July 5, 2006

Mr. David H. Hinds, Manager, ESBWR
General Electric Company
P.O. Box 780, M/C L60
Wilmington, NC 28402-0780

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 40 RELATED TO ESBWR DESIGN CERTIFICATION APPLICATION

Dear Mr. Hinds:

By letter dated August 24, 2005, General Electric Company (GE) submitted an application for final design approval and standard design certification of the economic simplified boiling water reactor (ESBWR) standard plant design pursuant to 10 CFR Part 52. The Nuclear Regulatory Commission (NRC) staff is performing a detailed review of this application to enable the staff to reach a conclusion on the safety of the proposed design.

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. This RAI concerns ESBWR Probabilistic Risk Assessment and Chapter 19 of the ESBWR Design Control Document. These questions were sent to you via electronic mail on May 18, 2006, and were discussed with your staff during a telecon on June 22, 2006. You agreed to respond to this RAI on the following schedule:

> July 31, 2006: 19.1-8, 10 thru 15, 17 thru 19, 19.2-3, 6 thru 18, 26, 27, and 35 thru 37.
> August 18, 2006: 19.1-9 and 16, 19.2-4, 19 thru 25, 28 thru 34, and 38.
> August 31, 2006: 19.2-5.

If you have any questions or comments concerning this matter, you may contact me at (301) 415-2863 or lwr@nrc.gov or you may contact Amy Cubbage at (301) 415-2875 or aec@nrc.gov.

Sincerely,

/RA/

Lawrence Rossbach, Project Manager
ESBWR/ABWR Projects Branch
Division of New Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 52-010

Enclosure: As stated

cc: See next page

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ACCESSION NO. ML061840014

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DATE	07/03/2006	07/05/2006

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Distribution for DCD RAI Letter No. 40 dated July 5, 2006

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RAI Number	Reviewer	Summary	Full Text
19.1-8	Palla R	Discuss impacts of severe accident conditions on PCCS operation	Discuss how the operating efficiency of the Passive Containment Cooling System (PCCS) (including thermo-physical properties, heat transfer coefficients, steam condensation efficiency, fission product removal, and axial and radial velocity distribution within the condenser tubes) is impacted by each of the following: (a) large quantities of non-condensible gases such as CO_2 and H_2, (b) corium-concrete interaction (CCI) - generated aerosols including plugging effects, and (c) increases in Isolation Condenser (IC) pool temperatures as the event progresses. Support the responses with an appropriate analysis for each case.
19.1-9	Palla R	Discuss implications of RPV head failure at alternate locations	It is traditionally assumed that Reactor Pressure Vessel (RPV) failure occurs at the bottom of the lower head. (All the analyses presented in the Safety Analysis Report (SAR) make this assumption.) However, calculations performed by Oak Ridge National Laboratory (ORNL) for operating BWR designs suggest that early relocation of stainless steel control blades and cladding material could result in alternative failure modes. Discuss the implications of the RPV failing at other locations than the very bottom. Include in this discussion an assessment of the following: (a) the impact of early relocation of non-heat-bearing debris to the lower plenum on failure location, and (b) the impact of a change in failure location (i.e., at the level of the lower grid plate) on sequence progression and containment loads. This should include consideration of the impact on fission product release, CCI, steam explosion, and actuation of the cavity flood system.
19.1-10	Palla R	Assess the impact of breaking the non-condensible gas line between the PCCS heat exchanger and the suppression pool	Provide an assessment of the risk (frequency and consequences) associated with a rupture of the pipe carrying non-condensible gases from the PCCS to the suppression pool. (It would appear that this would not only disable the operation of the PCCS, by eliminating the pressure differential, but would also cause the suppression pool to be bypassed and the containment pressure to increase in an unabated manner.) Based on this assessment, either address this failure in the Containment System Event Tree (CSET) or justify its omission.

RAI Number	Reviewer	Summary	Full Text
19.1-11	Palla R	Provide additional details regarding the PRA Level 1/2 interface	Section 8 outlines the details behind CSETs, Accident Classes, Containment Phenomenological Event Trees (CPETs), and the Source Term Release Category Grouping. However, the sequence binning process and the algorithm used to integrate these steps is not described. Thus, it is not possible to trace an accident sequence from its inception (accident initiation in Level 1 Probabilistic Risk Assessment (PRA)) to its final outcome (source terms in Level 2/3 PRA). In this regard, provide a description of the process and algorithms used to integrate the above mentioned steps. Include a discussion of how the sequences used to generate the source terms are representative of their respective Release Categories.
19.1-12	Basu S	Provide additional details regarding GDCS injection line break sequence (MLI_nVB_nCHR)	For sequence "MLI_nVB_nCHR" in the PRA, it is our understanding that the water in suppression pool is expected to flow to the lower drywell through the equalization line break, and flow back to the RPV through the other end of the line break when the water level inside the drywell reaches the elevation of the break, thus keeping the core cool. Elaborate on the sequences of events that are eventually expected to result in core damage, given this feature.
19.1-13	Palla R	Address impact on release categories of including risk from external events and shutdown operations	Provide a discussion on possible changes to the various Release Category source term magnitudes that could result for external events and shutdown severe accidents, as compared to the values calculated for the full power internal event accidents. Provide bounding levels for the core damage frequency (CDF) and containment failure frequencies for external events and shutdown operation accidents.

RAI Number	Reviewer	Summary	Full Text
19.1-14	Palla R	Address impact of alternate containment failure location on GDCS	Discuss how an over-pressure failure of the containment at the suppression pool slab wetwell joint would affect the operability of the GDCS system. Justify why this potential failure mode need not be addressed in the Level 2 analysis.
19.1-15	Palla R	Justify that core inventory is representative	Justify that the core loading and burnup assumed in developing the source term is representative of the way the ESBWR plant will be operated.
19.1-16	Basu S	Provide additional sensitivity analyses regarding ex-vessel steam explosion	The quantification of loads in the steam explosion calculations is based on a given set of initial and boundary conditions (e.g., melt pouring rate of 720 kg/s, premixing area of ~0.03 m^2, melt volume fraction of 22%, etc.) and certain assumed values of explosion parameters β and γ (see PRA, pages 21.4-7 and 8). Given that there are uncertainties in severe accident progression that provide initial and boundary conditions for explosion calculations, sensitivity analyses would be useful in providing insights into the uncertainties in the loads. The PRA provides only limited sensitivity calculations involving water pool depth. Provide additional sensitivity calculations involving pouring rate, premixing area, subcooling, and the choice of β to confirm that the loads are indeed bounding. Such sensitivity calculations proved useful for addressing uncertainties in steam explosion loads for AP1000 and more recently, as part of the international SERENA (Steam Explosion Resolution for Nuclear Applications) exercise.
19.1-17	Basu S	Provide additional details regarding PCCS and IC	Provide pipe wall thickness of the PCCS and IC inlet lines. Also, provide inlet pipe location relative to PCCS/IC pool, and confirm if it is insulated.

RAI Number	Reviewer	Summary	Full Text
19.1-18	Palla R	Assess ESBWR MAAP application against EPRI guidance on MAAP	Provide documentation of the analyses of uncertainties and sensitivities for the MAAP ESBWR model application. Discuss the applicability of the extended sensitivity analysis suggested by the Electric Power Research Institute MAAP Users Group (EPRI/MUG) for BWR applications.
19.1-19	Palla R	Assess Level 2 PRA against ASME Standard	Provide an assessment of the ESBWR Level 2 PRA against the High Level and Supporting Requirements of the large early release frequency (LERF) analysis in Section 4.5.9 of the American Society of Mechanical Engineers (ASME) PRA Standard, and a judgement regarding the capability categories of the model in key areas.
19.2-3	Palla R	Provide a general description of accident progression in ESBWR and contrast with ABWR	A generalized description of severe accident progression is not provided in the PRA, and is needed to assist in evaluating the approach used in the PRA for describing and quantifying potential core damage sequences. In this regard, provide a narrative description, with quantitative estimates of times, temperatures and pressures, of the complete progression (in-vessel and ex-vessel) of a representative severe accident sequence in ESBWR. Compare and contrast the ESBWR accident response with that for a comparable accident sequence in the advanced boiling water reactor (ABWR).
19.2-4	Palla R	Discuss applicability of in-vessel recovery for ESBWR	Discuss how in-vessel recovery of a damaged core would be approached in the ESBWR design, and the use of AC-independent fire water system for this purpose. Justify that the treatment (or lack of treatment) of in-vessel recovery in the Level 2 PRA is appropriate.
19.2-5	Palla R	Provide additional details regarding ROAAM peer review	A fundamental component of the validity of the Risk-Oriented Accident Analysis Methodology (ROAAM) approach is the quality of the independent peer review. Provide additional detailed information to substantiate that review was independent and comprehensive. This would include the

RAI Number	Reviewer	Summary	Full Text
			affiliations, qualifications and relevant experience of the reviewers to the area reviewed, an estimate as to level of effort each devoted to the review, the individual directions given regarding the scope and depth of their review, and information as to joint meetings and interviews.

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19.2-6	Palla R	Provide vacuum breaker design information	Provide additional information regarding the drywell to suppression chamber vacuum breakers, including drawings showing the vacuum breaker, proximity/position sensors, and DC motor-operated valve that would provide isolation if the vacuum breaker sticks open or leaks in its closed position (as described in Section 4.18.3.1 of the PRA).
19.2-7	Palla R	Provide additional information regarding vacuum breaker cycles and failure probability	Provide an estimate of the maximum number of cycles that each vacuum breaker might be exposed to during a potential severe accident sequence, and the basis for this estimate. Justify the probability of vacuum breaker leakage or failure to open/close given this number of cycles.
19.2-8	Palla R	Provide additional information regarding the vacuum breaker fault tree model	Vacuum breaker failure is modeled in the PRA as the probability of vacuum breaker leakage (1E-4) AND the probability of failure of vacuum breaker closure (events GT10-0103-1 through GT10-0105-1 in Figure B.4.18 of the PRA). Provide a description of each of the failures and basic events considered in the fault tree. Provide the values for events GT10-0103-1 through GT10-0105-1 for each accident class. Justify that the impacts of vacuum breaker leakage on the pressure suppression and PCCS functions are adequately addressed in the fault tree.
19.2-9	Palla R	Provide the basis for the vacuum breaker leakage probability estimate	Provide the basis for the assumed value of 1E-4 for both the probability of a vacuum breaker leak, and the probability of the failure to close the vacuum breaker (presumably using the DC motor-operated isolation valves.) Discuss the degree to which these values are based on vacuum breaker test data and/or operator actions, and the process by which these low values will be achieved and maintained.

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19.2-10	Palla R	Expand the coverage of vacuum breakers in Tier 1 and Tier 2 DCD and ITAAC	Discuss the safety classification of the vacuum breakers, proximity/position sensors, and DC motor-operated isolation valves. Given the importance of these systems, structures, or components (SSCs), explain why the latter SSCs are not included in Tier 1 and 2 of the DCD (e.g., the DC motor-operated isolation valves are not mentioned in Section 2.15 of Tier 1, and the vacuum breakers, proximity/position sensors, and DC motor-operated isolation valves are not mentioned in Sections 19.5.3 and 19.5.10 of Tier 2), and system ITAAC.
19.2-11	Palla R	Describe the emergency procedures related to failed vacuum breakers	Describe the guidance that will be provided to operators (in emergency procedure and severe accident guidelines) with regard to identification and isolation of failed/leaking vacuum breakers. Discuss how/when the guidance will be developed.
19.2-12	Palla R	Address the impact of vacuum breaker leakage impact on PCCS	Vacuum breaker leakage/failure is assumed to lead to loss of pressure suppression in Section 8.2.1 of the PRA. However, it appears that vacuum breaker leakage/failure could also lead to loss of PCCS. The leakage rate at which the pressure suppression function and the PCCS function are compromised could be different. Specify the maximum leak area that could exist before: (a) the pressure suppression function is compromised, and (b) the PCCS function is compromised.
19.2-13	Palla R	Provide additional information related to vacuum breaker leakage indication	Provide an estimate of the gap between the disk and seating surface that would exist if the total vacuum breaker leakage is at the maximum allowable value and uniformly distributed among all of the vacuum breakers. Discuss the ability of the position indication transducer to detect/measure such a gap. (The analysis in the PRA assumes that the position switch which provides annunciation in the control room can sense a gap between the disk and the seating surface corresponding to a leak area of 1 cm2.)

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19.2-14	Basu S	Provide additional details regarding containment spray system	Provide design information for the containment spray system, in particular, the elevation of the containment spray header inside the drywell, spray water temperature, and spray mean droplet diameter.
19.2-15	Palla R	Address potential adverse impacts of containment spray operation	If the containment sprays are turned on while the PCCS is removing heat, the resulting drop in drywell pressure may interrupt the flow to the GDCS, and eventually the RPV. Although the scenario progression from this point is not clear, core damage appears possible. In view of the potential risk significance, please provide an assessment of the affect of spray system operation on core cooling. Include in your response (a) a supporting thermal-hydraulic analysis for this event, and (b) a description of system design features, operating procedures, or administrative controls that reduce the likelihood of this operator action.
19.2-16	Palla R	Discuss the design philosophy leading to a manual containment vent design	Discuss the rationale for designing the containment over-pressure protection system (MCOPS) as a manually-actuated system in ESBWR versus a passively-actuated system in ABWR. Address the apparent inconsistency of this approach with the passive design philosophy of ESBWR.

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19.2-17	Palla R	Discuss containment venting for hydrogen control, and its treatment in the PRA	Steps PC/G-3 and PC/G-6 of the Emergency Procedure and Severe Accident Guidelines (EP/SAG) contain explicit instructions to vent the drywell or suppression chamber, respectively, given certain hydrogen/oxygen concentrations. Describe the vent lines that would be used for this purpose. Clarify whether vented releases pursuant to these instructions are included within the Level 2 PRA, and if not, why not.
19.2-18	Basu S	Provide additional details regarding containment vent design	Provide elevations of the containment venting system in both the suction and discharge sides. Also provide the length of various pipe sections in the vent lines.
19.2-19	Palla R	Provide additional information regarding protection of the deluge line	The deluge downcomers are presumably headered together at some point to feed into the basemat internal melt arrest and coolability system (BiMAC). Describe how the downcomers/headers are protected from being disabled by "corium splatter", corium jets from an off-center head failure, or a missile consequent to RPV head failure. Describe how such a disabling event would affect subsequent accident progression.
19.2-20	Basu S	Provide additional details regarding the BiMAC configuration	Provide the following information regarding the BiMAC geometry in the lower drywell region: (a) additional information on the shape/configuration of the 20 cm refractory layer (it appears as being 'cone-shaped'), and (b) additional information related to the water-cooling distribution system of BiMAC (e.g., the number of cooling pipes connected to the main header, the spacing/separation between the cooling pipes, etc.).

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19.2-21	Palla R	Describe the transient response of BiMAC	Provide additional information regarding coolant flow into the BiMAC device during the initial phase of BiMAC operation (beginning with debris relocation and deluge system actuation, and ending with establishment of natural circulation). This should include flow rates into the distributor versus time from (a) the GDCS, (b) the RPV, and (c) the BiMAC downcomers. Address the potential for local steam starvation and dryout due to countercurrent flow of water from the water pool into the BiMAC channel outlets. Provide the final bounding state (i.e., quasi-steady state) of the core debris within the lower drywell.
19.2-22	Palla R	Describe the final bounding state of the core debris within BiMAC	Describe the "final bounding state" of the core debris within BiMAC, including crust thickness, and thinning of BiMAC channels (if applicable) as a function of location within the piping array. Discuss the relationship between the final bounding state and the boundary conditions that would be evaluated in the BiMAC test program.
19.2-23	Basu S	Describe the BiMAC test program	As the PRA correctly points out (page 21.5-3), the effectiveness of the BiMAC design needs to be confirmed through testing. Until such data is available, the performance of BiMAC cannot be relied upon with a high degree of confidence. Describe the tests and analyses that will be performed to support design certification and/or issuance of a COL, who will perform these tests, and when the results of the tests will be submitted. Describe the test program planned to ensure reliable and predictable operation of the BiMAC device, including whether these tests will involve single and/or multiple cooling channels, and the anticipated scale of the tests.

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19.2-24	Palla R	Provide additional details regarding the BiMAC cover plate design	Provide additional details regarding the BiMAC cover plate/lid arrangement, which is said to serve a dual purpose of providing a work surface during plant maintenance and trapping core debris during a high pressure melt ejection event. (The lid is indicated to be a stainless steel top plate over a zirconium oxide mat over a normal floor grating.) Include information regarding the lid materials, properties, thickness, and any seal provisions to prevent normal reactor coolant system (RCS) leakage from entering the BiMAC cavity, if applicable. Discuss the potential for the cover plate/lid to impede debris transport to the BiMAC cavity, particularly if the high velocity debris/gas jet is disrupted/dispersed by the substantial control rod drive (CRD) structures below the RPV, which appear to be neglected in the ESBWR analysis.
19.2-25	Palla R	Provide additional details regarding protection of the LDW sumps from molten core debris	Provide additional information regarding the BiMAC cooling jacket arrangement in the vicinity of the two sumps in the lower drywell floor, which the BiMAC is designed to protect, and the wall/floor area adjacent to the downcomer/deluge lines and near-edge channels. Include an overlay of PRA Figures 21.5.2-1c and e, and an isometric drawing. Discuss how the BiMAC piping in these two areas was treated in the computational fluid dynamic (CFD) simulations. Discuss whether asymmetries in these areas and the protection of the wall/floor area adjacent to the downcomer/deluge lines by only a limited number of near-edge channels can introduce the potential for steam starvation and local burnout, particularly since the

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			maximum heat flux occurs near the intersection of the horizontal and riser pipes (as shown in Figure 21.5.4.3-1b).
19.2-26	Palla R	Provide additional information regards features controlling LDW water level	Provide a comprehensive discussion of the items/features controlling the lower drywell water level for the period before RPV failure and for the period after RPV failure. This discussion should address event timing, sensor activation, flow paths into the lower dry well (LDW), drainage and vent paths, gutters, curbs, boil-off, replenishment, squib valves and actuation systems, eutectic valves, and operator instructions when to use and when not to use containment sprays.
19.2-27	Palla R	Describe capabilities and guidance regarding LDW water level detection	Provide a description of how the operator will know the water level in the drywell and whether the instrumentation would be available for the key sequences, including station blackout and loss of DC bus events. Discuss the operator guidance regarding LDW flooding for those events in which water level instrumentation is not available.
19.2-28	Palla R	Discuss ITAAC related to LDW water level	Identify which of the features mentioned in the response to RAI 19.2-19 through 27 will be covered by RTNSS, ITAAC, or COL action items.
19.2-29	Palla R	Provide additional information related to the LDW flooding function	Some LDW flooding valves are actuated by thermocouples in the drywell floor. Others are passively activated through fusion of eutectic alloys exposed to the LDW thermal environment. Provide the following information: (a) a more detailed discussion of the thermocouple arrangement, including the number, location, and depth at which they are located in the floor, (b) an assessment of the reliability of the thermocouples and associated support systems in severe accidents, including station blackout events, (c) a more detailed discussion of the eutectic valve arrangement, including their location and expected reliability, (d) an estimate of the

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			time delay associated with actuation of the thermocouple-based valves and the eutectic-based valves, and (e) an assessment of the potential for pre-mature system actuation due to either a time-phased release of core debris from the vessel (a small initial discharge of core debris, followed by the release of the remainder of the core debris), or accident-induced LDW temperatures prior to RPV breach.
19.2-30	Palla R	Provide additional information regarding the 0.001 reliability value for LDW flooding	In PRA Section 21, the failure of BiMAC to function, including deluge activation, is judged to be physically unreasonable on the basis of the high reliability of the active system and the diverse passive system. Clarify whether a quantitative linked fault tree analysis of the reliability of the thermocouple-based squib valves and the eutectic-based valves been performed to confirm the asserted reliability level of <0.001 failure. If it has not been performed, provide alternate numerical-based justification of the reliability level.
19.2-31	Palla R	Describe the process for finalizing the design for LDW flooding	Describe the process for design, testing, and ultimately the selection of the structures, systems, and components (SSCs) for LDW flooding (i.e., squib valves and actuation system, and thermally-actuated eutectic valves), and how this process will assure that the reliability level will be achieved and maintained.
19.2-32	Palla R	Address the impact of BiMAC failure and CCI on RPV pedestal integrity	Provide an assessment of the potential for RPV pedestal failure given failure of BiMAC and continued corium-concrete interation (CCI). Provide plots of concrete ablation in the vertical and horizontal directions as a function of time for both limestone and basaltic concrete. Provide an assessment of whether the structural integrity of the reactor pedestal/RPV would be maintained under these conditions.
19.2-33	Basu S	Provide justification for required failures necessary for DCH	The ROAAM treatment of the direct containment heating (DCH) phenomenon concluded that containment failure from a DCH event is physically unreasonable. This, in large part, is predicated upon the assertion that all 8 DPVs, all 18 SRVs, and two ICs will have to fail to render the depressurization system non-functional (page 19.3-8 of DCD). Provide technical justification and analyses for this assumption regarding number of failures that must occur.

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19.2-34	Palla R	Discuss the impact of residual hydrogen combustion on DCH loads	The model used to quantify DCH loads in Section 21.3.4.3 does not appear to have an explicit term for the contribution of combustion of hydrogen with residual oxygen in the drywell atmosphere. Provide a discussion of the basis for this omission.
19.2-35	Basu S	Provide addition design data for reactor and containment system	Provide the following design data: (a) flow area, elevation and form loss coefficient for the junction between the separators and RPV downcomer, (b) flow area for the junction between RPV steam dome and downcomer, (c) clarification whether the entire annular space between the shield wall and the RPV is filled with insulation material, and the thickness and thermal conductivity of the materials, and (d) representative thickness, surface area (one side) and material for the structures in the lower drywell, e.g., CRD service machine and platform.
19.2-36	Basu S	Provide pressure drop and loss coefficient data	Provide pressure drops and form loss coefficients along the reactor core, specifically: (a) from 3.963 m (bottom of the core plate) to 4.405 m (bottom of active fuel). (b) from 4.405 m (bottom of active fuel) to 5.4211 m, (c) from 5.4211 m to 6.4372 m, (d) from 6.4372 m to 7.453 m, and (e) from 7.453 m (top of Active fuel) to 7.896 m (top of fuel assembly). Note that all elevations are relative to the bottom (inner) of RPV lower head.

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19.2-37	Palla R	Follow up RAI to 19.2-2 regarding the accident management program	GE's 12/29/2005 response to RAI 19.2-2 [originally 19.2.4-1] indicates that the DCD will include a combined license (COL) applicant commitment that: "The COL applicant referencing the ESBWR certified design will develop and implement severe accident management guidance, along with the required procedures and training, using the framework provided in DCD Chapter 18, Appendix A." However, the referenced "framework" is simply a general discussion regarding the ESBWR version of the Emergency Procedures and Severe Accident Guidelines. It does not address training (as implied in the COL Applicant commitment) and fails to address other important aspects of a licensee severe accident management program. Industry guidance regarding the severe accident management closure process for operating reactors and key severe accident management elements are provided in Section 5 of NEI 91-04, Revision 1, "Severe Accident Issue Closure Guidelines." Additional guidance to BWR licensees is contained in the "BWR Owners Group "Accident Management Guidelines Overview Document." Although developed for operating reactors, this guidance can also be applied to advanced reactors. The discussion and commitment regarding the accident management program for ESBWR should include a broader description of the severe accident management program and its elements, and/or appropriate references to these guidance documents and how they will be utilized by a COL applicant.
19.2-38	Palla R	Address alternate containment bypass scenarios	Discuss whether the reactor water cleanup (RWCU) break outside containment described in PRA Section 9.1 bounds a temperature-induced IC tube failure or a water hammer induced failure of the IC tubes in terms of fission product releases to the environment. Provide a brief assessment of these latter scenarios, including: (a) the probability of containment bypass sequence via an IC tube failure, and (b) the consequences of such a failure compared to the RWCU sequence analyzed in the PRA.

cc:

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