Chemical Decontamination Experiences on Shika Unit-1

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ABSTRACT

Shika unit-1 is the 540 MWe Boiling Water Reactor (BWR) type nuclear power station. This plant commenced commercial operation in 1993, and is now in the sixth operation cycle. In the past, efforts were made to reduce occupational radiation exposure (1). In the fourth annual outage (1998) and the fifth annual outage (1999), the suction and discharge piping for the Primary Loop Recirculation (PLR) system were chemically decontaminated for the purpose of reducing occupational exposure of PLR pump, PLR valves and valves related to PLR system maintenance.

The PLR system is the major radiation source in the Primary Containment Vessel (PCV). The suction and discharge nozzles for PLR system, which are provided on the Reactor Pressure Vessel (RPV), were shut off plugs to isolate the RPV and PLR system. The nozzle plugs isolated PLR system for a total period of 17 and 20 days including chemical decontamination and maintenance of PLR pump and valves.

CORD UV (Chemical Oxidation Reduction Decontamination / Ultra Violet light) method (2) was applied to the chemical decontamination of PLR (A) loop in the 4th outage. HOP (Hydrazine Oxalic acid, Potassium permanganate decontamination) method (3,4) was applied to the chemical decontamination of PLR (B) loop in the 5th outage.

As a result, the amount of $3.4 \times 10^{11}$ Bq radioactivity was removed by way of the ion exchange resins (0.76 m³) during 3 consecutive days in the 4th outage, and the amount of $6.5 \times 10^{11}$ Bq radioactivity was removed by way of the ion exchange resins (0.75 m³) during 4 consecutive days in the 5th outage.

Upon completion of the decontaminated by flushing the interior pipe surfaces with high-pressure water to completely eliminate the radioactive deposits.

PLR loop decontamination reduced the averaged surface dose rate of PLR pipe to one-fiftieth in each outage. The averaged environmental dose rates at the PLR pump floor was reduced to one-third in each outage. The averaged surface dose rate of PLR (A) pipe after one cycle operation came up to the half of before decontamination.

Consequently, the collective occupational exposure during the 4th outage was approx. 1.6 person-Sv. We assume that approx. 0.8 person-Sv has been reduced with applying the decontamination processes. The collective occupational exposure during the 5th outage was approx. 1.8 person-Sv. We assume that approx. 1 person-Sv has been reduced with applying the decontamination processes.

An attempt was made to reduce the occupational radiation exposure using a measurement combining the nozzle plugging and chemical decontamination. This combination of measurement to the nuclear power plant was the first attempt in Japan. The results revealed very effective to reduce the occupational radiation exposure.

This paper describes chemical decontamination experiences on Shika unit-1.
1. INTRODUCTION

The PLR system has two loops A and B, each of which is made of stainless steel piping having a diameter of 600 mm and a length of 30 m, and the PLR system is the major radiation source in the PCV.

Figure 1 shows the outline of the PLR system. The PLR system consists of the suction nozzle, the inlet valve, the PLR pump, the outlet valve, the header pipe and the four pipes called Rizer pipes. Each of the Rizer pipes is connected to the two Jet Pumps in the RPV.

Normally, the inlet valve, the outlet valve and the PLR pump are removed from the PLR loop, and they are overhauled, after draining off the water in the RPV and all the pipes connected to the RPV. The dose rate in the PCV tends to increase after draining off the water in the RPV and the pipes.

The suction and discharge nozzles for the PLR loop, which are provided on the RPV, were shut off plugs to isolate the RPV and the PLR loop for the purpose of dose reduction. One nozzle plug for the PLR suction nozzle and eight of another type of nozzle plugs for the Jet Pump nozzle were installed. The nozzle plugs were effective to prevent the increase of the dose rate in PCV.

The nozzle plugs isolated the RPV and the PLR (A) loop in the 4th outage, and the RPV and the PLR (B) loop in the 5th outage.

Figure 2 shows the outline of the nozzle plugging. Operators, fully trained, installed the nozzle plugs by remote operation from the operating floor. It took one day to install the plugs.

The exhaust lines were connected to the suction nozzle plug for the CO₂ gas ventilation in the chemical decontamination. In the 5th outage, improved type Jet Pump nozzle plugs were applied, which has the exhaust line for the CO₂ gas vent.
The nozzle plugs isolated the PLR loop for a total period of 17 days in the 4th outage and of 20 days in the 5th outage including chemical decontamination and maintenance of PLR pump and valves.

2. CHEMICAL DECONTAMINATION

2.1 Scope of Decontamination

Figure 3 shows the scope of the 4th outage decontamination. The scope of the decontamination involved the PLR (A) loop including the suction pipe, the discharge pipe, the inlet valve (F001A), the PLR (A) pump, the outlet valve (F002A), and the stopping valve (F017A) of the residual heat removal system (RHR) connected to the PLR (A) loop. The inlet valve (F001A), the PLR (A) pump and the outlet valve (F002A) were decontaminated in the PLR (A) loop. The total area to be decontaminated was 34 m², and the volume was 4.3 m³.

Figure 4 shows the scope of the 5th outage decontamination. The scope of the decontamination involved the PLR (B) loop including the suction pipe, the discharge pipe, the inlet valve (F001B), the PLR (B) pump and the outlet valve (F002B). And the stopping valve (F001) of the reactor water cleanup system (CUW), and the stopping valves (F010A, F010B, F017B) of the RHR system connected to the PLR (B) loop were included. The inlet valve (F001B), the PLR (B) pump and the outlet valve (F002B) were decontaminated in the PLR (B) loop. At the same time, the removed body and bonnet of the valves, which were the stopping valve (F001) of the CUW system and the stopping valves (F010A, F010B, F017B) of the RHR system, were decontaminated in the sinks (we called it sink). The sinks were connected to the decontamination loop to decontaminate the body and the inside of the bonnet of the valves. The sink was the top opened tank, which could be covered by the bonnet of the valve. The total area to be decontaminated was 40 m², and the volume was 5 m³.

2.2 Chemical Decontamination Process

CORD UV (Chemical Oxidation Reduction Decontamination / Ultra Violet light) method (2) was applied to the chemical decontamination of PLR (A) loop in the 4th outage. HOP (Hydrazine Oxalic acid, Potassium permanganate decontamination) method (3,4) was applied to the chemical decontamination of PLR (B) loop in the 5th outage.

The chemicals were the 2,000 ppm of oxalic acid as deoxidization chemical, the 200 ppm of permanganate as oxidation chemical for CORD UV, and the 300 ppm of potassium permanganate as oxidation chemical for HOP. The decontamination temperature was almost 90 °C. Oxalic acid was resolved by irradiation of ultra violet light under adding hydrogen peroxide in CORD UV process. And oxalic acid was resolved by using the...
catalyst under adding hydrogen peroxide in HOP process.

2.3 Decontamination Operation

In the 4th outage, three cycles of decontamination were planned. Actually two cycles of decontamination and the final purification were performed in 77 hours. The dose rate of PLR (A) loop and the removed radioactivity showed the good reduction after the first cycle of decontamination. Therefore third cycle of decontamination was bypassed. Total amount 0.76 m³ of the used cation exchange resin and mixed exchange resin was transferred to a spent resin tank.

In the 5th outage, three cycles of decontamination and the final purification were performed in 103 hours almost same as planned. Total amount 0.75 m³ of the used cation exchange resin and mix exchange resin was transferred to a spent resin tank.

Upon completion of the decontaminated by flushing the inner surface of pipe with high-pressure water to completely eliminate the radioactive deposits after the chemical decontamination in the both outage.

Metal, radioactivity and chemicals concentrations in the decontamination solution were measured periodically. Surface dose rate of PLR loop, and area dose rate in PCV were measured before and after decontamination.

In the 5th outage, personal computers were connected with network temporary. The computers supported the job, the recording of metal and radioactivity analysis results in hot laboratory, the monitoring results of PLR pipe surface dose rate measured every 10 minutes, the process monitoring data of the decontamination system, that is, temperature and conductivity. All of the data was shared among the decontamination operators, chemists, healthphysicists during the chemical decontamination process.

2.4 Chemical Decontamination Results

(1) Removed Radioactivity and Metal

Figure 5 shows the removed radio-activity and figure 6 shows the removed metal of the 4th outage decontamination. In the 4th outage, the total removed radio-activity was $3.4 \times 10^{11}$ Bq, the radioactivity removal ratios in decontamination cycles were 85 % in the 1st cycle, 15 % in the 2nd cycle. The dominant nuclide of the removed radioactivity was Co-60 (69 %), followed by Co-58 (12 %), Mn-54 (12 %) and Cr-51 (6 %).

2.6 kg of the metal oxides were removed as metal, 92 % in the 1st cycle, and 8 % in the 2nd cycle. The elemental distribution was 63 % of Fe, 30 % of Cr, and 7 % of Ni.

Figure 7 shows the removed radioactivity and figure 8 shows the removed metal of the 5th outage decontamination. In the 5th outage, the total removed radioactivity was $6.5 \times 10^{11}$ Bq, the radioactivity removal ratios in decontamination cycles were 76 % in the 1st cycle, 15 % in the 2nd cycle, and 9 % in the 3rd cycle. The dominant nuclide of the removed radioactivity was Co-60 (72 %), followed by Mn-54 (17 %), and Co-58 (9 %).
6.2 kg of the metal oxides was removed as metal, 89% in the 1st cycle, 9% in the 2nd cycle, and 2% in the 3rd cycle. The elemental distribution was 75% of Fe, 15% of Cr, and 10% of Ni.

(2) Dose Rate Reduction

Figure 9 shows the surface dose rate of the PLR (A) loop in the 4th outage and figure 10 shows the surface dose rate of the PLR (B) loop in the 5th outage. The averaged surface dose rate of the PLR (A) loop in the 4th outage was 1.9 mSv/h before chemical decontamination, 0.1 mSv/h after chemical decontamination and 0.04 mSv/h after mechanical washing with high-pressure water as shown in figure 9. The averaged surface dose rate of the PLR (B) loop in the 5th outage was 2.8 mSv/h before chemical decontamination, 0.12 mSv/h after chemical decontamination and 0.06 mSv/h after mechanical washing with high-pressure water as shown in figure 10.

The dose rate build-up measurements in the 5th outage showed that the averaged surface dose rate of decontaminated in the 4th outage came up to the half level of before decontamination in the 4th outage.

Figure 11 shows the averaged area dose rate in PCV in the 4th outage and figure 12 shows the averaged area dose rate in PCV in the 5th outage. The averaged area dose rate of the PLR Pump floor in the 4th outage was 0.31 mSv/h before chemical decontamination and 0.12 mSv/h after mechanical washing with high-pressure water. The averaged area dose rate of the PLR Pump floor in the 5th outage was 0.26 mSv/h before chemical decontamination and 0.085 mSv/h after mechanical washing with high-pressure water.

The surface dose rate of the sinks, decontaminated the one valve of the CUW system and the three valves of the RHR system, were reduced from 4.0 - 13 mSv/h before decontamination to 0.11 - 0.15 mSv/h after decontamination at the same condition, sinks were drained off.

(3) Dose Reduction

Figure 13 shows the projected and measured collective occupational exposure during the 4th and 5th outage. The collective occupational exposure during the 4th outage was approx. 1.6 person-Sv. We assume that approx. 0.8 person-Sv has been reduced with applying the decontamination processes. The collective occupational exposure during the 5th outage was approx. 1.8 person-Sv. We assume that approx. 1 person-Sv has been reduced with applying the decontamination processes.
3. SUMMARY

3.1 Summary of 4th outage
(1) CORD UV method was applied to the chemical decontamination of PLR (A) loop in the 4th outage. The amount of $3.4 \times 10^{11}$ Bq radioactivity and 2.6 kg of the metal oxides were removed by way of the ion exchange resins (0.76 m$^3$).
(2) The averaged surface dose rate of the PLR (A) loop was 1.9 mSv/h before chemical decontamination, 0.1 mSv/h after chemical decontamination and 0.04 mSv/h after mechanical washing with high-pressure water.
(3) The averaged area dose rate of the PLR Pump floor was 0.31 mSv/h before chemical decontamination and 0.12 mSv/h after mechanical washing with high-pressure water.

3.2 Summary of 5th outage
(1) HOP method was applied to the chemical decontamination of PLR (B) loop in the 5th outage. The amount of $6.5 \times 10^{11}$ Bq radioactivity and 6.2 kg of the metal oxides were removed by way of the ion exchange resins (0.75 m$^3$).
(2) The averaged surface dose rate of the PLR (B) loop was 2.8 mSv/h before chemical decontamination, 0.12 mSv/h after chemical decontamination and 0.06 mSv/h after mechanical washing with high-pressure water.
(3) The averaged area dose rate of the PLR Pump floor was 0.26 mSv/h before chemical decontamination and 0.085 mSv/h after mechanical washing with high-pressure water.

The averaged surface dose rate of PLR (A) pipe after one cycle operation came up to the half of before decontamination.
4. CLOSURE

The PLR loop decontamination plan of Shika unit-1 started in winter of 1996, after the 3rd annual outage. Hokuriku Electric Power Company people and Hitachi, Ltd., people, and all of the sections, maintenance section, chemical section and health physics section co-operated to study the maintenance schedule of PLR pumps and valves, the scope of decontamination and the decontamination process for the first attempt to the Shika unit-1.

An attempt was made to reduce the occupational radiation exposure using a measurement combining the nozzle plugging and chemical decontamination. This combination of measurement to the nuclear power plant was the first attempt in Japan. The results revealed very effective to reduce the occupational radiation exposure.

5. REFERENCES