AREVAEPRDCPEm Resource

From: BRYAN Martin (EXTERNAL AREVA) [Martin.Bryan.ext@areva.com]
Sent: Wednesday, November 03, 2010 4:36 PM
To: Tesfaye, Getachew
Cc: DELANO Karen (AREVA); ROMINE Judy (AREVA); BENNETT Kathy (AREVA); GUCWA Len (EXTERNAL AREVA)
Subject: Response to U.S. EPR Design Certification Application RAI No. 410, FSAR Ch. 6, Supplement 1
Attachments: RAI 410 Supplement 1 Response US EPR DC.pdf

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 410 on October 18, 2010. The attached file, "RAI 410 Supplement 1 Response US EPR DC.pdf" provides technically correct and complete responses to the 5 remaining 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 410 Questions 06.02.04-10, 06.02.05-16 and 06.02.05-19.

The following table indicates the respective pages in the response document, "RAI 410 Supplement 1 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 410 — 06.02.04-10	2	3
RAI 410 — 06.02.05-16	4	5
RAI 410 — 06.02.05-17	6	6
RAI 410 — 06.02.05-18	7	7
RAI 410 — 06.02.05-19	8	8

This concludes the formal AREVA NP response to RAI 410, 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
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Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Monday, October 18, 2010 4:37 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. 410, FSAR Ch. 6

Getachew,

Attached is AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 410 Response US EPR DC.pdf" provides a schedule since a technically correct and complete response to the 5 questions cannot be provided at this time.

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

Question #	Response Date
RAI 410 — 06.02.04-10	November 3, 2010
RAI 410 — 06.02.05-16	November 3, 2010
RAI 410 — 06.02.05-17	November 3, 2010
RAI 410 — 06.02.05-18	November 3, 2010
RAI 410 — 06.02.05-19	November 3, 2010

Sincerely,

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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Friday, September 17, 2010 10:16 AM
To: ZZ-DL-A-USEPR-DL
Cc: Grady, Anne-Marie; Jackson, Christopher; McKirgan, John; Carneal, Jason; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 410(4719_4720),FSAR Ch. 6

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on May 25, 2010, and discussed with your staff on June 9, 2010. As a result of that discussion, the RAI set was completely rewritten and a second draft was issued on July 27, 2010. The second draft was discussed with you staff on September 16, 2010. No changes were made to the 2nd 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: 2237

Mail Envelope Properties (BC417D9255991046A37DD56CF597DB7108256895)

Subject: Response to U.S. EPR Design Certification Application RAI No. 410, FSAR Ch. 6, Supplement 1
Sent Date: 11/3/2010 4:36:14 PM
Received Date: 11/3/2010 4:36:19 PM
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Files	**Size**	**Date & Time**
MESSAGE	3876	11/3/2010 4:36:19 PM
RAI 410 Supplement 1 Response US EPR DC.pdf		110744

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

Response to

Request for Additional Information No. 410(4719, 4720), Revision 1
Supplement 1

9/17/2010

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.04 - Containment Isolation System
SRP Section: 06.02.05 - Combustible Gas Control in Containment
Application Section: 6.2

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

Question 06.02.04-10:

Follow-up to RAI 12, Question 06.02.04-2:

General Design Criteria 55, 56 and 57 require that isolation valves outside containment shall be located as close to the containment as practical. FSAR Tier 2, Section 6.2.4.2.1, General System Design, states that isolation valves outside containment are located as close as practical to the containment or shield building walls. The DCA, while committing to this, does not provide any design criteria associated with this requirement, not does it provide any design information about the distances from the outside containment isolation valves (CIV) and the containment.

The ITAAC in FSAR Tier 1, Table 3.5-3 specify that the CIVs identified in FSAR Tier 1, Table 3.5-1 will be located according to Table 3.5-1 and Figure 3.5-1. The location of the CIVs identified in FSAR Tier 1, Table 3.5-1 identifies whether or not the valve is located inside or outside the containment and in which building the valve is located. The distances from the containment to the outboard CIVs are not provided.

In order for the staff to be able to evaluate the US EPR compliance with the requirements of GDCs 55, 56, and 57, provide the distance from each CIV outside containment and the containment. Add this information to the FSAR Tier 2, Table 6.2.4-1, Containment Isolation Valve and Actuator. Provide an ITAAC for each outboard CIV for this distance in their respective sections in Tier 1.

Response to Question 06.02.04-10:

The distance from the containment to each outboard containment isolation valve is one of the piping design parameters that will be determined during the detailed piping routing. AREVA will determine the distance from the containment penetration to the containment isolation valves using guidance contained in AREVA design procedures.

The guidance specifies that outside containment isolation valves shall be located as close to containment penetration as practical in accordance with GDC 55, 56 and 57. Sufficient space shall be provided between valves and containment boundary to permit the following:

- Inservice inspection of non-isolable welds.
- Appendix J of 10CFR50 leak testing.
- Cutout and replacement of isolation valves using standard pipe fitting tools and equipment.
- Local control.
- Valve seat resurfacing in place.

AREVA will add these design requirements for locating outside containment isolation valves as close to the containment penetration as practical to U.S. EPR FSAR Tier 2, Section 6.2.4.2.1.

A new ITAAC item will also be added to U.S. EPR FSAR Tier 1, Table 3.5-3 to specifically require verification that outside containment isolation valves have been located as close to the containment penetration as practical .

FSAR Impact:

U.S. EPR FSAR Tier 1, Table 3.5-3 and U.S. EPR Tier 2, Section 6.2.4.2.1 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.05-16:

Follow-up to RAI 323, Question 06.02.05-8:

In response to RAI 323, Question 06.02.05-8 (Supplement 1), AREVA noted that the KALI H2 tests examined PAR performance for a broad range of conditions consistent with those anticipated following a design-basis loss-of-coolant-accident, but did not address PAR performance impacts from fission product poisons.

The PAR performance database credited by AREVA NP for the U.S. EPR design is derived from several tests listed in the response. AREVA considers the Integrated Core-Melt-Simulation-Test (1996) program in the aerosol tests of the IPSN/EDF H2 PAR-Test program in Cadarache to be the most important test program concerning poisoning, deposition on and contamination of catalyst in a PAR in the post accident atmosphere. During this program, an AREVA NP designed PAR was subjected to a realistic aerosol exposure generated by a molten core, including poisons such as iodide, tellurium, cesium and antimony.

Provide the following test report(s) AREVA used in concluding that PAR performance would meet the US EPR design criteria for functional performance when exposed to aerosols generated by a molten core, including fission product poisons for significant beyond design basis accidents:

Ref. [1]
H2PAR Resultats Experimentaux Fiches d'Experiences
E1 a E19 et PHEB02
Rapport Sere #98/014
IPSN

Response to Question 06.02.05-16:

The passive autocatalytic recombiners (PARs) are part of the combustible gas control system described in U.S. EPR FSAR Tier 2, Section 6.2.5. The combustible gas control system consists of safety-related convection foils, rupture foils and mixing dampers. The PARs are non-safety-related components and designed for severe accidents. The safety evaluation of U.S. EPR FSAR Tier 2, Section 6.2.5.3 states:

> "For design basis accidents, a series of bounding assumptions were made for the volume of hydrogen released to the containment from each source. Under these conservative assumptions, it was shown that the hydrogen concentration remains below the threshold for combustion (4 percent) during the first 24 hours following a design basis LOCA with no credit taken for recombination. Based on this analysis, hydrogen generated during and following a design basis LOCA is not a threat to containment integrity".

According to Regulatory Guide 1.7, Rev 3 components that are designed to mitigate the hazard from the generation of combustible gas, which is mainly hydrogen, shall be designed to provide reasonable assurance that they will operate in the severe accident environment. Severe accident equipment survivability, respectively reasonable assurance, is discussed in chapter 19.2.3.3.7.

The requested test results are not provided because that information is vendor-specific. AREVA has not committed to a specific vendor for the PARs. To satisfy the NRC concerns about the PARs, U.S. EPR FSAR Tier 2, Section 6.2.5 will be revised to include the performance criteria of the intended functions of components under severe accident conditions in the design specification for component requirements. U.S. EPR FSAR Tier 2, Figure 6.2.5-9 will be revised to show containment hydrogen concentration over the first 24 hours of the event. Because this is the design basis analysis, no credit is taken for the PARs.

FSAR Impact:

U.S. EPR FSAR, Tier 2, Section 6.2.5 and Figure 6.2.5-9 will be revised as described in the response and indicated on the enclosed markup.

Question 06.02.05-17:

Follow-up to RAI 323, Question 6.02.05-1:

a. The test report EPRI TR-107517, vol. 3 documented the results of tests showing that FR90/1-150 PARs, when subjected to simulated containment spray, did not begin recombination for ~4.5 hours and when subjected to direct spray did not begin recombination for ~ 14.5 hours. AREVA's response to the question of the impact of the PAR performance under spraying conditions is that there is no or minimal impact. Provide the test reports which may refute the conclusions stated in EPRI TR-107517, vol. 3.

   Ref. [2]
   Etudes des Perfomances du Recombineur d'Hydrogene
   Siemens FR90/1-150 en presence d'aspersion
   CEA 96/003
   HO-400-5020

b. AREVA's response to the question of whether the PARs in the US EPR design have a hydrophobic coating was that the hydrophobic coating would be unnecessary. Confirm whether or not the PARs will have the hydrophobic coating. If the hydrophobic coating is part of the PAR design, revise the FSAR, section 6.2.5.2.1, and Table 6.2.5-1—CGCS Design and Performance Parameters, and section 19.2.3.3.2 to clarify the status of the hydrophobic coating.

Response to Question 06.02.05-17:

Part a. of question 06.02.05-17 requests vendor-specific test results. As discussed in the Response to Question 06.02.05-16 of this RAI, vendor-specific test results are not provided prior to acquiring a supplier. These components are not credited in the U.S. EPR FSAR Tier 2, Chapter 6 safety design basis.

Part b. of the question regards hydrophobic coating of the catalytic plates. No hydrophobic coating is required or specified in the design requirements of the PARs.

FSAR Impact:

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

Question 06.02.05-18:

Follow-up to RAI 323, Question 6.2.5-12:

Functionality of the PARs after H2 ignition and deflagration.

EPRI TR-107517, vol. 3 documented the results of tests showing that all the FR90/1-150 PARs when subjected to concentrations of H2 greater than 7% ignited and burned. The EPRI report, section 10, Table 4, description of ignitions occurring inside the KALI Vessel with Siemens PARs, indicates that all 5 tests where ignition occurred for H2 concentrations greater that 7%, the PARs were no longer functioning. These test results indicate that a deflagration at or within a PAR could disable that PAR.

AREVA's response to question 6.2.5-12 indicates that PAR tests were performed with the German inspection agency (TÜV) under an AREVA NP test program. Provide the test reports identified in the PAR Qualification Report as references [11] and [12]. These tests investigated PAR functional behavior following H2 ignition, as well as following oil and cable insulation fires.

Response to Question 06.02.05-18:

This question requests vendor-specific test results. As discussed in the Response to Question 06.02.05-16 of this RAI, vendor-specific test results are not provided prior to acquiring a supplier. These components are not credited in the U.S. EPR FSAR Tier 2, Chapter 6 safety design basis.

FSAR Impact:

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

Question 06.02.05-19:

Follow-up to RAI 323, Question 06.02.05-13:

The effects of the operating environment in containment on the performance of the PARs, in particular the effects of radiation, operational vibrations, welding fumes and solvent fumes.

a. Provide test reports which demonstrate the radiation effects on the PAR catalytic coatings, platinum and palladium.

b. Provide the test reports, references [11] and [12], which document PAR performance when subject to welding and solvent fumes.

c. While the PARs are enclosed by housing, they are open both at the bottom and at the top, to encourage convective flow. Discuss how the PARs will be protected from these fumes both during normal operation and maintenance activities.

Response to Question 06.02.05-19:

Part a

The catalytic plates consist of a stainless steel carrier plate and coating mixture of platinum and palladium. Radiation has no effect on those noble metals with regard to activation, brittleness, etc.

Part b

This question requests vendor-specific test results. As discussed in the Response to Question 06.02.05-16 of this RAI, vendor-specific test results are not provided prior to acquiring a supplier. These components are not credited in the U.S. EPR FSAR Tier 2, Chapter 6 safety design basis.

Part c

This question focuses on the protection from fumes during normal operation and maintenance activities. The catalytic plates need no protection from fumes that may occur during normal plant operation. During maintenance activities in the direct environment to the passive autocatalytic recombiners (PARs), which mainly occurs during an outage, the housing will be covered by a blanket. The blanket overlaps the entire PAR housing and will be tied at the lower end. The PARs will be tested to verify their function and required performance at the end of the outage. U.S. EPR FSAR Tier 2, Section 6.2.5.4 will be revised to describe the PAR covering during outage work.

FSAR Impact:

U.S. EPR FSAR, Tier 2, Section 6.2.5.4 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

3.10 Containment isolation piping shown as ASME Code Section III on Figure 3.5-1 retains pressure boundary integrity at design pressure.

3.11 ~~Containment isolation piping shown as ASME Code Section III on Figure 3.5-1 is installed and inspected in accordance with ASME Code Section III requirements~~Deleted.

3.12 Components listed in Table 3.5-1 as ASME Code Section III are designed in accordance with ASME Code Section III requirements.

3.13 Components listed in Table 3.5-1 as ASME Code Section III are fabricated in accordance with ASME Code Section III requirements.

3.14 Pressure boundary welds on components listed in Table 3.5-1 as ASME Code Section III are in accordance with ASME Code Section III requirements.

3.15 Components listed in Table 3.5-1 as ASME Code Section III retain pressure boundary integrity at design pressure.

3.16 Components listed in Table 3.5-1 as ASME Code Section III are installed in accordance with ASME Code Section III requirements.

3.17 Containment isolation valves are located close to the containment penetrations.

06.02.04-10

4.0 I&C Design Features, Displays and Controls

4.1 Displays listed in Table 3.5-2—Containment Isolation Equipment I&C and Electrical Design are retrievable in the main control room (MCR) as listed in Table 3.5-2.

4.2 The containment isolation equipment controls are provided in the MCR as listed in Table 3.5-2.

4.3 Equipment listed as being controlled by a priority and actuator control system (PACS) module in Table 3.5-2 responds to the state requested by a test signal.

5.0 Electrical Power Design Features

5.1 The components designated as Class 1E in Table 3.5-2 are powered from the Class 1E division as listed in Table 3.5-2 in a normal or alternate feed condition.

5.2 Valves listed in Table 3.5-2 fail as-is on loss of power.

5.3 Containment electrical penetrations routing Class 1E cables have only Class 1E cables or associated cables.

5.4 Separation exists between containment electrical penetration assemblies routing each division of Class 1E cables, and between assemblies containing Class 1E and non-Class 1E cables.

5.5 Containment electrical penetrations are protected from fault currents that are greater than continuous current rating.

Table 3.5-3—Containment Isolation ITAAC (6 Sheets)

	Commitment Wording	Inspections, Tests, Analyses	Acceptance Criteria
3.14	Pressure boundary welds on components listed in Table 3.5-1 as ASME Code Section III are in accordance with ASME Code Section III requirements.	Inspections of pressure boundary welds will be performed to verify that welding is performed in accordance with ASME Code Section III requirements.	For components listed as ASME Code Section III in Table 3.5-1, ASME Code Section III Data Reports (NCA-8000) exist and conclude that pressure boundary welding has been performed in accordance with ASME Code Section III.
3.15	Components listed in Table 3.5-1 as ASME Code Section III retain pressure boundary integrity at design pressure.	Hydrostatic tests will be performed on the components.	For components listed as ASME Code Section III in Table 3.5-1, ASME Code Section III Data Reports exist and conclude that hydrostatic test results comply with ASME Code Section III requirements.
3.16	Components listed in Table 3.5-1 as ASME Code Section III are installed in accordance with ASME Code Section III requirements.	An inspection of ASME Code Data Reports will be performed.	ASME Code Section III N-5 Data Reports exist and conclude that components listed as ASME Code Section III in Table 3.5-1 have been installed in accordance with ASME Code Section III requirements.
3.17	Containment isolation valves are located close to containment penetrations.	a. The design location of containment isolation valves will be close to the containment penetrations.	a. A design report concludes that the containment isolation valves listed in Table 3.5-1 are located close to the containment penetrations with consideration of the following: • Access for inspection of welds. • Containment leak testing. • Replacement. • Valve maintenance.

06.02.04-10

Table 3.5-3—Containment Isolation ITAAC (6 Sheets)

06.02.04-10

	Commitment Wording	Inspections, Tests, Analyses	Acceptance Criteria
		b. Inspection of the as-built location of containment isolation valves will be performed. Deviations to the design location of containment isolation valves will be reconciled to the design report.	b. An as-built inspection report concludes that deviations to the design location of containment isolation valves have been reconciled.
4.1	Displays exist or can be retrieved in the MCR as identified in Table 3.5-2.	Inspections will be performed for the existence or retrievability of the displays in the MCR as listed in Table 3.5-2.	The displays listed in Table 3.5-2 as being retrieved in the MCR can be retrieved in the MCR.
4.2	The containment isolation equipment controls are provided in the MCR as listed in Table 3.5-2.	Tests will be performed for the existence of control signals from the MCR to the equipment listed in Table 3.5-2.	The containment isolation equipment controls are provided in the MCR as listed in Table 3.5-2.
4.3	Equipment listed as being controlled by a PACS module in Table 3.5-2 responds to the state requested by a test signal.	A test will be performed using test signals.	Equipment listed as being controlled by a PACS module in Table 3.5-2 responds to the state requested by the test signal.
5.1	The components designated as Class 1E in Table 3.5-2 are powered from the Class 1E division as listed in Table 3.5-2 in a normal or alternate feed condition.	a. Testing will be performed for components designated as Class 1E in Table 3.5-2 by providing a test signal in each normally aligned division. b. Testing will be performed for components designated as Class 1E in Table 3.5-2 by providing a test signal in each division with the alternate feed aligned to the divisional pair.	a. The test signal provided in the normally aligned division is present at the respective Class 1E component identified in Table 3.5-2. b. The test signal provided in each division with the alternate feed aligned to the divisional pair is present at the respective Class 1E component identified in Table 3.5-2.
5.2	Valves listed in Table 3.5-2 fail as-is on loss of power.	Testing will be performed for the valves listed in Table 3.5-2 to fail as-is on loss of power.	Following loss of power, the valves listed in Table 3.5-2 fail as-is.
5.3	Containment electrical penetrations routing Class 1E cables have only Class 1E cables or associated cables.	Inspections will be performed	Containment electrical penetrations routing Class 1E cables have only Class 1E cables or associated cables.

6.2.4.2 System Design

6.2.4.2.1 General System Design

The containment isolation system provides the means of isolating fluid systems that pass through containment penetrations to confine radioactivity in the containment. Following a postulated accident, the containment isolation system isolates non-essential fluid systems penetrating the containment. The containment isolation system is comprised of the integrated functioning of selected elements of other physical systems, and isolation design is achieved by applying acceptable common criteria to the containment isolation portions of those systems, and by using containment pressure, high containment activity, or a safety injection actuation signal to generate a containment isolation actuation signal to close the appropriate valves. ESF actuation is described in Section 7.3.

Containment isolation is typically provided by two valves at each containment penetration, with one valve inside and one valve outside the containment. Table 6.2.4-1—Containment Penetration, Isolation Valve, and Actuator Data lists the containment isolation penetrations and provides a summary of the valve and actuator data. In addition to the penetrations for mechanical lines, Table 6.2.4-1 also lists containment openings for the personnel airlocks, equipment hatch, and fuel transfer tube. Sealed closed barriers are maintained under administrative control.

06.04.02-10

Isolation valves outside containment are located as close as practical to the containment or shield building walls considering required access for~~.~~:

- In-service inspection of non-isolable welds.
- 10CFR50 Appendix J, Containment Leakage Testing.
- Cutout and replacement of isolation valves using standard pipe fitting tools and equipment.
- In-place valve seat resurfacing.

Valves that may require local manual operation are located, taking into account accessibility and radiation levels resulting from postulated accidents.

Sumps in the Safeguard Buildings, Fuel Building, and Reactor Building are monitored and alarms or indications are provided to the operator to detect the presence of water in these areas. Sump monitoring provides an indication to the control room operator that remote manual containment isolation valves may need to be closed.

The functional arrangements of containment isolation valves are shown on system piping and instrumentation diagrams. Section 1.7 provides a list of piping and instrumentation diagrams. Figure 6.2.4-1—Representative Containment Isolation

- PARs distributed throughout containment recombine hydrogen and oxygen to reduce hydrogen concentrations. The PARs also promote natural convection within the containment.

Rupture and Convection Foils

During normal operation, the rupture and convection foils form a pressure equalization ceiling in each steam generator compartment. A pressure differential less than 1 psi is sufficient to burst the rupture and convection foils. Fusible links in the steel frames of the convection foils passively open the flow path at an elevated temperature.

Multiple passive actuation mechanisms fulfill requirements for flow areas and opening times under different loss of coolant accident (LOCA) scenarios. Following a large break LOCA, rupture foils open on differential pressure very early in the accident to create a large free flow area and limit the peak pressure differential in the containment. For a small break LOCA, the mass and energy release may be enough to open only a few rupture foils. However, the large free flow area required for sufficient atmospheric mixing is provided by the convection foils, which open due to the increased temperature.

Apart from breaks in the reactor coolant pressure boundary, hydrogen and steam can be released into containment via the pressurizer relief tank following intentional reactor coolant system depressurization. In this case, a rupture disk opens a path from the tank to the bottom rooms of the steam generator compartments. Reflection of the gas jet on the heavy floor generates a broad plume moving upward in the central part of the containment driven by a density gradient. The resultant opening of the rupture foils enables and promotes global containment convection flows.

Mixing Dampers

Mixing dampers separate the air space of the IRWST and the lower part of the annular rooms in containment. Each spring-loaded mixing damper is held closed during normal operation by a solenoid-operated actuator. The mixing dampers open automatically if the differential pressure between operational and equipment rooms is exceeded or if the containment pressure increases slightly above atmospheric pressure. The mixing dampers also open on loss of power to the solenoid-operated actuators and can be opened manually by the operator.

Passive Autocatalytic Recombiners

The PARs are part of the combustible gas control system. Unlike the rupture foils, convection foils, and mixing dampers, they are not safety-related components; instead, they are designed for severe accident condition applications.

06.02.05-16

Large and small PARs are arranged in containment to support global convection, homogenize the containment atmosphere, and reduce local and global peak hydrogen concentrations. The location of the PARs is shown in Figure 6.2.5-1—Arrangement and Location of the Passive Autocatalytic Recombiners.

A PAR consists of a metal housing with a gas inlet at the bottom and a lateral gas outlet at the top to promote convection. Numerous parallel plates with a catalytically active coating are arranged vertically in the bottom of the housing. Gas mixtures containing hydrogen are recombined upon contact with the catalyst, with the recombination rate depending primarily on the concentration of hydrogen at the PAR. In the presence of oxygen, the PARs will start automatically if the threshold hydrogen concentration is reached at the catalytic surfaces. The heat released from the catalyst helps drive gas flow through the PARs, resulting in high recombination efficiency.

The PARs are arranged inside the equipment rooms to promote convection within the containment, and thereby homogenize the atmosphere and reduce local peak hydrogen concentrations. PARs are also located in the containment dome and in the upper part of the annular rooms to support global convection and to prevent gas stratification. The PARs are installed above the floor to provide unobstructed inflow and for easy access to facilitate maintenance. They are located to avoid direct contact with spray water from the severe accident heat removal system, and the PAR cover also protects the catalyst from direct spray and aerosol deposition.

~~The PARs have been subjected to several international testing programs, during which the hydrogen reduction capability was proven for severe accident conditions. Simulated conditions included core melt aerosols and possible catalyst poisons such as tellurium, selenium, antimony, and iodine. Qualification studies, which included the PARs, were conducted that explored the depletion of hydrogen and its relationship with induced convection. Severe accident testing programs are presented in the U.S. EPR Severe Accident Evaluation (Reference 8).~~The PARs are designed to withstand severe accident ambient conditions. This includes the capability of reducing hydrogen under severe accident conditions as specified in Table 6.2.5-1. As is the case for other severe accident components, the PARs provide reasonable assurance that the equipment can perform its identified function during severe accident conditions as described in Section 19.2. The U.S. EPR severe accident evaluation is presented in Reference 8.

06.02.05-16

6.2.5.2.2 Hydrogen Monitoring System

Two subsystems of the HMS measure hydrogen concentrations within containment. The low range system measures hydrogen concentrations in the containment atmosphere during design basis events. The high range system measures hydrogen and steam concentrations in the containment atmosphere during and after beyond design

6.2.5.3.1 Post-LOCA Hydrogen Concentration

For the post-LOCA hydrogen evaluation, the design basis maximum allowable core oxidation level of 1 percent was assumed. The calculated concentration is displayed in Figure 6.2.5-2—Integrated Production of Hydrogen from 1% Core Oxidation. The analysis assumed this amount of hydrogen to be released in an instant at the beginning of the LOCA transient.

The radiolytic hydrogen generation was assumed to come from the entire inventory of RCS and IRWST water plus the radiolysis of Hypalon and PVC jacketed cable in the containment. Hydrogen generation from these sources are shown in Figure 6.2.5-3—Integrated Production of Hydrogen from Radiolysis.

In calculating the hydrogen released from corrosion of zinc and aluminum in the containment, typical corrosion rates were assumed and were applied at the actual design basis accident pressures and temperatures calculated in the containment analysis. These are discussed in Section 6.2.1.3. The surface areas of zinc and aluminum used as input to the hydrogen generation rate equation were developed in a bounding fashion. The entire concrete surface area was assumed to be painted with a zinc-based coating 466,620 ft^2 (43,350 m^2) and the entire surface area of steel was assumed to be galvanized 368,130 ft^2 (34,300 m^2). The use of aluminum materials in the containment is expected to be negligible; a surface area of 10,760 ft^2 (1,000 m^2) was assumed.

The hydrogen generation rates from zinc and aluminum are shown in Figure 6.2.5-4—Assumed Hydrogen Generation Rate from Zinc Sources and Figure 6.2.5-5—Assumed Hydrogen Generation Rate from Aluminum Sources. Applying these corrosion rates to the bounding assumptions for surface areas of each material resulted in the hydrogen generation from zinc and aluminum shown in Figure 6.2.5-6—Integrated Production of Hydrogen from Zinc-Based Paint, Figure 6.2.5-7—Integrated Production of Hydrogen from Galvanized Steel, and Figure 6.2.5-8—Integrated Production of Hydrogen from Aluminum.

Figure 6.2.5-9—Concentration of Hydrogen in the Containment shows the total hydrogen concentration within containment from all sources. The hydrogen remains below the threshold concentration necessary for combustion (4 percent) taking into account no hydrogen recombination from the 47 PARs. ~~Figure 6.2.5-9 also shows the hydrogen concentration within containment for various levels of PAR operation. When all PARs are functioning, the hydrogen concentration remains below a level of 1.5 percent, therefore, hydrogen concentration does not threaten containment integrity.~~

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~~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

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~~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

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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.

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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

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 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, Safety automation system, and 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

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

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 Note: The Passive Autocatalytic Recombiners are severe accident components and not credited for DBAs. They are listed in this FMEA table to cover all Combustible Gas Control System components.	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.

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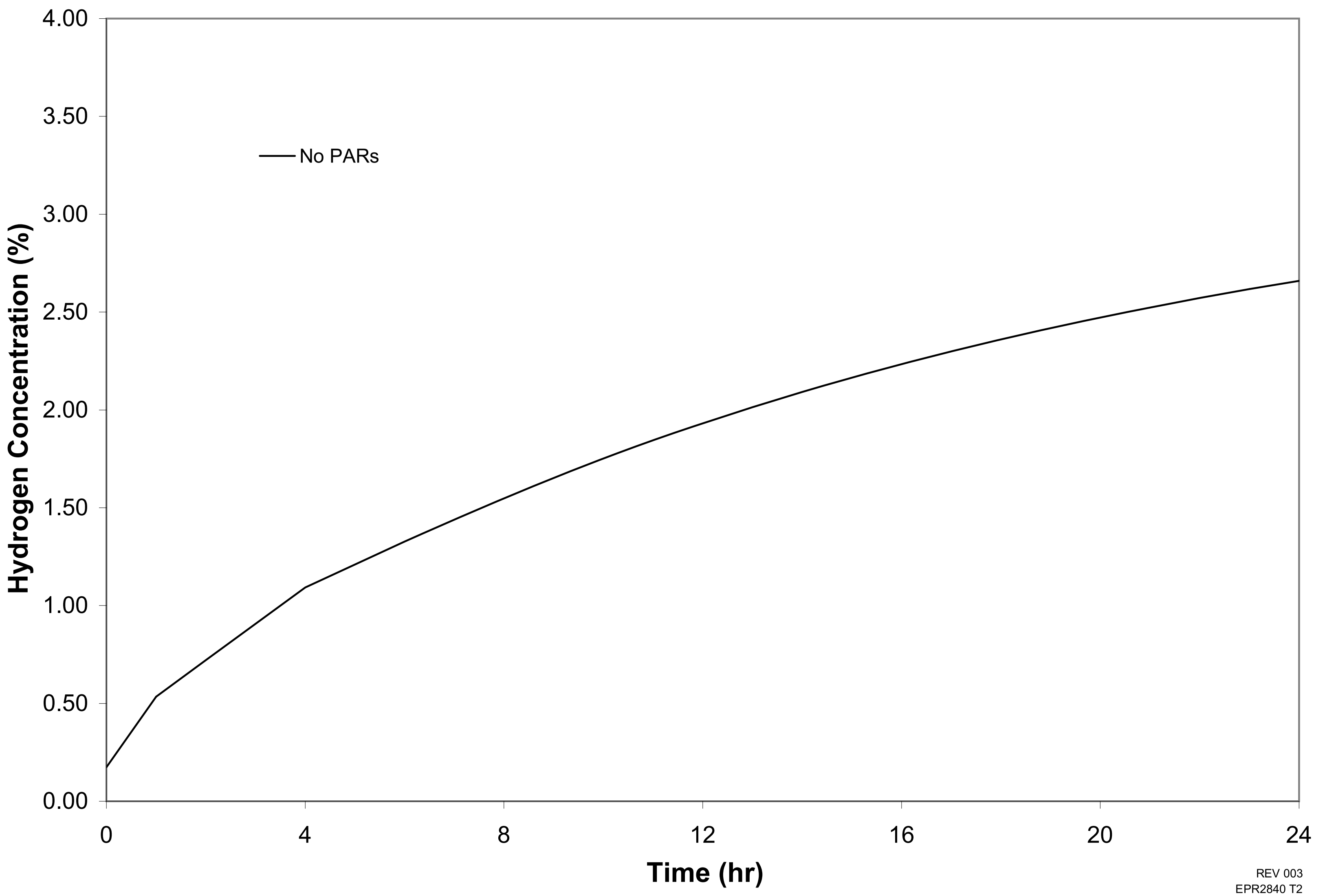
Figure 6.2.5-9—Concentration of Hydrogen in the Containment



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