HITACHI

GE Hitachi Nuclear Energy

Richard E. Kingston
Vice President, ESBWR Licensing

PO Box 780 M/C A-65
Wilmington, NC 28402-0780
USA

T 910 819 6192
F 910 362 6192
rick.kingston@ge.com

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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 312 Related to ESBWR Design Certification Application - Auxiliary Systems - RAI Number 9.4-29 S03**

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 312, dated February 26, 2009, Reference 1. The GEH response to RAI 9.4-29 S03 is addressed in Enclosure 1. Enclosure 2 contains the DCD markups associated with this response.

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

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 09-173, Letter from the U.S. Nuclear Regulatory Commission to Robert E. Brown, Request for Additional Information Letter No. 312, Related To ESBWR Design Certification Application, dated February 26, 2009

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 312 Related to ESBWR Design Certification Application - Auxiliary Systems - RAI Number 9.4-29 S03
2. Response to Portion of NRC Request for Additional Information Letter No. 312 Related to ESBWR Design Certification Application - Auxiliary Systems - RAI Number 9.4-29 S03 - DCD Markups

cc:	AE Cubbage	USNRC (with enclosures)
	J G Head	GEH/Wilmington (with enclosures)
	DH Hinds	GEH/Wilmington (with enclosures)
	eDRF Section	0000-0089-7048, Revision 3

Enclosure 1

MFN 09-380

Response to Portion of NRC Request for Additional Information Letter No. 312 Related to ESBWR Design Certification Application

Auxiliary Systems

RAI Number 9.4-29 S03

NRC RAI 9.4-29 S03

The purpose of RAI 9.4-29 is to obtain information on how the EFU delivers air to the CRHA and promotes mixing to support the assumption in the passive cooling analysis that the temperature is uniform throughout the CRHA without thermal stratification and that the concentrations of CO2 being developed through normal breathing were well mixed so that the fresh air would be available to the operator in the breathing zone. The RAI asked that this information be included in the DCD so that the staff could use it as the basis of a finding on the acceptability of air mixing in the CRHA.

A. The GEH response to RAI 9.4-29 S02 is based on the premise that there would be four flexible HVAC ducts distributing the EFU flow to the occupied parts of the main control room with sufficient velocity to promote mixing, prevent upward air flow and thermal stratification and that other areas of the main control room would not be occupied. The GEH response states that each duct would exhaust 100 cfm at a velocity of 80 fps. The 80 fps exhaust velocity is equivalent to a 55 mph wind. It would be noisy. It would require the equivalent of a 2 inch diameter opening. It would impact motor horse power requirements for the fan. Confirm the accuracy of 80 fps.

The GEH response preferentially distributes flow to the occupied areas. Other areas such as bathrooms, kitchens, and shift supervisor office are excluded from EFU supply flow. There are no physical barriers in the CRHA that divide the CRHA into occupied and unoccupied zones. The volume for the CRHA in Table 15.4-5 has a free air volume of 78,000 cubic feet. The GEH response reduces this volume to a volume containing ventilation ducting of 42,000 cubic feet and further reduces it to 33,600 cubic feet to allow for furniture and equipment. The staff understands the concept of delivering flow preferentially to the areas that are most likely to be occupied However, with the flow comes the heat (or cold) of unconditioned air and radioactive contamination not removed through the filter system. The current passive cooling analysis for the first 72 hours indicates that the temperature would be 86 degrees F in 12 hours. On a hot 117 degree F day, would temperatures rise in the occupied areas to a level that would make work conditions unacceptable possibly exceeding the 93 degree F limitation?

Could operators in the occupied area work effectively with cold unconditioned air at the winter design conditions blowing directly upon them?

Would concrete walls and ceilings in the unoccupied areas still provide cooling or heating for the CRHA since temperatures are unlikely to be uniform through out the room?

What would be the impact on safety-related equipment with hot unconditioned air blowing down on cabinets in the occupied area?

Has the impact of preferential flow to occupied areas been considered in the passive cooling analysis?

Has GEH considered the potential to lower the EFU supply duct to a location near the floor and raising the discharge point to a location near the ceiling in order to take credit for natural circulation to promote mixing?

Does the dose analysis for CR operators need to be revised to reflect that the radiation is being preferentially delivered to the occupied areas (36,000 cubic feet) as opposed to the whole CRHA (78,000 cubic feet) during the first 72 hours?

Wouldn't this reduction of volume to an occupied volume which receives fresh air in effect concentrate the dose? In the passive cooling analysis, GEH states that the false ceiling and the false floor do not provide a barrier for heat transfer since they are heavily ventilated for return air and supply air flow. How does the false ceiling prevent hot air from rising and stagnation from developing?

Horizontal or even downward velocities have not been shown to be sufficient to overcome gravitational effects of temperature to prevent stagnation and stagnation would have a detrimental impact on passive cooling. Provide details on how stagnation is prevented in the DCD so that the staff can use it in support of a finding of acceptability.

B. The information provided on temperatures inside cabinets and equipment qualification will be evaluated with RAI 3.11-18 and/or RAI 6.4-21. However, the preferential distribution of EFU supply air to occupied areas may affect the equipment qualification temperatures in the preferential distribution area. Provide assurance that the bulk temperatures upon which cabinet cooling is based are not affected by the preferential distribution of EFU air.

C. Fresh air requirements as presented in ASHRAE Standard 62-1989 are based on the room being fully mixed. In response to RAI 9.4-29 S02, GEH stated that the mixing would be achieved by 80 fps velocity of four flexible hose supplies of essentially 100 cfm each to the occupied areas of the CRHA. The staff requested in part "A" that this velocity be reviewed for accuracy. Does preferential supply of fresh air to occupied areas leave other unoccupied areas depleted in fresh air? Is there any thing that would prevent an operator from going to an unoccupied area (such as the shift supervisor's office or bathroom which do not have a fresh air supply) and experiencing effects of lack of fresh air?
In response to RAI 9.4-29 S02, GEH stated that CO2 is heavier than air, thus it would settle to the bottom and be preferentially removed by the discharge path. Is the CO2 removal based on the air in the CRHA being well mixed (the 80 fps mixing velocity argument) or is it based on CO2 having a higher density in a stagnant air environment? It should be noted that a portion of the air leaving the

CRHA exits through door seals and would have no benefit of gravitational density differences between CO2 and air. In response to RAI 9.4-29 S02, GEH stated that a CO2 concentration of 5,000 ppm is the lower limit enforced by OSHA, and recommended by NIOSH and ACGIH. State the specific OSHA enforcement regulation or provide a copy for staff review and discuss its applicability to the CRHA which is in essence a confined entry space operating with out air recirculation. The staff's concern is that the lower limit that GEH has sited was developed for industry applications where recirculation mechanisms and clean up mechanisms were available and people could be evacuated. CO2 alarms would also be available. The CRHA with essentially zero leakage is a confined entry space. CO2 levels build up in time based on the supply of fresh air and the removal of CRHA air containing some CO2 build up. The staff does not anticipate that CO2 levels by themselves will reach a level of toxicity to be life threatening. ASHRAE 62-1989 suggests a limit of 1000 ppm of CO2 as a point at which operators may start experiencing some degradation of performance. The reason is that in addition to CO2, other objectionable gasses build up from the process of breathing and human activities. The staff's concern is that at some point, operator performance would be degraded by a combination of CO2 and these additional gasses. Demonstrate in the DCD that mixing of the air in the CRHA would be adequate to prevent localized build up of CO2 and other irritants. CO2 is a readily measurable commodity that can provide an alarm when action is needed. Describe how the CRHA environment degradation is monitored during the 72-hour non-recirculation period and what actions can be taken to assure that air remains sufficiently fresh to prevent unacceptable operator performance degradation. References to confined entry vessel regulations that show the CRHA for its size and configuration has sufficient air flow and mixing for extended occupancy would be useful. In order to produce a finding of acceptability, the staff needs to have included in the DCD sufficient information to substantiate that the environment will remain reasonably fresh and not impair operator performance. The staff is specifically interested in the degree of mixing, control of temperature, control of dose, and control of air freshness to insure an adequate environment. Include the appropriate information in the DCD.

RAI 9.4-29 S03 GEH Response:

The purpose of RAI 9.4-29 is to obtain information on how the EFU delivers air to the CRHA and promotes mixing to support the assumption in the passive cooling analysis that the temperature is uniform throughout the CRHA without thermal stratification and that the concentrations of CO2 being developed through normal breathing were well mixed so that the fresh air would be available to the operator in the breathing zone. The RAI asked that this information be included in the DCD so that the staff could use it as the basis of a finding on the acceptability of air mixing in the CRHA.

DCD Section 9.4 and Section 6.4 have been updated to include the information requested as per the attached markups.

A. The GEH response to RAI 9.4-29 S02 is based on the premise that there would be four flexible HVAC ducts distributing the EFU flow to the occupied parts of the main control room with sufficient velocity to promote mixing, prevent upward air flow and thermal stratification and that other areas of the main control room would not be occupied. The GEH response states that each duct would exhaust (supply?) 100 cfm at a velocity of 80 fps. The 80 fps exhaust velocity is equivalent to a 55 mph wind. It would be noisy. It would require the equivalent of a 2 inch diameter opening. It would impact motor horse power requirements for the fan. Confirm the accuracy of 80 fps.

The 80 fps air velocity value provided in RAI 9.4-29 S02 was a typographical error. The correct air velocity value is approximately 800 fpm supply grille core velocity. This corresponds to the recommended inlet face velocity (>800 fpm) provided in 2007 ASHRAE Handbook HVAC Applications. The balance of the 800 fpm discussion in the response to RAI 9.4-29 S02, (question A) accurately clarifies that air circulation is sufficient to ensure that the maximum temperature (93° F) is not exceeded in the occupied zone. The location and configuration of the supply registers will be optimized during detailed design to distribute and mix the volume of outside air with air in the general area. The air velocity and register selection will effect "drop" and "throw" for optimum mixing to promote air motion to minimize temperature gradients. The airflow through the registers will not cause excessive noise.

The GEH response preferentially distributes flow to the occupied areas. Other areas such as bathrooms, kitchens, and shift supervisor office are excluded from EFU supply flow. There are no physical barriers in the CRHA that divide the CRHA into occupied and unoccupied zones. The volume for the CRHA in Table 15.4-5 has a free air volume of 78,000 cubic feet. The GEH response reduces this volume to a volume containing ventilation ducting of 42,000 cubic feet and further reduces it to 33,600 cubic feet to allow for furniture and

equipment. The staff understands the concept of delivering flow preferentially to the areas that are most likely to be occupied However, with the flow comes the heat (or cold) of unconditioned air and radioactive contamination not removed through the filter system. The current passive cooling analysis for the first 72 hours indicates that the temperature would be 86 degrees F in 12 hours. On a hot 117 degree F day, would temperatures rise in the occupied areas to a level that would make work conditions unacceptable possibly exceeding the 93 degree F limitation?

The CRHA heatup analysis indicates that the average temperature rise in the CRHA would not exceed the 93°F limit on a 117°F day which equates to the criteria specified in the EPRI URD for operator tolerance and reliable operation of electrical / electronic equipment. This acceptance criteria is for a CRHA bulk average air temperature increase and not for a local temperature increase. Although some areas of the CRHA may exceed 93°F, the bulk average air temperature meets the EPRI URD criteria as elaborated in RAI 6.4-21 response (MFN 09-081 dated 30 January, 2009). Also, as described in response to subsequent questions in this RAI, the air temperature from the top of the raised floor up to 2 meters is maintained below 93°F as illustrated on Figure 9.4-29-S03-1, *GOTHIC™ Model MCR Temperature elevation / Gradient Map at Design Heatup Condition*, attached. Temperature stratification in the MCR produces higher temperatures in the suspended ceiling and lower temperatures in the lower levels of the main control room. Note: This specific snapshot was taken at ESBWR worst-case design conditions of 117°F outside air temperature.

The NRC has accepted the guidance for temperature and humidity for other plant control room habitability area ventilation systems contained in MIL-HDBK-759C, 31 July 1995, "Human Engineering Design Guidelines". Mil-HDBK-759C states that an effective temperature of 29.5°C (85.1°F) should be considered the maximum limit for reliable human performance. The effective-temperature ranges are flexible because they vary according to the amount of work activity. In general, the ranges should be extended upwards for tasks requiring minimal physical effort. The Wet Bulb Globe Temperature (WBGT) index is more applicable than the effective-temperature index in the range beyond the comfort and discomfort zones of heat stress. As described in, NIOSH 86-113, "Criteria for a Recommended Standard: Occupational Exposure to Hot Environments "(Revised Criteria 1986), the psychometric wet bulb temperature may be an appropriate index for assessing heat stress and predicting heat strain under conditions where radiant temperatures and air velocity are not large factors and where increased humidity exist. NIOSH 86-113 provides a wet bulb temperature limit of about 30°C (86°F) for unimpaired performance on sedentary tasks (moderate levels of physical work) for normally clothed individuals at low airflows. Considering a maximum CRHA humidity of 60% (reference RAI 6.4-21 Figure 6.4-21-1), and a maximum dry bulb temperature of 93°F (design limit), the corresponding wet bulb temperature determined is less than 81°F. This is below the 86°F wet bulb temperature threshold. Therefore, no heat stress concerns exist. DCD Chapter 6 has been revised to include a statement describing the 86°F wet bulb temperature limit. DCD Figures 3H2 and 3H3 have been revised to reflect Temperature and Relative

Humidity Profiles for the 0% Exceedance Maximum Temperature Case. See attached markups.

Could operators in the occupied area work effectively with cold unconditioned air at the winter design conditions blowing directly upon them?

The air entering the CRHA from the EFU discharge following a design basis accident will mix with the existing air at the supply register outlet where mixing with bulk room air by entrainment helps reduce the jet velocity and equalizes the supply air temperature as it enters the occupied zone. The air velocity dissipates with the distance from the register and will not result in cold unconditioned air blowing directly at the operator (occupied zone). Operators can work effectively at winter ambient design conditions (cyclical from –40°F to –13°F outside air temperature) exposed to a minimum bulk air temperature in the CRHA of 61°F at 72 hours following a design basis accident. Response to RAI 14.3-218 S01 addresses CRHA minimum temperature concerns.

Would concrete walls and ceilings in the unoccupied areas still provide cooling or heating for the CRHA since temperatures are unlikely to be uniform through out the room?

The CRHA Heatup / Cooldown Analyses performed with CONTAIN and ECOSIMPRO uses the assumption that "the air in the thermal zone can be modeled as well mixed, meaning its temperature is uniform throughout the zone". This is consistent with the ASHRAE Fundamentals Handbook 2005, Nonresidential Cooling and Heating Load Calculations, as discussed in RAI 6.4-21 response (MFN 09-081 dated 30 January, 2009). Furthermore, this assumption was validated by using GOTHIC™ CRHA analysis to corroborate the values obtained with CONTAIN and ECOSIMPRO. The GOTHIC™ analysis has the capability to model the temperature stratification / variations during EFU operation.

While there is stratification throughout the room, it was shown that the heat removal rate was sufficient to maintain temperatures within acceptable limits in the occupied zone for the main control room and the rest of the CRHA rooms. 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 93°F at 72 hours following a design basis accident. The conclusions of the GOTHIC™ analysis and the CONTAIN / ECOSIMPRO analysis agree. The results are similar when comparing the CONTAIN and ECOSIMPRO analyses that assumes "well mixed" and "uniform temperature" with the GOTHIC™ model that assumes non-uniform, temperature stratified conditions. The NRC has accepted GOTHIC™ modeling for CRHA heatup analysis for certified advanced passive plant designs.

The purpose of the GOTHIC™ analysis is to demonstrate that a more detailed thermal analysis with improved nodalization confirms that the CONTAIN single node model is adequate and leads to acceptable results by using a simplifying assumption.

The GOTHIC™ model includes the same basic assumptions 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 CONTAIN. 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 and raised floor volumes are interconnected 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.

The results of the GOTHIC™ analysis show that the temperature from the top of the raised floor up until 2 meters height is below 93°F at 72 hours into the accident, and no significant differences were observed when comparing the temperature results to the CONTAIN analysis. 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 desired passive cooling of the CRHA.

The analysis also shows that MCR air circulation is approximately 7-9 times the EFU supply airflow.

What would be the impact on safety-related equipment with hot unconditioned air blowing down on cabinets in the occupied area?

The placement of the cabinets and supply registers will ensure that local convective plume chimneys, which channel the heat from safety-related cabinets, would be uninhibited. As stated in response to the previous supplement of this RAI and response to RAI 9.4-33S01 (MFN 08-064 dated June 9, 2008), Item 1, the temperature in the cabinets is expected to be slightly higher than the bulk air temperature. However, the bulk air temperature, which is the incoming temperature to safety-related cabinets, of 92°F is well below the mild environment equipment qualification temperature of 122°F (Ref. DCD, Revision 5, Tier 2, Table 3H-10).

The supply air (hot conditioned air) is below the mild environment equipment qualification temperature for safety related equipment. DCD Tier 1 ITAAC Table 3.8-

1, Environmental and Seismic Qualification of Mechanical and Electrical Equipment, is provided to ensure this CRHA equipment can perform its safety-related function under normal, abnormal and design bases accident environmental conditions.

Has the impact of preferential flow to occupied areas been considered in the passive cooling analysis?
A GOTHIC™ CRHA analysis confirmed the results obtained with CONTAIN and ECOSIMPRO CRHA models. This GOTHIC™ CRHA analysis considers preferential flow into the occupied area and has shown that when preferential flow is placed in the MCR, the temperature below 2 meters (occupied zone) remains below 93°F. GOTHIC™ analysis has been accepted by the NRC for CRHA heatup analysis for certified advanced passive plant designs.

Has GEH considered the potential to lower the EFU supply duct to a location near the floor and raising the discharge point to a location near the ceiling in order to take credit for natural circulation to promote mixing?
The existing EFU supply duct layout was one of several configurations considered during initial design. It was decided to locate the EFU supply duct at the ceiling location to preclude any negative operator visual display impacts during normal or accident conditions (HFE issues). While detailed design may indicate that providing the EFU supply air to the floor area with the discharge at the ceiling is a more optimal configuration, both configurations will adequately support the EFU supply fresh air distribution and provide adequate heat removal. The various mixing mechanisms for CRHA air are discussed below.

The staff has consistently questioned mixing as related to ASHRAE 62. It needs to be understood that mixing per ASHRAE 62 specifically means mixing within an AHU, which may serve multiple occupied areas. This is specified to preclude a contaminant buildup in poorly served or balanced areas on complex ventilation systems. It does not mean mixing on the room served. The main control room, occupied area, is served by 100% of the outside air. The CRHA exceeds the ASHRAE 62 outside air requirements even with a penalty for assumed ceiling supply of higher air temperatures, as discussed below.

Does the dose analysis for CR operators need to be revised to reflect that the radiation is being preferentially delivered to the occupied areas (36,000 cubic feet) as opposed to the whole CRHA (78,000 cubic feet) during the first 72 hours?
Reducing the volume of the Control Room (even for the first 72 hours) produces less conservative results using the ESBWR LOCA RADTRAD model (transmitted to the NRC in MFN 09-193 on 3/20/2009) supporting DCD Revision 6. This can be demonstrated by reducing the Control Room volume by 50% (to 39,000 ft^3) and re-running the LOCA case using RADTRAD. The resulting Control Room dose

decreases by about 1%. Conversely, if the Control room volume is doubled (to 156,000 ft^3), the resulting Control Room dose also decreases by about 1%.

In RADTRAD models (like the one used to determine the dose consequences following a LOCA outside containment), for any given concentration of radiation transported to the Control Room, if the remaining Control Room model parameters are held constant (intake flow, in leakage flow, etc.), there is a model specific characteristic Control Room volume that generates the maximum Control Room dose consequences. For the most significant radiological dose consequence analysis supporting the ESBWR DCD (the LOCA dose analysis of DCD Section 15.4) the volume that maximizes the Control Room dose is approximately 78,000 ft^3.

The dose consequence analyses presented in DCD Chapter 15 has been developed following the guidance provided in RG 1.183, evaluated using the NRC code RADTRAD v3.03, and the results meet GDC 19 acceptability requirements.

Wouldn't this reduction of volume to an occupied volume which receives fresh air in effect concentrate the dose?
The Control Room model parameters used in the dose analyses supporting the DCD were developed to maximize the Control Room dose consequences, and were not intended to maximize the concentration of radiation in the Control Room. No acceptance criteria for concentration were applied in the LOCA analysis or required by regulation.

It should further be noted that reducing the Control Room volume does not in itself increase the concentration of radiation in the Control Room. The equations describing the calculation of Control Room dose in RADTRAD (NUREG 6604) show the volume of the Control Room impacts constituent terms in both the numerator and denominator of the function describing the Control Room dose (further demonstrating there is a characteristic Control Room volume that maximizes the Control Room dose).

In the passive cooling analysis, GEH states that the false ceiling and the false floor do not provide a barrier for heat transfer since they are heavily ventilated for return air and supply air flow. How does the false ceiling prevent hot air from rising and stagnation from developing?

The false ceiling is just that, a boundary area that has built-in registers through which air is allowed movement between the occupied area / CRHA Proper and the Above Ceiling areas. This ceiling poses virtually no resistance to air movement up or down. Therefore, hot air rising will not have restricted movement as it displaces cooler air downward, either back to the MCR or downward in adjacent rooms where heat is removed. Note: The EFU supply air registers discharge downward below the false ceiling promoting mixing with the air beneath the false ceiling.

Horizontal or even downward velocities have not been shown to be sufficient to overcome gravitational effects of temperature to prevent stagnation and stagnation would have a detrimental impact on passive cooling. Provide details on how stagnation is prevented in the DCD so that the staff can use it in support of a finding of acceptability.

The mixing of the EFU supplied inlet air with the general CRHA air is performed via the following mechanisms:

1. Supply / Inlet registers mixing - The mixing is continuous as EFU provided outside air is delivered to the CRHA. For each cfm delivered it generates mixing with the CR air as it exits the supply registers. This is the most common type of space air diffusion called a Mixing System. The supply air jet is delivered by the air inlet registers, which create an air jet that then mixes the outside air with the room air by entrainment (induction), which helps to reduce the jet velocity and equalize the supply air temperature as it enters the occupied (CRHA) zone.
2. Displacement (Ventilation) Supply / Exhaust - As air is supplied to the CRHA, an amount is similarly exhausted from the space. This exhaust air will be designed to be at a remote location to ensure no short cycling and a properly scavenged control room.
3. Equipment and Personnel Convective Plumes due to air differential temperature / density – The higher temperature of the air surrounding operating equipment and personnel, generates convective air plumes which rise out of the occupied zone, along with any pollutants (body odors, etc.). The rising air is replaced by cooler air from below.
4. Personnel Movement – It is assumed that a certain activity level by the CRHA occupants which derived the airflow requirements. This activity generates mixing of the CRHA air.
5. Molecular Dispersion - For Contaminants, CO_2 and others, the movement of CO_2 and other molecules across a space is via molecular dispersion.

The airflow developed in the ESBWR control room during worst case (outside air temp of 117°F) accident conditions when the CRHA is isolated and the EFU is in operation with passive cooling is as follows and is illustrated on Figure 9.4-29-S3-2, *Control Room Habitability Area Airflows Emergency Operation - Based Upon Gothic™ Analysis Results*:

The EFU is operating providing 466 cfm clean outside airflow into the CRHA. This is delivered to the occupied MCR area, primarily since this area has the personnel on duty and houses the active electronic equipment. This supply air exits the ductwork at supply air diffusers (4), which perform mixing mechanism 1) above. Depending upon the delivered air temperature, the combined mixed volume either rises or drops. At the worst case outside air condition of 117°F, modeling shows this air mixture rises above the ceiling with a larger quantity of MCR heated air; the balance driven primarily by the equipment and personnel convective plumes (mechanism 3) above). The combined, rising air above the ceiling tiles draws the same quantity of air into the MCR space from the area below the raised floor volume (mechanism 2). This cooler, slow moving air slowly spreads over the raised floor and displaces the warmer, stale air toward the ceiling, where it leaves the room. The MCR with the high ceiling becomes thermally stratified, i.e., warmer stale air is concentrated above the occupied zone and cool, fresher air is concentrated in the occupied zone. When the cool air encounters a heat source, such as a person or heat generating equipment, the air heats up and buoyantly rises out of the occupied zone.

The hot air that collects above the suspended ceiling, with CO_2 and body generated odors, spills over into the adjacent rooms due to the air density difference due to differential temperature where heat is released to the cooler walls and concrete. Cooler lower temperature air in these adjacent rooms drops to the raised floor level where air continues to drop thru to the common space below the floor. Discharge flow of 466 cfm of this air, exits the main control room at a remotely opposite location from EFU supply to prevent any short cycle of the supply air and ensure a constant turnover of the CRHA air. This air then is drawn into the MCR and a circuit is complete.

A positive pressure is maintained in the CRHA. There is no buildup of any CO_2 in any of these areas since the areas are scavenged continuously by the EFU supply with exhaust airflow of 466 cfm. The exhaust is remote to the supply at one of the adjacent rooms lower common area.
As previously discussed, a snapshot temperature profile is shown on Figure 9.4-29-S03-1, *GOTHIC™ Model MCR Temperature elevation / Gradient Map at Design Heatup Condition*. This figure represents the area above the raised floor up to the false (hung) ceiling.

B. The information provided on temperatures inside cabinets and equipment qualification will be evaluated with RAI 3.11-18 and/or RAI 6.4-21. However, the preferential distribution of EFU supply air to occupied areas may affect the equipment qualification temperatures in the preferential distribution area. Provide assurance that the bulk temperatures upon which cabinet cooling is based are not affected by the preferential distribution of EFU air.
The distribution of EFU supply air is away from the natural convective cabinet / panel chimneys. There is no interference in the cabinet-cooling scheme, which will have inlet louvers at the floor level and exhaust louvers up near the ceiling. DCD Tier 1 ITACC Table 3.8-1 covers the temperatures in the preferential distribution area for equipment qualification mild environments.

C. Fresh air requirements as presented in ASHRAE Standard 62-1989 are based on the room being fully mixed. In response to RAI 9.4-29 S02, GEH stated that the mixing would be achieved by 80 fps velocity of four flexible hose supplies of

essentially 100 cfm each to the occupied areas of the CRHA. The staff requested in part "A" that this velocity be reviewed for accuracy. Does preferential supply of fresh air to occupied areas leave other unoccupied areas depleted in fresh air?
As previously stated in RAI 9.4-29 responses, the main control room (MCR) area of the CRHA is the area where operators will be stationed during an accident condition. This area is the largest area of the CRHA. While the design of the ventilation system is to preferentially supply air to this area, all areas in the CRHA are connected to this MCR area via the common above ceiling / below floor areas. The other smaller areas in the CRHA, connected to this general area, are accessible but will not contain significant levels of CO_2 because they are normally unoccupied. If these rooms are utilized, the small number of personnel occupying them will generate minimal CO_2, which will be scavenged as described above, by mechanisms 3,4,and 5, thus equalizing CO_2 concentrations for all areas.

ASHRAE 62 fresh air requirements are based upon fresh air being equally distributed to multiple occupied rooms separated by possibly large areas and complex configurations with doors and natural barriers. The CRHA is not a complex but a simple configuration. It consists of one large room with much smaller simply configured and connected / adjoining rooms, with the large room anticipated to be occupied by nearly all main control room personnel. As such, the MCR area is supplied with 100% of the outside airflow. This flow mixes 100% with the delivered room, the MCR; i.e. no flow goes to hypothetical, remote areas and thus starves the main habitable area. As stated earlier, under high outside air temperatures, the supplied air would enter, mix with the MCR air, and leave the space with a similar quantity of air forming a natural circuit. This natural cooling circuit moves air from the MCR to adjacent areas continuously.

Is there any thing that would prevent an operator from going to an unoccupied area (such as the shift supervisor's office or bathroom which do not have a fresh air supply) and experiencing effects of lack of fresh air?
As stated above, the whole CRHA will be habitable.

In response to RAI 9.4-29 S02, GEH stated that CO2 is heavier than air, thus it would settle to the bottom and be preferentially removed by the discharge path. Is the CO2 removal based on the air in the CRHA being well mixed (the 80 fps mixing velocity argument) or is it based on CO2 having a higher density in a stagnant air environment?
While response to RAI 9.4-29 S02 provided an accurate statement regarding CO_2 properties, it incorrectly conveyed an assumption not applicable in the ESBWR CRHA. The incorrect assumption was that CO_2 being heavier than air, would fall down and be removed from under the floor resulting in a greater concentration of CO_2 closer to the floor. It is not the case that pure unmixed CO_2 gas is piped into the CRHA falling to the floor (under floor) and collecting. The CO_2 that is in the CRHA is mixed in the air and as such does not settle out in this fashion. The CO_2 in the air in the CRHA will be

relatively uniform. The CO_2 will be removed, or prevented from building up, because it is displaced by a constant supply of lower CO_2 concentrated outside air and a constant exhaust from the CRHA. The net effect is a scavenging of CO_2 from the CRHA. This is coupled with the assumption that the generation rate within the CRHA is relatively constant. This is based upon ASHRAE 62-2007 Appendix C and supporting standard ASTM D6245-07.
Note: The room will not have uniform temperature and stratification will occur. This emergency mode stratification is even typical of the normal operating Under Floor Air Distribution (UFAD) CRHA system as described later in this response.

It should be noted that a portion of the air leaving the CRHA exits through door seals and would have no benefit of gravitational density differences between CO2 and air. In response to RAI 9.4-29 S02, GEH stated that a CO2 concentration of 5,000 ppm is the lower limit enforced by OSHA, and recommended by NIOSH and ACGIH. State the specific OSHA enforcement regulation or provide a copy for staff review and discuss its applicability to the CRHA which is in essence a confined entry space operating with out air recirculation. The staff's concern is that the lower limit that GEH has sited was developed for industry applications where recirculation mechanisms and clean up mechanisms were available and people could be evacuated. CO2 alarms would also be available. The CRHA with essentially zero leakage is a confined entry space. CO2 levels build up in time based on the supply of fresh air and the removal of CRHA air containing some CO2 build up. The staff does not anticipate that CO2 levels by themselves will reach a level of toxicity to be life threatening. ASHRAE 62-1989 suggests a limit of 1000 ppm of CO2 as a point at which operators may start experiencing some degradation of performance. The reason is that in addition to CO2, other objectionable gasses build up from the process of breathing and human activities. The staff's concern is that at some point, operator performance would be degraded by a combination of CO2 and these additional gasses.
Demonstrate in the DCD that mixing of the air in the CRHA would be adequate to prevent localized build up of CO2 and other irritants. CO2 is a readily measurable commodity that can provide an alarm when action is needed.
GEH has performed analysis and concluded that CRHA CO_2 remains below all requirements, recommendations and good practices of ASHRAE 62-2007. The CO_2 concentration does not build up due to temperature stratification. The CO_2 distributes effectively within the CRHA even without the mixing that occurs due to inlet air / exhaust ventilation, temperature plumes and movement of personnel in the CRHA, (see previous discussion in this RAI for mixing mechanisms).
ASHRAE 62 has undergone changes through the years but there has always been an Acceptable Indoor Air Quality. This quality (either stated or unstated) has a "health" component and a "comfort" component. The health component ensures that there is enough outside air to prevent buildup of known contaminants at harmful concentrations. The "comfort" component is further broken up into "Occupant" satisfaction and "Visitor" satisfaction. An "Occupant" satisfaction rate (5 cfm/per person) is expressed when 80% of occupants express odor satisfaction. A "Visitor"

satisfaction rate (15 cfm per person) is expressed when 80% of visitors express odor satisfaction. The above quoted airflow rates (up through the 1999 edition) even tolerated a certain "moderate amount of smoking" that will not be permitted in the ESBWR CRHA. The various Health rate / Visitor satisfaction rates of 5 cfm / 15 cfm per person, equates to an approximate 2,000 ppm / 700 ppm CO_2 concentration respectively above outdoor air levels, see table below. The 1000 ppm CO_2 limit per ASHRAE 62 is considered a design parameter, a surrogate for human comfort; at which point occupants may experience notice of other room contaminants (odor). The 1000 ppm CO_2 limit is not considered a health risk and there is no evidence that operator performance would in any way be degraded.

ASHRAE 62.1-2007, Table B-1 lists 5000 ppm as an Enforceable and/or Regulatory Level for Carbon Dioxide (reference B-5 OSHA 29CFR1910). The ESBWR CRHA, as stated previously, will be significantly below this value, however this value will be added to DCD Tier 2 Section 6.4, so there is no future confusion over the maximum value.

More recent ASHRAE 62 standard revisions have extrapolated upon the minimum ventilation rates to allow for minimum ventilation expressed as a total of people related sources and area (non-people) related sources. There are no indoor contaminants-of-concern generated within the CRHA. The ventilation airflow for each space must be calculated by adding the people related airflow to the building related airflow. This change accommodated for the known practice of over ventilation of high-density spaces. ASHRAE 62 – 2007 Equation 6-1 specifies the Breathing Zone Outdoor Airflow requirement, for which the ESBWR CRHA equates to 256 cfm. The below table illustrates this above discussion.

ASHRAE Threshold	Table B-1 OSHA Enforceable Level	Health Rate / 80% of Occupants Satisfied	80% of Visitors Satisfied	ASHRAE 62-2007 eq. 6.1 Vbz = (Rp x Pz) + (Ra x Az) = 256 cfm	Actual ESBWR EFU FlowRate 466 cfm (220 L/s) (11 people)
Outside Air/Person	2.1 cfm (1.03 L/s)	5 cfm (2.4 L/s)	15 cfm (7.1 L/s)	23 cfm (10.9 L/s)	42 cfm (20 L/s)
Anticipated ppm CO2 above outdoor air levels ASHRAE 62-2007 App'x C	5,000	2,153	728	474	258
% ESBWR flowrate above	1900	740	180	83	

If the Zone Air Distribution Effectiveness is less than adequate, Equation 6-2 allows a correction to account for the inadequacy. The ESBWR CRHA distribution system is adequate. However, if the system were inadequate, the 256 cfm would be divided by the appropriate Table 6-2 Ez value. For instance, dividing 256 cfm by 0.8 (Ceiling supply of warm air) yields a slightly higher 320 cfm requirement. The EFU flow is just under 2 times the minimum 256 cfm value and 1.5 times higher than the hypothetically corrected 320 cfm value.

The CRHA is not a zero leakage confined entry space. See discussion below.

Describe how the CRHA environment degradation is monitored during the 72-hour non-recirculation period and what actions can be taken to assure that air remains sufficiently fresh to prevent unacceptable operator performance degradation. References to confined entry vessel regulations that show the CRHA for its size and configuration has sufficient air flow and mixing for extended occupancy would be useful In order to produce a finding of acceptability, the staff needs to have included in the DCD sufficient information to substantiate that the environment will remain reasonably fresh and not impair operator performance. The staff is specifically interested in the degree of mixing, control of temperature, control of dose, and control of air freshness to insure an adequate environment. Include the appropriate information in the DCD

The Mixing, Temperature, Control of Dose and Control of Air Freshness have all been previously evaluated acceptable whether in this or previously submitted RAI responses and the EFU system is designed for emergency battery operation. There will be no automatic CO_2 monitoring systems for the CRHA environment during the 72-hour non-recirculation period. The EFU system is designed to ensure that the CRHA is habitable for the event duration; i.e. Temperature rise is limited, Buildup of Contaminants (e.g., CO_2,) is minimal and a freshness of air maintained.

GEH has evaluated the CB Environment with respect to Habitability. The EFU delivery and discharge system is optimized to ensure that there is adequate air mixing by mechanisms previously discussed in the CRHA. This is accomplished by using multiple supply registers which reasonably distribute the incoming supply air with the CR air volume and a remote exhaust (to prevent any short cycling of the inlet air) turning over the CR volume approximately 7-9 times per day. This forced air design in conjunction with the known convective air currents (due to heat loads/sinks) and personnel movement reasonably ensures that Heat is removed, Temperature is Acceptable, Buildup of Contaminants (e.g., CO_2) is minimal and a freshness of air is maintained during worst-case accident conditions. This was elaborated upon previously in this RAI supplement.

The CRHA <u>does not meet</u> the Confined Entry Vessel definitions provided under OSHA 1910.146(b) cited below:

1. It is not designed for continuous occupancy – The CRHA environment maintains a fresh air supply at all times; the quantity as recommended in ASHRAE 62. The inlet and exhaust from the CRHA are engineered to prevent any short cycling and to maximize distribution / mixing with space air.
2. It has limited or restricted means of entry or exit – The CRHA requires this as part of the design to keep potential radiological hazards out of the CRHA.
3. It contains or has the potential to contain a hazardous atmosphere. The CRHA does not have any material that meets the Hazardous Material definition (e.g., Flammable, Explosive, Compressed Gases, Oxidizers)

4. Has an internal configuration that might cause an entrant to be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section – The CRHA has none of these features.
5. Contains any other recognized serious safety or health hazards. – The CRHA has no other recognized serious safety or health hazards.

If the CRHA was considered a Confined Space, the CRHA emergency filtration system could be used to "air evacuate" prior to entry by supplying an adequate volume of outside fresh air. Fresh air could be supplied high and removed low (or vise-versa) with the airflows separated to prevent any short cycling. The CRHA is never without an outside fresh air supply since EFU operation is continuously in service when the normal CRHA Outside AHU is shut down, delivering approximately the same amount of fresh air before and after the anticipated accident, ensuring the freshness is maintained. The temperature will rise but there will be no odors or contaminant buildup. As can be seen from the above table, ESBWR is designed to have a 1900% higher flowrate than the flowrate required for a 5000 ppm CO_2 limit per ASHRAE 62 and a 740% higher flowrate than the minimum "health" rate recommended by ASHRAE.

DCD Impact

DCD changes will be made in response to this RAI as shown on the attached markups.

DCD Tier 2, Chapter 9, Section 9.4 has been revised to add the following text:
"The EFU delivery and discharge system is optimized to ensure that there is adequate fresh air delivered and mixed in the CRHA. This is accomplished by using multiple supply registers, which distribute the incoming supply air with the control room air volume, and a remote exhaust to prevent any short cycling. The EFU operation results in turning over the CR volume approximately 7-9 times per day. This diffusion design (mixing and displacement) in conjunction with the known convective air currents (due to heat loads/sinks) and personnel movement ensures that occupied zone temperature is within acceptable limits, buildup of contaminants (e.g., CO_2) minimal and a freshness of air is maintained."

DCD Tier 2 Chapter 9, Section 9.4.1.1, Power Generation Design Bases, 1st bullet, changed "ASHRAE 62-2001, Table 2" to "ASHRAE 62-2007, Section 6".

DCD Tier 2, Chapter 6, Section 6.4.1.1 added the following text to the 3rd bullet stating: "The Emergency Filter Unit System maintains CO_2 concentration in the CRHA to less than 5000 ppm.

DCD Tier 2, Chapter 6, Section 6.4.2 added the following text "The EFU delivery and discharge system is optimized to ensure that there is adequate fresh air delivered and mixed in the CRHA. This is accomplished by using multiple supply registers, which distribute the incoming supply air with the control room air volume, and a remote exhaust to prevent any short cycling. The EFU operation results in turning over the CR volume approximately 7-9 times per day. This diffusion design (mixing and displacement) in conjunction with the known convective air currents (due to heat loads/sinks) and personnel movement ensures that occupied zone temperature is within acceptable limits, buildup of contaminants (e.g., CO_2) minimal and a freshness of air is maintained".

DCD Tier 2, Chapter 6, Section 6.4.4 added the following text: "The CRHA temperature / humidity values calculated during the 72 hours following a design basis accident equate to less than 86°F wet bulb globe temperature (WBGT) and psychometric wet bulb temperature (WB). The 86°F value is the recommended threshold limit for instituting hot weather practices and recommended upper limit appropriate for assessing heat stress and predicting heat strain for moderate levels of work respectively. The psychometric wet bulb temperature (WB) is an appropriate index for assessing heat stress and predicting heat strain under conditions where radiant temperatures and air velocity are not large factors and where increased humidity exists. NIOSH 86-113 provides a wet bulb temperature limit of about 30°C (86°F) for unimpaired performance on sedentary tasks (moderate levels of physical work) for normally clothed individuals at low airflows. (Reference 6.4-5).

DCD Tier 2 Chapter 6, Section 6.4.10 added a new reference:
"6.4-5 NIOSH 86-113, Occupational Exposure to Hot Environments, 1986"

DCD Tier 2 Chapter 9, Table 9.4-1
Deleted "(Ref. 9.4.1-1)".
DCD Tier 2 Chapter 9, Table 9.4-17:
Changed "ASHRAE 62-2001" to "ASHRAE 62-2007" for the latest revision of this standard and to match DCD Tier 2 section 6.4-4 and DCD Tier 2 Chapter 1, Table 1.9-22 references.

DCD Tier 2 Chapter 3, figures 3H2 and 3H3:
These figures were revised per an Engineering Change and are attached to reflect the latest system design analysis.

References:

1. ANSI/ASHRAE Standard 62 - 2007 and previous editions 1989, 2001; Ventilation for Acceptable Indoor Air Quality; Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

2. ASHRAE Standard 55 – 2004, Thermal Environmental Conditions for Human Occupancy; Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.

3. ASHRAE, Fundamentals Handbook, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA, 2005

4. Ventilation through the Years: A Perspective; Dennis Stanke, Member Ashrae; ASHRAE Journal August 1999.

5. Underfloor Air Distribution: Thermal Stratification; Tom Webster, PE; Fred Bauman, PE; and Jim Reese, PE; ASHRAE Journal May 2002.

6. Displacement Ventilation; Sephir D. Hamilton; Kurt W. Roth, Ph.D.; and James Brodrick, Ph.D; ASHRAE Journal September 2004.

7. The Basics, Paul VanderMeulen, PE, Article from Tuttle & Bailey's Let's Talk, Vol #1, Issue #3.

8. William Popendorf, 2006, Industrial Hygiene Control of Airborne Chemical Hazards, (705 p.) CRC Press, Boca Raton, FL.

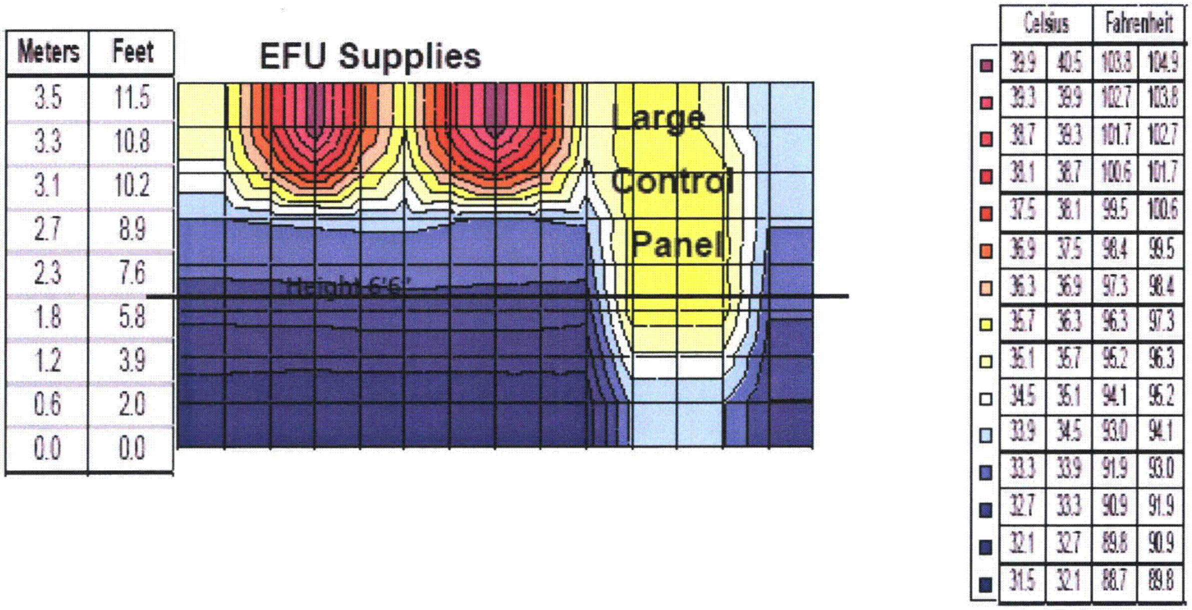
9. ASTM Standard D 6245 –07; Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation; West Conshohocken, PA.

10. Confined Space Entry: OSHA 1910.146(b).

11. NIOSH 86-113, Criteria for a Recommended Standard:Occupational Exposure to Hot Environments (Revised Criteria 1986)

12. Convective Heat Transfer in Building Energy and Thermal Load Calculations; ASHRAE Research Project, RP-664; Daniel E. Fisher, Ph.D. and Curtis O. Pedersen; ASHRAE Transactions

MCR Temp Cross-Section



Meters	Feet
3.5	11.5
3.3	10.8
3.1	10.2
2.7	8.9
2.3	7.6
1.8	5.8
1.2	3.9
0.6	2.0
0.0	0.0

	Celsius		Fahrenheit	
🟪	39.9	40.5	103.8	104.9
🟥	39.3	39.9	102.7	103.8
🟥	38.7	39.3	101.7	102.7
🟥	38.1	38.7	100.6	101.7
🟥	37.5	38.1	99.5	100.6
🟧	36.9	37.5	98.4	99.5
🟧	36.3	36.9	97.3	98.4
🟨	35.7	36.3	96.3	97.3
🟨	35.1	35.7	95.2	96.3
⬜	34.5	35.1	94.1	95.2
🟦	33.9	34.5	93.0	94.1
🟦	33.3	33.9	91.9	93.0
🟦	32.7	33.3	90.9	91.9
🟦	32.1	32.7	89.8	90.9
🟦	31.5	32.1	88.7	89.8

Figure 9.4-29-S3-1, GOTHIC™ Model MCR Temperature elevation / Gradient Map at Design Heatup Condition

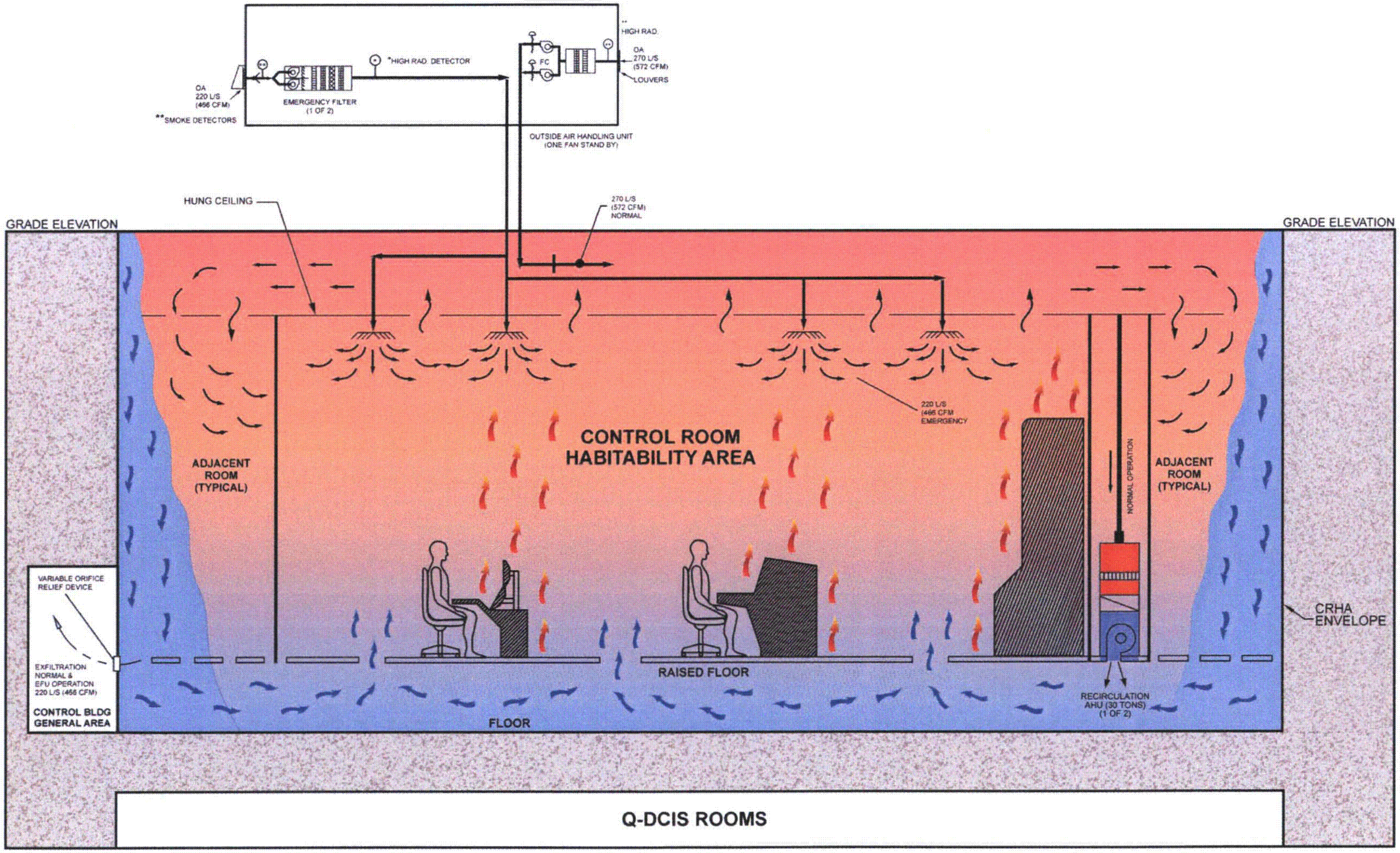


Figure 9.4-29-S3-2, Control Room Habitability Area Airflows Emergency Operation - Based Upon Gothic™ Analysis Results

Enclosure 2

MFN 09-380

Response to Portion of NRC Request for Additional Information Letter No. 312 Related to ESBWR Design Certification Application

Auxiliary Systems

RAI Number 9.4-29 S03

DCD Markup

- The CBVS outside air intake and return/exhaust openings are provided with tornado and tornado missile protection.

The CBVS provides a safety-related means to passively maintain habitable conditions in the CRHA following a design basis accident (radiological event concurrent with loss of normal AC power).

Radiation detected in the CRHA outside air inlet causes the following actions:

- The normally closed isolation dampers downstream of the operating EFU fan to open;
- The normal outside air inlet and restroom exhaust dampers to close; and
- An EFU fan to automatically start.

The CRHA is isolated during loss of normal AC power conditions and a safety-related EFU provides pressurization and breathing quality air. An EFU is powered from the safety-related battery supply for a 72 hour duration. For longer-term operation, (post 72 hrs) either of two (2) ancillary diesel generators can power either EFU fan system. The EFU delivery and discharge system is optimized to ensure that there is adequate fresh air delivered and mixed in the CRHA. This is accomplished by using multiple supply registers, which distribute the incoming supply air with the CR air volume, and a remote exhaust to prevent any short cycling. The EFU operation results in turning over the CR volume approximately 7-9 times per day. This diffusion design (mixing and displacement) in conjunction with the known convective air currents (due to heat loads/sinks) and personnel movement ensures that occupied zone temperature is within acceptable limits, buildup of contaminants (e.g., CO_2) minimal and a freshness of air is maintained.

The CBVS provides the capability to maintain the integrity of the CRHA with redundant safety-related isolation dampers in all ductwork penetrating the CRHA envelope. The active safety-related components (CRHA isolation dampers and EFUs), that ensure habitability in the CRHA envelope, are redundant. Two trains of safety-related EFUs, including HEPA and Carbon filters, serve the CRHA envelop. Redundant fans are provided for each EFU to allow continued operability during maintenance of electrical power supplies. Therefore a single active failure cannot result in a loss of the system design function.

During normal modes of operation and emergency modes with electrical power available, the CRHA is maintained within the temperature and relative humidity ranges noted in Table 9.4-1 by the nonsafety-related CRHAVS Recirculation AHU. During emergency operation, with a loss of normal AC power, a nonsafety-related CRHA recirculation air handling unit (AHU), powered from the nonsafety-related Uninterruptible AC Power Supply System, maintains the CRHA within the normal operating temperature range for two hours. This allows the continued operation of certain high heat producing nonsafety-related MCR DCIS electric loads.

Anytime during a loss of normal AC power, once either ancillary diesel generator is available, the power for either Recirculation AHU fan with auxiliary cooling unit can be provided via the ancillary diesel-powered generator. Thus, a Recirculation AHU can operate indefinitely during a CRHA isolation event. If the Recirculation AHUs are not available during the loss of normal AC power, safety-related temperature sensors with two-out-of-four logic automatically trip the power to N-DCIS components in the MCR, thus removing the heat load due to these sources. In the event the loss of normal AC power duration extends beyond two hours, the reduced CRHA heat load is passively cooled by the CRHA heat sink. The CRHA heat~~s~~ sinks consist of the following: the CRHA walls, floor, ceiling, and interior walls, and access corridors; adjacent Q-DCIS and N-DCIS equipment rooms and electrical chases; and, CRHA HVAC equipment rooms and HVAC chases. The CRHA heat sinks limit the CRHA temperature rise to no greater than 8.3°C (15°F) for 72 hours. ~~After 72 hours~~For the full duration of the design basis accident the EFU maintains the safety-related habitability of the CRHA by supplying filtered air for breathing and pressurization to minimize inleakage. During the initial 72 hours the EFU relies on safety-related batteries. Post 72 hours the EFU relies on RTNSS power supplies~~ when RTNSS power supplies are available~~.

Full capacity cooling and ventilation for the CRHA, 72 hours after an accident, is by operation of the auxiliary cooling units. The auxiliary cooling units are air cooled chillers located in the CB mechanical equipment room, outside of the CRHA, with remote condensers. The auxiliary cooling system provides chilled water to the cooling coils in both the CRHAVS Recirculation AHUs and the CBGAVS Supply AHUs, located in the MCR and Mechanical Equipment Rooms respectively. This includes auxiliary cooling units chilled water recirculation pumps, independent from the normal chilled water system (CWS).

The Main Control Room operator starts the auxiliary cooling system, in an accident scenario (post 72 hours) when AC power is being provided from the ADG. Interlocked motor operated isolation valves will close off the chilled water supply from the normal CWS and open the supply from the auxiliary cooling units. After the valves are in the proper lineup the auxiliary cooling system starts. All valves are located outside the CRHA. The valves are provided with RTNSS power, which is available 72 hours after an accident. The CHRA recirculation AHUs, CB general area supply AHUs, and supporting auxiliary cooling units use RTNSS power supplies to remove heat in support of post 72 hour main control room habitability.

The CBVS 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. In addition, augmented design standards are applied as described in Subsection 19A.8.3.

Power Generation Design Bases

The CBVS:

- Provides a controlled environment for personnel comfort and safety. Sufficient outside air is provided to meet the ventilation requirements for acceptable indoor air quality (Ref. ASHRAE 62-2007~~1~~, ~~Table 2~~Section 6). Table 9.4-1 depicts the area design temperature and humidity design parameters;
- Provides a controlled environment for the proper operation and integrity of equipment in the Control Building during normal, startup and shutdown operations;
- Provides redundant active components to increase reliability, availability and maintainability of the ventilation system;
- Provides shutoff dampers on the inlet and outlet of fans and AHUs if necessary to allow for maintenance;

Table 9.4-1

Design Parameters for the CBVS

CRHAVS and CBGAVS	
Operating periods:	Normal plant operation, plant startup, and plant shutdown
Outside Air Design Conditions:	
For CRHAVS and EFUs (Limiting values)	Summer: 47.2°C (117°F) Dry Bulb 26.7°C (80°F) Wet Bulb (Coincident) Winter: -40.0°C (-40°F) Dry bulb
For CBGAVS: (1% Exceedance values)	Summer: 37.8°C db (100°F) 26.1°C wb (79°F) (coincident), Winter: -23.3°C (-10°F) Dry bulb
Inside Design temperatures and humidity:	
CRHA (normal operation)	~~22.8~~21.1°C (70~~3~~°F) to 23.3~~25.6~~°C (74~~8~~°F) and 25% to 60% relative humidity (RH)
CRHA (Loss of normal AC power)	Maximum ~~8.3~~33.9°C (93~~15~~°F) ~~rise above normal operating~~ temperature for the first 72 hours into the event, RH not controlled
DCIS rooms/miscellaneous areas	18.3°C (65°F) to 25.6°C (78°F), RH not controlled
Safety-related DCIS rooms (Loss of normal AC power)	50°C (122°F) maximum
HVAC equipment room:	10°C (50°F) to 40°C (104°F), RH not controlled
Pressurization:	CBGAVS > atmospheric pressure CRHAVS > 31 Pa (1/8" w.g.) positive differential
CBGAVS	18.3°C (65°F) to 25.6°C (78°F), RH not controlled
CRHAVS Breathing air supply capacity:	~~9.5~~10.5 l/s (~~20~~ 22 cfm) per person for up to 21 persons (~~200~~ 220 l/s or ~~424~~ 466 cfm total) for 72 hours ~~(Ref. 9.4.1-1)~~. Note: CRHA heatup analysis assumes 11~~5~~ control room occupants for CRHA thermal loading (Table 3H-12)

Table 9.4-17

Industrial Codes and Standards[1] Applicable to ESBWR HVAC (Continued)

Code or Standard Number	Title
American Nuclear Society (ANS)	
56.7-1978	Boiling Water Reactor Containment Ventilation Systems
59.2-1985	Safety Criteria for HVAC Systems Located Outside Primary Containment
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)	
15-2001	Safety Standard for Refrigeration Systems
30-1995	Methods of Testing Liquid-Chilling Packages
33-2000	Methods of Testing Forced Circulation Air Cooling and Air Heating Coils
51-1999	Laboratory Methods of Testing Fans for Aerodynamic Performance Rating
52-1976	Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
52.1-1992	Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
52.2-1999	Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
62-2007~~1~~	Ventilation for Acceptable Indoor Air Quality
American Society of Mechanical Engineers (ASME)	
AG-1-2003	Code on Nuclear Air and Gas Treatment
B31.1-2004	Power Piping
B31.5-2001	Refrigeration Piping and Heat Transfer Components
American Society for Testing and Materials (ASTM)	
D3803	Standard Test Methods for Nuclear-Grade Activated Carbon
E741-00	Quality Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution
American Water Works Association (AWWA)	
C200-97	Steel Water Pipe – 6 in. (150mm) and Larger, 2nd Edition
C203-02	Coal-Tar Protective Coatings and Linings for Steel Water Pipelines – Enamel and Tape – Hot Applied
D100-96	Welded Steel Tanks for Water Storage
Institute of Electrical and Electronics Engineers (IEEE)	
338-1987	Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems

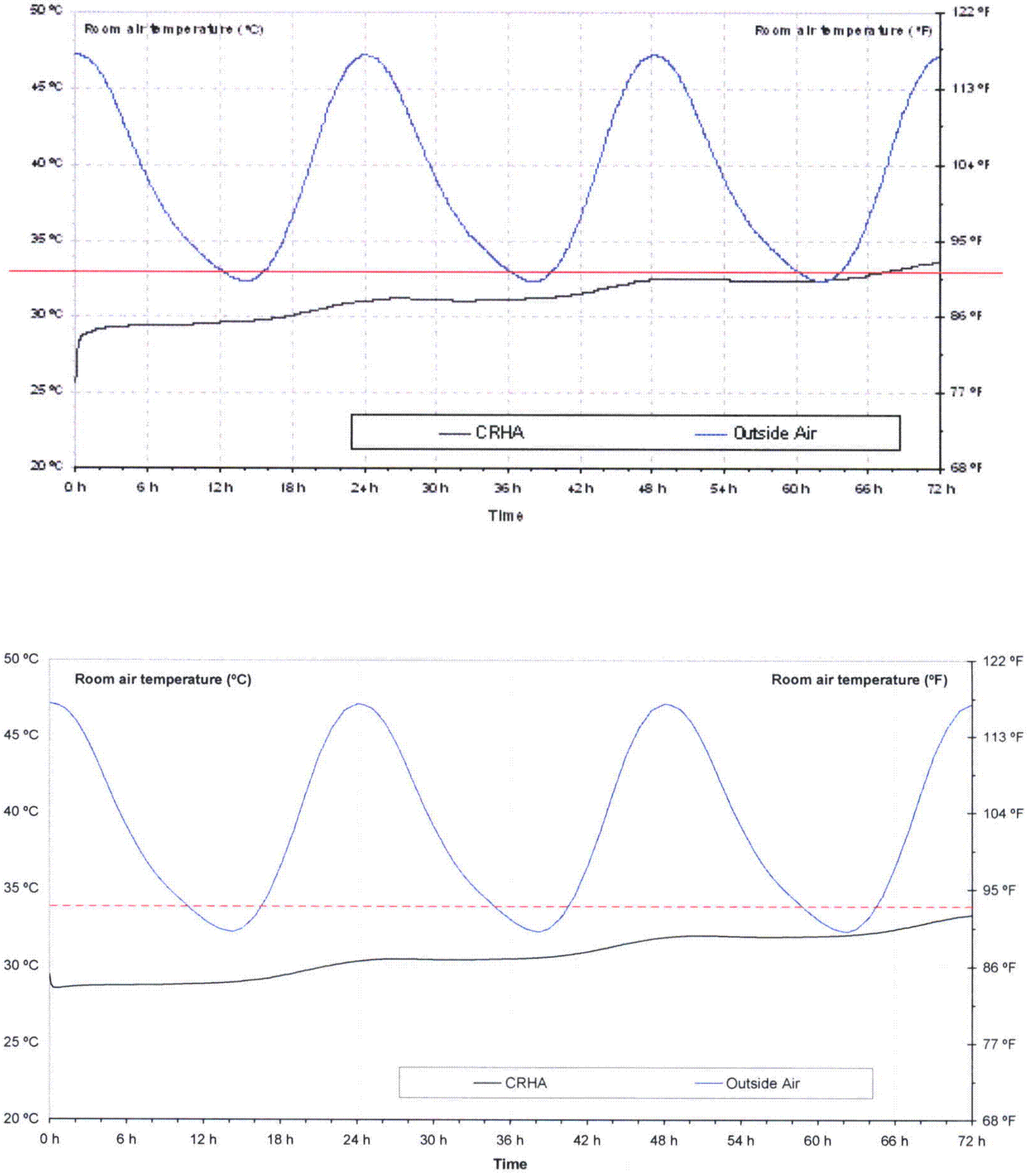


Figure 3H-2. Control Room Habitability Area Transient Analysis Heat up Profile– 0% Exceedance Maximum Temperature Case

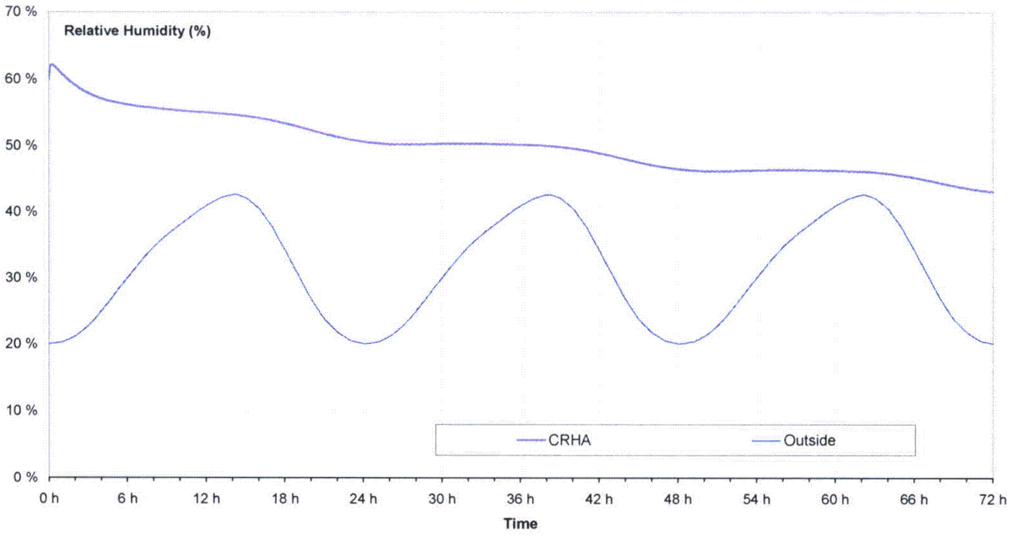


Figure 3H-3. Control Room Habitability Area Transient Analysis Relative Humidity Profile– 0% Exceedance Maximum Temperature Case

6.4.1 Design Bases

Criteria for the selection of design bases are found within Section 1.2.

The CRHA is contained inside a Seismic Category I structure (the Control Building) and is protected from wind and tornado effects as discussed in Section 3.3, from external floods and internal flooding as discussed in Section 3.4, from external and internal missiles as discussed in Section 3.5, and from the dynamic effects associated with the postulated rupture of piping as discussed in Section 3.6. The seismic qualification of electrical and mechanical components as discussed in Section 3.10 and environmental design is discussed in Section 3.11. Radiation exposure to control room personnel during postulated accidents is described in Chapter 15.

6.4.1.1 Safety Design Basis

The habitability systems maintain the main control room environment suitable for prolonged occupancy throughout the duration of the postulated accidents. Chapter 15 discusses dose protection requirement following a postulated radioactive release. Refer to Sections 3.1, 15.0, and Subsections 6.4.5 and 9.4.1 for discussions on conformance with GDC 19, and to Section 1.11 for a discussion on conformance with Generic Issues B-36 and B-66.

- The main control room is designed to withstand the effects of an SSE and a design-basis tornado as described in Section 3.8.
- The radiation exposure of main control room personnel throughout the duration of the postulated limiting faults discussed in Chapter 15 does not exceed the limits set by GDC 19.
- The emergency habitability system maintains the American Society of Heating, Refrigeration, and Air Conditioning Engineers fresh air requirements for up to 21 main control room occupants. (Reference 6.4-4). The Emergency Filter Unit System maintains CO_2 concentration in the CRHA to less than 5000 ppm.
- The habitability systems detect and protect main control room personnel from external fire, smoke, and airborne radioactivity.
- Automatic actuation of the individual systems that perform a habitability systems function is provided. Radiation detectors, and associated control equipment are installed at various plant locations as necessary to provide the appropriate operation of the systems.
- The CRHA includes all instrumentation and controls necessary during safe shutdown of the plant and is limited to those areas requiring operator access during and after a DBA.
- CRHA habitability requirements are satisfied without the need for individual breathing apparatus or special protective clothing.
- The CRHA EFUs and associated fans and ductwork, the CRHA envelope structures, the CRHA heat sink, doors, isolation dampers or valves, including supporting ductwork/piping, and associated controls are safety-related and Seismic Category I.
- Nonsafety-related pipe, ductwork, or other components located in the control room are designed as necessary to ensure that they do not adversely affect safety-related components or the plant operators during an SSE.

- The EFU trains are designed with sufficient redundancy to ensure operation under emergency conditions.
- The EFUs are operable during loss of normal AC power.
- The EFUs operate during an emergency to ensure the safety of the control room operators and the integrity of the control room by maintaining a minimum positive differential pressure inside the CRHA as noted in Table 6.4-1.
- The CRHA envelope is sufficiently leak tight to maintain positive differential pressure with one EFU in operation.
- Electrical power for safety-related equipment including EFUs, dampers, valves and associated instrumentation and controls is supplied from the safety-related uninterruptible power supply. Active safety-related components are redundant and their power supply is divisionally separated such that the loss of any two electrical divisions does not render the component function inoperable.

6.4.1.2 Power Generation Design Bases

- The CRHAVS is designed to provide a controlled environment for personnel comfort and for the proper operation and integrity of equipment when AC power is available.
- Provisions for periodic inspection, testing and maintenance of the principal components of both the EFUs and the CRHAVS are incorporated in the design.

6.4.2 System Design

Only the habitability portion of the CRHAVS is discussed in this subsection. The remaining systems are described only as necessary to define their functions in meeting the safety-related design bases of the habitability systems. Descriptions of the CRHAVS, FPS, Lighting System, and PRMS are found in Subsections 9.4.1, 9.5.1, 9.5.3, and Section 11.5, respectively. Figure 6.4-1 provides a schematic diagram of the CRHAVS.

The EFUs are redundant safety-related components that supply filtered air to the CRHA for breathing and pressurization to minimize inleakage. The EFUs and their related components form a safety-related subset of the CRHAVS. The EFU portion of the system and the associated components are designed, constructed, and tested as a safety-related nuclear air filtration system in accordance with ASME AG-1 requirements. An EFU is automatically initiated. There are two redundant EFU trains to provide protection against a single failure. Each train consists of an air intake, two 100% capacity fans, filtration housing, ductwork, and dampers as shown in Figure 6.4-1. The EFUs have been sized to provide sufficient breathing quality air and to maintain a positive pressure in the CRHA with respect to the adjacent areas.

The EFU delivery and discharge system is optimized to ensure that there is adequate fresh air delivered and mixed in the CRHA. This is accomplished by using multiple supply registers, which distribute the incoming supply air with the control room air volume, and a remote exhaust to prevent any short cycling. The EFU operation results in turning over the CR volume approximately 7-9 times per day. This diffusion design (mixing and displacement) in conjunction with the known convective air currents (due to heat loads/sinks) and personnel movement ensures that occupied zone temperature is within acceptable limits, buildup of contaminants (e.g., CO_2) minimal and a freshness of air is maintained.

6.4.3 Control Room Habitability Area

The CRHA boundary is located on elevation –2000 mm in the Control Building. The layout of the CRHA, which includes the MCR, is shown within Figure 3H-1, Control Room Habitability Area. The CRHA envelope includes the following areas:

• Admin Area	(Room 3270)
• RE/Shift Technical Advisor Office	(Room 3271)
• Shift Supervisor Office	(Room 3272)
• Kitchen	(Room 3273)
• Main Control Room	(Room 3275)
• Restroom A	(Room 3201)
• Restroom B	(Room 3202)
• Main Control Room Storage Room	(Room 3204)
• Electrical Panel Board Room	(Room 3205)
• Gallery	(Room 3206)
• Auxiliary Equipment Operators (AEO) Workshop	(Room 3207)
• Air Handling Unit (AHU) Room	(Room 3208)

These areas constitute the operation control area, which can be isolated and remain habitable for the duration of a DBA if high radiation conditions exist. Potential sources of danger such as steam lines, pressurized piping, pressure vessels, CO_2 fire fighting containers, etc. are located outside of the CRHA.

Heat Sink

The function of providing a passive heat sink for the CRHA is part of the CRHA emergency habitability system. The heat sink for each room is designed to limit the temperature rise inside each room during the 72 hour period following a loss of CRHAVS operation. The heat sinks consist of the thermal mass of the concrete that makes up the ceilings and walls of these rooms. The CRHA heat sinks consist of the following: the CRHA walls, floor, ceiling, and interior walls, and access corridors; adjacent Q-DCIS and Nonsafety-Related Distributed Control and Information System (N-DCIS) equipment rooms and electrical chases; and, CRHA HVAC equipment rooms and HVAC chases. The Control Building concrete characteristics with the material properties of the concrete used in the thermal analysis are provided in Table 3H-14.

After the 72 hour period, the EFU maintains the habitability of the CRHA when RTNSS power supplies are available. The recirculation AHU with supporting auxillary cooling units, is required to remove heat to support main control room habitability post 72 hours.

Upon a loss of normal AC power, the initial ranges of temperature/relative humidity in the CRHA are 21.1~~2.8~~-23.3~~5.6~~°C (70~~3~~-74~~8~~°F) and 25%-60% RH. The CRHA temperature / humidity values calculated during the 72 hours following a design basis accident equate to less than 30°C (86°F) wet bulb globe temperature and psychometric wet bulb temperature. The 30°C (86°F) value is the recommended threshold limit for instituting hot weather practices and the recommended upper limit appropriate for assessing heat stress and predicting heat strain for moderate levels of work respectively. The psychometric wet bulb temperature is an appropriate index for assessing heat stress and predicting heat strain under conditions where radiant temperatures and air velocity are not large factors and where increased humidity exists. NIOSH 86-113 provides a wet bulb temperature limit of about 30°C (86°F) for unimpaired performance on sedentary tasks (moderate levels of physical work) for normally clothed individuals at low airflows (Reference 6.4-5). During the first two hours of loss of normal AC power, most of the equipment in the MCR remains powered by the nonsafety-related battery supply. Anytime during a loss of normal AC power, once either ancillary diesel is available, the environmental conditions are maintained indefinitely. This is accomplished via the continued operation of a CRHA recirculation AHU and auxiliary cooling unit supplied with each recirculation AHU. Power is provided during the initial two hours from the same nonsafety-related battery supply that powers the non-safety MCR equipment. At any time during the initial two hours, or after, power can be provided by an ancillary diesel. ~~The cooling function provided by the recirculation AHUs and auxiliary cooling units is not a safety function.~~ If this cooling function is lost, the N-DCIS components in the MCR are automatically de-energized. This is accomplished via safety-related temperature sensors with two-out-of-four logic that automatically trip the power to selected N-DCIS components in the MCR, thus removing the heat load due to these sources.

The remaining CRHA ~~safety-related~~ equipment heat loads are dissipated passively to the CRHA heat sinks. The CRHA heat sinks limit the temperature rise to that listed in Table 6.4-1 by passively conducting heat into the heat sinks. The CRHA heat sinks consist of the following: the CRHA walls, floor, ceiling, and interior walls, and access corridors, adjacent Q-DCIS and N-DCIS equipment rooms and electrical chases; and CRHA HVAC equipment rooms and HVAC chases. The Control Building thermal analysis, including the CRHA, is presented in Subsection 3H.3.2. The temperatures presented in the analysis are acceptable for human performance and equipment qualification.

These actions discussed above protect the main control room occupants from a potential radiation release and maintain the CRHA as a safe and habitable environment for continued operator occupancy.

6.4.5 Design Evaluations

System Safety Evaluation

Doses to main control room personnel are calculated for the accident scenarios where the EFU provides filtered air to pressurize the CRHA. Doses are calculated for the following accidents:

Loss of Feedwater Heating with Failure of Control Rod Run-In	Table 15.3-16
Liquid-Containing Tank Failure	Table 15.3-19
Loss of Coolant Accident	Table 15.4-9

The COL Applicant will verify procedures and training for control room habitability address the applicable aspects of NRC Generic Letter 2003-01 and are consistent with the intent of Generic Issue 83 (Subsection 6.4.4).

6.4-2-A Toxic Gas Analysis

The COL Applicant will identify potential site specific toxic or hazardous materials that may affect control room habitability in order to meet the requirements of TMI Action Plan III. D.3.4 and GDC 19. The COL Applicant will determine the protective measures to be instituted to ensure adequate protection for control room operators as recommended under RG 1.78. These protective measures include features to (1) provide capability to detect releases of toxic or hazardous materials, (2) isolate the control room if there is a release, (3) make the control room sufficiently leak tight, and (4) provide equipment and procedures for ensuring the use of breathing apparatus by the control room operators (Subsection 6.4.5).

6.4.10 References

6.4-1 MIL-HDBK-759C, Human Engineering Design Guidelines.

6.4-2 MIL-STD-1472E, Human Engineering.

6.4-3 A Prioritization of Generic Safety Issues, NUREG-0933, October 2006.

6.4-4 ASHRAE Standard 62.1/2007, Ventilation for Acceptable Indoor Air Quality.

6.4-5 NIOSH 86-113, Occupational Exposure to Hot Environments