Review of Operating Conditions for Full System Decontamination Operation Procedure Development of Kori-1 Nuclear Power Plant

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1. Introduction

The Kori-1 nuclear power plant (NPP) operated for approximately 40 years in Korea, was permanently shut downed on June 18, 2017. Kori-1 NPP will be performed with the full system decontamination to reduce worker exposure to radiation by reducing the dose rate in the system before starting main decommissioning activities. In order to successfully complete system decontamination, it is very important not only how to efficiently remove the corrosion oxide film deposited on the inner surface of system, but also how to operate the plant. The operation of system decontamination is very different from the operating NPPs. The major differences from the operating NPP are that there is no need for various the operating variables such as temperature, pressure, interlocking signal, etc., applied to the NPP because there is no fuel in the reactor core and that some facilities in the system are removed or changed to maximize the decontamination effect. This paper deals with the results of the review of the circulating flow supply method and the decontamination operation temperature/pressure control method in operating conditions of Kori-1 NPP for the development of the system decontamination operating procedure.

2. Methods and Results

2.1 Concept of System Decontamination Operation

The principal goal of the decontamination is to re`duce the radiation exposure in fields to which the decommissioning workers will be exposed. The concepts of system decontamination operation for Kori-1 NPP are as follows [1].

- Decontamination Factor (DF): > 30
- Implement ALARA
- Minimization of secondary radioactive waste generation
- Utilization of plant facilities as much as possible
- Application of organic-acid based chemical process
- System decontamination temperature: ~95℃
- Decontamination scope: PRV, PZR, SG, CVCS, RHRS and RCS piping
- Decontamination facility connecting location: Residual Heat Removal System

● Circulating Flow Supply Method

System decontamination is known to have a close relation to the decontamination effect of the circulating flow formed in the range of system decontamination [2]. There are a variety of ways to provide the circulating flow for system decontamination as shown in Table 1 [3, 4]. In case of Kori-1 NPP system decontamination, RCP operation was considered to provide adequate the circulating flow to the decontamination scope, especially in SG U-tubes.

Table 1. System Decontamination operation in NPPs decommissioning

NPPs	Maine Yankee	Connecti-cut Yankee	Jose Cabrera
Decontamination Technology	DfD	HP CORD	DfD
Decontamination Scope	RCS, PZR, CVCS, RHRS (Excl. RPV & SG)	RCS, PZR, SG, CVCS, RHRS (Excl. RPV)	RCS, PZR, SG, CVCS, RHRS, RPV
Driving Force	Vendor's Pump	RHRS Pump	RCP

The RCP startup conditions are required to operate RCP as follows [5].

- Pressure in RCS: > 22.4 bar
- Differential Pressure of RCP Seal #1: > 14 bar
- Temperature of Seal Water: < 54.4 ℃
- Seal Leakage of RCP Seal #1: within the allowable flow rate
- Supply the Component Cooling Water

The oxidation step during the decontamination process has been reported to have a negative impact on the RCP seal. Figure 1 shows the schematic diagram of RCP seal. Manganese dioxide which is a solid material produced in the oxidation step has a negative effect on the RCP seal #1 and the chemical injected in the oxidation step also has a negative effect on RCP seal #2&#3 containing Cr component

[6]. Therefore, a separate approach is needed to protect the RCP seal.

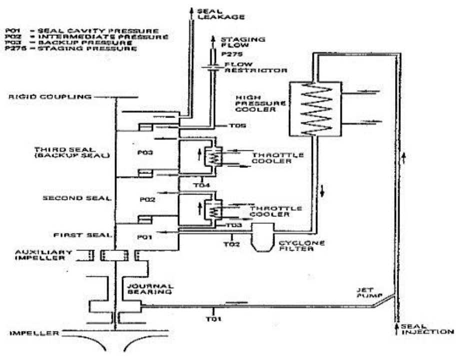

Fig. 1. Schematic Diagram of RCP Seal.

- Control of Temperature and Pressure

The heat sources for increasing RCS temperature are RCS pumps and PZR heaters. For normal operation (NOT & NOP) of NPPs, the operation temperature is maintained by RCS pumps and PZR heaters, and the pressure is controlled by vapor formed in upper portion of the PZR. The temperature and pressure requiring for system decontamination is 95℃ and 25~26 bar. The decontamination operating temperature is the same as the temperature control method during normal operation of NPP, but the decontamination operating pressure is adjusted by injecting and exhausting nitrogen gas into the upper portion of the PZR. The system decontamination operating pressure is associated with RCP NPSHR (Net Positive Suction Head Required) and LTOP (Low Temperature Ove Pressure) setpoint. Figure 2 shows the RCP performance characteristic of Kori1-1 NPP [5].

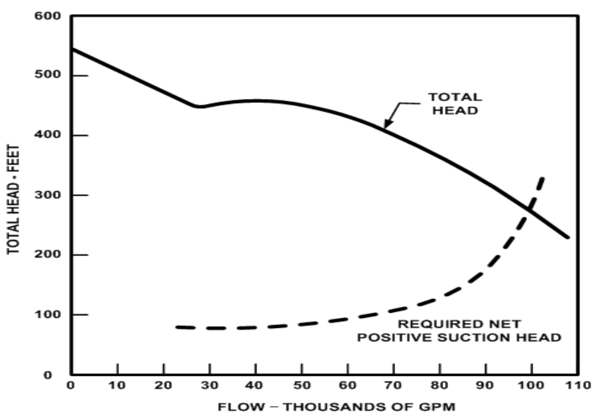

Fig. 2. RCP Estimated Performance Characteristic.

As shown in Fig.2, the RCP is operated at a pressure that satisfies the NPSHR. In case of no fuel in core, the requiring NPSH is about 200 psig but 300 psig considering the NPSH margin [7]. The components in RCS have the characteristic of being broken when the high pressure is formed at low temperature condition. It is called LTOP. The RCS in Kori-1 NPP is equipped with a release valve to prevent overpressure under low temperature. The LTOP setpoint of Kori-1 NPP is 450 psig. The release valve should be maintained below 405 psig as it opens at 90% of the LTOP setpoint. Therefore, the system decontamination operating pressure range will be 300 ~ 405 psig (20.7 ~ 27.9 bar). The system decontamination operating pressure should be controlled by solid operation or nitrogen gas because the vapor is not formed under the operating temperature of system decontamination. The operating pressure will be 370 psig slightly higher than the medium value of pressure range. This operating pressure is not enough margin with LTOP setpoint, so it is difficult to carry out the solid operation. Additionally, the pressure in the solid operation will change suddenly because the frequent pressure fluctuation is expected for system decontamination due to additional chemical injection, temperature change, and demineralized water injection. It is likely to be a burden on the operators. Therefore, it is desirable to control the pressure fluctuation by injecting/exhausting of nitrogen gas in the upper of the PZR

3. Conclusions

It was evaluated that a separate approach such as a demineralized water supply equipment is needed to protect the RCP seal because the oxidation step has been reported to have a negative impact on the RCP seal during the system decontamination operation, and that the temperature control is not much difficult compared with the normal operation and the pressure control was advantageous to pressurize the nitrogen gas in the upper of the PZR.

ACKNOWLEDGMENTS

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