April 24, 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. 20 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 seismic design as discussed primarily in Section 2.5, Section 3.7, and Appendix 3A, of the ESBWR design control document. These questions were sent to you via electronic mail on March 13, 22, and 25, 2006, and were discussed with your staff during a telecon on March 31, 2006. You agreed to respond to this RAI on the following schedule:

May 19, 2006: 2.5-1 thru 6, 3.7-1 thru 4, 6, 7, 9 thru 15, 17 thru 23, 28, 31, 36, 40 thru 49, 51, 53, and 56;
June 30, 2006: 3.7-5, 8, 25, 26, 29, 34, 52, and 55;
August 18, 2006: 3.7-16, 24, 27, 30, 32, 33, 35, 37, 38, 39, 50, 54, and 57.

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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Docket No. 52-010

Enclosure: As stated

cc: See next page
ACCESSION NO. ML061040533

OFFICE	NESB/PM	NESB/BC
NAME	LRossbach	LDudes
DATE	04/20/2006	04/21/2006

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Distribution for DCD RAI Letter No. 20 dated April 24, 2006

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Requests for Additional Information (RAIs)
ESBWR Design Control Document (DCD) Section 2.5

RAI Number	Reviewer	Question Summary	Full Text
2.5-1	Munson C	Update North Anna ESP SSE spectra.	The North Anna early site permit (ESP) site-specific Safe Shutdown Earthquake (SSE) spectra shown in DCD Tier 2, Figures 2.5-1 and 2.5-2 (DCD Pages 2.5-13 and 2.5-14) is not the final SSE approved by the staff for the North Anna ESP site. The final North Anna SSE for the ESP site incorporated site-specific amplifications (based on the local rock and soil properties) of both the horizontal and vertical ground motions as determined from the North Anna site controlling earthquakes. Please update the North Anna ESP SSE or justify the use of the North Anna ESP that does not include the local site effects.
2.5-2	Munson C	Add RG 1.198 to DCD Section 2.5.	DCD Tier 2, Sections 2.5.1 - 2.5.5 provide a list of the applicable Regulatory Guides that may be used to implement the requirements of 10 CFR 100.23, “Seismic and Geologic Siting Factors.” Regulatory Guide (RG) 1.198, “Procedures and Criteria for Assessing Seismic Soil Liquefaction at Nuclear Power Plant Sites,” issued in November 2003, is not listed in any of DCD Sections 2.5.1 - 2.5.5. Please update DCD Section 2.5 to include RG 1.198.
2.5-3	Munson C	Remove Appendix A to Part 100.	DCD Tier 2, Section 2.5 cites 10 CFR Part 100, Appendix A, “Seismic and Geologic Siting Criteria for Nuclear Power Plants,” as an applicable regulation. Appendix A to Part 100 has been superseded by 10 CFR 100.23, “Geologic and Seismic Siting Criteria,” for stationary power reactor site applications on or after January 10, 1997. Regulatory Guide 1.165, “Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion,” describes the geologic and seismic investigations that are necessary to meet the requirements of 10 CFR 100.23. Please remove Appendix A to Part 100 as an applicable regulation for DCD Tier 2, Section 2.5.

RAI Number	Reviewer	Question Summary	Full Text
2.5-4	Munson C	Correct title of DCD Section 2.5.3.4.	DCD Tier 2, Section 2.5.3.4 is titled “Ages of Host Recent Deformations.” Please correct this title to “Ages of Most Recent Deformations.”
2.5-5	Samaddar S	Clarify minimum shear wave velocity value.	DCD Tier 2, Table 2.0-1 provides an envelope of ESBWR reference plant site design parameters, considerations and/or limits. For subsection 2.5.4, Table 2.0-1 specifies a minimum shear wave velocity of 300 m/s (984 fps). The applicant should clarify if this minimum shear wave is applicable to each soil layer in the soil profile or is a value that is representative of some averaged value for the entire soil column to be used in the site response analysis.
2.5-6	Samaddar S	Clarify extent of no liquefaction restriction.	DCD Tier 2, Table 2.0-1 provides an envelope of ESBWR reference plant site design parameters, considerations and/or limits. For subsection 2.5.4, Table 2.0-1 specifies that the ESBWR design assumes no liquefaction potential resulting from an SSE. The applicant should clarify “no liquefaction potential” stating the area over which this limitation applies - the entire site or under the footprint of safety-related structures. If localized liquefaction is acceptable then identify the effect of localized liquefaction potential under structures on the standardized design or identify the COL applicant action item if a localized liquefaction potential is identified.

ESBWR Design Control Document (DCD) Sections 3.7.1 through 3.7.3

RAI Number	Reviewer	Question Summary	Full Text
3.7-1	Cheng T	Add the phrase "and within applicable stress, strain, and deformation limits." (3.7)	In the second paragraph of DCD Section 3.7 (Page 3.7-1), the applicant stated that seismic Category I structures, systems and components (SSCs) are designed to remain functional. The applicant is requested to modify this sentence to read "seismic Category I structures, systems and components (SSCs) are designed to remain functional and within applicable stress, strain, and deformation limits."
3.7-2	Cheng T	Provide design information for non-seismic (NS) SSCs. (3.7)	In the fifth paragraph in Page 3.7-1 (DCD Section 3.7), the applicant provided the seismic analysis and design criteria for the non-seismic (NS) SSCs. In order to assist the staff to complete its review, the applicant is requested to: (a) (1) identify the NS structures (which are to be designed to the International Building Code (IBC) seismic criteria) that are included in the scope of the ESBWR DCD; (2) explain why they are not classified as C-I or C-II; and (3) identify where the seismic design basis calculations are described in the DCD. (b) (1) identify what NS equipment is seismically qualified (either by test or analysis) to IBC seismic criteria; and (2) describe the technical rationale for such seismic qualification. (c) clarify what is the scope of the COL applicant's responsibility to implement IBC seismic design criteria for NS SSCs?
3.7-3	Cheng T	Request for clarification of the OBE. (3.7)	At the top of page 3.7-2 in DCD Section 3.7, the applicant stated "The Operating Basis Earthquake (OBE) is not an ESBWR design requirement." The applicant is requested to revise this statement to indicate that specification of the OBE is a design requirement, but requires no explicit analysis if it is chosen to be #1/3 of the safe shutdown earthquake (SSE).

3.7-4	Cheng T	Request for large size design structural drawings of RB/FB and CB. (3.7)	In order to facilitate the staff's review of DCD Section 3.7, the applicant is requested to submit clear, large scale, detailed structural drawings (These drawings show the location and description of water tanks, distance between buildings, thickness of floors and walls, elevation and thickness of seismic Category I foundations, etc.) of the ESBWR Seismic Category I structures and foundations, and any other structures and foundations that are within the scope of DCD Section 3.7.
3.7-5	Cheng T	Clarify the definition of the SSE used for the design, and justify the use of generic and North Anna ground motion will lead to acceptable design. (3.7.1)	In DCD Section 3.7.1, the applicant stated that seismic design parameters (including seismic ground motion response spectra) considered for the ESBWR seismic design comprise two site conditions, generic and North Anna early site permit (ESP) sites. It is not clear from the descriptions provided in DCD Section 3.7.1 if the intent of the DCD is to show that (a) the design is appropriate for the North Ana site and any other generic site for which the RG 1.60 response spectrum is the appropriate SSE; or (b) if the design is to be considered appropriate for any site whose design response spectrum falls below the envelope of the RG 1.60 and North Anna design spectrum. The applicant also stated on Page 3.7-1, that the SSE is based upon an evaluation of the maximum seismic potential at a site. The DCD indicates that the results from the two separate ground motion sets are considered in the plant evaluations and development of enveloped responses. If the envelope spectrum were to be specified as the SSE, then a single set of time histories appropriate for this envelope spectrum would be used to generate enveloped responses. The staff requests the applicant clarify the definition of the SSE being used for the plant design, and also justify that the enveloped responses from load cases using multiple time histories (generic and North Anna) in fact leads to a conservative result of responses that would be obtained from a single ground motion time history (envelope of generic and North Anna ESP sites).

3.7-6	Cheng T	Provide, in the DCD, a detailed description of analysis procedures, seismic model development, seismic analysis procedure, use of results in the design. (3.7.1)	In DCD Section 3.7.1, the applicant stated that seismic design parameters considered for the ESBWR comprise two site conditions: generic sites and ESP sites. In DCD Section 3.7.1.1 and Appendix 3A, the applicant provided a description of two sets of site conditions that are considered in the ESBWR design. In order to assist the staff in performing its review of seismic analyses and design of the reactor building (RB)/fuel building (FB) and control building (CB), the applicant should include a detailed description of the analysis procedures to show (1) how these two sets of seismic design parameters will be applied to perform seismic analyses; (2) how the structural models are combined as a seismic system model; (3) how the seismic analyses (including the soil-structure interaction (SSI) analyses) are performed; and (4) how the analysis results (seismic member forces, sliding forces, overturning moment and floor response spectra) from these two sets of design parameters are to be combined and used for the design. The applicant is requested to provide the above information in the DCD.
3.7-7	Cheng T	Provide a detailed description of North Anna ESP site conditions (e.g., geotechnical properties, etc.) in the DCD. (3.7.1)	In DCD Section 3.7.1, the applicant stated that because the Clinton and Grand Gulf site conditions are bounded by the envelope of the generic site and North Anna site conditions, the North Anna ESP site is selected for further consideration in conjunction with generic sites for site enveloping seismic design of the ESBWR standard plant. In addition to the ground motion response spectra, and time histories provided in the DCD, the applicant is requested to include in the DCD a detailed description of the North Anna site conditions (e.g., geotechnical properties), including response spectra at various depths through the profile consistent with design spectra.
3.7-8	Cheng T	Justify why the PGAs and ground response spectra are the same at two (2) different foundation elevations. (3.7.1)	In DCD Section 3.7.1.1 and DCD Section 3.7.1.1.1, respectively, the applicant stated that for generic site (1) the peak ground acceleration (PGA) of the SSE is 0.3g at the foundation level, and (2) the design response spectra are specified at the foundation level in the free field. It is the staff's understanding that the foundation level of the reactor/fuel building is located at 20m (66.0 ft) below grade and the foundation level of the control building is located at 15.05 m (49 ft) below grade. The applicant is requested to provide its technical basis to justify why the PGAs and ground response spectra are the same at these two (2) different foundation elevations.

3.7-9	Cheng T	Provide the strong motion durations of the time history, and comparison of the fits to the RG 1.60 response spectra. (3.7.1)	**In DCD Section 3.7.1.1.2, the applicant indicated that the total duration of the artificial time histories used to envelop the RG 1.60 spectra is 22 seconds. In addition, the applicant indicated that the response spectra computed from the synthetic time histories are computed at the additional frequencies of 40, 50 and 100 Hz. This sparse frequency set above 33 Hz is not considered adequate to judge the appropriateness of the time history fit between 33 and 100 Hz.** To assist the staff in its review, the applicant is requested to provide the following additional information: (a) the corresponding strong motion durations for the synthetic time history records. (b) a detailed comparison of the fits to the RG 1.60 spectra, up to 100 Hz.
3.7-10	Cheng T	**Include, in the DCD, details of implementing the SRP process (Appendix A to SRP 3.7.1) to develop the PSD for the vertical motion.** (3.7.1)	**In DCD Section 3.7.1.1.2, the applicant indicated that a target power spectra density (PSD) appropriate for the vertical RG 1.60 response spectrum was developed using the same process (Appendix A to SRP Section 3.7.2) as is used to develop the horizontal target. The staff requests the applicant to include the details of its implementation of this process in the DCD, to facilitate staff evaluation.**
3.7-11	Cheng T	Provide justification for the DCD conclusion and a comparison plot of two sets of ground response spectra. (3.7.1)	In the fourth sentence of the first paragraph of DCD Section 3.7.1.1.3 (Page 3.7-4), the applicant stated that, since the low frequency part of North Anna SSE ground response spectra are enveloped by the 0.3g RG 1.60 generic site response spectra with large margins, only the high frequency part needs to be explicitly taken into account. The staff requests the applicant to provide justifications for the conclusion drawn in the DCD and a comparison plot of these two sets of ground response spectra in Tier 2 DCD Section 3.7.1, “Seismic Design Parameters.”

3.7-12	Cheng T	Provide descriptions of North Anna ground motions and geotechnical information. (3.7.1)	DCD Section 3.7.1.1.3 provides a description of the North Anna ESP design ground motion (5% damping design ground response spectra at different foundation levels, comparisons of response spectra calculated from the modified ground motion time histories with the ESP ground response spectra, etc.). In order for the staff to reach a safety conclusion regarding the design adequacy (based on the ESP ground motion) of the RB/FB and CB, the applicant is requested to provide the following information in the DCD: (a) Which of the ESP ground response spectra (target spectra or spectra/1.10 or spectra*1.30) to be used for the seismic analysis and design? (b) The ESP response spectra for 2%, 3%, 4%, and 7% damping ratios. (c) Definition of the “modified” ground motion time histories. (d) Demonstrate that the response spectra calculated from the modified ground motion time histories envelop the design ESP ground response spectra for all damping ratios to be used in the analyses. (e) Demonstrate that the modified ground motion time histories satisfy the PSD requirements (including how the target PSD was calculated). (f) Basis for the statement in the second paragraph of Page 3.7-4, “the cross-correlations between the three individual components are all less than the 0.3 requirement.” (The staff’s position for the cross-correlations between the three individual components is 0.16. This staff’s position had been applied for other design certification review, such as AP600, AP1000, etc.)

3.7-13	Cheng T	Provide a basis for the damping values specified in DCD Table 3.7-1 and Figure 3.7-36. (3.7.1)	**Because friction-bolted steel structures are designed to eliminate slip of the bolted joints by applying a preload, and consequently behave more like welded steel structures, the staff considers 4% SSE damping to be appropriate for friction-bolted steel structures. For ≥50% fill of cable, and in the absence of physical restraint, the staff considers 10% SSE damping to be acceptable for cable trays with all types of supports, including welded steel supports. While higher damping values may be justifiable on a case-by-case basis, DCD Figure 3.7-36 does not distinguish between different types of supports, which is a key parameter in determining the cable tray/support system damping response.** In order to complete its review of DCD Section 3.7.1.2, the staff requests that the applicant submit the following additional information related to SSE damping values: (7) Identify whether friction-bolted steel structures are employed in the ESBWR design, and if used, identify and justify the SSE damping value used in the design basis analyses. (8) Provide a detailed technical basis for the applicability of DCD Figure 3.7-36 to all types of cable tray supports, or as an alternative, describe the types of cable tray supports that are applicable to the ESBWR design; define the damping value appropriate for each type of support; and provide the technical basis for the specified damping value. (9) Define and provide technical justification for cable tray damping values when there are physical restraints to free cable motion (e.g., sprayed-on fire retardant material).
3.7-14	Cheng T	Revise the DCD to include specific technical information from ASME Code Case - 411-1. (3.7.1)	The applicant is requested to revise the DCD to include the specific technical information from ASME Code Case - 411-1 that it plans to use, and specifically identify the restrictions on its use, consistent with the staff position delineated in prior revisions of Regulatory Guide 1.84.
3.7-15	Cheng T	Identify building structures to be covered by the scope of DCD Section 3.7.2. (3.7.2)	In DCD Section 3.7.2, the applicant stated that this DCD section applies to "building structures that constitute primary structural systems." The applicant is requested to (1) specifically identify and describe the building structures covered by DCD Section 3.7.2; (2) identify the seismic classification of each building structure; (3) confirm those design basis seismic analyses have been completed for these building structures; and (4) identify where the details and results of the design basis seismic analyses are presented in the DCD.

3.7-16	Cheng T	Address the limitation of the formulation of equations of motion described in Section 3.7.2.1.1. (3.7.2)	In DCD Section 3.7.2.1.1, the applicant presents the formulation of the equations of motion in terms of undamped eigenvalues and mode shapes, with solutions obtained by integration in the time domain. The applicant is requested to address the limitations of this formulation, particularly for the case of frequency-dependent SSI stiffness and damping coefficients.
3.7-17	Cheng T	Provide additional information regarding the analysis method and results of each seismic Category I buildings. (3.7.2)	From the information provided in DCD Section 3.7.2.1.1, the staff cannot determine which of the methods described were actually used for the design basis seismic analyses of the building structures, or how they were implemented. Therefore, the applicant is requested to provide the following information related to DCD Section 3.7.2.1.1: (1) For each building structure covered by DCD Section 3.7.2, identify the specific time history analysis method employed; describe the implementation of the method, including determination of the highest structural frequency of interest and determination/verification of an adequate integration time-step; and discuss how the analysis results were used. (2) If modal superposition time history analysis was employed, identify whether the alternative to the missing mass method documented in Appendix A to SRP Section 3.7.2 was used to account for the contribution of modes with frequencies above f_{ZPA}. If so, explain why it was used instead of the more accurate missing mass method; define the cutoff frequency; and explain how it was determined. The staff notes that the staff's position stated in Draft Regulatory Guide DG-1127 (DG-1127 was released for public comments in February 2005, and is scheduled to be published as Revision 2 of RG 1.92 in Spring 2006) does not accept this alternative procedure.
3.7-18	Cheng T	Provide additional information regarding the response spectrum analysis method. (3.7.2)	From the information provided in DCD Section 3.7.2.1.2, the staff cannot determine whether response spectrum methods were actually used for the design basis seismic analyses of the building structures. Therefore, the staff requests that the applicant identify, for each building structure covered by DCD Section 3.7.2, whether the response spectrum analysis method was employed; describe the implementation of the analysis methods, including the method used to account for the contribution of modes with frequencies above f_{ZPA}; and discuss how the analysis results were used.

3.7-19	Cheng T	Provide additional information regarding the static coefficient analysis method. (3.7.2)	From the information provided in DCD Section 3.7.2.1.3, the staff cannot determine whether the static coefficient method was actually used for the design basis seismic analyses of the building structures. Therefore, the staff requests that the applicant identify, for each building structure covered by DCD Section 3.7.2, whether the static coefficient method was employed; describe the implementation of this method and the technical basis for its use; and discuss how the results were used.
3.7-20	Cheng T	Provide a description of how the stick and finite element models are developed. (3.7.2)	In the first sentence of DCD Section 3.7.2.3, the applicant stated that the mathematical model of the structural system is generally constructed as a stick model or a finite element model. The staff requests the applicant to describe in detail in the DCD the development of the stick models and finite element models for the structural systems covered by DCD Section 3.7.2, including whether the stick model was developed to match the overall dynamic characteristics of a detailed finite element model, the computer code that was used for modeling and analysis, and the information that was required from the analysis.
3.7-21	Cheng T	Provide, in the DCD, the basis for neglecting certain dynamic properties (rotary inertia, etc.) of RB/FB and CB. (3.7.2)	The staff requests that the applicant describe in detail in the DCD how it has implemented the general criteria contained in the third paragraph of DCD Section 3.7.2.3 (i.e., rotary inertia may be neglected since its contribution to the total kinetic energy of the system is small; two- or one-dimensional models may be used if the directional coupling effect is negligible; structures are generally designed to keep eccentricities as small as practical to minimize lateral/torsional coupling and torsional response) in the seismic design/analysis of the primary structural systems covered by DCD Section 3.7.2.
3.7-22	Cheng T	Provide modeling information related to the live and snow loads. (3.7.2)	The second sentence in the second paragraph on page 3.7-10 (DCD Section 3.7.2.3) states that the mass properties in the model include all contributions expected to be present at the time of dynamic excitation, such as dead weight, fluid weight, attached piping and equipment weight, and appropriate part of the live load. For the modeling of live load, the staff requests the applicant to describe, in the DCD, which part and the amount of live and snow loads that are included in the seismic models. (The staff position is that 25% of the floor live load or 75% of the roof snow load, whichever is applicable, should be included as mass in the global seismic models.)

3.7-23	Cheng T	Provide modeling information related to the water masses located in the RB/FB complex. (3.7.2)	The third sentence in the second paragraph on page 3.7-10 (DCD Section 3.7.2.3) states that the hydrodynamic effects of any significant fluid mass interacting with the structure are considered in modeling of the mass properties. For the ESBWR, significant amounts of water mass are located at various elevations in the RB (PCC Pool and IC Pool at El. 88.58 ft, GDCS Pool at El. 15.26 ft, and Suppression Pool at El. -3.28 ft). Based on the staff's review experience, the dynamic mass effect and the fluid-structure interaction effect on the overall seismic response of the RB are extremely significant. The staff requests the applicant to provide, in the DCD, a detailed description of pool geometry, total height of water, location of free board, modeling procedure of water mass (sloshing effect and impulsive mass), and how the water was modeled with the main structure.
3.7-24	Cheng T	Provide a description of how the mass modeling criteria were applied. (3.7.2)	The last two sentences in the second paragraph on page 3.7-10 (DCD Section 3.7.2.3) state that the number of masses or dynamic degrees of freedom is considered adequate when additional degrees of freedom do not result in more than a 10% increase in response. Alternatively, the number of dynamic degrees of freedom is no less than twice the number of modes below the cutoff frequency. The staff generally agrees with this criteria, but it is not clear how the criteria has been implemented in the development of the seismic structural models. The applicant is requested to include in the DCD specific information on how these criteria were satisfied for each seismic structural model.
3.7-25	Cheng T	Provide a description of how the heavy cranes were included in the seismic model of the RB/FB complex. (3.7.2)	For the development of the RB/FB seismic model, the staff requests the applicant to specify in the DCD where the heavy crane (with trolley) is to be parked during plant operation. This information is needed to properly locate the mass and assess the effects of mass eccentricity in the seismic analysis. This information also needs to be identified as an interface item for the COL applicant.
3.7-26	Cheng T	Provide information of how the effects of out-of-plane vibration of floors and walls were considered. (3.7.2)	For seismic subsystem analysis, accurate in-structure response spectra are needed at the subsystem support points. The staff requests the applicant to describe in the DCD how it has considered the effects of out-of-plane vibration of floors and walls in the seismic structural models and the development of in-structure response spectra.

3.7-27	Cheng T	Include dimensions in the figures and consider them as Tier 1 information. (3.7.2)	In DCD Tier 1 Figures 2.17.5-1 through 2.17.5-11 and Tier 2 Figure 1.2-1, the applicant did not provide the foundation dimensions for the RB/FB and the CB, nor the distance from the center of the reactor vessel to the edge of the RB/FB foundation. Because this information is important for the structural modeling and the seismic response of seismic Category I structures, the staff requests the applicant to include these dimensions in the above figures and to consider them as DCD Tier 1 information.
3.7-28	Cheng T	Provide, in the DCD, more detailed information about the modeling of the hydrodynamic coupling effects in the RPV model. (3.7.2)	The applicant described modeling procedures for the reactor pressure vessel (RPV) in the fifth paragraph of DCD Section 3.7.2.3, stating that the RPV and its major internal components are analyzed together with the primary structure using a coupled RPV/supporting structure model. The applicant further stated that for the RPV, (1) the presence of fluid and other structural components introduces a dynamic coupling effect; (2) hydrodynamic coupling effects caused by horizontal excitation are considered by including coupling fluid masses lumped to appropriate structural nodes at the same elevations; (3) the details of the hydrodynamic mass derivation are given in DCD Reference 3.7-6; and (4) the hydrodynamic coupling effects are assumed to be negligible in the vertical excitation and fluid masses are lumped to appropriate structural locations. The staff requests the applicant to include in the DCD the following additional information related to modeling of the RPV and modeling of hydrodynamic coupling effects: a. Describe how the seismic analysis results for the RPV and its major internal components, obtained from the coupled RPV/supporting structure model, were used in design of the RPV. b. Describe how direct fluid loading on the major internal components was considered. Was the fluid load transferred from these internal components to the locations of attachment to/contact with the RPV? c. Describe the methodology in DCD Reference 3.7-6 to derive the hydrodynamic mass, and include the results of implementing the method for the RPV model. d. Provide the technical basis for the assumption that hydrodynamic coupling effects are negligible in the vertical excitation.

3.7-29	Cheng T	Clarify the definition of the SSE. (3.7.2)	The first sentence of DCD Appendix 3A, Section 3A.1 states that this appendix presents SSI analysis performed for two site conditions, generic site and North Anna ESP site-specific, adopted to establish seismic design loads for the RB, FB, and CB of the ESBWR standard plant under SSE excitation. The definition of the SSE is not clear to the staff: is it both the 0.3g RG 1.60 ground motion response spectra and the North Anna ESP ground motion response spectra, or is it a combination (envelop) of these two spectra? The staff requests the applicant to clarify the definition of the SSE used for the ESBWR standard plant design in the DCD.
3.7-30	Cheng T	Include, in the DCD, the limitation of using uniform site impedance function for the ESBWR design. (3.7.2)	The last part of the second paragraph on page 3A-4 of DCD Section 3A.3.1 states that three subsurface conditions (soft, medium, rock and hard rock sites) are considered to be uniform half-space, as provided in Table 3A.3-1 for SSI analyses. According to the staff's review experience, there are a number of sites composed of layered materials that should be considered for siting of nuclear plants. Such sites may have significant variation of shear wave velocity with depth, leading to potentially significant impedance mismatches between layers. Such profiles can have effective impedance functions that are significantly different from those associated with a uniform half-space. (See for example, "Handbook of Impedance Functions" by Sieffert and Cevaer). These sites are typically characterized by impedance functions that are highly frequency-dependent, particularly those associated with radiation damping. The approach of using a frequency-independent assumption for both stiffness and damping in SSI may lead to significantly different computed responses. The behavior (or response) of a massive structure (such as RB/FB or CB) may be significantly influenced by these variations due to site conditions. For the design of a standard plant such as ESBWR, the DCD should address the limitations on site layering that will be required, to ensure the applicability of the ESBWR design, which is based on the assumption of uniformity. The staff requests the applicant to include this information in the DCD, and also identify it as a COL interface item.

3.7-31	Cheng T	(1) Justify to vary the shear wave velocity by ± square root of 2 for North Anna site, and (2) specify the minimum shear wave velocity of 1000 ft/sec in the DCD. (3.7.2)	The shear wave velocity ranges shown in DCD Appendix 3A, Table 3A.3-1, for the generic site, imply that these wave velocity values are associated with Best Estimate site properties. When the SSI analyses were performed, the applicant would have to consider potential variation in these velocities by ± square root of 2. These requirements would indicate that the site wave velocity ranges used should vary from 707 feet/second to hard rock site with the shear wave velocity to be 8000 ft/sec or higher (fixed-base model). A soil site with the shear wave velocity less than 1000 ft/sec is not acceptable for building a nuclear power plant. (The staff's position that the minimum shear wave velocity of soil foundation is 1000 ft/sec or higher was applied for other design certification review, such as AP600, etc.; and early site permit review, such as Grand Gulf, etc.) Also, the staff noted that the variation shown for the North Anna site in DCD Table 3A.3-2 is ± square root of 1.5, which does not meet SRP acceptance criteria. The staff requests the applicant to (1) explain and justify this difference (variation in soil shear wave velocity by ± square root of 2 vs ± square root of 1.5) in criteria between the generic site and the North Anna site, and (2) revise the DCD to specify that the minimum shear wave velocity.
3.7-32	Cheng T	Clarify, in the DCD, how the material damping and SSI radiation damping were considered in the seismic analyses. (3.7.2)	DCD Appendix 3A, Tables 3A.3-1 and 3A.3-2, indicate material (hysteretic) damping values assumed for foundation soils for the various uniform site cases. However, no mention is made in the SSI description of how these damping parameters are combined with the SSI radiation damping values listed in Tables 3A.5-1 and 3A.5-2. The staff requests the applicant clarify in the DCD how these properties (material damping and radiation damping) were considered in the SSI calculations and how significant they are to facilitate responses.
3.7-33	Cheng T	Justify that the use of the ASCE 4-98 approach to calculate the lateral soil pressure will result in a conservative design. (3.7.2)	DCD Section 3A.5 indicates that the use of lateral pressures computed from the equivalent static pressure analysis listed in ASCE 4-98 is conservative. Based on reviews of a number of facilities, it is known that actual pressures computed from detailed SSI evaluations of embedded foundations are directly influenced by the characteristics of the foundation response spectrum used to define the ground motions as well as the relative stiffness (shear wave velocity) of the soils above the basemat level. The staff requests the applicant clearly indicate in the DCD either (1) the technical basis for the statement that these static pressures are conservative for any site, or (2) any limitations that need to be incorporated into the acceptable site profile characteristics to limit the actual dynamic pressures anticipated.

3.7-34	Cheng T	Provide a technical basis to demonstrate that the input design ground motion time histories meet the guidelines specified in the SRP Section 3.7.1. (3.7.2)	In the seismic analysis of the RB/FB and CB for the North Anna site conditions (ground motion and local geotechnical properties), the staff identified the following concerns: a. As indicated in DCD Figures 3.7-24 through 3.7-35, the North Anna ground motions at the base of the RB/FB are different from those at the CB base. The staff's concern is whether these ground motions are treated as design ground motions. If yes, it implies that the design ground motion is not uniquely defined (RG 1.60 ground motion and North Anna ground motions at the foundation base of the RB/FB and CB). The staff requests the applicant (1) clarify the definition of design ground motion in the DCD, and (2) define the design site parameters (Tier 1 information) in Tier 1 Table 5.1-1. b. Do the ground motion time histories generated for the North Anna ground response spectra satisfy the response spectrum enveloping requirements for all damping ratios to be used for the seismic design? If yes, the staff requests that the comparison plots be provided in the DCD. If not, the staff requests the applicant to provide, in the DCD, technical basis for not satisfying these SRP guidelines. c. Do the ground motion time histories generated for the North Anna ground response spectra satisfy the PSD enveloping guidelines? If yes, the staff requests that a detailed description showing how the target PSDs were developed, and showing the comparison, be provided in the DCD. If not, the staff requests the applicant provide, in the DCD, a technical basis for not satisfying these SRP guidelines.
3.7-35	Cheng T	Clarify, in the DCD, (1) what soil damping was used in the SSI analysis, and (2) how the embedded effects were considered in the SSI analysis. (3.7.2)	As stated in DCD Appendix 3A, Section 3A.7, the elastic half-space theory was used for modeling the soil foundation for both the generic site condition and the North Anna site condition. The staff identified the following issues in need of clarification: (1) what soil damping (material damping and energy loss due to wave propagation) was assigned for the SSI analyses, and (2) how the embedment effects (especially at relatively soft soil sites) were considered in the analysis. The applicant is requested to address these clarifications, and also describe how the elastic half-space theory was applied to the North Anna site, in the DCD.

3.7-36	Cheng T	Provide a description, in the DCD, of how to consider the missing mass in the seismic response calculation. (3.7.2)	In DCD Appendix 3A, Tables 3A.7-1 through 3A.7-14, the applicant presented the eigenvalue analysis results. Based on the data presented, it appears that the highest modal frequencies considered in the modal time history analyses of the RB/FB are in the range of 10.83 Hz (soft soil) to 11.89 Hz (hard rock). For the CB, it appears that the highest modal frequency considered in the modal time history analyses is 29.10 Hz. The staff requests the applicant include the following information in the DCD: (a) Discuss whether only the modes listed in the cited tables were included in the modal time history analyses. If not, then identify the additional modes included in each time history analysis and provide the basis for their inclusion. If yes, then identify the modes excluded from each time history analysis, up to f_{ZPA} of the spectrum, and provide the basis for their exclusion. **(b) Discuss how the missing mass (modal mass corresponding to modes with frequencies higher than the analysis cut-off frequency) was included in the seismic response analyses. The staff notes that the 10% criteria stated on page 3.7-10 of the DCD is no longer considered acceptable to the staff (RAI 3.7-17 provides the basis for not accepting the 10% criteria).**
3.7-37	Cheng T	Provide a description, in the DCD, of how to calculate the frequency-dependent and frequency-independent soil stiffness. (3.7.2)	In the third paragraph of DCD Appendix 3A, Section 3A.5, the applicant discussed how to use the frequency-independent soil-spring K_c, and damping coefficient C_c to represent the soil foundation in the SSI analysis of the RB/FB and CB. DCD Tables 3A.5-1 and 3A.2 provide tabulated numerical values of K_c and C_c for the RB/FB and CB. However, the applicant did not describe in the DCD how the frequency-dependent soil-springs (real and imaginary parts of the soil stiffness) were calculated, and how these frequency-dependent soil-springs were converted to frequency-independent soil-springs and damping ratios. The staff requests the applicant provide a detailed description in the DCD.
3.7-38	Cheng T	Provide a description, in the DCD, of theory and method for calculating soil stiffness. (3.7.2)	It is stated in DCD Appendix 3A that the shear wave velocities and material damping ratios are strain compatible. The staff requests the applicant provide the following information in the DCD: (1) the theory (methods or formula) for calculating all soil springs, (2) the method (or formula) for calculating damping ratios, and (3) a clear description how the strain dependency of these values is accounted for in the soil-springs used in the SSI analyses.

3.7-39	Cheng T	Describe how the structure-to-structure interaction effects were considered in the DCD. (3.7.2)	**For the SSI analyses that were performed, the staff requests the applicant to describe in detail in the DCD how it considered the effect of structure-to-structure interaction through the soil between the RB/FB and CB. The staff considers this a potentially significant effect, especially for the response of the CB.**
3.7-40	Cheng T	Provide, in the DCD, a description of how to apply the direct spectra generation method to calculate floor response spectra. (3.7.2)	In DCD Section 3.7.2.5, the applicant stated that direct spectra generation, without resorting to time history, is an acceptable alternative method for developing floor response spectra. The staff notes that application of the direct spectra generation method will require a detailed staff review of the technical basis and sample calculations that demonstrate results equivalent to using time history analysis. Therefore, the staff requests the applicant to (1) identify the specific applications of the direct spectra generation method in the ESBWR design/analysis; (2) describe the methodology used to confirm equivalency to the time history analysis method; and (3) submit numerical results of the comparative analyses.
3.7-41	Cheng T	Provide a description of how the 100-40-40 combination method was applied. (3.7.2)	The staff accepts the 100-40-40 method of combination, as described in and subject to the limitations specified in RG 1.92, Revision 2 (in pre-publication stage). Draft regulatory guide DG-1127, issued for public comment in 02/05, states the staff position on this combination method. The staff requests the applicant to confirm adherence to the staff position on use of the 100-40-40 method of combination.
3.7-42	Cheng T	Explain which specific method was used for combining spatial seismic responses. (3.7.2)	In DCD Section 3.7.2.6, the applicant provided a description of the method for combining seismic responses resulting from the three orthogonal components of the input ground motion. The staff requests the applicant to specifically identify in the DCD which spatial combination method delineated in DCD Section 3.7.2.6 has been used for each of the building structures' seismic analyses.

3.7-43	Cheng T	Justify the use of the 10% rule for the modal time history analyses. (3.7.2)	In DCD Section 3.7.2.7, the applicant indicated that for modal combination involving high-frequency modes, the missing mass procedure of SRP 3.7.2, Appendix A, applies. This is acceptable to the staff. The applicant also identified an alternative method: modal responses are computed for enough modes to ensure that the inclusion of additional modes does not increase the total response by more than 10%. The staff notes that this alternative method is no longer considered acceptable to the staff, because more accurate accountings of the total contribution from high-frequency modes can be achieved by direct calculation of the missing mass contribution. (The staff's position for not accepting this alternative method is stated in RAI 3.7-17.) The staff requests the applicant identify whether the 10% alternate method has been used, to describe all applications, and to provide a technical justification for each application.
3.7-44	Cheng T	Identify in the DCD which of the three methods were used to account for the modeling uncertainties when generating the floor response spectra. (3.7.2)	In DCD Section 3.7.2.9, the applicant stated that floor response spectra calculated according to the procedures described in Subsection 3.7.2.5 are peak-broadened to account for uncertainties in the structural frequencies resulting from uncertainties in the material properties of the structure and soil and from approximations in the modeling techniques used in the analysis. If no parametric variation studies are performed, the spectral peaks associated with each of the structural frequencies are broadened by ±15%. If a detailed parametric variation study is made, the minimum peak broadening ratio is ±10%. In lieu of peak broadening, the peak shifting method of Appendix N of ASME Section III, as permitted by Regulatory Guide 1.84, can be used. The staff finds the methods identified to be consistent with SRP acceptance criteria and related staff positions. However, to complete its review, the staff requests the applicant to specifically identify in the DCD which methods described in DCD Section 3.7.2.9 were actually used in the development of the design basis in-structure response spectra, to account for parameter variations. Describe the specific applications of each of the three methods.

3.7-45	Cheng T	Provide a description, in the DCD, of how the torsional effects were considered in the seismic response calculations. (3.7.2)	In DCD Section 3.7.2.11, the applicant stated that one method of treating the torsional effects in the dynamic analysis is to carry out a dynamic analysis that incorporates the torsional degrees of freedom. For structures having negligible coupling of lateral and torsional motions, the torsional effects are accounted for in the following manner: (a) The locations of the center of mass are calculated for each floor. (b) The center of rigidity and torsional stiffness are determined for each story. (c) Torsional effects are introduced in each story by applying a torsional moment about its center of rigidity. (d) The torsional moment is calculated as the sum of the products of the inertial force applied at the center of mass of each floor above and a moment arm equal to the distance from the center of mass of the floor to the center of rigidity of the story, plus 5% of the maximum building dimension at the level under consideration. (e) To be conservative, the absolute values of the moments are used in the sum. (f) The torsional moment and story shear are distributed to the resisting structural elements in proportion to each individual stiffness. The staff finds the methods identified to be consistent with SRP acceptance criteria. However, to complete its review, the staff requests the applicant to specifically identify in the DCD which of the methods described in DCD Section 3.7.2.11 were actually used to account for torsional effects in the design basis analyses for the building structures. Describe the specific applications of each method.
3.7-46	Cheng T	Explain how the limitation related to the stiffness-weighted damping was applied in the seismic response calculations. (3.7.2)	From its review of DCD Section 3.7.2.13, the staff identified that the limitation which is imposed on the use of composite modal damping in SRP 3.7.2(II)(13) is not addressed in this DCD section. This limitation, as described in SRP Section 3.7.2(II)(13), states that for models that take SSI into account by the lumped soil spring approach, only stiffness-weighted damping is acceptable. The staff requests the applicant to provide an explanation how this limitation has been considered in the applications of composite modal damping. If not considered, provide a detailed technical basis for the approach used.

3.7-47	Cheng T	Identify, in the DCD, which method was used to treat damping ratios in the seismic analyses. (3.7.2)	In DCD Section 3.7.2.13, the applicant presented several methods to develop composite modal damping when an SSC consists of structural elements with different damping properties. The applicant stated that for use in modal superposition (modal time history or response spectrum) analyses, the composite modal damping ratio can be obtained based on either stiffness-weighting or mass-weighting. The composite modal damping calculated by either method is limited to 20%. Additional approaches applicable to frequency domain analysis and direct integration time history analysis are also presented. The staff requests the applicant to identify which of the methods described in DCD Section 3.7.2.13 were actually used in the design basis seismic analyses of the building structures (RB/FB and CB). Describe the specific applications of each method.
3.7-48	Cheng T	Provide additional information to demonstrate the dynamic stability of the RB/FB and CB during an seismic event. (3.7.2)	DCD Section 3.7.2.14 describes the theory and analysis method for calculating the seismic Category I structure overturning moments. As a result of its review, the staff requests the applicant provide the following additional information: In DCD Section 3.7.2.14, the applicant described the use of an energy method to evaluate the stability of structures against seismically induced overturning moments. The applicant is requested to provide a more detailed description of the analysis method, including an explanation of how the energy components for the embedment (W_p) and buoyancy (W_b) are determined, and the technical justification for the two equations given for the velocity terms (V_h and V_v).

3.7-49	Cheng T	Provide information for the staff to perform its confirmatory analyses.	The applicant is requested to provide the following information needed for the staff to perform its confirmatory analyses: 1. Detailed finite element (FE) RB/FB model (including figures showing mesh plots, node numbering, etc.) used for the development of the lumped-mass stick model. 2. Detailed fixed-base (fixed at the top of the foundation mat) lumped-mass stick model used in GE's SSI analyses. 3. Large-size structural design drawings of the RB/FB. Specifically, drawings showing the detailed foundation mat and embedded side walls are needed. 4. Soil information used to develop soil springs and soil damping for the SSI analyses of the RB/FB supported by the soft soil condition. 5. Description of the computer code "DAC3N" used by GE for the SSI analyses. 6. Input ground motion time history text files in digitized form. 7. Description of the SSI analytical formulation and digitized response computation results.
3.7-50	Cheng T	Provide a detailed description of the method applied to determine the cracked concrete stiffness. (3.7.2)	DCD Section 3.7.2.3, "Procedures Used for Analytical Modeling," does not address the method used to develop stiffness values (uncracked concrete sections versus cracked concrete sections) for concrete structural elements for the seismic analysis models. The staff requests the applicant include in the DCD a detailed description of the method applied to determine the stiffness values for both cracked concrete sections and uncracked concrete sections in the seismic analysis models.

3.7-51	Cheng T	Provide a description of how the cut-off frequency is determined for calculating seismic response of subsystems. (3.7.3)	DCD Section 3.7.3.3.2 provides the approach and method for modeling the subsystems. The staff identified the need for the following additional information: (a) The alternate criterion in DCD Section 3.7.3.3.2 for ensuring a sufficient number of mass degrees of freedom relies on determination of the "cutoff frequency" for the analysis; DCD Section 3.7.2.1.1 is referenced. The staff's review of DCD Section 3.7.2.1.1 noted that only the missing mass method is considered acceptable for capturing the high frequency response contribution (above f_{zpa}). (The staff's position for the consideration of missing mass in the seismic analysis is stated in RAI 3.7-17.) Consequently, there is no acceptable basis in DCD Section 3.7.2.1.1 for determining the "cutoff frequency." The staff requests the applicant to define "cutoff frequency", as it relates to ensuring a sufficient number of mass degrees of freedom, and explain in detail how it is determined for structures, systems, and components. (b) The staff also requests the applicant to clarify its criterion in DCD Section 3.7.3.3.2 related to location of lumped masses, in order to ensure conservative dynamic loads. It appears that the goal would be to drive the natural frequency of the equipment mathematical model toward the peak of the response spectrum. However, the criterion appears to be aimed at lowering the natural frequency.
3.7-52	Cheng T	Provide a description of the analysis method and acceptance criteria for the design of "auxiliary systems." (3.7.3)	DCD Section 3.7.3.13 does not provide any detail about the methods of analysis employed or the acceptance criteria used to determine structural design adequacy of buried conduits, tunnels, and auxiliary systems. In addition, the applicant did not provide the definition for the term "auxiliary systems." The staff requests the following additional information to complete its review: (a) a description of the types of SSCs that are included under the category "auxiliary systems;" (b) a description of the analysis method and acceptance criteria for buried conduits; (c) a description of the analysis method and acceptance criteria for tunnels; (d) a description of the analysis method and acceptance criteria for auxiliary systems.

3.7-53	Cheng T	Provide, in the DCD, a description related to the SSI analysis of the above-ground tanks. (3.7.3)	In DCD Section 3.7.3.15, the applicant described the important elements to consider in the seismic analysis of above-ground tanks. However, several items in the analysis method for the above-ground tanks need to be clarified: (a) DCD Section 3.7.3.15 indicates that the beneficial effects of soil-structure interaction (SSI) may be considered in this evaluation. The applicant is requested to confirm that if SSI effects are important (i.e., may lead to higher responses) then they will (not may) be considered as well. This should be included in the DCD description. In addition, provide a description or reference to an appropriate SSI method of analysis (comparable to those identified in SRP 3.7.3(II)(14)) that is used for the tank analysis. (b) Describe how the damping values for the impulsive mode are determined and whether the values are in accordance with those specified in NUREG/CR-1161. If not, provide the justification for any alternative method.
3.7-54	Cheng T	Specify the lower bound of the soil shear wave velocity to be 1000 ft/sec in the DCD. (3.7.5)	In DCD Section 3.7.5, the applicant indicated that the COL applicant needs to confirm that the site-specific shear wave velocity is no less than 1,000 fps in order to confirm the design adequacy of the plant. However, in following the guidance of the SRP for an individual site evaluation, the COL applicant needs to perform site-specific response calculations, reducing the low-strain shear-wave velocity profile from the Best Estimate (BE) to a Lower Bound (LB) value, defined as the BE divided by the square root of 2. DCD Section 3.7.5 needs to indicate that 1,000 fps is a LB velocity and not a BE velocity, or, as an alternative, the minimum acceptable BE velocity can be specified. In addition, since all design analyses were performed for assumed uniform velocity profiles, the site acceptance criteria needs to include information on what degree of variation from the uniform velocity profile is acceptable for the design.
3.7-55	Cheng T	Provide the computer code validation packages, in English, for review. (3.7.2)	To facilitate the staff's evaluation of the adequacy of computer codes used for design and analysis of the ESBWR Seismic Category I structures, the staff requests the applicant submit validation packages, translated into English, for the following computer codes listed in DCD Appendix 3C: SSDP-2D TEMCOM2 DAC3N

3.7-56	Cheng T	Provide the validation package for the computer code "ERSIN" for review. (3.7.3)	DCD Appendix 3D (3D.4.6.1) identifies the ERSIN Computer Program, which provides direct generation of local or global acceleration response spectra. Its stated use is to generate response spectra for pipe-mounted and floor-mounted equipment. To facilitate the staff's evaluation of this computer code, the applicant is requested to submit a validation package for the specific types of ESBWR applications, including comparisons to response spectra generated by time history analysis.

RAI Number	Reviewer	Question Summary	Full Text
3.7-57	Cheng T	Demonstrate that the stick structural models developed based on the process described in the DCD can transmit frequencies up to 50 Hz and be able to capture the responses resulting from the high frequency components of North Anna input ground motions. (3.7.2)	DCD Tier 2, Section 3.7.2.3 indicates that the mathematical model of the structural system is constructed either as a stick model or a finite element model. These models are used in the soil-structure interaction (SSI) response analyses to determine seismic response of the soil-structure system as indicated in DCD Section 3.7.2.4 and described in Appendix 3A to DCD Section 3.7. The free-field ground motions used as input to the plant analysis and design are described in DCD Section 3.7.1 and are ground motions that envelope either the RG 1.60 low frequency response spectrum or the high frequency ground motion developed for the North Anna early site permit site. DCD Figure 3.7-30 presents a plot of the North Anna design ground response spectrum and indicates a response spectrum that possesses its primary spectral accelerations in the frequency range from about 10 Hz to 50 Hz with a peak spectral acceleration at a frequency of about 20 Hz for the horizontal response spectrum and about 30 to 50 Hz for the vertical response spectrum. Appendix 3A to DCD Section 3.7 presents descriptions of the stick models developed for use in SSI analyses for the primary structures and internals of the plant. DCD Tables 3A.7-5 through 3A.7-14 present the results of eigenvalue analyses that are carried to frequencies as high as 27 Hz. These indicate participation factors of 0.28 at frequencies as high as about 25 Hz. The staff requests that the applicant demonstrate that the stick structural models developed based on the process described in the DCD can transmit frequencies up to 50 Hz and be able to capture the responses resulting from the high frequency components of North Anna input ground motions.

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