RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**155-8167**
SRP Section:	**06.02.05 – Combustible Gas Control in Containment**
Application Section:	**6.2.5**
Date of RAI Issue:	**08/18/2015**

Question No. 06.02.05-1

10 CFR 52.44(c)(1) requires that a standard design certification applicant must ensure a mixed atmosphere in containment during design-basis and significant beyond design-basis accidents. A mixed atmosphere means that the concentration of combustible gases in any part of the containment is below a level that supports combustion or detonation that could cause loss of containment integrity.

Acceptance Criteria 4 of Standard Review Plan (SRP) Section 6.2.5, “Combustible Gas Control in Containment,” and Regulatory Position C.3 of Regulatory Guide (RG) 1.7, “Control of Combustible Gas Concentrations in Containment,” Revision 3 state that all containment types should have an analysis of the effectiveness of the method used for providing a mixed atmosphere and that this analysis should demonstrate that combustible gases will not accumulate within a compartment or cubicle to form a combustible or detonable mixture that could cause loss of containment integrity.

APR1400 Design Control Document (DCD), Tier 2, Section 6.2.5.3 states that mixing is achieved by natural convection processes. In addition, DCD, Tier 2, Section 19.2.3.3.2.2 states that the APR1400 hydrogen control analyses were performed using the Modular Accident Analysis Program (MAAP) to determine hydrogen mixing, distribution, and combustion inside containment. KHNP’s “Severe Accident Analysis Technical Report,” APR1400-E-P-NR-14003-P, Revision 0, provides the results of these MAAP analyses and describes that the containment model consisted of 36 nodes.

In order for the staff to reach a conclusion of reasonable assurance that the requirements for mixing are met, the staff needs to review the calculation which demonstrates mixing 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, either on the licensing docket or in the electronic reading room. The calculation should include:

- Hydrogen distribution and deflagration to detonation transition (DDT) potential for at power operation analysis for each of the 36 nodes, and at least 5 scenarios, showing the hydrogen, oxygen, and steam concentration for all nodes. Identify and address any nodes where the hydrogen concentration is greater than 10%. Identify and address any nodes with DDT potential, quantitatively and or qualitatively.

- The hydrogen generation curves versus time for each of the scenarios analyzed.

- The assumptions for crediting the hydrogen mitigation system. For example, provide the performance of the passive autocatalytic recombiners (PAR) and/or hydrogen igniters (HI). Include the PAR efficiency, number and locations of PARs and HIs credited.

- The criteria for the selection of the accident scenarios.

- DCD Tier 2, Figures 19.2.3-3 through 19.2.3-6 are labelled with scenario success criteria abbreviations. For each selected scenario, identify the mitigation systems or equipment credited, and to what extent. Elaborate on the success criteria for each scenario. For example, does HI credit all 8 igniters? Does 3WV credit both three way valves as being aligned to relieve in the steam generator compartments? A table of scenarios with corresponding assumptions with credited mitigating systems would be helpful.

This question is based upon material found in DCD Tier 2 Sections 6.2.5 (Combustible Gas Control in Containment), 19.2.3 (Severe Accident Mitigation), Tier 1 Section 2.11.4 (Containment Hydrogen Control System), and the Severe Accident Analysis Report, APR1400-E-P-NR-14003-P, Rev. 0.

Response

a) Based on MAAP analysis on hydrogen distribution, the concentration of hydrogen, oxygen, and steam for all nodes in the selected 5 accident scenarios are shown in Figure 1 through Figure 15. The description of the 5 scenarios is given in Table 1. The nodes whose hydrogen concentration exceeds 10% are found in the figures. As addressed in Section 4.2 of the Severe Accident Analysis Report (APR1400-E-P-NR-14003-P, Rev.0), DDT possibilities are estimated for the nodes with hydrogen exceeding 10% according to the SOAR methodology (Reference 6 of the Severe Accident Analysis Report). DDT indices for all nodes in the 5 accident scenarios are shown in Figure 16. Details of FA and DDT assessments are addressed in Ref. 2 of this response. Ref. 1 and 2 of this response will be placed in the electronic reading room from 15.11.23 to 16.02.22 for the staff’s review.

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Figure 1 Mole Fraction of Hydrogen for LLOCA

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Figure 2 Mole Fraction of Steam for LLOCA

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Figure 3 Mole Fraction of Oxygen for LLOCA

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Figure 4 Mole Fraction of Hydrogen for SLOCA

TS

Figure 5 Mole Fraction of Steam for SLOCA

TS

Figure 6 Mole Fraction of Oxygen for SLOCA

TS

Figure 7 Mole Fraction of Hydrogen for SBO

TS

Figure 8 Mole Fraction of Steam for SBO

TS

Figure 9 Mole Fraction of Oxygen for SBO

TS

Figure 10 Mole Fraction of Hydrogen for TLOFW

TS

Figure 11 Mole Fraction of Steam for TLOFW

TS

Figure 12 Mole Fraction of Oxygen for TLOFW

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Figure 13 Mole Fraction of Hydrogen for MLOCA base case

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Figure 14 Mole Fraction of Steam for MLOCA base case

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Figure 15 Mole Fraction of Oxygen for MLOCA base case

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Figure 16 DDT index for all nodes of each scenario

- Sensitivity analysis

  * MLOCA-H2-AHFSP0-MCCI

  Since the safety case of MLOCA-H2-AHFSP0-MCCI, has similar results to LLOCA-H2-AHFSP0-MCCI, it is described in the appendix of the calculation note, instead of in the calculation body. Details of analysis results are presented below;

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Figure 17 Mole Fraction of Hydrogen for MLOCA-H2-AHFSP0-MCCI

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Figure 18 Mole Fraction of Oxygen for MLOCA-H2-AHFSP0-MCCI

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Figure 19 Mole Fraction of Steam for MLOCA-H2-AHFSP0-MCCI

- Sensetivity Analysis

  * TLOFW-H2-0HFSDP3-MCCI

  The 3-way valve is the device which prevents hydrogen concentration in the IRWST during high pressure scenarios. The MAAP code allows for the modeling of two discharge points for the RCS effluents. The two IRWST compartments, where the RCS effluents are discharged through the spargers, were designated as the two discharge points for the base analysis. Half of the effluent from each RCS line is normally discharged into each of the two IRWST compartments. For the LOFW cases, Nodes 26 and 28 are designated as the two release compartments. However, for the 3-way valve operating case, the upper SG #2 compartment, Node 7, where the discharge nozzle of the 3-way valve is located, was designated as the release compartment, instead of the IRWST compart

  A sensitivity analysis was performed to review the operation time of the 3-way valve. The timing for manual operation of the 3-way valve is 30 minutes after the onset of core damage. The sensetivity case analyzed manual operation of the 3-way valve at 10 minutes after core damage. Details of analysis results are presented below;

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Figure 20 Mole Fraction of Hydrogen for TLOFW-H2-0HFSDP3-MCCI
(3 way valve operated 10 minutes after core)

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Figure 21 Mole Fraction of Oxygen for TLOFW-H2-0HFSDP3-MCCI
(3 way valve operated 10 minutes after core)

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Figure 22 Mole Fraction of Steam for TLOFW-H2-0HFSDP3-MCCI
(3 way valve operated 10 minutes after core)

TS

Table 1 Accident Scenarios Employed in MAAP Analysis

b) The hydrogen generation curve for each scenario is given in Figure 23. The figure shows the hydrogen generation at in-vessel and ex-vessel. The total mass of hydrogen is also illustrated.

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Figure 23 Hydrogen Generation Curve of Each Scenario

c) The hydrogen mitigation system, consisting of passive autocatalytic recombiners (PARs) and hydrogen igniters (HIs), is installed inside the containment building. PARs that are evenly spaced inside the containment building handle accident sequences in which the hydrogen release rate is expected to be low or moderate. Whereas, HIs protect PARs in case of an extremely unlikely accident involving rapidly released hydrogen and function to maintain the containment building's integrity by promoting hydrogen combustion, as they are installed near the hydrogen release points. The hydrogen mitigation system in the APR1400 consists of 30 PARs and 8 igniters whose locations are shown in Table 2. The size and type of each PAR and assumed PAR efficiency employed in MAAP analyses are also addressed. The Framatome-ANP GmbH PAR model was used for hydrogen analysis, and they are assumed to be 25% degraded by cable fire and iodine vapor. For detailed information regarding PAR modeling, the MAAP user manual for the PAR model used is attached as Ref. 3.

Table 2 PARs and Igniters Installed inside Containment. **TS**

d) Accident scenarios with variations of severe accident mitigation features available were used as a basis to cover a wide spectrum of accident conditions, including the representative level-1 PRA sequences with potential significance in-core damage frequencies. The analyzed accident sequences include 5 initiator types with a base case defined for each initiator type. For each initiator type, variations in the availability of accident mitigation systems are made such that their impact, if any, can be observed. The five initiator types are Large/Medium/Small break LOCA, Station Blackout, and Total loss of feedwater. These sequences represent the entire spectrum of severe accident conditions important to hydrogen accumulation and distribution in the containment. A more detailed description for the selection of the accidents in the analysis is given in Section 4.1 and 3.1.2 of Ref. 1of this response.

e) Table 1 illustrates the accident sequences selected in the analysis. Also the tables and description in Section 4.1 of Reference 1 to this response include more details. All 8 HI are assumed to be available. For the SBO and TLOFW case, both three way valves are assumed to be aligned to release the RCS to the SG compartment. Four POSRVs are assumed to be open for TLOFW and tow are assumed to be open for SBO.

References

1. KHNP Calculation note “Hydrogen generation and control during severe accident”, 1-035-N389-101 Rev. 2. 30, Sep. 2014.

2. KHNP Calculation note “Analysis of local DDT potential in the APR1400 containment”, 1-035-N389-103 Rev. 2. 30, Sep. 2014.

3. EPRI, MAAP4.08 User Manual, “Passive Autocatalytic Recombiner of Hydrogen”, Rev.0.3, 05, Feb., 2012.

Impact on DCD

There is no impact on DCD Tier 2, Section 6.2.5.3.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

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Docket No. 52-046

RAI No.:	**155-8167**
SRP Section:	**06.02.05 – Combustible Gas Control in Containment**
Application Section:	**6.2.5**
Date of RAI Issue:	**08/18/2015**

Question No. 06.02.05-2

10 CFR 52.44(c)(1) requires that a standard design certification applicant must ensure a mixed atmosphere in containment during design-basis and significant beyond design-basis accidents. A mixed atmosphere means that the concentration of combustible gases in any part of the containment is below a level that supports combustion or detonation that could cause loss of containment integrity. 10 CFR 52.44(c)(2) requires all non-inerted containments to 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, uniformly distributed, to less than 10 percent (by volume) and maintain containment structural integrity and appropriate accident mitigating features.

Acceptance Criteria 2 of Standard Review Plan (SRP) Section 6.2.5, "Combustible Gas Control in Containment," states that the applicant should demonstrate by analysis, for non-inerted containments, that the design can safely accommodate hydrogen generated by an equivalent of a 100 percent fuel clad-coolant reaction, while limiting containment hydrogen concentration, with the hydrogen uniformly distributed, to less than 10 percent (by volume), and while maintaining containment structural integrity.

KHNP's "Severe Accident Analysis Report," APR1400-E-P-NR-14003-P, Rev.0, provides the hydrogen concentration versus time for 24 hours for each of the five selected scenarios and for all of the 36 nodes in the MAAP4 containment analysis. This report identified certain nodes, such as the reactor cavity and the reactor cavity annulus, whose hydrogen concentration exceeds 10% for a period of time. The potential for deflagration to detonation transition (DDT) exists for any of the nodes where the hydrogen concentration exceeds 10%. Section 4 of the report states that "Evaluations of (1) AICC pressure, (2) hydrogen distribution and (3) potential of DDT for APR 1400 containment have been performed in three separate calculation notes, respectively." In order for the staff to reach a reasonable assurance finding that the mixed atmosphere criteria are met, please identify and provide these three calculation notes for staff review, either on the licensing docket or in the electronic reading room.

Response

Three calculation notes for evaluation of hydrogen distribution (Ref. 1), AICC pressure (Ref. 2), and FA and DDT possibilities (Ref. 3) are given in the electronic reading room.

References

1. KHNP Calculation note “Hydrogen generation and control during severe accident,” 1-035-N389-101 Rev. 2. 30, Sep. 2014.
2. KHNP Calculation note “Assessment of AICC pressure load due to hydrogen combustion in containment,” 1-035-N389-102 Rev. 1, 5, April, 2013.
3. KHNP Calculation note “Analysis of local DDT potential in the APR1400 containment” 1-035-N389-103 Rev. 2. 30, Sep. 2014.

Impact on DCD

There is no impact on DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

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Application Section:	**6.2.5**
Date of RAI Issue:	**08/18/2015**

Question No. 06.02.05-3

10 CFR 52.44(c)(1) requires that a standard design certification applicant must ensure a mixed atmosphere in containment during design-basis and significant beyond design-basis accidents. A mixed atmosphere means that the concentration of combustible gases in any part of the containment is below a level that supports combustion or detonation that could cause loss of containment integrity.

APR1400 Design Control Document (DCD) Tier 2, Section 6.2.5 credits the passive autocatalytic recombiners (PAR) with meeting the above criteria. DCD Tier 2, Table 3.2-1, Tier 2, Section 19.2.3.3.2.1, and Tier 1, Table 2.11.4-1 all describe the PARs and the hydrogen igniters (HI) as being designed to Seismic Category I criteria.

However, in DCD Tier 2, Table 19.1-42, “Seismic Equipment List,” the PARs and the HIs are not described as being designed to Seismic Category I criteria.

Please clarify the seismic design category for the PARs and the His and revise all of the affected DCD text and tables accordingly.

In addition, the following DCD sections and figures contain inconsistencies regarding the location of the PARs with respect to the in-containment refueling water storage tank (IRWST).

- Tier 2, Section 6.2.5.2.1 describes PAR(s) inside the IRWST.
- Tier 2, Table 6.2.5-1 identifies 4 PARs at the IRWST vent stack area.
- Tier 2, Figure 19.2.3-1 and Tables 19.2.3-1 and 19.2.3-2 indicate that 4 PARs are inside the IRWST.
- Tier 2, Figure 6.2.5-1 shows the PARs outside and above the IRWST.

- Tier 2, Section 6.8.2.2.5, “IRWST Pressure Devices,” states “The PARs are located at the vent stack area to prevent an accumulation of hydrogen in the IRWST.”

- Tier 1, Figure 2.11.4-1, “Containment Hydrogen Control System Functional Arrangement”, shows some PARs inside the IRWST.

Please clarify the location of the PARs with respect to the IRWST and revise all the affected DCD text, tables, and figures accordingly.

Response

Hydrogen Igniters (His) are not credited in the seismic margin analysis (SMA) because HIs are supported by non-seismic qualified equipment. However, passive autocatalytic recombiners (PARs) are credited in the SMA, thus it will be added in the Table 19.1-42 as shown in Attachment 1 of this response.

Subsection 6.2.5.2.1, 6.8.2.2.5, Table 6.2.5-1, and Table 19.2.3-1 in DCD Tier 2 will be revised to indicate the PARs are located “inside the IRWST vent stack”, and the PARs location in Figure 2.11.4-1 and Figure 19.2.3-1 will be revised from the IRWST to inside the IRWST vent stack, as indicated in Attachment 2 of this response. In addition, the IRWST vent stack will be added to Figure 6.2.5-1.

Table 19.2.3-2 in DCD Tier 2 does not indicate PAR locations.

Impact on DCD

Table 19.1-42 in DCD 19.1 will be revised to reflect the response of this RAI as shown in the Attachment 1.

In DCD Tier 2, Subsection 6.2.5.2.1and 6.8.2.2.5, Table 6.2.5-1 and 19.2.3-1, Figure 2.11.4-1, 6.2.5-1 and 19.2.3-1 will be revised as indicated in Attachment 2 of this response.

Impact on PRA

There is no impact on the PRA, because it is already considered in the PRA model.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Table 19.1-42 (19 of 19)

No.	Equipment ID	Equipment Description	Floor Elevation	Building
337	1-752-J-PA03B	ESF-CCS Group Controller Cabinet (Ch.BE)	157'	A/B
338	1-752-J-PA03C	ESF-CCS Group Controller Cabinet (Ch.CE)	157'	A/B
339	1-752-J-PA03D	ESF-CCS Group Controller Cabinet (Ch.DE)	157'	A/B
340	1-752-J-PA03A	ESF-CCS Cabinet(A, B, C, D)	157'	A/B
341	1-752-J-PA14B	PPS Cabinet Ch.B-1	157'	A/B
342	1-752-J-PA14C	Plant Protection System Cabinet(C)	157'	A/B
343	1-752-J-PA14D	PPS Cabinet Ch.D-1	157'	A/B
344	1-752-J-PA14A	Plant Protection System Cabinet(A)	157'	A/B
345	1-772-E-SW01C	Reactor Trip Switchgear	137'	A/B
346	1-772-E-SW01A	Reactor Trip Switchgear	137'	A/B
347	1-772-E-SW01D	Reactor Trip Switchgear	137'	A/B
348	1-772-E-SW01B	Reactor Trip Switchgear	137'	A/B
349	1-751-J-PM01	RO Console (Frame)	157'	A/B
350	1-751-J-PM02	TO/EO Console (Frame)	157'	A/B
351	1-751-J-PM03	SS Console (Frame)	157'	A/B
352	1-751-J-PM04	STA Console (Frame)	157'	A/B
353	1-751-J-PM05	Safety Console (Frame)	157'	A/B

Insert "A"

A

No.	Equipment ID	Equipment Description	Floor Elevation	Building
354	1-443-M-HR01A	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
355	1-443-M-HR01B	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
356	1-443-M-HR02A	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
357	1-443-M-HR02B	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
358	1-443-M-HR03A	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
359	1-443-M-HR03B	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
360	1-443-M-HR04A	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
361	1-443-M-HR04B	Large Passive Autocatalytic Recombiner (PAR)	270' 5"	Containment
362	1-443-M-HR05A	Large Passive Autocatalytic Recombiner (PAR)	147'	Containment
363	1-443-M-HR05B	Large Passive Autocatalytic Recombiner (PAR)	147'	Containment
364	1-443-M-HR06A	Large Passive Autocatalytic Recombiner (PAR)	182'	Containment
365	1-443-M-HR06B	Large Passive Autocatalytic Recombiner (PAR)	182'	Containment
366	1-443-M-HR07A	Large Passive Autocatalytic Recombiner (PAR)	185' 3"	Containment

A

No.	Equipment ID	Equipment Description	Floor Elevation	Building
367	1-443-M-HR07B	Large Passive Autocatalytic Recombiner (PAR)	185' 3"	Containment
368	1-443-M-HR08A	Large Passive Autocatalytic Recombiner (PAR)	185' 3"	Containment
369	1-443-M-HR08B	Large Passive Autocatalytic Recombiner (PAR)	185' 3"	Containment
370	1-443-M-HR09A	Medium Passive Autocatalytic Recombiner (PAR)	97'	Containment
371	1-443-M-HR09B	Medium Passive Autocatalytic Recombiner (PAR)	97'	Containment
372	1-443-M-HR10A	Medium Passive Autocatalytic Recombiner (PAR)	97'	Containment
373	1-443-M-HR10B	Medium Passive Autocatalytic Recombiner (PAR)	97'	Containment
374	1-443-M-HR11A	Medium Passive Autocatalytic Recombiner (PAR)	102'	Containment
375	1-443-M-HR11B	Medium Passive Autocatalytic Recombiner (PAR)	102'	Containment
376	1-443-M-HR12A	Medium Passive Autocatalytic Recombiner (PAR)	116'	Containment
377	1-443-M-HR12B	Medium Passive Autocatalytic Recombiner (PAR)	116'	Containment
378	1-443-M-HR13A	Medium Passive Autocatalytic Recombiner (PAR)	138' 6"	Containment
379	1-443-M-HR13B	Medium Passive Autocatalytic Recombiner (PAR)	138' 6"	Containment

A

No.	Equipment ID	Equipment Description	Floor Elevation	Building
380	1-443-M-HR14A	Small Passive Autocatalytic Recombiner (PAR)	120'	Containment
381	1-443-M-HR14B	Small Passive Autocatalytic Recombiner (PAR)	95'	Containment
382	1-443-M-HR15A	Small Passive Autocatalytic Recombiner (PAR)	146'	Containment
383	1-443-M-HR15B	Small Passive Autocatalytic Recombiner (PAR)	194' 6"	Containment

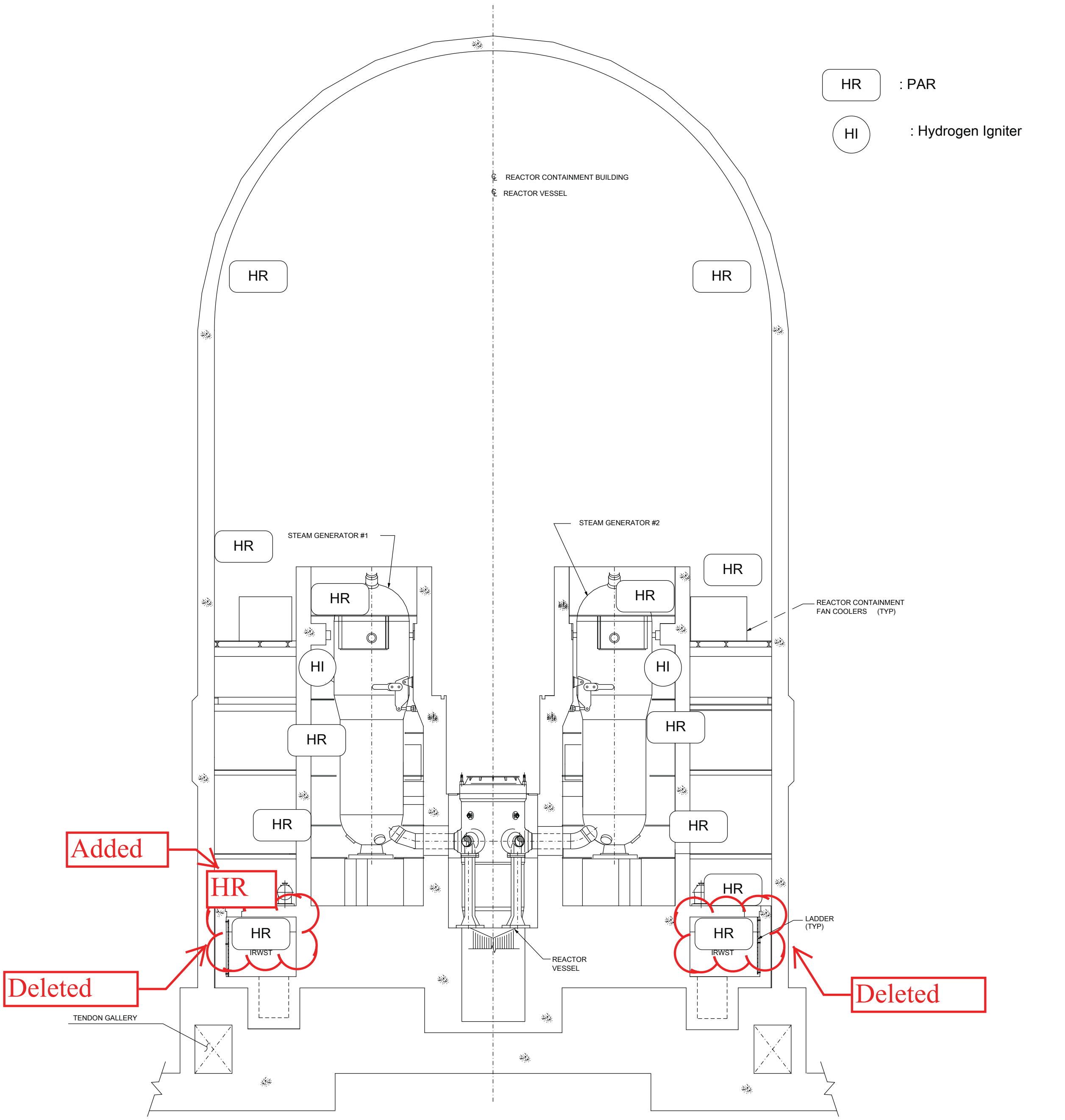


Figure 2.11.4-1 Containment Hydrogen Control System Functional Arrangement

compartments where the hydrogen release rate is greater than the depletion capability of PARs during a certain period of severe accident progression.

The failure modes and effects analyses (FMEA) of containment hydrogen monitoring system (CHMS) are presented in Table 6.2.5-2.

6.2.5.2 System Design

6.2.5.2.1 Provision against Severe Accidents

inside the IRWST vent stack,

The PARs and HIs are designed to control or allow adiabatic controlled burning of hydrogen at fairly low concentrations to preclude hydrogen concentration buildup to detonable levels. The system is designed to prevent the global and local hydrogen concentration in the containment and the IRWST from exceeding 10 percent by volume during a degraded core accident with 100 percent fuel clad metal-water reaction in accordance with 10 CFR 50.44(c). The PARs in the containment and ~~IRWST~~ and the HIs in the containment are installed.

The PAR assemblies consist of structures for device and a stainless steel enclosure in which the catalyst is installed. The enclosure is open on the bottom and top and extends above the catalyst elevation to provide a chimney to yield additional lift to enhance the efficiency and ventilation capability of the device. Cartridge type devices are coated with catalytic material and supported by the enclosure. The function of the bores or spaces inside the cartridge is air pass-through. Covers are installed over the chimney to protect the cartridge from containment spray or stagnant water.

For the PARs, provisions are not required because they can operate automatically and their function can be confirmed by technical performance specification. PARs do not need to be grouped because they work independently.

The HIs are ac-powered glow plugs and are powered directly from a step down transformer. Each HI assembly consists of a thick steel enclosure that contains the transformer and all electrical connections and partially encloses the HI. The enclosure satisfies the U.S. National Electrical Manufacturers Association (NEMA) Type 4 specifications for water-tight integrity under various environmental conditions including exposure to water jets.

The sealed enclosure incorporates a heat shield to minimize the temperature rise inside the HI assembly and a spray shield to reduce water impingement on the glow plug from above. The HI assembly is designed to meet seismic Category I requirements.

Although HI is classified as Non-class 1E, the electrical power for HIs is supplied from the Class 1E bus (Train A or B) with the electrical isolation device in order to enhance the reliability of HIs. At loss of offsite power and failure of the emergency diesel generators to start or run (station blackout), the HIs have the alternative power supply from the alternate alternating current (AAC) generator. During a complete loss of ac power including from the AAC generator, the HIs are powered from the DC battery.

The hydrogen burning by HI or the hydrogen recombination heat is not critical for the survivability of critical plant equipment.

Although the containment is designed to distribute the hydrogen concentration uniformly, the hydrogen mixing is promoted and augmented by PAR operations, and if necessary, the PARs and HIs are positioned in areas where hydrogen release and accumulation are expected during severe accidents.

inside the IRWST vent stack,

The PARs in the containment and ~~IRWST~~ and the HIs in the containment are designed to withstand severe accident conditions. The PARs and HIs provide reasonable assurance that the equipment can perform its identified function during severe accident conditions as described in Section 19.2.

PARs are considered a 15 percent efficiency reduction for iodine vapor and 10 percent efficiency reduction for cable fire. Thus, a total 25 percent efficiency reduction for the PAR was considered for capacity reduction. The HIs include a consideration of the combustion model of the MAAP computer code.

The PARs and HIs are designed to prevent any significant pocketing of hydrogen in order to minimize the potential for localized hydrogen detonation.

The PARs and HIs are able to withstand the effects of their own operations and are designed to provide reasonable assurance that equipment necessary for achieving and maintaining a safe shutdown of the plant and containment integrity are capable of performing their functions during and after their exposure to hydrogen burning.

The PARs and HIs are located throughout the containment open volumes and compartments. The following location criteria are used:

a. Flow path requirements

b. Consideration of enclosed spaces

c. Equipment performance efficiency

d. Installation and maintenance

e. Consideration of dynamic effect

For the surveillance test of PARs, a sample of the PAR cartridges or plates is selected and removed from each PAR. Surveillance bench tests are performed on the removed specimens to confirm continued satisfactory performance. The HIs are capable of attaining the surface temperature that is sufficient for igniting hydrogen gases under any environmental conditions including containment spray actuation. The HI configuration, including possible spray shields, is supported by combustion test data.

Because the PAR is self-actuated and does not need a power supply, operator action for the PAR is not needed. The HIs are actuated by manual actuation in the MCR or RSR on indication that the hydrogen concentration exceeds a predetermined setpoint of volume percent or an indication of the beyond DBA. The HIs are capable of a manual trip. Restart of the system on restoration of power is performed by manual actuation.

The PAR is designed-to provide reasonable assurance that the gas mixture flows into PAR inlets and thus augments the circulation of gas mixture within the containment to eliminate stagnant pockets of air where hydrogen could accumulate.

The PAR ~~in the IRWST~~ inside the IRWST vent stack is provided to remove hydrogen produced by sump radiolysis in the IRWST.

Replace with A

Table 6.2.5-1 (1 of 2)

Location of PARs and HIs

HMS No.	Location	Type	Elevation	Azimuth Angle (°)	Radius	
					m	ft
P1	IRWST vent stack area	Middle	97 ft 0 in	345.7	18.75	61 ft 6 in
P2	IRWST vent stack area	Middle	97 ft 0 in	227.3	19.66	64 ft 6 in
P3	IRWST vent stack area	Middle	97 ft 0 in	53.7	18.72	61 ft 5 in
P4	IRWST vent stack area	Middle	97 ft 0 in	162	18.44	60 ft 6 in
P5	In-core instrument tube chase	Small	120 ft 0 in	62.5	7.11	23 ft 4 in
P6	Cavity upper chamber room	Small	95 ft 0 in	94.9	7.95	26 ft 1 in
P7	Regenerative heat exchanger room	Small	146 ft 0 in	97.5	14.45	47 ft 5 in
P8	Pressurizer compartment	Small	194 ft 6 in	116.1	14.40	47 ft 3 in
P9	Pathway between annular and lower compartments (El. 100 ft)	Middle	102 ft 0 in	36	18.62	61 ft 1 in
P10	Pathway between annular and lower compartments (El. 100 ft)	Middle	102 ft 0 in	210	16.61	54 ft 6 in
P11	Pathway between annular and lower compartments (El. 114 ft)	Middle	116 ft 0 in	9.9	16.61	54 ft 6 in
P12	Pathway between annular and lower compartments (El. 114 ft)	Middle	116 ft 0 in	197.5	16.61	54 ft 6 in
P13	Pathway between annular and lower compartments (El. 136.5 ft)	Middle	138 ft 6 in	100	16.61	54 ft 6 in
P14	Pathway between annular and lower compartments (El. 136.5 ft)	Middle	138 ft 6 in	282.2	16.25	53 ft 4 in
P15	Steam generator room (El. 136.5 ft)	Large	147 ft 0 in	347.5	14.45	47 ft 5 in
P16	Steam generator room (El. 136.5 ft)	Large	147 ft 0 in	170	14.45	47 ft 5 in
P17	Steam generator room (El. 188.0 ft)	Large	182 ft 0 in	24.6	14.45	47 ft 4 in

A

Table 6.2.5-1 (1 of 2)

Location of PARs and HIs

Tag No.	Location	Type	Elevation (ft)	Azimuth Angle (°)	Radius	
					(m)	(ft)
HR-01A	Containment dome area	Large	EL.270'-5"	0.	22.07	72'-5"
HR-01B	Containment dome area	Large	EL.270'-5"	45	22.07	72'-5"
HR-02A	Containment dome area	Large	EL.270'-5"	90	22.07	72'-5"
HR-02B	Containment dome area	Large	EL.270'-5"	135	22.07	72'-5"
HR-03A	Containment dome area	Large	EL.270'-5"	180	22.07	72'-5"
HR-03B	Containment dome area	Large	EL.270'-5"	225	22.07	72'-5"
HR-04A	Containment dome area	Large	EL.270'-5"	270	22.07	72'-5"
HR-04B	Containment dome area	Large	EL.270'-5"	315	22.07	72'-5"
HR-05A	Steam Generator Room (El. 136.5 ft)	Large	EL.147'-0"	347.5	14.45	47'-5"
HR-05B	Steam Generator Room (El. 136.5 ft)	Large	EL.147'-0"	170	14.45	47'-5"
HR-06A	Steam Generator Room (El. 188.0 ft)	Large	EL.182'-0"	24.6	14.45	47'-4"
HR-06B	Steam Generator Room (El. 188.0 ft)	Large	EL.182'-0"	155.4	14.45	47'-4"
HR-07A	Upper compartment	Large	EL.185'-3"	314	22.38	73'-5"
HR-07B	Upper compartment	Large	EL.185'-3"	46	22.38	73'-5"
HR-08A	Upper compartment	Large	EL.185'-3"	134	22.38	73'-5"
HR-08B	Upper compartment	Large	EL.185'-3"	217	22.38	73'-5"
HR-09A*	IRWST Vent Stack Area	Medium	EL.97'-0"	345.7	18.75	61'-6"
HR-09B*	IRWST Vent Stack Area	Medium	EL.97'-0"	227.3	19.66	64'-6"
HR-10A*	IRWST Vent Stack Area	Medium	EL.97'-0"	53.7	18.72	61'-5"
HR-10B*	IRWST Vent Stack Area	Medium	EL.97'-0"	162	18.44	60'-6"
HR-11A	Pathway between annular and lower compartments (El. 100 ft)	Medium	EL.102'-0"	36	18.62	61'-1"
HR-11B	Pathway between annular and lower compartments (El. 100 ft)	Medium	EL.102'-0"	210	16.61	54'-6"
HR-12A	Pathway between annular and lower compartments (El. 114 ft)	Medium	EL.116'-0"	9.9	16.61	54'-6"
HR-12B	Pathway between annular and lower compartments (El. 114 ft)	Medium	EL.116'-0"	197.5	16.61	54'-6"
HR-13A	Pathway between annular and lower compartments (El. 136.5 ft)	Medium	EL.138'-6"	100	16.61	54'-6"
HR-13B	Pathway between annular and lower compartments (El. 136.5 ft)	Medium	EL.138'-6"	282.2	16.25	53'-4"
HR-14A	ICI tube chase	Small	EL.120'-0"	62.5	7.11	23'-4"
HR-14B	Cavity upper chamber room	Small	EL.95'-0"	94.9	7.95	26'-1"
HR-15A	Regenerative heat exchanger room	Small	EL.146'-0"	97.5	14.45	47'-5"
HR-15B	Pressurizer compartment	Small	EL.194'-6"	116.1	14.40	47'-3"

Replace with B

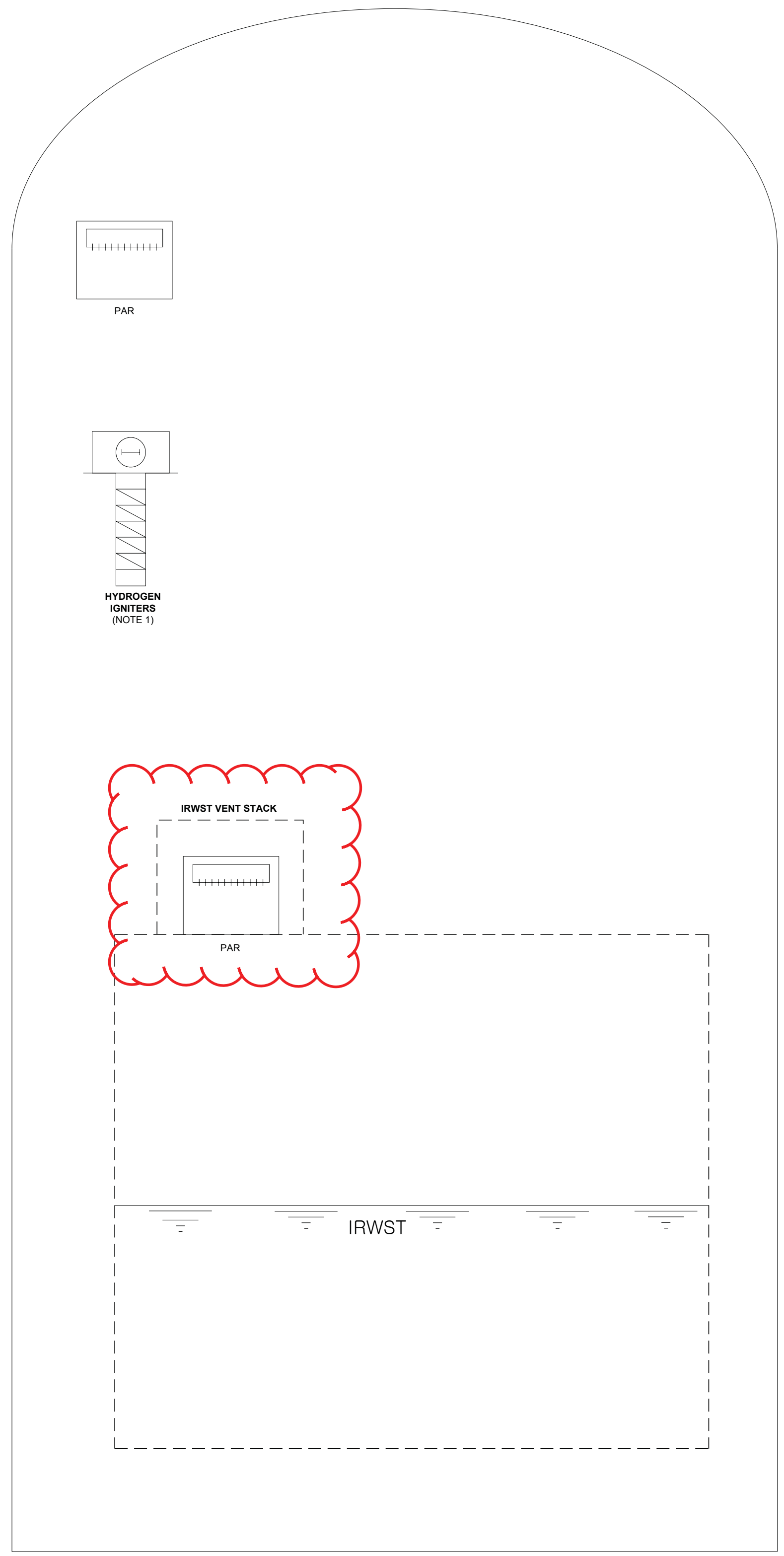
Table 6.2.5-1 (2 of 2)

HMS No.	Location	Type	Elevation (ft)	Azimuth Angle (°)	Radius	
					m	ft
P18	Steam generator room (El. 188.0 ft)	Large	182 ft 0 in	155.4	14.45	47 ft 4 in
P19	Upper compartment	Large	185 ft 3 in	314	22.38	73 ft 5 in
P20	Upper compartment	Large	185 ft 3 in	46	22.38	73 ft 5 in
P21	Upper compartment	Large	185 ft 3 in	134	22.38	73 ft 5 in
P22	Upper compartment	Large	185 ft 3 in	217	22.38	73 ft 5 in
P23	Containment dome area	Large	270 ft 5 in	0.	22.07	72 ft 5 in
P24	Containment dome area	Large	270 ft 5 in	45	22.07	72 ft 5 in
P25	Containment dome area	Large	270 ft 5 in	90	22.07	72 ft 5 in
P26	Containment dome area	Large	270 ft 5 in	135	22.07	72 ft 5 in
P27	Containment dome area	Large	270 ft 5 in	180	22.07	72 ft 5 in
P28	Containment dome area	Large	270 ft 5 in	225	22.07	72 ft 5 in
P29	Containment dome area	Large	270 ft 5 in	270	22.07	72 ft 5 in
P30	Containment dome area	Large	270 ft 5 in	315	22.07	72 ft 5 in
I1	Cavity access area	Glow plug	100 ft 0 in	94	13.00	42 ft 8 in
I2	Steam generator room (El. 156 ft)	Glow plug	163 ft 6 in	345.5	14.94	49 ft
I3	Steam generator room (El. 156 ft)	Glow plug	163 ft 6 in	12.5	14.94	49 ft
I4	Steam generator room (El. 156 ft)	Glow plug	163 ft 6 in	167.5	14.94	49 ft
I5	Steam generator room (El. 156 ft)	Glow plug	163 ft 6 in	194.5	14.94	49 ft
I6	Compartment below regenerative heat exchanger room	Glow plug	119 ft 0 in	104.2	14.94	49 ft 0 in
I7	Pressurizer compartment	Glow plug	153 ft 0 in	137.8	14.65	48 ft 1 in
I8	Pressurizer compartment	Glow plug	153 ft 0 in	116.7	12.88	42 ft 3 in

B

Table 6.2.5-1 (2 of 2)

HI01	Cavity access area	Glow Plug	EL.100’-0”	94	13.00	42’-8”
HI02	Compt. below regenerative HX room	Glow Plug	EL.119’-0”	104.2	14.94	49’-0”
HI03	Pressurizer compartment	Glow Plug	EL.153’-0”	137.8	14.65	48’-1”
HI04	Pressurizer compartment	Glow Plug	EL.153’-0”	116.7	12.88	42’-3”
HI05	Steam generator room (El. 156 ft)	Glow Plug	EL.163’-6”	12.5	14.94	49
HI06	Steam generator room (El. 156 ft)	Glow Plug	EL.163’-6”	167.5	14.94	49
HI07	Steam generator room (El. 156 ft)	Glow Plug	EL.163’-6”	194.5	14.94	49
HI08	Steam generator room (El. 156 ft)	Glow Plug	EL.163’-6”	345.5	14.94	49



NOTES

1. ALL HYDROGEN IGNITERS ARE CONTROLLED BY ONE (1)CONTROL HANDSWICH. THE HYDROGEN IGNITERS FOR SEVERE ACCIDENT HYDROGEN CONTROL ARE POWERED FROM AN ELECTRICALLY ISOLATED DIVISION Ⅱ CLASS 1E POWER BUS. IN THE EVENT OF A LOSS OF DIVISION Ⅱ CLASS 1E POWER BUS, THE HYDROGEN IGNITERS WILL BE POWERED FROM AN ELECTRICALLY ISOLATED DIVISION Ⅰ CLASS 1E POWER BUS.
   IN THE EVENT OF A LOSS OF OFFSITE POWER, THE HYDROGEN IGNITERS WILL BE POWERED FROM THE EMERGENCY DIESEL GENERATOR.
   ON LOSS OF OFFSITE POWER AND FAILURE OF THE EMERGENCY DIESEL GENERATOR TO START OF RUN (STATION BLACKOUT), THE IGNITERS WILL BE POWERED FROM THE AAC DIESEL GENERATOR. DURING THE COMPLETE LOSS OF AC POWER INCLUDING AAC DIESEL GENERATOR, THE HYDROGEN IGNITERS WILL BE POWERED FROM THE DC BATTERY.

Figure 6.2.5-1 Containment Hydrogen Control System

and -0004 are normally closed, and these motor-operated gate valves are in the flow paths that connect the HVT to the reactor cavity. These two groups of valves are designated as the CFS valves. These valves are opened by the operator from the MCR to flood the reactor cavity in the event of a severe accident. Controls are provided to allow the valves to be opened either individually or simultaneously for reactor cavity flooding.

Normally closed motor-operated gate valves are located in the IRWST suction line to the boric acid makeup pumps. These gate valves are opened from the MCR to allow adjustments of the IRWST boron concentration during normal operation or to supply the borated water to the reactor cavity for external reactor vessel cooling operation in a severe accident condition. These valves automatically close upon receiving a containment isolation actuation signal (CIAS).

Local-manual valves are normally locked open gate valves located upstream of the MOVs in each flow path connecting the IRWST to the HVT. These local manual valves are closed during stroke testing of the MOVs to prevent draining the IRWST.

6.8.2.2.5 IRWST Pressure Devices

Protection for overpressure and vacuum of the IRWST is provided by 12 swing panels on the side walls of four vent stacks. The vent stacks are located on the concrete slab at elevation 100 ft, the top of the IRWST. The swing panels are installed on three side walls of each vent stack as pressure relief device (two swing panels for overpressure protection and one swing panel for vacuum protection).

The swing panels are self-actuated by IRWST pressure and provided for hydrogen venting during a severe accident. The panels accommodate the consequences of a design basis accident (DBA) steam release and POSRV actuation, assuming that no cooling of the IRWST is available.

The swing panels provide 13.38 m^2 (144 ft^2) of free vent area for a severe accident with POSRV actuation. The swing panels work with the passive autocatalytic recombiners (PARs) to prevent detonable hydrogen concentrations in the IRWST during a severe accident. The PARs are located ~~at the IRWST vent stack area~~ inside the IRWST vent stack to prevent an accumulation in the IRWST. The hydrogen mitigation system is addressed in Subsection 6.2.5.

Table 19.2.3-1

Hydrogen Control System Design Status

Security-Related Information - Withheld Under 10 CFR 2.390

Security-Related Information - Withheld Under 10 CFR 2.390

Figure 19.2.3-1 Location of PARs and Igniters for APR1400 Containment (1 of 9)

Security-Related Information - Withheld Under 10 CFR 2.390

Figure 19.2.3-1 Location of PARs and Igniters for APR1400 Containment (2 of 9)

Security-Related Information - Withheld Under 10 CFR 2.390

Figure 19.2.3-1 Location of PARs and Igniters for APR1400 Containment (3 of 9)

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**155-8167**
SRP Section:	**06.02.05 – Combustible Gas Control in Containment**
Application Section:	**6.2.5**
Date of RAI Issue:	**08/18/2015**

Question No. 06.02.05-4

PAR recombination rates

10 CFR 52.44(c)(1) requires that a standard design certification applicant must ensure a mixed atmosphere in containment during design-basis and significant beyond design-basis accidents. A mixed atmosphere means that the concentration of combustible gases in any part of the containment is below a level that supports combustion or detonation that could cause loss of containment integrity.

APR1400 Design Control Document (DCD) Tier 2, Section 6.2.5 credits the passive autocatalytic recombiners (PAR) with meeting the above criteria.

However, in DCD Tier 1, Table 2.11.4-1, "Containment Hydrogen Control System ITAAC," there is insufficient information to determine that the containment hydrogen control system design meets the above criteria. In DCD Tier 2, Table 6.2.5-1, "Location of PARs and His," PAR and hydrogen igniters (HI) locations in containment are provided. This information should either be included in Tier 1, Table 2.11.4-1, or a link to Tier 2, Table 6.2.5-1 should be provided in Tier 1, Table 2.11.4-1.

Also, DCD Tier 2, Table 6.2.5-1 describes the PARs as "small, middle, large." The actual PAR recombination rates which form the basis of the hydrogen containment analysis should be provided in the DCD, either:

- Into both Tier 2, Table 6.2.5-1 and Tier 1, Table 2.11.4-1, or
- Into just Tier 2, Table 6.2.5-1 with a link to Tier 2, Table 6.2.5-1 being provided in Tier 1, Table 2.11.4-1.

Please provide the recombination rates of the PARs, and revise all the affected DCD text, tables, and figures accordingly.

Response

The information provided in DCD Tier 2, Table 6.2.5-1, “Location of PARs and HIs” will be referenced in DCD Tier 1, Table 2.11.4-1.

TS

References

1. EPRI, MAAP4.08 User Manual, “Passive Autocatalytic Recombiner of Hydrogen”, Rev.0.3, 05, Feb., 2012.

Impact on DCD

The information provided in DCD Tier 2, Table 6.2.5-1, “Location of PARs and HIs” will be added in DCD Tier 1, Table 2.11.4-1 as indicated in the attachment associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Table 2.11.4-1

(2)

Containment Hydrogen Control System Components List

Component Name	Item No. (1)	Location	ASME Section III Class	Seismic Category	Class 1E/Harsh Envir. Qual.	Display/ Control at MCR	Display/ Control at RSR	Control Signal	Active Safety Function	Loss of Motive Power Position
Passive Autocatalytic Recombiner	HR01A/01B ~ HR15A/15B	Containment	-	I	-/-	-/-	-/-	-	No	-
Hydrogen Igniter	HI01 ~ HI08	Containment	-	I	No/-	Yes/Yes	Yes/Yes	-	No	-

(1) The column "Item No." is information only (not part of certified design).

~~(2)~~ Dash(-) indicates not applicable.

(3)

(2) Locations of PARs and HIs are provided in DCD Tier 2, Table 6.2.5-1.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**155-8167**
SRP Section:	**06.02.05 – Combustible Gas Control in Containment**
Application Section:	**6.2.5**
Date of RAI Issue:	**08/18/2015**

Question No. 06.02.05-5

10 CFR 50.44(c)(4) (ii) Equipment must be provided for monitoring hydrogen in the containment. Equipment for monitoring hydrogen must be functional, reliable, and capable of continuously measuring the concentration of hydrogen in the containment atmosphere following a significant beyond design-basis accident for accident management, including emergency planning. In addition, 10 CFR 52.47(b)(1) requires that a design certification application contain the proposed inspections, tests, analyses, and acceptance criteria (ITAAC) that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification.

Acceptance Criteria 6.B of Standard Review Plan (SRP) Section 6.2.5, “Combustible Gas Control in Containment,” states that combustible gas control system designs should include instrumentation needed to monitor system or component performance under normal and accident conditions. The instrumentation should be capable of determining that a system is performing its intended function, or that a system train or component is malfunctioning and should be isolated. The instrumentation should have readout and alarm capability in the control room and the containment hydrogen and oxygen monitors should meet the provisions of Regulatory Position C.2 of Regulatory Guide (RG) 1.7, “Control of Combustible Gas Concentrations in Containment,” Revision 3.

In APR1400 Design Control Document (DCD) Tier 1, Table 2.11.4-2, there is insufficient information about the identity, capability and location of the instrumentation provided to monitor hydrogen concentration in the containment to determine that the combustible gas control system designs meets the above criteria and guidance. However, only some of this information is provided in Tier 2, Section 6.2.5.2.3. Tier 2, Section 6.2.5.2.3 should be revised to also include specific information regarding the capability of the monitors, including concentration range, pressure range, etc. In addition, all of this information should also be provided in Tier 1, Section 2.11.4, and in Tier 1, Table 2.11.4-3 as an ITAAC item to be satisfied as part of the certified design.

Response

DCD Tier 1, Subsection 2.11.4.1, Table 2.11.4-2, and Table 2.11.4-3 will be revised to include detailed information regarding the identity, measuring range, capability of monitors, and installed location of hydrogen monitoring instrumentation, as shown in Attachment 1 to this response. DCD Tier 2, Subsection 6.2.5.2.2 and 6.2.5.2.3 will also be revised to include specific information regarding the capability of the monitor including measuring range, containment pressure range, power supply, and operation mode change, as shown in Attachment 2 to this response.

Impact on DCD

APR1400 DCD Tier 1, Subsection 2.11.4, Table 2.11.4-2, and Table 2.1.4-3, and Subsections 6.2.5.2.2 and 6.2.5.2.3 of DCD Tier 2, will be revised as indicated in the attachments associated with this response.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.

Monitoring System Instrument List

2.11.4 Containment Hydrogen Control ~~System~~ and Monitoring System

2.11.4.1 Design Description

The hydrogen monitoring system (CHMS) consists of hydrogen analyzer cabinets and monitoring cabinets. Each hydrogen analyzer cabinet includes a hydrogen detector located outside the containment and performs sampling, transmission and measurement of the hydrogen concentration from the air sample extracted from inside the containment and in-containment refueling water storage tank. The monitoring cabinet performs data collection, calculation, and automatic or manual operation of all analyzers.

The containment hydrogen control system (CHCS) CHCS is used to maintain hydrogen gas concentra[tion] precludes an uncontrolled hydrogen and oxyge[n] following beyond design basis accidents.

The CHCS consists of the passive autocatalytic recombiners (PARs) and hydrogen igniters (HIs). The PARs and HIs are designed to control and allow adiabatic controlled burning of hydrogen at fairly low concentration in containment and in-containment refueling water storage tank (IRWST) from exceeding 10 volume percent during a degraded core accident with 100 percent fuel clad metal-water reaction.

To meet above functional requirements, the CHCS ~~is~~ and the CHMS are designed as follows:

1. The functional arrangement of the CHCS is as described in the Design Description of Subsection 2.11.4.1 and in Table 2.11.4-1 and as shown in Figure 2.11.4-1.

2. The seismic Category I components identified in Table 2.11.4-1 withstand seismic design basis loads without loss of safety function.

3. The CHCS provides PARs complemented by HIs to control the containment hydrogen concentration for beyond design basis accidents.

4. The electrical power for HIs is supplied from the Class 1E division. On loss of offsite power and failure of the emergency generator to start or run, the HIs have the alternate power supply from the alternate alternating current (AAC) generator. Also, HIs are powered by battery back-up.

5.a Controls exist in the MCR to start and stop the HIs identified in Table 2.11.4-1.

5.b Controls exist in the RSR to start and stop the HIs identified in Table 2.11.4-1.

5.c ~~Displays and alarms in the MCR exist as defined in Table 2.11.4-1.~~ Displays and alarms for concentration measured by a hydrogen concentration detector of the containment hydrogen monitoring system are provided in the MCR, as defined in Table 2.11.4-2.

5.d ~~Displays and alarms in the RSR exist as defined in Table 2.11.4-1.~~

Displays and alarms for concentration measured by a hydrogen concentration detector of the containment hydrogen monitoring system are provided in the RSR, as defined in Table 2.11.4-2.

2.11.4.2 Inspections, Tests, Analyses, and Acceptance Criteria

The inspections, tests, analyses, and associated acceptance criteria for the containment hydrogen control system are specified in Table 2.11.4-3.

Monitoring System Instrument List

Table 2.11.4-2

Containment Hydrogen Control System

Tag

AE

Display & Alarm at MCR/RSR/Local

Range

Instrument Name	Item No. [1]	Location	ASME Section III Class	Seismic Category	Class 1E/Harsh Envir. Qual.	Display/Alarm at MCR	Display/Alarm at RSR
Containment Hydrogen Concentration	A-005,007	Containment Building	-	I	Yes/Yes	Yes/Yes	Yes/Yes
IRWST Hydrogen Concentration	A-006,008	Containment Building	-	I	Yes/Yes	Yes/Yes	Yes/Yes

(1) The column "Item No." is information only (not part of certified design).

(2) Dash(-) indicates not applicable

Containment Building 229'-0", AZ. 330° and 215°, respectively

Containment Building 96'-9", AZ. 27° and 215°, respectively

0~15 % Volume

Yes/Yes/Yes

Insert

Pressure Range
(-) 0.352 kg/cm^{2}G ~ Maximum Containment Design Pressure
(-) 0.352 kg/cm^{2}G ~ Maximum Containment Design Pressure

Table 2.11.4-3 (2 of 2)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
4. The electrical power for HIs is supplied from the Class 1E division. On loss of offsite power and failure of the emergency diesel generator to start or run, the HIs have the alternate power supply from the alternate alternating current (AAC) generator. Also, HIs are powered by battery back-up.	4. Tests will be performed on the as-built HIs.	4. The as-built HIs listed in Table 2.11.4-1 are powered from class 1E division, the emergency diesel generator, the AAC generator, and DC battery.
5.a Controls exist in the MCR to start and stop the HIs identified in Table 2.11.4-1.	5.a Tests will be performed using the controls in the MCR.	5.a Controls in the as-built MCR start and stop the hydrogen igniters listed in Table 2.11.4-1.
5.b Controls exist in the RSR to start and stop the HIs identified in Table 2.11.4-1.	5.b Tests will be performed using the controls in the RSR.	5.b Controls in the as-built RSR start and stop the hydrogen igniters listed in Table 2.11.4-1.
5.c ~~Displays and alarms in the MCR exist as defined in Table 2.11.4-2.~~	5.c Inspections will be performed on the displays and alarms in the MCR.	5.c Displays and alarms exist and are retrieved in the MCR as defined in Tables 2.11.4-2.
5.d ~~Displays and alarms in the RSR exist as defined in Tables 2.11.4-2.~~	5.d Inspections will be performed on the displays and alarms in the RSR.	5.d Displays and alarms exist and are retrieved in the RSR as defined in Table 2.11.4-2.

Displays and alarms for concentration measured by a hydrogen concentration detector of the containment hydrogen monitoring system are provided in the MCR, as defined in Table 2.11.4-2.

Displays and alarms for concentration measured by a hydrogen concentration detector of the containment hydrogen monitoring system are provided in the RSR, as defined in Table 2.11.4-2.

6.2.5.2.2 Containment Hydrogen Monitoring System

The CHMS independent of the hydrogen recombiners, performs continuous ~~hydrogen~~ monitoring ~~inside containment~~ ~~for a severe accident.~~ Hydrogen monitoring system is a redundant seismic Category I system and consists of hydrogen analyzer cabinets and monitoring cabinets. A failure of one train does not prevent continuous monitoring of the hydrogen concentration. The hydrogen analyzer cabinet performs sampling, transmission and measurement of the sample. The monitoring cabinet performs data collection, calculation and automatic or manual operation of all analyzers. The monitoring system draws samples from two separate locations through dedicated penetrations (one sample location per division).

of hydrogen concentration from air samples extracted from inside the containment and the in-containment refueling water storage tank.

Deleted

The sample lines of this on-line monitoring system are provided with heat tracing to prevent dew condensation and are purged before sampling to ensure that sample are representative. The purge gas is routed back to the containment atmosphere.

Continuous post-accident indication of containment hydrogen concentration is provided in the control room through redundant safety indicators that report the percentage of hydrogen by volume in the containment. Radioactive gas is drawn from the containment by means of a sample pump, into the analysis unit where the sample temperature is lowered. After the gas passed through the measuring cell, it is returned to the containment through a pressure regulating network, which maintains pressure above containment pressure to provide reasonable assurance of the return of the sample gas.

and in-containment refueling water storage tank hydrogen concentration

The containment isolation valves of hydrogen monitoring system are opened or closed manually by soft control in the MCR. The containment hydrogen monitor located outside of the containment analyzes ~~the hydrogen concentration in containment air and continuously indicates hydrogen concentration in the MCR.~~

and continuously indicates the hydrogen concentration in the MCR.

The hydrogen concentration of the sample gas is analyzed using a thermal conductivity measurement cell by making the containment air sample flow through the measurement cell. The actual wet hydrogen concentration is calculated based on containment pressure and temperature measurement, and the measure value using established gas law equations.

The CHMS is fully operable within thirty (30) minutes of the initiation of safety injection or after switching from the standby mode to analysis mode. Mode switching is accomplished through a hand switch mounted on the hydrogen monitoring cabinet.

The two independent divisions of the CHMS are powered from each train of Class 1E 120 Vac, 480 Vac, and 125 Vdc power sources which are backed up by the Class 1E EDG.

MCR and RSR

The alarm for high hydrogen are annunciated in the MCR and RSR when the hydrogen concentration exceeds a volumetric concentration of 2.0 percent.

6.2.5.2.3 Alarm and Indication

The continuous indication of hydrogen concentration of containment air is provided in the ~~MCR~~ through redundant measurement channels. The channels are designed to measure ~~0~30~~ percent volume of hydrogen in a pressure range of -0.352 kg/cm^{2}G (-5 psig) to the maximum containment design pressure.

0~15

and in-containment refueling water storage tank

6.2.5.2.4 Design Features for Minimization of Contamination

The containment hydrogen control system and the containment monitoring system (CM) are designed with features that meet the requirements of 10 CFR 20.1406 (Reference 32) and NRC RG 4.21 (Reference 33). The basic principles of NRC RG 4.21 and the methods of control suggested in the regulations are delineated in four design objectives and two operational objectives and are discussed in Subsection 12.4.2.

The compliance of the containment hydrogen control system and the containment monitoring system with NRC RG 4.21 (Reference 33) is described in the Subsections 6.2.5.2.4.1 and 6.2.5.2.4.2.

6.2.5.2.4.1 Containment Hydrogen Control System

The containment hydrogen control system is designed to provide control of the combustible gases, mainly hydrogen, inside the containment and the IRWST, to within the acceptable limits through the use of the PARs and HIs located at various locations inside the containment and the use of PARs inside the IRWST. The PARs and HIs are designed to control the hydrogen by hydrogen recombination and hydrogen burning, respectively. There is no piping associated with the PARs and HIs, and the system has no interfaces with non-contaminated systems except electrical power. The containment hydrogen control system is designed to be on standby mode during normal operation. Hence, the containment hydrogen control system provides a low potential to contaminate other areas, facility systems, and the environment during normal operation including anticipated operational occurrences. This design is in conformance with the requirements of NRC RG 4.21.