ArevaEPRDCPEm Resource

From: WELLS Russell (AREVA) [Russell.Wells@areva.com]
Sent: Thursday, March 31, 2011 7:06 PM
To: Tesfaye, Getachew
Cc: DELANO Karen (AREVA); ROMINE Judy (AREVA); BENNETT Kathy (AREVA); GUCWA Len (EXTERNAL AREVA); RYAN Tom (AREVA)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 8
Attachments: RAI 389 Supplement 8 Response US EPR DC.pdf

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for technically correct and complete responses to the 5 questions in RAI 389 on June 30, 2010. On August 4, 2010 and September 1, 2010, AREVA NP provided revised response schedules in RAI 389 Supplement 1 and Supplement 2, respectively. On October 6, 2010, AREVA NP submitted Supplement 3 response to RAI 389, which provided a technically correct and complete response to 1 of the remaining 5 questions. On October 13, 2010, November 17, 2010, February 9, 2011, and March 8, 2011, AREVA NP submitted Supplement 4, Supplement 5, Supplement 6, and Supplement 7 responses to RAI 389, respectively, which provided revised response schedules.

The attached file, "RAI 389 Supplement 8 Response US EPR DC.pdf" provides technically correct and complete responses to 1 of the remaining 4 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 389 Question 06.02.02-49.

The following table indicates the respective pages in the response document, "RAI 389 Supplement 8 Response US EPR DC.pdf" that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 389 — 06.02.02-49	2	5

The schedule for technically correct and complete responses to the remaining 3 questions is unchanged and provided below:

Question #	Response Date
RAI 389 — 06.02.02-47	April 20, 2011
RAI 389 — 06.02.02-50	April 20, 2011
RAI 389 — 06.02.02-51	April 20, 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: Tuesday, March 08, 2011 11:41 AM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 7

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for technically correct and complete responses to the 5 questions in RAI 389 on June 30, 2010. On August 4, 2010 and September 1, 2010, AREVA NP provided revised response schedules in RAI 389 Supplement 1 and Supplement 2, respectively. On October 6, 2010, AREVA NP submitted Supplement 3 response to RAI 389, which provided a technically correct and complete response to 1 of the remaining 5 questions. On October 13, 2010, November 17, 2010, and February 9, 2011, AREVA NP submitted Supplement 4, Supplement 5, and Supplement 6 responses to RAI 389, respectively, which provided revised response schedules. To provide an opportunity for additional interaction with the NRC staff, AREVA NP is providing a revised schedule for responding to the remaining questions as provided below:

Question #	Response Date
RAI 389 — 06.02.02-47	**April 20, 2011**
RAI 389 — 06.02.02-49	**April 20, 2011**
RAI 389 — 06.02.02-50	**April 20, 2011**
RAI 389 — 06.02.02-51	**April 20, 2011**

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
AREVA NP, Inc.
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Mail Stop OF-57
Lynchburg, VA 24506-0935
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[*Russell.Wells@Areva.com*](mailto:Russell.Wells@Areva.com)

From: BRYAN Martin (External RS/NB)
Sent: Wednesday, February 09, 2011 4:57 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 6

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for technically correct and complete responses to the 5 questions in RAI 389 on June 30, 2010. On August 4, 2010 and September 1, 2010, AREVA NP provided revised response schedules in RAI 389 Supplement 1 and Supplement 2, respectively. On October 6, 2010, AREVA NP submitted Supplement 3 response to RAI 389, which provided a technically correct and complete response to 1 of the remaining 5 questions. On October 13, 2010 and November 17, 2010, AREVA NP submitted Supplement 4 and Supplement 5 responses to RAI 389, respectively, which provided revised response schedules. To provide an opportunity for additional interaction with the NRC staff, AREVA NP is providing a revised schedule for responding to Question 06.02.02-47. The schedule for the remaining questions is unchanged.

Question #	Response Date
RAI 389 — 06.02.02-47	**March 28, 2011**
RAI 389 — 06.02.02-49	March 10, 2011
RAI 389 — 06.02.02-50	March 10, 2011
RAI 389 — 06.02.02-51	March 10, 2011

Sincerely,

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

From: BRYAN Martin (External RS/NB)
Sent: Wednesday, November 17, 2010 9:28 AM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 5

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for technically correct and complete responses to the 5 questions in RAI 389 on June 30, 2010.   On August 4, 2010 and September 1, 2010, AREVA NP provided revised response schedules in RAI 389 Supplement 1 and Supplement 2, respectively. On October 6, 2010, AREVA NP submitted Supplement 3 response to RAI 389, which provided a technically correct and complete response to 1 of the remaining 5 questions. On October 13, 2010, AREVA NP submitted Supplement 4 response to RAI 389, which provided a revised response schedule. To provide an opportunity for additional interaction with the NRC staff, AREVA NP is providing a revised schedule below for responding to the remaining questions.

Question #	Response Date
RAI 389 — 06.02.02-47	February 9, 2011
RAI 389 — 06.02.02-49	March 10, 2011
RAI 389 — 06.02.02-50	March 10, 2011
RAI 389 — 06.02.02-51	March 10, 2011

Sincerely,

Martin (Marty) C. Bryan
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From: BRYAN Martin (External RS/NB)
Sent: Wednesday, October 13, 2010 12:07 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 4

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for technically correct and complete responses to the 5 questions in RAI 389 on June 30, 2010. On August 4, 2010 and September 1, 2010, AREVA NP provided revised response schedules in RAI 389 Supplement 1 and Supplement 2, respectively. On October 6, 2010, AREVA NP submitted Supplement 3 response to RAI 389, which provided a technically correct and complete response to 1 of the remaining 5 questions.

Proposed responses to the remaining RAI 389 questions were discussed with the NRC staff during an NRC containment functional design audit held on September 29-30, 2010. As a result of those discussions and to provide additional time for NRC interface, the schedule for responding to the remaining questions is revised and provided below.

Question #	Response Date
RAI 389 — 06.02.02-47	December 22, 2010
RAI 389 — 06.02.02-49	December 8, 2010
RAI 389 — 06.02.02-50	November 17, 2010
RAI 389 — 06.02.02-51	November 17, 2010

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
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Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Wednesday, October 06, 2010 4:14 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 3

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for technically correct and complete responses to the 5 questions in RAI 389 on June 30, 2010. On August 4, 2010 and September 1, 2010, AREVA NP provided revised response schedules in RAI 389 Supplement 1 and Supplement 2, respectively. The attached file "RAI 389 Supplement 3 Response US EPR DC.pdf," provides a technically correct and complete response to 1 of the remaining 5 questions.

The following table indicates the respective pages in the response document, "RAI 389 Supplement 3 Response US EPR DC.pdf," that contain AREVA NP's response to the subject question. 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 389 Question 06.02.02-48.

Question #	Start Page	End Page
RAI 389 — 06.02.02-48	2	4

The schedule for technically correct and complete responses to the remaining 4 questions is unchanged and is provided below.

Question #	Response Date
RAI 389 — 06.02.02-47	October 13, 2010
RAI 389 — 06.02.02-49	October 13, 2010
RAI 389 — 06.02.02-50	October 13, 2010
RAI 389 — 06.02.02-51	October 13, 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 (External RS/NB)
Sent: Wednesday, September 01, 2010 6:42 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); GUCWA Len (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 2

Getachew,

On June 30, 2010, AREVA NP Inc. provided a schedule for technically correct and complete responses to the 5 questions. On August 4, 2010, AREVA NP provided a revised schedule in Supplement 1. To provide additional time to interact with the staff on question 06.02.02-48, a revised schedule is provided below.

The schedule for technically correct and complete responses is changed and is provided below.

Question #	Response Date
RAI 389 — 06.02.02-47	October 13, 2010
RAI 389 — 06.02.02-48	**October 7, 2010**
RAI 389 — 06.02.02-49	October 13, 2010
RAI 389 — 06.02.02-50	October 13, 2010
RAI 389 — 06.02.02-51	October 13, 2010

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.

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Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Wednesday, August 04, 2010 4:53 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); GUCWA Len T (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 1

Getachew,

On June 30, 2010, AREVA NP Inc. provided a schedule for technically correct and complete responses to the 5 questions. To provide additional time to interact with the staff on question 06.02.02-48, a revised schedule is provided below.

The schedule for technically correct and complete responses is changed and is provided below.

Question #	Response Date
RAI 389 — 06.02.02-47	October 13, 2010
RAI 389 — 06.02.02-48	**September 1, 2010**
RAI 389 — 06.02.02-49	October 13, 2010
RAI 389 — 06.02.02-50	October 13, 2010
RAI 389 — 06.02.02-51	October 13, 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: Wednesday, June 30, 2010 7:34 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); GUCWA Len T (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 389 Response US EPR DC.pdf" provides a schedule since technically correct and complete responses to the 5 questions are not provided.

The following table indicates the respective pages in the response document, "RAI 389 Response US EPR DC.pdf" that contain AREVA NP's responses to the subject questions.

Question #	Start Page	End Page
RAI 389 — 06.02.02-47	2	2
RAI 389 — 06.02.02-48	3	3
RAI 389 — 06.02.02-49	4	5
RAI 389 — 06.02.02-50	6	6
RAI 389 — 06.02.02-51	7	7

A complete answer is not provided for the 5 questions. The schedule for technically correct and complete responses to these questions is provided below.

Question #	Response Date
RAI 389 — 06.02.02-47	October 13, 2010
RAI 389 — 06.02.02-48	August 4, 2010
RAI 389 — 06.02.02-49	October 13, 2010
RAI 389 — 06.02.02-50	October 13, 2010
RAI 389 — 06.02.02-51	October 13, 2010

Sincerely,

Martin (Marty) C. Bryan
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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Wednesday, June 02, 2010 7:12 AM
To: ZZ-DL-A-USEPR-DL
Cc: Jensen, Walton; Peng, Shie-Jeng; Hayes(NRO), Michelle; Jackson, Christopher; McKirgan, John; Carneal, Jason; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 389 (4615), FSAR Ch. 6

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on April 12, 2010, and discussed with your staff on April 22, 2010 and May 6, 2010. Drat RAI Question 06.02.02-49 was modified as a result of those discussions. 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: 2793

Mail Envelope Properties (1F1CC1BBDC66B842A46CAC03D6B1CD41042B9CC2)

Subject: Response to U.S. EPR Design Certification Application RAI No. 389, FSAR Ch. 6, Supplement 8
Sent Date: 3/31/2011 7:05:50 PM
Received Date: 3/31/2011 7:05:52 PM
From: WELLS Russell (AREVA)

Created By: Russell.Wells@areva.com

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"DELANO Karen (AREVA)" <Karen.Delano@areva.com>
Tracking Status: None
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Files	**Size**	**Date & Time**
MESSAGE	15654	3/31/2011 7:05:52 PM
RAI 389 Supplement 8 Response US EPR DC.pdf		104345

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

Response to

Request for Additional Information No. 389(4615), Revision 1, Supplement 8

6/2/2010

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.02 - Containment Heat Removal Systems
Application Section: FSAR Chapter 6

QUESTIONS for Containment and Ventilation Branch 1 (AP1000/EPR Projects) (SPCV)

Question 06.02.02-49:

In case of a postulated DBA, containment heat removal is a major safety function. Appropriate systems must be provided, and the capacity of the systems must be evaluated. Section 6.2.2 of the FSAR is the appropriate place for description of the containment heat removal systems, the performance evaluation of the systems and the demonstration of compliance with GDC 38.

U.S. EPR, Tier 2, Section 6.2.2 provides only a general description of containment heat removal following DBAs. It references Section 6.2.1 for containment pressure and temperature response calculations, and Section 6.3 for the design, inspection and testing of the SIS, and for sump screen blockage. This is important information, but not sufficient for an independent evaluation of the containment heat removal systems. More detail is needed

The FSAR should have, preferably in Section 6.2.2, the following information. If some of the information is provided in another section of the FSAR, this section should be referenced. Conclusions reached on containment heat removal systems should be summarized in Section 6.2.2. Safety systems frequently perform more than one function, in Section 6.2.2 the emphasis should be on short and long term containment cooling.

Provide the following information in the FSAR in accordance with RG 1.206:

a) General description of containment heat removal, identification of safety systems performing this function.

b) Detailed description of each system, safety classification of components of the system.

c) Identification of potential single active and single passive failures of the system, including common mode failures. Evaluation of the effects of these failures on containment heat removal.

d) Specification of design features of the heat removal systems that permit periodic inspection of components and periodic testing of the systems.

e) Analysis of the heat removal capacity of each system.

f) Evaluation of potential surface fouling of the LHSI heat exchangers in the recirculation system.

   Among other information, Section 6.2.2 should address or reference the following items:

   1. Design and operation of the ECCS including the IRWST as they function as containment heat removal system including the deliverance of cooled ECCS in a manner that will condense significant amounts of steam.

      2. Long term water source for the ECCS. Design principle used to prevent water accumulation in the containment. Flow path for gravity flow, draining of rooms with solid floors. Prevention of flow blockage in restricted places.

      3. Design features to retain debris: weirs, trash racks, retaining baskets, sump strainers.

      4. Quantitative evaluation of containment related input to the NPSH calculations: water holdup in the containment, head loss caused by debris blocking sump strainers, air ingestion based on sump hydraulic characteristics, downstream effects of debris

passing the sump strainers. Availability of sufficient NPSH for short and long term cooling of the containment.

5. Potential for surface fouling of heat exchangers. The effect of fouling on heat removal. Justification of fouling factors used. Verification of GOTHIC heat exchanger model.
6. Description and operation of the CONVECT system. Safety classification of the system, corresponding ITAAC and Tech. Spec., initial testing of the system.
7. Testing of components of the CONVECT system.
8. Redundancy and diversity in the control of the mixing dampers. Single failure and common mode failure analysis.
9. Performance of the CONVECT system in case of large and small LOCAs and large and small MSLBs, breaks located in equipment space, breaks located in annular space.

Response to Question 06.02.02-49:

a) U.S. EPR FSAR Tier 2, Section 6.2.2 will be revised to include a general description of the containment heat removal, as well as identification of safety-related systems performing this function.

b) U.S. EPR FSAR Tier 2, Section 6.2.2 and Section 6.2.5 will be revised to include a description of each system, as well as safety classification of the system components.

c) U.S. EPR FSAR Tier 2, Section 6.2.2 will be revised to identify potential single active and single passive failure of the system, including common mode failures, as well as an evaluation of these failures on containment heat removal.

d) U.S. EPR FSAR Tier 2, Section 6.2.2 will be revised to specify design features of the heat removal systems that allow periodic inspection of components and periodic system testing.

e) U.S. EPR FSAR Tier 2, Section 6.2.2 will be revised to include an analysis of the heat removal capacity of the safety injection system (SIS).

f) Part 5 of this subsection describes AREVA NP's position on the evaluation of potential surface fouling of the low head safety injection (LHSI) heat exchangers in the recirculation system.

1. U.S. EPR FSAR Tier 2, Section 6.2.2.2 will be revised to describe the design and operation of the emergency core cooling system (ECCS), including the in-containment refueling water storage tank (IRWST) as they function for containment heat removal system.
2. The long-term water source for the ECCS is the IRWST water volume.

   To prevent water accumulation in the containment, the U.S. EPR design principle and containment design provides a direct return flow path from the loss of coolant accident (LOCA) break to the IRWST. The reactor coolant system (RCS) loops are located directly above the containment heavy floor. An RCS loop break results in LOCA water draining directly to the heavy floor. The heavy floor contains four weir/trash rack heavy floor openings that allow the return water to drain directly to the IRWST. For a pressurizer line break, the LOCA return water is routed to the heavy floor, where it drains through the heavy floor openings to the IRWST.

LOCA water resulting from RCS line breaks and pressurizer line breaks gravity drains to the containment heavy floor. The containment heavy floor has four heavy floor openings, which allow the LOCA water to gravity drain into the heavy floor openings to the IRWST.

The containment design verifies that there is a direct gravity flow path from the LOCA breaks to the IRWST.

3. U.S. EPR FSAR Tier 2, Section 6.2.2.2 describes by reference the design features of the IRWST to retain debris.
4. The following information provides containment-related input to the U.S EPR net positive suction head (NPSH) calculations:
   - The Response to RAI 340, Question 06.02.01-57 discusses the water holdup in containment.
   - Technical Report ANP-10293, Revision 1, Appendix E, discusses head loss caused by debris blocking sump strainers.
   - Technical Report ANP-10293, Revision 1, Section 3.2.2 discusses air injection based on sump hydraulic characteristics.
   - "U.S. EPR Safety Injection Systems Analysis for Design Certification" (32-9017755-007) discusses the availability of sufficient NPSH. This document has been reviewed by the NRC staff. U.S. EPR FSAR Tier 2, Section 6.2.2.3 will be revised to describe the evaluation of NPSH availability of the SIS pumps.
5. AREVA NP agrees on the potential for surface fouling of heat exchangers resulting from normally occurring decay heat removal fluid conditions. The Response to RAI 297, Question 06.02.02-42 describes AREVA NP's position on the effects of debris laden post-LOCA recirculation fluid conditions on the heat exchanger fouling factors.

   As listed in the Response to RAI 82, Question 06.02.02-1, the fouling factors applied to the GOTHIC LHSI heat exchanger model used in the containment heat removal analysis are:

   - Tube Side Fouling Factor = 0.000170 (ft^2.hr.°F)/BTU.
   - Shell Side Fouling Factor = 0.000284 (ft^2.hr.°F)/BTU.

   These fouling factors are based on the reference plant design. An additional GOTHIC analysis was performed to demonstrate the effect of fouling on the containment pressure response. The following fouling factors were applied to the GOTHIC model:

   - Tube Side Fouling Factor = 0.0005 (ft^2.hr.°F)/BTU.
   - Shell Side Fouling Factor = 0.0005 (ft^2.hr.°F)/BTU.

The more conservative fouling factors modeled reflect values recommended in Reference 1 for demineralized water. The Response to RAI 266, Question 06.02.02-33 provides results from the sensitivity case performed on the GOTHIC model, which has an insignificant impact on the U.S. EPR FSAR containment analysis.

6. U.S. EPR FSAR Tier 2, Section 6.2.2.2 and Section 6.2.5 will be revised to describe the description and operation of the CONVECT system and the corresponding safety classification, ITAAC, and Technical Specification.

7. U.S. EPR FSAR Tier 2, Section 6.2.2.4 and Section 6.2.5 will be revised to describe the testing of CONVECT components.

8. U.S. EPR FSAR Tier 2, Section 6.2.2.5 and Section 6.2.5 will be revised to describe redundancy and diversity in the control of the hydrogen mixing dampers and single and common mode failure analysis.

9. The CONVECT system includes a combination of rupture and convection foils located in a steel frame above the steam generators (SGs). These foils open instantaneously on bi-directional pressure if the pressure exceeds 0.943 psi (0.725 psi + 30 percent). The convection foils also open when the temperature below the frame exceeds 185.9°F (180.5°F with a 3 percent tolerance).

   For the LOCA and main steam line breaks (MSLBs) in the equipment space, the lower convection foil frame is modeled to separate from the pressure equalization ceiling at a temperature of 185.9°F (180.5°F with a 3 percent tolerance) and a conservative 30 second delay. For MSLB accidents in the annular space, a longer delay of 300 seconds is assumed and is conservative as described in the Response to RAI 378, Question 06.02.01-84.

   For the large break cases, the rupture and convection foils open quickly, regardless of temperature or pressure. For the small break cases with a smaller pressure differential, it is uncertain that all of the foils above the intact tower will open as expected in the large break cases. The foils above the intact tower are only allowed to open on temperature for conservatism in small split break cases. The criterion for defining small break was selected to be 10 percent or less of the area of the cold leg. Break sizes of 0.52 ft^2 or less are small split breaks.

   The design of the foil frame recently changed, which increased the total vent area of the rupture foils. However, the change reduced the area of the convection foils by less than 8 ft^2 per loop. This change was not implemented in the GOTHIC model because the limiting breaks are large enough to rupture the foils and do not only rely on the convection foils.

References for Question 06.02.02-49:

1. Heat Exchanger Institute, Inc., “Standards for Power Plant Heat Exchangers,” Third Edition, March 1998, page 3.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 6.2.2 and Section 6.2.5 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

6.2.2 Containment Heat Removal Systems

06.02.02-49

The containment design includes integrated systems to limit the containment pressure and temperature increase and maintain them at acceptably low levels following the accident. These systems include the CONVECT system, recirculation and heat removal features built into the in-containment refueling water storage tank (IRWST), and re-alignment of the safety injection system (SIS) ~~emergency core cooling system (ECCS) system~~ to the hot legs.

The CONVECT system is further described in Section 6.2.5, while the IRWST and the SIS are further described in Section 6.3.

6.2.2.1 Design Bases

The containment heat removal systems include the CONVECT system, the IRWST, and the SIS. The design bases of the CONVECT system is described in Section 6.2.5.1, while the design bases of the IRWST and the SIS are described in Section 6.3.1.

6.2.2.2 System Design

In the event of an accident, communication is established between the accessible space and the equipment area by opening mixing dampers and a combination of rupture and convection foils, thereby transforming the divided containment volume into a single convective volume. This transformation to a single convective volume is performed by the CONVECT system. This enables equalization of pressure between the containment compartments and promotes efficient mixing of the atmosphere by establishing a global convective loop within the containment. The resulting atmospheric mixing increases convective cooling to walls and structures.

06.02.02-49

The CONVECT system of convection foils, rupture foils, and mixing dampers is part of the combustible gas control system (CGCS). The CONVECT system is designed to provide adequate mixing for both large and small breaks inside and outside of equipment rooms. Following a large-break LOCA, the pressure differential between rooms increases rapidly and the rupture foils open in either direction. For a small break, the pressure differential might not be sufficient at all locations, so only the rupture foils near the break open. However, as the equipment area temperature rises, the convection foils open to provide adequate vent area between the accessible space and the equipment rooms. Section 3.2 identifies and provides the safety and quality group classification for the CONVECT system components.

Following blowdown, the vapor in the atmosphere condenses on the passive containment heat sinks located throughout the containment. The saturated water drains along the intermediate floors, grates, stairwells, and walls to the IRWST. Condensation-induced circulation zones provide additional mixing of the containment atmosphere during and after blowdown. Saturated water drains from the heat sinks in

06.02.02-49

the equipment area, pools on the heavy floor, and mixes with the liquid break effluent. Curbed grates in the heavy floor direct the condensate and spilled reactor coolant back to the IRWST.

For the U.S. EPR design, a manual realignment of at least 75 percent of the low head safety injection (LHSI) system from the cold leg to the hot leg injection location takes place during the final LBLOCA phase (about 60 minutes after the initiating event). Hot leg injection serves both as a mechanism for removing core decay heat, leading to the complete cessation of steaming, and for maintaining core boron concentrations below the threshold concentration for precipitation.

Water from the IRWST water, which serves as the long term water source for the SIS, is recirculated by the LHSI pumps through the SISLHSI heat exchangers, where it is cooled by the component cooling water system (CCWS). Then it is pumped into the RCS to cool the core before it returns to the IRWST through the break.

~~The design basis containment analysis for loss of coolant accidents and main steam line breaks, and the containment pressure and temperature responses for these events, is discussed in Section 6.2.1. As shown in Figure 6.2.1-12, Figure 6.2.1-16, and Figure 6.2.1-20, containment pressure decreases to half its peak in less than twenty-four hours after a LOCA.~~

The SIS provides cooling of the IRWST in the event of a LOCA and provides long-term core cooling. The SIS consists of four independent trains, providing sufficient capacity, diversity, and independence to perform its required safety functions following design basis transients or accidents assuming a single failure in one train while a second train is out-of-service for preventive maintenance. ~~Section 6.3 discusses the SIS, including design bases, instrumentation, and inspection and testing requirements.~~ Section 3.2 identifies component classifications for the IRWST and SIS. Section 6.3.2.2.2 includes a discussion of the design features for avoidance of the potential loss of long-term cooling capability due to sump screen blockage in the IRWST and presents the performance evaluation of the design, a summary of component testing, and a comparison to the regulatory positions of RG 1.82.

The debris interceptor structures, including trash racks, retention baskets and ECCS strainers, are designed and analyzed per the provisions of ANSI/AISC N690-1994, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement 2 (S2). The structural qualification of the debris interceptors includes an evaluation of the structural integrity of the supports and anchorages as it relates to the abilities of the trash rack, retention baskets, and ECCS strainers to perform their intended function.

The following industry codes and standards are used for the structural qualification of the debris interceptors.:

1. Design Properties of Materials: ASME Boiler & Pressure Vessel Code, Section II, Part D, 2004 edition.

2. Steel Analysis: ANSI/AISC N690-1994,"Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," including Supplement No. 2.

3. Concrete Anchorages: ACI 349-01/349R-01, "Code Requirements for Nuclear Safety Related Concrete Structures and Commentary."

4. Damping Values: NRC Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1, March 2007.

A COL applicant that references the U.S. EPR design certification will prepare a structural evaluation and stress margin report for the debris interceptor structures that confirms their design to comply with the requirements of ANSI/AISC N690-1994, including Supplement 2.

The debris interceptor components such as IRWST retaining baskets, trash racks, TSP baskets and sump strainers are categorized as Seismic Category I mechanical equipment in U.S. EPR FSAR, Tier 1, Table 2.2.2-1. The seismic qualification of this equipment is covered by ITAAC Item 3.3 in U.S. EPR FSAR, Tier 1, Table 2.2.2-3.

06.02.02-49

6.2.2.3 Design Evaluation

The design basis containment analysis for loss of coolant accidents and main steam line breaks, and the containment pressure and temperature responses for these events, is discussed in Section 6.2.1. As shown in Figure 6.2.1-12, Figure 6.2.1-16, and Figure 6.2.1-20, containment pressure decreases to half its peak in less than twenty-four hours after a LOCA. Analysis of heat removal capacity of the LHSI heat exchanger in support of containment heat removal is discussed in Section 6.2.1.1.3.

The evaluation of NPSH availability of the SIS pumps is discussed in Section 6.3.3.3.

The failure modes and effects analyses of the CONVECT System are described in Section 6.2.5. The failure modes and effects analyses of the SIS are listed in Table 6.3-7 of Section 6.3. The common mode failure is addressed by the qualification program and periodic testing.

6.2.2.4 Tests and Inspections

Tests and inspections of the CONVECT system are described in Section 6.2.5.4, while the tests and inspections of the IRWST and the SIS are described in Section 6.3.4.

6.2.2.5 Instrumentation Requirements

Instrumentation requirements of the CONVECT system are described in Section 6.2.5.5, while the instrumentation requirements of the IRWST and the SIS are described in Section 6.3.5.

Next File

- The CGCS maintains containment structural integrity following an accident that releases hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by hydrogen burning (10 CFR 50.44(c)(5), GDC 41).
- The CGCS and HMS are not shared among multiple units (GDC 5).
- The CGCS is designed to permit periodic inspection and testing to confirm the integrity and operability of the systems (GDC 42, GDC 43).
- The CGCS and HMS conform to RG 1.7 to meet the requirements of 10 CFR 50.44.

Refer to Section 3.2 for the seismic and system quality group classifications of the CGCS and HMS.

6.2.5.2 System Description

Global convection reduces the likelihood of combustible gas buildup under accident conditions. This is aided by the containment geometry, which provides open-ended compartments and a large total volume (as shown in Figures 3.8-2 through 3.8-13). The CGCS enables the convection of gas mixtures from the lower elevations of the IRWST to the containment dome. This space includes the entire containment volume.

Additionally, the rupture disks of the pressurizer relief tank discharge to the equipment compartments in the lower containment (Section 5.4.11). The release of hydrogen and steam into the lower compartments of the containment drives an upward convection current that promotes mixing of combustible gases.

6.2.5.2.1 Combustible Gas Control System

The CGCS provides for a mixed and homogeneous gas atmosphere in the containment and controls the concentration of combustible gases following an accident that results in a release of hydrogen to the containment atmosphere. The design and performance parameters are listed in Table 6.2.5-1—CGCS Design and Performance Parameters. The CGCS consists of the following components:

- Rupture foils installed in the steel framework above the steam generators open passively on pressure differential to promote global convection and containment atmosphere mixing.
- Convection foils installed with the rupture foils open passively on pressure differential or temperature differential to promote global convection and containment atmosphere mixing.
- Hydrogen mixing dampers installed between the in-containment refueling water storage tank (IRWST) and the annular compartments within containment open passively on receiving a differential or absolute pressure signal~~pressure differential~~ or loss of power to promote global convection and mixing. In addition, the mixing dampers can be opened by manual operator action.

06.02.02-49

concentration is reduced to levels below 4 percent by volume before the activation of the severe accident heat removal system as displayed in Figure 19.2-9.

- The containment can withstand a global deflagration without loss of integrity as discussed in Section 19.2.4.4.1.4. Figure 19.2-7 shows the adiabatic isochoric complete combustion (AICC) pressure vs. time, which remains below the ultimate capacity pressure for the U.S. EPR containment.

The containment analysis considers hydrogen generated from fuel cladding oxidation and molten core-concrete interaction (MCCI). The analysis assumes that the hydrogen produced during MCCI is released to the containment and not consumed by auto-ignition. This conservative assumption compensates for unaccounted hydrogen, such as hydrogen generated from cladding oxidation outside the active fuel region, or from the oxidation of zinc-based material coatings and aluminum.

6.2.5.3.3 Design Evaluation

06.02.02-49

The PARs, rupture and convection foils, and hydrogen mixing dampers of the CGCS are passive devices that do not rely on electrical power to perform their primary functions and are not susceptible to single active failure. Loss of onsite or offsite power has no effect on the PARs and rupture and convection foils, and will cause the fail-safe mixing dampers to fail-safe open ~~to the safe position~~.

The CGCS is designed to operate in DBAs with elevated temperature, pressure and radiation. The mixing dampers, rupture and convection foils open early in the accident progression on pressure differential or temperature differential. If the DBA transitions into a Severe Accident, these components have to maintain integrity only. Their operation is not affected by localized pressure and temperature increase due to hydrogen combustion.

The PARs are designed for DBA, as well as SA conditions.

The PARs are not pressure retaining components and are open at the bottom and the top, therefore, are unaffected by localized pressure increase. The design covers hydrogen combustion temperature peaks and SA radiation.

~~The CGCS is capable of operating under the conditions expected during design basis accidents and severe accidents. The PARs are not pressure retaining components and are open at the bottom and the top, therefore, are unaffected by localized pressure increase. The mixing dampers, rupture and convection foils open on pressure differential or temperature differential, therefore, their operation is also not affected by localized pressure and temperature increase due to hydrogen combustion.~~

The CGCS operates effectively in a steam-saturated atmosphere (steam concentration greater than 55 percent by volume), and will function during and after exposure to the environmental conditions created by the burning of hydrogen, including local detonations. Equipment survivability analyses, described in Section 19.2.4.4.5, consider hydrogen concentrations equivalent to that generated from a fuel clad-coolant reaction involving 100 percent of the fuel cladding surrounding the active fuel region. The low range and high range HMS systems are capable of operating during design basis accidents and severe accidents, respectively.

The low range hydrogen sensors are located inside the containment and meet the single failure criterion. These sensors are located in seven physically separated areas of the containment. Additionally, the signal processing is carried out by separate channel cards installed within the signal processing unit that is located outside containment. The sensors and cables located inside containment are designed to remain operable during DBAs. The failure of one sensor or cable does not influence the reliability or accuracy of the other sensors.

The high range monitor for the HMS utilizes measuring modules and associated equipment of each independent train. The trains meet the single failure criterion by being physically separated and located in Safeguard Building 1 for train 1 and Safeguard Building 4 for train 2. The gas samplers of each train are installed in different areas of the containment. Each train is equipped with measuring points inside and outside the equipment rooms so that in case a measuring unit is lost, the measuring information can be substituted by the redundant train.

6.2.5.4 Inspection and Testing Requirements

06.02.02-49

Preoperational testing is performed to verify the design adequacy and performance of the CGCS and HMS system components. Preoperational tests are addressed in Section 14.2 (Test Abstract #013 and #145), .while Inspections, Tests, Analyses, and Acceptance Criteria of the CGCS are listed in Section 14.3.

For operational testing, the PARs have a removable inspection drawer for ease of maintenance and in-service inspection. The catalytic plates are visually examined for scratches, damage, or foreign objects that could limit the surface area for catalysis. The catalytic ability of the plates is tested with special equipment that subjects the plates to a premixed test gas.

Operability of the hydrogen mixing dampers is periodically verified and visual inspections of the dampers are performed to check for obstructions or loose or broken parts that could interfere with their proper operation. The rupture and convection foils are visually inspected for cracks or damage. Significant leakage through the foils is detectable during operation by monitoring of the ventilation system.

The HMS system components are tested periodically during normal plant operating conditions to confirm proper operation.

The low range hydrogen sensors are located inside the containment and meet the single failure criterion. These sensors are located in seven physically separated areas of the containment. Additionally, the signal processing is carried out by separate channel cards installed within the signal processing unit that is located outside containment. The sensors and cables located inside containment are designed to remain operable during DBAs. The failure of one sensor or cable does not influence the reliability or accuracy of the other sensors.

The high range monitor for the HMS utilizes measuring modules and associated equipment of each independent train. The trains meet the single failure criterion by being physically separated and located in Safeguard Building 1 for train 1 and Safeguard Building 4 for train 2. The gas samplers of each train are installed in different areas of the containment. Each train is equipped with measuring points inside and outside the equipment rooms so that in case a measuring unit is lost, the measuring information can be substituted by the redundant train.

6.2.5.4 Inspection and Testing Requirements

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For ~~operational~~periodic testing, the PARs have a removable inspection drawer for ease of maintenance and in-service inspection. The catalytic plates are visually examined for scratches, damage, or foreign objects that could limit the surface area for catalysis. The catalytic ability of the plates is tested with special equipment that subjects the plates to a premixed test gas. During outages, the PARs are covered by blankets to avoid direct exposure to dust and fumes generated by local work operations.

Operability of the hydrogen mixing dampers is periodically verified and visual inspections of the dampers are performed to check for obstructions or loose or broken parts that could interfere with their proper operation. The rupture and convection foils are visually inspected for cracks or damage. Significant leakage through the foils is detectable during operation by monitoring of the ventilation system.

The HMS system components are tested periodically during normal plant operating conditions to confirm proper operation.

6.2.5.5 Instrumentation Requirements

06.02.02-49

The PARs, rupture foils, and convection foils of the CGCS are passive components that do not require instrumentation or controls. The hydrogen mixing dampers (HMD) are safety-related and their operation and actuation logic is controlled by the protection system, safety automation system, and diverse actuation system. There are two sensors

06.02.06-49

per steam generator loop for a total of eight, safety-related delta pressure sensors powered from their respective electrical divisions. This arrangement meets the single failure requirements such that a sensor can be out for maintenance and a single-failure can occur without affecting the HMD control. If two out of eight sensor signals exceed the delta pressure setpoint all eight HMDs receive a signal to open. The delta pressure setpoint is 0.5 psid. The delta pressure is measured across the steam generator pressure equalization ceiling and measures the difference in pressure between the accessible and equipment area. The delta pressure signal accounts for a pressure increase in either of the regions to provide an actuation signal for the HMDs.

In addition, there are a total of four safety-related absolute containment service compartment pressure sensors. Their operation and actuation logic is also controlled by the protection system and the diverse actuation system. For each steam generator loop an associated absolute pressure sensor is located in the accessible area of the containment. If two out of four of the absolute pressure sensors exceed the absolute pressure setpoint of 17.4 psia, the HMDs receive a signal to open. This arrangement and logic also meets the single failure requirements in that a sensor can be out for maintenance and a single-failure can occur without affecting the HMD control. There are no restrictions placed on plant operation if one of the absolute pressure sensors is out of service.

The combination of delta and absolute pressure sensors fulfills redundancy and diversity requirements. Position sensors indicate the HMD position in the main control room. If an HMD opens unintentionally, it can be closed by either the actuator or the mechanical backup closing mechanism. In the unlikely case that a mixing damper remains open, the resulting leakage (cross-sectional area approximately 8 ft^2), compared to the total leakage of penetrations and doors across the in-accessible and accessible rooms, is negligible. HMDs are installed in the accessible area which provides for maintenance access to the component during normal operation. Section 7.3 provides further detail about the I&C logic and logic diagrams of the HMDs.

The redundancy of the eight hydrogen mixing dampers meets FMEA requirements so that one HMD can be out for maintenance and a single failure can occur at a second HMD without affecting the global convection between the equipment and operational rooms (see Table 6.2.5-3, which lists the CGCS Failure Modes and Effects Analysis).

On-site periodic testing verifies the proper functioning of each installed HMD (see Section 6.2.5.4). The common mode failure is addressed by the qualification program and periodic testing. ~~The hydrogen mixing dampers receive a signal to open automatically on high differential pressure between compartments or on high containment pressure. The mixing dampers can also be opened or closed by manual operator action. Position sensors in the main control room indicate the damper position. The mixing dampers fail open on loss of power.~~

Table 6.2.5-1—CGCS Design and Performance Parameters

Parameter	Value
Large PARs	
• Number of units	41
• Nominal hydrogen reduction rate (per PAR)	11.8 lb_m/hr
• Catalyst	Pt / Pd coating
Small PARs	
• Number of units	6
• Nominal hydrogen reduction rate (per PAR)	2.6 ~~lb^m~~ lb_m/hr
• Catalyst	Pt / Pd coating
Hydrogen mixing dampers	
• Number of units	8
• Approximate opening cross section (total)	64 ft^2
• Nominal actuation pressure	0.5 psid or 17.4 psia
Rupture foils	
• Approximate opening cross section (total)	~~375~~420 ft^2
• Nominal actuation pressure	0.7 psid
Convection foils	
• Approximate opening cross section (total)	~~480~~450 ft^2
• Nominal actuation pressure	0.7 psid
• Nominal actuation temperature	180.5°F

06.02.02-49

Table 6.2.5-3—Combustible Gas Control System Failure Modes and Effects Analysis Sheet 1 of 2

Component	Component Function	Failure Mode	Failure Mechanism	Failure Symptoms / Effects	Can CGCS Satisfy Success Mission Criteria
Passive Autocatalytic Recombiners (PARs): 30JMT10 AT001 through 30JMT10 AT047	Reduce hydrogen concentration in the containment to maintain containment integrity and promote global convection	Failure to recombine hydrogen	Catalytic	No reduction of hydrogen at PAR location	Yes, the failure only affects the PAR location. Global convection assures a mixed atmosphere and homogeneous distribution of hydrogen in the containment.
Convection Foils: 30JMT20 AB101 through 30JMT20 AB130 30JMT20 AB201 through 30JMT20 AB230 30JMT20 AB301 through 30JMT20 AB330 30JMT20 AB401 through 30JMT20 AB430	Separate the equipment and service compartments during normal plant operation Opens on exceeding the pressure or temperature threshold and transfers the two-room containment into a single volume to promote global convection and atmospheric mixing	a) Open during normal operation	Mechanical	Minor leakage between the equipment and service compartments	Yes, the occurring leakage is negligible compared to the allowed total leakage between the equipment and service compartments.
		b) Failure to open during an accident	Mechanical	No convection at the Convection Foil location	Yes, the blocked free flow area is negligible compared to the total combined opening area of the convection foils.

06.02.02-49

Table 6.2.5-3—Combustible Gas Control System Failure Modes and Effects Analysis
Sheet 2 of 2

Component	Component Function	Failure Mode	Failure Mechanism	Failure Symptoms / Effects	Can CGCS Satisfy Success Mission Criteria
Hydrogen Mixing Dampers: 30JMT20 AA001 30JMT20 AA002 30JMT20 AA003 30JMT20 AA004 30JMT20 AA005 30JMT20 AA006 30JMT20 AA007 30JMT20 AA008	Separate the equipment and service compartments during normal plant operation by holding the Hydrogen Mixing Dampers closed	a) Open during normal operation	Mechanical / Electrical / I&C	Minor leakage between the equipment and service compartments	Yes, the occurring leakage is negligible compared to the allowed total leakage between the equipment and service compartments.
	Opens on exceeding a delta or absolute pressure threshold or loss of power. Transfers the two-room containment into a single volume to promote global convection and atmospheric mixing	b) Failure to open during an accident	Mechanical / Electrical / I&C	No convection at the Hydrogen Mixing Damper location	Yes, the blocked free flow area is negligible compared to the total combined opening area of the Hydrogen Mixing Damper.

06.02.02-49