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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 96 - Emergency Core Cooling Systems - RAI Number 6.3-79**

Enclosure 1 contains the GE-Hitachi Nuclear Energy Americas LLC (GEH) response to the subject NRC RAI transmitted via the Reference 1 letter.

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

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

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NRO

Reference:

1. MFN 07-231, Letter from U.S. Nuclear Regulatory Commission to Robert Brown, *Request for Additional Information Letter No. 96 Related to ESBWR Design Certification Application*, April 12, 2007

Enclosure:

1. MFN 07-377 - Response to Portion of NRC Request for Additional Information Letter No. 96 - Related to ESBWR Design Certification Application - Emergency Core Cooling Systems - RAI Number 6.3-79

cc:	AE Cubbage	USNRC (with enclosures)
	GB Stramback	GEH/San Jose (with enclosures)
	RE Brown	GEH/Wilmington (with enclosures)
	eDRF	0000-0065-5487R1

Enclosure 1

MFN 07-377

Response to Portion of NRC Request for

Additional Information Letter No. 96

Related to ESBWR Design Certification Application

Emergency Core Cooling Systems

RAI Number 6.3-79

NRC RAI 6.3-79:

The Standard Review Plan (SRP), Section 6.3, Draft Rev. 3, April 1996, in Chapter III, Review Procedures, No. 20, states that the long term cooling capacity is adequate in the event of failure of any single active or passive component of the ECCS. Please state if the ESBWR design takes credit for any passive component during long term post LOCA (i.e., beyond 72 hours) cooling. If so, confirm that the ESBWR design meets the requirements of the reference given above.

GEH Response:

The ESBWR design meets the requirements stated in NUREG-0800, Standard Review Plan (SRP) 6.3, Draft Revision 3, April 1996, in Chapter III, Review Procedures, No. 20.

For the ESBWR design, conformance to the requirement of adequate long term cooling is assured and demonstrated for any loss-of-coolant accident (LOCA) where the water level can be restored and maintained at a level above the top of the reactor core. The following paragraphs provide a summary description of the ESBWR Emergency Core Cooling Systems (ECCS), and provide an evaluation of ECCS performance in maintaining a level above the top of the reactor core during the long-term period (30 days) following a LOCA.

A. Summary Description of the ESBWR ECCS

The ESBWR ECCS consists of the following four systems (DCD Tier 2, Revision 3, Subsection 6.3.1):

1. Gravity-Driven Cooling System (GDCS)

   The GDCS consists of eight GDCS injection lines that connect the reactor pressure vessel (RPV) annulus to the three separate GDCS pools, and four equalization lines that connect the RPV annulus region to the suppression pool. When actuated, the GDCS injection lines provide post-LOCA makeup water to the RPV from the three GDCS pools. When actuated, the equalization lines provide long-term post-LOCA makeup water to the RPV from the suppression pool.

   Delivery of water from each GDCS pool is designed to be single failure proof (i.e., a failure of one of the injection lines will not prevent the complete draining of the GDCS pool water to the RPV, and to the drywell (DW) annulus in the case of GDCS injection line break).

2. Automatic Depressurization System (ADS)

   The ADS consists of ten safety-relief valves (SRVs) and eight depressurization valves (DPVs). When actuated, the ADS depressurizes the RPV to provide the lower pressure that is needed for GDCS to be able to provide makeup water to the RPV.

3. Isolation Condenser System (ICS)

   The ICS consists of four individual units and they are designed to be single failure proof to initiate. However, the safety analyses assume one of the isolation condenser units is out of service and not available during the LOCA.

4. Standby Liquid Control (SLC) System

   The SLC System consists of two individual SLC accumulators and they are designed to be single failure proof.

   The ESBWR design utilizes the Passive Containment Cooling System (PCCS) to remove post-LOCA decay heat from the DW atmosphere. The reactor core decay heat continuously generates steam by boiling off a portion of the RPV inventory. The steam enters into the DW through the DPVs and pipe break (high elevation break). A small portion of the steam entering into the DW annulus may condense on the DW wall surface and drain down to the lower DW. The DW wall surface condensation rate reduces as the transient progress due to heating of the wall surface. The remaining (majority) portion of the steam enters into the DW and mixes with the non-condensable gases in the DW, and the mixture enters into the six PCCS condensers. The PCCS condenses the steam, directs non-condensable gases to the wetwell via a vent line, rejects decay heat to the Isolation Condenser (IC)/Passive Containment Cooling (PCC) pools, and returns the condensate to the GDCS pools. For pipe breaks other than the GDCS injection line, a major portion of the RPV inventory that is turned into steam by the reactor core decay heat is returned back to the RPV in the form of condensate from the PCCS condensers via the GDCS injection lines. For a GDCS injection line break, a portion of the RPV inventory is drained to the DW annulus through the broken pipe (from the GDCS pool side) instead of returning to the RPV. There is no component in the PCCS that could fail. Therefore the safety analyses assume no single failure of the PCCS in the long-term cooling period.

   The IC/PCC pool is designed with a minimum of 72 hours capacity without operator action. After 72 hours following a LOCA, the Fire Protection System provides makeup water to the IC/PCC pool.

B. ECCS performance evaluation

For the ESBWR design, conformance to the requirement of adequate long term cooling is assured and demonstrated for any LOCA where the water level can be restored and maintained at a level above the top of the reactor core.

1. Short Term (0 to 2000 seconds)

   DCD Tier 2, Subsection 6.3.3, presents the results of the short term (0 to 2000 seconds) ECCS performance evaluation. This evaluation considers all credible single failures and the spectrum of break sizes and locations. The results show that the water level can be restored and maintained at a level above the top of the reactor core. For a given pipe break, the results also show that the RPV water level is restored shortly after the initiation of GDCS flow and the long term water level response is not sensitive to the assumption of the type of single failure.

2. Long Term (0 to 72 hours)

   DCD Tier 2, Subsection 6.2.1.1.3 presents the results of the long term (0 to 72 hours) ECCS performance evaluation. This evaluation includes a feedwater line break with failure of one SRV, a GDCS line break, a bottom drain line break, and a main steam line break with one DPV failure. The results show that the water level is maintained at a level above the top of the reactor core. These results also show that the equalization lines are not activated for these cases because the RPV water level is restored shortly after the initiation of GDCS flow and maintained at a water level above 8.453 m (set point for actuation of equalization line) from the RPV bottom (See response to RAI 6.3-40, MFN 06-488, dated December 22, 2006).

3. Long Term (72 hours to 30 days)

<u>Bottom Drain Line Break (BDLB)</u>

The BDLB pipe break elevation is lower than the GDCS pool bottom, and also lower than the long term DW annulus water level. The results from the 72-hour calculation show that the GDCS pools are completely drained in about six hours into the transient.

The RPV water level is restored shortly after the injection of GDCS flow into the RPV and the RPV water level rises to higher than 20 m at one hour following the LOCA. The broken pipe continues to drain the RPV water into the DW annulus. As a result, the RPV water level drops and the DW annulus water level rises. Shortly after the complete draining of the GDCS pools, the RPV water level and the DW annulus water level reach an equilibrium elevation of about 12 m above the RPV bottom.

A major portion of the RPV inventory that is turned into steam by the reactor core decay heat is returned back to the RPV in the form of condensate from the PCCS condensers via the GDCS injection lines. A small portion of the steam entering into the DW annulus may condense on the DW wall surface and drains down to the lower DW. The DW wall condensation rate reduces as the transient progresses due to the heating of the wall surface. This process of steam production and condensation do not affect the equilibrium water level because there is no net loss of inventory.

The equilibrium water level remains at about 12 m for a period greater than 30 days. At this water level, the reactor core is covered at a level above the top of the fuel and long term cooling is assured.

<u>GDCS Injection Line Break (GDLB)</u>

The GDLB pipe break elevation is lower than the GDCS pool bottom, and also lower than the long term DW annulus water level. The results from the 72-hour calculation show that the GDCS pools are completely drained in about six hours into the transient.

The RPV water level is restored shortly after the injection of GDCS flow into the RPV and the RPV water level rises to higher than 20 m at one hour following the LOCA. The broken pipe continues to drain the RPV water into the DW annulus. As a result, the RPV water level drops and the DW annulus water level rises. Shortly after the complete draining of the GDCS pools, the RPV water level and the DW annulus water level reach an equilibrium elevation of about 12 m from the RPV bottom.

A major portion of the RPV inventory that is turned into steam by the reactor core decay heat is returned back to the RPV in the form of condensate from the PCCS condensers via the GDCS injection lines. A portion of the condensate drains to the DW annulus directly through the broken pipe (from the GDCS pool side). A small portion of the steam entering into the DW annulus may condense on the DW wall surface and drains down to the lower DW. The DW wall condensation rate reduces as the transient progresses due to the heating of the wall surface. This process of steam production and condensation do not affect the equilibrium water level because there is no net loss of inventory.

The equilibrium water level remains at about 12 m for a period greater than 30 days. At this water level, the reactor core is covered at a level above the top of the fuel and long term cooling is assured.

Main Steam Line Break (MSLB)

The MSLB pipe break elevation is higher than the GDCS pool bottom. The results from the 72-hour calculation show that the long-term RPV downcomer water level is at an elevation slightly below the DPVs and the GDCS pool will drain to a level corresponding to that of the downcomer. At this equilibrium water level, the GDCS pools have about 2/3 of the drainable water (~ 1200 m^3) remaining in the pools. The DW annulus water level reaches an elevation of about -5 m (referenced to the RPV bottom).

A major portion of the RPV inventory that is turned into steam by the reactor core decay heat is returned back to the RPV in the form of condensate from the PCCS condensers via the GDCS injection lines. A small portion of the steam entering into the DW annulus may condense on the DW wall surface and drains down to the lower DW. The DW wall condensation rate reduces as the transient progresses due to the heating of the wall surface. As a result of this process, the RPV water level decreases over time. Based on the results from the 72-hour calculation, the estimated rate of water level decrease is about 0.05 m per day. At the end of 72 hours, the RPV water level is about 21.6 m. The projected RPV water level at the end of 30 days would be at about 20.2 m.

The RPV water level remains at greater than 20 m for a period of 30 days. At this water level, the reactor core is covered at a level above the top of the fuel and long term cooling is assured.

Feedwater Line Break (FWLB)

The FWLB pipe break elevation is lower than the GDCS pool bottom, but above the long term DW annulus water level. The results from the 72-hour calculation show that the GDCS pools are completely drained in about six hours into the transient.

The RPV water level is restored shortly after the injection of GDCS flow into the RPV and the RPV water level rises to higher than 20 m at one hour following the LOCA. The broken pipe continues to drain the RPV water into the DW annulus. As a result, the RPV water level drops and the DW annulus water level rises. Shortly after the complete draining of the GDCS pools, the DW annulus level reaches an elevation of about 9 m from the RPV bottom. The long term RPV water level remains at about 15.8 m (3.1 m below the break elevation) at the end of 72 hours. The RPV water level remains steady at this elevation from 24 to 72 hrs.

Compared to the MSLB case, the effect of DW wall condensation on the long term RPV water level is not as pronounced in the FWLB case. The reason is that the DW annulus water level is lower in the MSLB case (-5 m in MSLB versus 9 m in FWLB). Therefore, more DW wall surface is available for condensation in the MSLB case. However, for the FWLB case the RPV water level is conservatively assumed to decrease at a rate of

0.05 m per day, the same rate as that for the MSLB case. The projected RPV water level for the FWLB case at the end of 30 days would be at about 14.45 m.

The RPV water level remains at greater than 14.45 m for a period of 30 days. At this water level, the reactor core is covered at a level above the top of the fuel and long term cooling is assured.

Isolation Condensation Return Line Break (ICRLB)

The ICRLB pipe break elevation is 13.025 m from the RPV bottom, which is lower than the GDCS pool bottom but above the long term DW annulus water level. The long term RPV water level is conservatively calculated as described below.

The ICRLB and the FWLB cases are similar in terms of break elevation, except that the break area for the ICRLB is about 40% of that for the FWLB. Because of the smaller break area, the distance between the RPV water level at 72 hours and the break elevation is expected to be smaller in the ICRLB case than that for the FWLB case. However, the same delta (i.e., -3.1 m) is assumed in the ICRLB case at 72 hours for a conservative estimate. The DW annulus water level responses between these two cases are expected to be very similar because of the complete draining of the GDCS pools. Again, the RPV water level is conservatively assumed to decrease at a rate of 0.05 m per day after 72 hours, the same rate as that for the MSLB case.

Based on the above conservative assumptions, the RPV water level at 72 hours is estimated to be at 9.9 m, and the projected RPV water level at the end of 30 days would be at about 8.575 m.

The RPV water level remains at greater than 8.5 m for a period of 30 days. At this water level, the reactor core is covered at a level above the top of the fuel and long term cooling is assured.

4. Actuation of the GDCS Equalization Lines

   The initiation set point to open the GDCS equalization lines is when the RPV water level drops below Level 0.5 (1.0 m above the top of active fuel, or 8.453 m from the RPV bottom). For all credible single failures considered, the long term RPV water level following a LOCA remains higher than 8.453 m for a period of 30 days. The equalization lines are not actuated under these situations.

   However, if the RPV water level drops below Level 0.5, these equalization lines would be actuated. After actuation, these equalization lines provide the long term post-LOCA makeup water to the RPV from the suppression pool. The suppression pool water level is about 10 m from the RPV bottom, or 2.5 m above the top of the active fuel. The addition of the suppression pool water will assure the reactor core is covered at a level above the top of the active fuel for an indefinite long-term period.

Based on the above discussions, the ESBWR design meets the requirements stated in NUREG-0800, Standard Review Plan (SRP) 6.3, Draft Revision 3, April 1996, in Chapter III, Review Procedures, No. 20.

DCD Impact:

No DCD changes will be made in response to this RAI.