ArevaEPRDCPEm Resource

From:	RYAN Tom (AREVA) [Tom.Ryan@areva.com]
Sent:	Friday, June 17, 2011 12:22 PM
To:	Tesfaye, Getachew
Cc:	BENNETT Kathy (AREVA); DELANO Karen (AREVA); ROMINE Judy (AREVA); CORNELL Veronica (EXTERNAL AREVA); WILLIFORD Dennis (AREVA); HALLINGER Pat (EXTERNAL AREVA); BREDEL Daniel (AREVA)
Subject:	DRAFT Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Questions 03.08.01-51 and 03.08.01-52
Attachments:	RAI 448 Q3.8.1-51,52 Response US EPR DC (DRAFT-R1).pdf

Getachew,

Attached are revised draft responses for RAI No. 448, FSAR Ch 3, Question 03.08.01-51 and Question 03.08.01-52 in advance of the July 8, 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,

Tom Ryan for
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: Wednesday, June 08, 2011 8:14 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. 448, FSAR Ch. 3, Supplement 6

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 448 on November 22, 2010. 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. On May 12, 2011, AREVA NP submitted Supplement 4 to provide a revised schedule for Question 03.08.01-49. On May 20, 2011, AREVA NP submitted Supplement 5 to provide a final response to Question 03.08.01-50.

The attached file, “RAI 448 Supplement 6 Response US EPR DC.pdf” provides a technically correct and complete FINAL response to Question 03.08.01-49, as committed. Appended to this file are the affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 448 Question 03.08.01-49.

The following table indicates the page in the response document, "RAI 448 Supplement 6 Response US EPR DC.pdf" that contains AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 448 — 03.08.01-49	2	10

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 — 03.08.01-51	July 8, 2011
RAI 448 — 03.08.01-52	July 8, 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: WILLIFORD Dennis (RS/NB)
Sent: Friday, May 20, 2011 1:48 PM
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. 448, FSAR Ch. 3, Supplement 5

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 448 on November 22, 2010. 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, 03.08.01-51 and 03.08.01-52. On May 12, 2011, AREVA NP submitted Supplement 4 to provide a revised schedule for Question 03.08.01-49.

The attached file, "RAI 448 Supplement 5 Response US EPR DC.pdf" provides a technically correct and complete final response to Question 03.08.01-50, as committed. Appended to this file are the affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 448 Question 03.08.01-50.

The following table indicates the page in the response document, "RAI 448 Supplement 5 Response US EPR DC.pdf" that contains AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 448 — 03.08.01-50	2	6

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

Question #	Response Date
RAI 448 — 03.08.01-49	June 10, 2011
RAI 448 — 03.08.01-51	July 8, 2011
RAI 448 — 03.08.01-52	July 8, 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: 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

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: 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,

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: 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,

Russ Wells
U.S. EPR Design Certification Licensing Manager

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3315 Old Forest Road, P.O. Box 10935
Mail Stop OF-57
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Fax: 434-382-3884
Russell.Wells@Areva.com

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,

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 (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,

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: 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: 3130

Mail Envelope Properties (8D609EE2F807714CBF5297D9BA8602FB012EFAD7)

Subject: DRAFT Response to U.S. EPR Design Certification Application RAI No. 448, FSAR Ch. 3, Questions 03.08.01-51 and 03.08.01-52
Sent Date: 6/17/2011 12:21:55 PM
Received Date: 6/17/2011 12:22:20 PM
From: RYAN Tom (AREVA)

Created By: Tom.Ryan@areva.com

Recipients:
"BENNETT Kathy (AREVA)" <Kathy.Bennett@areva.com>
Tracking Status: None
"DELANO Karen (AREVA)" <Karen.Delano@areva.com>
Tracking Status: None
"ROMINE Judy (AREVA)" <Judy.Romine@areva.com>
Tracking Status: None
"CORNELL Veronica (EXTERNAL AREVA)" <Veronica.Cornell.ext@areva.com>
Tracking Status: None
"WILLIFORD Dennis (AREVA)" <Dennis.Williford@areva.com>
Tracking Status: None
"HALLINGER Pat (EXTERNAL AREVA)" <Pat.Hallinger.ext@areva.com>
Tracking Status: None
"BREDEL Daniel (AREVA)" <Daniel.Bredel@areva.com>
Tracking Status: None
"Tesfaye, Getachew" <Getachew.Tesfaye@nrc.gov>
Tracking Status: None

Post Office: AUSLYNCMX02.adom.ad.corp

Files	**Size**	**Date & Time**
MESSAGE	16261	6/17/2011 12:22:20 PM
RAI 448 Q3.8.1-51,52 Response US EPR DC (DRAFT-R1).pdf	3559937	

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)
Question 03.08.01-51 and Question 03.08.01-52, 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 03.08.01-51:

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.

Response to Question 03.08.01-51:

The methodology of calculating reduction in thermal moments consistent with References [1] and [2] is no longer considered for design of critical sections. Thermal modification factors described in the response to Items (a) through (e), based on mesh refinement and concrete cracking, are considered to reduce the thermal moments in the Reactor Containment Building (RCB).

Item a:

In response to RAI 03.08.01-22, six-degree slice finite element model (FEM) models were considered with a coarse mesh density and refined mesh density. The slice model with coarse and refined mesh densities are referred to as “equivalent slice model” and “refined slice model,” respectively. The equivalent slice model has similar element thickness and mesh density as the Nuclear Island (NI) static model RCB, and contains five and four elements through thickness of the RCB wall and dome, respectively. The refined slice model has 15 and 12 elements through thickness of the RCB wall and dome, respectively. The equivalent and refined slice models are used for linear structural analysis of the model.

Figure 03.08.01-51-1 and Figure 03.08.01-51-2 show mesh densities of the RCB wall and dome for equivalent and refined slice models.

Item b:

The equivalent and refined structural models are converted to thermal coarse and thermal refined models by changing the element types from structural to thermal. Transient thermal analyses are performed for thermal models to calculate the distribution of temperature through thickness of the containment. The thermal gradients through thickness of the containment at different time points along with equivalent liner pressure are applied for linear structural analysis of the equivalent and refined slice models. The moments calculated from linear analysis are compared between the equivalent and refined model at different sections of the containment wall, ring girder, and dome. Thermal modification factors for mesh refinement are obtained from the ratio of linear thermal moments between the equivalent and refined slice models for different sections of the containment dome and wall. The variation of modification factors due to mesh refinement for thermal moments at critical time points are shown in Table 03.08.01-51-1.

Instead of applying a modification factor resulting from mesh refinement only, Table 03.08.01-51-3 shows the cumulative modification factors from both the mesh refinement factor and the concrete cracking factor applied to different sections of the containment. U.S. EPR FSAR Tier 2, Section 3.8.1.4.5 will be revised to clarify that mesh refinement is used to determine thermal moments.

Item c:

Elements of the linear refined slice model are converted to a nonlinear refined model by changing the constitutive model, as well as by adding cracking capability. Nonlinear structural analysis is performed for the nonlinear refined slice model with the thermal gradients through thickness obtained from transient thermal analysis, along with equivalent liner pressure and other loads, as described in the Response to RAI 155, Question 03.08.01-22. Thermal moments from the linear and nonlinear refined slice models are compared at different sections of the containment wall to calculate the modification factors due to concrete cracking. Modification factors for thermal moments due to concrete cracking at critical time points at each section of the containment vary from 0.96 to 1.00, except at gusset-wall connections. Variation of thermal modification factors at gusset-wall connections (at elevation -7.55 ft (-2.30 m)) is shown in Table 03.08.01-51-2.

Instead of applying a modification factor resulting from concrete cracking only, Table 03.08.01-51-3 shows the cumulative modification factors from both the mesh refinement factor and the concrete cracking applied to different sections of the containment. U.S. EPR FSAR Tier 2, Section 3.8.1.4.5 will be revised to clarify that mesh refinement is used to determine thermal moments.

Item d:

Nonlinear analysis is performed on the nonlinear refined slice model only. The calculation of thermal modification factors includes two independent steps:

1. Factor due to mesh refinement.
2. Factor due to cracking of concrete.

RCB thermal moments calculated in the NI model are based on coarse mesh and linear structural analysis. The mesh refinement will modify the RCB thermal moment of NI. In addition, allowance of concrete cracking will further modify the RCB thermal moment of NI. Calculating the thermal modification factor by multiplying the mesh refinement factors and concrete cracking factor is appropriate. The final thermal moment modification factors due to mesh refinement and concrete cracking at critical time points are shown in Table 03.08.01-51-3. The time point of 360,000 seconds was considered critical due to axial forces on containment wall sections, and therefore, is not considered when determining the thermal moment reduction factors.

Modification factors shown in Table 03.08.01-51-3 envelop thermal modification factors (i.e., multiplier of mesh refinement and concrete cracking factors) for different sections of the containment. The modification factors shown in Table 03.08.01-51-3 are applicable to thermal moments for designing RCB sections for critical load combinations used in the U.S. EPR design.

Item e:

See the Response to RAI 448, Question 03.08.01-51, Item d.

Item f:

From the transient thermal analysis, temperature gradients through thickness of the containment are established at different time points (27 time points) in a one year period. From a different structural analysis, equivalent pressures due to liner thermal expansion are calculated at the same time points as described in response to RAI Question 03.08.01-27 (Item 3). In the analysis with accidental temperature loads, the model is subjected to temperature gradients for the 27 time points in a quasi static manner. In the nonlinear analysis, if an element cracks, the element remains cracked for the rest of the analysis. In each analysis, the temperature gradients through thickness are applied as body force temperature. In addition, equivalent pressure due to liner expansion is applied to the containment interior face. Accidental pressure loads are also applied to the containment interior face.

References:

1. Gurfinkel, G., "Thermal Effects in Walls of Nuclear Containments – Elastic and Inelastic Behavior," Proceedings, First International Conference on Structural Mechanics in Reactor Technology, V. 5-J, pp 277-297, 1971.
2. Gurfinkel, G., and Robinson, A., "Determination of Strain Distribution and Curvature in a Reinforced Concrete Section Subjected to Bending Moment and Longitudinal Load," Journal of the American Concrete Institute, Vol. 64, No.7, July 1967.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 3.8.1.4.5 will be revised as described in the response and indicated on the enclosed markup.

Table 03.08.01-51-1—Variation of Thermal Moment Modification Factors due to Mesh Refinement at Critical Time Points

Section Location	Post accident time in Seconds		
	0.005	5000	86400
Containment Wall near Gusset-Wall Junction	0.33~0.49	0.63~0.72	0.95~1.02
Containment Wall	0.16~0.18	0.59~0.60	1.0
Containment Ring Girder	0.23~0.28	0.61~0.65	0.97~1.01
Containment Dome	0.22~0.23	0.65~0.66	1.01~1.02

Table 03.08.01-51-2—Variation of Thermal Moment Modification Factors due to Concrete Cracking at Critical Time Points at Gusset Wall Connection

Section Location Containment Wall near Gusset-Wall Junction	Post accident time in seconds		
	0.005	5000	86400
Moment about Tangential Axis	1.25~1.28	0.95~0.99	0.80~0.83
Moment about Meridional Axis	1.01	0.87~0.90	0.91~0.93

Table 03.08.01-51-3—Final Thermal Moment Modification Factors due to Mesh Refinement and Concrete Cracking at Critical Time Points

Section Location	Post accident time in Seconds		
	0.005	5000	86400
Containment Wall near Gusset-Wall Junction	0.63	0.71	0.88
Containment Wall	0.18	0.60	1.00
Containment Ring Girder	0.28	0.65	1.01
Containment Dome	0.23	0.66	1.02

Figure 03.08.01-51-1—Coarse Slice Model Mesh Density (a) Typical RCB Section (b) Typical RCB Dome (c) Typical RCB Wall

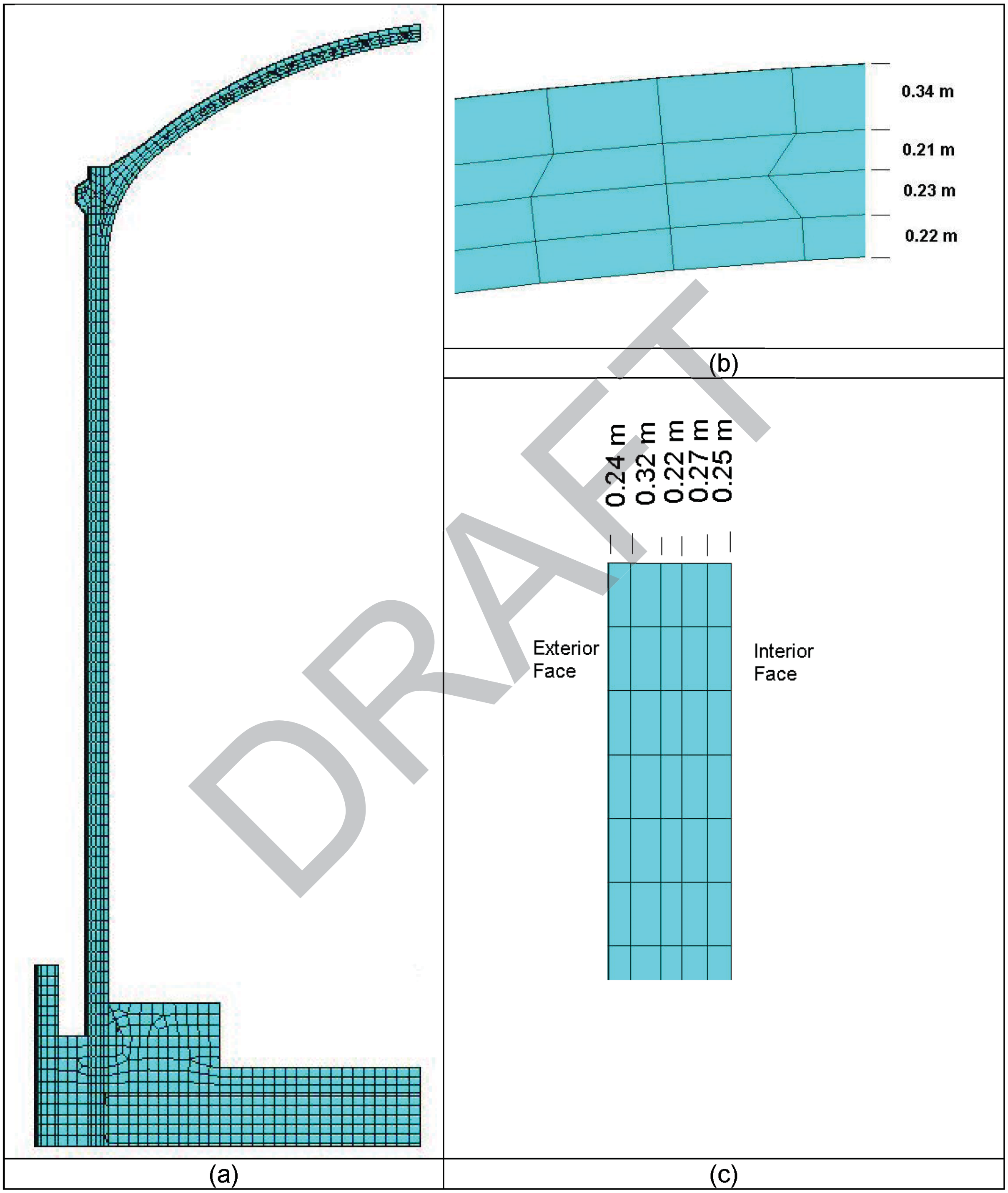
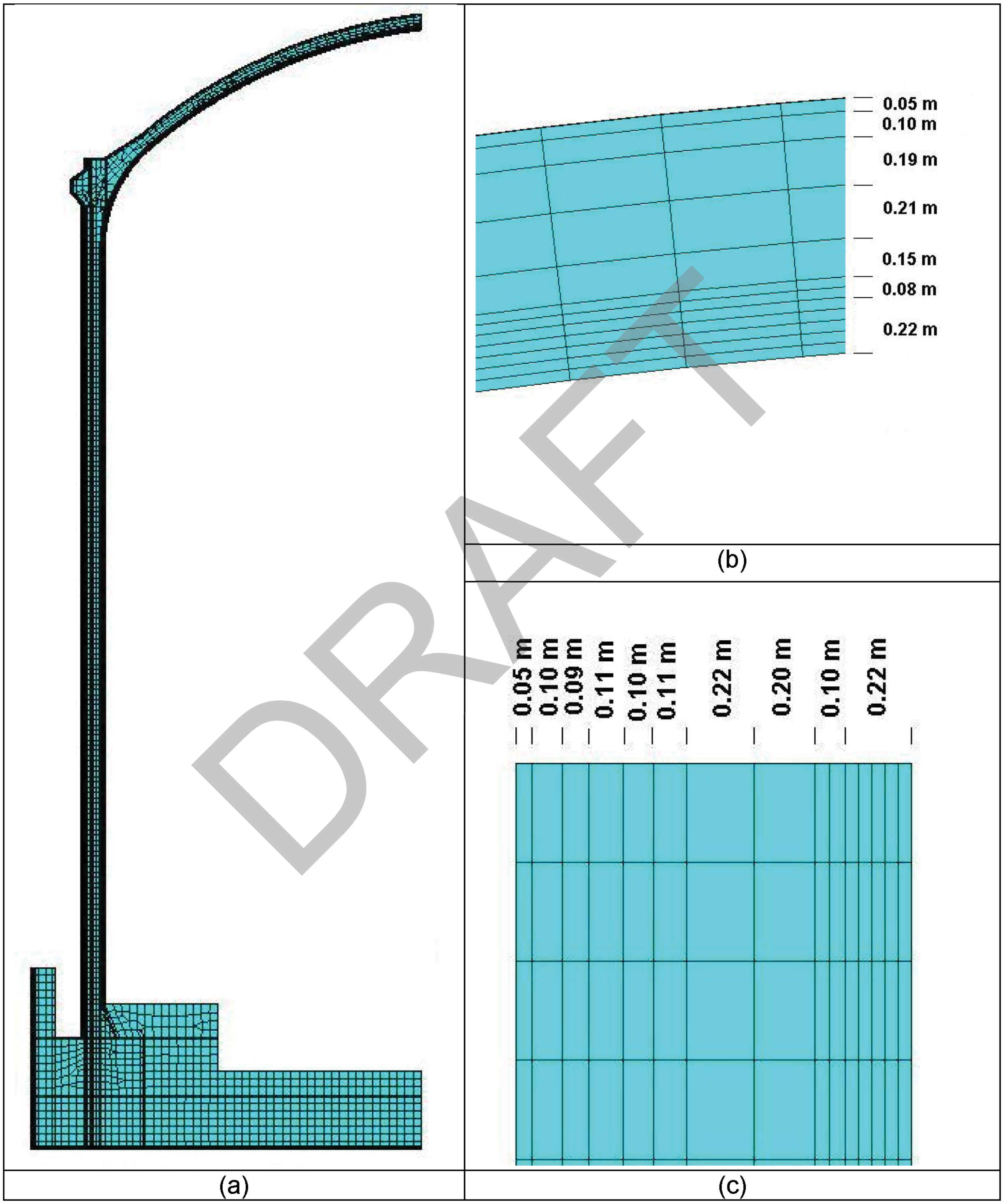


Figure 03.08.01-51-2—Refined Slice Model Mesh Density (a) Typical RCB Section (b) Typical RCB Dome (c) Typical RCB Wall



Question 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.

Response to Question 03.08.01-52:

Item a:

Variation in temperatures through the thickness of the containment wall (at 65.86 feet) and dome (75 degrees from horizontal) at different time points for the equivalent slice model and refined slice models are shown in Figures 03.08.01-52-1 and 03.08.01-52-2.

Thermal moments at the containment wall (at 65.86 feet) and dome (75 degrees from horizontal) sections for the equivalent slice model and refined slice model are shown in Table 03.08.01-52-1 and Table 03.08.01-52-2, respectively. Thermal moments from the refined model are significantly reduced at the beginning of the accident time period because of better approximation of thermal gradients. At later time periods, refinement of mesh shows similarity in thermal moments.

Use of thermal moment modification factors for the RCB design sections reduces the conservatism observed in linear thermal moments.

Item b:

The FEM procedure with ANSYS smeared concrete cracking constitutive models described in the Response to RAI 155, Question 03.08.01-27, Item 4 is used to calculate the thermal moment reduction factors in the nonlinear analysis.

The concrete in the containment liner model in the Response to RAI 155, Question 03.08.01-27, Item 3 is represented with linearly elastic SOLID45 elements for calculating additional liner pressures. The calculated equivalent additional liner pressures at different time points are used with thermal gradients as accidental temperature loads in determining thermal moment modification factors.

FSAR Impact:

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

Table 03.08.01-52-1—Thermal Moments at Elevation 65.86 ft from Equivalent and Refined Slice Models

Time Point for Accident Period	Equivalent Slice Model		Refined Slice Model	
	My (Kip-ft/ft)	Mz (Kip-ft/ft)	My (Kip-ft/ft)	Mz (Kip-ft/ft)
Acc-Start	837.57	834.52	146.69	144.52
Acc-20 m	890.45	886.88	300.48	297.30
Acc- 1.39 h	868.52	869.47	518.33	516.44
Acc- 24 h	1033.55	1035.08	1036.63	1037.69
Acc-100 h	683.78	687.77	688.08	692.00
Acc- 365 d	221.42	223.01	221.48	223.03

Table 03.08.01-52-2—Thermal Moments at 75 Degrees of Dome from Equivalent and Refined Slice Models

Time Point for Accident Period	Equivalent Slice Model		Refined Slice Model	
	My (Kip-ft/ft)	Mz (Kip-ft/ft)	My (Kip-ft/ft)	Mz (Kip-ft/ft)
Acc-Start	578.05	548.01	135.59	126.98
Acc-20 m	610.22	579.09	247.22	233.38
Acc- 1.39 h	664.00	631.02	436.18	412.78
Acc- 24 h	660.18	599.00	673.46	611.12
Acc-100 h	404.71	325.84	404.93	328.72
Acc- 365 d	142.68	109.86	142.26	110.77

Figure 03.08.01-52-1—Comparison of Temperature Gradients across the Thickness at Elevation 65.86 ft for (a) Steady State Condition, (b) 1200 Seconds, (c) 1.39 Hours, (d) 24 Hours, (e) 110 Hours, and (f) 1 Year

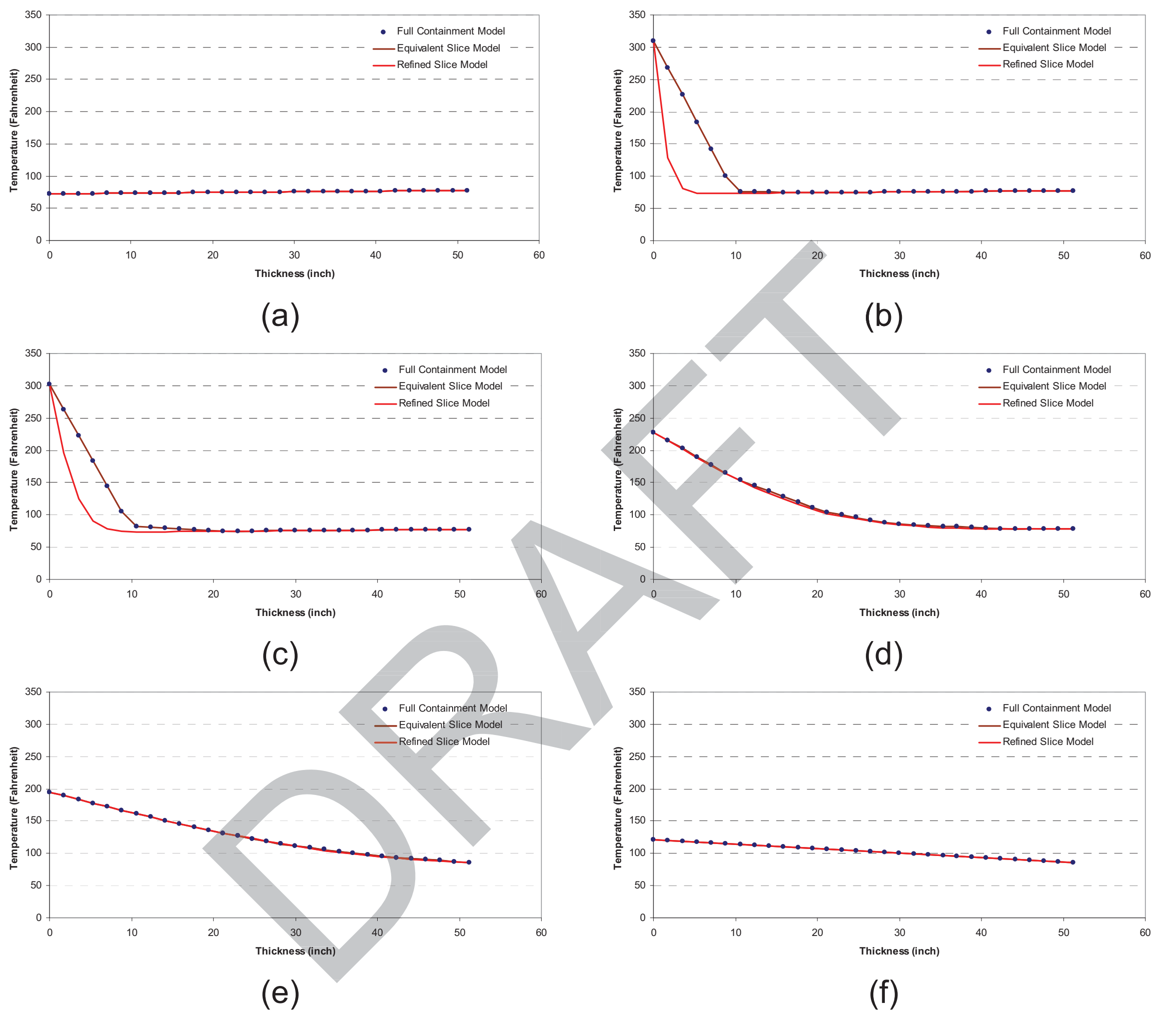
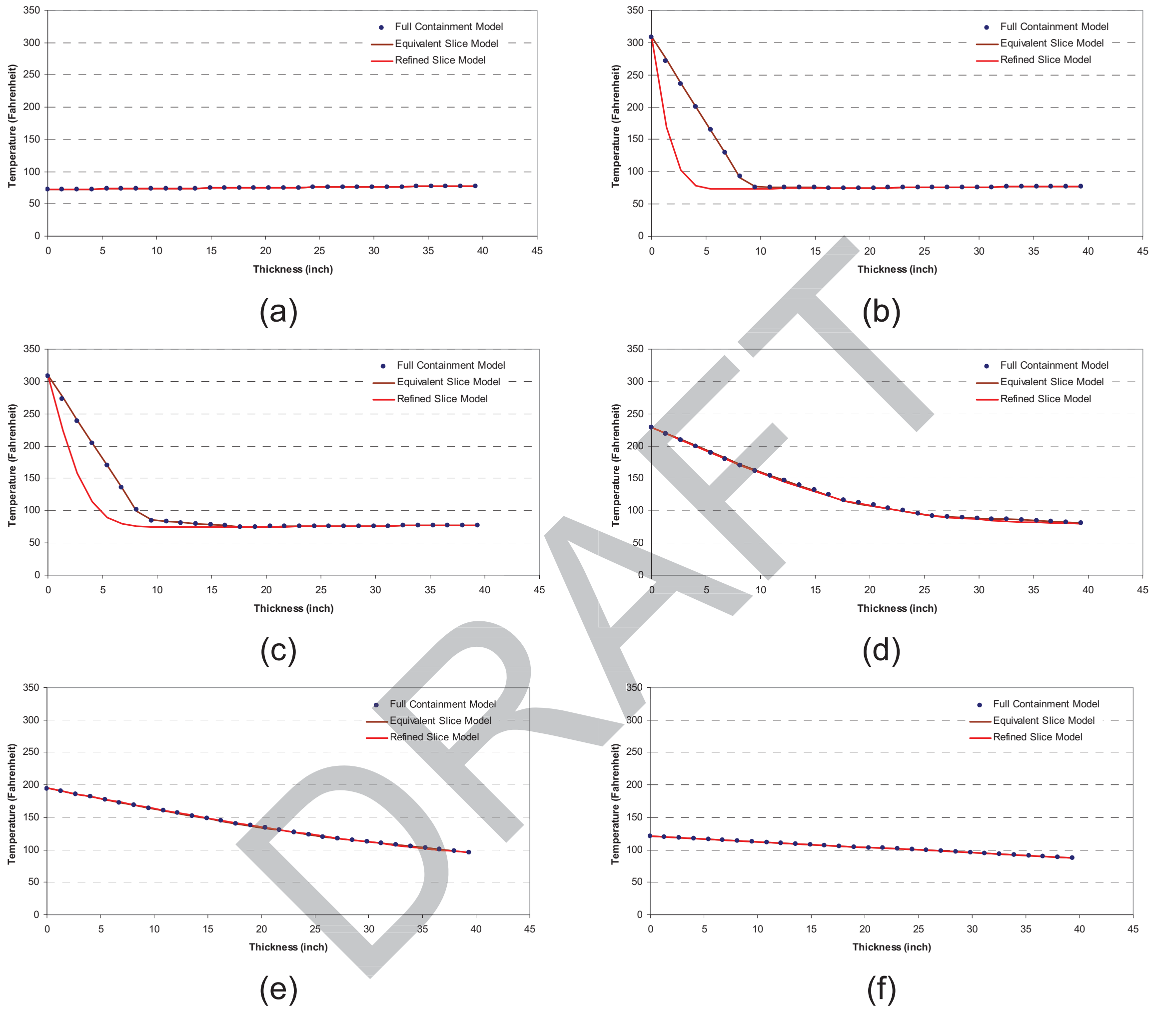


Figure 03.08.01-52-2—Comparison of Temperature Gradients across the Thickness at 75.05 Degree of Dome for (a) Steady State Condition, (b) 1200 Seconds, (c) 1.39 Hours, (d) 24 Hours, (e) 110 Hours and, (f) 1 Year



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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.

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 mesh refinement and cracked-section analysis using analytical techniques. The ANSYS

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