July 18, 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. 43 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 the containment fragility evaluation for the ESBWR as described primarily in Sections 19.2 and 6.2 of the design control document and Sections 8, 15, and 21 of the probabilistic risk assessment. These questions were sent to you via electronic mail on June 4, 2006, and were discussed with your staff during a telecon on June 29, 2006. You agreed to respond to this RAI on the following schedule:

August 11, 2006: 19.2-41, 44 thru 46, 49, 50, 57, 58, 63, and 65; 6.2-95 and 97.
August 31, 2006: 19.2-51, 56, 59 thru 62, and 64.
October 27, 2006: 19.2-39, 40, 42, 43, 47, 48, 52 thru 55, and 66 thru 68; 6.2-96.

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. ML061980474

OFFICE	NESB/PM	NESB/BC(A)
NAME	LRossbach	ACubbage
DATE	07/18/2006	07/18/2006

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REQUEST FOR ADDITIONAL INFORMATION (RAI)
ESBWR DESIGN CONTROL DOCUMENT (DCD), SECTION 19.3, SEVERE ACCIDENT PERFORMANCE

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-39	Bagchi G / Cruz Perez Z	Provide deterministic containment performance assessment for meeting the requirements of 10 CFR 50.44(c)(5) and SECY-93-087. (DCD 19.2.4-1)	In DCD Tier 2, Section 19.2.4, General Electric (GE) provides a containment performance assessment for the ultimate pressure capability. This assessment was described in the context of the containment pressure fragility estimates. However, it is the staff's expectation that deterministic containment performance assessment addressing the criteria in SECY 93-087 and 10 CFR 50.44(c)(5) be located in this section and the structural calculations and assumptions need to be presented in Chapter 19 or in Section 3.8. All relevant structural assessments of the critical elements necessary to maintain containment performance and integrity, such as reinforced concrete containment structure, drywell head and its connections, critical bellows and their connections, large diameter piping connections, instrumentation or power supply penetrations should be described and discussed in Chapter 19. Provide the following information for the deterministic containment performance assessment in this section: a) A discussion of the deterministic containment performance assessment of the ultimate pressure capability of all relevant critical elements of containment integrity and performance. b) In order to ensure that the as-built plant implements the containment performance as reviewed by the staff for the design certification, it is necessary to provide essential details and drawings of critical sections of all critical components and connections in the table of Inspection, Test, Analyses and Acceptance Criteria (ITAAC) with clear statements related to as-procured engineering specifications, certified as-built engineering reports, test data and results, walkdown and measurements of dimensions, as appropriate.

RAI Number	Reviewer	RAI Summary	RAI Description
			c) A discussion of how 10 CFR 50.44(c)(5) is met, and, if the issue is addressed in other sections of the DCD Tier 2, provide a direct reference. d) SECY-93-087 requires satisfaction of Service Level C limits, including considerations of structural instability, for the more likely severe accident challenges for approximately 24 hours following the onset of core damage under the most likely severe accident challenges, and, following this period, the containment should continue to provide a barrier against the uncontrolled release of fission products. Provide: 1) a discussion of how the SECY-93-087 requirements are addressed in the GE deterministic containment performance analysis, include any transient condition in which the containment could be subjected to negative external pressure caused by condensation of internal hot gases and, 2) the estimate of the Service Level C pressure capability of the ESBWR containment and associated failure modes for the challenges discussed in response to question (1) above.
19.2-40	Bagchi G / Cruz Perez Z	Provide information to ensure adequate anchorage of the drywell head to the top slab. (DCD 19.2.4-2)	In DCD Tier 2, 6.2.5.4 and 19.2.4, respectively, GE provides a deterministic analysis and a fragility analysis for the containment performance under internal pressurization. However, neither information nor discussion of adequate anchorage of the drywell head into the top concrete slab to ensure the anchorage capacity exceeds the load capacity of the drywell head is provided in these sections. The design pressure for the ESBWR containment is 0.31 MPa (45 psi); the stated Service Level C pressure capability for the drywell head is 1.182 MPa (171 psi), which is about 4 times the design pressure. Provide the following information: a) In determining the Service Level C pressure capability for the drywell

RAI Number	Reviewer	RAI Summary	RAI Description
			head, how was the primary axial load path through the bolted flange closure (DCD Figure 3G.1-51, Detail B), to the anchored support cylinder (DCD Figure 3G.1-51, Detail C), and into the concrete evaluated? b) Include in the DCD details of the calculation which demonstrates that the Service Level C pressure capability for the bolted flange closure, anchored support cylinder, and supporting concrete exceeds 1.182 MPa (171 psi), including: (1) a description of the load transfer from the drywell head, through the bolted closure, to the overall concrete upper slab; (2) the location and magnitude of the maximum radial shear load due to internal pressure; (3) the location and magnitude of the maximum shear stress in the concrete; (4) a discussion of potential leakage through the bolted flange closure at 1.182 MPa (171 psi) internal pressure; and (5) a discussion of potential bolt failure due to combined axial tension and transverse shear loading.
19.2-41	Bagchi G / Cruz Perez Z	Provide adequate documentation for the fragility analysis for containment ultimate strength in DCD Tier 2, 19.2.4 (DCD 19.2.4-3)	In DCD Tier 2, 19.2.4, GE only provides a reference to the GE Probabilistic Risk Assessment (PRA) report. The detailed fragility analysis for containment ultimate strength is contained in the GE PRA report, Revision 1, Appendix B.8. It is unclear how the 10 CFR Part 50.44(c)(5) requirement is addressed. It is also unclear how the SECY 93-087 requirement, which requires satisfaction of Service Level C limits, including considerations of structural instability, for the more likely severe accident challenges for approximately 24 hours following the onset of core damage under most likely severe accident challenges, and, following this period the containment should continue to provide a barrier against the uncontrolled release of fission products, is satisfied by the fragility analysis. Provide the following information in ESBWR DCD Tier 2, Section 19.2.4: a) a summary of the GE PRA report, Revision 1, Appendix B.8, including all pertinent results;

RAI Number	Reviewer	RAI Summary	RAI Description
			b) a discussion of how the 10 CFR Part 50.44(c)(5) requirement and the SECY 93-087 requirement are satisfied; c) available test data of over-pressurization of containment structures similar to the ESBWR design (with more geometric discontinuities than typical containments in the current fleet of reactors) at both ambient and severe temperature environments.
19.2-42	Bagchi G / Cruz Perez Z	Indicate what parts or aspects of the containment performance attributes, such as, critical sections, anchorage details, editions of the industry codes, etc., will be described as Tier 2* in the DCD.	What provision has GE made in the DCD to ensure that the containment structure geometry, critical dimensions and details, and materials of construction will not be subject to change without prior review and approval by the staff?
19.2-43	Bagchi G / Cruz Perez Z	Provide adequate documentation of seismic HCLPF capacity results and the ultimate containment pressure capability results in ITAAC. (DCD 19.2.2.4-1)	In DCD Tier 2, Section 19.2.2.4, GE provides a brief summary of the seismic fragility evaluation using the Zion method in NUREG/CR-2300. However, the details of the fragility results are presented in Section 15.0 of the PRA. These fragility results should be included in this DCD section. Further, the seismic fragility results and the ultimate containment pressure capability results should be adequately included in ITAAC tables of DCD Tier 1. Provide the following information: a) Include the seismic HCLPF values from Tables 15-1 through 15-13 of the ESBWR PRA in DCD Tier 2, Section 19.2.2.4 and make appropriate entries into DCD Tier 1, ITAAC tables.

RAI Number	Reviewer	RAI Summary	RAI Description
			b) Also make appropriate entries into DCD Tier 1, ITAAC tables that address the ultimate containment pressure capability results from both the deterministic and fragility containment performance assessments.
6.2-95	Bagchi G / Cruz Perez Z	Provide additional information for concrete containment design details to enable evaluation for beyond-design basis loads. (DCD 6.2.5.4-1)	In DCD Tier 2, 6.2.5.4, for the concrete containment, the statement is made: "The analysis results show that when the internal pressure reaches as high as 1.468 MPa, the maximum liner strain is only 0.165% tension, which is well within the 0.3% limit for Factored Load Category specified in ASME Table CC-3720-1." Provide the following additional information in the DCD: a) Comparison of the concrete and rebar stresses to their factored load allowables. b) Of the liner, concrete, and rebar, which limits the Level C pressure capability of the concrete containment (ignoring the steel penetrations)? c) Compare the rebar strains to the liner strains at the 1.468 MPa load level. Explain any significant differences between the two. d) The spacing between the anchors for the liner plate, including drawings to show how the liner is anchored into the concrete. e) Locations (typical) of the heat affected zone at the liner weld seams and the proximity to liner anchors.

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6.2-96	Bagchi G / Cruz Perez Z	Provide an adequate description of the containment assessment to address 10 CFR50.44(c)(5) requirement. (DCD 6.2.5.4-2)	In ESBWR DCD Tier 2, rev 01, Section 6.2.5.4, which addresses 10 CFR 50.44(c)(5) - Hydrogen Rule, GE states that the pressure capability of the containment's limiting component is higher than the pressure (GE does not quantify this pressure) that results from assuming 100 percent fuel clad-coolant reaction. Provide the following information: a) the estimate of the internal pressure loading on the ESBWR containment structure, assuming an "accident that releases hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by hydrogen burning." b) where the estimate is in response to question (a), above, documented in DCD Tier 2. c) what the estimated temperature of the containment structure is at the time of this event discussed in question (a). d) a justification for the use of ambient temperature material properties, in the case that the estimated temperature is higher than ambient temperature, or a revision to the Service Level C pressure capabilities for each containment structural component, consistent with its estimated structural temperature. e) details of the analysis described in the last paragraph of ESBWR DCD Tier 2, rev 01, Section 6.2.5.4.2, for the concrete containment, "A nonlinear finite element analysis of the containment concrete structure including liner plates is performed for over-pressurization." If the analysis is contained in another section of the DCD, provide the reference. f) the estimate of the Level C pressure capability of the drywell head if evaluation of instability is NOT included? Provide details of the calculation. g) the estimate of the Level C pressure capability of the drywell head if the

RAI Number	Reviewer	RAI Summary	RAI Description
			method of Code Case N-284-1 (linear bifurcation buckling prediction, capacity reduction factor for imperfections, capacity reduction factor for inelastic response, SF=1.67 for Level C) is used, instead of DCD Tier 2, rev 01, Section 6.2.5.4.2, Eq. (6.2-2). Provide details of the calculation.
6.2-97	Bagchi G / Cruz Perez Z	Provide a description of the assessment for the Level C pressure capability for the other steel penetrations of the concrete containment (DCD 6.2.5.4-3)	In DCD Tier 2, 6.2.5.4, for other steel penetrations, the statement is made: "The Level C pressure capabilities of the steel components of major penetrations are summarized in Table 6.2-46. The governing pressure is 1.182 MPa, which is controlled by the buckling strength of the drywell head." Include in the DCD a description of the calculations performed to predict the Level C pressure capability for the other steel penetrations.
19.2-44	Bagchi G / Cruz Perez Z	Provide additional information for RCCV nonlinear analysis (PRA 8.1-1)	In PRA Revision 1, Appendix B.8.1, GE provides the reinforced concrete containment vessel (RCCV) nonlinear analysis using an ANSYS axisymmetric reinforced concrete model. The analysis result from the ANSYS model was used to determine the containment ultimate pressure strength at ambient temperature. Since ANSYS uses the smeared material model for reinforced concrete, certain subjective inputs are required such as tension stiffening and shear retention when concrete cracks, material properties and failure criteria. Discuss the ANSYS model, including: a) the GE selection of the parameters for tension stiffening and shear retention in the model and the bases for the selection; b) the adequacy of the mesh refinement to capture local stress/strain concentrations in regions where geometry changes sharply, such as the corners between top slab/upper dry well(UDW) wall, wet well (WW) wall/suppression pool (SP) floor, SP floor/pedestal, pedestal/basemat;

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			c) the validation of the ANSYS reinforced concrete material model against other known commercial codes, such as ANACAP or ABAQUS, etc., on similar structures and loading, and their analysis comparisons; d) a clarification of the last statement in Appendix B.8.1.3 “The strength of the non-axisymmetric top slab region is evaluated by extrapolation of the elastic analysis results using a 3D finite element model,” since the RCCV analysis GE used is based on a nonlinear ANSYS model; e) input material properties (including stress-strain relations up to failures) applied in the ANSYS model for concrete, rebars and liners. Explain how the strain hardening behavior of mild steel used for rebars is modeled in ANSYS; f) a description of how the liner is connected to concrete elements in the ANSYS model; g) how the non-axisymmetric Gravity-Driven Cooling System (GDCS) pool structures are considered in the ANSYS axisymmetric model/analysis. Was the weight (structure and water) and an approximation of its stiffness used in the ANSYS model? If yes, explain in detail. If not, provide a detailed technical basis for exclusion. h) a detailed explanation regarding the importance of modeling the soil below the foundation mat. The extent of the foundation in the ANSYS model is only a piece of the much larger foundation mat supporting the containment, reactor building, and fuel building. If coupling to the soil is important for this analysis, justify why it is not necessary to include the entire foundation with representation of the other stiffness characteristics of the building. i) a detailed explanation regarding the statement in Appendix B.8.1.2 "The [ANSYS] program utilizes a stepwise linear iteration technique." Are both material and geometric non-linearity effects considered in the ANSYS

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			analysis? What numerical technique is used to establish convergence (e.g., modified Newton-Raphson) at each load step? What is the convergence criterion applied to ensure satisfaction of the nonlinear equilibrium equations at each load step? Describe the load step/iteration strategy.
19.2-45	Bagchi G / Cruz Perez Z	Provide additional information for RCCV nonlinear analysis in Table 8.1-1 (PRA 8.1-2)	In PRA Revision 1, Appendix B.8.1, GE provides the result of a nonlinear ANSYS analysis for RCCV under internal pressurization and dead load. Four load cases were presented, including the design pressure, integrity test pressure, and two severe accident pressures. Provide the following information: a) In Appendix B.8, GE stated "The analysis results show that the liner strains are much smaller than the ASME code allowable for factory load category when the internal pressure is as high as 1.468 MPa." (213 psi). Provide the numerical ASME allowable liner strain referred to here. b) It appears that for load cases SA-1 and SA-2, GE defines the allowable using the ultimate failure strength (F_u for steels and f'_c for concrete). Explain the source for the "code allowable limits", including applicable ASME Service Level, the Code section, and the Code acceptance criteria for rebar, liner plate and concrete (factor times yield stress for steel? factor times f'_c for concrete?). c) Explain why in Table B.8-1 of the PRA report, Revision 1, the max. rebar stresses under the 2nd column heading do not match the max. rebar stresses under the component rebar stresses heading, and identify the components and locations where the max. rebar stresses under the 2nd column heading are taken from. d) Provide the max. rebar strains (including locations) at each pressure level for all components in Table B.8-1, and provide a discussion of comparisons

RAI Number	Reviewer	RAI Summary	RAI Description
			of max. rebar strains with the max. liner strains listed in Table 8.1-1. e) Explain the response changes from design pressure (PD) to Structural Integrity Test 1 pressure (IT), considering IT =1.15xPD; ratios of IT/PD responses vary from 0.63 to 1.67. f) What is the radius at the location of the reported “Max. Radial Defl. Wetwell”, and what are the calculated strains at this location (i.e., radial deflection divided by radius)? Compare to the rebar strains.
19.2-46	Bagchi G / Cruz Perez Z	Provide a basis for extrapolation of the ANSYS analysis results for estimating the ultimate containment pressure capacity at ambient temperature (PRA 8.1.2.1-1)	In PRA, Appendix B.8.2.1, GE describes the estimate of the ultimate containment pressure capacity at ambient temperature by extrapolating the ANSYS analysis result to meet a set of failure criteria: rebar at both faces of a cross section reaches yield or concrete fails by shear. Provide the following information: a) A detailed description of the extrapolation method or analysis and associated data used to arrive at the ultimate component pressure capacities in Table B.8-2 of the PRA report. b) Detailed data of max rebar stresses (and strains, if available), and strengths of concrete, and liner strains for all components comprising the containment pressure boundary when one component in Table B.8-2 reaches its pressure limit (a table form similar to Table B.8-1 is desirable). c) Since the concrete failure is characterized as shear failure, describe the shear failure criteria applied. d) For wetwell and upper drywell, the failure modes are rebar yielding at the DF joint, describe the max strain level in the liner near the DF joint for these failure modes.

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19.2-47	Bagchi G / Cruz Perez Z	Provide a justification for the estimate of the ultimate containment pressure capacity at 500°F based on taking a 10% reduction in the containment pressure capacity at ambient temperature (PRA 8.1.2.1-2)	In PRA Appendix B.8.2.1, GE provides an estimate of containment pressure capacity at 500 °F temperature. This estimate was based on an ANL study, which concluded that the failure pressure for RCCV at temperatures up to 700 °F was reduced by about 11% from that predicted at ambient temperature, for pressure load alone. Provide: a) a discussion of the applicability of the ANL study to the ESBWR containment. b) a discussion of an estimate of the containment pressure capacity at 500 °F, if the ANSYS model had been used (Repeat the ANSYS analysis with degraded material properties at 500 °F), and a comparison of the ANSYS analysis result for 500°F with the pressure capacity reduction estimate of 10% based on the ANL study. c) a justification for using 500°F, based on the NUREG-1540 analysis of Oyster Creek drywell. This analysis considered an accident scenario where the uniform temperature was 800 °F. Is 500 °F just "typical", or is it the true maximum accident temperature that needs to be considered? Does 500 °F represent a creditable upper bound to the temperature challenge? d) a discussion of any available test data of containment pressure capacity at high temperatures for containments similar to ESBWR.
19.2-48	Bagchi G / Cruz Perez Z	Provide a basis for the ultimate pressure strength estimates of the drywell head (PRA 8.1.2.1.2-1)	In PRA Appendix B.8.2.1.2, GE presents the results of its analysis for estimating the ultimate pressure capacity for the drywell head at 500 °F. Failure of the drywell head is either by buckling (elastic or inelastic) in the knuckle (toroidal) region or rupture due to tensile strains approaching the material ultimate strain limit. GE's analysis relies on the use of two (2) approximate equations. GE claims that the Shield and Drucker equation (B.8-1) addresses plastic yielding, and the Galletly equation (B.8-3) addresses buckling. Please address the following:

RAI Number	Reviewer	RAI Summary	RAI Description
			(a) The staff noted that the Shield and Drucker equation (B.8-1) and the Galletly equation (B.8-3) give essentially identical results. Using the geometric parameters from DCD Figure 3G.1-51, equation (B.8-1) predicts 0.005156 Sy and equation (B.8-3) predicts 0.00503 Sy. The staff also noted that both equations include the yield strength, but not the elastic or tangent modulus. It is unclear to the staff that these equations consider 2 different and distinct modes of failure. GE is requested to submit the 2 referenced papers for staff review, and to provide additional documentation in the DCD that supports its claims. (b) GE has compared the Galletly equation (B.8-3), taken from Reference B.8-3, to "all known test results (43 in total)" taken from Reference B.8-2. Reference B.8-2 is dated June 1961. This reference also contains the Shield and Drucker equation (B.8-1). GE is requested to submit the test data used, including geometry and materials of the test specimens, and to confirm that there is no new test data available on failure of torispherical heads since this compilation in 1961. (c) The first step in assessing the applicability of the test results to the ESBWR drywell head is to compare the key geometric ratios tested and the materials tested to the ESBWR drywell head parameters, to ensure inclusion in the test database. If included, then the factor of conservatism should be developed using only the subset of test data that applies to the ESBWR drywell head. If excluded, then there is no basis to develop a factor of conservatism based on this test data. The staff noted that in PRA Figure B.8-2, it appears that the highest ratio of predicted pressure to yield strength for any of the test specimens is about 0.0026. For the ESBWR drywell head, this ratio is 0.00503. GE is requested to provide its technical justification why this test data is applicable to the ESBWR drywell head. (d) Explain how the Reference B.8-2 test data was used to develop and/or correlate with the Shield and Drucker equation (B.8-1), which is presented in

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			the same reference. (e) In the absence of buckling in the elastic stress range, the actual failure mode will likely be either gross yielding at the apex of the head or inelastic buckling in the knuckle region, depending on the specific material plastic behavior and the geometric parameters of the torispherical head. As the material yields at loads above the elastic limit, the stiffness is reduced due to a decrease in the tangent modulus. For mild steels, exhibiting a pronounced yield point and plateau up to about 3% strain, a buckling instability in the knuckle region, in the presence of a compressive stress field, would be expected. However, there may be residual postbuckling strength because the stress field in the head is predominantly tensile. GE has relied on simple semi-empirical formulas to predict the ultimate pressure capacity of the limiting structural element of the containment. There is a long history of study of failure of torispherical heads under internal pressure. Many options exist for conducting computer-based numerical analysis, including consideration of inelastic behavior, buckling failure, and even post-buckling behavior. GE is requested to discuss the correlation between the semi-empirical equations used and available numerical analysis methods (e.g., BOSOR5) in estimating the ultimate pressure capacity of the ESBWR drywell head. (f) At the end of PRA Section B.8.2.1.2, in the comparison of failure pressures between the plastic yielding failure and buckling, the pressure for the buckling failure mode was estimated based on a best estimate value (factor of 2.27 applied to Equation B.8-3), while the plastic yielding failure pressure was computed directly from Equation (B.8-1). Discuss whether Equation (B.8-1) was intended for design purposes, and represents a lower-bound prediction, or if it is considered to be a best-estimate prediction. If it is intended to be a lower-bound prediction, explain the technical basis for the comparison of the lower bound yield pressure with the best estimate (median) buckling pressure.

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19.2-49	Bagchi G / Cruz Perez Z	Provide a basis for determining the ultimate pressure capacity for PCCS heat exchangers (PRA 8.1.2.1.3-1)	In PRA Appendix B.8.2.1.3, GE stated that analytical calculations are carried out to obtain maximum pressure capacity for Passive Containment Cooling System (PCCS) heat exchangers in accordance with Level D limit of ASME Section III, Division 1, Subsection NC, Class 2 Components. Provide a detailed description of these calculations (and associated data) for estimating the ultimate pressure capacity for PCCS heat exchangers at both ambient and 500°F temperatures.
19.2-50	Bagchi G / Cruz Perez Z	Provide a justification for large strain in liners (PRA 8.1.2.2.1-1)	In PRA Appendix B.8.2.2.1, GE described an analysis which scaled the maximum strains in liners from the ANSYS model by a concentration factor of 33, resulting in 3.96% strain at the penetrations, which is much higher than Service Level C limits of ASME Section III, Division 2. GE further stated that this strain level is still far lower than the ultimate fracture strain of 21 percent for the liner material. Provide: a) a description of the characteristics of the liner material used for the primary containment boundary, including stress-strain relations; b) justification for using the 21% ultimate fracture strain for the liner material. It should be noted that effective overall liner strain has been limited to 3 percent based on tests performed at Sandia National Labs.

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19.2-51	Bagchi G / Cruz Perez Z	Discuss DCH effect on liner thermal induced buckling (PRA 8.1.2.2.1-2)	In PRA Appendix B.8.2.2.1, GE stated that the thermal induced loading would not pose a challenge to liner buckling since the increase in internal pressure could be much faster than the heat conduction through the containment wall for the typical temperature load (GE stated that the representative severe accident temperature for the ESBWR containment is 500°F). However, a postulated direct containment heating (DCH) event could induce much higher temperature than 500°F within a short period of time due to particle entrainment. In PRA, Section 21.3.4.5, GE stated that strains in liners due to DCH induced thermal stresses are about 8 percent (which could be considered high for carbon steels). Provide: a) a description of the characteristics of a DCH induced temperature load in liners above 500 °F; b) a discussion of the possible DCH induced thermal load build-up before the build-up of internal pressure sufficient to prevent the thermal induced buckling in liners; c) a discussion of liner materials to sustain high strains, especially near penetrations; d) a discussion of thermal induced local liner tearing, including any test data if available.

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19.2-52	Bagchi G / Cruz Perez Z	Provide a justification for larger than springback leakage gaps found for drywell head seal, and drywell and wetwell equipment hatches (PRA 8.1.2.2.2-1)	In PRA, Revision 1, Appendix B.8.2.2.2, GE used a Sandia-proposed springback for leakage prevention at seals. According to PRA, Revision 0, Section 8.2.1.3, the allowable technical specification leakage is 0.5 percent of containment air volume per day at rated pressure. GE further stated in the same section that based on MAAP test runs, the effective flow area required to allow 0.5% of the containment air volume to leak per day at design pressure is approximately 3.4E-6 m^2 (3.4 mm^2). However, in PRA, Revision 1, Appendix B.8.2.2.2, GE estimated that the seal gaps for the drywell head and both drywell and wetwell hatches exceed the springback limit and possibly have a flow area greater than the allowable technical specification leakage area. Provide justification for the statement that the resulting maximum gap of 0.077 mm is deemed small.
19.2-53	Bagchi G / Cruz Perez Z	Provide an explanation for inconsistent statement regarding leakage potential. (PRA 8.1.2.2-1)	In PRA, Revision 0, Section 8.1, GE stated that "However, for source term calculations, leakage in terms of leak areas is conservatively estimated for pressures below the capability pressure." However, Section 8.1.2.2 "Leakage Potential" seems to conclude that the leakage potential for the liner and penetrations is negligible. Explain the apparent discrepancy.
19.2-54	Bagchi G / Cruz Perez Z	Provide a justification for using Equation (8.1-10) for median failure pressure estimate of drywell head (PRA 8.1.3-1)	In PRA, Appendix B.8.3, GE treated the failure pressure due to plastic failure mode calculated using Equation (B.8-10) as a median value. Provide justification for this judgement, including a description of the development of this equation, assumptions used, stress-strain relation assumed, and magnitude of failure strain, as well as test data available to support the median failure pressure capacity estimate.

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-55	Bagchi G / Cruz Perez Z	Clarify that the containment fragility curve in Figure 8.1-5 and Table 8.1-3 was developed for 500°F using a lognormal distribution for the pressure capacity (PRA 8.1.3-2)	In PRA, Appendix B.8.3, GE described the development of a containment pressure capacity fragility curve using a lognormal distribution. Confirm that this fragility is developed for 500°F and it also bounds the ambient temperature. Also provide a detailed description of the ultimate pressure capacity estimates for 1000°F as shown in Table B.8-2, including material models at 1000°F for both concrete and steels.
19.2-56	Bagchi G / Cruz Perez Z	Provide information on the impact of the failure of vent clearing on the drywell temperature increase (PRA 21.3-1)	In PRA, Section 21.3, GE described that the DCH events to induce damage of the containment are physically unreasonable, based on: a) the initiating events for DCH is 2.8×10^{-9} per year, b) the DCH generated superheated gases (>1000 °K) failing the inlets to SRV, DPV, and IC lines, leading to natural depressurization of the RPV, and c) vent clearing from UDW into a huge heat sink of the WW in less than 1 second. Provide the following information: a) Provide a discussion of a scenario that, given the locations of the inlets to SRV, DPV, and IC lines in UDW, it is reasonable to assume that the containment liner is also exposed to a 1000°K temperature during the same time frame, which is required to fail the inlets to SRV, DPV, and IC lines, and if so, the liner integrity could be breached, especially near penetrations. b) Although GE stated that vent clearing was modeled with a high degree of fidelity, there is still a possibility, albeit small, that the vent may be cleared beyond the time frame required to redirect the superheated gases from UDW to WW suppression pool. What is the impact of the vent clearing failure or delay on the containment integrity?

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-57	Bagchi G / Cruz Perez Z	Provide information on the high temperature effect on concrete (PRA 21.3-2)	In PRA, Section 21.3, GE described that the DCH generated superheated gas could induce temperatures in excess of 1000°K in the upper drywell space. It is not clear how the concrete performs under such high temperatures. Provide: a) a discussion of the duration of concrete exposure to high temperatures, and the depth of thickness of the concrete which will degrade due to exposure to high temperatures. b) information and a discussion of available test data that supports the GE analysis regarding the concrete performance at high temperatures.
19.2-58	Bagchi G / Cruz Perez Z	Provide information on the liner failure due to greater than 1000 °K temperature (PRA 21.3.4.4-1)	In PRA, Section 21.3.4.4, GE described an analysis to address the liner integrity for temperatures greater than 1000°K, using LS-DYNA3D. In the GE model, a piece of liner between a neighboring set of anchors and the presence of concrete behind the liner were considered. GE showed in Figures 21.3.-22 that the resulting maximum effective plastic strains in the liner between anchors at temperatures 1400°K and 1650°K are 1.4 percent and 7.26 percent, respectively. In Section 21.3.4.3, GE stated that the drywell pressure is predicted to be around 6 bar (0.6Mpa). However, it is not obvious that the pressure load is included in the LS-DYNA 3D model. Provide: a) the material models for both liner and concrete at high temperature used in LS-DYNA3D model, including stress-strain relation and strain rate effect. b) a discussion of the effect of high temperature degradation on the ability of the liner and concrete to resist the pressure load.

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-59	Bagchi G / Cruz Perez Z	Provide justification for the failure probability of 1E-3 given in Figure 8.3.3-4 (PRA 21.3.4.4-2)	In PRA, Revision 0, Section 21.3.4.4, GE stated that "...the detailed definition of a complete fragility that includes probability of failure as a function of load is rather superfluous." However, in Figure 8.3.3-4 of PRA Revision 0, the probability of failure of DCH, given RPV failure at HP and IC, steam line, SRVs intact, is presented as 1E-03. Provide justification for arriving at this failure probability, including a description of any analyses which may have been performed.
19.2-60	Bagchi G / Cruz Perez Z	Provide justification for the statement that liner must be strained to failure (typically ~30% effective plastic strain) (PRA 21.4.4.1-1)	In PRA, Revision 0, Section 21.4.4.1, GE stated that "...to lose containment integrity, either the liner must be strained to failure (typically ~30 percent effective plastic strain)..." Provide justification for this statement, including the basis and possible test data to support the 30% failure effective plastic strain for liner materials.

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-61	Bagchi G / Cruz Perez Z	Provide justification for limiting the quantities of sub-cooled water in the LDW cavity. (PRA 21.4.2-1)	In PRA, Revision 1, Section 21.4.2, GE described that the key parameter for limiting ex-vessel steam explosion (EVE) loads is to limit the amount of sub-cooled water entering the lower dry well (LDW) before the melt resulting from the RPV lower head breach reaches to the LDW floor. GE described certain design changes, including preventing the GDCS overflow. However, GE's description of preventing the GDCS from overflowing emphasizes the system aspects, and does not discuss whether other natural phenomena such as earthquakes will induce the GDCS failure, leading to spilling water in the cavity. Provide the following discussions: a) An explanation of whether or not the severe accident is initiated by a large earthquake, and if not, a discussion of postulating a condition under which a severe accident progress combined with an earthquake, and its effect on EVE. b) A discussion of what the impact is of the pressure impulse due to EVE on the structural integrity of the hatch, given the equipment hatch on the pedestal being located at 2 m above the BiMAC cover plate, if the depth of sub-cooled water reaches above the equipment hatch. c) Discuss any severe accident event sequence in which the initiating event is an earthquake greater than the safe shutdown earthquake (SSE) and failures or partial failures of GDCS pools, isolation condenser coolers, or suppression pool downcomers can occur prior to the accident progression to severe accident stage. If such an event sequence was considered, discuss the resulting containment pressure and temperature conditions, and show that the containment ultimate pressure capability is not challenged.

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-62	Bagchi G / Cruz Perez Z	Provide information on the LS-DYNA3D analyses for EVE loads (PRA 21.4.4.4-1)	In PRA, Section 21.4.4.4, GE described the structural response analyses for the pedestal and the BiMAC device subjected to EVE pressure impulses. The K&C model (Karagozian and Case) was used for concrete and rebars included in the model. The pressure impulse loads analyzed range from 200 kPa-s to 600 kPa-s. The impulse loads are characterized as high frequency loads and, therefore, strain rate effect on material properties is expected to be important. Provide: a) a description of how the strain rate effect is considered for both concrete and steel material models (material properties are typically obtained from pseudo static tests (low cyclic)); b) a detailed description of the K&C model; c) a description of how the reinforced concrete pedestal is modeled in the LS-DYNA3D model; d) a description of how the failure of the pedestal impacts the RPV supports, which are structurally supported by the pedestal.
19.2-63	Bagchi G / Cruz Perez Z	Provide a description of the calculation for the percentage contributions to CDF for the three depths of subcooled water pools in PRA Section 21.4.5. (PRA 21.4.5-1)	In PRA, Revision 0, Section 21.4.5, GE described the prediction of failure probability for EVE-induced failures of pedestal and liner, as well as the BiMAC device. GE did not provide a detailed description of how these failure probabilities were calculated. Provide: a) a description of the calculations performed to obtain the failure probability, based on the LS-DYNA3D analyses, for EVE-induced pedestal failure, liner failure, and BiMAC device failure, and RPV support failure; b) a description of the structural performance of pedestal and RPV support, given failure of BiMAC and continued core-concrete interactions.

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-64	Bagchi G / Cruz Perez Z	Provide a justification for the statement that the reactor pedestal and BiMAC structural designs are capable to resist explosion load impulses of magnitudes in the 100's of kPa-s. (PRA 21.4.6-1)	In PRA, Revision 1, Section 21.4.5, GE made a statement that the reactor pedestal and BiMAC structural designs are capable of resisting explosion load impulses of magnitudes in the 100's of kPa-s. Provide the technical justification, including failure criteria used, for this statement.
19.2-65	Bagchi G / Cruz Perez Z	Provide a detailed calculation for the failure probability of 1E-03 for pedestal failure, given LDW water level between 0.7 m and 1.5 m (PRA 8.3-1)	In PRA, Revision 0, Section 8.3.3 [and PRA Revision 1 Appendix A.8.2.4?], GE described the containment phenomenology event trees. The sequence EVE-DAM EVE relates to the failure of the pedestal for water levels between 0.7 m and 1.5 m; the probability of pedestal failure is stated as 1E-3 for physical unreasonable events. Provide the detailed calculation that was used to arrive at this probability value.

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-66	Bagchi G / Cruz Perez Z	Provide justification for applying median values of material strengths in the Barda et al. equation for the ultimate shear strength of reinforced concreted shear walls. (PRA 15.1.3.1.1-1)	In PRA, Revision 0, Section 15.1.3.1.1, GE described a method for calculating the ultimate shear strength of reinforced shear walls. This method utilizes the Barda Equation, which applies to low rise flat reinforced concrete shear walls with the height/length (h/l) ratio less than two. According to studies (Figure C4.2-1 of ASCE 43-05), which compared the Barda Equation with test data for shear walls with different aspect ratios (h/l), the Barda equation gives results that are consistent with the median of the test data, when code-specified minimum material strengths are used in the equation. However, GE stated that in computing ultimate shear strength with this equation, the median material strengths of the concrete and reinforcing steel are used. This appears to double count for the material strengths, since the Barda Equation has already taken the median effect into consideration. Provide justification for applying median values of material strengths in the Barda Equation for the ultimate shear strength of reinforced concreted shear walls.

RAI Number	Reviewer	RAI Summary	RAI Description
19.2-67	Bagchi G / Cruz Perez Z	Provide a description of the shear failure mode for the containment fragility calculation (PRA 15.1.3.1.1-2)	In PRA, Revision 0, Section 15.1.3.1.1, GE described a method for calculating the ultimate shear strength of reinforced shear walls. GE also described the shear strength calculation for the reactor building as an example. In Table 15-3, GE presented the seismic fragility for containment walls, and the governing failure is described as the lower wall with shear failure mode. GE did not describe the detailed analysis for containment walls, which have cylindrical geometry (Note that the Barda et al. equation does not apply to this geometry). Provide the following information: a) Provide a detailed description of the calculation for the strength factor for the reinforced concrete containment, including assumptions and data applied. b) Provide a description of criteria used for the ultimate strength determination for both shear and flexural modes of failure of the reinforced concrete containment. c) Provide the containment HCLPF value in terms of spectral acceleration, and the fundamental frequency of the reinforced concrete containment structure.
19.2-68	Bagchi G / Cruz Perez Z	Provide justification for the selection of both aleatory and epistemic uncertainty values. (PRA 15.1.3-1)	In PRA, Revision 0, Section 15.1.3, GE used a fragility method for calculating structural HCLPFs, based on scaling the design seismic response with safety factors and associated aleatory and epistemic uncertainty values. The determination of these uncertainty values typically requires substantial subjective inputs as compared to the deterministic engineering approach such as CDFM (Conservative Deterministic Failure Margin). Provide a discussion of the selection and basis for the aleatory and epistemic uncertainty values in Table 15-3 used for the RCCV HCLPF calculation.

cc:

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

Mr. George B. Stramback
Manager, Regulatory Services
GE Nuclear Energy
1989 Little Orchard Street, M/C 747
San Jose, CA 95125

Mr. David Lochbaum, Nuclear Safety Engineer
Union of Concerned Scientists
1707 H Street, NW., Suite 600
Washington, DC 20006-3919

Mr. Paul Gunter
Nuclear Information & Resource Service
1424 16th Street, NW, Suite 404
Washington, DC 20036

Mr. James Riccio
Greenpeace
702 H Street, Suite 300
Washington, DC 20001

Mr. Adrian Heymer
Nuclear Energy Institute
Suite 400
1776 I Street, NW
Washington, DC 20006-3708

Mr. Paul Leventhal
Nuclear Control Institute
1000 Connecticut Avenue, NW
Suite 410
Washington, DC 20036

Mr. Ron Simard
6170 Masters Club Drive
Suwanne, GA 30024

Mr. Brendan Hoffman
Research Associate on Nuclear Energy
and Environmental Program
215 Pennsylvania Avenue, SE
Washington, DC 20003

Mr, Jay M. Gutierrez
Morgan, Lewis & Bockius, LLP
1111 Pennsylvania Avenue, NW
Washington, DC 20004

Mr. Glenn H. Archinoff
AECL Technologies
481 North Frederick Avenue
Suite 405
Gaithersburg, MD. 20877

Mr. Gary Wright, Director
Division of Nuclear Facility Safety
Illinois Emergency Management Agency
1035 Outer Park Drive
Springfield, IL 62704

Mr. Charles Brinkman
Westinghouse Electric Co.
Washington Operations
12300 Twinbrook Pkwy., Suite 330
Rockville, MD 20852

Mr. Ronald P. Vijuk
Manager of Passive Plant Engineering
AP1000 Project
Westinghouse Electric Company
P. O. Box 355
Pittsburgh, PA 15230-0355

Mr. Ed Wallace, General Manager
Projects
PBMR Pty LTD
PO Box 9396
Centurion 0046
Republic of South Africa

Mr. Russell Bell
Nuclear Energy Institute
Suite 400
1776 I Street, NW
Washington, DC 20006-3708

Mr. Jerald S. Holm
Framatome ANP, Inc.
3315 Old Forest Road
P.O. Box 10935
Lynchburg, VA 24506-0935

Mr. Robert E. Sweeney
IBEX ESI
4641 Montgomery Avenue
Suite 350
Bethesda, MD 20814

Mr. Eugene S. Grecheck
Vice President, Nuclear Support Services
Dominion Energy, Inc.
5000 Dominion Blvd.
Glen Allen, VA 23060

Mr. George A. Zinke
Manager, Project Management
Nuclear Business Development
Entergy Nuclear, M-ECH-683
1340 Echelon Parkway
Jackson, MS 39213

E-Mail:
tom.miller@hq.doe.gov or
tom.miller@ nuclear.energy.gov
sfrantz@morganlewis.com
ksutton@morganlewis.com
jgutierrez@morganlewis.com
mwetterhahn@winston.com
whorin@winston.com
gcesare@enercon.com
jerald.holm@framatome-anp.com
eddie.grant@exeloncorp.com
joseph_hegner@dom.com
mark.beaumont@wsms.com
steven.hucik@ge.com
patriciaL.campbell@ge.com
bob.brown@ge.com
david.hinds@ge.com
chris.maslak@ge.com
james1beard@ge.com
louis.quintana@gene.ge.com
wayne.massie@ge.com
kathy.sedney@ge.com
mgiles@entergy.com
george.stramback@gene.ge.com