ArevaEPRDCPEm Resource

From: WILLIFORD Dennis (AREVA) [Dennis.Williford@areva.com]
Sent: Monday, June 27, 2011 2:45 PM
To: Tesfaye, Getachew
Cc: BENNETT Kathy (AREVA); DELANO Karen (AREVA); HALLINGER Pat (EXTERNAL AREVA); ROMINE Judy (AREVA); RYAN Tom (AREVA); WILLIFORD Dennis (AREVA); CORNELL Veronica (EXTERNAL AREVA); BREDEL Daniel (AREVA); WILLIAMSON Rick (AREVA)
Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 306, FSAR Ch. 3, Question 03.08.01-39
Attachments: RAI 306 Question 3.8.1-39 Response US EPR DC - DRAFT (R1).pdf

Getachew

Attached is a revised draft response to RAI No. 306, FSAR Ch 3, Question 03.08.01-39 in advance of the July 21, 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,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
7207 IBM Drive, Mail Code CLT 2B
Charlotte, NC 28262
Phone: 704-805-2223
Email: Dennis.Williford@areva.com

From: WILLIFORD Dennis (RS/NB)
Sent: Tuesday, June 07, 2011 9:03 AM
To: 'Tesfaye, Getachew'
Cc: BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 306, FSAR Ch. 3, Supplement 5

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 306 on December 4, 2009. AREVA NP provided responses to 8 of the 10 questions of RAI No. 306 on March 11, 2010. The schedule for technically correct and complete responses to the remaining 2 questions was changed May 12, 2010 to allow time to address items raised during the May 10, 2010 phone call and to interact with the NRC on the revised response. On June 2, 2010, AREVA NP submitted Supplement 3 to provide final responses to Question 03.12-19 and Question 03.12-20.

The final response to Question 03.08.01-39 was submitted in RAI 306 Supplement 1 on March 11, 2010. To address NRC comments received during the U.S. EPR FSAR Section 3.8 audit held February 14 – 17, 2011, the response to Question 03.08.01-39 is being revised. The schedule for a revised response to Question 03.08.01-39 was added in Supplement 4 which was submitted on March 21, 2011.

The schedule for a revised response to Question 03.08.01-39 has been changed. The schedule for a technically correct and complete FINAL response to this remaining question is provided below:

Question #	Response Date
RAI 306 — 03.08.01-39	July 21, 2011

Sincerely,

Dennis Williford, P.E.
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
7207 IBM Drive, Mail Code CLT 2B
Charlotte, NC 28262
Phone: 704-805-2223
Email: Dennis.Williford@areva.com

From: WELLS Russell (RS/NB)
Sent: Monday, March 21, 2011 4:39 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. 306, FSAR Ch. 3, Supplement 4

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 306 on December 4, 2009. AREVA NP provided responses to 8 of the 10 questions of RAI No. 306 on March 11, 2010. The schedule for technically correct and complete responses to the remaining 2 questions was changed May 12, 2010 to allow time to address items raised during the May 10, 2010 phone call and to interact with the NRC on the revised response. On June 2, 2010, AREVA NP submitted Supplement 3 to provide final responses to Question 03.12-19 and Question 03.12-20.

The final response to Question 03.08.01-39 was submitted in RAI 306 Supplement 1 on March 11, 2010. To address NRC comments received during the U.S. EPR FSAR Section 3.8 audit held February 14 – 17, 2011, the response to Question 03.08.01-39 is being revised. The schedule for a FINAL revised response to Question 03.08.01-39 has been added.

The schedule for technically correct and complete FINAL response to the remaining question is provided below:

Question #	Response Date
RAI 306 — 03.08.01-39	June 8, 2011

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
Phone: 434-832-3884 (work)
434-942-6375 (cell)
Fax: 434-382-3884

Russell.Wells@Areva.com

From: BRYAN Martin (EXT)
Sent: Wednesday, June 02, 2010 11:56 AM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); HAMMOND Philip R (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 306, FSAR Ch. 3, Supplement 3

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 306 on December 4, 2009. AREVA NP provided responses to 8 of the 10 questions of RAI No. 306 on March 11, 2010. The schedule for technically correct and complete responses to the remaining 2 questions was changed May 12, 2010 to allow time to address items raised during the May 10, 2010 phone call and to interact with the NRC on the revised response. The attached file, "RAI 306 Supplement 3 Response US EPR DC" provides technically correct and complete responses to the remaining 2 questions, 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 306 Questions 3.12-19 and 3.12-20.

The following table indicates the respective pages in the response document, "RAI 306 Supplement 3 Response US EPR DC" that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 306 — 03.12-19	2	2
RAI 306 — 03.12-20	3	6

This concludes the formal AREVA NP response to RAI 306, and there are no questions from this RAI for which AREVA NP has not provided responses.

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Wednesday, May 12, 2010 4:26 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); HAMMOND Philip R (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 306, FSAR Ch. 3, Supplement 2

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 306 on December 4, 2009. On March 11, 2010, AREVA NP provided responses to 8 of the 10 questions for RAI No. 306.

The schedule for technically correct and complete responses to the remaining 2 questions has been changed and is provided below. This change is to allow time to address items raised during the May 10, 2010 phone call and to interact with the NRC on the revised response.

Question #	Response Date
RAI 306 — 03.12-19	June 10, 2010
RAI 306 — 03.12-20	June 10, 2010

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Thursday, March 11, 2010 3:02 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); HAMMOND Philip R (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 306, FSAR Ch. 3, Supplement 1

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 306 on December 4, 2009. The attached file, "RAI 306 Supplement 1 Response US EPR DC" provides technically correct and complete responses to 8 of the remaining 10 questions, 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 306 Questions 03.08.01-42 and 3.12-18.

The following table indicates the respective pages in the response document, "RAI 306 Supplement 1 Response US EPR DC," that contain AREVA NP's response to the subject questions. Please note that AREVA NP requests an opportunity for interaction with the staff regarding environmentally-assisted fatigue as it relates to the response to question 03.12-18.

Question #	Start Page	End Page
RAI 306 — 03.03.01-4	2	2
RAI 306 — 03.08.01-39	3	8
RAI 306 — 03.08.01-40	9	11
RAI 306 — 03.08.01-41	12	13

RAI 306 — 03.08.01-42	14	14
RAI 306 — 03.08.01-43	15	16
RAI 306 — 03.12-18	17	18
RAI 306 — 03.12-19	19	19
RAI 306 — 03.12-20	20	20
RAI 306 — 03.12-21	21	21

The schedule for technically correct and complete responses to the remaining 2 questions has been changed due to administrative reasons and is provided below:

Question #	Response Date
RAI 306 — 03.12-19	May 12, 2010
RAI 306 — 03.12-20	May 12, 2010

Sincerely,

Martin (Marty) C. Bryan
Licensing Advisory Engineer
AREVA NP Inc.
Tel: (434) 832-3016
Martin.Bryan.ext@areva.com

From: Pederson Ronda M (AREVA NP INC)
Sent: Friday, December 04, 2009 4:08 PM
To: 'Tesfaye, Getachew'
Cc: BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC); HAMMOND Philip R (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 306, FSAR Ch. 3

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 306 Response US EPR DC.pdf," provides the schedule for technically correct and complete responses to these questions.

The following table indicates the respective pages in the response document, "RAI 306 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 306 — 03.03.01-4	2	2
RAI 306 — 03.08.01-39	3	3
RAI 306 — 03.08.01-40	4	4
RAI 306 — 03.08.01-41	5	5
RAI 306 — 03.08.01-42	6	6
RAI 306 — 03.08.01-43	7	7
RAI 306 — 03.12-18	8	8
RAI 306 — 03.12-19	9	9
RAI 306 — 03.12-20	10	10
RAI 306 — 03.12-21	11	11

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

Question #	Response Date
RAI 306 — 03.03.01-4	March 12, 2010
RAI 306 — 03.08.01-39	March 12, 2010
RAI 306 — 03.08.01-40	March 12, 2010
RAI 306 — 03.08.01-41	March 12, 2010
RAI 306 — 03.08.01-42	March 12, 2010
RAI 306 — 03.08.01-43	March 12, 2010
RAI 306 — 03.12-18	March 12, 2010
RAI 306 — 03.12-19	March 12, 2010
RAI 306 — 03.12-20	March 12, 2010
RAI 306 — 03.12-21	March 12, 2010

Sincerely,

Ronda Pederson

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An AREVA and Siemens company
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Cell: 434-841-8788

From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Wednesday, November 04, 2009 12:14 PM
To: ZZ-DL-A-USEPR-DL
Cc: Patel, Jay; Xu, Jim; Hawkins, Kimberly; Hsu, Kaihwa; Dixon-Herrity, Jennifer; Miernicki, Michael; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 306(3642,3787,3755), FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on October 9, 2009, and discussed with your staff on November 4, 2009. 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: 3160

Mail Envelope Properties (2FBE1051AEB2E748A0F98DF9EEE5A5D47AF096)

Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 306, FSAR Ch. 3, Question 03.08.01-39
Sent Date: 6/27/2011 2:44:32 PM
Received Date: 6/27/2011 2:45:21 PM
From: WILLIFORD Dennis (AREVA)

Created By: Dennis.Williford@areva.com

Recipients:
"BENNETT Kathy (AREVA)" <Kathy.Bennett@areva.com>
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"ROMINE Judy (AREVA)" <Judy.Romine@areva.com>
Tracking Status: None
"RYAN Tom (AREVA)" <Tom.Ryan@areva.com>
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Tracking Status: None
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Files	**Size**	**Date & Time**
MESSAGE	12675	6/27/2011 2:45:21 PM
RAI 306 Question 3.8.1-39 Response US EPR DC - DRAFT (R1).pdf	536469	

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

Response to

Request for Additional Information No. 306, Question 03.08.01-39, Revision 1

11/04/2009

U.S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.03.01 - Wind Loading
SRP Section: 03.08.01 - Concrete Containment
SRP Section: 03.12 - ASME Code Class 1, 2, and 3 Piping Systems and Piping Components and Their Associated Supports

Application Section: FSAR Ch 3

QUESTIONS for EPR Projects Branch (NARP)
QUESTIONS for Structural Engineering Branch 2 (ESBWR/ABWR Projects) (SEB2)
QUESTIONS for Engineering Mechanics Branch 1 (AP1000/EPR Projects) (EMB1)

Question 03.08.01-39:

Follow-up to RAI Question No. 3.8.1-16

The RAI response provided information regarding a parametric study performed to address the issue of the variation of material properties and the use of best estimate values for material properties in the design of the Reactor Containment Building (RCB). The following information is needed to resolve this RAI:

1. Provide the range of values used in the parametric study and demonstrate that these range of values are appropriate by comparing them to the properties (or range of properties) used in the design of the RCB. This comparison of properties between the study and design values should consider the variation of properties corresponding to the range of temperatures for the containment under the different loading conditions.
2. Confirm whether the values in FSAR Tables 3.8-1 through 3.8-4 are best-estimate values used for the analysis and design of the RCB, because it appears that some of these values (e.g., modulus of elasticity for concrete) may be based on code specified values instead. As requested in the RAI, provide the technical basis for using the properties listed in the FSAR Tables 3.8-1 through 3.8-4 (i.e., identify the source for the values). Where a reference to an industry code, standard, guide, or textbook is not available, provide the technical basis for using the listed values. Also, explain why the best-estimate values are used for design purposes and not a conservative value which would account for potential uncertainties inherent in the parameters, as is done in design codes.
3. Provide the same information in Item 2 above for FSAR Sections 3.8.2 through 3.8.5.
4. Explain how the detrimental effects of radiation were considered for the concrete and steel structures in and within the primary and secondary shield walls.
5. The response to RAI Number 3.8.1-14 states that the axisymmetric model of the RCB was also used to study the effect of the variations in the temperature of the annulus relative to the 79F value used to date, and that the results of this study would be given in the response to this RAI. Since the RAI response only marginally mentions this issue, provide a complete discussion on the results of this study.

Response to Question 03.08.01-39:

1. Table 03.08.01-39-1 provides the parameters and range of values used in the material variation parametric study of the Reactor Containment Building (RCB).

   Thermal and structural analyses are performed under accidental temperature and pressure transients using the design values for the RCB as part of the parametric study. These analyses establish reference design forces and moments that can be compared with the results from the adjusted parameter models. Parameter adjustments were made by comparing material property values at the average normal room temperature with material property values at the maximum design temperature under accident conditions.

   Experimental data from Reference 1 indicates that specific heat values of concrete increase slightly with a rise in temperature. The value of 15 percent was selected based on Reference 1, Figure 7.

The modulus of elasticity for concrete experiences a reduction in value at elevated temperatures. Reference 1, Figure 2 shows the upper and lower bound curves for test results. At 300°F, the upper bound curve indicates a modulus of 0.9 E_c while the lower bound curve indicates a modulus of 0.45 E_c. For this parametric study, the average of these bounding curves was considered.

Considering the effect of a rise in temperature from ambient to 300°F on the specific heat of steel, NUREG/CR-6900, Figure 4 indicates that a 10 percent increase is an appropriate variation.

2. Table 03.08.01-39-2 shows the values from U.S. EPR FSAR Tier 2, Tables 3.8-1 through 3.8-4 and the information source for those data. The values generally fall into one of three categories: (1) code or standard specified values, (2) design specifications, or (3) engineering estimates that can be justified by experience or a technical basis. The effect of variation of select engineering estimated values has been quantified in the parametric study addressed in Item 1 of this question. The study concluded that this variation had an insignificant effect on the resulting forces and moments of the RCB wall.

   Tendon friction losses provided in Table 03.08.01-39-2 are based on in-situ pull tests on horizontal tendons with different lengths, deviations, and configurations. Test measurements included pressure readings on active and passive jacks with corrections for jack friction losses. The tests also included measurement of tension strain at various times during tensioning. The test results were used to calculate friction losses in the tendons and to determine the curvature coefficients. The test results showed that the friction coefficient (curvature) was between 0.14 and 0.16, which is lower than the design value (0.18). The required prestressing force is obtained along the profile of the tendon when the design value is used.

   The tendon friction losses shown in Table 03.08.01-39-2 are within the recommended ACI ranges for friction coefficients with the exception of the wobble coefficients for the vertical tendons. The wobble coefficients outside the ACI recommended range are considered acceptable based on manufacturer's recommendation for like tendons currently installed in European EPR applications.

3. Thermal properties for concrete and steel in U.S. EPR FSAR Tier 2, Sections 3.8.2 through 3.8.5 are consistent with the properties listed in U.S. EPR FSAR Tier 2, Tables 3.8-1 through 3.8-4. Material properties for concrete and steel in U.S. EPR FSAR Tier 2, Sections 3.8.2 through 3.8.5, including unit weight and Poisson's ratio, are consistent with the values listed in the subject tables. The specified nominal compressive strength (f'_c) varies as described in U.S. EPR FSAR Tier 2, Sections 3.8.3.6, 3.8.4.6, and 3.8.5.6. The modulus of elasticity for concrete is calculated based on the compressive strength using the formula from ACI 349-01, Section 8.5.1.

4. Primary and secondary shield wall thicknesses are determined by selecting the maximum thickness based on radiation shielding requirements described in ANSI/ANS-6.4-2006 or structural requirements contained in ACI 349-01 and ACI 349.1R-07. Concrete aggregates conforming to ASTM C637 will be used in radiation shielding applications, where applicable. No material variation is expected for primary or secondary shield walls because industry operating experience has not indicated a loss of strength for reinforced concrete exposed to radiation. Governing civil/structural design codes and standards for structural steel and reinforced concrete design in nuclear applications do not contain design considerations that

indicate a variation in material properties or allowables for structural materials exposed to radiation.

Neutron fluence and gamma dose rates were evaluated at the peak location on the surface of the reactor cavity biological shield wall, and compared to the threshold limits specified in ANSI/ANS 6.4 assuming continuous operation for 60 years less outage durations. The outage duration was estimated to be 20 days on an 18 month cycle. The results of the evaluation are:

- Gamma dose = 2.06E+09 rad.
- Gamma dose limit = 1.00E+10 rad.
- Neutron Fluence = 1.09E+19 n/cm^2.
- Neutron Fluence Limit = 1.00E+19 n/cm^2.

The evaluation concludes that the gamma dose is acceptable and the neutron fluence is above the cut off for minimal effects. Based on Figure 4.7 in NUREG/CR 6927, Reference [2], this conclusion is considered acceptable because the value for the neutron fluence (1.09E+19 (n/cm^2)) is on the flat portion of the compressive strength ratio curve.

5. The axisymmetric model of the RCB was used to study the variation of annulus temperatures ranging from a minimum of 45°F to a maximum of 113°F. The results at four critical time points from this study are the same time points used for the RCB wall design, as described in U.S. EPR FSAR Tier 2, Section 3.8.1.4.4. The four critical time points were selected by choosing time points where maximum forces and moments occurred for different sections of the RCB under accidental temperature and pressure distribution. In the parametric study, the results for the thermal analysis at these four critical time points indicate that the minimum annulus temperature of 45°F results in larger design forces and moments, while the maximum annulus temperature of 113°F results in a reduction of design forces and moments in the RCB wall. The combination of variation in thermal properties, mechanical properties, and annulus temperature has an insignificant effect on the resulting forces and moments of the RCB wall. U.S. EPR FSAR Tier 2, Section 3.8.1.4.4 will be revised to update the four time points used in the temperature and pressure analysis.

Response to RAI 248, Question 03.08.01-33, Item 1a:

A parametric study was performed to develop the Response to RAI 248, Question 03.08.01-33. The parametric study shows that the variation in thermal and mechanical properties has an insignificant effect on forces and moments that affect the RCB wall. The study shows that an increase in annulus temperature reduces the design forces and moments of the RCB wall, which is conservative. However, a decrease in annulus temperatures, to minimum of 45°F, increases the design forces and moments, as shown in Table 03.08.01-39-3 for the four selected critical time points.

The 45°F minimum annulus temperature concurrent with loss of coolant accident temperatures on the interior face of RCB is an unlikely scenario. An annulus temperature of 45°F could only occur when the equipment hatch is open during an outage (typically 20 days on an 18 month cycle). Therefore, the additional thermal forces and moments at 45°F are unlikely to occur in the RCB wall.

Figure 03.08.01-44-4(a), in the Response to RAI 335, Question 3.8.1-44, shows the additional capacity of the containment wall against the demand. Table 03.08.01-39-3 shows that the maximum thermal moment of 185 kip-ft/ft, along with the tensile axial force of 17 kip/ft, represents the worst case scenario for the additional thermal moment due to minimum annulus temperature (45°F). The extra thermal force and moments are added to the existing demand and plotted against the RCB wall capacity interaction diagrams in Figure 03.08.01-39-1. Figure 03.08.01-39-1 shows that there is sufficient section capacity (615 (=2050-1435) kip-ft/ft or 573 (=1859-1286) kip-ft/ft) in the wall at the 45°F minimum annulus temperature. Therefore, design capacity shown in Figure 03.08.01-39-1 adequately envelopes the additional demand for the unlikely scenario of a 45°F minimum annulus temperature.

Figure 03.08.01-39-1 is based on the current critical section design. The margin shown in Figure 03.08.01-39-1 is not expected to vary significantly from the final critical section design. The final response to RAI 155, Question 3.8.4-6 will include confirmation that sufficient margin is provided.

References for Question 03.08.01-39:

1. M.K. Kassir, K.K. Bandyopadhyay, and M. Reich, "Thermal Degradation of Concrete in the Temperature Range From Ambient to 315°C (600°F)," June 1993.
2. NUREG/CR-6927, "Primer on Durability of Nuclear Power Plant Reinforced Concrete Structures – A Review of Pertinent Factors.

FSAR Impact:

The U.S. EPR FSAR Tier 2, Section 3.8.1.4.4 will be revised as described in the response and indicated on the enclosed markup.

Table 03.08.01-39-1—Range of Values Used in the RCB Material Variation Parametric Study

	Parameter	Minimum Study Value	Maximum Study Value	Design Value
Concrete	Specific Heat	1000 J/kg°C	1150 J/kg°C	1000 J/kg°C
	Modulus of Elasticity	3.22×10^6 psi	4.77×10^6 psi	4.77×10^6 psi
Steel	Specific Heat	434 J/kg°C	477.4 J/kg°C	434 J/kg°C

Table 03.08.01-39-2—RCB Design and Analysis Values

	Property	Value	Source/Justification
Concrete	Thermal Conductivity (kW/m*C)	0.0023	Thermal Property[1]
Concrete	Specific Heat (J/kg*C)	1000	Thermal Property[1]
Concrete	Modulus of Elasticity (ksi)	4769	ACI 349-01 Sec. 8.5.1
Concrete	Poisson's Ratio	0.17	Poisson's Ratio for concrete usually falls in the range of 0.15 to 0.20. The selected value was chosen to be near the middle of this typical range. Section 3-5, page 74 of "Reinforced Concrete Mechanics and Design," Fourth Edition, by James G. MacGregor and James K. Wight
Concrete	Nominal Strength f'_c (ksi)	7	The nominal compressive strength of concrete is a design specification which will be verified by testing.
Concrete	Unit Weight (lb/ft^3)	150	PCI Design Handbook Precast and Prestressed Concrete, 5th Edition, Section 2.2.5
Concrete	Film Coefficient (BTU/hr*ft^2*°F)	1.41	Thermal Property[1]
Concrete	Thermal Diffusivity (ft^2/hr)	0.037	Thermal Property[1]
Steel	Thermal Conductivity (kW/m*C)	0.041	Thermal Property[1]
Steel	Specific Heat (J/kg*C)	434	Thermal Property[1]
Post-Tensioning Cable	Modulus of Elasticity (ksi)	28000	"Estimating Prestress Losses", by Paul Zia, H. Kent Preston, Norman L. Scott, and Edwin B. Workman, published in Concrete International magazine
Post-Tensioning Cable	Poisson's Ratio	0.30	AISC Manual of Steel Construction: Allowable Stress Design, 9th Edition, Page 6-37
Post-Tensioning Cable	Nominal Strength F_{pu} (ksi)	270	ASTM A416
Post-Tensioning Cable	Unit Weight (lb/ft^3)	490	AISC Code of Standard Practice for Steel Buildings and Bridges, Adopted Effective September 1, 1986, Section 9.2.1

Table 03.08.01-39-2—RCB Design and Analysis Values

		Property	Value	Source/Justification
Tendon Friction Losses	Hoop	K (per foot)	0.00050	The selected values for analysis in U.S. EPR FSAR Tier 2, Table 3.8-3, are based on design experience with a similar post-tensioned system in European EPR applications. The tendon friction losses are based on testing that confirms the values used for the analysis. Based on design experience and test results from European EPR applications, the selected coefficients are considered appropriate.
		μ (per radian)	0.18	
	Vertical	K (per foot)	0.00025	
		μ (per radian)	0.16	
	Gamma	K (per foot)	0.00037	
		μ (per radian)	0.16	
Reinforcing Bar		Modulus of Elasticity (ksi)	29000	ACI 349-01 – Sec. 8.5.2
		Poisson's Ratio	0.30	AISC Manual of Steel Construction: Allowable Stress Design, 9th Edition, Page 6-37
		Nominal Strength F_y (ksi)	60	The nominal strength of reinforcing steel is a design specification. Conventional reinforcement steel will conform to ASTM A615.
		Unit Weight (lb/ft^3)	490	AISC Code of Standard Practice for Steel Buildings and Bridges, Adopted Effective September 1, 1986, Section 9.2.1

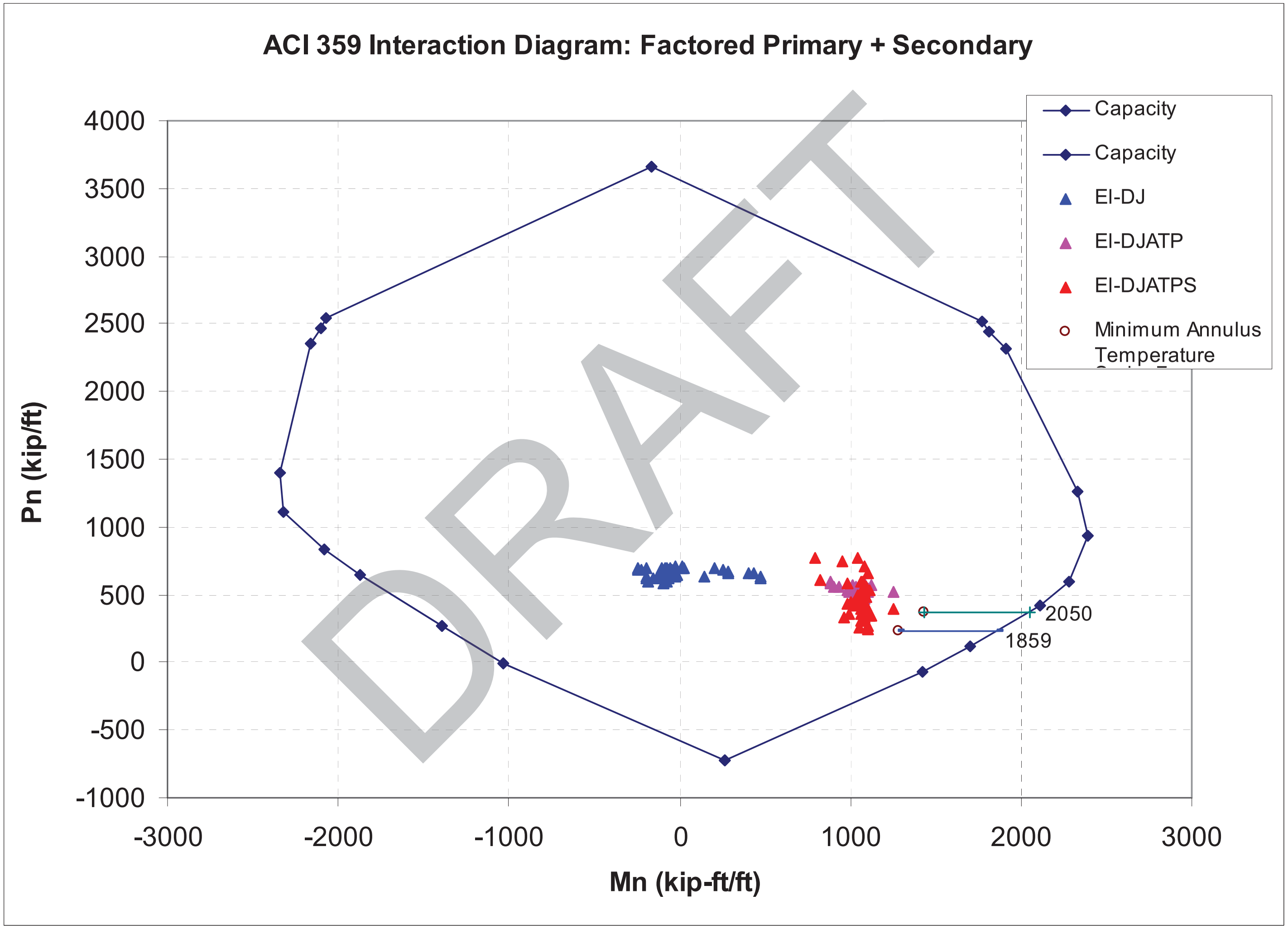
Note:

1. Thermal Properties for concrete are dependent on concrete mix design. As the mix design will be determined based upon field testing, the thermal properties cannot be definitively determined during design certification. The values selected to analyze concrete and steel are best estimate values based on experience with European EPR applications.

Table 03.08.01-39-3—Additional Thermal Forces and Moments for Minimum Annulus Temperature

Critical Time Point (Hrs)	Additional Thermal Moment					
	Elevation 0m		Elevation 20.08m		Dome Location	
	Force (kip/ft)	Moment (kip-ft/ft)	Force (kip/ft)	Moment (kip-ft/ft)	Force (kip/ft)	Moment (kip-ft/ft)
0	0	1	1	9	0	4
1.39	29	66	29	76	21	58
24	23	160	23	166	16	106
100	17	185	16	178	10	97

Figure 03.08.01-39-1—Plot of Additional Thermal Demand against the Interaction Diagrams for Containment Wall Section



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Containment Building) and Figure 3.8-21—Accident Pressure versus Time (Reactor Containment Building).

A heat transfer analysis was performed for the RCB accident temperature using the ANSYS computer code. Temperature gradients through the wall and dome were calculated with respect to time using the curve, and annulus temperature of 79°F (26°C) and the thermal properties in Table 3.8-1—Thermal Properties for Heat Transfer Analysis-Reactor Containment Building.

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Structural forces were computed, with time, based on the heat transfer analysis using the ANSYS computer code. Figure 3.8-22—Temperature Gradient Through Cylinder Wall, Figure 3.8-23—Temperature Gradient Through Dome, and Figure 3.8-24—Temperature Gradient Through Basemat provide the generic results of this analysis. These results and those of the accident pressure analysis were reviewed in detail to establish critical time points for the development of load cases to be used in the structural analysis. Forces and moments at times ~~0.33 hour, 2 hours, 24 hours, and 110 hours~~ 0 second, 1.39 hours, 24 hours and 100 hours were selected as critical for cylinder, dome, and basemat forces and moments. Additional internal pressure was added to the RCB due to the heating of the liner plate.

The RCB, including the steel liner, is designed to resist the effects of impulse loads and dynamic effects. Structural members designed to resist impulse loads and dynamic effects in the abnormal, extreme environmental, and abnormal and extreme environmental categories are allowed to exceed yield strain and displacement values. The allowable stresses applicable to the determination of section strength are as specified in Subsections CC-3400 and CC-3700 of the ASME Code, Section III, Division 2. In determining tensile yield strength of reinforcing steel (i.e., f_y) the dynamic effect of the loading may be considered. The applicable design assumptions in Subsection CC-3930 of the ASME Code, Section III, Division 2 are used in calculating the effects of impact or impulse.

The ductility limits used in design for impact load do not exceed two-thirds the ductility determined at failure. The ductility limits used in design for impulse load do not exceed one-third the ductility determined at failure. See Section 3.8.5 for a description of additional requirements for missile barrier design and ductility requirements applicable to the design of the RCB.

3.8.1.4.5 Creep, Shrinkage, and Cracking of Concrete

Conservative values of concrete creep and shrinkage 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

Table 3.8-1—Thermal Properties for Heat Transfer Analysis-Reactor Containment Building

Material Property	Concrete	Steel
Thermal conductivity (kW/m*C)	0.0023	0.041
Specific heat (J/kg*C)	1000	434

Table 3.8-2—Material Properties – Reactor Containment Building

Material	Modulus of Elasticity (ksi)	Poisson Ratio	Nominal Strength (ksi)	Unit Weight (lb/ft^3)
Concrete	4,769	0.17	f'_c=7.0	150
Post Tensioning Cable	28,000	0.30	F_{pu} =270	490
Reinforcing Bar	29,000	0.30	F_y = 60	490

Table 3.8-3—Tendon Frictional Losses

Tendon	K (per foot) Wobble Loss	μ (per radian) Curvature Loss
Hoop	0.00050	0.18
Vertical	0.00025	0.16
Gamma~~Dome~~	0.00037~~50~~	0.16

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Table 3.8-4—Thermal Properties – Reactor Containment Building

Specific Heat ($Btu/lb_m{*}°F$)	Thermal Conductivity (BTU/hr*ft*°F)	Film Coefficient ($BTU/hr{*}ft^2{*}°F$)	Thermal Diffusivity (ft^2/hr)
0.24	1.33	∞ (Inside Containment) 1.41 (Outside Containment)	0.037