperatures (including differential temperature) calculated for the FAPCS heat exchanger. DCD Section 9.2 should also address how the 34 MW FAPCS heat load is handled by the FAPCS support systems. For example, the write-up should address revisions to DCD Table 9.2-3, "RCCWS Nominal Heat Loads," Table 9.2-5, "RCCWS Configuration by Mode," and Table 9.2-1, "PSWS Heat Loads." The Tier 1 PSWS interface requirements should be evaluated and modified as appropriate to be consistent with the changes made to DCD Section 9.2 in response to this RAI.

GEH Response

Many of the concerns described in this RAI were addressed in the response to the previous supplement (Letter MFN 09-546, dated August 14, 2009), though GEH can provide some additional clarification.

As explained in Supplement 4, the heat exchanger and pumps are designed to physically withstand the higher-than-normal temperatures associated with the PRA analysis, and DCD Tier 2 Subsection 9.1.3.2 was modified as part of that response to make this an explicit requirement. In order to provide additional assurance, language will be added to clarify that the differential temperature between the hot and cool side will be taken into account in the heat exchanger design.

An additional clarifying statement will also be added to DCD Tier 2 Subsection 19A.4.2 to explain the concept by which the FAPCS heat exchanger (described in terms of nominal rated performance in DCD Tier 2 Table 9.1-8) can remove as much as 34 MW at higher differential temperatures, and to state that the heat exchanger can accommodate these differential temperatures.

DCD Tier 2 Section 9.2 is not an appropriate place to describe RCCWS and PSWS beyond design basis scenarios. This part of the DCD describes the design basis, and Chapter 19 explains how to take credit for system capacity beyond this design basis, if necessary. This is also the reason DCD Tier 2 Table 9.1-8 does not discuss FAPCS heat loads beyond the 8.3 MW design basis.

There is no need to take any additional credit for PSWS or RCCWS capacity beyond the design basis requirements in Chapter 9. DCD Tier 2 Table 9.2-3 indicates that a single train of RCCWS can accommodate as much as 50.5 MW of heat removal. This bounds the 34 MW being rejected by FAPCS in the PRA Analysis.

It is also worth noting that for the purpose of this PRA analysis, FAPCS is the RTNSS system credited with removing heat from containment and not the Reactor Water Cleanup / Shutdown Cooling (RWCU/SDC) System. Therefore, in this PRA scenario, decay heat is rejected only through FAPCS; meaning that the RCCWS will not simultaneously receive heat from RWCU/SDC at the same time FAPCS is performing its severe accident heat removal. A brief statement will be added to DCD Tier 2 Subsections 9.2.1.1 and 9.2.2.1 stating that the design basis requirements of these support systems are sufficient to satisfy beyond design basis criteria described in Chapter 19.

The discussion in Chapter 19 will be expanded to note that the RCCWS can accommodate the severe accident heat load from FAPCS without any need to credit anything beyond its design-basis capabilities. By extension, no special consideration is needed to credit PSWS operating beyond its design basis. Therefore, no changes or clarifications are needed for DCD Tier 2 Tables 9.2-1 or 9.2-3. Table 9.2-5 describes various heat load combinations to the RCCWS during normal operation, and does not factor into this discussion.

Regarding other concerns mentioned in this RAI, DCD Tier 2 Table 9.1-8 describes available NPSH to the FAPCS pumps. The calculation that determined this NPSH margin conservatively assumed that the process fluid was at a temperature of 100°C even though it normally will not exceed 48.9°C. This conservative assumption for NPSH bounds even the temperatures considered in the PRA analysis. Because sufficient NPSH has been provided for the beyond design basis scenario, the pumps will not be subject to voiding or water hammer.

DCD Impact

The following DCD Subsections will be modified as noted in the attached DCD Markups:

Tier 2, Subsection 9.1.3.2

Tier 2, Subsection 9.2.1.1

Tier 2, Subsection 9.2.2.1

Tier 2, Subsection 19A.4.2

Enclosure 2

MFN 09-761

Response to Portion of NRC Request for Additional Information Letter No. 391 Related to Design Control Document (DCD) Revision 6

Fuel and Auxiliary Pool Cooling System

RAI Number 9.1-20 S05

DCD Markups

- Mechanical damage caused by dropping of fuel assemblies, bundles, or other objects onto stored fuel.

Summary of Radiological Considerations

By adequate design and careful operational procedures, the design bases of the spent fuel storage arrangement are satisfied. Thus, the exposure of plant personnel to radiation is maintained well below regulatory limits and in accordance with As Low As Reasonably Achievable (ALARA) principles. Further details of radiological considerations, including those for the spent fuel storage arrangement, are presented in Chapter 12.

9.1.3 Fuel and Auxiliary Pools Cooling System

9.1.3.1 Design Bases

Safety Design Basis

FAPCS is a nonsafety-related system, except for the following safety-related items:

- Containment isolation valves,
- High-pressure interface with the Reactor Water Cleanup / Shutdown Cooling System,
- Emergency water supply flow paths to the spent fuel pool and Isolation Condenser/Passive Containment Cooling System (IC/PCCS) pools; andGravity Driven Cooling System (GDCS) interconnecting pipes.

Power Generation Design Basis

FAPCS provides continuous cooling and cleaning of the spent fuel storage pool during normal plant operation. It also provides occasional cooling and cleaning of various pools located inside the containment during normal plant operation and refueling outages.

9.1.3.2 System Description

System Description Summary

The FAPCS consists of two physically separated cooling and cleanup trains, each with 100% capacity during normal operation. Each train contains a pump, a heat exchanger and a water treatment unit for cooling and cleanup of various cooling and storage pools except for the IC/PCCS pools (refer to Figure 9.1-1). A separate subsystem with its own pump, heat exchanger and water treatment unit is dedicated for cooling and cleaning of the IC/PCCS pools independent of the FAPCS cooling and cleanup train operation during normal plant operation (refer to Figure 9.1-1).

The primary design function of FAPCS is to cool and clean pools located in the containment, RB and FB (refer to Table 9.1-1) during normal plant operation. FAPCS provides flow paths for filling and makeup of these pools during normal plant operation and during post-accident conditions, as necessary.

FAPCS is also designed to provide the following accident recovery functions in addition to the Spent Fuel Pool cooling function:

- Suppression pool cooling (SPC);

- Drywell spray;
- Low pressure coolant injection (LPCI) of suppression pool water into the Reactor Pressure Vessel (RPV); and
- Alternate Shutdown Cooling.

In addition to its accident recovery function, the SPC mode is also designed to automatically initiate during normal operation in response to a high temperature signal from the suppression pool.

A crosstie to the Reactor Water Cleanup/Shut Down Cooling (RWCU/SDC) System is provided in the suppression pool suction and discharge headers such that this system may be used as an alternative for post-accident decay heat removal. For details regarding the crosstie, refer to Subsection 5.4.8.

Redundancy and physical separation are provided in accordance with SECY-93-087 for active components in lines dedicated to LPCI and SPC modes.

During normal plant operation, at least one FAPCS cooling and cleanup train is available for continuous operation to cool and clean the water of the Spent Fuel Pool, while the other train can be placed in standby or other mode for cooling the GDCS pools and suppression pool. If necessary during a refueling outage, both trains may be used to provide maximum capacity for cooling the Spent Fuel Pool. The water treatment units can be bypassed when necessary, and will be bypassed automatically on a high temperature signal downstream of the heat exchangers.

Each FAPCS cooling and cleanup train has sufficient flow and cooling capacity to maintain Spent Fuel Pool bulk water temperature below 48.9°C (120°F) under normal Spent Fuel Pool heat load conditions (normal heat load condition is defined as irradiated fuel in the Spent Fuel Pool resulting from 20 years of plant operations). During the maximum Spent Fuel Pool heat load conditions of a full core offload plus irradiated fuel in the Spent Fuel Pool resulting from 20 years of plant operations, both FAPCS cooling and cleanup trains are needed to maintain the bulk temperature below 60°C (140°F).

During a loss of the FAPCS cooling trains, cooling of the Spent Fuel Pool, buffer pool and IC/PCCS pools is accomplished by allowing the water to heat and boil. The Spent Fuel Pool is maintained at a water level of at least 14.35 m (47 ft) and a free volume above the TAF of at least 1690 m^3 (59700 ft^3). The buffer pool is maintained at a water level of at least 6.7 m (22.0 ft) and a free volume above TAF of at least 288 m^3 (10169 ft^3). For both pools, the water levels and free volumes are sufficient to ensure that following a loss of active cooling without makeup that persists for 72 hours, the water levels in the pools remain above TAF. After 72 hours, post-accident makeup water can be provided through safety-related connections to the Fire Protection System (FPS) or another onsite or offsite water source.

All operating modes (refer to Table 9.1-2) are manually initiated and controlled from the Main Control Room (MCR), except the SPC mode, which is initiated either manually, or automatically on high suppression pool water temperature signal. Instruments are made for indication of operating conditions to aid the operator during the initiation and control of system operation. Provisions are provided to prevent inadvertent draining of the pools during FAPCS operation by including anti-siphon holes on all FAPCS piping that is normally submerged.

The FAPCS is designed to provide for the collection, monitoring, and drainage of pool liner leaks from the spent fuel pools, auxiliary pools, and IC/PCCS pools (refer to Table 9.1-1) to the Liquid Waste Management System.

Containment isolation valves are provided on the lines that penetrate the primary containment and are powered from independent safety-related sources.

The containment isolation valves are automatically closed upon receipt of a containment isolation signal from the Leakage Detection and Isolation System (LD&IS), with the exception of the containment isolation valves needed for post-accident recovery modes, which do not receive an isolation signal.

The FAPCS is a nonsafety-related system with the exception of piping and components required for:

- Containment isolation;
- Refilling of the IC/PCCS pools and the Spent Fuel Pool with post-accident water supplies from the Fire Protection System or another onsite or offsite source; and
- The high-pressure interface with the Reactor Water Cleanup/Shutdown Cooling system used for low pressure coolant injection.

The piping and components needed for the following functions are classified as Regulatory Treatment of Non-Safety Systems (RTNSS):

- Suppression pool cooling
- Low pressure coolant injection

This includes the suction line from the suppression pool, all of the piping and components in the cooling and cleaning trains except the water treatment units, and the discharge lines to the suppression pool and the LPCI interface up to the safety-related isolation valves.

The FAPCS piping and components that are required to support safety-related or accident recovery function have Quality Group B or C and Seismic I or II classification (Table 9.1-3). A Seismic I classification is required for all safety-related functions. The remaining nonsafety-related piping and components that support accident recovery functions are Seismic Category II. This classification satisfies the requirements of SRP 9.1.3 Section I.1.

Detailed System Description

The FAPCS is provided with two cooling and cleanup trains with 100% capacity during normal operation. Each FAPCS train is physically separated and has one pump, one heat exchanger and one water treatment unit consisting of a prefilter and a demineralizer.

A manifold of four motor-operated valves is attached to each end of the FAPCS cooling and cleanup trains (refer to Figure 9.1-1). These manifolds are used to connect the FAPCS cooling and cleanup train with one of the two pairs of suction and discharge piping loops to establish the desired flow path during FAPCS operation. One loop is used for the fuel pools and auxiliary pools, and the other loop for the GDCS pools and suppression pool and for injecting water to drywell spray sparger and reactor vessel via the RWCU/SDC System and feedwater pipes.

The use of manifolds with proper valve alignment and separate suction-discharge piping loops:

- Allows operating of one train independent of the other train to permit on-line maintenance or dual mode operation using separate trains if necessary; and
- Prevents inadvertent draining of the pool and minimizes mixing of contaminated water in the Spent Fuel Pool with cleaner water in other pools.

Each water treatment unit is equipped with a prefilter, a demineralizer and a post-strainer. A bypass line is provided to permit bypass of the water treatment unit, when necessary. To protect demineralizer resin, the water treatment units are bypassed automatically on a high temperature signal. The prefilter and demineralizers of the water treatment units are located in shielding cells so that radiation exposure of plant personnel is within acceptable limits.

Proper physical separation is provided between the active components of the two redundant trains to assure operation of one train in the event of failure of the other train.

A reactor makeup water discharge line is provided for injecting suppression pool water or water from the Fire Protection System to the reactor vessel via Reactor Water Cleanup/Shutdown Cooling System (SDC) Loop B and Feedwater Loop A discharge pipes. The suction location in the suppression pool is designed with consideration given to the strainer plugging issues encountered in previous operating experience. The strainer is designed with perforated plate hole sizes of $\leq$ 2.508 mm (0.0988 inches). This operating mode can utilize two sources of water. The primary flow path draws water from the suppression pool and uses one of the FAPCS trains to discharge it into the RWCU/SDC System. This injection line includes redundant shutoff valves such that the flow path branches to include two parallel flow paths, each with a motor-operated gate valve (refer to Figure 9.1-1). This line branches again downstream of the shutoff valves to include a pair of safety-related testable check valves which isolate the FAPCS from the safety-related RWCU/SDC System piping downstream. A secondary flow path draws water from the Fire Protection Storage Tank using an Adjustable Speed Drive (ASD) equipped motor-driven pump located in the fire pump enclosure. This secondary flow path injects its water into the primary flow path upstream of the motor-operated shutoff valves. All piping between the RWCU/SDC System and the motor-operated shutoff valves are designed to withstand the full reactor pressure. The motor-operated shutoff valves fail as-is, are normally closed, and are prevented from opening by a high reactor pressure signal from the Nuclear Boiler System to protect the low pressure portion of FAPCS piping and components. A pressure relief valve is located upstream of the motor-operated shutoff valves. Any leakage of high-pressure coolant through the safety-related check valves and motor-operated shutoff valves is discharged through the pressure relief valve and measured before being sent to the Liquid Waste Management System. Redundant valves are contained in separate fire zones for improved reliability.

A drywell spray discharge line and a ring header with spray nozzles mounted on the header are provided for spraying water inside the drywell to reduce the drywell pressure 72 hours following a LOCA to assist in post-accident recovery. In order to prevent excessive negative differential pressure on the containment liner the drywell spray flow rate must be less than 127 m^3/hr (560 gpm). The drywell spray flow rate is maintained below this value by a sized, flow-restricting orifice located in the drywell spray discharge line. The ring header equipped with spray nozzles is located in the drywell.

A separate cooling and cleanup subsystem completely independent of FAPCS cooling and cleanup trains and their piping loop is provided for cooling and cleanup of the IC/Passive

Containment Cooling System (PCCS) pools to prevent radioactive contamination of these pools. The subsystem consists of one pump, one heat exchanger, and one water treatment unit .

FAPCS contains two containment isolation valves on the lines that penetrate the primary containment.

For details related to FAPCS containment isolation, refer to Subsection 6.2.4.3.2.

Pipes equipped with normally closed manual valves are provided for establishing flow paths from onsite or offsite post-accident water supplies or the Fire Protection System to refill the IC/PCCS pools and Spent Fuel Pool following a design basis loss-of-coolant accident.

With the exception of the suppression pool suction line, anti-siphoning devices are used on all submerged FAPCS piping to prevent unintended drainage of the pools. The redundant anti-siphoning holes for all FAPCS discharge lines are located at the elevation ~~of normal water level to prevent significant draining of the pool~~that will preserve a safe shielding level of at least 3.05 m (10 ft) above the top of the active fuel in a stored fuel bundle in ~~case~~the event of a ~~suction~~ line break at a lower elevation. The anti-siphoning holes in the suction piping of the GDCS Pools and IC/PCCS cooling and cleanup subsystem are located at the elevation of minimum water level to prevent significant draining of the pool in case of a suction line break at a lower elevation. The post-accident makeup lines to the Spent Fuel Pool and IC/PCCS Pools are not submerged below the normal water level. Analysis will be performed on the suppression pool suction line, per the requirements of Subsection 3.6.2.1.2 for moderate energy piping, to show that the piping from the pool to the containment isolation valves remains below the threshold limit for postulating leakage cracks.

The spent fuel pool is equipped with drainage paths behind the liner welds. These paths are designed to:

- Prevent stagnant water buildup behind the liner plate;
- Prevent the uncontrolled loss of contaminated pool water; and
- Provide liner leak detection and measurement.

The reactor well, equipment storage pool, buffer pool, upper and lower fuel transfer pools, cask pool, and IC/PCCS pools are also equipped with stainless steel liners, and are equipped with leak detection drains as part of the FAPCS. All leak detection drains are designed to permit free gravity drainage to the Liquid Waste Management System.

The containment isolation valves and other equipment required for the post-accident recovery function are provided with electric power from reliable power supplies. In the event of loss of offsite power, these electric power supplies are automatically connected to the onsite power sources. The electrical power supplies, control and instrumentation of the two FAPCS trains and their supporting systems are electrically and physically separated. Pneumatic power assisted containment isolation valves on the suppression pool supply and return lines are designed to fail as-is upon loss of its electric power or pneumatic (air or nitrogen) supply. All other containment isolation valves are designed to fail closed.

Provisions are provided to protect FAPCS components from fire, missile generating event, plant internal flooding, or seismic event of intensity up to and including a Safe Shutdown Earthquake (SSE) so that sufficient capability is retained for the fuel pool cooling function.

The FAPCS is designed to permit surveillance testing and in-service inspection of the safety-related components in accordance with ASME Section XI. Additionally, the FAPCS is designed to permit leak rate testing of its components required to perform containment isolation, in accordance with 10 CFR 50 Appendix J.

Piping and components completely separate from FAPCS pool cooling piping provide flow paths for post-accident makeup water transfer from the Fire Protection System (or offsite water supply sources) to the IC/PCCS pool and spent fuel pool. Active FAPCS valves located inside the RB are not required to operate to accomplish this makeup. This piping and components are designed to meet Quality Group C and Seismic Category I requirements.

The equipment storage pool and reactor well contains valves that, when opened, create a connection between the two IC/PCCS expansion pools through the equipment storage pool. These valves are designed to open on receiving a low level signal from either of the IC/PCCS expansion pools, and allow makeup water supplied to one of the IC/PCCS expansion pools to communicate with the other expansion pool.

Branch connections are provided on the suppression pool suction line and return line, which serve as attachments for portable external cooling equipment that bypasses the FAPCS cooling and cleanup trains.

FAPCS piping and components, relied upon for containment integrity, are designed to Quality Group B and Seismic Category I requirements.

System Operation

FAPCS cooling and cleanup trains operate continuously to cool and clean the water in the Spent Fuel Pool during normal plant operation and refueling outages. Operation of only one FAPCS cooling and cleanup train is sufficient to handle the cooling requirements under the normal heat load condition in the Spent Fuel Pool. Operation with up to two FAPCS cooling and cleanup trains is sufficient to handle the cooling requirement under the maximum heat load condition. At least one FAPCS cooling and cleanup train is available for cooling the Spent Fuel Pool, except for a short period as long as the water temperature in the pool remains below the maximum temperature limit for normal operation.

During a refueling outage, FAPCS can be operated in the Fuel and Auxiliary Pool Cooling and Cleanup mode with both cooling and cleanup trains under the maximum heat load condition in the Spent Fuel Pool.

If necessary the FAPCS can operate in a dual mode using two separated FAPCS cooling and cleanup trains with separate suction and discharge piping loops. However, dual mode operation using a single train is prohibited by logic in the Nonsafety-related Distributed Control and Information System (N-DCIS), because it could result in redistribution of water between pools containing contaminated water and pools containing clean water.

As necessary during normal plant operation, the standby FAPCS cooling and cleanup train is placed in operation to cool and clean the water in the Suppression Pool and GDCS pools. The IC/PCCS pools cooling and cleanup subsystem operates as necessary to cool and clean the water in the IC/PCCS pools during normal plant operation.

The FAPCS may be operated in the following modes for post-accident recovery:

- Spent Fuel Pool Cooling;
- Low Pressure Coolant Injection (LPCI);
- Suppression Pool Cooling (SPC);
- Drywell Spray; and
- Alternate Shutdown Cooling (ASDC).

All FAPCS lines penetrating the containment that do not have a post-accident recovery function are automatically isolated upon receipt of a containment isolation signal from Leak Detection and Isolation System (LD&IS).

The FAPCS piping provides flow paths for delivery of makeup water to IC/PCCS pools and Spent Fuel Pool from onsite or offsite post-accident water sources or the Fire Protection system as needed 72 hours after a design basis accident.

For the RTNSS function of low pressure coolant injection, a single train of the FAPCS is capable of pumping water from the suppression pool at a rate of 340 m3/hr (1500 gpm) at a differential pressure of 1.03 MPa (150 psi). The secondary injection path using the motor-driven pump in the fire pump enclosure is capable of supplying water at a rate of 90.8 m^3/hr (400 gpm) from the fire protection storage tank at a pressure of 2.61 MPa (379 psig). At a lower pressure of 1.72 MPa (250 psig), the secondary flow path is capable of supplying water at a rate of 409 m^3/hr (1800 gpm).

System Operating Modes

FAPCS is designed to operate in the modes listed in Table 9.1-2. The following paragraphs describe the major operating modes of FAPCS.

Spent Fuel Pool Cooling and Cleanup Mode – One of the FAPCS cooling and cleanup trains is continuously operated in this mode to cool and clean the water in the Spent Fuel Pool during normal plant operation and refueling outages. This mode may be initiated following an accident to cool the Spent Fuel Pool for accident recovery. During this mode of operation, water is drawn from the skimmer surge tanks, pumped through the heat exchanger and water treatment unit to be cooled and cleaned and then returned to the Spent Fuel Pool (SFP). As the SFP level rises, water spills into the weir and flows back to the skimmer surge tanks. When necessary, a portion or all of the water may bypass the water treatment unit.

Fuel and Auxiliary Pool Cooling and Cleanup Mode - During a refueling outage, one or both FAPCS cooling and cleanup trains are placed in this mode of operation to cool and clean the water in the Spent Fuel Pool and pools listed below depending on the heat load condition in these pools.

- Upper fuel transfer pool;
- Buffer pool;
- Reactor well; and
- Dryer and separator storage pool.

Once the core decay heat has dropped to a manageable level, this mode can be used as an alternate to the shutdown cooling function of the RWCU/SDC System.

During this mode of operation, water is drawn from the skimmer surge tanks, pumped through the heat exchanger and water treatment unit to be cooled and cleaned and then returned to these pools. When necessary, a portion or all of the water may bypass the water treatment unit.

IC/PCCS Pool Cooling and Cleanup Mode –The FAPCS-IC/PCCS pool cooling and cleanup subsystem is placed in this mode as necessary during normal plant operation. During this mode of operation, water is drawn via a common suction header from each IC/PCCS subcompartment. Water is cooled and cleaned by the IC/PCCS pool cooling and cleanup subsystem and is then returned to the two expansion pools through a common line that branches and discharges deep into each pool.

GDCS Pool Cooling and Cleanup Mode – One train of the FAPCS cooling and cleanup subsystem that is not operating in Spent Fuel Pool cooling mode is placed in this mode as necessary during normal plant operation. Water is drawn from GDCS pools A and D in this mode of operation. The water is cooled and cleaned and is then returned to GDCS pool B/C. The water level in GDCS pool B/C rises and the water is cascaded and discharged at a submerged location in the adjacent GDCS pools A and D during this mode of operation.

Suppression Pool Cooling and Cleanup Mode – One of the FAPCS cooling and cleanup trains that is not operating in Spent Fuel Pool cooling mode is placed in this mode as necessary during normal plant operation. Water is drawn from the suppression pool and is cooled and cleaned and then returned to the suppression pool in this mode of operation. This mode may be manually initiated following an accident to cool the suppression pool for accident recovery. This mode may also be automatically initiated during normal operation in response to a high temperature signal from the suppression pool. The portions of the FAPCS needed for suppression pool cooling are designed to accommodate severe accident wetwell pressures as high as 411 kPa (59.6 psia), and severe accident differential temperatures resulting from suppression pool water temperatures as high as 91.0°C (196°F) with the cooling water restricted to the same values described in Table 9.1-8. ~~and severe accident wetwell pressures as high as 411 kPa (59.6 psia).~~

Low Pressure Coolant Injection (LPCI) Mode - This mode may be initiated following an accident after the reactor has been depressurized to provide reactor makeup water for accident recovery. In this mode the FAPCS pump takes suction from the suppression pool and pumps it into the reactor vessel via RWCU/SDC loop B and then Feedwater loop A. Alternatively, a separate motor-driven pump in the fire pump enclosure can take suction from the fire protection storage tank and pump water into the reactor vessel via a tie in with the primary LPCI flow path.

Alternate Shutdown Cooling Mode – This mode may be initiated following an accident for accident recovery. In this mode, FAPCS operates in conjunction with other systems to provide reactor shutdown cooling in the event of loss of other shutdown cooling methods. FAPCS flow path is similar to that of LPCI mode during this mode of operation. Water is drawn from the suppression pool, cooled and then discharged back to the reactor vessel via the LPCI injection flow path. The warmer water in the reactor vessel rises and then overflows into the suppression pool via two opened safety-relief valves on the main steam lines, completing a closed loop for this mode operation.

Drywell Spray Mode - This mode may be initiated following an accident for accident recovery. During this mode of operation, FAPCS draws water from the suppression pool, cools and then spays the cooled water to drywell air space to reduce the containment pressure.

9.2 WATER SYSTEMS

9.2.1 Plant Service Water System

9.2.1.1 Design Bases

Safety Design Bases

The Plant Service Water System (PSWS) does not perform any safety-related function. There is no interface with any safety-related component.

The PSWS has RTNSS functions as described in Appendix 19A, which provides the level of oversight and additional requirements to meet the RTNSS functions. Performance of RTNSS functions are assured by applying the defense-in-depth principles of redundancy and physical separation to ensure adequate reliability and availability as described in Subsection 19A.8.3. The design basis capabilities of the PSWS are sufficient to meet the RTNSS performance requirements described in Chapter 19A.

The PSWS meets the requirements of GDC 2 as it pertains to Position C.2 of RG 1.29. The PSWS also meets the intent of GDC 2 as it pertains to Position C.1 of RG 1.29.

The PSWS meets the intent of the acceptance criteria of GDC 4 for normal operation, maintenance, and testing. The PSWS meets the intent of the acceptance criteria of GDC 4 with respect to dynamic effects associated with water hammer. The PSWS is vented at components and high points vents and operation and maintenance procedures are used to assure sufficient measures are taken to avoid water hammer. The PSWS also meets the intent of the acceptance criteria of GDC 4 for other dynamic effects, including the effects of missiles, jet impingement, pipe whipping, and discharging fluids, as clarified by the following design considerations:

- Pipe routing;
- Piping design considerations, such as material selection, pipe size and schedule;
- Protective barriers as necessary; and
- Appropriate supports and restraints.

The PSWS meets GDC 5 for shared systems and components important to safety. The PSWS Standard Plant design does not share any structure, system, or component (SSC) with any other unit.

Although the PSWS is a nonsafety-related system, it meets the intent of certain acceptance criteria of GDCs 44, 45 and 46, as clarified by the following design considerations:

- Capability of transferring heat loads from SSCs to a heat sink under normal and accident conditions;
- Component redundancy so the system remains functional assuming a single active failure coincident with a loss of offsite power;
- Capability to isolate components or piping so system function is not compromised; and
- Design provisions to permit inspection and operational testing of components and equipment.

The pump discharge strainers have remote manual override features for their automatic cleaning cycle. Pressure drop across the strainer is indicated in the MCR and a high-pressure drop is annunciated in the control room.

Supply and return header temperatures and supply header pressure are indicated in the MCR.

Each TCCWS and RCCWS heat exchanger has a pressure differential transmitter to indicate the pressure drop across the heat exchangers. In addition, a discharge flow transmitter is placed after each RCCWS and TCCWS heat exchanger. Flow elements and transmitters in the PSWS provide monitoring of system flow in the MCR and can be used to assist in leak detection.

This PSWS instrumentation conforms with GDC 13. Refer to Subsection 3.1.2.4 for a general discussion of the GDC.

9.2.1.6 COL Information

9.2.1-1-A Material Selection

The COL Applicant will determine material selection, including the need for valve hard seat material, and provide provisions to preclude long-term corrosion and fouling of the PSWS based on site water quality analysis (Subsection 9.2.1.2).

9.2.1.7 References

9.2.1-1 RG 1.29 "Seismic Design Classification"

9.2.1-2 ANSI/HI 2.6 (M108) American National Standard for Vertical Pump Tests

9.2.2 Reactor Component Cooling Water System

9.2.2.1 Design Bases

Safety Design Bases

The RCCWS does not perform any safety-related function. Therefore, the RCCWS has no safety design basis.

The RCCWS has RTNSS functions as described in Appendix 19A, which provides the level of oversight and additional requirements to meet the RTNSS functions. Performance of RTNSS functions is assured by applying the defense-in-depth principles of redundancy and physical separation to ensure adequate reliability and availability as described in Subsection 19A.8.3. The design basis capabilities of the RCCWS are adequate to meet the RTNSS performance requirements described in Chapter 19A.

The RCCWS meets the requirements of GDC 2 as it pertains to Position C.2 of Reg. Guide 1.29. The RCCWS also meets the intent of GDC 2 as it pertains to Position C.1 of Reg. Guide 1.29.

The RCCWS meets the intent of the acceptance criteria of GDC 4 for normal operation, maintenance, and testing. The RCCWS meets the intent of the acceptance criteria of GDC 4 with respect to dynamic effects associated with water hammer. The RCCWS has high point vents and operation and maintenance procedures assure sufficient measures are taken to avoid water hammer. The RCCWS also meets the intent of the acceptance criteria of GDC 4 for other safe shutdown earthquake (SSE). Only passive safety-related systems are credited in the seismic event tree. In addition, FPS is classified as nonsafety-related but is designed so that the diesel driven pump in the Fire Pump Enclosure (FPE), the FPS water supply, the FPS suction pipe from the water supply to the pump, one of the FPS supply pipes from the FPE to the Reactor Building, and the FPS connections to the FAPCS remain operable following a seismic event. Piping and components completely separate from FAPCS pool cooling piping provide flow paths for post-accident make-up water transfer to the IC/PCCS pools and spent fuel pool. The piping and components are designed to meet Quality Group C and Seismic Category I requirements. Therefore, there are no seismic-related candidates for RTNSS consideration.

19A.4.2 Assessment of Uncertainties

The ESBWR PRA addresses passive system thermal-hydraulic uncertainty issues in a systematic process that identifies potential uncertainties in passive components or thermal-hydraulic phenomena and then applies an appropriate treatment to the component to ensure that the uncertainties are treated conservatively.

Passive system thermal-hydraulic uncertainties manifest themselves in the PRA model within failure probabilities and success criteria. Passive components that must rely on natural forces, such as gravity, have lower driving forces than conventional pumped systems so additional margin is incorporated into the design. Some passive functions are based on new engineering design, with limited operating experience to establish confidence in the failure rate estimates. The PRA models the effectiveness of passive safety functions in the failure rate estimated and success criteria that are factored into the event trees. Assessing the event tree success criteria in the PRA model identifies thermal-hydraulic uncertainties. Sensitivity studies show that the PRA results are not sensitive to changes in success criteria.

There are also uncertainties associated with the manual alignment and operation of long-term decay heat removal systems identified under RTNSS Criterion B. These uncertainties can influence the results such that there is a challenge to the CDF and LRF goals in transient sequences. This is not an issue for low frequency scenarios, such as large LOCA or seismic events.

In order to address uncertainties in the performance of passive systems, an active system with the capability to provide backup functions is added to the scope of RTNSS. The portions of FAPCS (Subsection 9.1.3.2) that provide low pressure injection and suppression pool cooling are added in the scope for RTNSS. These FAPCS modes of operation are chosen because they provide a diverse method of core cooling and containment heat removal using active components.

Using the design parameters for the FAPCS heat exchanger found in Table 9.1-8, analysis shows that additional capacity can be credited in which elevated suppression pool temperature results in a higher differential temperatures in the heat exchanger such that the heat transfer rate increases to as much as 34 MW, which is sufficient to prevent containment failure during a beyond design basis accident.

The support systems needed for FAPCS are: Reactor Component Cooling Water System (RCCWS), standby diesel generators, standby diesel generator auxiliary systems (including standby diesel generator fuel oil storage and transfer system), PIP buses, Electrical Building HVAC (to cool the standby diesel generators and the PIP buses), RCCWS and Fuel Building

HVAC (to cool the FAPCS pumps), Nuclear Island Chilled Water (to cool HVAC), and Plant Service Water System (PSWS) (to cool the RCCWS). These support systems are in scope for RTNSS Criterion C and their design basis capacity is sufficient to accommodate the beyond design basis performance of FAPCS described above. The FAPCS trains are physically and electrically separated such that no single active component failure can fail the function. This provides the CDF and LRF reduction needed to address the PRA uncertainty concerns associated with the performance of passive system components.

19A.4.3 PRA Initiating Events Assessment

The At-Power and Shutdown PRA models have been reviewed to determine whether non-safety SSCs could have a significant effect on the estimated frequency of initiating events. The following screening criteria are imposed on the at-power and shutdown initiating events:

(1) Are nonsafety-related SSCs considered in the calculation of the initiating event frequency?

(2) Does the unavailability of the nonsafety-related SSCs significantly affect the calculation of the initiating event frequency?

(3) Does the initiating event significantly affect CDF or LRF for the baseline PRA?

If the answer to all three of these questions is "Yes," then the non-safety SSC is a RTNSS candidate. The results are discussed below.

19A.4.3.1 At-Power Generic Transients

Initiating events that are considered Generic Transients are listed in Subsection 19.2.3.1. Because several initiating events in this group are caused by the failures of nonsafety-related SSCs, screening questions 1, 2, and 3 are answered "Yes." However, this category of transient initiating events includes various failures of components or operator errors. No specific nonsafety-related systems have a significant effect on risk, and there are no RTNSS candidates from this category.

19A.4.3.2 At-Power Inadvertent Opening of a Relief Valve

SRVs are safety-related. Therefore, they are not RTNSS candidates.

19A.4.3.3 At-Power Transient with Loss of Feedwater

The initiating events in this group begin with a prompt and total loss of feedwater and require the success of other mitigating systems for reactor vessel level control. The SSCs related to feedwater and condensate are nonsafety-related, and thus Questions 1, 2, and 3 are answered "Yes." The loss of feedwater is a significant contributor to CDF, so the feedwater and condensate systems are RTNSS candidates. However, several features in the advanced design of the new generation feedwater level control system add significant reliability and, thus, a lower failure probability for loss of feedwater initiating events. The feedwater level control system is implemented on a triplicated, fault-tolerant digital controller. Therefore, a control failure is much less likely to occur in the ESBWR than in the design of current generation of reactors. Also, due to the capacity of the pumps and the digital control system capability, loss of a single feedwater pump does not cause a turbine trip or scram.