AREVA

July 12, 2013
NRC: 13:055

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Response to U.S. EPR Design Certification Application RAI No. 471, Supplement 10

In Reference 1, the NRC provided a request for additional information (RAI) regarding the U.S. EPR design certification application. Reference 2 through Reference 11 provided schedules for responding to or responses to the six questions in RAI 471.

The enclosure to this letter provides revised technically correct and complete final responses to two questions (Question 06.02.05-20 and Question 06.02.05-23). These revised responses supersede the previous responses provided in Reference 10.

AREVA NP Inc. (AREVA NP) considers some of the material contained in the enclosed response to Question 06.02.05-21 to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support the withholding of the information from public disclosure. Proprietary and non-proprietary versions of the enclosure to this letter are provided.

The following table indicates the respective pages in the enclosure that contain AREVA NP's final response to the subject questions.

Question #	Start Page	End Page
RAI 471 — 06.02.05-20	2	2
RAI 471 — 06.02.05-23	5	12

This concludes the formal AREVA NP response to RAI 471, and there are no questions from this RAI for which AREVA NP has not provided responses.

AREVA NP INC.

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D077
NRO

If you have any questions related to this submittal, please contact Len Gucwa by telephone at 434-832-3466, or by e-mail to Len.Gucwa.ext@areva.com.

Sincerely,

Pedro Salas, Director
Regulatory Affairs
AREVA NP Inc.

Enclosures

cc: A.M. Snyder
Docket No. 52-020

References

Ref. 1: E-mail, Getachew Tesfaye (NRC) to Martin C. Bryan (AREVA NP Inc.), "U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6," February 15, 2011.

Ref. 2: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6," March 17, 2011.

Ref. 3: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 1" March 31, 2011.

Ref. 4: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 2," May 25, 2011.

Ref. 5: E-mail, Russell Wells (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 3," July 27, 2011.

Ref. 6: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 4," August 17, 2011.

Ref. 7: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 5," September 21, 2011.

Ref. 8: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 6," December 14, 2011.

Ref. 9: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 7," January 25, 2012.

Ref. 10: E-mail, Dennis Williford (AREVA NP Inc.) to Getachew Tesfaye (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 (5387, 5426, 5389), FSAR Ch. 6, Supplement 8," March 5, 2012.

Ref. 11: Letter, Pedro Salas (AREVA NP Inc.) to Document Control Desk (NRC), "Response to U.S. EPR Design Certification Application RAI No. 471 Supplement 9," May 23, 2012.

AFFIDAVIT

STATE OF WASHINGTON)
) ss.
COUNTY OF BENTON)

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for AREVA NP Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in the Document titled "Response to U.S. EPR Design Certification Application RAI No. 471(5387, 5426, 5389), Supplement 10, Revision 0," and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b), 6(d) and 6(e) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 12th day of July, 2013.

Susan K. McCoy
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 1/14/2016

SUSAN K. MCCOY
COMMISSION EXPIRES
NOTARY PUBLIC
01-14-16
STATE OF WASHINGTON

Response to

Request for Additional Information No. 471(5387, 5426, 5389), Supplement 10, Revision 0

2/15/2011

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.02 - Containment Heat Removal Systems
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 06.02.05-20:

POTENTIAL OPEN ITEM

The staff performed confirmatory calculations and sensitivity studies and compared the results to calculations performed by AREVA. The confirmatory calculations generally showed higher hydrogen concentrations in the staff calculation and noted the dominant sensitivity was the efficiency of the PARS. In order for staff to understand the differences between the two analyses, provide the input assumptions for the FSAR figure 19.2-5, including:

a. % PARs effective, and at what efficiency
b. % foils open
c. % dampers open
d. Number of open safety related doors in pressurizer rooms
e. Identify doors credited with being open, other than in pressurizer rooms.
f. Time period in accident scenario when H_2 from MCCI is added to containment

Provide curves for H_2 concentration for all nodes vs. time with 100% of the PARs at 100% efficiency. Provide curves for H_2 concentration for all nodes vs. time with 100% of the PARs at 50% efficiency.

AREVA has provided H_2 concentration curves for sensitivity cases involving PARs in response to RAI 69, Question 6.2.5-1. However, in Figure 6.2.5-1-6, not all nodes were included, and in figure 6.2.5-1-5, for the PARs sensitivity cases, only the global i.e., well mixed concentrations were provided.

Response to Question 06.02.05-20:

The response below supersedes the previous response sent regarding Question 06.02.05-20.

a) U.S. EPR FSAR Tier 2, Figure 19.2-5—Hydrogen Concentrations through the U.S. EPR Containment is a plot of Case 01 of the uncertainty analysis. In this scenario, it is assumed that 100 percent of the passive autocatalytic recombiners (PARs) are active, and that the PARs are operating at 94.5 percent efficiency.

b) The timing for the opening of junctions that represent the rupture/convection foils in the U.S. EPR design are shown in Table 06.02.05-20-1—Rupture/Convection Foil Opening Timing for the scenario shown on U.S. EPR FSAR Tier 2, Figure 19.2-5 (Case 01 of the uncertainty analysis).

Both the rupture foils and convection foils are modeled to open when there is a differential pressure of 5 kPa across the junction in either direction. In addition to this pressure based opening criteria, there is a second opening criterion that applies only to the convection foils based on temperature. If the temperature of Containment **[ ]** goes above 358.15 K (185°F), then the foils associated with that containment node will open.

For Case 01, the timing of the opening of the convection foils corresponds to opening of the pressurizer relief tank rupture discs. For this case, the temperature opening criterion is reached before the pressure criterion. Because only the convection foils contain these opening criteria, they are predicted to open. The opening of these foils equalizes the pressure across the foil junctions so that the pressure based opening criterion is never met. For this case, only approximately 50 percent of the total foil area is predicted to open.

c) The timing for the opening of junctions that represent the hydrogen mixing dampers (HMDs) in the U.S. EPR design are shown in Table 06.02.05-20-2—Damper Opening Timing for the scenario shown on U.S. EPR FSAR Tier 2, Figure 19.2-5 (Case 01 of the uncertainty analysis).

   Each junction shown in Table 06.02.05-20-2 represents four parallel HMDs. Each HMD junction is modeled with two separate pressure based opening criteria, one based on a delta pressure between the upper steam generator rooms ([ ]) and the containment dome ([ ]) of 3.5 kPa, and a second criterion based on the absolute pressure of the containment dome exceeding 120 kPa. After one of these opening criteria is reached, there is a delay of 18 seconds until the junctions representing the HMDs open.

   Table 06.02.05-20-2 shows that for Case 01, 100 percent of the HMDs open. By design, the timing of the opening of the HMDs is nearly identical to the timing of the opening of the convection foils.

d) A review of the results of the scenario shown on U.S. EPR FSAR Tier 2, Figure 19.2-5 (Case 01 of the uncertainty analysis) shows that no doors in the pressurizer rooms are predicted to open.

e) A review of the results of the scenario shown on U.S. EPR FSAR Tier 2, Figure 19.2-5 (Case 01 of the uncertainty analysis) shows that no doors in the remainder of the containment compartments are predicted to open.

f) For the scenario shown on U.S. EPR FSAR Tier 2, Figure 19.2-5 (Case 01 of the uncertainty analysis), hydrogen production because of molten corium-to-concrete interaction begins 5.5 hours into the accident and ends 8.1 hours into the accident.

Curves for hydrogen concentration because of 100 percent of the PARs at 100 percent efficiency, and 100 percent of the PARs at 50 percent efficiency were provided as part of the Response to RAI 553, Question 06.02.05-31, Part a) with respect to the four relevant scenarios. Results for the [ ] are described in this Response.

In U.S. EPR FSAR Tier 2, Section 19.2.4.4.1.3 the second paragraph will be replaced and additional text will be added to the third paragraph in order to describe better the results from the updated analysis discussed in this section. U.S. EPR FSAR Tier 2, Figure 19.2-5 will also be replaced to show the updated analysis results.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 19.2.4.4.1.3 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR FSAR Tier 2, Figure 19.2-5 will be revised as described in the response and indicated on the enclosed markup.

Table 06.02.05-20-1—Rupture/Convection Foil Opening Timing

Junction #	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
	Rupture Foil				Convection Foil			
Case 01	N/A	N/A	N/A	N/A	4183 s	4285 s	4285 s	4285 s

Table 06.02.05-20-2—HMD Opening Timing

Junction #	[ ]	[ ]
Case 01	4626 s	4626 s

Question 06.02.05-23:

POTENTIAL OPEN ITEM

Follow-up to response to RAI 262, Question 19-321, part a, with reference to responses to RAI 1, Question 6.2.1-07c, Table 6.2.1-07-3, and RAI 209, Question 06.02.01-14, Supplement 1:

RAI 262, question 19-321, part a, asked about the failure junctions in the MAAP parameter file and the accident conditions under which each junction might be assumed to open, including loss of offsite power. AREVA responded that access between compartments in containment is provided by doorways, dampers and foils, and that the principal mechanism for opening these closed doors, dampers and foils is by differential pressure.

a. For the doors, which AREVA has identified in response to RAI 1, question 6.2.1-07c, Table 6.2.1-07-3, please indicate which doors, if any, fail open on loss of offsite power.

b. In the AREVA analysis which demonstrates the CGCS performance during bounding severe accident scenarios, identify all doors credited with being open.

c. In the AREVA analysis which demonstrates the CGCS performance during a design basis accident, identify all doors credited with being open.

Response to Question 06.02.05-23:

The response below supersedes the previous response to Question 06.02.05-23.

a) The majority of the doors inside containment are non-safety-related grade. For analysis of subcompartment pressures in response to subcompartment high energy line breaks (HELBs), the non-safety-related grade doors are conservatively not open to maximize subcompartment pressures. The doors that are assumed to open during subcompartment analysis are those assigned as safety-related grade. A list of these safety-related grade doors is provided in U.S. EPR FSAR Tier 2, Table 6.2.1-13—Safety Grade Doors Credited to Open in Subcompartment Analyses. None of the doors are designed to fail open on loss of off-site power. These doors open/close on differential pressure.

b) The uncertainty analysis was used as the basis for analyzing the combustible gas control system performance during a severe accident. For this analysis, the doors in containment are assumed to be in an initially closed state and are modeled to open when the differential pressure across the door exceeds a value of 10 kPa(d), with the exception being the heavy shield doors that open at a greater differential pressure of 50 kPa(d).

Table 06.02.05-23-1 shows the results of the doors that are predicted to open for the 59 cases of the uncertainty analysis. In 49 of the 59 cases, no doors are predicted to open throughout the simulation. In eight of the 59 cases, there is sufficient overpressurization in [ ] directly after the pressurizer relief tank rupture discs open so that two doors in [ ] that are connected to [ ] are predicted to open.

For the remaining two cases (Case 13 and Case 44), Table 06.02.05-23-1 shows that a large number of doors are predicted to open. Further investigation of these two cases shows that a drop in pressure is predicted to occur in [ ], directly after the pressurizer relief tank rupture discs open. Although the duration of this drop in pressure is relatively short lived (the pressure is sub-atmospheric for only one plotting point with a plotting frequency of 60s), its magnitude is large enough so that the differential pressure criteria are reached for a large number of doors.

The pressure drop appears to be caused by the prediction of negative steam mass in the pressurizer relief tank that consequentially leads to the prediction of negative steam mass in [ ]. This is most likely because of numerical instabilities that are experienced directly after the sudden opening of the pressurizer relief tank rupture discs.

The MAAP code is not designed as a blowdown code, and can experience numerical instabilities when trying to model abrupt changes to boundary conditions (i.e., the opening of the pressurizer relief tank rupture discs). The prediction of negative steam mass in the pressurizer relief tank is only predicted for approximately six minutes, and other than the accidental opening of a large number of doors, does not appear to have an impact on the overall progression of the accident sequence for these two cases.

c) U.S. EPR FSAR Tier 2, Table 6.2.1-13 identifies the safety-related doors that can be credited following a design basis accident.

See the response to Question 06.02.05-20 for a description of related changes to the FSAR.

FSAR Impact:

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

Table 06.02.05-23-1—Door Opening Times

Case #	Case Type	Junction #	Upstream Node	Downstream Node	Opening Time (s)	Event Preceding Opening Time
01	LBOP	N/A	-	-	-	-
02	LOOP TR	N/A	-	-	-	-
03	LOOP SS	N/A	-	-	-	-
04	LOOP SS	[ ]	[ ]	[ ]	13057	Pressurizer Relief Tank Rupture Discs Fail
		[ ]	[ ]	[ ]	13057	
05	LOOP SS	N/A	-	-	-	-
06	LOOP SS	N/A	-	-	-	-
07	SLOCA	[ ]	[ ]	[ ]	5673	Pressurizer Relief Tank Rupture Discs Fail
		[ ]	[ ]	[ ]	5673	
08	SLOCA	N/A	-	-	-	-
09	LOOP SS	N/A	-	-	-	-
10	LOOP TR	N/A	-	-	-	-
11	LOOP TR	N/A	-	-	-	-
12	LOOP SS	[			45494	Pressurizer Relief Tank Rupture Discs Fail
					45494	
13	LBOP				4748	Pressurizer Relief Tank Rupture Discs Fail
					4748	
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				]	4748	

Table 06.02.05-23-1—Door Opening Times

Case #	Case Type	Junction #	Upstream Node	Downstream Node	Opening Time (s)	Event Preceding Opening Time
		[			4748	
					4748	
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					4748	
					4748	
				]	4748	
14	LBOP	N/A	-	-	-	-
15	LOOP SS	[ ]	[ ]	[ ]	72446	Pressurizer Relief Tank Rupture Discs Fail
		[ ]	[ ]	[ ]	72446	
16	LOOP TR	N/A	-	-	-	-
17	LOOP TR	N/A	-	-	-	-
18	SLOCA	N/A	-	-	-	-
19	LOOP TR	N/A	-	-	-	-
20	LOOP TR	N/A	-	-	-	-
21	LOOP TR	N/A	-	-	-	-
22	LOOP SS	N/A	-	-	-	-
23	LOOP TR	N/A	-	-	-	-
24	LOOP SS	N/A	-	-	-	-
25	LOOP SS	[ ]	[ ]	[ ]	34457	Pressurizer Relief Tank Rupture Discs Fail
		[ ]	[ ]	[ ]	34457	
26	SLOCA	N/A	-	-	-	-
27	LOOP SS	N/A	-	-	-	-
28	LOOP SS	N/A	-	-	-	-
29	LBOP	N/A	-	-	-	-

Table 06.02.05-23-1—Door Opening Times

Case #	Case Type	Junction #	Upstream Node	Downstream Node	Opening Time (s)	Event Preceding Opening Time
30	LOOP SS	[ ]	[ ]	[ ]	26728	Pressurizer Relief Tank Rupture Discs Fail
		[ ]	[ ]	[ ]	26728	
31	LOOP TR	N/A	-	-	-	-
32	LOOP SS	N/A	-	-	-	-
33	LOOP SS	N/A	-	-	-	-
34	LOOP TR	N/A	-	-	-	-
35	LOOP SS	N/A	-	-	-	-
36	LBOP	N/A	-	-	-	-
37	LOOP SS	N/A	-	-	-	-
38	LBOP	N/A	-	-	-	-
39	LOOP SS	N/A	-	-	-	-
40	LOOP SS	[ ]	[ ]	[ ]	65498	Pressurizer Relief Tank Rupture Discs Fail
		[ ]	[ ]	[ ]	65498	
41	LOOP TR	N/A	-	-	-	-
42	LBOP	N/A	-	-	-	-
43	LOOP SS	[			50013	Pressurizer Relief Tank Rupture Discs Fail
					50013	
44	LBOP				4775	Pressurizer Relief Tank Rupture Discs Fail
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					4775	]

Table 06.02.05-23-1—Door Opening Times

Case #	Case Type	Junction #	Upstream Node	Downstream Node	Opening Time (s)	Event Preceding Opening Time
					4775	
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					4775	
					4775	
					4775	
45	LBOP	N/A	-	-	-	-
46	LOOP SS	N/A	-	-	-	-
47	LOOP TR	N/A	-	-	-	-
48	LOOP SS	N/A	-	-	-	-
49	LOOP SS	N/A	-	-	-	-
50	LBOP	N/A	-	-	-	-
51	LOOP TR	N/A	-	-	-	-
52	LOOP TR	N/A	-	-	-	-
53	LOOP SS	N/A	-	-	-	-
54	LOOP TR	N/A	-	-	-	-
55	LOOP SS	N/A	-	-	-	-
56	SLOCA	N/A	-	-	-	-

Table 06.02.05-23-1—Door Opening Times

Case #	Case Type	Junction #	Upstream Node	Downstream Node	Opening Time (s)	Event Preceding Opening Time
57	LOOP SS	N/A	-	-	-	-
58	LOOP SS	N/A	-	-	-	-
59	LOOP TR	N/A	-	-	-	-

U.S. EPR Final Safety Analysis Report Markups

Table 6.2.1-13—Safety Grade Doors Credited to Open in Subcompartment Analyses

Reactor Building Elevation and Door Number	Vent Path Direction		Burst Pressure (psid)	Vent Area (ft^2)	Opening Time (s)	Door Function – Pressure Relief
	From Room	To Room				
-8 ft Door 4 [2]	-8 ft Room 7	-8 ft Room 2	1.45+20%	5.92	0.50	Non Radiation Door, Blowout Panel
-8 ft Door 7	-8 ft Room 16	-8 ft Room 13	1.45+20%	5.92	0.50	Non Radiation Door, Blowout Panel
-8 ft Door 10	-8 ft Room 15	-8 ft Room 11	1.45+20%	5.92	0.50	Non Radiation Door, Blowout Panel
-8 ft Door 11	-8 ft Room 14	-8 ft Room 9	1.45+20%	5.92	0.50	Non Radiation Door, Blowout Panel
-8 ft Door 13	-8 ft Room 11	-8 ft Room 5	1.45+20%	5.92	0.50	Non Radiation Door, Blowout Panel
-8 ft Door 14	-8 ft Room 9	-8 ft Room 5	1.45+20%	5.92	0.50	Non Radiation Door, Blowout Panel
+5 ft Door 4 [2]	+5 ft Room 16	+5 ft Room 14	2.90+20%	28.63	0.75	Radiation Door, Swing Open
+5 ft Door 5	+5 ft Room 17	+5 ft Room 16	2.90+20%	20.77	0.50	Radiation Door, Swing Open
+5 ft Door 13	+5 ft Room 21	+5 ft Room 15	2.90+20%	19.91	0.75	Radiation Door, Swing Open
+5 ft Door 14 [2]	+5 ft Room 16	+5 ft Room 13	2.90+20%	13.89	0.75	Radiation Door, Swing Open
+29 ft Door 2 [2, 3]	+29 ft Room 18	+29 ft Room 15	2.90+20%	21.64	0.75	Radiation Door, Swing Open
+45 ft Door 2 [2]	+45 ft Room 18	+45 ft Room 22	2.90+20%	21.85	0.75	Radiation Door, Swing Open
+45 ft Door 15 [2]	+45 ft Room 22	+45 ft Room 13	1.45+20%	5.92	0.50	Non Radiation Door, Blowout Panel

Notes:

1. Doors open into "To Room."
2. Door also credited to open in LBLOCA pressurizer surge line breaks discussed in Section 6.2.1.3.
3. The stairwell denoted as +29 ft Room 29 is part of the flow path connecting +29 ft Room 18 to +29 ft Room 15. The door is denoted as venting from the source room to the terminal room.

19.2.4.4.1.3 Hydrogen Distribution

The issue of hydrogen distribution is the transport of hydrogen from production sources (i.e., the reactor core and MCCI) to locations in which concentrations can result in combustible configurations. As a very light element, hydrogen easily diffuses through heavier gaseous substances. In spaces without inherent convection currents, hydrogen may stratify, consolidating in high concentrations that pose a combustion risk. An inherent mitigating consideration is that steam, either from a large break or the pressurizer relief valves, reduces the combustion potential in two ways: by enhancing the homogenization of hydrogen and thus reducing the peak hydrogen concentrations, and by reducing the flammability through higher steam volume concentrations.

RAI 471, Question 06.02.05-20

The containment is designed such that a natural circulation pattern develops between the two annular compartments during postulated accidents. Steam/hydrogen from the primary system initially enters in the lower portions of the steam generator equipment rooms (either from the PRT or a LOCA). Shortly after the steam/hydrogen enter these rooms the rupture foils, which separate the steam generator compartment ceiling from the containment dome, ruptures allowing the steam/hydrogen to rise into the containment dome. After entering the containment dome, the steam/hydrogen begins to cool and sink through the volumes in the outer annular rings, reaching the lower annulus room. Hydrogen mixing dampers (HMDs) are provided between the lower annulus and the IRWST, which are designed to open automatically during an accident. The IRWST has openings in the ceiling that supply a connection back to the steam generator equipment rooms, completing the recirculation process and thereby establishing a natural circulation pattern.

The core spreading area, the reactor pit and the cooling channels lie outside of this natural circulation flowpath.

~~The release of hydrogen into the containment is predominant in the spreading room and chimney, the reactor pit, and the equipment rooms (pumps and steam generators). Excluding the spreading room and chimney, and the reactor pit compartment, Figure 19.2-5—Hydrogen Concentrations through the U.S. EPR Containment reveals that the hydrogen concentrations are close to each other and behave very similarly, as would be expected for a well-mixed containment atmosphere. These concentrations are calculated using the methodology described in Reference 1.~~

Each trace appearing in Figure 19.2-5 represents a different compartment hydrogen concentration result. The figure shows that the hydrogen concentrations in each node behave similarly, as would be expected for a well-mixed containment atmosphere. Specifically, it can be seen that spikes of hydrogen concentration into specific nodes are very short lived and are followed shortly thereafter by increases in hydrogen concentration in the surrounding nodes. This shows that hydrogen being injected into one part of the containment is quickly circulated into other adjacent nodes due to the natural circulation flows. The observable differences correspond to the relationship of those compartments to the locations in which hydrogen originally appears. The ~~small~~ variation demonstrates the desired occurrence of global convection and resolves the concern of possible secluded recesses of high concentrations of trapped hydrogen.

19.2.4.4.1.4 Hydrogen Combustion

The combustion mechanism for hydrogen can be classified into two regimes, deflagration and detonation. A deflagration is a laminar combustion process where the flame speed, or the combustion front, is sub-sonic. These can be further divided into slow deflagration and fast deflagration. Slow deflagrations are typically classified with a flame speed below 330 ft/s. Fast deflagration is produced as a result of flame acceleration, which is also the driving mechanism for detonation. A detonation is a combustion process where the flame speed is sonic or supersonic.

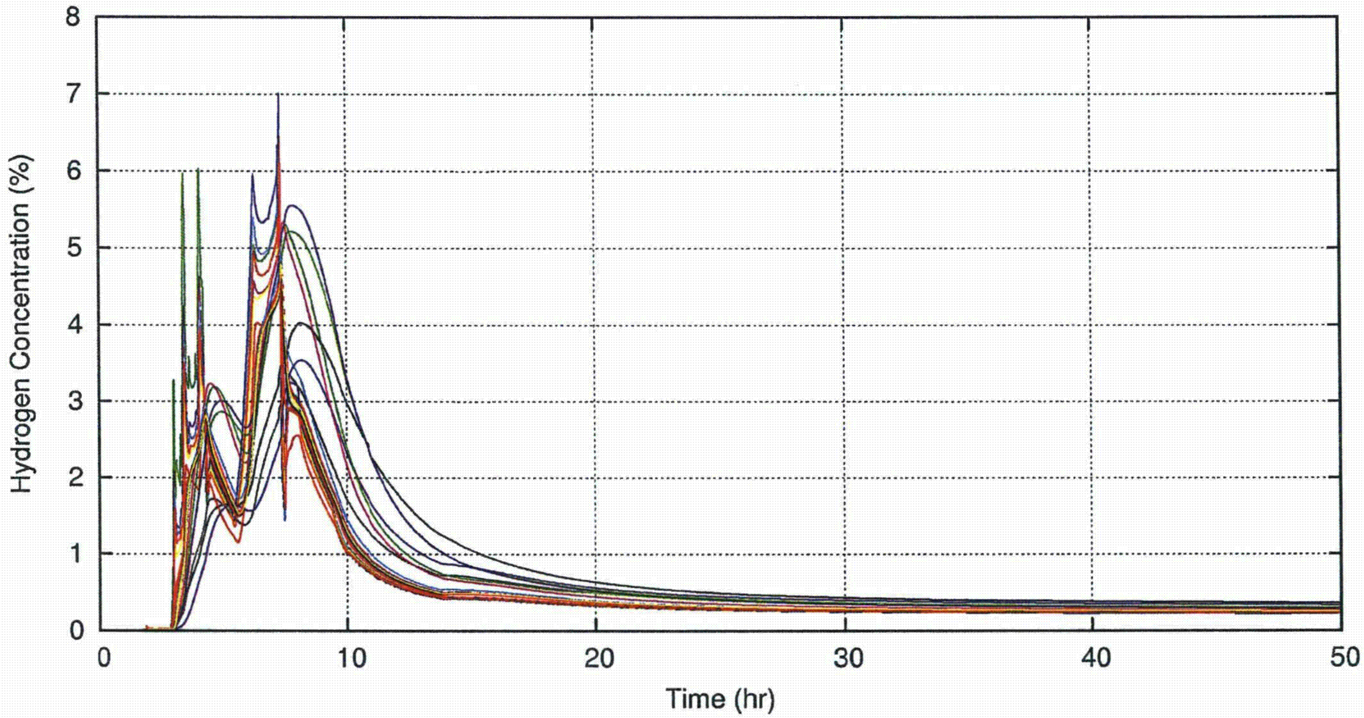
Hydrogen combustion can have two damaging effects on the containment and equipment, those resulting from either pressure or temperature. The primary function of the CGCS is to minimize the threat of combustion by maintaining the global concentration of hydrogen below 10 percent by volume, as required by 10 CFR 50.44. This is accomplished through global convection and the distribution of the PARs (which itself aids in global convection). Figure 19.2-6—Tolerance Limit Plot of Hydrogen Concentration shows that the global hydrogen concentration did not reach or exceed 10 percent by volume for any of the scenarios.

Containment structural integrity must be maintained per 10 CFR 50.44. Thus, the containment response was monitored to ensure that the pressure loads resulting from the accumulation and combustion of hydrogen did not exceed the containment ultimate capacity pressure limit. To provide reasonable assurance that structural integrity was not compromised, the containment was qualified with regard to two phenomena: (1) global hydrogen deflagration and (2) flame acceleration.

With regard to global deflagration, the AICC pressure was used as a bounding value for the pressure that would result should a single large deflagration occur. From Figure 19.2-7—Tolerance Limit Plot of Containment AICC Pressure the global maximum AICC pressure is 100.5~~105~~ psia, for all the uncertainty cases. This does not exceed the containment ultimate capacity pressure presented in Table 3.8-6.

To further address Part 50.44(c)(5), the MAAP4 computer code was used to calculate the containment thermal and pressure loads of a severe accident coincident with a combustion event. That calculation assumed 100 percent metal-water reaction of the clad surrounding the active fuel and a combustion event occurring at the moment of maximum AICC pressure.

Figure 19.2-5—Hydrogen Concentrations through the U.S. EPR Containment



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