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Subject: **Supplemental Response to Portion of NRC Request for Additional Information Letter No. 278 Related to the ESBWR Design Certification – Reactor Vessel Level and Shutdown Cooling – RAI Number 5.4-59 S02**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) supplemental response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by NRC letter No. 278 (Reference 1). Supplement 1 was submitted via Reference 2 with GEH's response provided via Reference 3. GEH response to RAI Number 5.4-59 S02 is addressed in Enclosure 1. DCD markups associated with this response are provided in Enclosure 2.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

References:

1. MFN 08-956, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 278 Related To ESBWR Design Certification Application*, dated December 4, 2008
2. MFN 08-560, Letter from U. S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 219 Related to the ESBWR Design Certification Application*, dated June 30, 2008
3. MFN 08-414, Supplement 1, Letter from Richard E. Kingston, GEH to U.S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 219 Related to the ESBWR Design Certification Application - Nuclear Boiler System - RAI Numbers 5.2-71 S01 and 5.4-59 S01*, dated October 6, 2008

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 278 Related to ESBWR Design Certification Application – Reactor Vessel Level and Shutdown Cooling – RAI Number 5.4-59 S02
2. Response to Portion of NRC Request for Additional Information Letter No. 278 Related to ESBWR Design Certification Application – Reactor Vessel Level and Shutdown Cooling – RAI Number 5.4-59 S02 – DCD Markups

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Enclosure 1

MFN 08-414, Supplement 2

Response to NRC Request for Additional Information Letter No. 278 Related to ESBWR Design Certification Application

Reactor Vessel Level and Shutdown Cooling

RAI Number 5.4-59 S02

<u>NRC RAI 5.4-59 S02</u>:

A) The staff reviewed GEH's response to 5.4-59S01 and reviewed Section 5.4 of the DCD, Revision 5. The DCD does not document that vessel level at the first stage water spill of the steam separators is the analytical lower limit of shutdown cooling core circulation. As stated by GEH in the RAI response, vessel level below the analytical lower limit would result in thermal stratification. GEH further states in the RAI response: "shutdown core cooling would cease in this situation with the consequent onset of liquid volume heatup inside the shroud, chimney, and separator column regions of the vessel." GEH is requested to document the following items in the DCD:

1) Vessel level at the first stage water spill of the steam separators is the analytical lower limit of shutdown cooling core circulation for Modes 4, 5, and 6.

2) Vessel level below the analytical lower limit would result in thermal stratification. Shutdown core cooling would cease in this situation with the consequent onset of liquid volume heatup inside the shroud, chimney, and separator column regions of the vessel.

3) A COL action item to establish an administrative lower water level limit to build margin between the operating range for shutdown cooling and the analytical lower limit of the design for core circulation to meet the intent of GE SIL 357. This measure is needed to ensure that the frequency of the loss of the decay heat removal function during Modes 4, 5, and 6 does not impact the shutdown PRA results and the shutdown RTNSS evaluation.

4) A risk insight in Table 19.2-3 of the DCD for the COL applicants to establish an administrative lower water level limit to build margin between the operating range for shutdown cooling and the analytical lower limit of the design for core circulation to meet the intent of GE SIL 357. This measure is needed to ensure that the frequency of the loss of the decay heat removal function during Modes 4, 5, and 6 does not impact the shutdown PRA results and the shutdown RTNSS evaluation.

B) GEH is also requested to provide the following:

Evaluate the need for level instrumentation and annunciators alerting the operator when shutdown cooling core circulation is disrupted, or evaluate this failure in the shutdown PRA. Failure of the operator to maintain or to recover vessel level above the first stage spill over was not included in the Shutdown PRA or in the RTNSS assessment.

C) In addition, the staff is preparing a Computational Fluid Dynamics model to assess the capability of the RWCU/Shutdown Cooling System to remove decay heat. Additional details are needed for the Feedwater sparger. Provide a drawing showing the main ring internal diameter and pipe schedule, overall radius or diameter of the ring, entrance details from the external FW nozzle weld to the ring split (neckdown), nozzle type(s), locations, orientation and size, or, if drilled holes, the locations and size(s). Also, if there are any external components which may block the circulation path in the reactor vessel, such as a thermal sleeve, lift lugs, or supports, provide a drawing with sufficient details for CFD model input.

<u>GEH Response</u>:

A) 1) DCD Tier 2 Subsection 5.4.8.2.2 will be revised in Revision 6 to discuss the analytical lower limit of the shutdown cooling core circulation path.

A) 2) DCD Tier 2 Subsection 5.4.8.2.2 will be revised in Revision 6 to discuss preventing thermal stratification by maintaining proper water level.

A) 3) A COL action item to establish a lower water level limit is not warranted. The supporting information in this response discusses why the frequency of the loss of the decay heat removal function during Modes 4, 5, and 6 does not have a significant effect on the shutdown Probabilistic Risk Assessment (PRA) results and the shutdown Regulatory Treatment of Non-Safety Systems (RTNSS) evaluation.

A) 4) A PRA Risk Insight is not warranted because the frequency of a loss of the natural circulation flow path during Modes 4, 5, and 6 does not have a significant effect on the shutdown PRA results and the shutdown RTNSS evaluation.

B) The frequency of a loss of the natural circulation flow path during Modes 4, 5, and 6 does not have a significant effect on the shutdown PRA results and the shutdown RTNSS evaluation. Regardless, the need for operator diagnosis and control of shutdown cooling is in the scope of operational procedures that are discussed in DCD Tier 2 Subsection 13.5.2.

C) GEH has supplied the requested details, in letter MFN 09-131, dated February 19, 2009, to assist the NRC staff in understanding the capability of the Reactor Water Cleanup/Shutdown Cooling (RWCU/SDC) System to remove decay heat. It is important to note that the loss of the natural circulation shutdown cooling flow path is an adverse operating condition; however, the consequences of a loss of natural circulation are not significant to core damage frequency.

Supporting Information:

RAI 5.4-59 requested information on the capability of RWCU/SDC to maintain adequate core cooling during shutdown conditions.

Supplement 1 to this RAI requested additional information on decay heat removal capability in Modes 4, 5 and 6 in order to understand the capability of RWCU/SDC in these modes and the impact of RWCU/SDC on the ESBWR Shutdown PRA. The Supplement 1 request implied that the requested information was needed for two reasons: 1) an event during shutdown operations at the Ciaux nuclear plant in France resulted in a rupture of Residual Heat Removal (RHR) piping, and 2) the ESBWR shutdown Core Damage Frequency (CDF) is dominated by LOCA events.

RAI 5.4-59 Supplement 2 requests that GEH provide documentation in the DCD on specific items related to shutdown cooling operations, and also requests information for preparing a computation flow dynamics analysis of the capability of RWCU/SDC to remove decay heat during shutdown operations. Supplement 2 states that the requested information is needed to ensure that the frequency of the loss of decay heat removal function during Modes 4, 5 and 6 does not impact the shutdown PRA results and the shutdown RTNSS evaluation.

GEH considers the concerns of RAI 5.4-59 and its supplements to be as follows:

1. Understand the capability of RWCU/SDC in Modes 4, 5 and 6;
2. Understand why the ESBWR design prevents events similar to the event that occurred during shutdown operations at the Ciaux nuclear plant in France, which resulted in a rupture of RHR piping (acknowledging that the ESBWR shutdown CDF is dominated by LOCA events); and
3. Ensure that the frequency of the loss of natural circulation does not adversely affect the decay heat removal function during Modes 4, 5 and 6 and, thus does not impact the shutdown PRA results and the shutdown RTNSS evaluation.

Concern 1: During a normal plant shutdown, both RWCU/SDC and Control Rod Drive (CRD) systems are required to function properly in order to proceed from Mode 4 to Mode 5. Cooling down the Reactor Pressure Vessel (RPV) to below saturation temperature is not possible without RWCU/SDC in operation.

If RPV water level is not maintained at the proper level during normal plant shutdown (similar to the events described in SIL 357), the plant remains in the Hot Shutdown or Stable Shutdown mode (Mode 3 or 4). If a loss of the natural circulation cooling path in Mode 5 is caused by density change in the cooled water, and thus a lower water level, the water level within the shroud rises back to above the first stage water spill of the steam separators as the RPV water heats up due to the loss of cooling. Therefore, this postulated problem is self-correcting.

In Modes 4 and 5, RPV water level is maintained above the first stage water spill of the steam separators to ensure natural circulation through the reactor core. If water level falls below the desired band, the disruption of the core circulation is obvious to operators because the plant would lose the capability to continue the cooldown process. The rise in coolant temperature is indicated in the Main Control Room, as supplied by redundant core inlet temperature sensors located in each Local Power Range Monitor assembly below the core plate elevation. In Mode 5, with relatively low decay heat and the large mass of water in the RPV, there are several hours available to take corrective actions before the water temperature would reach bulk boiling. At that point, there is still ample time to restore decay heat removal and increase coolant inventory so the fuel integrity is maintained.

Loss of shutdown cooling while in Mode 6 is less severe because the decay heat is lower and the water level is raised.

Concern 2: This is addressed in GEH response to RAI 5.4-59 Supplement 1, which explains why the thermal fatigue problems experienced at the French plant are not applicable to the ESBWR.

Concern 3: Given a loss of the natural circulation flow path, fuel integrity is not challenged unless multiple additional failures occur, and the resultant CDF of such sequences would be several orders of magnitude lower that the current estimates, which are already not significant. In addition, circumstances that lead to a significant loss of RPV water inventory, which in turn induces a loss of shutdown cooling, are bounded by the RPV drain-down events modeled in the current revision of ESBWR shutdown PRA model, and which incorporates the GEH response to RAI 19.1.0-4 S02 (Part E Assumptions 2, 3, and 4).

DCD Impact:

The DCD Tier 2, Subsection 5.4.8.2.2 attached markup will be reflected in Revision 6.

Enclosure 2

MFN 08-414, Supplement 2

Response to NRC Request for Additional Information Letter No. 278 Related to ESBWR Design Certification Application

DCD Markups

RAI Number 5.4-59 S02

The redundant trains of RWCU/SDC permit shutdown cooling even if one train is out of service; however, cooldown time is extended when using only one train.

In the event of loss of preferred power, the RWCU/SDC system, in conjunction with the isolation condensers, is capable of bringing the RPV to the cold shutdown condition in a day and a half, assuming the most limiting single active failure, and with the isolation condensers remove the initial heat load. Refer to Subsection 5.4.8.1.2 for a description of the RWCU/SDC pump motor ASD and its operation for shutdown cooling.

In the event of a severe accident resulting in fuel failure, train A of the RWCU/SDC system can be cross-connected to the FAPCS suppression pool suction and the FAPCS containment cooling line to provide containment cooling capabilities. This will allow containment cooling while maintaining the contaminated water inside the reactor building. In this condition the RWCU/SDC system has the capability to return cooled suppression pool water to the reactor vessel through the RWCU mid-vessel suction to preclude using the feedwater injection flowpath, which exits the reactor building.

System Operation

The modes of operation of the shutdown cooling function are described below:

Normal Plant Shutdown — The operation of the RWCU/SDC system at high reactor pressure reduces the plant reliance on the main condenser or ICS. The entire cooldown is controlled automatically. As cooldown proceeds and reactor temperatures are reduced, pump speeds are increased and various bypass valves are opened, as described below. During the early phase of shutdown, the RWCU/SDC pumps operate at reduced speed to control the cooldown rate to less than the maximum allowed RPV cooling rate.

In order to maintain less than the maximum allowed RPV cooling rate, both RWCU/SDC trains are placed into operation early during the cooldown, but with the pumps and system configuration aligned to provide a moderate system flow rate. The flow rate for each train is gradually increased as RPV temperature drops. To accomplish this, in each train, the bypass line around the RHX, and the bypass line around the demineralizer are opened to obtain the quantity of system flow required for the ending condition of the shutdown cooling mode. Flow continues through the in-service NRHX of both RWCU/SDC trains with the capability of controlling the RCCWS inlet valve to increase, or decrease cooling water as necessary.

The automatic reactor temperature control function controls the ASD, controlling the cooldown by gradually increasing the speed of the system pumps up to the maximum pump flow. Water purification operation is continued without interruption.

Over the final part of the cooldown, maximum flow is developed through the RWCU/SDC pumps. After about two weeks, flow rate reduction becomes possible while maintaining reactor coolant temperatures within target temperature ranges.

CRD System flow is maintained to provide makeup water for the reactor coolant volume contraction that occurs as the reactor is cooled down. The RWCU/SDC design assumes that ~~RPV water level~~ during normal shutdown operation the RPV water level is maintained above the first stage water spill of the steam separators. The design assumes that water rising from the core is returned to the vessel annulus through passages provided in the steam separator assembly, and this minimum level assumption ~~This~~ is to ensure natural circulation is maintained through the reactor core. The spilled water from the separators mixes with the incoming colder shutdown water (through the Feedwater nozzle) in the upper downcomer, and the mixture flows down. Hotter shutdown water (through the RWCU/SDC nozzle) returns to the NRHX in order to remove the decay heat. To avoid entering a thermal stratification condition, it is expected based on existing BWR operating experience (refer to Section 18.3) that the plant is operated (see also Sections 13.5 and 18.9) with reactor vessel water level sufficiently above the minimum level assumption during use of RWCU/SDC system in the shutdown cooling mode.

The RWCU/SDC system overboarding line is used for fine level control of the RPV water level as needed.

Hot Standby — During hot standby the RWCU/SDC system may be used as required in conjunction with the main or isolation condenser to maintain a nearly constant reactor temperature by processing reactor coolant from the reactor bottom head and the mid-vessel region of the reactor vessel and transferring the decay heat to the RCCWS by operating both RWCU/SDC trains and returning the purified water to the reactor via the feedwater lines.

The pumps and the instrumentation necessary to maintain hot standby conditions are connectable to the Standby AC Power supply during any loss of preferred power.

Refueling — The RWCU/SDC system can be used to provide additional cooling of the reactor well water when the RPV head is off in preparation for removing spent fuel from the core.

Operation Following Transients— In conjunction with the isolation condensers, one-half hour after control rod insertion, the RWCU/SDC system has the capability of removing core decay heat and overboarding excess makeup due to the CRD purge flow.

If the reactor is in the "run" mode of operation, a shutdown caused by an isolation event causes the ICS to activate. Assuming the most restrictive single active failure, any number of the Isolation Condensers can be valved-out by the operator in order to provide easier pressure and water regulation of the RWCU/SDC system.

Post-LOCA Shutdown (With Fuel Failure) — The preferred method of reaching and maintaining cold shutdown after a LOCA is the FAPCS. In the unlikely event there has been a fuel failure, the RWCU/SDC system will be utilized. For this mode of operation, the RWCU/SDC system requires manual realignment of cross-connections with the FAPCS. Each cross-connection contains spectacle flanges and closed manual isolation valves. These provisions preclude the possibility of intersystem LOCA during normal modes of operation. There is also an intersystem cross-connection, which must be realigned for mid-vessel injection.

The NRHX provides the heat removal capacity to sufficiently cool the plant from stable shutdown conditions to cold shutdown conditions (Table 5.4-3).

5.4.8.2.3 Safety Evaluation

The RWCU/SDC system does not perform or ensure any system level safety-related function, and thus, is classified as nonsafety-related.

Refer to Subsection 5.4.8.1.3 for an evaluation of the safety-related containment isolation, and instrumentation for pipe break detection outside the containment functions of the RWCU/SDC system.