Development Status of Full System Decontamination Technology by Reactor Types

Hak-Soo Kim*, Cho-Rong Kim
KHNP Central Research Institute, 70, 1312-gil, Yuseong-daero, Yuseong-gu, Daejeon, Korea, 34101
**Corresponding author:hskim0071@khnp.co.kr*

1. Introduction

KHNP prepared the technology development roadmap for PWR decommissioning as the design life of the NPPs operating in domestic reached [1, 2]. The main goal of this roadmap is to completely secure NPP decommissioning technology by 2022. However, after KHNP Board decided to permanently shut down Kori-1 NPP on June 16, 2015, the technology development roadmap was revised to secure commercial technologies for Kori-1 decommissioning. In the revised roadmap [3], 17 decommissioning technologies that have not yet been secured among the commercial technologies required for PWR decommissioning have been identified and one of these, the research for securing full system decontamination technology was completed at the end of September 2018. Through this study, the system decontamination process, CRI_RWDecom (Chemical Reagent Injection and RadWaste Decomposition& Treatment), and the basic design of commercial facility, CIDF (Chemical Injection and Decomposition& Treatment Facility), for the full system decontamination have been completed. The research for the detailed design and manufacturing of the system decontamination commercial facility was launched in October 2019.

Wolsong-1 NPP, the first PHWR in domestic, started construction in May 1977 and began commercial operation on 22 April, 1983. Its 30-year operating license expired in 2012. Prior to the expiration of Wolsong-1 NPP operation license, KHNP's application for the 10-year life extension until November 2022 was approved by the regulator. But KHNP Board decided to permanently cease Wolsong-1 NPP on 15 June, 2018. KHNP plans to prepare the technology development roadmap for PHWR decommissioning and was started a research to secure the full system decontamination technology for PHWRs including Wolsong-1 based on the CRI_RWDecom in April 2019.

This paper describes the major characteristics of full system decontamination process, CRI_RWDecom, developed for PWRs and outlines the research plan for development of full system decontamination technology for PHWRs.

2. Full system decontamination process for PWRs

This process is an organic acid-based system decontamination process and basically consists of oxidation, reduction, decomposition & treatment and purification process. In oxidation process, chromium metal ions in oxide films are removed by using permanganic acid as an oxidizing agent. The concentration of oxidizing agent is lower than that of a competitive technology. In order to elute the chromium ions in oxide film, pH should be maintained at about 2 to 3. For this, pH adjuster is used to compensate for pH value resulting from lowering the permanganic acid concentration. In reduction process, iron and nickel metal ions in oxide film are removed by using oxalic acid as a reducing agent. The concentration of reducing agent is almost the same as that of a competitive technology. Decomposition & treatment process removes the suspended particles and metal ions in the chemical decontamination liquid waste and decomposes the oxalic acid to recycle it as the system decontamination process water. In this process, the H_2O_2 is used to improve the oxalic acid decomposition performance. Purification process removes the residual metal ions in chemical waste which is decomposed and treated in decomposition & treatment process. The characteristics of CRI_RWDecom are shown in Table I.

Table I: Characteristics of CRI_RWDecom Process

Technology	Competitive Technology	CRI_RWDecom
Oxidizing Agent (Concentration)	$HMnO_4$ (300 ppm)	$HMnO_4$ (200 ppm)
pH Adjuster (Concentration)	-	A* (Equivalent with $HMnO_4$)
Reducing Agent (Concentration)	$H_2C_2O_4$ (2,000 ppm)	$H_2C_2O_4$ (2,000 ppm)
UV Lamp Type	UVB	UVC

* indicates pH adjuster

3. Research plan for development of PHWR full system decontamination technology

In PWRs decommissioning, various full system decontamination technologies have been developed and implemented worldwide. However, it is known that there is no full system decontamination for PHWR decommissioning. The deposit parameters and compounds of oxide film deposited in piping and systems of PHWRs are somewhat different from PWRs as shown in Table II and III [4]. Therefore, it seems to be a limitation in applying the full system

decontamination technology used in PWRs to PHWRs. In the full system decontamination process for PWRs, considering the characteristics of the oxide film, an oxidation process is performed to remove the chromium ion and then a reduction process is performed to remove iron and nickel ions present in the oxide film.

Table II: Typical Deposit Parameters for PHWs and PHWRs

Reactor Type		Deposit Thickness, μm	Deposit Density, g/㎤	Specific Weight, mg/㎠
PWR	Piping	3	4	1.2
	SG	2	4	0.8
PHWR	Piping	75	4	30
	SG	25	4	10

Table III: Principal Compounds in Oxide Films in PWRs and PHWRs

Reactor Type	Inner Layer	Outer Layer
PWR	Cr_2O_3 $Ni_xFe_{1-x}OFe_yCr_{2-y}O_3$	$NiOFe_2O_3$ Fe_3O_4
PHWR	Fe_3O_4	Fe_3O_4 $NiOFe_2O_3$

Unlike PWRs, some piping and systems of PHWRs are mainly composed of carbon steel. In the case of adapting the oxidation process in these systems and piping, the permanganic acid is decomposed by iron and cannot remove chromium ions. To overcome the limit of system decontamination process and maximize the decontamination effect of the Wolsong-1 NPP, it is necessary to establish the optimal system decontamination process by evaluating the decontamination technologies according to the PHWR system and pipe materials, and develop the conceptual design and operation procedures for system decontamination. The research project was started in April 2019. Experimental equipment that was used to develop PWR full system decontamination process will be used to develop the PHWR full system decontamination process. Figure 1 shows the experimental equipment.

Fig. 1. Experimental equipment for system decontamination process development

The major objectives for each year of this project are as follows.

- 1st year
  - Establishment of simulated specimen manufacturing method
  - Evaluation of characteristics by system decontamination range
- 2nd year
  - Selection of chemical decontamination process by PHWR materials and chemicals
  - Selection of system decontamination range and establishment of operation control methods
- 3rd year
  - Process development of optimum system decontamination and chemical waste decomposition & treatment
  - Development of conceptual design and operation procedures

4. Future plan

KHNP plans to develop the PHWR decommissioning technology development roadmap including this research project for development of PHWR full system decontamination technology. This project will be completed in September 2021. After completion of this project, another project for the detailed design of system decontamination commercial facility will be carried out using commercial facility, CIDF, developed for PWRs and the results of these projects will be applied to Wolsong-1 NPP decommissioning.

ACKNOWLEDGMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP), granted financial resources from the Ministry of Trade, Industry & Energy(Number 20191510301310)

REFERENCES

[1] Korea Hydro & Nuclear Power Co. Ltd., “PWR Decommissioning Technology Development Roadmap”, 2013 March
[2] Korea Hydro & Nuclear Power Co. Ltd., “Implementation Plan of PWR Decommissioning Technology Development Roadmap”, 2013 October
[3] Korea Hydro & Nuclear Power Co. Ltd., “Revised PWR Decommissioning Technology Development Roadmap”, 2015 December
[4] EPRI. “Decontamination Handbook”, TR-112352, 1999