REVISED 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.:	**541-8724**
SRP Section:	**06.02.05 – Combustible Gas Control in Containment**
Application Section:	**6.2.5**
Date of RAI Issue:	**02/21/2017**

Question No. 06.02.05-12

This is a follow up question to KHNP's response to RAI 155-8167, Question 6.2.5-4, regarding passive autocatalytic recombiner (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.

The response stated that the equation for the recombination rate for the large (FR1-1500) PARs has the two coefficients, A and B. The staff's review indicates that these coefficients, A and B, should be larger. These coefficients were deduced by comparing the recombination rate that is predicted by the formula to the performance specifications published for an AREVA PAR.

KHNP's response to RAI 472-8564, Question 6.2.5-11, confirmed the larger coefficients above were used by KHNP in their analyses. This is in agreement with the coefficients used in staff's MELCOR confirmatory calculation.

In the original RAI 155-8167, question 6.2.5-4, staff also requested the following:

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 three sizes of PARs which establish the capacity of the containment hydrogen control system.

Response – Rev.1

The reference data for hydrogen depletion rates by PAR size are provided in the table below. They will be added to DCD Tier 2 as Table 6.2.5-3.

Reference data of hydrogen depletion rate by PAR size

Condition / Size	Hydrogen 4 v/o (percent by volume)	Hydrogen 8 v/o (percent by volume)
Small	0.9 kg/hr	1.8 kg/hr
Medium	1.8 kg/hr	3.6 kg/hr
Large	4.0 kg/hr	8.0 kg/hr

The hydrogen depletion rates are based on the hydrogen depletion equation from the MAAP manual. The initial condition is of 1.5 bar at 60^{o}C.

In addition, a link to Tier 2, Table 6.2.5-1 in Tier 1, Table 2.11.4-1 (regarding the location of PARs and HIs provided in response to RAI 155-8167, question 6.2.5-4) will be deleted. The PARs and HIs locations will be provided in Tier 1 Table 2.11.4-1 at the qualitative level. The PAR depletion rates will not be provided in Tier 1. The depletion rates are derived from proprietary data and are not appropriate for Tier 1. The hydrogen depletion rates are determined to meet or exceed RG 1.7 criteria of a hydrogen concentration of 10 percent, (by volume), in the containment and IRWST, as discussed in DCD Tier 1 Section 2.11.4.1 and Table 2.11.4-3.

DCD Tier 1 Table 2.11.4-1 will be revised to address the hydrogen depletion rates and location criteria. DCD Tier 1 DCD Table 2.11.4-3 will be revised to address the location and performance criteria. Tier 2 Table 14.3.4-2 will be revised to address the PAR and HI locations.

Impact on DCD

DCD Tier 2, Subsections 6.2.5.2.1 and 6.2.8 and Table 14.3.4-2 will be revised and Table 6.2.5-3 will be added as indicated in Attachment 1.

DCD Tier 1, Tables 2.11.4-1 and 2.11.4-3 will be revised as indicated in the Attachment 2.

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.

The PARs in the containment and inside the IRWST vent stack, 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 CS actuation. The HI configuration, including possible spray shields, is supported by combustion test data.

~~The performance criteria for depletion rates of PARs is provided in Table 6.2.5-3.~~

The reference data of hydrogen depletion rate by PAR size for PAR surveillance test is provided in Table 6.2.5-3. The reference data is based on the hydrogen depletion equation from MAAP manual (Reference 43) and the initial condition is of 1.5 bar and 60°C.

39. ASME Section III, Division 1, Article NE 2300, “Fracture Toughness Requirements for Material,” The American Society of Mechanical Engineers.

40. NUREG-0800, Section 6.2.1.2, “Subcompartment Analysis,” Rev. 3, U.S. Nuclear Regulatory Commission, March 2007.

41. NRC RG 1.141, “Containment Isolation Provisions for Fluid Systems.”

42. APR1400-E-P-NR-14003-P(Proprietary)&NP(Non-Proprietary) “Severe Accident Analysis Report,” Rev. 1 KHNP, February 2017.

43. FAI/12-0005, "MAAP 4.0.8 Transmittal Document," Electric Power Research Institute, February 2012.

Table 6.2.5-2 (6 of 6)

Name/Valve No.	Potential Failure Mode	Plant Condition	Symptoms and Local Effect Including Dependent Failure	Method of Detection	Inherent Compensating Provision	Remarks and Other Effects
6. Channel B containment monitor discharge to containment CM-010	a) Fails to open on demand	Detection of hydrogen in containment building	• No safety-related impact on plant • Isolation is achieved by redundant valve	Valve information: • Valve position indication in MCR	Isolation is achieved by redundant containment isolation valve (CM-009)	• Normally closed • Fail closed
	b) Fails to close on demand	• Loss of electrical power • Receipt of high containment pressure signal • Receipt of low pressurizer pressure signal	• No safety-related impact on plant • H_2 monitoring line is formed in the closed loop		H_2 monitoring line is formed in the closed loop	

← add Table 6.2.5-3 in next page

Reference Data for Hydrogen Depletion Rate by PAR Size

Table 6.2.5-3

~~Performance criteria for depletion rate of PARs~~

Condition / Size	Hydrogen concentration 4 v/o (percent by volume)	Hydrogen concentration ~~8%~~ 8 v/o (percent by volume)
Small	0.9 kg/hr	1.8 kg/hr
Medium	1.8 kg/hr	~~3.57~~ 3.6 kg/hr
Large	~~4.04~~ 4.0 kg/hr	~~8.04~~ 8.0 kg/hr

1) This PAR performance criteria uses PAR depletion rate equation from MAAP manual (Reference 43)

2) Performance criteria is hydrogen depletion rate at 1.5 bar, 60oC condition, and it also considers the 25%degradation in PAR performance.

Table 14.3.4-2 (7 of 7)

Item #	Tier 1 Reference	Design Features	Tier 2 Reference
2-47	2.11.4 Design Description ITAAC #3	The containment hydrogen control system (CHCS) is non-safety-related system. The CHCS is used to maintain hydrogen gas concentration in containment at a level that precludes an uncontrolled hydrogen and oxygen recombination within containment 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.	6.2.5 19.1.3 19.2.3
2-48	2.11.4 ITAAC #3	The CHCS provides PARs complemented by HIs to control the containment hydrogen concentration for beyond-design-basis accidents.	6.2.5 19.1.3 19.2.3
2-49	2.11.4 ITAAC #3.a	At least 30 PARs and 8 hydrogen igniters are provided inside containment.	6.2.5 19.2.3
2-50	3.2 a.	The UHS provides the capability to reject the heat under normal and accident conditions (safe shutdown or post-accident) assuming a single active failure concurrent with a loss of offsite power.	9.2.5 19.1.3
2-53	2.11.4 ITAAC #3.b	A report exists and concludes that the hydrogen depletion rates for each installed PAR and HI will maintain containment hydrogen concentration of less than or equal to 10 percent by volume.	6.2.5 19.2.3

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Table 2.11.4-1

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Containment Hydrogen Control System Components List

Component Name	Item No.	Location(1)	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	-
Containment Temperature Element	CM-TE-031A	Containment	-	I	Yes/Yes	Yes/No	Yes/No	-	No	-

(1) ~~Location of PARs and His are provided in DCD Tier 2, Table 6.2.5-1~~

Deleted

(2) Dash (-) indicates not applicable.

Table 2.11.4-1

Containment Hydrogen Control System Components List

Component Name	Item No.	General 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
Large PAR	HR01A/01B ~ HR04A/04B	Containment Dome Area	-	I	-/-	-/-	-/-	-	No	-
	HR05A/05B ~ HR06A/06B	Steam Generator Compartment								
	HR07A/07B ~ HR08A/08B	Upper Compartment								
Medium PAR	HR09A/09B ~ HR10A/10B	Inside IRWST								
	HR11A/11B ~ HR13A/13B	Lower Compartment								
Small PAR	HR14A/14B	Reactor Detector Tube Compartment, Cavity Region								
	HR15A/15B	Regenerative heat exchanger and Pressurizer compartment								
Hydrogen Igniter	HI01	Cavity access area	-	I	No/-	Yes/Yes	Yes/Yes	-	No	-
	HI02	Regenerative heat exchanger Room								
	HI03~HI04	Pressurizer Compartment								
	HI05~HI08	Steam Generator Compartment								
Containment Temperature Element	CM-TE-031A	Containment	-	I	Yes/Yes	Yes/No	Yes/No	-	No	-

(1) Dash (-) indicates not applicable.

Table 2.11.4-3 (1 of 2)

Containment Hydrogen Control System ITAAC

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
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.	1. Inspection of the as-built CHCS will be conducted. and their general location,as described in Table 2.11.4-1,	1. The as-built CHCS conforms with the functional arrangement 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.	2. Inspections will be performed to verify that the as-built seismic Category I components are located in the seismic Category I structure.	2. The as-built seismic Category I components identified in Table 2.11.4-1 are located in a seismic Category I structure.
3. The CHCS provides PARs complemented by HIs to control the containment hydrogen concentration for beyond design basis accidents.	3.a Inspection for the number of PARs and hydrogen igniters will be performed.	3.a At least thirty PARs and eight hydrogen igniters are provided inside containment.
	3.b Operability testing will be performed on the PARs and hydrogen igniters. A report exists and concludes that the hydrogen depletion rates for each installed PAR and HI will maintain containment hydrogen concentration of less than or equal to 10 percent by volume.	3.b ~~A report exists and concludes that the PAR depletion rate for each installed PAR is equal to or greater than that of predetermined PAR hydrogen depletion capacity.~~ For hydrogen igniters, the surface temperature exceeds 1,700 °F
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.