## ArevaEPRDCPEm Resource

**From:** Pederson Ronda M (AREVA NP INC) [Ronda.Pederson@areva.com]
**Sent:** Friday, February 13, 2009 7:18 PM
**To:** Getachew Tesfaye
**Cc:** BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); VAN NOY Mark (EXT); HARRIS Carolyn A (AREVA NP INC)
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 155, FSAR Ch. 3
**Attachments:** RAI 155 Response US EPR DC.pdf

Getachew,

Attached please find AREVA NP Inc.'s (AREVA NP) response to the subject request for additional information (RAI). The attached file, "RAI 155 Response US EPR DC.pdf" provides technically correct and complete responses to 5 of the 78 questions.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the responses to RAI 155 Questions 03.08.01-15, 03.08.01-18, 03.08.01-19, and 03.08.01-26.

The following table indicates the respective pages in the response document, "RAI 155 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

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A complete answer is not provided for 73 of the 78 questions. The schedule for a technically correct and complete response to these questions is provided below.

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| RAI 155 — 03.08.01-02 | March 31, 2009 |
| RAI 155 — 03.08.01-03 | October 30, 2009 |
| RAI 155 — 03.08.01-04 | March 31, 2009 |
| RAI 155 — 03.08.01-05 | March 31, 2009 |
| RAI 155 — 03.08.01-06 | October 30, 2009 |
| RAI 155 — 03.08.01-07 | April 30, 2009 |
| RAI 155 — 03.08.01-08 | May 29, 2009 |
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| RAI 155 — 03.08.02-05 | May 29, 2009 |
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| RAI 155 — 03.08.02-07 | July 31, 2009 |
| RAI 155 — 03.08.02-08 | July 31, 2009 |
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| RAI 155 — 03.08.03-02 | March 31, 2009 |
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| RAI 155 — 03.08.03-05 | April 30, 2009 |
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| RAI 155 — 03.08.05-16 | June 30, 2009 |
| RAI 155 — 03.08.05-17 | March 31, 2009 |
| RAI 155 — 03.08.05-18 | June 30, 2009 |

Sincerely,

*Ronda Pederson*

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**Sent:** Wednesday, January 14, 2009 9:33 AM
**To:** ZZ-DL-A-USEPR-DL
**Cc:** Jim Xu; Samir Chakrabarti; Sujit Samaddar; Michael Miernicki; Joseph Colaccino; ArevaEPRDCPEm Resource
**Subject:** U.S. EPR Design Certification Application RAI No. 155 (1671, 1831,1672, 1834, 1833, 1836), FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on December 12, 2008, and discussed with your staff on January 13, 2009. No changes were made to the Draft RAI Questions as a result of that discussion. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
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**Hearing Identifier:** AREVA_EPR_DC_RAIs
**Email Number:** 223

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**Request for Additional Information No. 155 (1671, 1831, 1672, 1834, 1833, 1836), Revision 0**

**01/14/2009**

**U. S. EPR Standard Design Certification**
**AREVA NP Inc.**
**Docket No. 52-020**
**SRP Section: 03.08.01 - Concrete Containment**
**SRP Section: 03.08.02 - Steel Containment**
**SRP Section: 03.08.03 - Concrete and Steel Internal Structures of Steel or Concrete Containments**
**SRP Section: 03.08.04 - Other Seismic Category I Structures**
**SRP Section: 03.08.05 - Foundations**
**Application Section: FSAR Section 3.8**

**QUESTIONS for Structural Engineering Branch 2 (ESBWR/ABWR Projects) (SEB2)**

**Question 03.08.01-1:**

FSAR Section 3.8.1.1 states that the reactor containment building (RCB) accommodates the calculated pressure and temperature conditions resulting from a loss of coolant accident (LOCA) without exceeding the design leakage rate and with sufficient margin. The FSAR indicates that the design pressure is 62 psig and the design temperature is 309.2 ºF. For calculation of the ultimate pressure capacity of the containment, Table 3.8-6 identifies that the maximum design basis temperature is 395 ºF. For performance of the in-service inspection (ISI) of the containment, Table 3.8-7 provides the ISI schedule. Depending on the number of years from construction, either $P_d$ (design pressure) or $P_a$ (accident pressure) is specified. FSAR Section 6.2.1.1.2 states that the design pressure and temperature of the containment are 62 psig and 338°F, respectively. Based on this information, AREVA is requested to address the following:

1. If the containment design pressure ($P_d$) is 62 psig, explain what is the containment accident pressure ($P_a$) used in the ISI schedule. If they are different values explain the basis for selecting the accident pressure.
2. Explain why the containment design temperature of 309.2 ºF, presented in Section 3.8.1.1, is not consistent with the maximum design basis temperature of 395 ºF, presented in Table 3.8-6, nor consistent with the design temperature of 338°F, presented in Section 6.2.1.1.2.

**Response to Question 03.08.01-1:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-2:**

FSAR Section 3.8.1.1.3 states that the liner plate is not used as a strength element to carry design basis loads. However, in the same section it states that no load transfer attachments are used at the bottom of the liner plate to transfer loads from the concrete reactor building (RB) internal structure into the lower portion of the nuclear island (NI) common basemat foundation. Instead the RB internal lateral reaction loads are transferred through the liner plate by lateral bearing on the haunch wall. If the entire lateral load from the RB internal structure is resisted by the haunch wall then describe how the lateral load and overturning moment from the internal structure were considered in the analysis and design of the haunch wall and NI basemat. This should include a description of how this behavior was represented in the finite element model (FEM), and how it was demonstrated that no uplift occurred between the containment internal structure and the containment liner as well as uplift between the containment liner and the NI basemat due to the overturning loads.

**Response to Question 03.08.01-2:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-3:**

FSAR Section 3.8.1.1.1 indicates that Appendix 3E provides details of the design and reinforcement for the containment cylinder and buttresses. However, design details for the containment dome could not be located. Since the containment dome is also considered to be a key structural component of the containment, AREVA is requested to provide the design details for the containment dome comparable to the details presented for the containment cylinder wall in Appendix 3E. In addition, Section 3.8.1.1 indicates that structural attachments to the containment wall and dome are made to support various piping, HVAC, electrical, and equipment, as well as the polar crane rails. AREVA is requested to provide design details for representative attachments to the containment wall and dome, both internal and external to the containment. These details should clearly demonstrate how the load would be transferred from the supported components to the containment structure.

In addition, FSAR Section 3.8.1.1.3 discusses the liner plate, headed studs welded to the liner, and steel shapes welded to the liner to provide rigidity during prefabrication, erection, and concrete placement. Provide a description and identify on the details shown in the FSAR the size and spacing of the headed studs and the type, size, and spacing of the stiffeners. Explain whether the stiffeners are also relied upon for strength once the concrete is cured, and therefore, are included in the FEM and are designed for all applicable containment loads.

**Response to Question 03.08.01-3:**

A response to this question will be provided by October 30, 2009.

**Question 03.08.01-4:**

FSAR Section 3.8.1.2 describes the codes, standards, and specifications followed for the design, fabrication, construction, testing and inservice inspection of the RCB. AREVA is requested to explain the following items:

1. Since the RCB is founded on the same NI basemat as several other seismic category I structures, explain where is the ASME containment jurisdictional boundary defined for the EPR plant which must satisfy the code requirements of the ASME Section III, Division 2. The response should consider the fact that the containment basemat is integrally connected to the rest of the NI foundation, and thus additional peripheral volume of concrete and anchorage of the containment shell reinforcement beyond the containment wall should be included in the jurisdictional boundary. In addition, AREVA is requested to confirm that all loads (e.g., wind, lateral earth pressure, etc.) arising from the evaluation of the common basemat outside the rules of ASME Code Section III, Division 2, are considered in combination with those specified for the ASME Code Section III, Division 2 basemat.
2. ASCE Standard 4-98, Seismic Analysis of Safety-Related Nuclear Structures and Commentary is identified under the heading of applicable codes in Sections 3.8.1.2.1 and 3.8.2.2.1 of the FSAR. AREVA should recognize that this Standard is not a code and should explain where this standard is utilized in the design of the containment. AREVA should preferably not reference this Standard because the NRC staff has not generically endorsed it for seismic analysis of nuclear power plants, or alternatively AREVA should explain the specific provisions from this Standard that were utilized and provide the technical basis for their use. This also needs to be addressed for FSAR sections 3.8.2 – 3.8.5.
3. ASCE/SEI Standard 43-05, Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities is also identified under the heading of applicable codes in Sections 3.8.1.2.1 and 3.8.2.2.1 of the FSAR. AREVA should recognize that this Standard is not a code and should explain where this standard is utilized in the design of the containment. AREVA should preferably not reference this Standard because the NRC staff has not generically endorsed it for seismic analysis of nuclear power plants, or alternatively AREVA should explain the specific provisions from this Standard that were utilized and provide the technical basis for their use. This also needs to be addressed for FSAR sections 3.8.2 – 3.8.5.

**Response to Question 03.08.01-4:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-5:**

FSAR Section 3.8.1.3.1 - Design Loads, defines the various loads to be utilized for the analysis and design of the containment. AREVA is requested to address the following items related to design loads:

1. For dead loads (D), explain whether the term “permanent equipment” used in the definition includes the weight of components such as cable tray systems, conduit systems, HVAC systems, etc. in addition to individual equipment/components. Provide the magnitude of the “permanent equipment load” and “other loads” used in addition to the dead weight of the structural element. Explain why the dead weight of the piping and its contents are included under “Pipe Reactions (Ro)” rather than under dead loads (D). Typically, Ro is reserved for piping reaction loads arising from loads other than dead load and earthquake. Treating the pipe dead load as Ro results in its elimination in some load combinations. Explain why hydrostatic loads (F) due to water stored in pools and tanks are defined separately from dead loads. This has resulted in its elimination from the load combinations as noted in RAI 3.8.1-7.
2. For live loads (L), explain what magnitude was utilized for analysis and design, and the basis for this load magnitude.
3. For SSE (E’), the FSAR indicates that SSE loads are considered due to applied inertial loads, including dead loads, live loads, and hydrodynamic loads (i.e., water in storage pools and tanks). Explain whether the entire dead load, including the weight of all components discussed under item 1 above, were included as mass in the seismic model(s) to develop the member forces used for design. Explain what portion of the live load (discussed under item 2 above) was included as mass (in addition to the dead load mass) in the seismic model(s) to develop the member forces for design. Explain where does the FSAR provide a description of all the storage pools and tanks used in all seismic category I structures.

**Response to Question 03.08.01-5:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-6:**

FSAR Section 3.8.1.3.1 and Section 3.8.2.3.1 – Design Loads, under the heading Other Loads, discuss the combustible gas pressurization loads that result from a fuel-clad metal-water reaction (WMR) and an uncontrolled hydrogen burn. Reference is made to Regulatory Guide 1.136, Regulatory Position C.5 for the loads and load combinations. FSAR Sections 3.8.1.3.1 and 3.8.2.3.1 state that "RG 1.136, Regulatory Position C.5 and RG 1.7 specify a pressure of 45 psig combined with dead load (D) as a minimum design condition. Therefore, the strains and stresses for the RCB calculated using the U.S. EPR design pressure in the load combinations in Table CC-3230-1 of the ASME BPV Code bounds the results of the pressure specified in RG 1.136 and RG 1.7." The staff position is that RG 1.136, RG 1.7, SRP 3.8.1, and 3.8.2 specify the load combinations which are to be used for the pressurization arising from the hydrogen generation and hydrogen burn. An additional criterion is that the pressure utilized should be as a minimum 45 psig. Thus, the higher pressure arising from the actual hydrogen generation/burn due to assumed 100% WMR and 45 psig should be used. AREVA is requested to identify what is the maximum pressure load (and associated containment temperature transient) from the hydrogen generation/burn event due to assumed 100% WMR; evaluate the containment integrity for the higher pressure from this event and 45 psig; and include the proper loads, load combinations, acceptance criteria, and analysis description in the FSAR. In addition, explain why satisfying both stresses and strains are being discussed for evaluation of the combustible gas pressurization loads, since the acceptance criteria for the concrete sections of containment only require meeting strain limits as described in RG 1.7 and ASME Code, Section III, Division 2, Subarticle CC – 3720.

**Response to Question 03.08.01-6:**

A response to this question will be provided by October 30, 2009.

**Question 03.08.01-7:**

FSAR Section 3.8.1.3.2 describes the load combinations used for design of the containment. AREVA is requested to address the items listed below related to these load combinations.

1. This FSAR section indicates that 25% of the design live load is considered with tornado load combinations and the full live load is used for local analysis of structural members. Unless some reduction in live load is more conservative, AREVA is requested to explain why 25% of the design live load is considered with tornado load combinations rather than 100% of the live load.
2. The last factored load combination for abnormal/severe environmental loads is the same as the second load combination except for the deletion of relief valve loads (G) and thermal load (To). This suggests that the load combinations are not being used properly. Therefore, AREVA is requested to confirm that for every load combination, where any load reduces the effects of other loads, a load factor of zero is applied to that load. If it can be demonstrated that the load is always present or occurs simultaneously with the other loads, then the load can be considered in the load combination even though it reduces the effects of other loads. If this criteria is followed, then explain why is the last factored load combination for abnormal/severe environmental loads listed in the FSAR.
3. Explain why the hydrostatic load (F) is excluded from the various load combinations. Even if the hydrostatic loads from pools and tanks inside containment are considered in the design of RB internal structures, which in turn exert reaction loads on the RCB and NI Common basemat foundation, they should still be defined as one of the components of loads for the containment. The FSAR included hydrodynamic loads as part of the SSE (E') load definition for containment; and therefore, the hydrostatic forces from the same pools and tanks should also be defined as a load for containment. As discussed in a previous RAI above, this is typically included as part of the dead load definition.
4. Since relief valve loads (G) are defined for the containment load combination, does the EPR plant design rely on any relief valve discharge into pools of water? If so, explain if the load factors defined in SRP 3.8.1, Appendix A, will be utilized for the load combinations applicable to containment and other affected structures, systems, and components (SSCs). Also, discuss the dynamic load combination method used to combine the responses (e.g., stresses and deformations) of SSCs due to SSE, LOCA, and relief valve discharge loads.
5. In accordance with SRP 3.8.1.II.3.D, AREVA is requested to confirm that the post-LOCA flooding is a design consideration, in which case the load combination in the ASME Code, Section III, Division 2, containing LOCA along with OBE may need to be considered. Where post-LOCA flooding is combined with OBE set at one-third or less of the SSE, this load combination may be eliminated provided the load combination is shown to be less severe than one of the other load combinations.

**Response to Question 03.08.01-7:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.01-8:**

FSAR Section 3.8.1.4 describes the design and analysis procedures for the post-tensioned RCB, which utilizes a finite element model (FEM) of the containment. AREVA is requested to address the items listed below related to the FEM and load applications:

1. Confirm that one FEM representing the RCB, RB internal structures, RSB, FB, SB, and common basemat is utilized for design analysis. Also, confirm that this one model is used for analysis of all loads identified in Section 3.8.1.3.1. Provide a description of how each of the different loads is applied to the model. In the case of seismic loads, explain which seismic model and seismic analysis they are taken from, in what form (e.g., maximum acceleration value from the time history analysis in each direction at each node) and how are they applied to the FEM.
2. FSAR Section 3.8.1.4.1 indicates that five layers of ANSYS SOLID45 elements are used through the thickness of the containment wall and dome. Explain why FSAR Figure 3.8-15 only shows four elements through the thickness of the containment dome. Provide the technical basis for concluding that four or five elements through the thickness of the containment shell are considered to be sufficient.
3. FSAR Section 3.8.1.4.1 indicates that the ANSYS SOLID45 finite element is a three-dimensional, four node brick element that is suitable for moderately thick shell elements. Explain whether this should have stated that the SOLID45 element is an eight node brick element instead.
4. Describe how the reinforcement is represented/modeled in the concrete brick type finite elements used in the model.
5. Explain where and why the ANSYS SOLID95 and SOLID92 finite elements are utilized.
6. Describe how the liner and anchorage of the liner were modeled in the RCB FEM, including the liner anchorage attachment method and spacing compared to the actual liner anchorage spacing. If the liner anchor spacing in the FEM does not match the actual spacing, explain (a) why the liner strains obtained from this analysis are considered to be accurate for checking against the strain limits specified in the ASME Code and (b) how are the liner anchor loads determined from the FEM analysis results and how are the loads used in checking the design adequacy of the anchors. As noted in FSAR Section 3.8.4.1, the strength of the liner is not relied upon to carry structural loadings; explain how this was achieved in the FEM.
7. FSAR Section 3.8.4.1, states that forces from the tendons are applied to the finite element "links" by imposing stains along the lengths of the modeled tendons and tensioning losses are explicitly included in these calculations. The calculated reactions forces from the tendon model are then applied as forces to the RCB model. Explain whether the analysis of the RCB model was performed for the maximum tendon forces due to initial pre-tensioning of the tendons, as well as the minimum (reduced) tendon forces occurring at the end of the 60 year period of performance of the EPR. If both cases were not analyzed, explain why not.

**Response to Question 03.08.01-8:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.01-9:**

FSAR Section 3.8.1.4.5 describes how creep, shrinkage, and cracking of concrete were considered in the design of the RCB. It states that moments, forces, and shears are obtained on the basis of uncracked section properties in the static analysis. However, cracking of concrete sections was considered for the thermal loading case. If cracking can occur due to the thermal loading case, internal accident pressure, and/or the structural integrity test (SIT), what is the technical basis for not considering cracked section properties for loads other than the thermal loading case? It should be noted that ASME Code Section III, Division 2, Article CC-3320 – Shells, indicates that "Containments are normally thin shell structures. Elastic behavior shall be the accepted basis for predicting internal forces, displacements, and stability of thin shells. Effects of reduction in shear stiffness and tensile membrane stiffness due to cracking of the concrete shall be considered in methods for predicting maximum strains and deformations of the containment."

**Response to Question 03.08.01-9:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.01-10:**

FSAR Section 3.8.1.4.11 describes the calculation to determine the ultimate pressure capacity of the RCB. AREVA is requested to address the items listed below.

1. The introductory sentence to this FSAR section states that "The ultimate capacity of the RCB is determined for use in probabilistic risk assessments (see Section 19) and severe accident analyses." NRC RG 1.136 indicates that the ultimate capacity of the concrete containment should be performed and refers to the guidance provided in SRP 3.8.1. As noted in SRP 3.8.1.II.4.K (Revision 2 – March 2007), the purpose of the containment ultimate pressure capacity evaluation is to obtain a measure of the safety margin above the design-basis accident pressure. This should be done utilizing deterministic calculations with minimum code-specified material stress-strain curves. The calculation of containment ultimate pressure capacity for use in probabilistic risk assessments (PRAs) should be evaluated separately using different criteria than those presented in SRP 3.8.1.II.4.K. These PRAs should be presented in Section 19 of the FSAR.Thus, FSAR Section 3.8.1.4.11should be revised to reflect the intent of this section and AREVA is requested to confirm whether the approach and criteria utilized to calculate the containment ultimate pressure capacity was performed in accordance with the guidance in SRP 3.8.1.II.4.K. Otherwise, provide the technical basis for any deviations from this guidance.
2. FSAR Section 3.8.1.4.11 indicates that the pressure capacity for various structural elements were based on the median pressure capacity. As discussed under item 1 above, the containment ultimate pressure capacity should not be determined on a probabilistic basis. Provide the containment ultimate pressure capacity for the various containment elements on a deterministic basis in accordance with SRP 3.8.1.II.4.K, or provide the technical basis for alternative criteria.
3. To support the results presented in FSAR Table 3.8-6, provide a description (including figures) which summarize and show: the models, material properties and material modeling, computer codes, loading sequences, tendon relaxation effects, concrete shrinkage & creep, potential failure modes, assumptions, and results.
4. Confirm that all of the material properties were based on code-specified material properties at the design-basis accident temperature.
5. The end of the last paragraph of FSAR Section 3.8.1.4.11 indicates that the ultimate pressure capacity reported corresponds to the ASME Service Level C stress limits for the hatch cover and cylinder. Explain why this limit was selected to determine the ultimate pressure capacity of the hatch cover and cylinder rather than the true ultimate capacity of the components.
6. In addition to the structural integrity calculations, how was leakage from the various containment elements (e.g., penetrations, bolted connections, seals, hatches, bellows) evaluated and what leakage acceptance criteria were utilized to verify the final ultimate capacity of the containment?

**Response to Question 03.08.01-10:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.01-11:**

FSAR Section 3.8.1.4.12 which is entitled Design Report indicates that design information and criteria for Seismic Category I structures are provided in Sections 2.0, 2.4, 2.5, 3.3, 3.5, 3.8.1 through 3.8.5. It also states that design results are presented in Appendix 3E for Seismic Category I structure critical sections. As noted in SRP 3.8.1.II.4.M (as well as corresponding sections in SRP 3.8.2 through 3.8.5), a design report is considered acceptable when it satisfies the guidelines of Appendix C to SRP Section 3.8.4. Appendix C to SRP 3.8.4 indicates that a design report contains design and construction information more specific than that contained in safety analysis reports (SARs). The design report should include a description of the structure and geometry, structural material requirements, structural loads, structural analysis and design, summary of results, and conclusions. Specific topics under each of these headings are also listed in Appendix C to SRP 3.8.4. Therefore, AREVA is requested to provide all of this information in a single Design Report that is referenced by the FSAR and to provide the Design Report to the staff for review, or alternatively, AREVA should include all of this information in a single Section/Appendix of the FSAR without the need to search numerous other FSAR sections. This also needs to be addressed for FSAR Sections 3.8.2 through 3.8.5.

**Response to Question 03.08.01-11:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.01-12:**

RG 1.90 requires that the reactor containment be tested to 1.15 times the design pressure at years three and seven. In FSAR Section 3.8.1.7.2, it states that pressurization at years three and seven uses $P_a$ instead of 1.15 times the design pressure. It also states that testing at 1.15 times the design pressure unduly fatigues the structure. Provide sufficient technical justification for not following the criterion for pressure testing in RG 1.90 and the basis for stating that testing at 1.15 times the design pressure unduly fatigues the structure.

In addition, FSAR Section 3.8.1.7.2 states that an exception is taken with respect to RG 1.90 whereby the force monitoring of ungrouted tendons is not provided. The FSAR states that this "is acceptable because all tendons used with the RCB are fully grouted." This is not an acceptable technical basis for taking an exception to providing three tendons in each tendon group (horizontal, vertical, and dome) as specified in RG 1.90. AREVA is requested to provide a valid technical basis for not meeting RG 1.90 or provide an alternate method for meeting the intent of this provision in RG 1.90.

**Response to Question 03.08.01-12:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.01-13:**

FSAR Section 3.8.1.4.1 - Computer Programs, refers only to the ANSYS computer code for analysis of the RCB and other structures. FSAR Section 3.8.4 discusses the use of another computer code GT STRUDL. AREVA is requested to address the following items related to the use of computer programs for all aspects of structural analysis and design:

1. Identify all versions of the computer programs that are utilized for all aspects of analysis and design of structures. This should include identification of the programs that are used for postprocessing of results of one computer code for use in another and combining output results.
2. For each of these computer programs, identify the program name and version number, describe what analyses they are used for, and how they were validated.
3. Confirm for each of these programs that the validation methods used are consistent with those described in SRP3.8.1 II.4.F.

**Response to Question 03.08.01-13:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-14:**

FSAR Section 3.8.1.4.4 discusses the temperature effects through the RCB wall. AREVA is requested to address the items listed below regarding how these temperature effects were considered:

1. Section 3.8.1.4.4 of the FSAR states that for purposes of this calculation an annulus temperature of 79 F was assumed. FSAR Section 3.8.1.3.1 states that the RB annulus internal ambient temperature can vary from 113F maximum to 45F minimum. Provide the basis for not assuming a lower annulus temperature in determining the temperature gradient through the wall and describe the impact on the wall analysis and design.
2. For the wall temperature gradient described in FSAR Section 3.8.1.4.4, describe the effect of temperature on tendon prestress and whether this effect was considered in the analysis and design of the containment wall. Also describe how the variations in the temperature of the RB annulus were considered in this analysis and if they were not considered provide justification for not doing so.

**Response to Question 03.08.01-14:**

1. To determine the temperature gradient of the reactor containment building (RCB) wall the average annulus temperature of 79°F was used on the exterior surface. The time dependent temperature profile due to a loss of coolant accident (LOCA), provided in U.S. EPR FSAR Tier 2, Figure 3.8-20, was used as the temperature variation on the interior surface of the RCB wall. Using these temperature loads, a thermal transient analysis was performed using ANSYS to determine the internal forces in the containment wall.

   The analysis did not consider lower annulus temperature because it is not credible that both the accidental temperature in the RCB (309.2°F) and the minimum annulus temperature (45°F) will occur at the same time. Furthermore, it is anticipated that the temperature variation between the average and minimum temperatures of the annulus (79°F - 45°F = 34°F) will have minimal effect on stresses in the wall. RAI 155, Question 3.8.1-16 response will show that an axisymmetric model is generated to investigate effects of varying material properties. This model will also investigate the effect of annulus temperature variation relative to the 79°F value used to date.
2. Tendon average temperature affects pre-stress losses due to steel relaxation. An average tendon temperature of 117.5°F was used in the calculation of pre-stress losses. This was determined as follows:
   - U.S. EPR FSAR Tier 2, Section 3.8.1.3.1 shows the maximum ambient temperatures for normal plant operation of the annulus (outside face of the RCB wall) and the two rooms of the containment (inside face of the RCB wall).
   - Maximum annulus temperature (113°F) was used for the RCB wall outer face temperature. This is conservative in calculating pre-stress losses because steel has higher relaxation at higher temperatures.
   - Maximum equipment area temperature is 131°F and the service area is 86°F. Consistent with containment HVAC system heat load calculations, an average temperature of 122°F was used for the RCB wall inside face.

- Average tendon temperature was determined as the average of the exterior and interior face temperatures of the RCB wall [(113°F + 122°F) / 2 = 117.5°F].

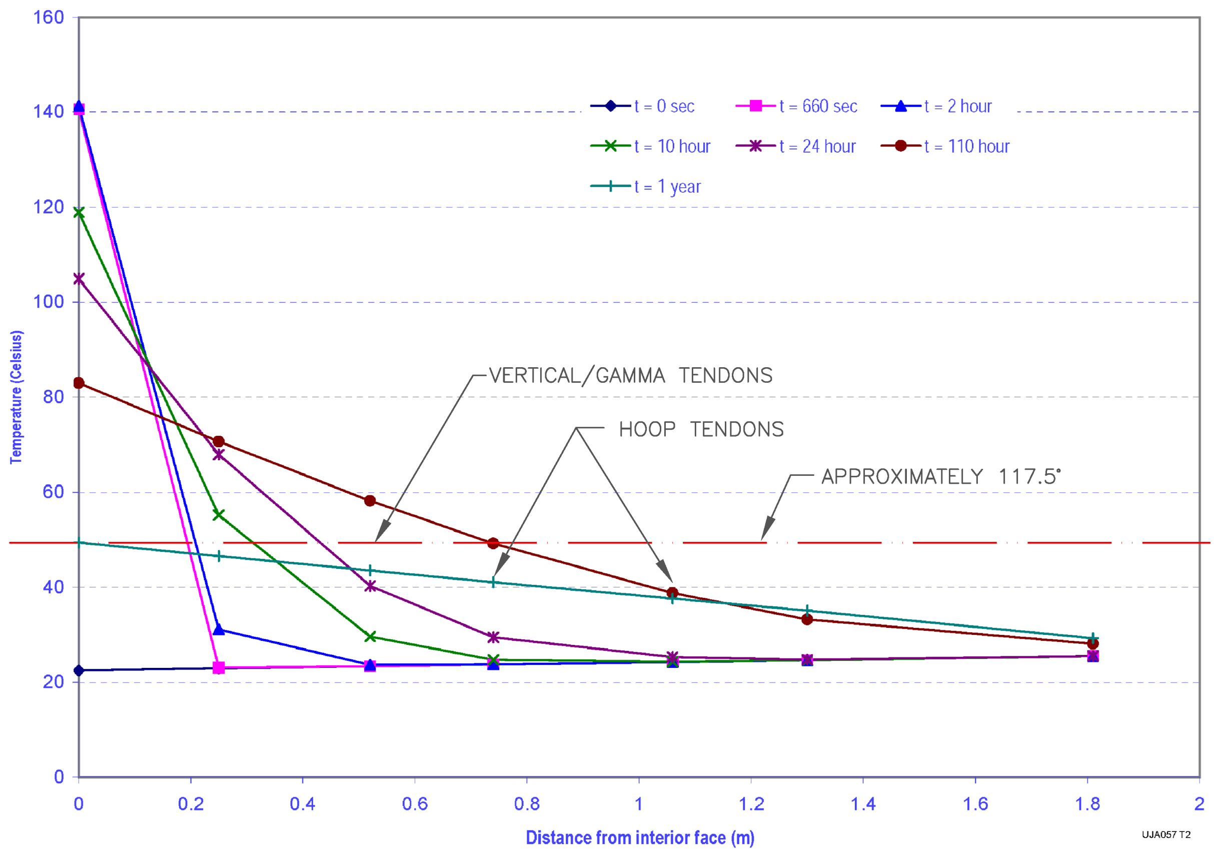
Once the average temperature of the tendons was determined, results of several recent 1000-hour steel relaxation tests for ASTM A416 material were reviewed and a representative $\rho_{1000}$ (1000-hour steel relaxation percentage) value of 1.7% was selected. These tests were performed at a temperature of 68°F, as prescribed by ASTM A416. No recent test data was found for ASTM A416 material at temperatures other than 68°F. Therefore, to provide additional margin for temperatures above 68°F, the selected value for $\rho_{1000}$ was increased by 50%. The 1000-hour steel relaxation percentage used for the determination of steel relaxation was (1.7%)(1.5) = 2.55%.

Consideration of the LOCA temperature gradient was not directly incorporated into the calculation for steel relaxation losses. Figure 03.08.01-14 (also U.S. EPR FSAR Tier 2 Figure 3.8-22—Temperature Gradient Through Cylinder Wall) shows temperature gradients of the cylindrical wall at:

| | | |
|---|---|---|
| t = 0 sec | t = 660 sec | t = 2 hour |
| t = 10 hour | t = 24 hour | t = 110 hour |
| t = 1 year | | |

All time points except for the t = 1 year time point are relatively short term, and therefore have little effect on long term phenomena such as tendon relaxation. Effective tendon temperature as pertinent to stress relaxation is estimated using the average of the t = 110 hour and t = 1 year time points. As shown in Figure 03.08.01-14, vertical/gamma tendon temperature during a LOCA is approximately 117.5ºF. Maximum hoop temperature is approximately 115ºF. Therefore, the tendon temperature used for determining pre-stress losses (117.5ºF) exceeds LOCA tendon temperature and is conservative.

**Figure 03.08.01-14 — Tendon Temperature Gradient**




Annulus temperature variations were not considered in determining pre-stress loss due to steel relaxation. Steel relaxation varies directly with temperature. Therefore, use of maximum annulus temperature (113°F) results in a higher average tendon temperature and a higher pre-stress loss due to steel relaxation (i.e., the calculation is conservative).

**FSAR Impact:**

1. The U.S. EPR FSAR will not be changed as a result of this question.
2. The U.S. EPR FSAR will not be changed as a result of this question.

**Question 03.08.01-15:**

SRP 3.8.1 requires that creep and shrinkage values used for concrete should be established by test or from data obtained on completed containments constructed of the same concrete. Paragraph CC 2231.5 of the ASME Code provides requirements for determining creep limits using a test procedure based on ASTM C 512. FSAR Section 3.8.1.4.5 states that creep and shrinkage are based on past experience. Provide the basis of the past experience including the use of 7000 psi concrete in a pre-stressed concrete containment and how this experience meets the requirements of Paragraph CC 2231.5 of the ASME Code and guidance in SRP 3.8.1.

FSAR Table 3.8-5 provides losses in tendon pre-stress forces due to elastic shortening, concrete creep and shrinkage. The ASME Code provides specific requirements and the SRP 3.8.1 provides guidelines for the determination of creep and shrinkage values to be used in the design of the RCB. Provide the material properties used in calculating the tendon losses, how they were determined, and what variations were considered in their selection and the basis for using the properties selected.

**Response to Question 03.08.01-15:**

1. U.S. EPR FSAR Tier 2, Section 3.8.1.4.5, 1$^{st}$ paragraph, 1$^{st}$ sentence will be updated to read as follows:

   "Conservative values of creep and shrinkage are used in the design of the RCB."

   U.S. EPR FSAR Tier 2, Table 3.8-5—Tendon Losses and Effective Forces with Time will also be revised by adding a negative sign to the percentage loss due to shrinkage values for the hoop and gamma tendons at T = zero.

   FSAR Section 3.8.1.4.5 describes creep and shrinkage (C/S) values. AREVA is aware of no completed pre-stressed containment design in the United States that uses 7000 psi concrete. In addition, material tests on the specific concrete to be used were not conducted during Design Certification. Therefore, typical concrete properties and a reasonable estimate of the relative humidity at the containment construction site, 60% for the Central and Eastern United States, were used to estimate C/S values for the U.S. EPR. U.S. EPR FSAR Tier 2, Table 3.8-5 shows the calculated losses due to C/S for the U.S. EPR tendons at T = zero (plant startup) and T = 60 years (plant shutdown). The pre-stress losses in U.S. EPR FSAR Tier 2, Table 3.8-5 were compared to losses for several operating U.S. plants and were found to be comparable.

2. Material properties used to calculate pre-stress losses due to elastic shortening (ES), creep (C), and shrinkage (S) are listed in Table 03.08.01-15.

**Table 03.08.01-15—Material Properties Used For Calculating Pre-stress Losses**

| Material property used for calculating pre-stress losses due to ES, C, and S | How the material property was determined / the basis | Variations considered |
|---|---|---|
| $E_{ps}$ = 28,000 ksi (modulus of elasticity of tendons) | Textbook value | None |
| $f'_c$ = 6,000 psi (28-day concrete compressive strength) | Value originally specified for RCB | See note below |
| $E_{ci}$ = 4,415 ksi (modulus of elasticity of concrete) | $57{,}000\sqrt{(f'c)}$ (ACI 349-01, Section 8.5.1) | None |
| $\varphi(t_e,t_o)$ = 1.0237 (basic creep coefficient at T = 0 for cylinder tendons) | Textbook value using typical concrete properties | None |
| $\varphi(t_e,t_o)$ = 1.5227 (basic creep coefficient at T = 60 years for cylinder tendons) | Textbook value using typical concrete properties | None |
| $\varphi(t_e,t_o)$ = 1.5227 (basic creep coefficient at T = 0 for dome tendons) | Textbook value using typical concrete properties | None |
| $\varphi(t_e,t_o)$ = 2.1464 (basic creep coefficient at T = 60 years for dome tendons) | Textbook value using typical concrete properties | None |
| $\varepsilon_{shu}$ = 0.00080 (ultimate shrinkage strain at T = ∞ for moist cured concrete) | Textbook value using typical concrete properties | None |

**Note:** Preliminary analysis indicated that a value of 7,000 psi is necessary for the RCB, and the design criteria document was updated accordingly. Use of the lower 6,000 psi value is conservative for determining pre-stress losses and is, therefore, not updated.

**FSAR Impact:**

1. U.S. EPR FSAR Tier 2, Section 3.8.1.4.5 and U.S. EPR FSAR Tier 2, Table 03.08.01-15 will be revised as described in the response and indicated on the enclosed markup.
2. The U.S. EPR FSAR will not be changed as a result of this question.

**Question 03.08.01-16:**

FSAR Section 3.8.1.4.8 states that in the design and analysis of the RCB consideration is given to the effects of possible variations in the physical properties of material on the analysis results. It further states that the properties used were established based on past engineering experience with similar construction and materials. Provide a discussion of how the variation of properties in the design of the containment was addressed in Tables 3.8-1, 3.8-2, 3.8-3, and 3.8-4 and provide a technical basis for using the properties listed. In addition, explain how variation in material properties was considered for other structures described in FSAR Sections 3.8.2 through 3.8.5. This should include the potential effects of high irradiation on structural members close to the reactor pressure vessel such as the reactor vessel concrete support structure.

**Response to Question 03.08.01-16:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.01-17:**

FSAR Section 3.8.1.4.9 states that small penetration openings through the concrete RCB defined as having diameters of less than six feet are not included in the overall computer model of the containment. Provide the basis for the exclusion of these penetrations from the analysis and describe how local analysis and design is performed for these penetrations. State the assumptions used in the boundary conditions and how the effects of temperature, pressure, pre-stress loads, etc. were considered in the analysis.

**Response to Question 03.08.01-17:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.01-18:**

Subarticle CC-2440 of the ASME Code, Section III, Division 2, requires that tendon ducts must be made of ferrous materials and shall meet other provisions specified therein. FSAR Section 3.8.1.6.3 states that tendon raceways consist of corrugated metal tubing, rigid conduit or high density polyethylene tubing. Provide the technical justification for the use of non-ferrous material which is a deviation from the Code, and explain how all of the requirements in the Code associated with tendon ducts will be satisfied for the non-ferrous and corrugated duct. This should include the provisions in Subarticle CC-2441 related to the duct properties and CC-4282 for ensuring that the grouting procedure can effectively fill the corrugated duct.

**Response to Question 03.08.01-18:**

U.S. EPR FSAR Tier 2, Section 3.8.1.6.3, 2nd to last paragraph, 2nd sentence, will be updated to read as follows:

"Tendon raceways consist of corrugated steel ducts and rigid metal conduit."

As stated in U.S. EPR FSAR Tier 2, Section 3.8.1.1.2, the RCB will be post-tensioned using the Freyssinet C-range post-tensioning system. There are two variations of this system available: System N°1 and System N°2. Both systems use corrugated steel tendon ductwork as well as ferrous trumpet and transition cone parts. In some areas, rigid metal pipe will be used instead of corrugated steel ductwork. All of these non-load-carrying materials meet the requirements of ASME Section III, Division 2, Subarticle CC-2441.

System N°2 includes an additional polyurethane sheathing around each seven-wire strand. All 55 strands and their associated polyurethane sheathing are contained within the corrugated steel ductwork. To provide room necessary for polyurethane sheathing, corrugated steel duct diameter for System N°2 is approximately 10% larger than that of System N°1. The primary benefit of System N°2 is reduction of friction loss coefficients.

Corrugated steel ducts have been used extensively in post-tensioned concrete construction. ASME Section III, Division 2, Subarticle CC-4282 requirements will be satisfied by developing a grouting procedure designed for specific job conditions. The grouting procedure will incorporate grout manufacturer and tendon manufacturer recommendations.

**FSAR Impact:**

U.S. EPR FSAR Tier 2, Section 3.8.1.6.3 will be revised as described in the response and indicated on the enclosed markup.

**Question 03.08.01-19:**

10 CFR 50.55a requires that inservice inspection of concrete containments be conducted as outlined in ASME Code Section XI Subsection IWL. In FSAR Section 3.8.1.7, Testing and Inservice Inspection Requirements, no mention is made of the ASME Code, Section XI, Subsection IWL requirements. Additional information should be provided to identify how each of the Section XI Code requirements and 10 CFR 50.55a supplemental inspection requirements will be met.

**Response to Question 03.08.01-19:**

U.S. EPR FSAR Tier 2, Section 3.8.1.7.2, 1st paragraph, 1st sentence will be revised to read as follows:

"The RCB is monitored periodically throughout its service life in accordance with 10 CFR Part 50.55a and 10 CFR Part 50, Appendix J…"

U.S. EPR FSAR Tier 2, Section 3.8.1.7.2, 2nd Bullet item will be deleted and replaced to read as follows:

- Supplemental inspection requirements of 10 CFR Part 50.55a.

U.S. EPR FSAR Tier 2, Section 3.8.1.7.2, 3rd Bullet item will be deleted and replaced to read as follows:

- ASME BPV Code, 2004 Edition, Section XI, rules for Inservice Inspection of Nuclear Power Plant Components, Subsection IWL does not contain specifications for inservice inspection of grouted tendons. For inservice inspection of grouted tendons, the following guidelines of RG 1.90, Revision 1 (February 1977) are followed with the following exceptions:

U.S. EPR FSAR Tier 2, Section 3.8.1.7.2, 3rd Bullet item, 1st sub-bullet will be revised to read as follows:

  – Force monitoring of ungrouted test tendons is not provided.

U.S. EPR FSAR Tier 2, Section 3.8.1.7.2, 4th Bullet item will be revised to read as follows:

- Tendons are surrounded with cementitious grout injected into the tendon duct; the alkaline composition of the grout mixture, in accordance with RG 1.107, Revision 1 (February 1977), inhibits corrosion of the steel strands and prevents the ingress of corrosive fluids (e.g., water).

Use of ASME Code, Section XI, Subsections IWL and IWE is specified in U.S. EPR FSAR Tier 2, Section 3.8.1.7.2. However, U.S EPR FSAR Tier 2, Section 3.8.1.7.2 will be updated to clarify that ASME Code, Section XI, Subsections IWL and IWE requirements must be satisfied, including 10 CFR Part 50.55a supplemental inspection requirements. Also, this section will be updated to clarify that RG 1.90 shall be followed, except as noted, to perform inservice inspections of containments with grouted tendons.

**FSAR Impact:**

U.S. EPR FSAR Tier 2, Section 3.8.1.7.2 will be revised as described in the response and indicated on the enclosed markup.

**Question 03.08.01-20:**

FSAR Section 3E.1 describes the three critical sections relating to the RCB which are the wall to foundation connection, equipment hatch area, and typical cylinder wall and buttress. AREVA is requested to include the dome, ring girder (thickened section of concrete at the top perimeter of the cylindrical containment wall where it transitions into the spherical dome), and the temporary construction opening as critical sections. Unless there is sufficient technical basis for excluding these locations, they should be included as critical sections for analysis and design.

**Response to Question 03.08.01-20:**

A response to this question will be provided by October 30, 2009.

**Question 03.08.01-21:**

FSAR Table 3E.1-1 lists the loads considered in the FEM of the RCB, and Table 3E.1-2 lists the loads not considered in the FEM but evaluated separately and added to the other loads for design. AREVA is requested to explain why the construction loads and combustion gas load C, which are defined in FSAR Section 3.8.3.1 are not also considered. In addition, explain why $P_a$ in Table 3E.1-1 is only considered for the containment wall, since the jurisdictional boundary of the containment should include the basemat foundation and liner as well.

**Response to Question 03.08.01-21:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-22:**

FSAR Section 3E.1.1 and other sections of Appendix E state that a separate analysis was performed to estimate the effects of cracked concrete and based on the results of the analysis the thermal moments carried by portions of the RCB were reduced. Describe the analysis performed including a description of computer codes, identify other concurrent loads that were considered in the analysis, the method used for reducing the thermal moments, how the final design loads were determined, and identify the portions of the RCB where this was done. Provide a similar description for the treatment of thermal moments in FSAR section 3.8.3, 3.8.4, and 3.8.5. Include in this discussion under what conditions these moments were considered and where in each structure thermal moments were reduced.

**Response to Question 03.08.01-22:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.01-23:**

FSAR Section 3E.1.1 describes the element forces and moments obtained from the ANSYS FEM of the containment in accordance with Figure 3E.1-1. These element forces are in terms of shell element forces (e.g., membrane forces, shear forces, and bending forces) across the entire concrete section not the individual brick elements that make up the through wall section of the wall. Tables for the governing design data for the critical sections also provide such loads across the entire concrete section. Explain how these shell type section forces are developed when the FEM utilizes solid brick elements through the thickness of the walls.

**Response to Question 03.08.01-23:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-24:**

FSAR Section 3E.1.1, under the heading “Results of Critical Section Design,” describes the design of the primary gusset and the upper gusset critical sections. Table 3E.1-3 is identified as the Summary of Governing Design Data for the Wall to foundation Connection. AREVA is requested to explain the information presented in the table so it is clearly understood by someone other than the originator of the calculations. This information is also requested for Tables 3E.1-5 through 3E.1-9, Tables in 3E.2, and Tables in 3E.3 which are applicable to the other Category I structures. Some examples of items needing clarification are listed below. Unless noted otherwise, these examples are taken from Table 3E.1-3.

1. For the column heading Location, where in the gusset critical sections are these 8 force components located?
2. For the column heading Location, what is meant by the row labeled Upper & Primary Gusset and how is this row different than the others?
3. For the column heading LC, explain why the other load combinations were not considered.
4. For the column heading AC, which corresponds to the governing soil case, explain what is meant by the term “Fixed” in front of each soil case.
5. For the column heading Condition, explain what is meant by the different entries in this column, and why are there a different set of 8 force components for each of these Conditions.
6. Provide an explanation/figure for the definition/orientation of the 8 member forces.
7. Explain why there are two footnotes labeled with a star symbol; while only one of these is referred to directly in the table. Also, explain what is meant by the second footnote which has a star.
8. For the last footnote in the table, explain what is done if the envelope of the forces and moments resulting from multiple load combinations and soil analysis cases is not used and what is meant by the second sentence in this footnote.
9. Explain what is meant by the second sentence in the last footnote which refers to “the envelope is extended to include a larger range of associated values.”
10. Explain whether the worst combinations of plus or minus of the maximum values of the 8 individual member forces are used simultaneously in design of all concrete sections. If not, then how is seismic (which can take on plus or minus values) considered with the other signed loads?
11. Explain whether the required reinforcement of the gusset is based on the maximum and minimum forces regardless of the physical location around the azimuth, and explain whether the same reinforcement is utilized around the entire azimuth of the gusset. If the response is no, explain why and how the design is performed.
12. In Table 3E.1-4, include the “provided area of steel (in $in^2/ft$)” in another column so that a comparison can easily be made between the “required steel areas” and the “provided steel areas.”
13. Explain the phrase in the last sentence of Section 3E.1, under the heading “Results of Critical Section Design,” which states “Section thicknesses and reinforcing quantities may be optimized based on subsequent analysis results.” It should be noted that the design

certification for the EPR is based on the design information of critical sections presented in the FSAR. In order for the staff to arrive at a safety determination, any optimization of the design referred to in FSAR Section 3E should be included in the FSAR.

14. In Table 3E.1-34, define the moments Mxu and Myu, and identify a figure that shows these member forces, along with the other member forces.
15. In Tables 3E.1-5, 3E.1-29 through 3E.1-32, explain why the torsional moment and bending moment is reported as a single load, i.e., Mx + Mxy and My + Mxy. Explain how the combined bending and torsional loads are utilized in design using ACI 349.

**Response to Question 03.08.01-24:**

A response to this question will be provided by October 30, 2009.

**Question 03.08.01-25:**

FSAR Section 3.E.1.3 states that a separate analysis was performed to determine the magnitude of in-plane shear produced by accidental torsion in the various walls of the NI common basemat structures. Describe the separate analysis including computer codes that is used to determine the in-plane torsional shear in the RCB and how these loads are combined with other loads in the structure.

**Response to Question 03.08.01-25:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.01-26:**

FSAR Section 3.8.1.4 states that the evaluation of the effects of locally applied loads to the RCB is done by manual calculations. Describe the applied loads and the manual methods used to determine the effects of concentrated loads on the RCB and how these effects are combined with the effects of other loads that must be considered, i.e. accident pressure load, accident temperature loads, pre-stress loads, earthquake loads, etc., in meeting the appropriate stress and strain limits of the ASME Code.

For attachments to the RCB, the ASME Code, Section III, Division 2, indicates that “The effects of anchors, embedments, or other attachment details not attached to the steel liner or a load carrying steel element, that provide anchorage into the containment concrete from the external surface, shall be considered. The anchors are, however, not under the jurisdiction of the Code.” Therefore, explain whether the ACI 349-01 Appendix B and Regulatory Guide 1.199 (November 2003) is used to design these anchors or provide the alternate code and design approach for these anchors. Also, include the code/regulatory guide and a description of the anchor design approach in the appropriate locations in FSAR Section 3.8.1.

**Response to Question 03.08.01-26:**

1. Nuclear Island ANSYS FEM load combinations include the following independent loads:
   - Dead (D).
   - Live (L).
   - Post-tension (J).
   - Lateral Earth Pressure (H).
   - Hydrostatic (F).
   - Buoyancy ($F_b$).
   - Seismic (E’).
   - Piping - normal operating conditions ($R_o$).
   - Piping - accident conditions ($R_a$).
   - Wind - severe environmental (W).
   - Wind - extreme environmental ($W_t$).
   - Pressure - test conditions ($P_t$).
   - Pressure - accident conditions - containment wall only ($P_a$).
   - Temperature - accident conditions - containment wall only ($T_a$).

   ANSYS determined the stresses acting on the elements of the model. For shell elements, ANSYS has the capability to also report forces and moments acting on the element. For brick elements, these stresses were turned into forces and moments using Excel macros.

Nuclear Island ANSYS FEM load combinations did not include the following independent loads:

- Relief Valve (G).
- Pipe Rupture ($R_r$).
- Compartment Flood ($F_a$).
- Temperature - normal operating ($T_o$).
- Temperature - test conditions ($T_t$).
- Containment Wall Pressure Variant ($P_v$).
- Sub-compartment pressurization ($P_a$).

When applicable to the particular member being designed, the additional load was applied and internal resisting moments and forces were determined by performing hand calculations using formulas taken from engineering reference manuals, or by using ANSYS sub-models. These forces and moments were combined with those determined by the FEM/Excel macros according to the proper load combinations.

U.S. EPR FSAR Tier 2, Section 3.8.1.4, 2nd paragraph states: "In many cases, classical methods and manual techniques are also used for the analysis of localized areas of the containment structure and its subassemblies."

Example: RCB – Typical Wall Section.

Accidental torsion was not accounted for by the Nuclear Island FEM during generation of results. The effects of accidental torsion on the RCB, Fuel Building, and Safeguard Building walls were determined in a separate calculation. The controlling in-plane shear loads for the typical RCB wall section were obtained from the Nuclear Island FEM results. These results were then increased by the amount determined in the separate accidental torsion calculation.

Wall design was then completed according to ASME Section III, Division 2 requirements.

Example: RBIS - Design of Steam Generator Separator Wall.

Sub-compartment pressurization, $P_a$, was applied to the wall by hand because it was not included in the FEM. The pressure was determined along the length/height of the wall. Segments of uniform pressure loading were determined. The equation $wl^2/12$ (beam with fixed ends) was applied to determine the maximum moment acting at the ends of the segment. The equation $wl/2$ was applied to determine max shear at the ends of the segment. These forces and moments were multiplied by the proper load factor and added to those determined with the FEM analysis.

Design of the wall was then completed according to the appropriate requirements of ACI 349.

2. The last paragraph of U.S. EPR FSAR Tier 2, Section 3.8.1.1.1 states: “Structural anchorages embedded in the containment wall support the polar crane.” The following sentence will be added to U.S. EPR FSAR Tier 2, Section 3.8.1.5:

   “Limits for allowable loads on concrete embedments and anchors are in accordance with ACI 349-2001, Appendix B and guidance from RG 1.199.”

**FSAR Impact:**

1. The U.S. EPR FSAR will not be changed as a result of this question.
2. U.S. EPR FSAR Tier 2, Section 3.8.1.5 will be revised as described in the response and indicated on the enclosed markup.

**Question 03.08.01-27:**

FSAR Section 3.8.1.4.4 summarizes the finite element procedures used to model the thermal and pressure transients from LOCA events. AREVA is requested to address the items listed below related to this analysis:

1. FSAR Figure 3.8-22 provides the thermal transient that RCB experiences. With 5 linear elements through the thickness, the element size appears to be about .36m (in the thickness direction). The large thermal gradients illustrated in Figure 3.8-22 for times shortly after initiation of the event (660 seconds and 2hrs) occur over a distance of about .2m. Explain how the heat transfer model was validated for the mesh refinement used since a more refined mesh is often needed for the thermal portion of a thermal/structural analysis.
2. The physical variation of material properties with temperature should be accounted for in the thermal analysis. FSAR Table 3.8-2 lists one value of elastic modulus, presumably at room temperature. Concrete properties vary with temperature and this can be an important factor to consider. Explain whether temperature dependent material property changes were included in the LOCA transient analyses. If not, justify why they were not.
3. FSAR Section 3.8.1.4.4, paragraph 3, states that “additional internal pressure was added to the RCB due to the heating of the liner plate.” Explain how this additional pressure was determined and applied to the finite element model.
4. FSAR Section 3.8.1.4.5 discusses the modeling of concrete cracking during accident thermal loading. Explain whether the ANSYS smeared concrete cracking constitutive models were used for this purpose. If so, describe how these were applied. If not, clarify how the modeling of concrete cracking was accomplished.

**Response to Question 03.08.01-27:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.02-1:**

SRP 3.8.2 provides the acceptable codes and regulatory guides for design of metal containments. For the EPR RCB, metal components not backed by concrete that perform a containment function must be designed to the ASME Code Section III, Division 1, Subsection NE. FSAR Section 3.8.2.2 does not delineate the boundaries between the concrete pressure boundary components and the steel pressure boundary components. SRP 3.8.2 requires that sufficient information be provided to define the primary structural elements relied upon to perform the containment function. Provide additional detail to describe the steel components providing a containment function under Subsection NE of the ASME III Division 1 Code, including figures which show the code boundaries, complete geometric details and dimensions, and material thicknesses for the equipment hatch, the air locks, the construction opening, and the high energy piping penetrations.

FSAR Section 3.8.2.6 states “Steel items that are not backed by concrete that are part of the containment pressure boundary are fabricated from materials that meet the requirements specified in Article NE-2000 of Section III, Division 1 of the ASME BPV Code, except as modified by applicable and acceptable ASME BPV Code cases.” The specific materials used in fabrication are not identified. Provide a list of the specific materials used for the steel components of the RCB pressure boundary, along with their procurement and supplemental requirements, and the extent of compliance with Article NE-2000 of the ASME Code, Section III, Division 1.

**Response to Question 03.08.02-1:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.02-2:**

SRP 3.8.2 requires that descriptive information be provided for steel containments. FSAR Section 3.8.2.1.1 states that the construction opening closure cap is designated as a class MC component in compliance with Article NE 3000 of the ASME Code, Section III, Division 2. There does not appear to be any information for the construction opening and closure cap. Provide a description and figure(s) showing the details of this large penetration and how it will meet the requirement under GDC 16 to provide a leak tight boundary under design load conditions.

**Response to Question 03.08.02-2:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.02-3:**

FSAR Figure 3.8-31 is titled "Fuel Transfer Tube Penetration (Conceptual View)." Define the meaning of the notation "conceptual view"; describe the current status of the design and analysis of the fuel transfer tube; if not completed, provide the schedule for completion; and identify the detailed report/calculation that will be available for audit by the staff.

**Response to Question 03.08.02-3:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.02-4:**

FSAR Section 3.8.2.4 - Design and Analysis Procedures, states that the evaluation of buckling for shells with more complex geometries and loading conditions than those covered by Article NE 3133 of the Code, is in accordance with ASME BPV Code Case N-284-1 and additional guidance in RG 1.193. Describe the specific applications of NE 3130 and Code Case N-284 to buckling analysis of steel closures for containment penetrations.

Also describe how geometric imperfections were considered in the calculation and the basis for the assumptions made. This is a requirement in NE 3133 of the Code.

**Response to Question 03.08.02-4:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.02-5:**

Under the acceptance criteria of SRP 3.8.2, the computer codes used for design and analysis should be described and validated by procedures or criteria in Subsection II.4.e of SRP 3.8.1. In FSAR Section 3.8.2.4, describe the methods of analysis that are used to qualify the ASME III, Division 1, Subsection NE components covered in FSAR Section 3.8.2, including a description of the computer codes and their validation basis.

Also identify the detailed reports/calculations for the NE components that will be available for audit by the staff.

**Response to Question 03.08.02-5:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.02-6:**

GDC 16 requires that reactor containment and associated systems shall be provided to establish an essentially leak tight barrier against the uncontrolled release of radioactivity. FSAR Section 3.8.2.1.3 discusses electrical penetrations through the containment boundary. What qualification and testing will be done, or has been done, to assure that electrical penetrations will meet the requirements of GDC 16 and will withstand the pressure and temperature conditions under the design basis accident? Provide details of the electrical penetrations including any spares.

**Response to Question 03.08.02-6:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.02-7:**

10 CFR 50.55a requires that inservice inspection of steel containments be conducted as outlined in ASME Code Section XI Subsection IWE. In FSAR Section 3.8.2.7, Testing and Inservice Inspection Requirements, no mention is made of the ASME Code, Section XI, Subsection IWE requirements. Provide additional information to identify how each of the Section XI Code requirements and 10 CFR 50.55a supplemental inspection requirements will be met.

**Response to Question 03.08.02-7:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.02-8:**

GDC 16 requires the containment to act as a leak tight membrane to prevent the uncontrolled release of radioactive effluent to the environment. In FSAR Section 3.8.2.2, Design Load Combinations, describe how differential movement between the RCB and the RSB is considered in the analysis of the equipment hatch, the air locks, and the construction opening, for the design-basis accident pressure and temperature conditions.

**Response to Question 03.08.02-8:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.02-9:**

In FSAR Section 3.8.2.3.2, under Level B Service Limits, it states that if a component screens out of analysis for cyclic operation, Level B service limit load combinations may be eliminated. Define the technical basis for “screening out of analysis for cyclic operation.” If the screening criteria are based on Subsection NE of the ASME III Division 1 Code, identify the specific Code paragraph. If not based on the Code, describe what precedents exist for the criteria applied.

**Response to Question 03.08.02-9:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.02-10:**

FSAR Section 3.8.2.1.1 describes the equipment hatch, personnel air lock and emergency air lock as having doors with sealed double gaskets. Since the gaskets for the equipment hatch and air locks must assure a leak tight boundary during the design-basis LOCA event, describe the basis for qualification of these seals under the design-basis LOCA pressure and temperature conditions.

**Response to Question 03.08.02-10:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.03-1:**

FSAR Section 3.8.3.1.1 provides some description of the reactor vessel (RV) support structure and reactor cavity. Since this description and associated figures are not sufficient to understand the structural elements, connections, and load path from the components to the containment internal structures, provide the following additional information:

1. Provide additional details which show how the RV ring is embedded into the concrete and the anchorage details.
2. Provide details of the components described in the second paragraph of FSAR Section 3.8.3.1.1 which include the large penetrations in the circular RV support concrete wall, permanently installed cavity seal ring, and neutron shield assembly resting on the embedded ring at the top of the wall.
3. Provide details of the embedment plates, baseplates, grout (if applicable) and anchorages for the RV; vertical and horizontal supports of the steam generators, reactor coolant pumps, and pressurizers; and the polar crane steel plate support brackets.

**Response to Question 03.08.03-1:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.03-2:**

FSAR Section 3.8.3.1.10 - Distribution System Supports, indicates that structural steel supports are provided for distribution systems as part of the RB internal structures. These include pipe supports, equipment supports, cable tray and conduit supports, HVAC duct supports, and other component supports. Distribution system supports are primarily constructed of steel shapes and tubing, which are anchored to the concrete RB internal structures using embedded steel plates, cast-in place anchor bolts, and drilled-in concrete anchors. For concrete anchors of all types that are discussed in FSAR Sections 3.8.1 through 3.8.5, for all components attached to concrete structural elements (not just distribution systems), AREVA is requested to explain whether the criteria listed below is utilized and to insert the criteria the FSAR, or explain why not:

1. The design and installation of all anchor bolts are performed in accordance with Appendix B to ACI 349-01 - “Anchoring to Concrete,” subject to the conditions and limitations specified in RG 1.199 (November 2003).
2. The design and installation of all anchor bolts are also performed in accordance with the information presented in NRC IE Bulletin 79-02, Revision 2, which includes criteria for anchor bolt safety factors, baseplate flexibility, and other criteria.

**Response to Question 03.08.03-2:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.03-3:**

FSAR Section 3.8.3.2 as well as Sections 3.8.4.4.1 and 3.8.5.4, indicate that ACI 349-01 with exceptions described in FSAR Section 3.8.4.4 and 3.8.4.5 is utilized for design and construction of reinforced concrete structures inside and outside containment. Currently, NRC Regulatory Guide 1.142 endorses the use of ACI 349-97 (with certain regulatory positions) for design of reinforced concrete members. Since ACI 349-01 is not endorsed by Regulatory Guide 1.142, the staff reviews the applicability of ACI 349-01 on a case-by-case basis. Some prior NPP designs have utilized ACI 349-01; however, the acceptance of this ACI standard was reviewed and accepted on a case-by-case basis considering the application of this standard to the particular plant and subject to certain limitations/exceptions. Therefore, AREVA is requested to provide the following:

1. Identify the differences between ACI 349-01 and ACI 349-97.
2. Which of these differences are as relaxations of the provisions in ACI 349-01.
3. The technical basis for the use of these relaxed provisions.
4. FSAR Sections 3.8.4.4 and 3.8.4.5 state that the design of concrete members is performed using the strength design methods described in ACI 349-2001, with the exception that the shear strength reduction factor of 0.85 is used as allowed in ACI 349-06. The staff notes that Section 9.3.2 of ACI 349-01 allows a shear strength reduction factor of 0.85 for shear. Explain what AREVA is proposing to do that is different by referring to ACI 349-06.

**Response to Question 03.08.03-3:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.03-4:**

FSAR Sections 3.8.3.2.1, 3.8.4.2 and 3.8.5.2 indicate that standards AISC 303-05, Code of Standard Practice for Steel Buildings and Bridges, ANSI/AISC 341-05, Seismic Provisions for Structural Steel Buildings, including Supplement 1, and AISC 348-04/2004 RCSC, Specification for Structural Joints Using ASTM A325 and A490 Bolts are utilized for the design of steel structures. SRP 3.8 references the use of ANSI/AISC N690-1994, including Supplement 2 (2004), Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities. The N690 Standard references other AISC standards in turn, but not these three AISC standards with the noted revisions. Therefore, AREVA is requested to justify the use of these new AISC standards for use of steel structures in FSAR Sections 3.8.3 through 3.8.5. This should include a description and listing of the differences between these new standards and N690 standard (including any of the referenced standards within N690), and justify any differences that are identified as a relaxation of the design provisions.

**Response to Question 03.08.03-4:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.03-5:**

FSAR Section 3.8.3.3.2 describes the load combinations used for concrete and steel structures inside containment. AREVA is requested to address the following items related to the load combinations used for these structures:

1. For reinforced concrete containment, explain why the first load combination does not include the pipe reaction load $R_o$ as required by ACI 349.
2. FSAR Section 3.8.3.3.2 states “For factored load combinations, in computing the required section strength (S), the plastic section modulus of steel shapes may be used, except for those which do not meet the ANSI/AISC N690 criteria for compact sections. This appears to be an exception to the provisions in ANSI/AISC N690 which is endorsed by SRP 3.8.3. In addition, this deviation does not appear in FSAR Section 3.8.4.Therefore, AREVA is requested to eliminate this deviation from ANSI/AISC N690 or provide sufficient technical justification for this approach.
3. FSAR Section 3.8.3.3.2 appears to include selected footnotes from ANSI/AISC N690, Table Q1.5.7.1 when describing the load combinations and stress limits. Confirm that all footnotes as well as other provisions of ANSI/AISC N690, including Supplement 2 (2004), are included in design of the EPR.
4. Confirm that for every load combination, where any load reduces the effects of other loads, a load factor of zero is applied to that load unless that load is always known to be present. This issue was already identified under RAI 3.8.1-7 for FSAR Section 3.8.1, and therefore this issue should also be confirmed for load combinations described in FSAR Sections 3.8.2 through 3.8.5. The FSAR sections should be revised to make this clear.

**Response to Question 03.08.03-5:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.03-6:**

FSAR Sections 3.8.3.4.1 and 3.8.4.4.1 describe the overall analysis and design of containment internal structures and other Category I structures, respectively. AREVA is requested to address the following items related to the analysis and design criteria in this FSAR section:

1. This FSAR section states that "For steel members, thermal loads may be neglected when it can be shown that they are secondary and self limiting in nature." Provide the technical basis for this statement or revise the criteria to be consistent with the provisions in ANSI/AISC N690.
2. This FSAR section states that "For load combinations including loads Rrr, Rrj, and Rrm, the load combinations are first satisfied with these loads set to zero. However, when considering these concentrated loads, local section strength capacities may be exceeded under the effect of these concentrated loads, provided there is not a loss of function of any safety-related SSC." Provide the definition of loss of function for both concrete and steel structures. Also, confirm whether this means that the methodology and acceptance criteria for impactive loads are consistent with ANSI/AISC N690 for steel structures and ACI 349 (and RG 1.142, Rev. 2) for concrete structures.

**Response to Question 03.08.03-6:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.03-7:**

FSAR Section 3.8.3.1.2 describes removable panels in the interior walls of each steam generator (SG) cubicle and states that these reinforced concrete wall panels are keyed into the side walls of the SG cubicles and to the slab at the bottom of the panels to prevent dislodgement during seismic events. As the panels must maintain their structural integrity and remain in place under a combination of loads, provide the method of analysis used for qualification of such non-integral concrete structural systems. Also describe how the reaction loads from these panels are imposed on the side walls and slab of the SG cubicle.

**Response to Question 03.08.03-7:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.03-8:**

FSAR Section 3.8.3.4.1 states that for RB internal structures, localized abnormal loads are not included in the overall analysis. These loads include sub compartment pressure loads, pipe break thermal loads, accident pipe reactions, pipe break loads, and local flood loads. Instead local analyses are used to address these localized loads. Some additional information on the local analysis and design is provided in FSAR Section 3.8.3.4. In order to understand how these analyses and design are performed AREVA is requested to address the items listed below. This information is also requested for the localized analyses for other Category I structures described in FSAR Sections 3.8.4 and 3.8.5 (if applicable):

1. Provide the method and basis for performing the localized analysis for each type of abnormal load. This should include the potential effects of concrete cracking due to accident thermal loads and redistribution of member forces due to cracking of concrete if significant.
2. Describe how the results of the localized analyses are combined with the results of the overall structural analyses for other loads.

**Response to Question 03.08.03-8:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.03-9:**

FSAR Section 3.8.3.4.2 indicates that openings in walls and slabs of RB internal structures are shown on construction drawings and that openings are acceptable without analysis if they meet the criteria identified in ACI 349, Section 13.4.2. This referenced section of ACI 349 is applicable to openings in slabs, not walls. Therefore, provide the technical justification for the use of these criteria for walls or revise the approach described in the FSAR to be consistent with the provisions in ACI 349 for design of openings in concrete walls, which among other provisions must also meet the requirements of Chapter 21 – Special Provisions for Seismic Design.

**Response to Question 03.08.03-9:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.03-10:**

FSAR Sections 3.8.3.4.4, 3.8.4.4, and 3.8.5.4.1 indicate that the seismic loads from the three components of the earthquake are combined using the SRSS method or the 100-40-40 percent rule described in ASCE 4-98. The staff has noted from past experience that the application of the 100-40-40 method may not always give results consistent with the guidance provided in Regulatory Guide 1.92, Rev. 2. If the FSAR is not revised to use the 100-40-40 method defined in RG 1.92, Rev. 2, AREVA is requested to provide the technical basis which demonstrates the adequacy of the 100-40-40 method taken from ASCE 4-98. This should include a quantitative demonstration, using the set of member forces for critical concrete element(s) that govern the design and where seismic loads are significant, which shows that the results from the 100-40-40 method are the same or more conservative than the results using the RG 1.92, Rev. 2 method.

**Response to Question 03.08.03-10:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.03-11:**

FSAR Section 3.8.3.1.8 provides a brief description of the polar crane support structure and FSAR Section 3.8.3.4.4 provides a description of the development of polar crane seismic loads. Since these descriptions are presented in FSAR Section 3.8.3, provide the following information:

1. Explain what structural members are considered to be within the scope of containment internal structures. Provide a detail showing the boundary of these structural members and the crane assembly, and the jurisdictional boundary between these structural members and the RCB.
2. Describe the analysis methods including computer codes that were used to analyze and design these intervening structural members between the polar crane assembly and the RCB wall.
3. Provide the materials and design codes that were used for the crane girder and the intervening structural members.

**Response to Question 03.08.03-11:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.03-12:**

Table 3.8-8 provides materials for structural steel shapes and plates used for design of steel members for containment internal structures and other seismic Category I structures addressed in FSAR Sections 3.8.3 through 3.8.5. Provide the information requested below related to the steel materials:

1. Steel materials ASTM A333, A537, and A633 are not listed as accepted materials under ANSI/AISC N690, including Supplement No. 2. Provide the technical basis for the use of these materials or revise the FSAR to be consistent with the ANSI/AISC Standard.
2. The actual material specifications, along with their procurement and supplemental requirements are not identified. The materials specifications, along with procurement and supplemental requirements, for the actual steel structural materials to be used should be provided.

**Response to Question 03.08.03-12:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.03-13:**

FSAR Sections 3.8.3.6.5, 3.8.4.6.3, and 3.8.5.6.3 provide a brief description of modular construction methods and composite type structural members used in the EPR. Provide a more detailed description, including figures, of each specific type of module or composite member used in the EPR. Also provide a description of the analysis and design approach used for each type of module and composite member. FSAR Sections 3.8.3.6.5 and 3.8.4.6.3 also state that decking, plates, and beams, as well as other types of formwork, may be left in place and become a permanent part of the structure. Provide details and a description of the analysis and design approach used for each of these items.

**Response to Question 03.08.03-13:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.03-14:**

FSAR Section 3.8.3.7 and 3.8.4.7 indicate that monitoring and maintenance of structures is performed in accordance with RG 1.160. Explain why monitoring and maintenance of structures is not performed in accordance with the requirements of 10 CFR 50.65 and supplemented with the guidance in RG 1.160.

**Response to Question 03.08.03-14:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.03-15:**

FSAR Section 3E.1.4 describes critical sections for the SG and RCP cubicle walls. Based on the staff's review of information presented under the FSAR heading - Applicable Loadings, Analysis, and Design Methods, AREVA is requested to address the items listed below. In the response, explain whether the same approach is utilized for the other critical structures described in FSAR Appendix 3E.

1. In the description, it states that the reinforcement configurations for the concrete sections of the floor slab and typical cavity walls uses forces and moments generated for the ANSYS finite element model. It then states that critical cases are selected for design based on maximum axial forces, maximum bending moments, maximum out-of-plane shear reinforcement force required, maximum in-plane shear forces, and maximum areas of total required steel. Explain whether cases refer to load cases or specific finite element cases and explain how the selection of the critical cases is done in a manner that ensures that these cases bound all load combinations and all finite element locations. This explanation should include how all load cases (i.e., load combinations and soil cases) were considered and whether every finite element was checked separately for design or was each section force (i.e., Tx, Ty, Txy, Nx, Ny, Mx, My, and Mxy) determined individually by selecting the maximum value from all the finite elements.
2. This FSAR section states that the design of required reinforcement is accomplished by averaging results from elements within a justifiable distance. To determine the acceptability of this process, provide the criteria and justification for the averaging of results and describe how it provides adequate design of the concrete sections in accordance with ACI 349 Code.
3. This FSAR section states that the upper portion of the SG/RCP wing wall and SG separation wall are subject to a pressurization load of 20 psi. Provide the method that was used to calculate the additional bending moments and out-of-plane shear forces that result from this pressure load. It also states that the additional bending moments and out-of plane shear forces are added to the extracted forces and moments from the ANSYS analysis. Describe the process for combining the reaction forces from the pressurization load with those from the ANSYS FEM.
4. This FSAR section states that additional shear forces and bending moments are also added to the floor slab to account for the remaining 75% of the live load that is not included in the ANSYS FEM. Explain whether the FEM analysis is first performed for seismic loads using 25% live load (in addition to dead load) for mass, a separate static FEM analysis of 25 percent live load, and a third separate static analysis of the remaining 75% live load which is referred to in FSAR Section 3E.1.4. If not, then explain why 75% is used for live load analysis rather than 100% of the live load when combining it with seismic and other loads. Explain what method was used to calculate the additional shear forces and bending moments that result from this live load, and the process for combining the reaction forces from this live load with those from the ANSYS FEM results.

**Response to Question 03.08.03-15:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.03-16:**

FSAR Sections 3.8.3 through 3.8.5 and Appendix 3E describe the finite element models used for containment internal structures and other seismic Category I structures. To determine the acceptability of these models, provide the additional information requested below for all seismic Category I structures:

1. From the information provided, it is not clear whether the finite element discretization is sufficient. The FSAR does not describe what procedures are used to select the appropriate number of elements for meshing concrete regions such as walls and slabs. The mesh density used for both the global and local finite element models, described in Section 3.8.3 and Appendix 3E, in many cases appear coarse for 4-noded and 3-noded shell elements. Explain how the mesh refinement was determined and validated for each model. Describe any finite element options that were selected to improve the accuracy of the results, and describe why they were appropriate.
2. Since triangular finite elements were used in addition to rectangular elements and it is recognized that generally triangular elements are not as accurate as rectangular elements, what steps were taken in the finite element model development to ensure that sufficient accuracy is achieved. Also, since the angle between some of the finite elements in the model appear to deviate from optimum angles for triangular and rectangular finite elements (e.g., Figure 3.8-34, lower right hand region of elevated slab), explain how it was assured that the results using such finite elements are still accurate.
3. The ANSYS finite element models of the RCB internals are shown in Figure 3.8-32 with the cut models visible in Figures 3.8-33 to 3.8-37 and Appendix 3E. While most of the internal structures use shell elements, clearly define which use solid brick type finite elements. Explain how the shell/solid interfaces are modeled and how does that approach ensure acceptable compatibility at the interface since solid elements do not have rotational degrees of freedom. Explain how solution accuracy is ensured for both linear and nonlinear analyses (presumably used for accident thermal cases).
4. FSAR 3.8.3.4.1 discusses when creep, shrinkage, and differential settlement are considered. Explain the criterion used to distinguish when these effects need to be considered and how they are included in a particular analysis.

**Response to Question 03.08.03-16:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.03-17:**

FSAR Section 3.8.3.1 “Description of the Internal Structures”, second paragraph, states:

> “The RB internal structures are Seismic Category I, except for miscellaneous structures such as platforms, stairs, guard rails, and other ancillary items. These miscellaneous structures are designed as Seismic Category II to prevent adverse impact on the Seismic Category I structures in the event of a SSE. Seismic classification of structures, systems and components (SSC) is addressed in Section 3.2.”

FSAR Section 3.2.1.2 “Seismic Category II,” states:

> “Per RG 1.29, some U.S. EPR SSCs that perform no safety-related function could, if they failed under seismic loading, prevent or reduce the functional capability of a Seismic Category I SSC, or cause incapacitating injury to main control room occupants during or following an SSE. These non-safety-related SSCs are classified as Seismic Category II.
>
> U.S. EPR SSCs classified as Seismic Category II are designed to withstand SSE seismic loads without incurring a structural failure that permits deleterious interaction with any Seismic Category I SSC or that could result in injury to main control room occupants. The seismic design criteria that apply to Seismic Category II SSCs are addressed in Section 3.7.
>
> Seismic Category II SSCs are subject to the pertinent quality assurance program requirements of 10 CFR Part 50, Appendix B.”

FSAR Section 3.7.2.3.3 “Seismic Category II Structures,” states:

> “The seismic analysis and design of Seismic Category II structures and members meets the requirements for Seismic Category I structures and members.”

FSAR Section 3.7.2.8 “Interaction of Non-Seismic Category I Structures with Seismic Category I Structures,” states:

> “In the case where damage to Category I SSCs cannot be precluded by the criteria above, the structure is classified as Seismic Category II and designed to the same criteria as Seismic Category I structures.”

FSAR Section 3.7.3.8 “Interaction of Other Systems with Seismic Category I Systems”, 1st paragraph (page 3.7-306), states:

> “The U.S. EPR uses state-of-the-art computer modeling tools for design and location of structures, subsystems, equipment, and piping. These same tools are used to minimize interactions of seismic and non-seismic components, making it possible to protect Seismic Category I subsystems from adverse interactions with non-seismic subsystem components. In the design of the U.S. EPR, the primary method of protection for seismic SSCs is isolation from each non-seismically analyzed SSC. In cases where it is not possible, or practical to isolate the seismic SSCs, adjacent non-seismic SSCs are classified as Seismic Category II and analyzed and supported so that an SSE event

> does not cause an unacceptable interaction with the Seismic Category I items. An interaction evaluation may be performed to demonstrate that the interaction does not prevent the Seismic Category I distribution subsystem from performing its safety-related function."

Based on the above, it appears that FSAR does not differentiate between Seismic Category I and Seismic Category II for seismic design/analysis and QA requirements. AREVA is requested to confirm this, and also to specifically describe the analysis methods and acceptance criteria that have been implemented for the seismic design of Seismic Category II miscellaneous structures inside containment, and other seismic Category I structures covered in FSAR Sections 3.8.3 through 3.8.5.

**Response to Question 03.08.03-17:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.04-1:**

FSAR Section 3.8.4 does not discuss the design of Radwaste Structures. It is also noted that FSAR Section 3.8.4.2.5 does not reference RG 1.143, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in LWR Plants.” FSAR Tables 3.2.2-1 and 3.7.2-29 state that the Nuclear Auxiliary Building (NAB) and the Radioactive Waste Processing Building (RWPB) are Radwaste Structures and are designed in accordance with guidance for RW-IIa structures in RG 1.143. Since these structures are part of the design certification and are designed in accordance with RG 1.143, provide in FSAR Section 3.8.4 the design details for these structures comparable to that provided for other Category I structures. The staff notes that FSAR Section 1.2.3.1.2 states that the NAB and RWPB are described in FSAR Section 3.8.4.

**Response to Question 03.08.04-1:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.04-2:**

FSAR Section 10.4.7.3 states that the non-safety related portions of feedwater piping located outside the structures may be impacted from external missiles. This appears to be the case for the main steam piping and possibly other high energy lines as well. External missiles may cause direct damage to high energy lines that may result in pipe whip or jet impingement loads on safety-related SSCs. Explain in FSAR Section 3.8.4 which Seismic Category I structures are susceptible to such loading conditions and explain how these structures are designed for such loads.

**Response to Question 03.08.04-2:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.04-3:**

FSAR Section 3.8.4.3.1 defines loads on other Seismic Category I structures in accordance with ACI 349-2001 and RG 1.142, Revision 2, November 2001 for concrete structures, and in accordance with ANSI/AISC N690-1994, including Supplement 2 (2004) for steel structures. Provide the following additional information to clarify certain assumptions in defining loads used in the design:

1. Provide the basis for selecting a live load of 100 psf applied to concrete floors and to steel grating floors and platforms in Seismic Category I structures other than the FB. Also explain the basis for the live load of 400 psf applied to FB concrete floors, as well as RB internal structures as discussed in FSAR Section 3.8.3.3.1. Furthermore, explain how it is ensured that these live load limits are not exceeded.
2. For buried items, the live load includes the effects of surface traffic such as truck loads, rail loads, construction equipment, and construction or maintenance activities. Provide the live load to be used for buried items.
3. Provide justification for assuming a ground temperature of 50F.
4. FSAR Section 3.8.4 indicates that the evaluation of structures resulting from external hazards of aircraft, explosion, and missile loading, are considered as part of the plant safeguards and security measures. However, no discussion is given about the external hazards of aircraft hazard, explosion, and missile loading required for the design of the plant structures as described in SRP 3.8.4. FSAR Sections 3.5.1.5 and 3.5.1.6 indicate that the COL applicant will evaluate the effects of aircraft hazard, explosion, and missile loading applicable to the specific site. Therefore, provide in FSAR Section 3.8.4 a description of these external hazard loadings and the need by the COL applicant to evaluate the effects of these loadings on plant structures.
5. The AREVA response to RAI 93 Supplement 1, entitled “Response to Request for Additional Information No. 93 Supplement 1 (1085), Revision 0,” dated 10/9/2008, related to FSAR Section 2.3.1 – Regional Climatology, provided a proposed revision to FSAR Section 3.8.4 on the subject of live load due to rain, snow, and ice. The proposed revision indicates that the design live load due to rain, snow, and ice is based on 100 psf on the ground, as described in FSAR Section 2.4. This value is postulated as a meteorological site parameter for the extreme winter precipitation load and includes the weight of the normal winter precipitation event and the weight of the extreme winter precipitation event. Roof snow and ice loads are determined using Chapter 7 of ASCE/SEI 7-05, “Minimum Design Loads for Buildings and Other Structures.” From this description it is not clear what the calculated live load is for rain, snow, and ice on the roof. Using the information given in FSAR Section 2.4, describe in FSAR Section 3.8.4 the magnitude of the calculated roof live loads for use in design for all Seismic Category I structures. Since the proposed wording in the RAI 93 response suggests that a 100 psf roof load is applicable for normal and extreme precipitation, explain how the single value of live load is utilized in the load combinations for concrete and steel roof structures. Also, explain how the calculation of the live load for roofs and its use in the load combinations compare to the current NRC interim staff guidance (ISG) entitled “Interim Staff Guidance on Assessment of Normal and Extreme Winter Precipitation Loads on the Roofs of Seismic Category I Structures,” available from the NRC web site.

**Response to Question 03.08.04-3:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.04-4:**

FSAR Section 3.8.4.4.2 states that gaps are maintained between structures adjacent to Seismic Category I structures to allow for structural movements during seismic events, containment pressurization, missile strikes, aircraft impact, explosions, and other loading conditions. In addition, exterior walls and roofs of the hardened SBs 2 and 3, RSB, and the FB are modeled to be independent of the internal structures, because there is no physical connection of internal walls and slabs in these structures with the outside walls and roof. Provide the following additional information on the gaps between the structures:

1. Specify the dimensions of the gaps to be provided between all structures adjacent to Seismic Category I structures and compare them to the calculated building responses.
2. Specify the dimensions of the gaps to be provided between the hardened structures noted above and the internal structures. Also, compare them to the calculated structural responses.

**Response to Question 03.08.04-4:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.04-5:**

FSAR Sections 3.8.4.1.2 and 3.8.4.4.2 state that FSAR Section 9.1.2 addresses fuel storage racks. FSAR Section 9.1.2 states that the design of the spent fuel storage racks are the responsibility of the COL applicant and that the COL applicant will provide a summary of the structural dynamic and stress analyses associated with fuel racks. Describe whether the spent fuel racks will be free standing or anchored to the fuel pool. In either case, describe the analysis and procedures for the spent fuel pool and racks, and explain how they compare to the criteria in Appendix D to SRP Section 3.8.4, “Guidance on Spent Fuel Pool Racks.” This description should include an explanation of how the loads from the fuel racks are included in the design of the spent fuel pool. This description of the analysis and design approach for the spent fuel pool and racks should be presented in the FSAR.

**Response to Question 03.08.04-5:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.04-6:**

FSAR Appendix 3E provides analysis results of a very limited number of critical sections for various Seismic Category I structures. The FSAR Appendix indicates that the RSB connections to the FB and SB 2 and 3 roofs are considered to be critical sections because these areas are sections of the plant where high levels of stresses are anticipated as a result of seismic loadings and geometry changes. Similarly, the walls below grade are chosen as critical sections to assess the impact of the soil on the walls under all applicable load combinations. For EPGBs, the foundation, typical wall at column line 11 and the RC slab and composite beams at elevation 51 ft-6 in are chosen as critical sections. For ESWBs, the foundation at elevation 16 ft - 0 in, shear wall at column line 4, and the fan deck slab at elevation 63 ft - 0 in are chosen as critical sections. Provide the following additional information on the selection and analysis results of critical sections:

1. Several sections in Appendix 3E state “Section thicknesses and reinforcing quantities may be optimized based on subsequent analysis results.” For each of the Seismic Category I structures discussed in Appendix Sections 3E.1.7, 3E.1.8, 3E.2, and 3E.3, the analysis of the buildings, which are within the scope of the design certification, should have been completed. Therefore, confirm that analyses of all Seismic Category I structures are completed or provide the basis for not completing them as part of the design certification application.
2. The selection of critical sections for design of Seismic Category I structures should include representative walls and slabs throughout the entire structure at highly stressed locations of these panels (e.g., center of panels, middle edge of panels at the support perimeter, and corner of panels). In the case of the RSB, critical sections should have also included connections at the wall to basemat, connection to roofs of adjacent structures, transition between cylindrical wall and dome, and center of the dome. Provide the analysis and design results at the above critical sections for each Seismic Category I structure or provide detailed justification for selecting the very limited number of critical sections that have been identified.

**Response to Question 03.08.04-6:**

A response to this question will be provided by October 30, 2009.

**Question 03.08.05-1:**

FSAR Section 3.8.5.1.1 states that the NI Common Basemat Structure foundation basemat is a cruciform shape that has outline dimensions of approximately 360 feet by 360 feet by 10 feet thick, a foundation basemat of lesser thickness will be considered for rock sites. It is the staff's understanding that the design certification is based on the details for the 10 foot basemat described in FSAR Section 3.8.5 and Appendix 3E. If a foundation basemat of lesser thickness will be used for rock sites, then all the details presented in the FSAR for the design of the 10 foot basemat need to be included in the FSAR for a basemat of lesser thickness. AREVA needs to either delete the statement "a foundation basemat of lesser thickness will be considered for rock sites" or present the complete design details for any other alternate foundation designs that they want the staff to certify. If rock will be considered in the design, then define what is meant by rock and provide the material properties attributed to rock that are applicable to the various analyses and design.

**Response to Question 03.08.05-1:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.05-2:**

FSAR Section 3.8.5.1.1 states that the connection of the tendon gallery to the NI Common Basemat Structure foundation basemat allows for differential movement between the concrete structures. Discuss how this connection will be designed and provide a figure showing the details of this connection. Also discuss how the tendon gallery, including the above connection, will be designed to prevent water infiltration into the tendon gallery space. An accumulation of water into this space could lead to corrosion of the tendon anchorages and inhibit inspection procedures.

**Response to Question 03.08.05-2:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.05-3:**

FSAR Section 3.8.5.4.1 states that the design of steel structures used for Seismic Category I foundations is performed in accordance with ANSI/AISC N690. Clarify where this specification will be used for foundation design since the FSAR does not describe any steel Seismic Category I foundations. If any steel foundations are used in the EPR design, provide descriptions of these foundations and information comparable to that provided for the concrete foundations.

**Response to Question 03.08.05-3:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.05-4:**

FSAR Section 3.8.5.4.1 includes a discussion of general procedures applicable to Seismic Category I foundations. With regard to the discussion in this section, AREVA is requested to provide the following information:

1. FSAR Table 3.8-11 provides minimum required factors of safety against overturning, sliding and flotation for foundations for various load combinations that are consistent with SRP 3.8.5. FSAR Table 3.8-12 provides the corresponding minimum factors of safety for the NI Common Basemat Structure foundation. For the load combinations including W, Wt, and Fb, explain the method used to calculate the reported minimum factors of safety.
2. FSAR Table 3.8-12 refers to FSAR Section 3.8.5.4.2 for the minimum factors of safety for overturning and sliding for the load combination including E.' No values are provided in this section. However, FSAR Section 3.8.5.5 states that for the load combination containing seismic loads, the calculated minimum factors of safety are less than the values provided in NUREG 0800. These calculated factors of safety for overturning and sliding for this load combination should be provided in the FSAR along with a description of the methods used to determine these factors of safety. The need for additional information on this issue is discussed under RAI 3.8.5-8.
3. In the discussion of lateral earth pressure loads, it is stated that lateral earth effects are considered in structure sliding and overturning analyses. If the sliding resistance is the sum of the shear friction along the basemat and passive pressures induced by embedment effects, describe the contribution of each in determining the overall factor of safety against sliding. This should consider the fact that in order to develop the full passive resistance sufficient sliding deformation is required. Once sliding occurs then the full static coefficient of friction cannot be utilized.
4. How has the potential effect of saturated soils from groundwater, flood, or water infiltration from the surface been considered in all seismic soil structure interaction (SSI) analyses, overall NI structural analysis, and the second model used for bearing, sliding, and overturning calculations. This explanation should include the development of soil springs for the overall NI structure (beneath the foundation and the side walls), the brick element layer beneath the basemat in the second model, the coefficient of friction for sliding, calculation of lateral earth pressures, and other calculations.
5. If lateral earth pressure loads are needed to resist the structure sliding and overturning, presumably at the same time, provide the seismic pressure distribution used in the design of the foundation walls and compare them to the maximum calculated soil pressure load distribution from the sliding and overturning seismic analysis.
6. It is stated that justification is provided for live loads that are included in loading combinations when evaluating structures for the effects of sliding and overturning. Provide specific examples and bases for the types of live loads that are considered and the expected effect when determining the factor of safety for sliding and overturning.
7. It is stated that the effects of differential foundation settlements are applied concurrently with the dead load using the same load factors. Describe how the effects of differential foundation settlements are applied concurrently with dead load and in which load combinations these are considered.
8. It is stated that sliding distance estimates may be computed using the reserve energy approach described in ASCE/SEI 43-05 as a conservative alternate to time-history

computed sliding displacements. Explain whether this alternate approach has been used. If it has been used or it is still desired to remain as an option, then as noted in RAI 3.8.1-4, ASCE/SEI 43-05 has not been generically endorsed by the NRC. Therefore, technical justification for the use of this method should be submitted for review and approval.

**Response to Question 03.08.05-4:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.05-5:**

FSAR Section 3.8.5.4.2 states that the NI Common Basemat Structure foundation basemat is analyzed and designed using the ANSYS finite element overall computer model (a static model) which is described in FSAR Section 3.8.1.4.1. This model is also used to determine the static bearing pressure on the supporting soils. AREVA is requested to provide the following information regarding this model:

1. A description of the development of spring parameters for the various soil cases is provided. However, such spring models are simplified representations at best of soil-structure interaction effects, particularly for dynamic load cases. Discuss the impact of the selection of these spring results on computed seismic demands and provide the results of sensitivity studies to support any conclusions.
2. It appears that the selection of properties of tri-linear spring parameters is based on subjective judgments and not from available numerical studies using appropriate soil constitutive models. Provide information to justify the basis of these developments.
3. Since the foundation is a cruciform shape, there are areas of the foundation that may be more susceptible to large bending moments. These areas may be even more susceptible if soft or hard spots occur beneath the foundation. For these and other susceptible areas, provide the results of studies that assess the effects of stiff and soft spots in the foundation soil to maximize the bending moments used in the design of the foundation mat. Based on these studies, what criteria needs to be placed in the FSAR regarding the limits in horizontal variation in soil properties and vertical variation in soil properties from the specific soil cases analyzed.

**Response to Question 03.08.05-5:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.05-6:**

In FSAR Section 3.8.5.4.2, an equation is provided for determining spring constants used to represent the soil that provides support for the foundation basemat in the ANSYS FEM model. AREVA is requested to provide the following additional information regarding the development of the soil springs used in the model:

1. Provide the source and justification for the use of this equation. As the plan view of the foundation mat cannot be quantified as a simple shape, explain how the constants A and B used in this equation and tabulated in FSAR Table 3.8-13 were determined. Discuss any variations considered in the properties of the subgrade modulus in determining the values of the spring constants.
2. The FSAR states that the Gazetas equation was used to evaluate the total soil spring ($K_o$) for the foundation of the common basemat NI structure. It further states that although Gazetas addresses the dynamic stiffness of the foundation basemat, the use of one-half the dynamic shear modulus in the equation approximates the total stiffness of the supporting soil medium under static conditions. Provide the justification for this approximation and state why the Gazetas equation is acceptable for determining $K_o$.
3. FSAR Figure 3.8-106 does not appear to provide the elastic displacement for soil case 1u. This information should be provided similar to Figures 3.8-107 through 115.

**Response to Question 03.08.05-6:**

A response to this question will be provided by May 29, 2009.

**Question 03.08.05-7:**

In FSAR Section 3.8.5.4.2 there is a discussion of the use of tri-linear springs used for the development of soil cases 4u and 2sn4u. AREVA is requested to provide the following additional information regarding the development and use of these tri-linear springs in the analysis of the foundation of the common basemat NI structure:

1. Describe what is meant by the statement that the tri-linear springs are developed in order to mitigate unrealistic analysis results generated by the NI common basemat structure static model. Provide a comparison of results to support this discussion.
2. Discuss why the other soil conditions do not produce this situation.
3. Provide the basis for the development of the properties used in the tri-linear springs for this application.
4. These springs were developed assuming a subsurface soil of relatively high plasticity clay. What is the impact of assuming a variation of this clay material for these two soil cases? Why was clay material selected and how would the results compare if granular material were selected?
5. Provide the relationship developed between the displacement of the foundation base mat and the corresponding average reaction imposed by the underlying soil medium.

**Response to Question 03.08.05-7:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.05-8:**

FSAR Section 3.8.5.4.2 describes a “second model” that was developed to evaluate the soil bearing pressures, sliding and overturning due to seismic events. AREVA is requested to provide the following information regarding this model:

1. Provide a figure showing the details of this model and explain what computer code is used to perform the analysis.
2. It is indicated that the properties of the model are established in a way that ultimately allows the model to respond in agreement with the SASSI analysis fundamental modes. Reference is made to FSAR Table 3.8.-15 which compares fundamental mode frequencies for three models. Clarify that the third column in this table are the results for the “second model” described above. Explain in detail the models discussed in the first two columns of this table, including how the soil was represented in the model in the first column and how the soil springs were determined in the model in the second column. Explain why the first column of this table refers to an “Equivalent to SASSI Analysis” rather than the SASSI model used for the SSI analysis discussed in FSAR Section 3.7.2. Provide a comparison of results (e.g., bearing pressures, sliding, and uplift) from each analysis corresponding to the three models shown in Table 3.8-15. Also, explain why soil case 1u was not included in the table since it is indicated that this soil case was part of the analytical study.
3. Because of a number of simplifying assumptions made in developing the “second model,” provide a comparison of the maximum soil bearing pressure, displacement, and location from the overall static NI building model and the “second model” used for bearing, sliding, and overturning analysis, for three load cases. The three load cases should correspond to the equivalent static seismic acceleration loads in the vertical, North-South, and East-West directions, applied in the same manner to both models.
4. Provide the basis for using a shear coefficient of 0.7 in the analysis. This should consider the potential for sliding at the various interfaces such as sliding between basemat and upper mud mat, mud mat and waterproofing material, lower mud mat and soil surface, and shear failure within the soil medium beneath the lower mud mat. Describe the extent to which this parameter is applicable to soil conditions found at most potential sites that may use the EPR design. It is also noted that the above reported coefficient of friction appears to be the static coefficient of friction. Since the analysis concludes that the structure slides, the full static coefficient of friction should not be used.
5. It is indicated that full passive pressure is assumed to occur at displacement of 1% of the depth of burial of the foundation depth. This mobilization displacement is clearly a subjective value and on other generic designs numbers of the order of 2% were used. Provide a discussion of the impact of the sensitivity of the computed results to these assumptions.
6. It is indicated that damper elements were obtained from the SASSI results to include with the spring results in the simplified sliding/overturning studies. Clarify what SASSI results are being referred to. Also, provide the following information regarding the damping elements: (a) Were these parameters generated for every soil case?, (b) Were they generated from half-power frequency considerations?, (c) Were separate dampers developed for horizontal and vertical springs?, (d) Were damping parameters selected as functions of location in the basemat as are the spring values?, (e) Were different dampers selected as a function of frequency?, (f) Were the results sensitive to the selection of these parameters?

7. It is stated that the "second model" is excited by simultaneous application of "three EUR seismic transients" that are simultaneously applied to the base of the soil elements, for soil cases 1u, 2sn4u, 2n3u, 2u, 4u and 5a representing soft, medium and hard sites. Identify the specific three transient motions that were used, location in the soil media where these transients were developed, and where they are described in the FSAR. Explain why the application of these transients at the bottom of the single layer of soil brick elements is appropriate. Provide a description of how they were developed and confirm that these three transients are statistically independent based on the criterion in FSAR 3.7.1.1.2. Furthermore, explain why other soil cases used in the analysis of the EPR were not considered for this analysis.

8. The results of the analyses are summarized in FSAR Table 3.8-16 and discussed in FSAR Section 3.8.5.5.1. It is stated that these results are sufficiently small so that they can be considered inconsequential with respect to sliding and overturning. This conclusion is too qualitative and does not provide sufficient information to demonstrate that the required factors of safety specified in FSAR Table 3.8-11 have been met. Provide a quantitative basis to demonstrate why the sliding and uplift values presented in Table 3.8-16 are acceptable and, as a result meet the required factors of safety in FSAR Table 3.8-11. One approach might be to raise the level of earthquake to the required safety factor of 1.1 and perform a calculation to show that the structure does not overturn and the sliding is sufficiently small such that soil failure does not occur. This evaluation should also demonstrate that the actual soil pressures calculated on the walls and vertical edge of the slab from this seismic analysis provide sufficient margin when compared to the soil passive pressures considered in design. Also, it should be demonstrated that the sliding and uplift that is predicted to occur, using the design earthquake loads (not 1.1 E'), do not have an effect on floor response spectra, building member forces, and other building design parameters, such as the effect of differential displacement on distribution systems exiting the NI common structure.

9. It is stated in FSAR Section 3.8.5.5.1, that because friction will not prevent sliding of the RB internal structures basemat above the containment liner, the surrounding concrete haunch wall is designed with sufficient capacity to resist the total base shear force. Explain how the base shear force is calculated and how the concrete haunch is designed to resist this load. Also, as discussed in item 8 above, provide a quantitative basis for the factor of safety against sliding after taking the effect of the haunch into account.

10. It is stated in FSAR Section 3.8.5.5.1 that the minimum factor of safety against overturning for the RB internal structures basemat above the containment liner is 1.22, occurring for soil case 2sn4u. Explain how this factor of safety is calculated.

**Response to Question 03.08.05-8:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.05-9:**

FSAR Section 3.8.5.4.3 for the EPGB and FSAR Section 3.8.5.4.4 for the ESWB state that elastic boundary conditions are included in the finite element model for each structure in order to simulate the stiffness of the supporting soil. As these structures are designed for an envelope of soil conditions, describe how the stiffness of the soil springs are determined for each of the soil cases and how an envelope of design loads is produced for each structure.

**Response to Question 03.08.05-9:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.05-10:**

Section 3.8.5.5.1 indicates that bearing pressure demands under the NI Common Basemat structures are 22 ksf for static loads and 25 ksf for dynamic load conditions. For other Category I foundations, FSAR Sections 3.8.5.5.2 and 3.8.5.5.3 state that the maximum bearing pressures under static and dynamic loading conditions “will be performed” to confirm that applicable acceptance criteria are met. Provide the maximum bearing pressures under static and dynamic loading conditions for the other Category I foundations, and include them in FSAR Section 3.8.5 and the other applicable sections of the FSAR.

**Response to Question 03.08.05-10:**

A response to this question will be provided by July 31, 2009.

**Question 03.08.05-11:**

FSAR Section 3.8.5.5.1 states that the NI foundation basemat can accommodate tilt settlements of 0.5 inches in 50 feet in any direction across the basemat. Provide a detailed explanation as to how this differential settlement was determined and how the effects of these settlements are considered in the design of the NI Common Basemat Structures.

**Response to Question 03.08.05-11:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.05-12:**

FSAR Section 3.8.5.5.2 for the EPGB and FSAR Section 3.8.5.5.3 for the ESWB state that the evaluation of the foundation basemats for maximum bearing pressures under static and dynamic loading conditions, settlements, flotation, sliding and overturning will be performed to confirm that applicable acceptance criteria are met. For each of these structures provide this information and include it in the FSAR. If it is currently not available, explain when it will be available for review by the staff and included in the FSAR.

**Response to Question 03.08.05-12:**

A response to this question will be provided by April 30, 2009.

**Question 03.08.05-13:**

FSAR Section 3.8.5.6.1 states that epoxy coated rebar will be considered on a site-specific basis, for use in foundations when groundwater may adversely affect the long-term durability of the concrete foundation. The implication is that epoxy coated rebar should be used for sites where groundwater may induce corrosion of rebar. However, no criteria are provided that can be used by a COL applicant to judge if such potential exists. Furthermore, epoxy coating may not provide significant protection against corrosion if small cracks or knicks in the epoxy are developed as is typical at construction sites. Provide in the EPR FSAR guidance that can be used by the COL applicant to compare with site-specific parameters to decide if groundwater corrosion is a concern and epoxy coated rebar should be used.

Section 3.8.5.6.1 also indicates that requirements for epoxy-coated rebar may be waived if a site-specific permanent dewatering system is provided. The EPR FSAR should specify that if a permanent dewatering system is used to protect Seismic Category I SSCs, then such a system should also be designated as a Seismic Category I system, unless further technical justification is provided to justify otherwise.

**Response to Question 03.08.05-13:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.05-14:**

FSAR Section 3.8.5.6.1 indicates that a textured geo-synthetic material will be considered on a site-specific basis for use as a waterproofing material, as shown in Figure 3.8-117. This figure indicates that the membrane will be placed between two halves of the mud mat, each about 3" thick. AREVA is requested to address the items listed below related to the use of this waterproofing material and provide further guidance in the EPR FSAR regarding its use:

1. If the first 3" thick half is poured (a very thin mud mat), what will be its potential for cracking and separation under site operational loads? What is the minimum mesh steel to be used for each half of the mud mat? What should be the crack size limits for the mud mat before the water-stopping capability of the membrane is compromised? How is the horizontal membrane to be placed between the two halves to be connected to the vertical waterproofing placed on the surrounding construction walls to provide a complete water barrier for the Category I structures?
2. The waterproofing membrane is indicated in Figure 3.8-117 to be "double-textured," implying that it is roughened on both sides. Explain how this waterproofing membrane achieves a 0.7 coefficient of friction, and how does the construction sequence (placing it on the already hardened concrete mud mat) affects this coefficient of friction. Furthermore, provide the basis for stating that the membrane is not safety related in light of the fact that it must transfer bearing loads, shear loads, and achieve a coefficient of friction of 0.7.
3. FSAR Section 3.8.5.6.1 indicates that the waterproofing membrane will be required for sites with a high water table. Considering that most soils can attract water to significant heights above the free ground water level by capillarity effects, how close does the free ground water table have to be to the bottom of the basemat before such waterproofing is required? Will the existence of perched ground water conditions also require the use of waterproofing? In fact, since the location of perched aquifers is always a serious potential at soil sites, explain why the waterproofing membrane should not always be included in the construction?

**Response to Question 03.08.05-14:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.05-15:**

FSAR Section 3.8.5.6.3 indicates that no special construction techniques need to be considered for this foundation system. However, as with all such heavy foundations of this size, the process for pouring these heavy sections needs to be carefully considered to ensure that differential settlements, particularly at softer soil sites, will not cause any distress to the system. For other generic plant designs, studies were performed to provide limitations to the construction process to ensure relatively uniform loads over the plan area. Although some mention is made in FSAR Section 3.8.5.5.1 of such differential settlement questions, no indication is provided to indicate if such studies have been performed for the EPR. AREVA is requested to provide the details of such studies of potential differential construction settlements for review.

**Response to Question 03.08.05-15:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.05-16:**

Various parts of FSAR Section 3.8.5 describe seismic analyses performed for the foundation of the structures. These seismic analyses had assumed certain soil properties in developing the models and calculating the response of the structures. These soil properties were used in developing soil springs for the overall NI structure, the brick element layer beneath the basemat in the second model, the coefficient of friction for sliding, calculation of lateral earth pressures, and other calculations. These include the soil properties beneath the basemat and the backfill materials at the embedded walls and basemat. AREVA is requested to identify the set of soil properties used in the various seismic analyses and designs of Seismic Category I structures and explain how this set of parameters will be ensured by the COL applicant. In addition, identify what testing requirements are to be performed by the COL applicant to be assured that the set of soil criteria are met. This information should be included in the EPR FSAR.

**Response to Question 03.08.05-16:**

A response to this question will be provided by June 30, 2009.

**Question 03.08.05-17:**

FSAR Section 3E.2.1 for the EPGB foundations and FSAR Section 3E3.1 for the ESWB foundations describe the basemat typical reinforcement configurations in FSAR Figures 3E.2-3 and 3E.3-3, respectively. These figures indicate the horizontal reinforcement pattern for each foundation design, but do not indicate whether this reinforcement is in the top or bottom of the slab. Provide additional figures showing key cross sections of the slabs that indicate the size, location and spacing of the top and bottom reinforcement, as well as any vertical reinforcement. Also, please reconcile the difference in the reinforcement for the NI foundation specified in FSAR Table 3E.1-37 and shown in FSAR Figure 3E.1-75.

**Response to Question 03.08.05-17:**

A response to this question will be provided by March 31, 2009.

**Question 03.08.05-18:**

A review of EPR FSAR Tier 1, Table 5.0-1, Site Parameters for the U.S. EPR Design and Tier 2, Table 2.1-1, U.S. EPR Site Design Envelope shows that a number of site parameters used in the analysis and design of structures are not included. Some examples include the bearing capacities for all Seismic Category I structures (not just the NI basemat), the dynamic bearing capacities (not just the static bearing capacity), soil parameters such as the soil minimum friction angle of 35 degrees, permissible horizontal and vertical variation in soil properties, and total building settlements beneath each Seismic Category I structure (not just relative displacements). AREVA is requested to review all important analysis and design parameters used in the calculations and ensure that these parameters are included in these two tables, or provide the technical justification for excluding them.

**Response to Question 03.08.05-18:**

A response to this question will be provided by June 30, 2009.

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description of additional requirements for missile barrier design and ductility requirements applicable to the design of the RCB.

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### 3.8.1.4.5 Creep, Shrinkage, and Cracking of Concrete

Conservative values of concrete creep and shrinkage ~~based on past experience~~ are used in the design of the RCB. Moments, forces, and shears are obtained on the basis of uncracked section properties in the static analysis. However, in sizing the reinforcing steel required, the concrete is not relied upon for resisting tension. Thermal moments are modified by cracked-section analysis using analytical techniques. The ANSYS computer code and the RCB model thermal stress evaluation, based on results from the heat transfer analysis, were used to evaluate cracking due to accident thermal loading. The material properties, specifically E (Young's modulus), for the finite elements, were redefined as bilinear. This approximation allows the moment of inertia of a wall section to reduce in proportion to the amount of cracking developed due to the thermal loading. The threshold tensile value for cracking, maximum tension in the concrete, is taken as $4\sqrt{f'_c}$. Elements are not allowed to heal once cracked. Results from this analysis are used to factor the thermal moments from the RCB static analysis for the design of concrete sections.

Section 3.8.1.6.1 describes methods used to confirm that concrete properties satisfy design requirements.

### 3.8.1.4.6 Dynamic Soil Pressure

Soil loads are not applicable to the design of the RCB because the building is completely surrounded by other structures above the NI Common Basemat Structure foundation basemat.

### 3.8.1.4.7 Tangential Shear

The design and analysis procedures for tangential shear are in accordance with the ASME BPV Code Section III, Division 2 and RG 1.136.

Tangential shear is resisted by the vertical reinforcement and the horizontal hoop reinforcement in the RCB wall.

### 3.8.1.4.8 Variation in Physical Material Properties

In the design and analysis of the RCB, consideration is given to the effects of possible variations in the physical properties of materials on the analytical results. The properties used for analysis purposes were established based on past engineering experience with similar construction and materials. Values used are delineated in Tables 3.8-2—Material Properties – Reactor Containment Building, 3.8-3—Tendon Frictional Losses, and 3.8-4—Thermal Properties – Reactor Containment Building.

### Table 3.8-5—Tendon Losses and Effective Forces with Time

| | | Hoop Tendons | | | | Vertical Tendons | | | | Gamma Tendons | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T = zero[1] (plant startup) | | T = 60 years[1] (plant shutdown) | | T = zero[1] (plant startup) | | T = 60 years[1] (plant shutdown) | | T = zero[1] (plant startup) | | T = 60 years[1] (plant shutdown) | |
| Description | | Value (ksi) | % loss | Value (ksi) | % loss | Value (ksi) | % loss | Value (ksi) | % loss | Value (ksi) | % loss | Value (ksi) | % loss |
| Tension at lock off | $f_{p\text{-ini}}$ | 197.10 | N/A | 197.10 | N/A | 197.10 | N/A | 197.10 | N/A | 197.10 | N/A | 197.10 | N/A |
| Loss due to friction | $\Delta f_{p\text{-fr}}$ | -49.38 | -25.1% | -49.38 | -25.1% | -9.66 | -4.9% | -9.66 | -4.9% | -43.81 | -22.2% | -43.81 | -22.2% |
| Loss due to elastic shortening | $\Delta f_{p\text{-es}}$ | -6.50 | -3.3% | -6.50 | -3.3% | -3.17 | -1.6% | -3.17 | -1.6% | -4.57 | -2.3% | -4.57 | -2.3% |
| Loss due to creep | $\Delta f_{p\text{-cr}}$ | -13.44 | -6.5% | -19.88 | -10.1% | -7.28 | -3.7% | -10.92 | -5.5% | -12.72 | -6.5% | -18.22 | -9.2% |
| Loss due to shrinkage | $\Delta f_{p\text{-sh}}$ | -3.36 | -1.7% | -11.20 | -5.7% | -3.36 | -1.7% | -11.20 | -5.7% | -3.65 | -1.9% | -11.77 | -6.0% |
| Loss due to steel relaxation | $\Delta f_{p\text{-sr}}$ | -7.88 | -4.0% | -9.86 | -5.0% | -7.88 | -4.0% | -9.86 | -5.0% | -7.88 | -4.0% | -9.86 | -5.0% |
| Sum of all losses | $\Sigma\Delta f_{p}$ | -80.56 | -40.9% | -96.82 | -49.2% | -31.35 | -15.9% | -44.81 | -22.7% | -72.63 | -36.9% | -88.23 | -44.7% |
| Effective Post Tension | $f_{p\text{-eff}}$ | 116.54 | 59.1% | 100.28 | 50.8% | 165.75 | 84.1% | -152.29 | 77.3% | 124.47 | 63.1% | 108.87 | 55.3% |

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**Note:**

1. To account for the length of the construction period and the relative ages of the RCB wall, dome and tendons, the tendon losses above assumed that at "T=zero (plant startup)," the age of the tendons is 4.0 years, the age of the RCB dome is 4.1 years, and the age of the RCB wall is 5.0 years.

#### 3.8.1.6.3 Tendon System Materials

*Tendons*

The post-tensioning tendon system consists of load-carrying and non-load-carrying components. The load-carrying components include the post-tensioning wires that make up the tendons, and anchorage components composed of bearing plates, anchor heads, wedges, and shims. Non-load-carrying components include the tendon sheathing (including sheaths, conduits, trumpet assemblies, couplers, vent and drain nipples, and other appurtenances) and corrosion prevention materials.

Materials used for the RCB post-tensioning system (including post-tensioning steel, anchorage components, and non-load-carrying and accessory components) meet the requirements of Subarticle CC-2400 of the ASME BPV Code, Section III, Division 2.

The Freyssinet C-range post-tensioning system has the following properties:

- ASTM A416 (Reference 36), Grade 270, low-relaxation tendon material.
- Tendon ultimate strength $F_{pu} = 270$ ksi
- Tendon minimum yield strength $F_{py} = (0.9)(270) = 243$ ksi
- Modulus of elasticity of tendon material $E_{ps} = 28{,}000$ ksi
- Number of strands per tendon $N_{strands} = 55$
- Total area of each tendon $A_p = 12.76$ in$^2$

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The materials used for the anchorage components are compatible with the tendon system. Tendon raceways consist of corrugated ~~metal tubing, rigid conduit, or high-density polyethylene tubing~~steel ducts and rigid metal conduit. These components are non-structural and are sealed to prevent the intrusion of concrete during construction.

*Grouting of Tendons*

Cement grout for the grouted tendon system in the RCB is selected based on the testing and material requirements of the ASME BPV Code, Section III, Division 2, as amended by RG 1.136, which endorses the Regulatory Positions of RG 1.107, Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures.

#### 3.8.1.6.4 Liner Plate System and Penetration Sleeve Materials

The 0.25 inch thick liner plate is ASTM A516, Grade 55, 60, 65 or 70 material, which conforms to Subarticle CC-2500 of the ASME BPV Code, Section III, Division 2 (GDC and temporary stiffeners are used on liner plate sections to satisfy code requirements for structural integrity of the modular sections during rigging operations.

### 3.8.1.7 Testing and Inservice Inspection Requirements

#### 3.8.1.7.1 Structural Integrity Test

Following construction, the RCB is proof-tested at 115 percent of the design pressure. During this test, deflection measurements and concrete crack inspections are made to confirm that the actual structural response is within the limits predicted by the design analyses (GDC 1).

The SIT procedure complies with the requirements of Article CC-6000 of the ASME BPV Code, 2004 Edition, Section III, Division 2, and with Subsections IWL and IWE of Section XI of the ASME BPV Code.

#### 3.8.1.7.2 Long-Term Surveillance

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The RCB is monitored periodically throughout its service life in accordance with 10 CFR Part 50.55a and 10 CFR Part 50, Appendix J, to evaluate the integrity of containment over time (GDC 1 and GDC 16). As part of this monitoring program, containment deformations and exterior surface conditions are determined while the building is pressurized at the maximum calculated DBA pressure ($P_a$). Initial conditions, baseline measurements taken at $P_a$, during depressurization following the SIT are established prior to initial operation. Initial measurements and in-service inspection meet the requirements of the following ~~requirements~~:

- ASME BPV Code, 2004 Edition, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Subsections IWE and IWL.
- Supplemental Inspection Requirements of 10 CFR Part 50.55a.~~RG 1.107, Revision 1 (February 1977).~~
- ASME BPV Code, 2004 Edition, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Subsection IWL, does not contain specifications for inservice inspection of grouted tendons. For inservice inspection of grouted tendons, the guidelines of RG 1.90, Revision 1 (February 1977) are followed with the following~~,~~ exceptions: ~~that:~~
  - Force monitoring of ungrouted test tendons is not provided:
    - This exception to RG 1.90 is acceptable because all tendons used within the RCB are fully grouted.
  - Pressurization at year one uses $P_a$ instead of $P_N$:
    - This exception is acceptable because the value of $P_a$ is higher than that of $P_N$.

– Pressurization at years three and seven uses $P_a$ instead of $1.15P_D$:

  - This exception is acceptable because the structural integrity is confirmed at year zero. Additional overpressurization to $1.15P_D$ unduly fatigues the structure and interrupts the surveillance tracking of containment response to $P_a$.

The EPR containment uses fully grouted tendons in each location. This methodology has several advantages:

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- Tendons are surrounded with a cementitious grout injected into the tendon duct; the alkaline composition of the grout mixture, in accordance with RG 1.107, Revision 1 (February 1977), inhibits corrosion of the steel strands and prevents the ingress of corrosive fluids (e.g., water).

- In the event of one or more strand failures during the life of the structure, the bond of the strand with grout and the grout to the concrete wall enables the remaining portion of the post-tensioning to be transmitted to the structure.

- Grouted tendons and tendon anchorages are less vulnerable to local damage than ungrouted tendons. Therefore, if the end anchorages are damaged, for instance by fire or missile impact, the post-tensioning force will be maintained along the effective length of the tendon.

- Grouted tendons increase the overall wall tightness by filling any voids from within the structure. This reduces the risk of water or other contaminates from entering through wall cracks or tendon end caps.

- European experience has found that grouted tendons significantly improve concrete crack distribution when the containment is pressurized to a point where the tensile stress of the concrete is exceeded. Less local large tensile strains are likely to occur thus diminishing the risk of having large concrete cracks behind the containment liner. The absence of large cracks improved the safety margin of the liner with regard to air tightness.

The use of grouted tendons precludes the possibility of directly measuring the post-tension force over time by lifting off at the anchorages. The U.S. EPR mitigates this concern by extensively monitoring the movement of the RCB during 10 CFR Part 50, Appendix J, leak-rate testing at $P_a$. The pressure test schedule is a part of the inservice inspection program. Movements obtained from the initial test will be used to baseline a structural analysis that will be used to predict the capacity of the RCB over time. Thirty-six RCB locations will be monitored for radial displacement, 6 for vertical displacement and 13 on the dome for tri-directional displacement. Table 3.8-7—ISI Schedule for the U.S. EPR.

The RCB is fully enclosed by the RSB; therefore, the potential for corrosion of the tendon system is significantly reduced.

Pressure capacities were evaluated for the reinforced area around the equipment hatch opening. The evaluation considered a horizontal plane and a vertical plane section passing through the centerline of the opening. The vertical plane section, which corresponds to hoop stress direction, was the weaker of the two planes. The ultimate pressure capacity reported is the median pressure capacity for the vertical plane section.

The equipment hatch cover and cylinder, shown inFigure 3.8-25—Equipment Hatch General Assembly has a cover ultimate pressure capacity based on ASME Section II, Part D material specification minimum required strengths and an elastic, perfectly plastic stress-strain relationship at 400°F. The internal pressure from containment is applied to the convex surface of the cover and non-embedded portion of the cylinder. The ultimate pressure capacity reported corresponds to ASME Service Level C stress limits for the hatch cover and cylinder.

### 3.8.1.4.12 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections 2.0, 2.4, 2.5, 3.3, 3.5, 3.8.1, 3.8.2, 3.8.3, 3.8.4, and 3.8.5. Design results are presented in Appendix 3E for Seismic Category I structure critical sections.

### 3.8.1.5 Structural Acceptance Criteria

The limits for RCB allowable stresses, strains, deformations and other design criteria are in accordance with the requirements of Subsection CC-3400 of the ASME BPV Code, Section III, Division 2 and RG 1.136 (GDC 1, GDC 2, GDC 4, GDC 16, and GDC 50). This applies to the overall containment vessel and subassemblies and appurtenances that serve a pressure retaining function, except as noted in Section 3.8.2. Specifically, allowable concrete stresses for factored loadings are in accordance with Subsection CC-3420 and those for service loads are in accordance with Subsection CC-3430.

The limits for stresses and strains in the liner plate and its anchorage components are in accordance with ASME BPV Code, Section III, Division 2, Tables CC-3720-1 and CC-3730-1.

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Limits for allowable loads on concrete embedments and anchors are in accordance with ACI 349-2001, Appendix B and guidance from RG 1.199.

Section 3.8.1.6 describes minimum requirements for concrete, reinforcing, post-tensioning tendons, and the liner plate system for the RCB.

A SIT is performed as described in Section 3.8.1.7.1.