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Subject: **Response to NRC Request for Additional Information Letter No. 352 Related to ESBWR Design Certification Application – Engineered Safety Features - RAI Number 6.4-21 S01**

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) sent by NRC letter 352, dated June 17, 2009, Reference 1. The GEH response to RAI 6.4-21 S01 is addressed in Enclosure 1.

If you have any questions about the information provided here, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

Reference:

1. MFN 09-429, Letter from the U.S. Nuclear Regulatory Commission to Jerald G. Head, Request for Additional Information Letter No. 352, Related To ESBWR Design Certification Application, dated June 17, 2009

Enclosure:

1. Response to NRC Request for Additional Information Letter No. 352 Related to ESBWR Design Certification Application – Engineered Safety Features - RAI Number 6.4-21 S01

cc:	AE Cubbage	USNRC (with enclosures)
	J G Head	GEH/Wilmington (with enclosures)
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Enclosure 1

MFN 09-464

Response to NRC Request for

Additional Information Letter No. 352

Related to ESBWR Design Certification Application

Engineered Safety Features

RAI Number 6.4-21 SO1

NRC RAI 6.4-21S01

With respect to the GEH response to RAI 6.4-21, the staff has the following additional questions keyed to the GEH response items:

1. *The use of a 15 °F temperature differential does not set an upper limit for satisfactory operator performance unless the starting temperature is identified. The EPRI URD does not identify a starting temperature or a basis for the statement that operators can tolerate the rise. In addition, humidity level is a key factor and there is no mention of a corresponding humidity with the 15 °F temperature rise. MIL STD 1472 F in the chart on page 122 identifies temperatures for limited tolerance hot zone. These temperatures are tied to exposure times. For an 8 hour shift, the value would be approximately 86 °F WBGT (Wet bulb globe temperature) which is an index that considers both wet bulb and dry bulb temperatures. This appears to be inconsistent with the ESBWR CRHA temperature profile although it is less than the ESBWR limiting temperature of 93 °F unless humidity is identified. The staff is unable to identify where it accepted MIL STD 1472 F guidance for another plant control room. The staff requests that GEH identify the plant.*

   NIOSH 86-13 in section VIII discusses the basis for a Heat Stress standard. It reports that ACGIH, OSHA, the Armed Forces use 86 °F WBGT as a maximum temperature for light work.

   Remove the reference to ALWR URD (Vol lll. Chapter 9 Section 8.2.1.1). It applies to "Areas with Infrequent Inspection". Of specific note "the work period will not exceed two hours before a 30 minute rest break is taken in a cool environment." This is not practical for CR operators. The threshold values presented do not apply.

   Consideration of air speed as presented is not applicable. Jets of hot unconditioned air at 80 fps directly on operators as presented in the response to RAI 9.4-29 do not increase operator cooling. The staff has supplemented RAI 9.4-29.

   Show that the temperature profiled does not exceed 86 ° F WBGT or justify the temperature profile if exceeds 86 °F WBGT during the 0-72 hour period as being acceptable for operator performance in a light work but highly stressful environment. Consider the fact that there is no acclimation to the temperature that some operators with health conditions may be more adversely impacted, and that time of exposure is important.

2. *Post 72 hour cooling: This item is closed.*

3. *Lighting: Provide a comparison of the lighting level in the CRHA for normal and 0-72 hour emergency lighting in terms of light intensity (lumens) and state in the DCD the light intensity to be provided during the 0-72 hour LOCA/LOOP emergency operation and the anticipated power consumption.*

4. *Control Room Occupancy: This item is closed.*

5. *Accident Scenario-Non Safety Heat loads: This item is closed.*

6. *Thermal Properties of Concrete: Explain why the concrete characteristics assumed in the analysis are not conservative with respect to industry standards. Are the ESBWR concrete characteristic design values conservative with industry standards? Present a comparison of the concrete characteristics used in the analysis with the ESBWR design characteristics and the Industry standard concrete characteristics. What is the basis for any deviation of the ESBWR design values from industry standard concrete characteristics?*

   The staff requested that GEH supply reference 5.7 of the passive cooling analysis. GEH has declined to provide the reference. Remove the reference from the passive cooling analysis and provide a statement that all information derived from this reference has been removed from the passive cooling analysis.

7. *The staff acknowledges receipt of the compact disc with general arrangement drawings in .pdf and .dwg formats. The information used from these drawings will require confirmation with actual construction drawings or physical inspection in the plant. Create or identify an ITAAC that verifies that the actual construction is consistent with the information in the analysis.*

8. *Modeling Assumption: There does not appear to be a sufficient basis to accept a single node model for the CRHA in the passive cooling analysis. No mechanism has been established that demonstrates sufficient mixing occurs to justify using a uniform bulk temperature on the heat transfer surfaces as the driver for heat transfer. Inconsistent statements about stratification, mixing velocities, barriers to air flow in the CRHA and air supply locations from the EFU add doubt to the determination of a realistic temperature profile. The responses to RAI 9.4-29 original, supplement 1, supplement 2, and draft supplement 3 are not acceptable and draft supplement 3 will be supplemented if issued in its present form. Please provide a basis acceptable for the single node uniform temperature assumption in the analysis or redo the analysis with actual temperatures at the heat transfer surfaces.*

   The staff is concerned since stratification occurs with very limited mixing that there would be the potential for significant differences between the bulk temperature and the localized temperature. The localized temperature is the temperature of concern for heat stress and equipment qualification issues. Demonstrate that the localized temperatures experienced by operators will not *exceed a WBGT index of 86 °F and that the equipment qualification is based on the maximum localized temperature it will experience.*

Remove the reference to the ASHRAE Chapter 30 (actually 30.15) Heat Balance Method. While the most fundamental assumption is that the air in the thermal zone can be modeled as well mixed, there is no basis for saying that the air in the ESBWR CRHA is well mixed and thus making that assumption is not applicable.

The GOTHIC analysis model has not been received or reviewed by the staff and can not be commented on in this supplement.

9. *Computer Model: The node diagram presented will be considered in the passive cooling evaluation.*

10. *Heat Sinks: The information presented is useful and will be considered in the passive cooling evaluation.*

GEH Response

1. ***The use of a 15 °F temperature differential does not set an upper limit for satisfactory operator performance unless the starting temperature is identified. The EPRI URD does not identify a starting temperature or a basis for the statement that operators can tolerate the rise.***

1. GEH agrees that use of a 15 °F temperature differential does not set an upper limit for satisfactory operator performance unless the starting temperature is identified. GEH has approved an Engineering Change that provides the upper limit for satisfactory operator performance at 93 °F maximum dry bulb temperature. The 93 °F maximum dry bulb temperature limit is based on a 15 °F temperature differential (ref: URD Vol. III Chapter 9 section 8.2.2.1.1.1) applied to the maximum recommended operating temperature (ref: URD Vol. III Chapter 9 section 8.2.2.1.1). This change is reflected in DCD revision 6 in Tier 1 Table 2.16.2-4, Item 4; Tier 2; Appendix 3H, Table 3H-10 and Table 3H-15; Subsection 6.4.4 and Table 6.4-1; Subsection 9.4.1 and Table 9.4-1; and Chapter 16 TS Bases, B3.7.2. The 93˚F maximum temperature is acceptable for human habitability and equipment operation. The 93˚F value was shown to be conservative using a limit of 86˚F wet bulb (WB) temperature as discussed in RAI 9.4-29 S03. The 93˚F maximum dry bulb temperature also has considerable margin over equipment operational temperature limits.

1. ***In addition, humidity level is a key factor and there is no mention of a corresponding humidity with the 15 °F temperature rise. MIL STD 1472 F in the chart on page 122 identifies temperatures for limited tolerance hot zone. These temperatures are tied to exposure times. For an 8 hour shift, the value would be approximately 86 °F WBGT (Wet bulb globe temperature) which is an index that considers both wet bulb and dry bulb temperatures. This appears to be inconsistent with the ESBWR CRHA temperature profile although it is less than the ESBWR limiting temperature of 93 °F unless humidity is identified.***

1. GEH agrees that the humidity level is a key factor in evaluating heat stress limits for satisfactory operator performance. Response to RAI 9.4-29S03 considers both wet bulb and dry bulb temperatures reached in the CRHA during passive heat sink operation following a design basis accident and provides justification for an 86 °F wet bulb temperature limit.

1. ***The staff is unable to identify where it accepted MIL STD 1472 F guidance for another plant control room. The staff requests that GEH identify the plant.***

1. GEH agrees that reference to MIL STD 1472 F in the previous response to this RAI was in error. The NRC accepted MIL STD 1472 revision **E** guidance as design basis for the advanced passive light water Design Control Document associated with AP-1000, Rev 16.

1. ***NIOSH 86-113 in section VIII discusses the basis for a Heat Stress standard. It reports that ACGIH, OSHA, the Armed Forces use 86 °F WBGT as a maximum temperature for light work.***

   Remove the reference to ALWR URD (Vol III. Chapter 9 Section 8.2.1.1). It applies to "Areas with Infrequent Inspection". Of specific note "the work period will not exceed two hours before a 30 minute rest break is taken in a cool environment." This is not practical for CR operators. The threshold values presented do not apply.

1. GEH agrees that 86 °F WBGT is a conservative heat stress limit for maximum temperature for light work. GEH agrees that the ALWR URD (Vol III. Chapter 9 Section 8.2.1.1) section referred to in response to RAI 6.4-21 is not directly applicable to the ESBWR CRHA. Response to RAI 9.4-29S03 provides a discussion regarding the relationship between effective temperature, WBGT and wet bulb temperatures for the conditions existing in the CRHA during passive heat sink operation following a design basis accident. Response to RAI 9.4-29S03 updates the DCD Tier 2, Chapter 6, Section 6.4.4 with an 86 °F wet bulb temperature limit in accordance with NIOSH 86-113 guidance.

1. ***Consideration of air speed as presented is not applicable. Jets of hot unconditioned air at 80 fps directly on operators as presented in the response to RAI 9.4-29 do not increase operator cooling. The staff has supplemented RAI 9.4-29.Show that the temperature profiled does not exceed 86 ^{o} F WBGT or justify the temperature profile if exceeds 86 ^{o}F WBGT during the 0-72 hour period as being acceptable for operator performance in a light work but highly stressful environment. Consider the fact that there is no acclimation to the temperature that some operators with health conditions may be more adversely impacted, and that time of exposure is important.***

1. The 80 fps velocity was corrected in RAI 9.4-29 S03 and the velocity of this inlet air is not credited in any operator cooling. The response to RAI 9.4-29S03 discusses the airflow mechanisms involved in the CRHA during the 72 hours following a design basis event and provides the temperature profile that exists in the "occupied zone". Response to RAI 9.4-29S03 updates DCD Chapter 6, Subsection 6.4.4, with an 86 ^{o}F wet bulb temperature limit as recommended in NIOSH 86-113. RAI 9.4-29 S03 also provides DCD Tier 2, Chapter 3, Figure 3H-2 and 3H-3 markups (updated in Revision 6) showing the temperature and humidity conditions in the CRHA post accident. The equivalent conditions existing in the CRHA during passive heat sink operation following a design basis accident are less than the wet bulb temperature limits of 86 ^{o}F WBGT and 86 ^{o}F WB. These limits are used by ACGIH, OSHA and the Armed Forces as maximum temperature guidelines for light work with consideration for acclimation and health conditions.

2. ***Post 72 hour cooling: This item is closed.***

3. ***Lighting: Provide a comparison of the lighting level in the CRHA for normal and 0-72 hour emergency lighting in terms of light intensity (lumens) and state in the DCD the light intensity to be provided during the 0-72 hour LOCA/LOOP emergency operation and the anticipated power consumption.***

3. DCD Tier 2 Table 9.5-3, Typical Luminance Ranges for Normal Lighting, which provides ranges for normal lighting at various areas of the plant, has been updated in DCD Revision 6 to provide a comparison of lighting levels in the CRHA and Remote Shutdown Station for normal and 0-72 hour emergency lighting. A minimum of 10 ft-candles is provided for emergency lighting in the CRHA and Remote Shutdown Station. This design requirement is validated under DCD Tier 1 subsection 2.13.8 Item 4:

   "The Control Room and Remote Shutdown Station Emergency Lighting provides illumination levels equal to or greater than those recommended by the IESNA for at least 72 hours following a design basis accident and a loss of all AC power sources".

As described in the response to RAI 6.4-21, the CRHA heat up analysis was updated to assume a heat load of 400 Watts (from 200 Watts) for emergency lighting during a loss of offsite power. DCD Tier 2 Table 3H-12, Room Heat Loads, was updated under DCD revision 6 to incorporate this emergency lighting design power consumption in the CRHA room heat load.

4. ***Control Room Occupancy: This item is closed.***

5. ***Accident Scenario-Non Safety Heat loads: This item is closed.***

6. ***Thermal Properties of Concrete: Explain why the concrete characteristics assumed in the analysis are not conservative with respect to industry standards. Are the ESBWR concrete characteristic design values conservative with industry standards? Present a comparison of the concrete characteristics used in the analysis with the ESBWR design characteristics and the Industry standard concrete characteristics. What is the basis for any deviation of the ESBWR design values from industry standard concrete characteristics***

6. As discussed in response to RAI 6.4-21, the concrete thermal characteristics assumed in the CRHA heatup analysis are conservative with respect to the ESBWR design values as reflected in Table 6.4-21S01-1 below. The CRHA concrete thermal properties were adjusted to account for structural steel and rebar and therefore will not correspond identically to thermal properties presented in industry standards for concrete. The adjustment of CRHA concrete thermal properties due to non-homogeneous constituents (structural steel and rebar) results in a difference from published industry standard concrete (only) characteristics. The concrete utilized for the CRHA heat sink will be procured and tested to validate that the as-built concrete thermal properties meet or exceed the requirements presented in DCD Table 3H-14, Input Parameters, Initial Conditions and Assumptions used in Reactor Building and Control Building Heat up Analyses. ITAAC Table 2.16.2-4 Item 4 confirms that the as-built heat sink thermal properties meet the design criteria.

PARAMETER	CRHA HEATUP ANALYSIS	ESBWR DESIGN VALUE
Concrete Thermal Conductivity for RB and CB W/m°C (Btu·in/h·ft²·°F)(	0.865 (6.00)	1.63 (11.3)
Concrete Specific Heat J/kg·°C (Btu/lb°F)	653.1 (0.156)	879.2 (0.210)
Concrete Density kg/m³ (lb/ft³)	1922.2 (120.00)	2394.8 (149.50)

Table 6.4-21S01-1, Comparison of Concrete Thermal Properties

6. ***The staff requested that GEH supply reference 5.7 of the passive cooling analysis. GEH has declined to provide the reference. Remove the reference from the passive cooling analysis and provide a statement that all information derived from this reference has been removed from the passive cooling analysis.***

6. As described in response to RAI 6.4-21, the concrete characteristics assumed in the analysis are conservative with respect to the ESBWR design values. Therefore, including the Reference 5.7 with this RAI response is unnecessary. The characteristics for the concrete used in the analysis and the design values are presented in DCD Tier 2 Revision 5, Table 3H-14. The thermal properties of the CRHA concrete were adjusted to account for structural steel and rebar by determining the representative thermal conductivity of the steel/concrete structure compilation. The thermal conductivity was determined for the four possible heat flux pathways. Those pathways are identified as an all concrete path, a concrete and vertical rebar path, a concrete and horizontal rebar path, and a vertical rebar horizontal rebar and concrete path. The representative thermal conductivity for each path was then determined. The conductivity of the resulting material is estimated by weighing the resistivity of each path against the surface area for the evaluated volume. The density and specific heat are proportional to the quantity of each material inside each path. The material used in the calculation for the CRHA is homogeneous concrete with the characteristics calculated. DCD Tier 1, ITAAC Table 2.16.2-4 Item 4 confirms that the as-built heat sink thermal properties meet the design criteria.

7. ***The staff acknowledges receipt of the compact disc with general arrangement drawings in .pdf and .dwg formats. The information used from these drawings will require confirmation with actual construction drawings or physical inspection in the plant. Create or identify an ITAAC that verifies that the actual construction is consistent with the information in the analysis.***

7. The critical CRHA heat sink dimensions assumed for the Control Building Heatup Analysis are listed in Table 3H-14, Input Parameters, Initial Conditions and Assumptions used in Reactor Building and Control Building Heat up Analyses. DCD Tier 1 subsection 2.16.2.2 Control Building HVAC System, Item 4 states: The CRHAVS heat sink passively maintains the temperature of the CRHA within an acceptable range for the first 72 hours following a design basis accident. ITAAC Table 2.16.2-4 validates Item 4:

Design Commitment: The CRHAVS heat sink passively maintains the temperature of the CRHA within an acceptable range for the first 72 hours following a design basis accident.
Inspections, Tests, Analyses: A thermal analysis will be performed using the as-built heat sink dimensions, the as-built heat sink thermal properties, the as-built heat sink exposed surface area, the as-built thermal properties of materials

covering parts of the heat sink, and the as-built heat loads to confirm the results of the control room design basis heat up analysis.

8. ***Modeling Assumption: There does not appear to be a sufficient basis to accept a single node model for the CRHA in the passive cooling analysis. No mechanism has been established that demonstrates sufficient mixing occurs to justify using a uniform bulk temperature on the heat transfer surfaces as the driver for heat transfer. Inconsistent statements about stratification, mixing velocities, barriers to air flow in the CRHA and air supply locations from the EFU add doubt to the determination of a realistic temperature profile. The responses to RAI 9.4-29 original, supplement 1, supplement 2, and draft supplement 3 are not acceptable and draft supplement 3 will be supplemented if issued in its present form. Please provide a basis acceptable for the single node uniform temperature assumption in the analysis or redo the analysis with actual temperatures at the heat transfer surfaces.***

8. Response to RAI 9.4-29S03 has been revised from draft copies which have been discussed by GEH and the Staff, to support acceptance of a single node model for the CRHA in the passive cooling analysis. The RAI 9.4-29S03 response describes sensitivity results from GOTHIC software that does utilize multiple nodes and volumes and provides supporting analysis that confirms the results and conclusions reached under CONTAIN and ECOSIM models. The supporting analysis (GOTHIC) model includes the similar assumptions as provided in the CONTAIN model (i.e. heat loads, EFU flow, outside temperature profile, humidity, initial temperatures). The GOTHIC calculation includes the entire Control Building as an integrated model, which is similar to the CONTAIN model. The key difference between the CONTAIN and GOTHIC models is that the CONTAIN model considers the CRHA to be a single node while the GOTHIC model considers the CRHA envelope to be several volumes. The MCR is separated into a multidimensional (3D) volume, with multiple nodes, that allows for temperature gradients and stratification to be seen. The raised floor and false ceiling for the MCR and other rooms in the CRHA are modeled separately. All the false ceiling volumes are interconnected as well as all the raised floor volumes. All the rooms in the CRHA are connected to their respective false ceiling and raised floor volumes. However, the MCR is not connected to the other rooms in the CRHA (i.e. all doors are closed). The EFU flow is introduced below the volume that represents the false ceiling (into the MCR) and the exhaust exits through the bottom of another volume that represents the raised floor. While there are differences with the Licensing Bases Analysis of Record (CONTAIN) and the GOTHIC supporting analysis, the results validate each other and confirm that a single node uniform temperature assumption is reasonable.

There have been inconsistent statements about stratification, mixing velocities, barriers to air flow in the CRHA and air supply locations from the EFU expressed under previously issued RAI's. The following statements are consistent with response to RAI 9.4-29S03:

- Stratification: During an accident, when there is no power for CRHA cooling, there will be temperature stratification. This is modeled in GOTHIC.
- Mixing Velocities: During an accident, outside air enters the CRHA from the operating EFU though inlet registers. These registers, with minimal pressure drop, increase the velocity of the air entering the MCR occupied area. Mixing of MCR air with the balance of the CRHA is discussed with a flowrate developed many times greater than the EFU flow.
- Barriers to Air Flow: The CRHA airflow has been described in detail previously in response to RAI 9.4-29S03. The MCR area is connected to the above ceiling and below floor areas via openings in both, as are the CRHA adjacent rooms. There is no restriction to air flows between these areas since they are designed large enough for operation with minimal pressure drop with the normal recirculation AHU flow of 11,125 cfm. There are doors, which connect the MCR to the adjacent areas. These doors are modeled closed in the temperature analysis.
- Air Supply Locations: The EFU discharges outside air through the inlet registers, in the CRHA located in the MCR area. RAI 9.4-29S02 described a typical location and number of these registers.

The results of the GOTHIC analysis show that the temperature from the top of the raised floor up to an elevation of 2 meters is below 93ºF at 72 hours into the accident, and thermally stratified. No significant differences were observed when comparing the temperature results of the GOTHIC model to the CONTAIN analysis. Under thermal stratification, with the raised floor and false ceiling openings, the thermal forces promote natural circulation inside the CRHA that allows cooling by taking advantage of the cold structures or heat sinks to obtain the required passive cooling of the CRHA. Response to RAI 9.4-29S03 provides DCD updates describing design features of the EFU delivery and discharge system to ensure that there is adequate fresh air delivered and mixed in the CRHA to ensure that occupied zone temperature is within acceptable limits, buildup of contaminants (e.g., CO_2) minimal and a freshness of air is maintained.

8. ***The staff is concerned since stratification occurs with very limited mixing that there would be the potential for significant differences between the bulk temperature and the localized temperature. The localized temperature is the temperature of concern for heat stress and equipment qualification issues. Demonstrate that the localized temperatures experienced by operators will not exceed a WBGT index of 86 °F and that the equipment qualification is based on the maximum localized temperature it will experience.***

RAI 9.4-29S03 discusses the mechanisms involved in circulation of air in the CRHA during the 72 hours following a design basis event and illustrates the temperature profile that exists in the “occupied zone”.

While there is stratification, there is mixing of the MCR air. Response to RAI 9.4-29S03 updates the DCD with the basis for an 86 ^{o}F wet bulb temperature limit in accordance with NIOSH 86-113 guidance. As described in response to RAI 9.4-29 S03, for the conditions existing in the CRHA during passive heat sink operation following a design basis accident, this dry bulb temperature limit is equivalent to the 86 ^{o}F WBGT used by ACGIH, OSHA and the Armed Forces as a maximum temperature for light work with consideration for acclimation and health conditions. The CRHA temperatures obtained following a DBA are below the limit for equipment qualification in mild environments (122 ^{o}F) provided in DCD Tier 2, Table 3H-13, Typical Mild Environment Parameter Limits.

8. ***Remove the reference to the ASHRAE Chapter 30 (actually 30.15) Heat Balance Method. While the most fundamental assumption is that the air in the thermal zone can be modeled as well mixed, there is no basis for saying that the air in the ESBWR CRHA is well mixed and thus making that assumption is not applicable.***

   Response to RAI 9.4-29S03 supports acceptance of a single node model for the CRHA in the passive cooling analysis. RAI 9.4-29S03 response describes sensitivity results from GOTHIC software that does utilize multiple nodes and volumes that correspond to the results and conclusions reached under CONTAIN and ECOSIM models. Since the results and conclusions agree between the single node analysis and the multiple node analysis, the “model assumption” that air in the ESBWR CRHA is modeled well mixed can be applied to the simple single node model of the CRHA. As previously stated, the air in the CRHA, during accident conditions, will be stratified. Therefore, reference to ASHRAE Chapter 30.15, Heat Balance Method, is considered appropriate.

8. ***The GOTHIC analysis model has not been received or reviewed by the staff and can not be commented on in this supplement.***

   The supporting GOTHIC analysis model summary (preliminary), providing an alternate approach to the CONTAIN and ECOSIM models for the CRHA, was presented to the NRC Staff during a telepresence meeting on 23 June, 2009. In addition, the latest CRHA heatup analysis (CONTAIN and ECOSIM models), including DCD Revision 6 changes were provided to the NRC staff during this telepresence meeting to resolve open issues.

9. ***Computer Model: The node diagram presented will be considered in the passive cooling evaluation.***

10. ***Heat Sinks: The information presented is useful and will be considered in the passive cooling evaluation.***

DCD Impact

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