Status of PAR Installation in Korean NPPs and Experiences in Regulatory Activities

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1. Introduction

Following TMI-2 and Chernobyl accidents, concerns on the safety problems of nuclear power plants (NPPs) have been increased, especially for severe accident phenomena including hydrogen risk. To reduce the potential of hydrogen combustion, much of international efforts have been made for decades and it resulted in development of an innovative device, i.e. passive autocatalytic recombiner (PAR), for hydrogen removal in containment during an accident. On the designing and implementing a PAR, Bachellerie et al. [1] provided a good instruction. Actually not only most new NPP designs but also NPPs to be refurbished are considering the installation of PARs for hydrogen control following a design basis accident (DBA) and severe accident (SA). For some Korean NPPs, the utility, KHNP, also has decided to equip PARs in containment and KINS has performed relevant regulatory reviews and preoperational inspections.

In this paper, the status of PAR installation in Korean NPPs and KINS' experiences in regulatory activities including onsite findings as well as some recommendations, are described.

2. Status of PAR Installation

All Korean new NPPs such as OPR1000 and APR1400 were designed to install PARs as the countermeasure against hydrogen risk during DBAs and/or SAs. Refurbished NPP such as Kori-1 Unit is in operation with PARs in its containment and Wolsong-1 Unit also has a plan to install PARs. Among them, the OPR1000 NPPs under construction and Kori-1 unit each had decided the PAR designs (AREVA and AECL PARs) and other NPPs are to be in progress. Table 1 summarizes the status of PAR installation of Korean NPPs.

3. PAR Designs in Korean NPPs

3.1 OPR1000 NPPs

AREVA PAR is to be installed in OPR1000 NPPs (four units) for DBA hydrogen control, which is shown in Fig. 1. There are several commercial models based on their hydrogen removal capacities and FR1-380T and FR1-750T models are to be installed in OPR1000 NPPs as small and medium PAR, respectively. There is difference in the number of catalyst plates and the cabinet size differs from each other, which is proportional to the number of plates.

3.2 Kori-1 Unit

AECL PAR was installed in Kori-1 Unit to deal with hydrogen risk during SA as well as DBA. There are two kinds of modules, PAR1 and PAR2, by the hydrogen removal capacity and they are distinguished by the number of catalyst plates, while the size of cabinet is the same. A picture taken after the installation in Kori-1 Unit is also shown in Fig. 1.

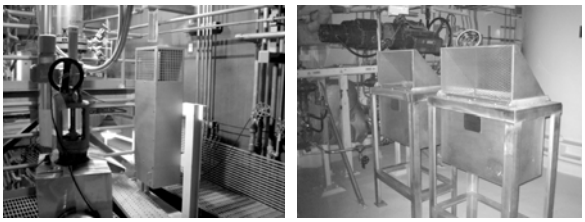

Fig. 1. PARs installed in Shin-Kori-1(left, AREVA, small) and in Kori-1 (right, AECL, medium). Medium size PAR for AECL in Kori-1 consists of two PAR modules.

4. Regulatory Experiences

4.1 Regulatory Reviews

Regulatory reviews on PAR as combustible gas control system for DBA and hydrogen mitigation system for SA for several NPP units have been conducted by KINS. These activities include regulatory reviews in the construction permit (CP) stage for OPR1000 and APR1400 NPPs and of the life extension

Table 1. Status of PAR installation in Korean NPPs.

Unit	Reactor type	Status	Manufacturer	Number of PAR[1]		Remark
				DBA	SA	
Shin-Kori-1/2	OPR1000	installed[2]	AREVA	6	-	new NPP
Shin-Kori-3/4	APR1400	planed	to be decided	12	18	new NPP
Shin-Wolsong-1/2	OPR1000	planed	AREVA	6	-	new NPP
Shin-Ulchin-1/2	APR1400	planed	to be decided	12	18	new NPP
Kori-1	W-type PWR	installed	AECL	4	14	life extension
Wolsong-1	CANDU	planed	to be decided	to be decided	to be decided	life extension planed

1) The number exactly means the number of location where PAR installed. For OPR1000 plants, PARs consist in 2-medium and 4-small AREVA modules. For Kori-1 Units, there are 6-large, 4-medium and 8-small AECL PARs. For Wolsong-1 Unit, the details of PAR design is under consideration.
2) Shin-Kori-2 Unit is now in preoperational test stage and PARs will be installed soon.

for Kori-1 Unit. For Wolsong-1 Unit, the related application has been submitted recently and now the review process is ongoing. Up to now, KINS' experience for the detailed reviews of specific PAR designs includes Shin-Kori-1/2 (AREVA PAR) and Kori-1 (AECL PAR) Units.

In each review stage, the appropriateness of quality class, correlation of hydrogen removal rate, adverse effect test results, minimum hydrogen concentrations for initiation and end of catalytic reaction, factory acceptance test (FAT) results and etc., have been investigated. In this process, the applicant also provided the operation procedures containing the methods for in-service test and inspection, test interval and each PAR location.

The reviews confirmed that the both PAR designs were properly designed in terms of their safety function.

4.2 Onsite Inspections

Onsite inspection consisted of the verification of physical installation condition as well as each location and the observation on the performance testing for hydrogen removal of catalytic plates.

Physical condition of each installed PAR unit was acceptable. The location of PARs was also generally suitable as submitted in review process. For several PARs, however, it was found that there might be some problems in the accessibility for testing and maintenance during the reactor outage time. Fig. 2 shows the examples of such PARs. For Shin-Kori-1 Unit two PARs located high level in containment can be approached only by using containment polar crane. In Kori-1 Unit such PARs can be reached for only with temporary structures such as a ladder or scaffolding. Although the locations are appropriate based upon the accident analyses, careful management on the testing might be needed for the protection of workers as well as the guarantee of testability. During the preoperational inspection for PAR system of Kori-1 Unit, these findings were discussed between inspectors and managers of the plant to provide a follow-up measures.

Though the general PAR performance has also been verified in various research projects such as OECD/NEA THAI Project [2], the preoperational onsite PAR performance testing for the catalytic plates has been conducted in each NPP and it has been shown that the actual hydrogen removal rate is guaranteed as suggested in review process. Acceptance criteria were decided following those described in the surveillance test requirements in technical specification (TS) of each plant in consistent with the manufacturer's specification. The specific parameters measured in testing and the requirements compared in Table 2, may differ from each PAR design based on the manufacturer's technologies.

Fig. 2. PARs installed high level in Shin-Kori-1 and in Kori-1 containments. Caution should be used for the access.

Table 2. PAR testing information.

	Shin-Kori-1/2	Kori-1
PAR Design	AREVA	AECL
Test Device	TIIE (transportable in-service inspection equipment)	WPT (whole plate tester)
Source	3vol.%-H_2 (N_2 balance)	2vol.%-H_2 (N_2 balance)
Accept. Criteria (TS & procedures)	$C(H_2)_{out} \leq 0.75 \cdot C(H_2)_{in}$ within 15 min, $C(H_2)_{out,final} \leq 0.5$vol.%	$\Delta T_{plate} \geq 25$℃ within 30 sec, or $\Delta T_{plate} \geq 43$℃ within 60 sec

4.3 Revision of Inspection Guides

Installation of PARs in new and refurbished NPPs also needs to revise the KINS' preoperational and periodic inspection guides. Existing guides deal with only the thermal hydrogen recombiner, which is used in most current operating plants. A draft of preoperational inspection guide was recently provided and will be confirmed via official review process, while periodic inspection guides will be established.

5. Conclusions

PAR-system has been successfully installed and tested so far for Shin-Kori-1 and Kori-1 Units, and several new plants in Korea are considering the PAR for combustible gas control. Since the performance of PAR controlling hydrogen following accidents even under the adverse environmental conditions, has been verified through various research projects, PAR installation seems to be a good practice against hydrogen risk and is coincidental with the international trend.

KINS has appropriately performed the relevant regulatory activities including licensing reviews and onsite inspections. From the viewpoint of the accessibility to each PAR, some discussions on the periodic maintenance and testing including the protection of workers have to be taken. Also it is recommended that a long-term plan for installing PARs in all operating NPPs be established in consideration of the ageing of current thermal recombiner systems.

REFERENCES

[1] E. Bachellerie *et al*., Generic Approach for Designing and Implementing a Passive Autocatalytic Recombiner PAR-System in Nuclear Power Plant Containments, *Nucl. Eng. Des.*, 221, pp.151-165, 2003.

[2] NEA/CSNI/R(2010)3, OECD/NEA THAI Project: Hydrogen and Fission Product Issues Relevant for Containment Safety Assessment under Severe Accident Conditions, Final Report, June 2010.