ArevaEPRDCPEm Resource

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Sent:	Friday, September 17, 2010 8:25 AM
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Subject:	Draft - U.S. EPR Design Certification Application RAI No. 448 (4898, 5084), FSAR Ch. 3
Attachments:	Draft RAI_448_SEB2_4898_5084.doc

Attached please find draft RAI No. 448 regarding your application for standard design certification of the U.S. EPR. If you have any question or need clarifications regarding this RAI, please let me know as soon as possible, I will have our technical Staff available to discuss them with you.

Please also review the RAI to ensure that we have not inadvertently included proprietary information. If there are any proprietary information, please let me know within the next ten days. If I do not hear from you within the next ten days, I will assume there are none and will make the draft RAI publicly available.

Thanks,
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U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.08.01 - Concrete Containment
Application Section: 3.8.1

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

03.08.01-49

Follow-up to RAI 155, Question 3.8.1-10 (3)

The RAI response provided information about the FEM analysis of the RCB structure to determine its ultimate pressure capacity. The staff has evaluated the response and determined that the information provided is inadequate with respect to meeting 10 CFR 50, Appendix A, General Design Criterion (GDC) 50, as it relates to the reactor containment structure being designed with sufficient margin of safety to accommodate appropriate design loads, and as described in SRP 3.8.1.II.4.K (Rev. 2) The staff requests that the applicant clarify the response to Item 3 of the RAI as discussed below:

a. Regarding the FEM analysis of the RCB structure, provide technical justification to show that using a 2-degree slice of the RCB (one finite element thick) is acceptable to accurately represent axisymmetric behavior (e.g., RCB curvature). The staff notes that FEM studies of the RCB provided for other RAI responses (e.g., RAIs 3.8.1-9, 3.8.1-22, and 3.8.1-27) have used a 6-degree slice that is several elements thick. In addition, explain what is meant by the statement that the accident temperature load was applied in load steps 4 and 5 and how was this performed. The RAI response simply states that "accident temperature load (is applied) to liner elements." However, it is not clear whether the analysis considered the variation of the temperature gradient across the containment thickness or whether the maximum temperature gradient was utilized. Also, explain whether a thermal analysis for application of forces was performed and/or only to identify the temperatures in the different structural elements for selection of the appropriate material properties.

b. Regarding the FEM analysis of the equipment hatch, provide technical justification to show that ANSYS contact elements are appropriate to simulate leak tightness of the equipment hatch, and possibly other major penetrations that may need to be modeled (see Item d below). Explain why it is realistic to assume that no leakage occurs until the contact elements open, rather than to assume some minimum preload at the joint is necessary to ensure that no leakage occurs. In addition, it is not clear if the second failure mechanism described in the RAI response addresses the issue of buckling of the torispherical hatch cover resulting from hoop compression in the knuckle region, as indicated in SRP 3.8.1.II.4.K.iv "Special Considerations for Steel Elliptical and Torispherical Heads." If it does not, address this issue or provide the technical basis for deviating from SRP guidance.

c. There appears to be an inconsistency in the last line of the revised FSAR Table 3.8-6 included with the RAI response. Under "Failure Mode/Location" it states "'Loss' of leak tightness in protruding sleeve due to principal strain which approach ultimate." However, as described in the RAI response, loss of leak tightness in the FEM analysis is associated with opening of the contact elements and not with principal strains approaching limit values. Clarify this inconsistency.

d. The RAI response provides the results of deterministic analyses performed to calculate the ultimate capacity of the RCB structure and the equipment hatch. However, no results are given for the other penetrations of the RCB. The staff emphasizes that, according to SRP 3.8.1.II.K.iii, a complete evaluation of the internal pressure capacity must also address major containment penetrations as well as other potential leak paths through mechanical and electrical penetrations. To address this issue, provide the results of additional FEM analyses for other major penetrations, or provide the technical basis for not considering the other penetrations.

In addition, revise and update the relevant sections of the FSAR as needed to address the staff's concerns listed above.

03.08.01-50

Follow-up to RAI 155, Question 3.8.1-12

The RAI response has provided additional information regarding the U.S. EPR ISI program. The staff has evaluated the response and determined that the information provided is inadequate with respect to meeting 10 CFR 50.55a and 10 CFR 50, Appendix A, GDC 1, as they relate to concrete containment being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed, and as described in SRP 3.8.1.II.7.D and RG 1.90. The staff requests that the applicant provide clarifications as discussed below:

a. Regarding the criterion for using Pa as ISI test pressure in years 3 and 7, instead of 1.15Pd indicated in RG 1.90, the response states that: (a) using 1.15Pd as initial structural integrity test (ISIT) pressure confirms containment integrity and quality of construction; (b) continued pressurization of the containment to 1.15Pd would induce "unnecessary cyclic loading of the structure;" and (c) using Pa instead of 1.15Pd as ISI test pressure, "will establish a continuous basis for comparison of results, will minimize gradual propagation of cracking during subsequent pressure tests, and will be in compliance with the ISI requirements of ASME BVP Code Subsection IWL, Paragraph IWL-5220."

   The above justification for the exception taken to the ISI test pressures stipulated in RG 1.90 for years 3 and 7 is inadequate for reasons explained in the following.

   The statement of compliance with the ISI requirements of ASME BVP Code Subsection IWL, Paragraph IWL-5220 is not appropriate because Article 5000 of the Code is applicable to pressure testing of containments following repair/replacement activities and not the periodic ISI pressure tests. Also, the response implies that using 1.15Pd as ISI test pressure for years 3 and 7 is unnecessarily conservative and possibly detrimental. However, the staff notes that one of the considerations for using Alternative B (deformation monitoring under pressure tests, also see Item 2 below) given in RG 1.90 is that the design of the containment should be demonstrated with adequate conservatism (i.e., membrane compression stresses maintained and maximum tensile stress in reinforcement limited to one half of the yield strength during ISI pressure tests) so that cracking under repeated ISI pressure tests is minimized. It follows that, whether 1.15Pd or Pa is used as the ISI test pressure, the containment should be designed to minimize cracking under repeated ISI pressure tests in either case. Consequently, the design and pressure testing of the containment should meet the regulatory positions in RG 1.90 or adequate technical justification, preferably supported by quantitative data, should be provided for the exception taken to RG 1.90.

b. Regarding the exception to RG 1.90, by which force monitoring of ungrouted test tendons is not provided, the response states that: (a) ungrouted test tendons are used to evaluate prestress losses due to concrete creep and shrinkage, and tendon steel relaxation; however, since the ungrouted test tendons will be subject to cyclic loading during every ISI, the measured results may not accurately reflect the prestress losses in the containment as a whole, and this has been acknowledged in the past by NRC (Information Notice 99-10, Attachment 3); (b) rather than using ungrouted test tendons for the force monitoring of prestress losses, the U.S. EPR ISI program will implement deformation monitoring of the containment under Pa pressure, and compare results with expected deformation and ISIT deformation; (c) deformation monitoring of the containment during ISI pressure testing has been accepted in the past by NRC (Three Mile Island and Forked River NPPs); and (d) the technical literature reports one instance (Quinshan NPP, China) where monitoring of the prestress level in the containment has been accomplished using overall deformation measurements as an alternative to tendon force measurements.

   The response above gives insufficient technical justification for not providing force monitoring of ungrouted test tendons, as prescribed in RG 1.90. According to RG 1.90, the ISI program should consist of three distinct activities: (a) force monitoring of ungrouted test tendons; (b) periodic reading of instrumentation for determining prestress level (Alternative A) or monitoring of deformations under pressure (Alternative B) at preestablished sections; and (c) visual examination. Therefore, the deformation monitoring of the containment (item (b), Alternative B) does not eliminate the requirement to provide force monitoring of ungrouted test tendons (item (a)), but is an additional criterion of RG 1.90. Regarding Item (2)(c) in the above paragraph, explain how the acceptance by the NRC in two old NPPs for deformation monitoring of the containment during ISI tests demonstrates that monitoring of ungrouted tendons is not required. Regarding Item (2)(d) in the above paragraph, although the referenced paper reports an interesting case study where force monitoring was not used, the staff considers that it does not provide a technical basis for the exception taken to RG 1.90. Consequently, provide adequate technical justification, preferably supported by quantitative data, to demonstrate that ungrouted tendons are not needed.

c. FSAR Section 3.8.1.1 states that Pd is equal to 62 psig. The response to RAI 3.8.1-32 states that Pa (as used in the ISI) is set to 55 psig. This information should be added to FSAR Table 3.8-7 “ISI Schedule for the U.S. EPR.”

In addition, revise and update the relevant sections of the FSAR as needed to address the staff’s concerns listed above.

03.08.01-51

Follow-up to RAI 155, Question 3.8.1-22

The response to this RAI explains that an FEM analysis of a typical 6-degree slice of the RCB structure (away from discontinuities) was performed to evaluate the change in magnitude of the thermal moments in the RCB resulting from mesh refinement (linear analysis) and cracking of concrete (nonlinear analysis). Details of the FEM model are provided, including the computer code, the loading sequence, and the types of finite elements used in the analyses. Finally, the response indicates that the RCB is the only structure expected to develop a significant thermal gradient across its thickness; therefore, AREVA did not consider thermal loading for the RBIS, EPGB or ESWB.

To ensure compliance with 10 CFR 50, Appendix A, GDC 50, as it relates to the concrete containment being designed with sufficient margin of safety to accommodate appropriate design loads such as thermal loads, and as described in SRP 3.8.1.II.4.C and D, the staff finds that additional information is necessary to determine whether the approach used to reduce the thermal stresses in the RCB is conservative.

a. The RAI response states that the mesh density in the 6-degree slice FEM model is increased to calculate the change in thermal moments due to mesh refinement. Provide a description of this mesh refinement, include a figure of each model, and identify the relative sizes of the original vs. the refined mesh.

b. The RAI response indicates that a thermal modification factor due to mesh refinement was computed. Explain whether a single factor was used for the entire RCB, or multiple factors (e.g., different factor for each element or region) were used. If the latter is the case, also provide representative (max., min.) values of these modification factors and the elements/regions of the RCB to which they apply.

c. The RAI response indicates that thermal moments from the nonlinear FEM model, with concrete cracking included, are compared to the linear FEM model with the refined mesh and no concrete cracking, to determine the thermal modification factor due only to concrete cracking. Explain whether a single factor was used for the entire RCB, or multiple factors were used. If the latter is the case, also provide representative (max., min.) values of these modification factors and the elements/regions of the RCB to which they apply.

d. The final thermal moment reduction factor is calculated as the multiplication of the two thermal moment modification factors described in items 2 and 3 above. Again, explain whether a single factor was used for the entire RCB, or multiple factors were used. If the latter is the case, also provide representative (max., min.) values of these thermal moment reduction factors and the elements/regions of the RCB to which they apply.

e. Since the thermal modification factors are based on a nonlinear analysis (of the coarser-mesh FE model), identify the basis for stating that the final modification factors are simply the product of the thermal modification factors and the mesh refinement factors.

f. Explain how the thermal loads are applied to the nonlinear FEM model. The RAI response simply states that "the model is subjected to accidental pressure loads," or "the model is subjected to accidental temperature and pressure loads."

However, it is not clear whether the analysis considered the variation of the temperature gradient across the containment thickness at the four critical time points identified in the temperature and pressure transient analysis, or whether the maximum temperature gradient was utilized. Also, it is not clear whether the analysis considered the additional internal pressure due to the thermal expansion of the liner plate.

03.08.01-52

Follow-up to RAI 155, Question 3.8.1-27

The response to this RAI provides additional information on the FEM analysis procedures used to model the thermal and pressure transients from LOCA events. The staff has evaluated the response and determined that the information provided is inadequate with respect to meeting 10 CFR 50, Appendix A, GDC 50, as it relates to the concrete containment being designed with sufficient margin of safety to accommodate appropriate design loads such as thermal and pressure loads, and as described in SRP 3.8.1.II.4.C and D. The staff requests that the applicant provide additional information necessary to determine whether the FEM analysis is conservative, as described below:

a. Item 1 of the RAI response indicates that a six degree slice of the containment is studied for mesh refinement in consideration with thermal moment calculations, presumably as described in the response to RAI 3.8.1-22. Based on this study, AREVA indicates that the existing 4/5 element mesh through the thickness of the RCB overestimates the thermal gradient across the thickness, at the beginning of the accident period, and provides an accurate estimate of the thermal gradient at the later period of the accident, compared to the thermal gradient for a refined mesh. To complete the response to Item 1 of the RAI, provide some representative (max., min.) comparison results determined in this study, for selected elements/regions of the RCB, such that the magnitude of the stated conservatism can be quantified. Since the computed thermal moments are subsequently reduced by “thermal moment reduction factors,” as explained in the response to RAI 3.8.1-22, confirm that this conservatism is actually eliminated from the forces/moments used in the RCB design. Information regarding this issue should be provided in conjunction with the response to the follow-up to RAI 3.8.1-22, Items 1 and 2.

b. Item 4 of the RAI response confirms that ANSYS smeared concrete cracking constitutive models are used to model concrete cracking during thermal loading, presumably as described in the response to RAI 3.8.1-22. To complete the response to Item 4 of the RAI, confirm that the described FEM procedure is used to determine “thermal moment reduction factors,” as explained in the response to RAI 3.8.1-22. Information regarding this issue should be provided in conjunction with the response to the follow-up to RAI 3.8.1-22, Item 3.

03.08.01-53

Follow-up to RAI 211, Question 3.8.1-31

The RAI response has provided the additional information regarding the U.S. EPR ISI program. The staff has evaluated the response and determined that the information provided is inadequate with respect to meeting 10 CFR 50.55a and 10 CFR 50,

Appendix A, GDC 1, as it relates to concrete containment being designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed, and as described in SRP 3.8.1.II.7.D and RG 1.90. The staff requests that the applicant provide further clarification as discussed below:

a. Regarding the issue of maximum tensile stresses in the RCB reinforcement under the ISI test pressure, the RAI response appears to contradict subsequent discussions with AREVA. During the meeting on December 14 and 15, 2009, AREVA indicated that the RCB design is consistent with the criterion in RG 1.90, Alternative B, which prescribes a maximum tensile stress of 0.5fy in the reinforcement under the ISI test pressure. The staff notes that one of the considerations for using Alternative B (deformation monitoring under pressure tests) given in RG 1.90 is that the design of the containment should be conservative so that cracking under repeated ISI pressure tests is minimized. It follows that, whether 1.15Pd or Pa is used as the ISI test pressure, the containment should be designed to minimize cracking under repeated ISI pressure tests in either case. Therefore, confirm that the RCB is designed so that, under ISI test pressure, membrane compression stresses are maintained and maximum tensile stresses in the reinforcement are limited to 0.5fy, regardless of whether 1.15Pd or Pa is used as the ISI test pressure. It is emphasized that the issue of ISI pressurization levels is pending resolution under RAI 3.8.1-12.

b. No mention is made in either FSAR Section 3.8.1.7.2 or the RAI response of the visual examination component of the ISI program. The staff notes that according to RG 1.90 the ISI program should consist of three distinct activities: (a) force monitoring of ungrouted test tendons; (b) periodic reading of instrumentation for determining prestress level (Alternative A) or monitoring of deformations under pressure (Alternative B) at preestablished sections; and (c) visual examination. The force monitoring of ungrouted test tendons is pending resolution under RAI 3.8.1-12. However, additional information should be provided on the visual examination component of the ISI program. This information should also be included in the appropriate sections of the FSAR.

In addition, revise and update the relevant sections of the FSAR as needed to address the staff's concerns listed above.

03.08.01-54

Follow-up to RAI 155, Question 03.08.01-8

1. The response to Item 1 of the RAI confirms that a single FE model of the NI, including RCB, RSB, RBIS, SB, FB, and common basemat, has been used for analysis of all loads identified in FSAR Section 3.8.1.3. The response also provides a description of how each of the following loads is applied to the FE model: dead loads (D), live loads (L), soil loads (H), hydrostatic loads (F), thermal loads (To), normal pipe reactions (Ro), tendon loads (J), relief valve loads (G), pressure variant loads (Pv), construction loads, test loads (Pt and Tt), temperature loads (Ta), pressure loads (Pa), accident pipe reactions (Ra), pipe break loads (Rr), and seismic loads (E').

   The staff has evaluated the response and determined that the information provided is inadequate with respect to meeting 10 CFR 50, Appendix A, GDC 2, as it relates to the design of safety-related structures being able to withstand the most severe natural phenomena such as earthquakes, and GDC 50, as it relates to the concrete containment being designed with sufficient margin of safety to accommodate appropriate design loads, and as described in SRP 3.8.1.II.3 and 4. The staff requests that the applicant clarify the response to Item 1 of the RAI as discussed below.

In addition, the staff finds several inconsistencies between loads described in this RAI response and those described in other RAI responses. Some of these inconsistencies are related to RAIs pending resolution, while others are due to ongoing changes in the analysis methods (e.g., new FEM SSI analysis of the NI, revised set of soil cases). Therefore, to resolve Item 1 of this RAI, reconcile and resubmit the response to reflect the current status of the DC application.

a. The RAI response indicates that there are no (L), (H) and (F) loads applied to the FE model of the RCB. However, the response to RAI 3.8.1-5 Item 2 states that (L) loads are applied "in the Reactor Building near the equipment hatch (due to staging of equipment during a refueling outage)." Also, the response to RAI 3.8.1-7 Item 2 indicates that (L), (H), and (F) loads are applied to the RCB indirectly through the basemat. Clarify these inconsistencies.

b. The RAI response states that (Ro) and (Ra) loads are not applied to the FE model of the RCB since they are considered part of the local design. However, the response to RAI 3.8.1-26 indicates that these are independent loads applied to the FE model of the NI. Clarify this inconsistency. In addition, provide additional details of how these loads are applied to the FE model of the NI; especially, a description of how multi-directional effects are considered.

c. The RAI response provides details on how (J) loads are developed and applied to the FE model of the RCB to account for three-dimensional tendon profiles, geometric and material properties of the tendons and containment, wobble and curvature effects, creep and shrinkage properties of concrete, relaxation of tendon materials, and number of jacking ends, for both a 0-year and a 60-year period. Since the response to RAI 3.8.1-35 states "Bonding between the tendon and surrounding grout is not assumed in RCB design," explain whether the methodology used for determining (J) loads is consistent with the unbounded tendon assumption.

d. The RAI response provides details of how seismic ZPA values in the three principal directions are computed for different elevations of the RCB. The response indicates that these ZPA computations are based on stick models used in the SSI analysis for the various soil types and ground motions considered in the FSAR. However, as indicated in the response to RAI 3.8.5-8, a new FEM SSI analysis of the NI has been performed using fully embedded conditions for a reduced number of soil cases. The stick models have been superseded by this new analysis methodology and are no longer applicable. Clarify this inconsistency.

2. . The response to Item 6 of the RAI indicates that the RCB liner is modeled with 4-node SHELL181 elements applied on the inner surface as a pressure load transfer element, smeared over the inner face of the SOLID45 concrete elements. The liner and its anchorages are not considered as structural elements in the structural design of the RCB, so the liner anchorage is not explicitly modeled in the FE model. The stiffness of the liner material is reduced to 1% of its actual value to make the liner structurally inactive in the FE model. Finally, liner anchorage design loads are not determined from FE analysis but are determined using an energy approach described in Bechtel Topical Report BC-TOP-01 Rev. 1 (1971) "Containment Building Liner Plate Design Report."

To ensure compliance with 10 CFR 50, Appendix A, GDC 16, as it relates to the capability of the concrete containment to act as a leak-tight membrane, and as described in SRP 3.8.1.II.4.J, explain how the liner plate is designed for “local” loads that are not applied to the FE model of the RCB (e.g., jet impingement loads). Also, provide a description of the energy approach used to determine anchorage design loads (which is stated to follow Bechtel Topical Report BC-TOP-01 Rev. 1), as well as a discussion on how the anchorage design satisfies ASME BVP Code, Section III, Division 2, Article 3810, items (a) through (h). Finally, include a summary of this information in the relevant sections of the FSAR.

03.08.01-55

Follow-up to RAI 306, Question 3.8.1-42

The RAI response states that the design of structural steel members is based on the conservative use of the minimum allowable material stress values provided in FSAR Table 3.8-8. The design specifies a particular minimum value to be used in the fabrication of the component, and the stress values of the materials actually used in fabrication will be confirmed by certified material test reports and certificates.

To resolve this RAI: (a) add the above statements to the FSAR, and (b) explain why FSAR Table 3.8-8 lists A276 (martensitic) steel twice, with inconsistent stress ranges.