August 4, 2008

Mr. Robert E. Brown
Senior Vice President, Regulatory Affairs
GE Hitachi Nuclear Energy
3901 Castle Hayne Road, MC A-50
Wilmington, NC 28401

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 230 RELATED TO NEDE-33392, "BIMAC TEST REPORT"

Dear Mr. Brown:

By letter dated April 18, 2008, the U. S. Nuclear Regulatory Commission (NRC) staff informed you of the result of the acceptance review of NEDE-33392, "BiMac Test Report." In that letter, the staff determined that the material presented in the topical report was sufficient to begin a detailed review as part of the ESBWR design certification review.

The NRC staff has identified that additional information is needed to continue portions of the review. The staff's request for additional information (RAI) is contained in the enclosure to this letter.

Pursuant to 10 CFR 2.390, we have determined that the enclosed RAIs contain proprietary information. We have prepared a non-proprietary version of the RAIs (Enclosure 1) that does not contain proprietary information. The proprietary information is indicated in brackets and underlined in Enclosure 2. We will delay placing this document in the public document room for a period of ten (10) working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects only. If you believe that any additional information in the enclosure is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.390 before the public release date.

If you have any questions or comments concerning this matter, you may contact me at 301-415-5787 or rocky.foster@nrc.gov or you may contact Amy Cubbage at (301) 415-2875 or amy.cubbage@nrc.gov.

Sincerely,

/RA/

Rocky D. Foster, Project Manager
ESBWR/ABWR Projects Branch 2
Division of New Reactor Licensing
Office of New Reactors

Docket No. 52-010

Enclosure:
1. Request for Additional Information (Non-Proprietary)
2. Request for Additional Information (Proprietary)

cc: See next page (w/o enclosure 2)

If you have any questions or comments concerning this matter, you may contact me at 301-415-5787 or rocky.foster@nrc.gov or you may contact Amy Cubbage at (301) 415-2875 or amy.cubbage@nrc.gov.

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ADAMS ACCESSION NO.: ML082130159 NRO-002

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DATE	8/4/2008	7/24/2008	7/31/2008

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SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 230 RELATED TO ESBWR DESIGN CERTIFICATION APPLICATION DATED AUGUST 4, 2008

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Request for Additional Information (RAI)
NEDE-33392, "BiMac Test Report"

RAI Number	Reviewer	Question Summary	Full Text
19.2-93	Fuller E	Verification of final BiMAC tube design specifications	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) 2. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** Reference [1] states that the final design will be decided after the MAC experiments. Reference [2] argues in favor of a system incorporating tubes with [[ ]] diameter and [[ ]] inclination. The experiments (single tube and multiple tubes) are also based on this design. Please confirm that the final design in the ESBWR plant will have [[ ]] tubes, [[ ]] in diameter each at an inclination of [[ ]] with the horizontal plane. If not, provide the final dimensions.
19.2-94	Fuller E	Tube diameters and inclinations affect on heat loads	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** Reference [1] implies that the final BiMAC design may most likely choose [[ ]]. Please confirm this interpretation, and discuss the effects of differences in tube diameters and inclinations on the calculated heat loads.
19.2-95	Fuller E	Core melt situations where GDCS pools are depleted, preventing the deluge function	The GDCS's main function is to serve as an emergency cooling supply to the core in any event that threatens the reactor coolant inventory. In addition, if the vessel fails, it is important to ensure that the GDCS can provide sufficient water to cool the debris in the lower drywell by utilizing the BiMAC. Please provide documentation of any core melt situations in which the GDCS pools have already been depleted by providing water to the vessel, and there is not sufficient inventory for ex-vessel cooling. Describe the amount of water that is required to sustain the BiMAC system.

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19.2-96	Fuller E	Correct values for heat loads	**[REFERENCE]** 1. GE-Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** The calculated heat loads shown on Page 7 come from Figures 3.1, 3.2, and 3.3 [1]. It was difficult to verify the values because these figures display only the normalized values. For Figures 3.1 and 3.2 [1], the normalization value appears to be 100 kw/m^2, but for Figure 3.3 [1] it appears to be 300 kw/m^2. Please provide sufficient information to verify that these are the correct values.
19.2-97	Fuller E	CFD simulations	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** Please provide responses to the following questions, and include any additional clarifications on the CFD simulations: (a) What is the rationale for choosing the volumetric heat generation rate and time into the accident, which were used during the CFD simulations in Reference [1]? (b) Why a single combination chosen and no other possible variations were evaluated? (c) What CFD code was used for the DCD analyses [1] and what turbulence model does it contain? (d) How do the calculated steady-state temperatures in Reference [1] compare with the melt superheat on its first arrival into the LDW? Was the presence of Zirconia credited during the CFD simulations reported in Reference [1], and if yes, what was the thickness and what is the basis for this value?

RAI Number	Reviewer	Question Summary	Full Text
19.2-98	Fuller E	Effects of crusts on heat loads	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** The heat loads applied in Reference [1] were representative of decay heat in a full core melt pool with the boundary condition being the solidification temperature of the melt. If, however, there is formation of significant crust thickness all around the periphery, there could be a number of potential effects, as described below: 1. The actual circulation patterns that affect the distribution may be constricted because of the smaller melt volume. 2. There is likely to be decay heat continued in the solidified crust regions. 3. Conduction in the crust regions could tend to alter the distribution. Please discuss the effects of crusts on heat loads, and the expected ranges of crust thicknesses.
19.2-99	Fuller E	Structural integrity of Zirconia and impacts on heat loads	Zirconia is a very brittle material subject to failure by thermal shock as a result of the monoclinic-to-tetragonal phase change at about 1470 K. Please discuss the structural integrity of Zirconia for thermal transient conditions expected in the lower drywell, and consequent effects on heat loads. Please address the initial transient thermal loads on the Zirconia, and demonstrate that the BiMAC Zirconia structural integrity can be maintained under such transient conditions. In addition, address stabilization by the addition of materials such as MgO, CaO, and Y_2O_3, and evaluate the exothermic dissolution of these materials and consequent contributions to the transient heat loads. Include possible effects of the initial superheat.

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19.2-100	Fuller E	Thermal load boundary conditions used in the experiments justification	The molten pool and core debris thermal state depends on the total mass, configuration and the boundary conditions at the outer edges. Please elaborate on the assumption of decoupling between the cooling afforded by BiMAC channels and molten pool thermal loads. Please justify the thermal load boundary conditions used in the experiments and the ESBWR BiMAC design.
19.2-101	Fuller E	Clarification on the values of the driving head and assumed GDCS inventory	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** The driving head for the BiMAC system cannot be easily deduced based on the documents cited here. Reference [1], on Page 23, states that "the BiMAC (will be) subjected to [[ ]] of gravity head" and on Page 48 states that "a good mean value of the pool height is [[ ]]". Based on the experimental facility design (Reference [1], Page 16), the driving head appears to be [[ ]]. Please provide the value for the driving head for the BiMAC system in the experiments and in the actual plant. Identify the GDCS inventory that is assumed while deriving the driving head for the plant.
19.2-102	Fuller E	Downcomer and riser elevations	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) 2. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** Table E.21.4-1 in Reference [1] mentions that the downcomer height is 1.8 m whereas the height of the vertical section of the riser is 0.83 m. If the height due to the inclination (at a 10º angle) is considered the total height of the vertical portion from the bottom of the LDW would be ~1.7 m. Therefore, this would make the elevation of the downcomer higher than the vertical section of the riser. Further, the experimental arrangement [2] shows that the 'downcomer' inlet is [[ ]] lower than the vertical section. Please provide information regarding the elevations of the downcomer and riser (vertical) sections of the BIMAC in the plant.

RAI Number	Reviewer	Question Summary	Full Text
19.2-103	Fuller E	Verification of the assumed extent of subcooling	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** Reference [1] (Page 23) notes that the subcooling, once the LDW pool reaches saturation, will be [[ ]] with the BiMAC subjected to [[ ]] of gravity head. Please provide details as to how these numbers were arrived at.
19.2-104	Fuller E	Scaling relations	The scaling base of the MAC multi-channel test is not clear. Please explain how the multi-channel test is scaled relative to the prototype and what the scaling relations are.
19.2-105	Fuller E	Near-edge tubes no tests	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** It appears that the single tube tests were only for the mid-section tubes. Please identify the relevant tests for the near-edge tubes that are shorter but have less margin to burnout as indicated by Figure 21.5.4.5.2 [1]. If there are none, justify why the existing test data are sufficient.
19.2-106	Fuller E	Heat flux doubling	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** For the 20 tube experiments, as the length of the tubes were ½ full-length [1], it appears that the applied heat fluxes should be twice the calculated values for the full scale. Please explain why the heat fluxes do not need to be doubled.

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19.2-107	Fuller E	Effects of subcooling and void fractions on flow rate	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** It is presumed that there is a significant driving force in natural convection because a significant void fraction is developed in the tubes. However, the result shown in Figure 5.1 in Reference [1] indicates that, up to an achieved flow rate of [[ ]], the exit void fraction was still zero. However, the flow rate decreased markedly as inlet subcooling decreased down to [[ ]] over the flow range up to [[ ]]. Please explain this behavior.
19.2-108	Fuller E	Effects on location of downcomer on flow distribution in the tubes	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** The SE test apparatus (Figure 4.4 of Reference [1]) shows the downcomer entering the mid section of the distributor instead of at one end. Please explain how this affects the flow distribution in the tubes.
19.2-109	Fuller E	Heat flux not increased beyond 112.5 kW/m^2	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** Please confirm if the following interpretation of the single tube experiments (SC series), based on information in Reference [1], is correct: A uniform heat flux of [[ ]] was applied for which stable behavior was observed. At the increased e heat flux of [[ ]] (using double-stacked copper band heaters), temperature oscillations were observed. No measurements for values between [[ ]] and [[ ]] were performed. In addition, heat fluxes exceeding [[ ]] were not

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			tested. If this interpretation is correct, explain why the heat flux was not increased beyond [[ ]] to determine the boundary for onset of instabilities, and whether the limit of [[ ]] was imposed due to limitation of copper heaters or based on CFD results. In addition, explain why heat fluxes higher than [[ ]] were not tested.
19.2-110	Fuller E	Interpretations of oscillation and flow reversal for multiple tube experiments	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** From the multiple tube experiments, in particular Run # [[ ]] [1], oscillations and flow reversal have been observed for heat fluxes higher than [[ ]] along the inclined section in the presence of subcooling. Please explain the oscillation and flow reversal for the multiple tube experiments. In addition, provide the margin to oscillatory behavior for the BiMAC system, using the heat fluxes obtained from the CFD study as reference.
19.2-111	Fuller E	Locations of probes and pressure transducers	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** It is stated in Reference [1] that the void fraction measurement for single tube experiments was performed using traversing conductivity probe at the exit of the riser section. Please confirm that the location is at the exit of the single tube (at an elevation of [[ ]] from the bottom of the tank) and not at (or near) the bottom of the tank (at an elevation of [[ ]] (from the beginning of the vertical section). Also, provide the location of the pressure transducers used for measuring the inlet and exit pressures.
19.2-112	Fuller E	Results for near-edge tubes	The failure modes evaluated in the tests were the potential for burnout and dryout of the tubes as a result of any deficient natural convection cooling at the applied heat loads. Although the vertical piping may have a higher heat flux peaking, it is important to demonstrate that the near edge piping sections also have sufficient

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			margin for coolability. For the MAC tests to be conclusive in establishing robustness with respect to these failure modes, it appears that a single tube test of the near-edge tubes is needed. Please indicate which tests in the existing test matrix address near-edge effects, and what the pertinent results are. Otherwise, please carry out such a test or justify why it is not necessary.
19.2-113	Fuller E	Draining of water from GDCS pools	The MAC tests address the period after both sets of deluge lines have been activated and the system has reached a quasi steady state. Please identify what fraction of the water in the GDCS pool would be drained into the lower drywell and BiMAC tubes, and what the resulting depth of the overlying water pool would be. What is the minimum depth that would ensure effective natural convection capability of the BiMAC?
19.2-114	Fuller E	Results documentation of calculation of melt jet impingement	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** The Saito correlation is appropriate for evaluating the melt jet impinging on a flat surface. The value of 13 MW/m^2 for heat flux [1] was not reproducible. Please provide the results of the calculation with the appropriate units.
19.2-115	Fuller E	Potential for uncovered tube sections	**[REFERENCE]** 1. T. G. Theofanous, "The MAC Experiments Fine Tuning of the BiMAC Design", NEDE-33392P Rev. 0 (March 2008) **[QUESTION]** The BiMAC design (Figure 2.2 of Reference [1]) indicates that the tubes get shorter as the downcomers are approached. At the downcomer location, there seems to be a "transition" potential to have a small area of the liner not fully covered. Please explain whether or not this is the case and, if so, how this particular area is dealt with.

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19.2-116	Fuller E	Clarification of success criteria for number of deluge lines	**[REFERENCE]** 1. GE-Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** On Page 21.5-3 of Reference [1] is this note: "The lines [deluge] are sized so that any three of them would be sufficient to ensure proper BiMAC functioning …". Was this meant to say: "…any one of the three…"?
19.2-117	Fuller E	Line feed into downcomers	There are apparently six (6) deluge lines coming from the GDCS. Do three feed the BiMAC tubes and three feed the direct deluge? If three feed the BiMAC tubes, explain how the three lines are fed into the two downcomers.
19.2-118	Fuller E	Values for driving head and length of pipe	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** Please provide the values for the driving head and length of the pipe used for the theoretical analysis in of Reference [1] to obtain the mass flow rate versus the heat flux curves for different pipe sizes.
19.2-119	Fuller E	Correlation used for "correction of inclination"	**[REFERENCE]** 1. GE Hitachi ESBWR NEDO 33201 Rev. 3, Chapter 21, General Electric-Hitachi (GEH) (May 2008) **[QUESTION]** With regard to the two-phase natural circulation model (Table E.21.2-1 in of Reference [1]) please provide details of the correlation used for 'correction for inclination' including a nomenclature of the terms involved.

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