Response to

Request for Additional Information No. 69 (773), Revision 0

10/16/2008

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 06.02.05 - Combustible Gas Control in Containment
Application Section: 6.2.5
SPCV Branch

Question 06.02.05-1:

Atmospheric Mixing of Hydrogen in Containment during design basis and significant beyond-design-basis accidents

10 CFR 50.44, (c)(1) requires a capability for ensuring a mixed atmosphere in containment during design-basis and significant beyond-design-basis accidents. The mixed atmosphere criteria in 10 CFR 50.44 (a)(2) are that the concentration of combustible gases in any part of the containment is below a level that supports combustion, or detonation that could cause the loss of containment integrity. SRP 6.2.5, Revision 3, II Acceptance Criterion 4 reiterates this requirement.

Part A

Provide analyses which demonstrates the mixing of hydrogen in the containment during design basis and beyond-design-basis accidents. These analyses should demonstrate that excessive stratification of combustible gases will not occur within the containment or within a containment subcompartment. The containment internal structures should have design features that promote the free circulation of the atmosphere. An analysis of these features for convective mixing should be provided.

Part B

These analyses should identify the sources and quantities of hydrogen used as input. Identify any systems required to ensure a mixed atmosphere. Address the function of the: passive autocatalytic recombiners (PARs); pressurizer relief tank rupture disks; rupture foils; convection foils; and, mixing dampers in providing the mixing of hydrogen in containment. The results should indicate, by compartment and region, e.g. the dome, the resulting hydrogen concentrations by volume.

Part C

Describe the design of the rupture foils, convection foils and mixing dampers in providing open ended compartments in containment. Identify the specific location of each foil or damper and describe their interaction. The description in FSAR section 6.2.5.2.1 implies that the rupture foils and the convection foils are installed at the top of the steam generator compartments. Address the functionality of all foils opening. Identify assumptions and resulting local hydrogen concentrations if only some foils open. Similarly, address the functionality of all mixing dampers. Identify any compartments subject to hydrogen release or generation which would no be open to the containment atmosphere.

Part D

Provide the individual PAR locations. The PAR locations shown schematically in FSAR Tier 2, Figure 6.2.5-1, Arrangement and Location of the Passive Autocatalytic Recombiners, are difficult to relate to the arrangement and location drawings reviewed (FSAR Tier 2, Figures 3.8-2 through 3.8-13, Reactor Building Plan & Section Drawings.) FSAR Tier 1, Table 2.3.1-1, CGCS Equipment Design, confirms neither the exact number of PARs, nor their actual locations. Identify which, and how many, PARs must operate to limit hydrogen concentration or promote mixing. Show that the assumed performance of PARs is verified by experimental evidence.

Consider the impact of possible poisons on PAR performance. Discuss the time response on PAR efficiency.

Identify any compartments subject to hydrogen release or generation which would not be open to the containment atmosphere.

Response to Question 06.02.05-1:

Part A

The passive autocatalytic recombiners (PAR), rupture foils, convection foils, and mixing dampers promote global convection in the U.S. EPR containment during a severe accident. The response to RAI 6, Supplement 1, Question 19-114 addresses analyses which demonstrate the performance of combustible gas control system (CGCS) components during bounding severe accident scenarios.

Part B

Hydrogen in the U.S. EPR containment may be generated following an accident as a result of high temperature reactions between the fuel cladding and coolant, radiolysis of reactor coolant water or emergency core cooling water, corrosion of aluminum and zinc in the containment, or as a consequence of molten core-concrete interaction (MCCI). The quantity of hydrogen generated in a design basis accident is addressed in the response to RAI 81, Question 06.01.01-12. For a severe accident, the sources are high temperature reactions between the fuel cladding and coolant, and the MCCI. The other sources are considered minimal during a severe accident. U.S. EPR FSAR Tier 2, Section 19.2.4.2.1 and ANP-10268P-A, "U.S. EPR Severe Accident Evaluation Topical Report" provide more details on hydrogen sources.

Passive Autocatalytic Recombiners (PARs) Function

The PARs are installed in various parts of the containment to reduce the hydrogen concentration to maintain containment integrity during severe accidents and in the long-term post loss of coolant accident (LOCA) phase.

Pressurizer Relief Tank (PRT) Rupture Disk Function

The PRT rupture disks establish that the PRT does not exceed a differential pressure of 300 psia.

Rupture Foil Function

The rupture foils separate the equipment and operating compartments until the pressure difference between the two compartments exceed the given threshold. When the pressure difference is sufficient, the rupture foils fail passively under pressure, and the division between the two compartments is removed.

Convection Foil Function

The convection foils function in the same way as the rupture foils, with the added feature that these fail under a temperature difference as well. When the temperature exceeds the threshold, the convection foils fail passively and the division between the two compartments is removed.

Hydrogen Mixing Dampers Function

The hydrogen mixing dampers separate the equipment and operating compartments. During normal operation, the dampers are held in a closed position that maintains the separation between the two compartments. Upon exceeding the differential pressure threshold or in case of a power failure, the mixing dampers open, resulting in the division of the two compartments being removed.

Part C

Rupture and Convection Foil Designs

The design of the rupture foils combines the protection against overpressure and sub-pressure in one compartment. This is possible by using the reliable principles of the three segment bursting disc and the reverse buckling-pin bursting disk. The venting takes place over the entire discharge area. The rupture foils are equipped with predefined buckling and predetermined breaking points, and open without fragmented particles. This is established by H-shaped bursting and a predefined pivot at two sides.

The convection foils consist of rupture foils combined with a temperature sensitive opening mechanism. The rupture foils open passively either due to the pressure difference or to exceeding a predefined temperature.

Integrated into a steel frame are bursting elements, which open the convection foils when they exceed their specified differential pressure. The steel frame is held closed by the thermo-link which integrates fusible links. The design of the fusible link allows the convection foil to open at a predefined temperature. A fusible link consists of two brass plates that are joined with solder. The composition of the solder is eutectic, designed to fuse at a specific temperature between 176-185°F (80-85^{o}C). The air-tightness of the steel frame will be provided by seals.

The rupture and convection foils are located above the steam generators and form the steam generator ceiling (level 103.5 ft (+31.55m)).

To evaluate the rupture and convection foils related to hydrogen concentration, several MAAP calculations were completed with 25 percent, 50 percent, and 75 percent of the rupture and convection foils failing to open. Figure 06.02.05-1-1 shows the global hydrogen concentration for 0 percent, 25 percent, 50 percent, and 75 percent failure of the rupture and convection foils. The global hydrogen concentration remains below 10 percent for all cases. The compartments affected by the rupture and convection foils failing to function would remain open to containment because the mixing dampers are also located in the same affected compartments. Figure 06.02.05-1-2 shows, for 75 percent rupture and convection foil failure, the hydrogen concentration for containment nodes. This figure shows an increase and decrease in every node, which is evidence of hydrogen distribution and mixing throughout the U.S. EPR containment. Figure 06.02.05-1-2 shows local hydrogen concentrations from the MAAP model for the IRWST (NFH2RB(2)), lower equipment room for broken loop (NFH2RB(3)), lower equipment rooms for unbroken loop (NFRH2RB(4)), middle equipment room for broken loop

(NFH2RB(5)), middle equipment rooms for unbroken loop (NFRH2RB(6)), upper equipment room for broken loop (NFH2RB(7)), reactor cavity (NFH2RB(9)), upper equipment rooms for unbroken loop (NFH2RB(10)), surge line (NFH2RB(11)), pressurizer (NFH2RB(12)), components (NFH2RB(13)), first stage steam generator blowdown cooler (NFH2RB(14)) containment nodes.

Hydrogen Mixing Damper Design

The hydrogen mixing dampers are designed to fail open and follow the widely used fire damper design. The dampers are equipped with actuators following the fail-open principle and position indicators.

The actuator maintains a “CLOSE” position during normal operation. While the damper is closed, a spring is compressed. The spring is held in a loaded position by a solenoid brake. In case of a power failure to the solenoid, the spring will drive the actuator and damper to the “OPEN” position. The actuator is available for normal operation after power returns. The associated dashpot controls the spring speed and provides a safe closing of the dampers.

The hydrogen mixing dampers are arranged in the openings of the lower annular rooms towards the in-containment refueling water storage tank (IRWST). Table 06.02.05-1-1 provides information on the location and arrangement of the hydrogen mixing dampers.

To evaluate the mixing dampers related to hydrogen concentration, several MAAP calculations were completed with 25 percent, 50 percent, and 75 percent of the mixing dampers failing to open. Figure 06.02.05-1-3 shows the global hydrogen concentration for 0 percent, 25 percent, 50 percent, and 75 percent failure of the mixing dampers. The global hydrogen concentration remains below 10 percent for all cases. The compartments affected by the mixing dampers failing would remain open to containment because PARs and rupture and convection foils are also located in affected compartments. Figure 06.02.05-1-4 shows, for 75 percent mixing damper failure, the hydrogen concentration for containment nodes. This figure shows an increase and decrease in every node, which is evidence of hydrogen distribution and mixing throughout the U.S. EPR containment. Figure 06.02.05-1-4 shows local hydrogen concentrations from the MAAP model for the IRWST (NFH2RB(2)), lower equipment room for broken loop (NFH2RB(3)), lower equipment rooms for unbroken loop (NFRH2RB(4)), middle equipment room for broken loop (NFH2RB(5)), middle equipment rooms for unbroken loop (NFRH2RB(6)), upper equipment room for broken loop (NFH2RB(7)), reactor cavity (NFH2RB(9)), upper equipment rooms for unbroken loop (NFH2RB(10)), surge line (NFH2RB(11)), pressurizer (NFH2RB(12)), components (NFH2RB(13)), first stage steam generator blowdown cooler (NFH2RB(14)) containment nodes.

Part D

The individual PAR location information was documented in the response to RAI 6, Question 19-95, Table 19-95h-1.

To evaluate the PARs related to hydrogen concentration and mixing, several MAAP calculations were completed with 25 percent, 50 percent, 70 percent, and 75 percent of the PARs unable to function. Table 06.02.05-1-2 shows the number of PARs functioning in-containment for each MAAP calculation.

Figure 06.02.05-1-5 plots the global hydrogen concentration for 0 percent, 25 percent, 50 percent, 70 percent, and 75 percent failure of the PARs. The global hydrogen concentration remains below 10 percent for all cases with the exception of the 75 percent failure of the PARs case as shown in Figure 06.02.05-1-5. Therefore, even if 70 percent of the PARs do not function the uniformly distributed hydrogen concentration will remain below the limit of 10 percent as required by 10 CFR 50.44 (c).

Figure 06.02.05-1-6 shows, for 70 percent PAR failure, the hydrogen concentration for containment nodes. This figure shows an increase and decrease in every node, which is evidence of hydrogen distribution and mixing throughout the U.S. EPR containment. Figure 06.02.05-1-6 shows local hydrogen concentrations from the MAAP model for the IRWST (NFH2RB(2)), lower equipment room for broken loop (NFH2RB(3)), lower equipment rooms for unbroken loop (NFRH2RB(4)), middle equipment room for broken loop (NFH2RB(5)), middle equipment rooms for unbroken loop (NFRH2RB(6)), upper equipment room for broken loop (NFH2RB(7)), reactor cavity (NFH2RB(9)), upper equipment rooms for unbroken loop (NFH2RB(10)), surge line (NFH2RB(11)), pressurizer (NFH2RB(12)), components (NFH2RB(13)), first stage steam generator blowdown cooler (NFH2RB(14)) containment nodes.

EPRI Technical Report, TR-107517, “Generic Tests of Passive Autocatalytic Recombiners (PARs) for Combustible Gas Control in Nuclear Power Plants,” provides experimental evidence on the PAR performance, impact of possible containment conditions, and time response of the PARs. This experimental data is applicable to the U.S. EPR.

FSAR Impact:

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

Table 06.02.05-1-1—Mixing Damper Locations

Component	Description	Room Number
30JMT20AA001	H2 Mixing Damper 01	30UJA07015
30JMT20AA002	H2 Mixing Damper 02	30UJA07015
30JMT20AA003	H2 Mixing Damper 03	30UJA07015
30JMT20AA004	H2 Mixing Damper 04	30UJA07015
30JMT20AA005	H2 Mixing Damper 05	30UJA07014
30JMT20AA006	H2 Mixing Damper 06	30UJA07014
30JMT20AA007	H2 Mixing Damper 07	30UJA07014
30JMT20AA008	H2 Mixing Damper 08	30UJA07014

Table 06.02.05-1-2—Functioning PAR Locations

Containment Nodes	0% Fail	25% Fail	50% Fail	70% Fail	75% Fail
Reactor Cavity	1	1	0	0	0
Surge Line	2	1	1	0	1
Pressurizer	3	2	2	1	1
Middle Equipment Room for Broken Loop	4	3	2	1	1
Middle Equipment Rooms for Unbroken Loop	12	9	6	5	3
Upper Equipment Room for Broken Loop	4	3	2	1	1
Upper Equipment Rooms for Unbroken Loop	4	3	2	1	1
Middle Annular Rooms 1 and 2	2	2	1	0	0
Middle Annular Rooms 3 and 4	2	1	1	0	0
Upper Annular Rooms 1 and 2	1	1	0	0	0
Containment Dome	12	9	6	6	3
Total Functioning PARs	**47**	**35**	**23**	**15**	**11**

Figure 06.02.05-1-1—Global Hydrogen Concentration (Rupture/Convection Foils)

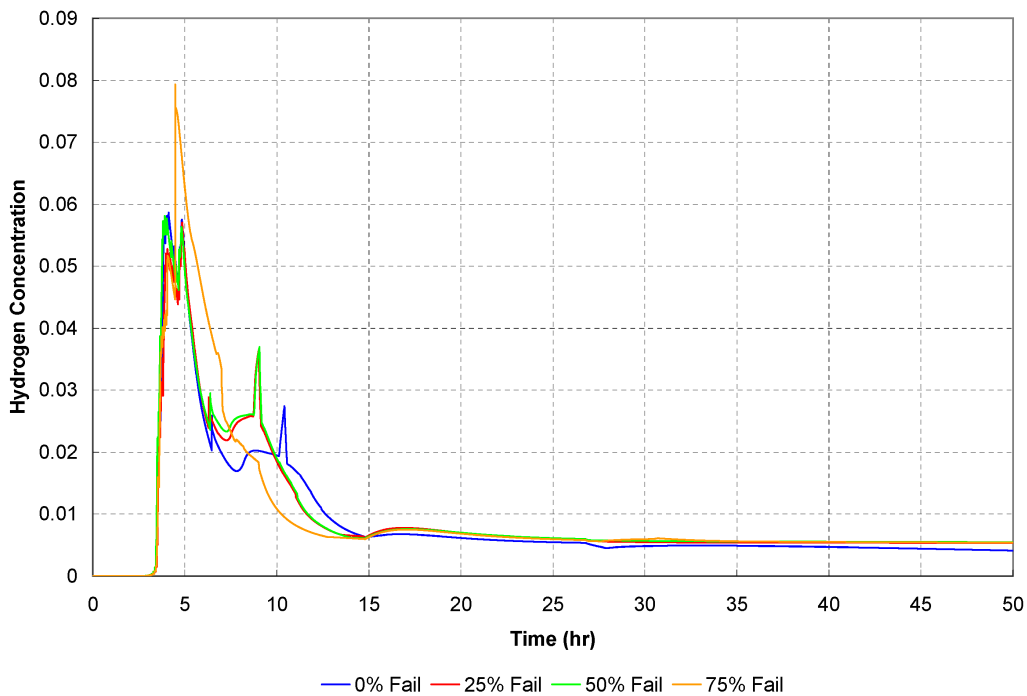


Figure 06.02.05-1-2—Local Hydrogen Concentration for 75% Failure of Rupture and Convection Foils

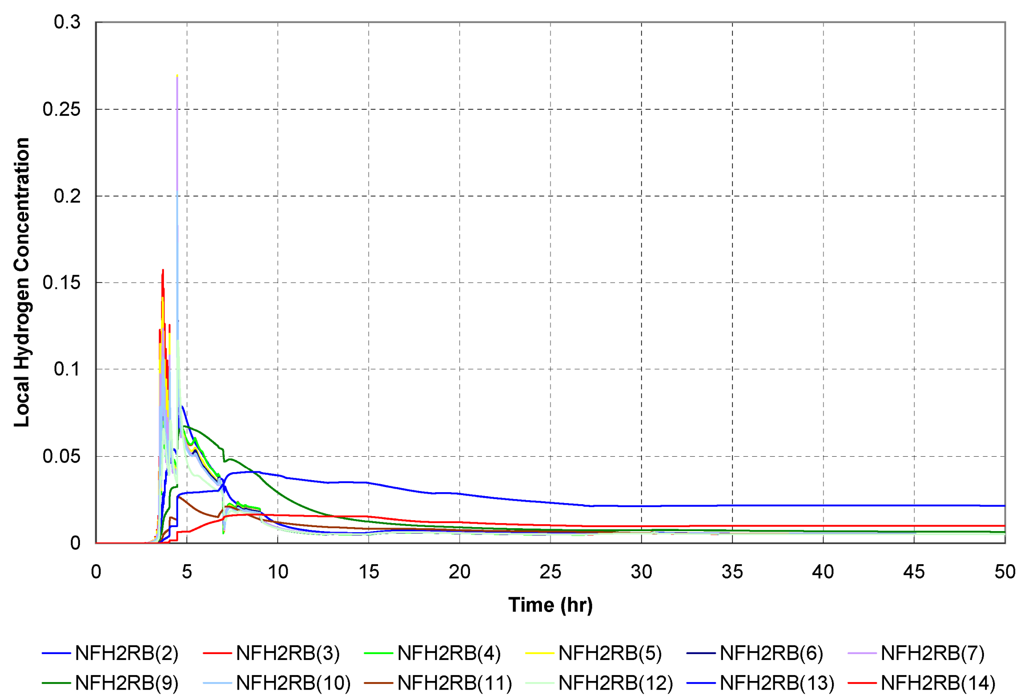


Figure 06.02.05-1-3—Global Hydrogen Concentration (Mixing Dampers)

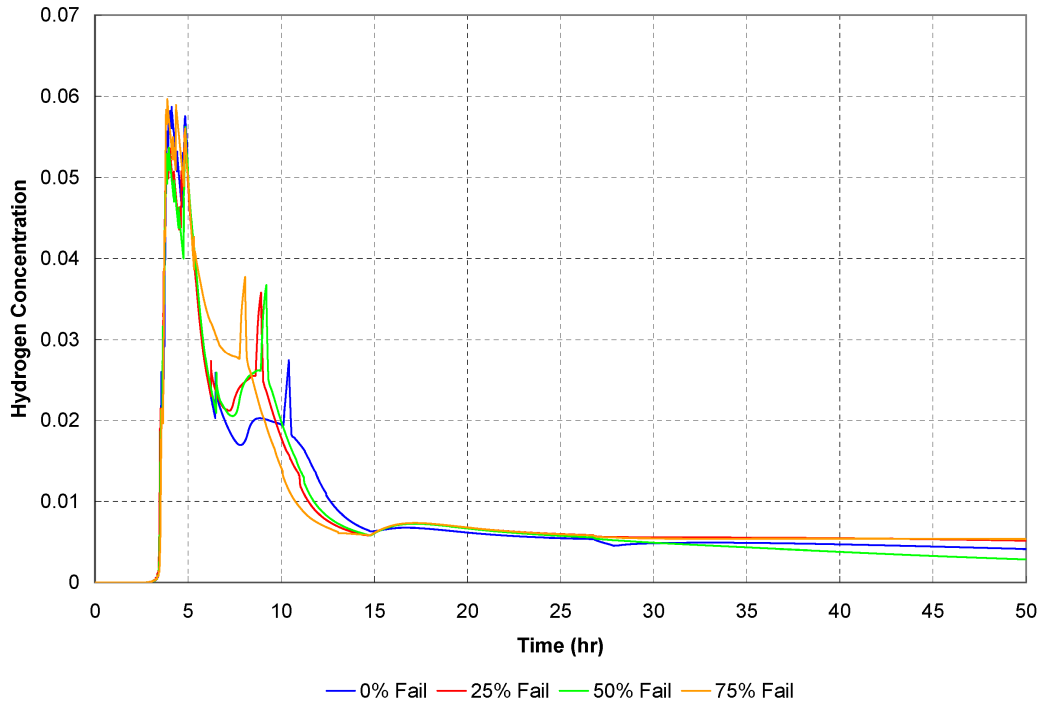


Figure 06.02.05-1-4—Local Hydrogen Concentration for 75% Failure of Mixing Dampers

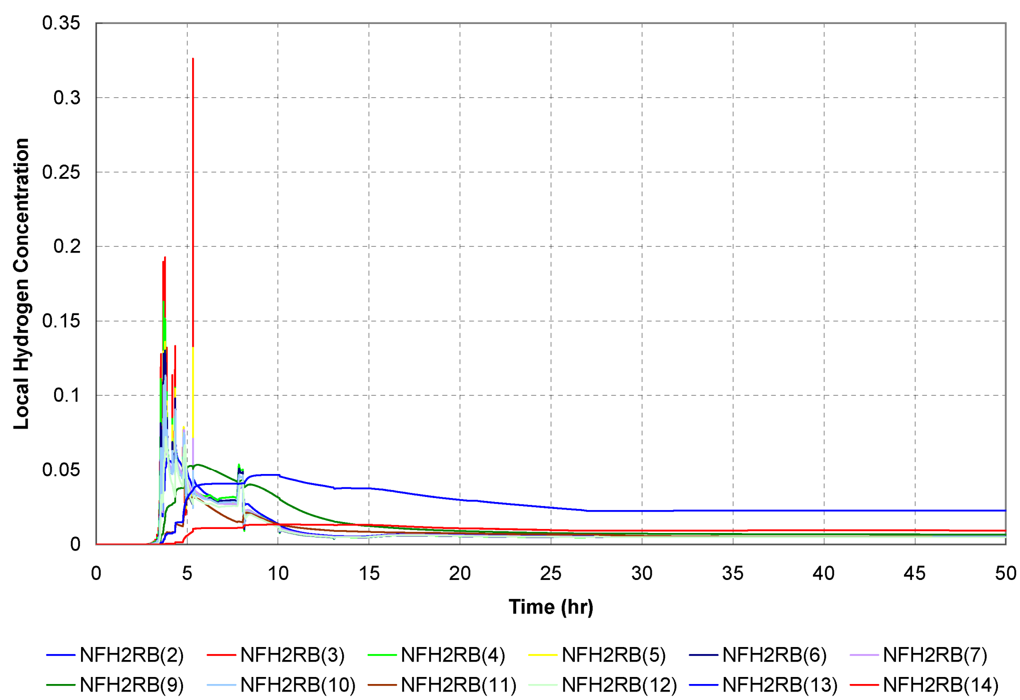


Figure 06.02.05-1-5—Global Hydrogen Concentration (PARs)

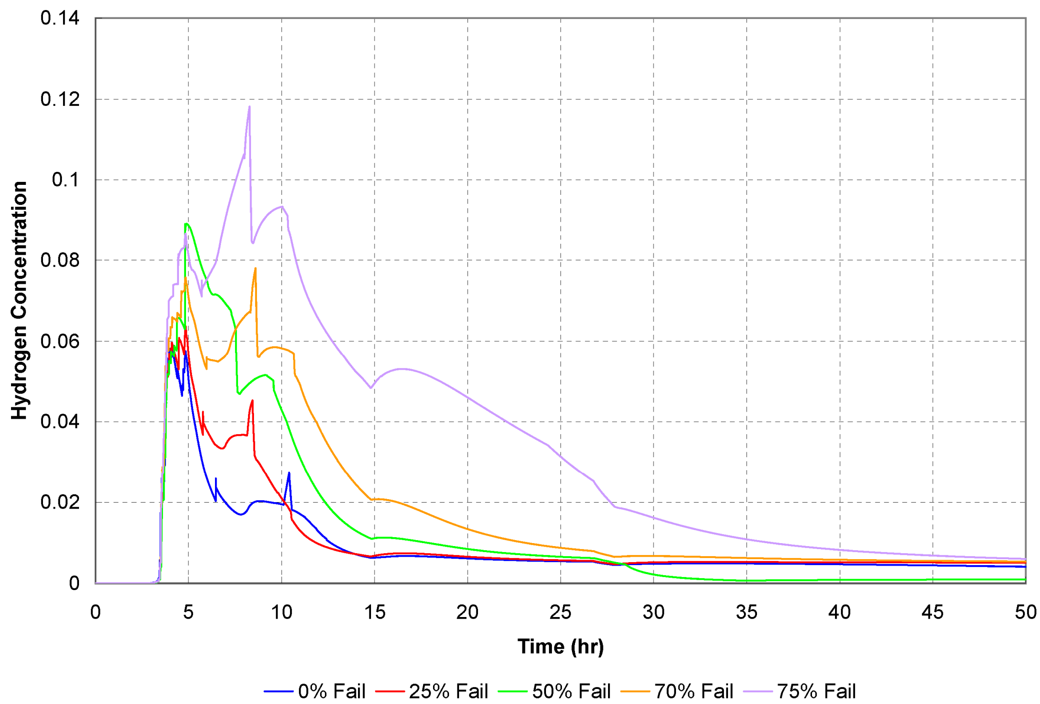
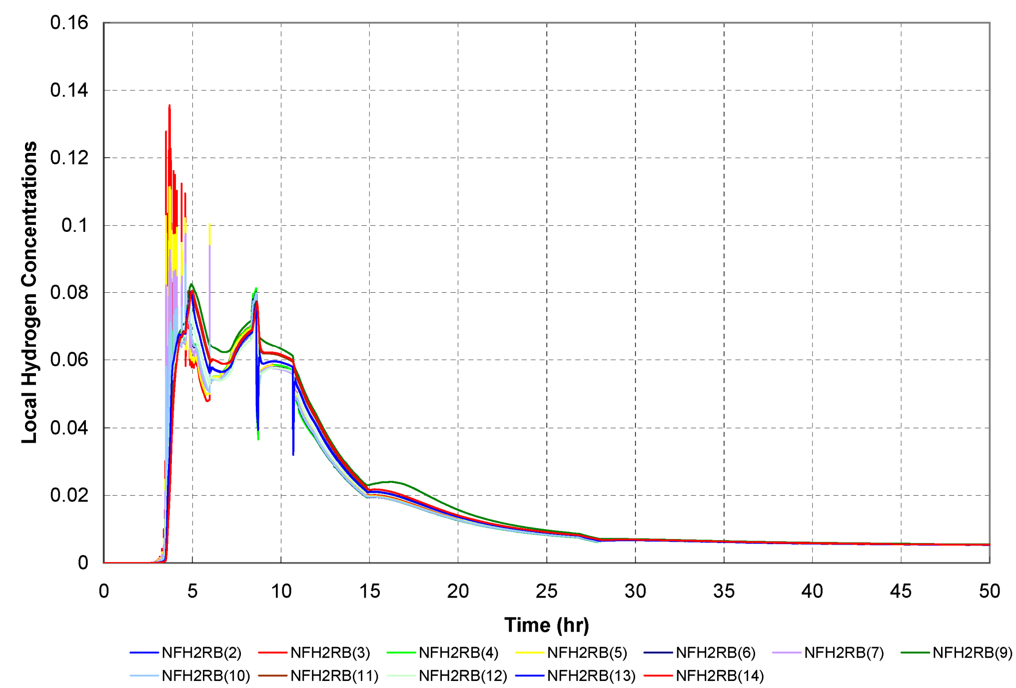


Figure 06.02.05-1-6—Local Hydrogen Concentration for 70% Failure of PARs



Question 06.02.05-2:

Combustible Gas Control

10 CFR 50.44 (c)(2) requires that the containment must limit hydrogen concentrations in containment during and following an accident that releases an equivalent amount of hydrogen as would be generated from a 100 percent fuel clad-coolant reaction, when uniformly distributed, to less than 10 percent by volume.

Identify significant beyond-design-basis accidents. The analysis should be based on severe accident methodology and rely only on equipment that will function in the accident environment, including hydrogen combustion. Select the limiting cases that bound the accident consequences. For the limiting cases, provide a detailed analysis of hydrogen generation, distribution and accumulation in various containment compartments. Show that:

a. resultant hydrogen concentration uniformly distributed is less than 10 percent,
b. local hydrogen concentrations do not reach detonation level which threaten containment integrity, and
c. by compartment and region, the resulting hydrogen concentration by volume.

Discuss the various beyond design basis scenarios considered and the rationale for the selection of the limiting case.

FSAR, Tier 2, section 19.2.4.4.1.3, Hydrogen Distribution, and FSAR Figure 19.2-5, Hydrogen Concentrations Through the US EPR Containment, address hydrogen concentration results in various compartments following a severe accident. Since Figure 19.2-5 “excludes” the compartments where release of hydrogen is predominant, provide the hydrogen concentration in the steam generator and reactor coolant pump rooms, the reactor pit and the spreading room for the same 50 hour time frame.

Response to Question 06.02.05-2:

The severe accident methodology used is described in ANP-10268P-A, “U.S. EPR Severe Accident Evaluation Topical Report.” As part of that methodology, five scenarios were identified as relevant (see U.S. EPR FSAR Tier 2, Section 19.2.4.2.2). The relevant scenarios include three loss of offsite power (LOOP) cases, one loss of balance of plant (LBOP) case, and one small loss of coolant accident (SLOCA). These cases are relevant because their Level 1 probabilistic risk assessment (PRA) core damage frequency (CDF) was above the threshold of 1x10E-8 per year. These relevant scenario cases form the basis for the 59 case uncertainty analysis. Each case in the uncertainty analysis is one of the relevant scenarios, modified so that each of the 27 parameters is varied randomly within their uncertainty domain, or range of uncertainty. With the completion of the 59 cases, the uncertainty analysis demonstrates the most likely outcomes of a severe accident. This uncertainty analysis forms the limiting conditions. One of the 59 cases may be limiting for the initial part of a transient, while at other times, other cases may be more limiting. The limiting case, for a particular time, also changes depending on the output parameter in question. Therefore, when using this methodology, it is important to view the suite of all 59 cases together as they collectively form the limiting conditions, as opposed to just a single case. U.S. EPR FSAR Tier 2, Section 19.2.4.2.3 summarizes the analytical methodology of the uncertainty analysis.

A detailed analysis of the combustible gas control system (CGCS), which shows the performance of the system while dealing with hydrogen generation, distribution and accumulation in various containment compartments has been provided in the response to RAI 6, Supplement 1, Question 19-114. RAI 6, Supplement 1, Question 19-114, Figure 19-114-4 shows the global hydrogen concentration for all 59 cases of the uncertainty analysis. No case exceeds 10 percent hydrogen concentration at any time.

Local hydrogen concentrations are shown in RAI 6, Supplement 1, Question 19-114, Figure 19-114-1 and Figure 19-114-2 for the broken loop and unbroken loop steam generator compartments respectively. Hydrogen concentrations in these compartments are slightly higher than the global average as they receive hydrogen via the primary system effluent. Any deflagration inside containment does not burn fast enough to transition to a detonation. For further details, see the RAI 6, Supplement 1, Question 19-114, “Flame Acceleration” section.

RAI 6, Supplement 1, Question 19-114, Figure 19-114-3 shows, for a single case, the hydrogen concentrations throughout most of the containment’s compartments. With the hydrogen concentrations for all compartments shown on a single graph, it is observed that the overall containment is well mixed, as a rise in hydrogen concentration in one compartment is similarly reflected in the other compartments. When it is established that the containment is well mixed, the reverse can also be applied to RAI 6, Supplement 1, Question 19-114, Figure 19-114-1 and Figure 19-114-2. The hydrogen concentrations in the figures for the steam generator compartments closely match the hydrogen concentration for the other compartments inside containment.

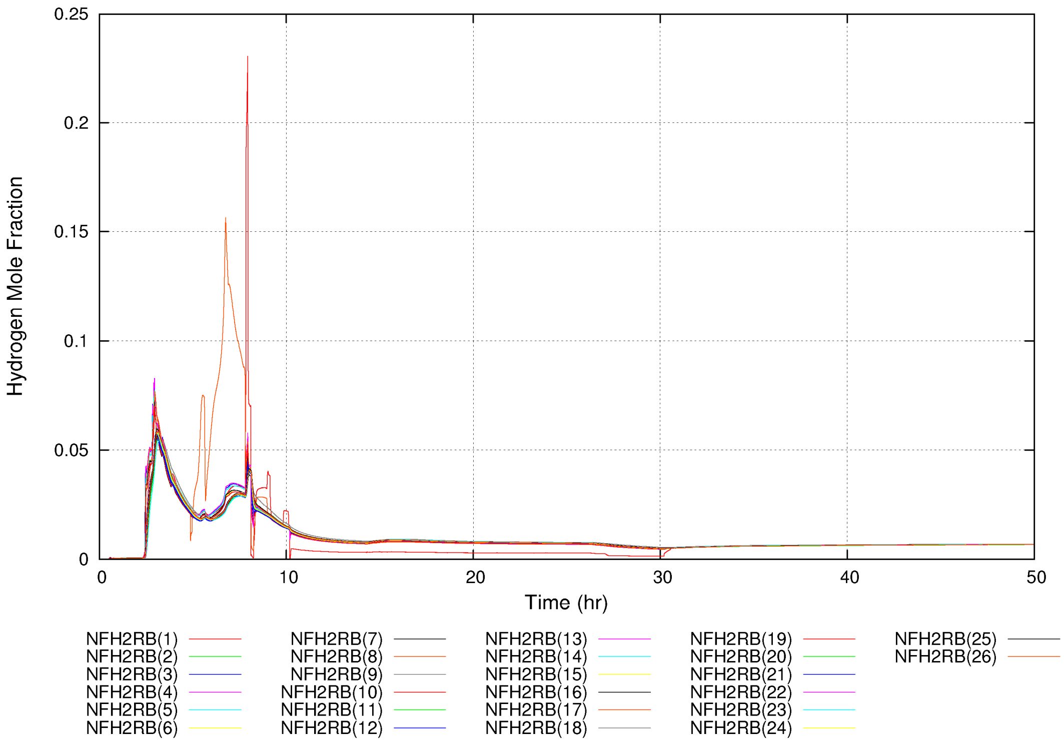
U.S. EPR FSAR Tier 2, Figure 19.2-5 shows the hydrogen concentrations in various compartments within the containment. The text referring to this figure incorrectly indicates that the figure excludes the equipment rooms (pumps and steam generators). U.S. EPR FSAR Tier 2, Figure 19.2-5 includes the equipment rooms (pumps and steam generators). The spreading room and steam chimney and reactor pit compartments were excluded, as the hydrogen released in these compartments, through the molten corium-concrete interaction (MCCI) process, occurs at temperatures above the auto-ignition temperature. Therefore, the hydrogen immediately burns upon generation. The hydrogen concentration in these compartments has little meaning. The hydrogen concentration of those compartments has been included in Figure 06.02.05-2-1, which shows the hydrogen concentration in all compartments of the MAAP model.

U.S. EPR FSAR Tier 2, Section 19.2.4.4.1.3 will be revised to clarify that excluding the spreading room and chimney, and the reactor pit compartments, that hydrogen concentrations throughout the U.S. EPR containment are close to each other and behave similarly.

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.

Figure 06.02.05-2-1—Hydrogen Concentration for All Compartments



Question 06.02.05-3:

Equipment Survivability

To meet the requirements of 10 CFR Part 50.44 (c)(3) regarding equipment survivability, systems and components necessary for establishing and maintaining safe shutdown of the plant and containment structural integrity following a severe accident shall be capable of performing their functions during and after exposure to the environmental conditions created by the burning of hydrogen. Environmental conditions caused by local detonations of hydrogen must also be included, unless such detonations can be shown to be unlikely to occur. The amount of hydrogen to be considered must be equivalent to that generated from a fuel clad-coolant reaction involving 100 percent of the fuel cladding surrounding the active fuel region.

Provide a list of the systems necessary for establishing and maintaining safe shutdown of the plant and containment structural integrity during and following a severe accident. Provide a list of the components in these systems that are exposed to the containment environment.

Justify that these components will operate following a severe accident in containment, including the environmental conditions created by hydrogen burning. Provide pressure, temperature, and other environmental conditions these components would be subject to.

Explain why the equipment and instrumentation listed in the US EPR FSAR, chapter 19, Table 19.2-3, Severe Accident Instrumentation and Equipment is not identical to the equipment discussed in section 19.2.4.4.5 titled Equipment Survivability. For example, containment isolation valves are identified among the equipment inside containment which must withstand severe accident conditions, but they are not identified in Table 19.2-3.

In the US EPR FSAR, chapter 19, subsection 19.2.4.4.5.2, fifth paragraph, it is stated "…only equipment relied upon to actively mitigate the consequences of hydrogen in the containment atmosphere is required to survive such occurrences per 10 CFR 50.44". Explain how this design meets the equipment survivability requirements of 10 CFR 50.44 (c)(3).

Response to Question 06.02.05-3:

U.S. EPR FSAR Tier 2, Section 19.2.3.3.7.1 lists the four systems specifically designed for mitigating severe accidents. U.S. EPR FSAR Tier 2, Section 19.2.4.4.5 provides a list of instrumentation and components relied upon to perform operator actions, survey the effectiveness of the installed mitigation measures, and survey the overall plant conditions including possible releases to the environment during a severe accident. U.S. EPR FSAR Tier 2, Section 19.2.4.4.5 provides information regarding the containment environment such as pressure, temperature, and humidity. Additional information and an expanded description of the equipment survivability for the U.S. EPR were provided in responses to RAI 6, Question 19-113 and RAI 22, Supplement 1, Question 19-154.

U.S. EPR FSAR Tier 2, Table 19.2-3 summarizes instrumentation and equipment necessary to monitor the severe accident progression and to allow for operator action. This instrumentation and equipment is specifically designed for the mitigation of a severe accident. Equipment (e.g., inboard containment isolation valves, equipment and personal hatch gaskets), is required to maintain leak-tightness during a severe accident, but are not required or relied upon as part of the severe accident mitigation strategy. Instrumentation and equipment in that category merely provides additional information beyond that required as a minimum or continues to perform its primary function during the progression of a severe accident.

U.S. EPR FSAR Tier 2, Section 19.2.4.2.5 and Section 19.2.4.4.1, provide details on the analysis and results regarding evaluation for hydrogen generation and reduction within the containment during a severe accident. Based on the results and findings of the analysis, the equipment survivability concludes that equipment relied upon to function within the containment will not be affected by hydrogen burning or detonation. Additional details can be found in the responses to RAI 6, Question 19-113 and RAI 22, Supplement 1, Question 19-154. The response to RAI 22, Supplement 1, Question 19-113 also explains and justifies how the combustible gas control system equipment and other equipment, relied upon to mitigate a beyond design basis event, meet the requirements of 10 CFR 50.44 (3)(c).

FSAR Impact:

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

Question 06.02.05-4:

Structural Analysis

10 CFR 50.44, (c)(5) requires an analysis which demonstrates containment structural integrity following an accident that releases the hydrogen generated from 100 percent fuel clad-coolant reaction accompanied by hydrogen burning.

Regulatory Guide 1.7, Rev. 3, Control of Combustible Gas Concentrations in Containment, describes methods which are acceptable to NRC staff for implementing 10 CFR 50.44 (c). RG 1.7, section C.5, finds acceptable concrete containments that meet the containment structural integrity requirements of the ASME, Boiler and Pressure Vessel Code, Section III, Division 2, subsubarticle CC-3720, Factored Load Category, by considering internal pressure and dead load alone as having met the minimum design conditions for this accident.

Regulatory Guide 1.136, Rev 3, Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments, describes an approach acceptable to the NRC staff to consider structural loads and determine the containment response in order to demonstrate containment structural integrity. RG 1.136, Position C.5.B (1) provides loads and load combinations for pressure loads that result from a fuel clad-coolant reaction, accompanied by an uncontrolled hydrogen burn. The applicable load combination for the Factored Load Category is:

$$D + P_{g1} + [P_{g2} \text{ or } P_{g3}]$$

D = dead load

P_{g1} = pressure resulting from an accident that releases hydrogen generated from 100 percent fuel clad-metal water reaction

P_{g2} = pressure resulting from uncontrolled hydrogen burning

P_{g3} = pressure resulting from post accident inerting, assuming carbon dioxide is the inerting agent

US EPR DCD Tier 2 Figure 19.2-7, the Tolerance Limit Plot for AICC Pressure shows the global maximum pressure is 105 psia. Confirm that this corresponds to P_{g2} for the Factored Load combination above. Provide P_{g1} and P_{g2} (if produced during the severe accident). Compare this total load combination to the ultimate capacity pressure of 119 psig (Tier 2, Table 3.8-6, Containment Ultimate Pressure Capacity).

Response to Question 06.02.05-4:

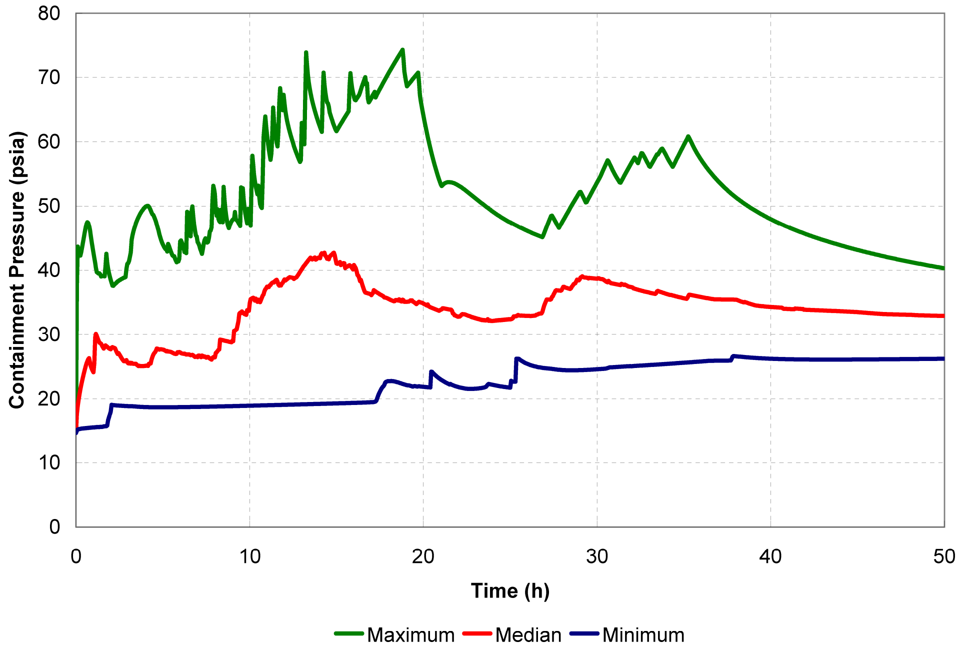
U.S. EPR FSAR Tier 2, Figure 19.2-7 shows the containment maximum global pressure as 105 psia. This value is inclusive of both the pressure resulting from an accident that releases hydrogen generated from 100 percent fuel clad-metal water reaction (P_{g1}) and the pressure resulting from uncontrolled hydrogen burning (P_{g2}). The pressure resulting from severe accidents without combustion, P_{g1}, is displayed in Figure 06.02.05-4-1 and is the containment pressure tolerance limit. The maximum pressure is shown to be 75 psia. Subtracting P_{g2} (75 psia) from the combination of P_{g1} + P_{g2} (105 psia) yields a P_{g1} of 30 psia.

The factored load combination consists of D + P_{g1} + (P_{g2} or P_{g3}), the effective pressure on containment is generated from P_{g1} + P_{g2} and as previously stated, is taken as 105 psia. Subtracting the atmospheric pressure of 14.7 psi results in a maximum global pressure value of 90.3 psig. This pressure value is smaller than the ultimate capacity pressure that containment can withstand of 119 psig as stated in U.S. EPR FSAR Tier 2, Table 3.8-6 and is therefore bounded by the ultimate capacity of containment.

FSAR Impact:

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

Figure 06.02.05-4-1: Tolerance Limit Plot for Containment Pressure



Question 06.02.05-5:

Additions

Expand FSAR Tier 1 Table 2.3.1-2, CGCS ITAAC, to include the location of all the rupture and convection foils.

Complete FSAR Tier 1, Table 2.3.1-1, CGCS Equipment Design to include every PAR and the location of each.

Response to Question 06.02.05-5:

A response to this question will be provided by January 16, 2009.

Question 06.02.05-6:

Corrections

Correct the following errors in FSAR Tier 1, Table 2.3.1-1, CGCS Equipment Design:

1. The PAR location “Annulus Space Accumulator Tank Loop 4 (180 to 270)” should be Loop 1.
2. The PAR location “Annulus Space Accumulator Tank Loop 4 (270 to 0)” should be Loop 2.
3. The “Rupture Disks” should be “Rupture Foils”. The location of the discharge of the *rupture disks* of the pressurizer relief tank is relevant but does not match the association and location.

Response to Question 06.02.05-6:

U.S. EPR FSAR Tier 1, Table 2.3.1-1 will be revised:

- The equipment location for “Annulus Space Accumulator Tank Loop 4 (180° to 270°)” will be changed to “Annulus Space Accumulator Tank Loop 1 (180° to 270°).”
- The equipment location for “Annulus Space Accumulator Tank Loop 4 (270° to 0°)” will be changed to “Annulus Space Accumulator Tank Loop 2 (270° to 0°).”
- The two equipment descriptions for “Rupture Disks and Convection Foils” will be changed to “Rupture Foils and Convection Foils.”

FSAR Impact:

U.S. EPR FSAR Tier 1, Table 2.3.1-1 will be revised as described in the response and indicated on the enclosed markup.

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dependent on the uncertainties associated with in-vessel progression. Because core melt is sufficiently rich in metals capable of reacting during the ex-vessel phase, the 1300 lbms approximates the total hydrogen generation uncertainty. Figure 19.2-4—Tolerance Limit Plot of Hydrogen Production shows the range of hydrogen production observed in the uncertainty analysis, verifying that the 2000 lbm threshold is exceeded by the minimum observed in the analyses. The median result is very near 3300 lbms of hydrogen mass, nearly exactly the 100 percent oxidation of fuel cladding surrounding the active fuel, and the maximum value is significantly above the requirement of 10 CFR 50.44.

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.

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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 ~~previous compartments~~ 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. Each trace appearing in Figure 19.2-5 represents a different compartment hydrogen concentration result. 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

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Table 2.3.1-1—CGCS Equipment Design	
Equipment Description	**Equipment Location**
Passive Autocatalytic Recombiner (PAR) (One or more)	Pressurizer Area
PAR (One or more)	Reactor Cavity Area
PAR (One or more)	Containment Dome Area
PAR (One or more)	Steam Generator (SG) Loop 1 Area
PAR (One or more)	SG Loop 2 Area
PAR (One or more)	SG Loop 3 Area
PAR (One or more)	SG Loop 4 Area
PAR (One or more)	Reactor Coolant Pump (RCP) Loop 1 Area
PAR (One or more)	RCP Loop 2 Area
PAR (One or more)	RCP Loop 3 Area
PAR (One or more)	RCP Loop 4 Area
PAR (One or more)	Annulus Space Accumulator Tank Loop 3 (0º to 90º)
PAR (One or more)	Annulus Space Accumulator Tank Loop 4 (90º to 180º)
PAR (One or more)	Annulus Space Accumulator Tank Loop ~~4~~1 (180º to 270º)
PAR (One or more)	Annulus Space Accumulator Tank Loop ~~4~~2 (270º to 0º)
PAR (One or more)	Access Area (Equipment Hatch)
PAR (One or more)	Set Down Area Operating Floor
PAR (One or more)	Operating Floor Access
Mixing Damper	Reactor Coolant Loop 3 Area
Mixing Damper	Reactor Coolant Loop 4 Area
Mixing Damper	Reactor Coolant Loop 1 Area
Mixing Damper	Reactor Coolant Loop 2 Area
Rupture ~~Disks~~ Foils and Convection Foils	SG Loop 1 and Loop 2
Rupture ~~Disks~~ Foils and Convection Foils	SG Loop 3 and Loop 4