ArevaEPRDCPEm Resource

From:	WELLS Russell (AREVA) [Russell.Wells@areva.com]
Sent:	Thursday, May 12, 2011 7:34 PM
To:	Tesfaye, Getachew
Cc:	CORNELL Veronica (EXTERNAL AREVA); WILLIAMSON Rick (AREVA); BREDEL Daniel (AREVA); Miernicki, Michael; BENNETT Kathy (AREVA); DELANO Karen (AREVA); HALLINGER Pat (EXTERNAL AREVA); ROMINE Judy (AREVA); RYAN Tom (AREVA); WILLIFORD Dennis (AREVA)
Subject:	Draft Revised Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Question 03.08.01-49
Attachments:	RAI 448 Q3.8.1-49 Response MASTER - DRAFT Rev 1 - US EPR DC.pdf

Getachew,

Attached is a revised draft response for RAI No. 448, FSAR Ch 3, Question 03.08.01-49 in advance of the June 10, 2011 final response date.

Let me know if the staff has questions or if the draft response can be sent as a final response.

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
AREVA NP, Inc.
3315 Old Forest Road, P.O. Box 10935
Mail Stop OF-57
Lynchburg, VA 24506-0935
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Russell.Wells@Areva.com

From: WELLS Russell (RS/NB)
Sent: Thursday, May 12, 2011 7:30 PM
To: 'Tesfaye, Getachew'
Cc: CORNELL Veronica (External RS/NB); BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Supplement 4

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 448 on November 22, 2010. To allow additional time to finalize the responses and interact with NRC staff, the schedule has been revised. On February 11, 2011, AREVA NP submitted Supplement 1 to provide a revised schedule for the final responses. On March 17, 2011, AREVA NP submitted Supplement 2 to provide a final response to Question 03.08.01-55 and a revised schedule for the final responses to Questions 03.08.01-49, 03.08.01-50, 03.08.01-51, 03.08.01-52, 03.08.01-53 and 03.08.01-54. On April 27, 2011, AREVA NP submitted Supplement 3 to provide final responses to Questions 03.08.01-53 and 03.08.01-54 and a revised schedule for Questions 03.08.01-50, 03.08.01-51and 03.08.01-52.

The schedule for Question 03.08.01-49 is being revised. The schedule for the remaining questions is unchanged.

The schedule for technically correct and complete responses to the remaining questions is provided below.

Question #	Response Date
RAI 448 — 03.08.01-49	**June 10, 2011**
RAI 448 — 03.08.01-50	May 24, 2011
RAI 448 — 03.08.01-51	July 8, 2011
RAI 448 — 03.08.01-52	July 8, 2011

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
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From: WELLS Russell (RS/NB)
Sent: Wednesday, April 27, 2011 5:04 PM
To: 'Tesfaye, Getachew'
Cc: CORNELL Veronica (External RS/NB); BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Supplement 3

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 448 on November 22, 2010. To allow additional time to finalize the responses and interact with NRC staff, the schedule has been revised. On February 11, 2011, AREVA NP submitted Supplement 1 to provide a revised schedule for the final responses. On March 17, 2011, AREVA NP submitted Supplement 2 to provide a final response to Question 03.08.01-55 and a revised schedule for the final responses to Questions 03.08.01-49, 03.08.01-50, 03.08.01-51, 03.08.01-52, 03.08.01-53 and 03.08.01-54.

The attached file, “RAI 448 Supplement 3 Response US EPR DC.pdf” provides technically correct and complete FINAL responses to Questions 03.08.01-53 and 03.08.01-54, as committed.

The following table indicates the page in the response document, “RAI 448 Supplement 3 Response US EPR DC.pdf” that contains AREVA NP’s response to the subject questions.

Question #	Start Page	End Page
RAI 448 — 03.08.01-53	2	3
RAI 448 — 03.08.01-54	4	8

The schedule for Question 03.08.01-50 is being revised to allow additional time for AREVA NP to interact with the NRC. The schedule for Questions 03.08.01-51and 03.08.01-52 is being revised to allow AREVA NP additional time to address NRC Comments. The schedule for the remaining question is unchanged.

The schedule for technically correct and complete responses to the remaining questions is provided below.

Question #	Response Date
RAI 448 — 03.08.01-49	May 16, 2011
RAI 448 — 03.08.01-50	**May 24, 2011**
RAI 448 — 03.08.01-51	**July 8, 2011**
RAI 448 — 03.08.01-52	**July 8, 2011**

Sincerely,

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From: WELLS Russell (RS/NB)
Sent: Thursday, March 17, 2011 10:55 AM
To: 'Tesfaye, Getachew'
Cc: CORNELL Veronica (External RS/NB); BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Supplement 2

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 448 on November 22, 2010. To allow additional time to finalize the responses and interact with NRC staff, the schedule has been revised. On February 11, 2011, AREVA NP submitted Supplement 1 to provide a revised schedule for the final responses.

The attached file, “RAI 448 Supplement 2 Response US EPR DC.pdf” provides a technically correct and complete FINAL response to question 03.08.01-55, as committed.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 448 Question 03.08.01-55.

The following table indicates the page in the response document, “RAI 448 Supplement 2 Response US EPR DC.pdf” that contains AREVA NP’s response to the subject question.

Question #	**Start Page**	**End Page**
RAI 448 — 03.08.01-55	2	2

The schedule for Questions 03.08.01-49, 03.08.01-50, 03.08.01-51, 03.08.01-52, 03.08.01-53 and 03.08.01-54 is revised to allow additional time for AREVA NP to interact with the NRC.

The schedule for technically correct and complete responses to the remaining questions is provided below.

Question #	Response Date
RAI 448 — 03.08.01-49	May 16, 2011
RAI 448 — 03.08.01-50	April 27, 2011
RAI 448 — 03.08.01-51	April 27, 2011
RAI 448 — 03.08.01-52	April 27, 2011
RAI 448 — 03.08.01-53	April 27, 2011
RAI 448 — 03.08.01-54	April 27, 2011

Sincerely,

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From: BRYAN Martin (External RS/NB)
Sent: Friday, February 11, 2011 3:18 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Supplement 1

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 448 on November 22, 2010. To allow additional time to finalize the responses and interact with NRC staff, the schedule has been revised.

The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 448 — 03.08.01-49	March 25, 2011
RAI 448 — 03.08.01-50	March 18, 2011
RAI 448 — 03.08.01-51	March 18, 2011
RAI 448 — 03.08.01-52	March 18, 2011
RAI 448 — 03.08.01-53	March 18, 2011
RAI 448 — 03.08.01-54	March 18, 2011
RAI 448 — 03.08.01-55	March 18, 2011

Sincerely,

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From: BRYAN Martin (External RS/NB)
Sent: Monday, November 22, 2010 10:13 AM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 448 Response US EPR DC.pdf" provides a schedule since a technically correct and complete response to the 7 questions can not be provided at this time.

The following table indicates the respective pages in the response document, "RAI 448 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 448 — 03.08.01-49	2	3
RAI 448 — 03.08.01-50	4	5
RAI 448 — 03.08.01-51	6	7
RAI 448 — 03.08.01-52	8	8
RAI 448 — 03.08.01-53	9	9
RAI 448 — 03.08.01-54	10	11
RAI 448 — 03.08.01-55	12	12

A complete answer is not provided for the 7 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 448 — 03.08.01-49	February 28, 2011
RAI 448 — 03.08.01-50	February 28, 2011
RAI 448 — 03.08.01-51	February 28, 2011
RAI 448 — 03.08.01-52	February 28, 2011
RAI 448 — 03.08.01-53	February 28, 2011
RAI 448 — 03.08.01-54	February 28, 2011
RAI 448 — 03.08.01-55	February 28, 2011

Sincerely,

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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Monday, October 25, 2010 4:41 PM
To: ZZ-DL-A-USEPR-DL
Cc: Xu, Jim; Hawkins, Kimberly; Miernicki, Michael; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 448 (4898, 5084),FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on September 17, 2010, and discussed with your staff on October 25, 2010. No changes were made to the draft RAI 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
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 2983

Mail Envelope Properties (1F1CC1BBDC66B842A46CAC03D6B1CD41045A4EAE)

Subject: Draft Revised Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Question 03.08.01-49
Sent Date: 5/12/2011 7:33:43 PM
Received Date: 5/12/2011 7:33:57 PM
From: WELLS Russell (AREVA)

Created By: Russell.Wells@areva.com

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Files	**Size**	**Date & Time**
MESSAGE	11535	5/12/2011 7:33:57 PM
RAI 448 Q3.8.1-49 Response MASTER - DRAFT Rev 1 - US EPR DC.pdf	351494	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

Response to

Request for Additional Information No. 448(4898, 5084), Revision 0
Question 03.08.01-49, Revision 1

10/25/2010

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)

Question 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.

Response to Question 03.08.01-49:

Item a:

Both two degree (one element thick in this analysis) and six degree slices (multiple elements thick in other analyses) were used considering solid elements that provide plasticity and rebar input in the hoop direction. Either a two degree slice or a six degree slice would give similar or identical results when axisymmetric boundary conditions are applied to reduce the problem from a 3D to a 2D, (i.e., axisymmetric), problem. In the two degree slice model, boundary nodes at zero degrees and two degrees were constrained tangentially and radial and/or vertical growth was allowed in the Reactor Containment Building (RCB) cylinder and dome. In addition, node pairs at the same elevation and radius were coupled radially and vertically. Radial constraint is needed at the symmetry axis (R=0), and at vertical constraints along the underside of the basemat. Tendons and reinforcement were modeled as membrane elements only. The three rotational degrees of freedom of membrane elements were constrained for all nodes. This reduces the model to a true axisymmetric problem. As a result of pseudo axisymmetric boundary conditions nodal displacements are similar to an axisymmetric model and are the same for a one element or multiple elements thick model. Since the stiffness matrix is based on the tangent modulus calculated at Gaussian points of every element, the stiffness matrix of the one element thick, two degree slice is similar to the multiple elements thick model. Strains are calculated from displacements of nodes for each element using the strain displacement matrix. Stresses are calculated from strains. The number of elements across the width within the slice is therefore not a factor.

Load steps were as follows:

1. Initialization (no applied loads).
2. Dead load.
3. Hoop, vertical, and dome tendon prestress at 60 years. In step 3, tendon tensile prestress is verified. Also, other components are verified to remain in compression.
4. Accident temperature load is applied statically as a non-transient element temperature load in ANSYS and is, based on 309° F at the liner. In a separate transient thermal analysis for the RCB wall, the temperature at the location of inner rebar is 194° F and the exterior concrete surface is 86° F when the liner reaches 309° F. Therefore, the concrete and liner material properties at elevated temperatures are used for steps 4 and 5 analyses. The rebar and tendon material properties do not change significantly at elevated temperatures and hence remain unchanged in the analyses.
5. Containment pressure is applied to the liner SHELL181 elements in one psi increments from zero up to the ultimate pressure defined at 0.8 percent limiting membrane strain for potential failure locations or until the analysis fails to converge. Material properties and stress-strain curves are determined based on the applied temperature in step 4. The concrete

constitutive model includes tensile cracking. At high pressures, most concrete elements will be in tension and crushing will occur in local areas, such as the basemat top surface.

NUREG/CR-6906, Appendix A results show that temperatures up to 400° F have only a small effect on the ultimate capacity since the cracked concrete carries no tension, regardless of temperature. The ultimate capacity is therefore primarily determined by the rebar or tendons. In accordance with NUREG/CR-6906, the pressure transient may be considered independent of the thermal load because the peak pressure may not occur simultaneously with peak thermal loads. The transient nature of the pressure and thermal loading is usually ignored since the duration of the loading is usually longer than the period of the structure. Therefore, static analysis methods are considered adequate.

A closed form solution was used to verify the ultimate pressure capacity based on the assumption that steel components reach their self yield strains simultaneously, specifically 0.8 percent for tendon, 0.21 percent for rebar, and 0.12 percent for the liner with concrete neglected. In the finite element pseudo-axisymmetric model, the rebar and liner exceed their yield strains, but remain below the 0.8 percent limiting strain, well before the tendons reach 0.8 percent strain. Since the tendon yield strain is more than 0.8 percent, the tendons remain elastic up to the ultimate pressure capacity.

The safety margin from the closed form solution for each steel component away from the discontinuity is either equal to or greater than the corresponding safety margin in the finite element solution. This further validates the use of the pseudo-axisymmetric model (with respect to boundary conditions, two degree slice, etc.). The calculated safety margins are conservative based on NUREG/CR-6906, where the failure criterion can be based on an average hoop strain of one to two percent. The liner does not contribute significantly to the overall pressure capacity of the concrete containment.

The equipment hatch ultimate analysis results with buckling, and containment building ultimate capacity pressure values in U.S. EPR FSAR Tier 2, Section 3.8.1.4.11 and Table 3.8-6 will be revised to be consistent with the updated containment pressure and temperature analysis results.

Item b:

The complete length of the sleeve backed by the containment wall is modeled in the equipment hatch finite element analysis. Boundary conditions between the concrete wall and sleeve of the hatch cylinder are simulated with non-linear springs (compression only). The imposed displacements of the containment wall due to dead weight, tendon prestress, accident temperature, and overpressure are simulated as displacements at spring supports that may act as a restraint force within the hatch cylinder and tend to ovalize the cylinder.

The contact of the flanges between the clamps is modeled by non-linear leak-tightness springs (compression only) that carry the vertical dead load of the hatch cover using the contact compression force, and contact elements with elastic Coulomb friction. The contact compression force is generated by the prestressing force within the clamps. The prestressing force provides leak-tightness in the sealing ring and compression forces to activate friction for the load transfer of the hatch cover dead load. There is no loss in compression forces in the joints at twice the design pressure; therefore leak tightness of the hatch is maintained.

Inside the RCB, the internal pressure load acts only on protruding parts of the hatch, which are the hatch cover and protruding part of the hatch cylinder. The sealing strip between the clamps remains in compression, which means that the contact springs that represent the contact surface of the flanges between the clamps remain in compression, and remains leak-tight up to an internal pressure, 131 psi (greater than two times design pressure). All other steel component strains are within the allowable strains.

The internal pressure load on the hatch cover results in very high axial forces in the axial direction of the hatch because of the large exposed surface, as compared to other penetrations. The load is transmitted into the concrete by 120 embedded radial ribs (one inch thick plates). The radial ribs are designed to carry more than 156 psi overpressure (greater than 2.5 times design pressure) and serve as buckling stiffeners for the sleeve. The buckling analysis confirms that the torispherical hatch cover and the one inch thick protruding sleeve buckle at 128.5 psi.

Item c:

The safety margin for ultimate pressure capacity of containment is controlled by the ASME Service Level D allowable buckling, pressure or the stability of the hatch cover. The safety margin for ultimate pressure capacity of containment is not controlled by the strains in other steel components that have higher safety margins. U.S. EPR FSAR Tier 2, Section 3.8.1.4.11 and Table 3.8-6 will be revised to clarify the ultimate pressure controlling mode.

Item d:

An ultimate pressure capacity evaluation was performed for other major containment penetrations including the construction opening closure, containment dedicated spare penetration, personnel airlocks, fuel transfer tube, and the main steam and feedwater line penetrations. U.S. EPR FSAR Tier 2, Section 3.8.1.4.11 will be revised to describe the ultimate pressure capacity evaluations.

The ultimate capacity is evaluated using the design basis accident temperature and the following criteria:

1. Structural Capacity - A pressure 2.5 times the containment design pressure (2.5 x 62 psig = 155 psig) is applied to the penetration. The resulting strain levels are compared against the ASME Subsection CC factored strain allowable values in Table CC-3720-1. The 2.5 times design pressure is considered to be adequate to demonstrate sufficient margin above the design pressure for the ultimate capacity evaluation.

2. Stability (or buckling) - A stability analysis is performed to determine the buckling pressure in accordance with ASME Subsection NE, paragraph NE-3222, where one-third of the basic compressive allowable stress is considered or the buckling pressure is determined in accordance with NE-3133. ASME Service Level D allowable buckling pressures are determined. Strain values are determined from application of the allowable buckling pressure in an analysis with non-linear material properties and compared against the ASME Subsection CC factored strain allowable values in Table CC-3720-1.

   The deterministic stability (buckling) capacity is a code based calculation which, although reported as a Service Level D pressure, still contains a large safety margin. For the equipment hatch cover, the construction opening closure, and the personnel airlock hatch cover, the calculated allowable pressure for stability (buckling) controls the predicted ultimate capacity of the penetration. Although buckling is not a ductile failure mode, the actual stability failure pressure values are expected to be in the range of 2.5 times the design pressure as a result of the stability pressure being calculated based on the ASME Service Level D code.. The equipment hatch structural capacity based on limiting strains will be the predicted initial ultimate capacity controlling mode.

3. Potential Leak Paths - The sealing mechanisms and strain levels in the metallic components at the ultimate capacity pressure are evaluated to demonstrate that no containment leak paths are created.

Construction Opening Closure

The structural capacity of the construction opening closure is determined by finite element analysis techniques as described in the revised response to RAI 354, Question 03.08.02-11. The resulting strains from the application of the ultimate capacity pressure evaluations are compared with ASME Table CC-3720-1 factored allowable strain values in Table 03.08.01-49-1.

The construction opening closure is a spherical shell. The stability analysis is performed in accordance with NE-3133.4 as described in the revised Response to RAI 354, Question 03.08.02-13. The allowable pressure for buckling is 79 psig. In accordance with NE-3222, the compressive allowable stress is increased by 150 percent for Service Level D, which gives an ultimate capacity buckling pressure of 118.5 psig.

The calculated strains at the buckling pressure are compared with ASME, Table CC-3720-1 factored allowable strain values in Table 03.08.01-49-1. The construction opening closure is a welded cap. The calculated strain values do not exceed the values in ASME Table CC-3720-1. Therefore, the leak-tight integrity of the penetration is maintained at the evaluated pressures.

Containment Dedicated Spare Penetration

The capacity of the containment dedicated spare penetration sleeve is bounded by the main steam line penetration. The containment dedicated spare penetration closure capacity is bound by the construction opening closure as described in the Response to RAI 354, Question 03.08.02-11. The ultimate capacity of the containment dedicated spare penetration does not govern the ultimate capacity of the U.S. EPR containment and is not evaluated explicitly.

Personnel Airlocks

The structural capacity of the personnel airlocks is determined by finite element analysis techniques as described in the revised Response to RAI 354, Question 03.08.02-11. The resulting strains from the application of the ultimate capacity pressure evaluations are compared with ASME Table CC-3720-1 factored allowable strain values in Table 03.08.01-49-2.
The personnel airlocks consist of a complex geometry. The stability analysis is performed by a rigorous analysis in accordance with NE-3222.1(a)(1), as described in the revised Response to RAI 354, Question 03.08.02-13.

The basic allowable pressure for buckling of the airlock door is 79.6 psig. In conformance with NE-3222, the basic compressive allowable stress is increased by 150 percent for Service Level D, which gives an ultimate capacity buckling pressure of 119.4 psig.

The basic allowable pressure for buckling of the airlock cylinder is 81.67 psig. In conformance with NE-3222, the basic compressive allowable stress is increased by 150 percent for Service Level D, which gives an ultimate capacity buckling pressure of 122.5 psig. The airlock cylinder ultimate capacity buckling pressure is being re-evaluated to take into account the size of imperfections assumed in the buckling analysis. The final ultimate capacity buckling pressure will be reported in the final response to this RAI question.

The calculated strains at the buckling pressures are compared with ASME Table CC-3720-1 factored allowable strain values in Table 03.08.01-49-2. The airlock cylinder calculated strain values are based on a conservative pressure of 124.5 psig compared to the predicted strain values at the calculated buckling pressure of 122.5 psig. The higher value is reported based on a previous analysis.

The airlock leak-tight integrity is maintained by limiting the strains of the metallic parts to less than the allowable strain values in ASME Table CC-3720-1. The airlock seals are positive seating with the containment internal pressure. Since the airlock seals remain compressed with the strain limits for the metal components in the vicinity of the airlock door seals. The leak-tight integrity of the penetration is maintained at the containment ultimate capacity pressures.

Fuel Transfer Tube

The structural capacity of the fuel transfer tube is determined by finite element analysis techniques as described in the revised Response to RAI 354, Question 03.08.02-12. The resulting strains from the ultimate capacity pressure evaluations are compared with ASME Table CC-3720-1 factored allowable strain values in Table 03.08.01-49-3.

The stability analysis of the fuel transfer tube is performed by a rigorous analysis in accordance with NE-3222.1(a)(1) and Code Case N-284-1. A non-linear finite element analysis is performed by incrementally applying pressure until the solution no longer converges. The allowable pressure for buckling is 230 psig, which is greater than 2.5 x Pd (155 psig). The ultimate capacity results are reported at 2.5 Pd (155 psig).

The fuel transfer tube leak-tight integrity is maintained by limiting the strains of the metallic parts to less than the allowable strain values in ASME Table CC-3720-1. The fuel transfer tube has a blind flange on the containment side which has positive seating with the containment internal pressure. The fuel transfer tube flange remains seated with the strain limits considered for the metal components in the vicinity of the blind flange. The leak-tight integrity of the penetration is therefore maintained at the containment ultimate capacity pressures.

Main Steam and Feedwater Line Penetrations

The structural capacity of the main steam and feedwater line penetrations is determined by finite element analysis techniques as described in the revised Response to RAI 354, Question 03.08.02-11. The resulting strains from the application of the ultimate capacity pressure evaluations are compared with ASME Table CC-3720-1 factored allowable strain values in Table 03.08.01-49-4.

Buckling is not a failure mechanism for the main steam and feedwater line penetrations because the penetrations act as short columns with a slenderness ratio (kl/r) less than 89 (structural steel).

The main steam and feedwater line penetrations leak-tight integrity is maintained by limiting the strains of the metallic parts to less than the factored allowable strain values in ASME Table CC-3720-1. The leak-tight integrity of the penetration is maintained at the containment ultimate capacity pressure.

The minimum ratio of the ultimate capacity pressure (Pu) and the design pressure (Pd) and controlling mode or location is summarized in Table 03.08.01-49-5. Table 03.08.01-49-5 information will be added to U.S. EPR FSAR Tier 2, Table 3.8-6.

Table 03.08.01-49-1—Construction Opening Closure Strains

Pressure	Membrane		Combined Membrane and Bending	
	ε_{st} in/in	ε_{sc} In/in	ε_{st} in/in	ε_{sc} In/in
2.5 x Design Pressure (155 psig)	0.002782	0.002803	0.004058	0.002963
Level D Buckling Pressure (118.5 psig)	0.002779	0.002803	0.004058	0.002963
Allowable (Table CC-3720-1)	0.003	0.005	0.010	0.014

Table 03.08.01-49-2—Personnel Airlock Strains

Pressure	Membrane		Combined Membrane and Bending	
	ε_{st} in/in	ε_{sc} In/in	ε_{st} in/in	ε_{sc} In/in
Airlock Door				
2.5 x Design Press (155 psig)	0.0016	-0.0012	0.0021	-0.0015
Buckling Pressure (119.4 psig)	0.0011	-0.0008	0.0014	-0.0008
Airlock Cylinder				
2.5 x Design Press (155 psig)	0.002539	0.003665	0.004723	0.003849
Buckling Pressure (122.5 psig)[1]	0.002540	0.003575	0.004547	0.003754
Allowable (Table CC-3720-1)	0.003	0.005	0.010	0.014

Note 1: The airlock cylinder buckling strain values are reported for a conservative pressure of 124.5 psig.

Table 03.08.01-49-3—Fuel Transfer Tube Strains

Pressure	Membrane		Combined Membrane and Bending	
	ε_{st} in/in	ε_{sc} In/in	ε_{st} in/in	ε_{sc} In/in
2.5 x Design Press (155 psig)	0.003	0.0025	0.0031	0.0025
Allowable (Table CC-3720-1)	0.003	0.005	0.010	0.014

Table 03.08.01-49-4—Main Steam and Feedwater Line Penetration Strains

Pressure	Membrane		Combined Membrane and Bending	
	ε_{st} in/in	ε_{sc} In/in	ε_{st} in/in	ε_{sc} In/in
2.5x Design Press (155 psig)	0.003	0.0032	0.0047	0.0033
Allowable (Table CC-3720-1)	0.003	0.005	0.010	0.014

Table 03.08.01-49-5—Ultimate Pressure Capacity

Penetration	Pressure Capacity		Controlling Mode/ Location
	Pu (psi)	Minimum Ratio (Pu/Pd)	
Construction Opening Closure	118.5	1.91	ASME Code Level D allowable pressure to ensure no stability/buckling in the knuckle region of the opening cover
Personnel Airlocks	119.4	1.93	ASME Code Level D allowable pressure to ensure no stability/buckling in the airlock hatch cover
Fuel Transfer Tube	155[1]	2.5[1]	High strains in the containment sleeve portion not backed by concrete
Main Steam and Feedwater Line Penetrations	155[1]	2.5[1]	High strains in the containment sleeve portion not backed by concrete

Note 1- The ultimate pressure capacity is 2.5 times the design pressure.

FSAR Impact:

U.S. EPR FSAR, Tier 2, Section 3.8.1.4.11 and Table 3.8-6 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

Design of the steel liner plate and anchorage system is based on minimum strengths for the materials that are specified for fabrication of the steel components and their interface with the concrete containment. Deviations in the geometry of the liner plate due to fabrication and erection tolerances are considered in the design.

The materials of the liner and its stiffening and anchorage components that are exposed to the internal environment of containment are selected, designed, and detailed to withstand the effects of imposed loads and thermal conditions during design basis conditions.

3.8.1.4.11 Containment Ultimate Capacity

The Ultimate Pressure Capacity Deterministic Analyses for the RCB is performed in accordance with RG 1.136, RG 1.216 and guidance provided in SRP 3.8.1.II.4.K (Rev. 2)

Analysis results for the various containment elements are summarized in Table 3.8-6. These results are based on ANSYS non-linear finite element containment model with nominal stress-strain elasto-plastic materials properties under accident temperature and with cracked concrete section behavior.

The Ultimate Nominal Pressure Capacities for the cylinder and dome sections are calculated using the ~~2~~two degree~~-~~ slice finite element model with simulated axisymmetric boundary conditions. The ultimate conditions in these cases are 0.8 percent strain level in tendon areas located away from discontinuities (according to SRP 3.8.1.II.4.K). The simplified cross-checking hand calculation confirms the finite element model results.

The Ultimate Nominal Pressure Capacities for the ring and gusset sections are evaluated using the same finite element model as above with non-linear analysis run until the first 0.8 percent strain level in the rebars in the critical sections.

Non-Linear 3-D Finite Element Model is used for the hatch Ultimate Nominal Pressure Capacities evaluation. The non-linear steel properties for hatch, flanges, and sleeves are based on elastic-perfectly plastic model with bilinear kinematic hardening according to Von Mises yield criteria. Geometric nonlinearity is accounted for in the large displacement (stability) calculation. The results of calculations are summarized in Table 3.8-6.

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The equipment hatch is a spherical shell. The stability analysis is performed in accordance with NE-3133.4. The allowable pressure for buckling is 85.67 psig. In accordance with NE-3222, the compressive allowable stress is increased by 150 percent for ASME Service Level D, which gives an ultimate capacity buckling pressure of 128.5 psig.

Since the hatch performs a leak tightness role, the allowable strain criteria in accordance with ASME Code, Section III, Div. 2, Subsection CC, Article CC-3720 is conservatively used for the hatch ultimate pressure capacity evaluation. These allowable strains are: membrane strain of ε_C=0.5%, ε_T=0.3% and combined membrane + bending strain of ε_C=1.4%, ε_T=1%.

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The estimated Ultimate Pressure Capacities are determined from the principal strain levels, which approach ultimate in the protruding sleeves while remaining below yield in the hatch and flange areas. Under ultimate internal pressure that exceeds 2.0 times the design pressure, the sealing strip between the clamps remains in compression and remains leak tight. The radial ribs on the sleeve serve as buckling stiffeners for the hatch sleeve and are designed to carry axial force that exceeds 2.5 times the design pressure. The hatch cover and protruding sleeve buckle at greater than 2.0 times the design pressure.

An ultimate pressure capacity evaluation has been performed for the other major containment penetrations including the construction opening closure, the containment dedicated spare penetration, the personnel airlocks, the fuel transfer tube, and the main steam and feedwater line penetrations.

The ultimate capacity is evaluated using the design basis accident temperature and the following criteria.

1. Structural Capacity- A pressure 2.5 times the containment design pressure (2.5 x 62 psig = 155 psig) is applied to the penetration. The resulting strain levels are compared against the ASME Subsection CC factored strain allowable values in Table CC-3720-1. The 2.5 times design pressure is considered adequate to demonstrate sufficient margin exists above the design pressure for the ultimate capacity evaluation.

2. Stability (or buckling) - A stability analysis is performed to determine the buckling pressure in accordance with ASME Subsection NE, paragraph NE-3222, where one-third of the basic compressive allowable stress is considered or the buckling pressure is determined in accordance with NE-3133. ASME Level D allowable buckling pressures are determined. Strain values are determined from application of the allowable buckling pressure in an analysis with non-linear material properties and evaluated against the ASME Subsection CC factored strain allowable values in Table CC-3720-1.

3. Potential Leak Paths - The sealing mechanisms and strain levels in the metallic components at the ultimate capacity pressure are evaluated to demonstrate that no containment leak paths are created.

The minimum ratio of the ultimate capacity pressure (Pu) to the design pressure (Pd) and the controlling mode/location is presented in Table 3.8-6.

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Construction Opening Closure

The structural capacity of the construction opening closure is determined by finite element analysis techniques. The construction opening closure is a spherical shell. The stability analysis is performed in accordance with NE-3133.4. The allowable pressure for buckling is 79 psig. The compressive allowable stress is increased by 150 percent for Service Level D. Therefore, the ultimate capacity buckling pressure is 118.5 psig.

The construction opening closure is a welded cap. The calculated strain values do not exceed the factored allowable strain values in ASME Table CC-3720-1. Therefore, the leaktight integrity of the penetration is maintained at the evaluated pressures.

Containment Dedicated Spare Penetration

The capacity of the containment dedicated spare penetration sleeve is bounded by the main steam line penetration. The penetration closure capacity is bound by the construction opening closure as described in Section 3.8.2.4.1. Therefore, the ultimate capacity of the containment dedicated spare penetration does not govern the ultimate capacity of the U.S. EPR containment.

Personnel Airlocks

The structural capacity of the personnel airlocks is determined by finite element analysis techniques. The personnel airlocks consist of a complex geometry. The stability analysis is performed by a rigorous analysis in accordance with NE-3222.1(a)(1).

The basic allowable pressure for buckling is controlled by the capacity of the airlock door and is 79.6 psig. The compressive allowable stress is increased by 150 percent for Service Level D. Therefore, the ultimate capacity buckling pressure determined is 119.4 psig.

The airlock leak tight integrity is maintained by limiting the strains of the metallic parts to less than the factored allowable strain values in ASME Table CC-3720-1. The airlock seals are positive seating with the containment internal pressure. The airlock seals remain compressed with the strain limits considered for the metal components in the vicinity of the airlock door seals. Therefore, the leak tight integrity of the penetration is maintained at the containment ultimate capacity pressures.

Fuel Transfer Tube

The structural capacity of the fuel transfer tube is determined by finite element analysis techniques. The stability analysis of the fuel transfer tube is performed by a rigorous analysis in accordance with NE-3222.1(a)(1) and Code Case N-284-1. A non-

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linear finite element analysis is performed by incrementally applying pressure until the solution no longer converges. The allowable pressure for buckling is 230 psig, which is greater than 2.5 x Pd (155 psig). Therefore, the ultimate capacity results are reported at 2.5 Pd (155 psig).

The fuel transfer tube leak tight integrity is maintained by limiting the strains of the metallic parts to less than the factored allowable strain values in ASME Table CC-3720-1. The fuel transfer tube has a blind flange on the containment side which has positive seating with the containment internal pressure. The fuel transfer tube flange remains seated with the strain limits considered for the metal components in the vicinity of the blind flange. Therefore, the leak tight integrity of the penetration is maintained at the containment ultimate capacity pressures.

Main Steam and Feedwater Line Penetrations

The structural capacity of the main steam and feedwater line penetrations is determined by finite element analysis techniques. Buckling is not a failure mechanism for the main steam and feedwater line penetrations because the penetrations act as short columns with a slenderness ratio (kl/r) less than 89 (structural steel).

The main steam and feedwater line penetrations leak tight integrity is maintained by limiting the strains of the metallic parts to less than the factored allowable strain values in ASME Table CC-3720-1. Therefore, the leak tight integrity of the penetration is maintained at the containment ultimate capacity pressure.

3.8.1.4.12 Design Report

Design information and criteria for Seismic Category I structures are provided in Sections 2.4, 2.5, 3.3, 3.5, 3.7, 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. A cross-reference between U.S. EPR FSAR sections and information required by SRP Section 3.8.4, Appendix C is provided in Table 3.8-17.

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 Code, Section III, Division 2, ~~and~~ RG 1.136, and RG 1.216 (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.

Table 3.8-6—Containment Ultimate Pressure Capacity (P_u) at Accident Temperature of 309°F

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Sections	Pressure Capacity (P_u)		~~Failure~~Controlling Mode/ Location
	Pu (psi)	Minimum Ratio P_u/P_d (~~2~~1)	
Cylinder (Hoop)	~~267~~272	~~4.31~~4.39	~~Failure due to m~~Maximum allowable membrane strains away from structural discontinuities.
Dome	~~249~~208	~~4.02~~3.35	~~Failure due to m~~Maximum allowable membrane strains away from structural discontinuities.
Dome Belt	~~173~~211	~~2.79~~3.40	~~Failure due to m~~Maximum allowable flexural strains at structural discontinuities.
Gusset Base	~~315~~316	~~5.08~~5.10	~~Failure due to m~~Maximum allowable flexural strains at structural discontinuities.
~~Equipment Hatch (1)~~	~~156~~	~~2.52~~	~~"Loss" of structural integrity in protruding sleeve area due to principal strain which approaches ultimate.~~
Equipment Hatch ~~(1)~~	~~125~~128.5	~~2.02~~2.07	~~"Loss" of leak tightness in protruding sleeve due to principal strain which approaches ultimate.~~ASME Code Level D Stability/Buckling limit in the equipment hatch cover.
Construction Opening Closure	118.5	1.91	ASME Code Level D allowable pressure to ensure no stability/ buckling of the opening cover.
Personnel Airlocks	119.4	1.93	ASME Code Level D allowable pressure to ensure no stability/ buckling of the airlock hatch cover.
Fuel Transfer Tube	155(2)	2.5(2)	High strains in the containment sleeve portions not backed by concrete.
Main Steam and Feedwater Line Penetrations	155(2)	2.5(2)	High strains in the containment sleeve portions not backed by concrete.

Notes:

~~Conservatively calculated under Accident Temperature of 338°F (170°C).~~

1. P_d – design pressure.

2. The ultimate pressure capacity is reported at 2.5 times the design pressure.

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