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ISOE INFORMATION SHEET

Replacement of Reactor Internals and Full System Decontamination at a Japanese BWR

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A replacement construction of the weld-type reactor core shroud and other reactor internals was conducted at The Tokyo Electric Power Co. (TEPCO) Fukushima Daiichi NPS Unit 3 (BWR, 784MW) during 16th periodic inspection from May 1997 to July 1998. This Information Sheet presents the results and performances of the Full System Decontamination (FSD) effect on reduction of dose rate and the results of occupational exposure. Information in this paper was provided by TEPCO.
The chief achievements are the following.
The average decontamination factors of 43 at the RPV bottom and 46 at the RRS surface were obtained of FSD. The activity and metal removal were approximately 10 TBq and 72 kg and the waste generated by the FSD was only 5.4 m^3 of ion exchange resins. After mechanical cleaning, the dose rate at the RPV bottom under water was 0.03 mSv/h, and with shieldings in the RPV the dose rate at the RPV bottom in the air was 0.2 mSv/h. Due to dose rate in the RPV decreasing remarkably, occupational exposure for workers engaged in replacement works in the RPV was 11.5 person-Sv, which was able to attain the target value of 12.6 person-Sv.

1. Introduction

Since 1990, shroud crackings caused by stress corrosion cracking (SCC) have been reported in foreign BWR plants. In Japan, also, SCC was found across the weld line of the shroud in 1994 at TEPCO's Fukushima Daiichi 2, and in response to which, the several R&D had been carried out in Japan to establish the countermeasures for the core shroud cracking. As a result of R&D, the shroud replacement process was confirmed and TEPCO decided to applied it at Fukushima Daiichi NPS Unit 3.
The strategy of this shroud replacement was to replace the shroud made of SUS304 which has relatively higher potential of SCC with new one made of SUS316L which has much less potential of IGSCC. In addition to the core shroud, the majority of the internal components made of 304SS are replaced. These replacement technologies make it possible to improve the SCC-resisting quality of the entire RPV.

2. Outline of replacement process

The major components to be replaced with the shroud were the top guide, the core plate, the feed water spargers, the core spray spargers, the jet pumps, the differential pressure detector / stand-by liquid control piping, and the in-core monitor (ICM) guide tubes, as well as the various piping and nozzle safe ends connected to them. The cutting process of the existing shroud and other components inside the reactor was basically done under water using Electric Discharge Machining (EDM) remotely, while the welding process was took place in air automatically.

1. Removal of detachable components inside the reactor
   Reactor detachable internal components such as the dryer, the control rods, the control rod guide tubes, the fuel assemblies were taken away.
2. Chemical decontamination inside the reactor
   Radioactive metal oxides on the surface of the components and pipings were removed by chemical decontamination.
3. Removal of shroud and other components
   The shroud and other components were cut basically using EDM underwater, then they were removed in order of feed water spargers, top guide, upper portion of core shroud, core plate, ICM guide tubes, lower portion of core shroud, and jut pumps.
4. Mechanical cleaning and shielding
   Shieldings were installed on the inner surface and bottom of RPV after mechanical cleaning. And then, following the drainage of reactor water from RPV, the scaffolding was set up inside the RPV for the next work of new jet pumps installation.
5. New jet pumps installation
   The new jet pumps were installed, and the scaffolding was removed.
6. New shroud and other components installation
   The new shroud, the new core plate and other internal components were installed.
7. Reactor recovery

3. Measures taken to reduce exposure

Since the replacement was expected to bring many operations inside RPV such as the installation and fine adjustments of equipments by worker under the high radiation condition, reduction of dose rate in RPV was mandatory. Chemical decontamination technique is considerably beneficial for reduction of dose rate and occupational exposure in Nuclear power plant. Therefore it was performed the FSD of the reactor pressure vessel and the reactor recirculation system by applying the CORD/UV process (Chemical Oxidation Reduction Decontamination/Ultra Violet light) in the first experience in Japan prior to the replacement work. In addition to that, mechanical cleaning method and installation of shieldings were applied to lower the dose rate inside RPV. As preliminary evaluation of the FSD, all relevant materials in contact with the decontamination agents were investigated and confirmed no detrimental effect on the integrity.

3.1. Chemical Decontamination

The chemical decontamination was applied during June 29 to July 6 in 1997.

(1) Preparation before the FSD
Reactor detachable internals were taken away from the RPV in advance. All of undecontamination system lines were isolated by valves or mechanical plugs. The FSD scope included inside the RPV and the two reactor recirculation system (RRS) loops as shown in Fig.1.

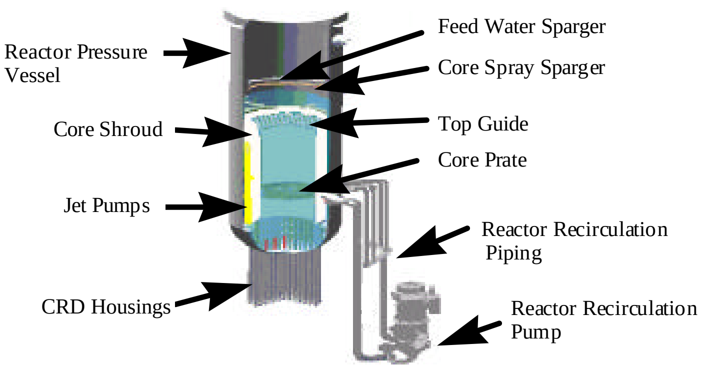

Fig.1 Full System Decontamination Scope in 1F-3

(2) Decontamination Method

The CORD／UV process by Siemens was adopted as the FSD method. This process uses permanganic acid and oxalic acid as the decontamination agents and UV light for decomposing the chemicals.

Comparing with other decontamination methods, the CORD／UV process has a characteristic of simple operation, providing a high decontamination factor (DF) and minimizing the waste volume. Generally the corrosion products deposited on the reactor internals and pipings are considered as metal (iron) oxides with radioactive nuclides. For decreasing these oxides efficiently, the CORD/UV process consists of several steps: decontamination, decomposition, oxidation, reduction, and purification.

(3) Decontamination Process

Time schedule of the FSD performance is shown in Fig.2. **[decontamination step];** Three cycles of CORD/UV process was performed in 1F-3. In the first cycle, metal oxides including the radioactive nuclides are dissolved by the addition of the dilute oxalic acid. Then dissolved those oxides were trapped by cation resins. **[decomposition step];** Following this step, UV light irradiation was started and added hydrogen peroxide to decompose the oxalic acid and oxalates into carbon dioxides and water. **[oxidation step];** At the beginning of the second cycle, permanganic acid was added in order to oxidize the chromium oxides easier to dissolve and release from contaminated surface. **[reduction step];** After the chromium dissolution was ended, oxalic acid was added again and permanganic acid was decomposed quickly into manganese ions. Manganese ions were removed with the corrosion products by cation resins. **[purification];** In the end of the final decontamination cycle (3rd cycle), the oxalic acid was decomposed by using UV light and addition of hydrogen peroxide. Finally, residual impurities and released ions in the reactor solution were removed by mixed resins bed.

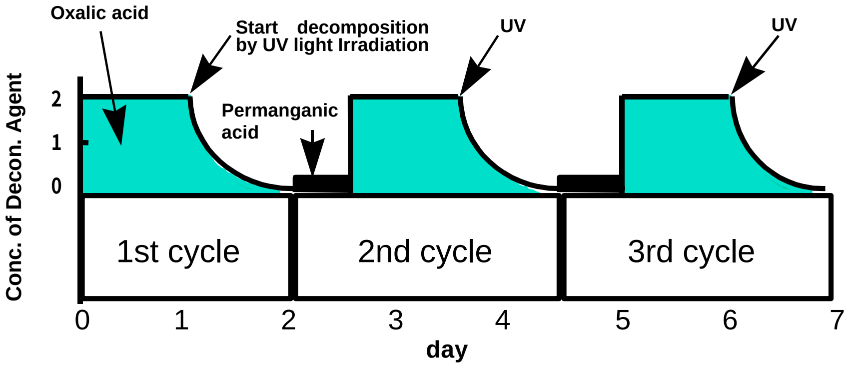

Fig.2 Time Schedule of the CORD/UV

(4) Decontamination System

The decontamination loop was shown in Fig.3. One circulation of the decontamination solution in the RPV was obtained by two RRS pumps. These pumps were operated at the minimum flow rate to hold an efficiency circulation flow especially for the RPV bottom. The other circulation of decontamination was withdrawn from the CRD housings/ICM housings and back through spray ring equipment in the RPV head. This temporary circuit consists of pumps, UV skid, ion exchange resins columns, heater, cooler and chemical injection skid.

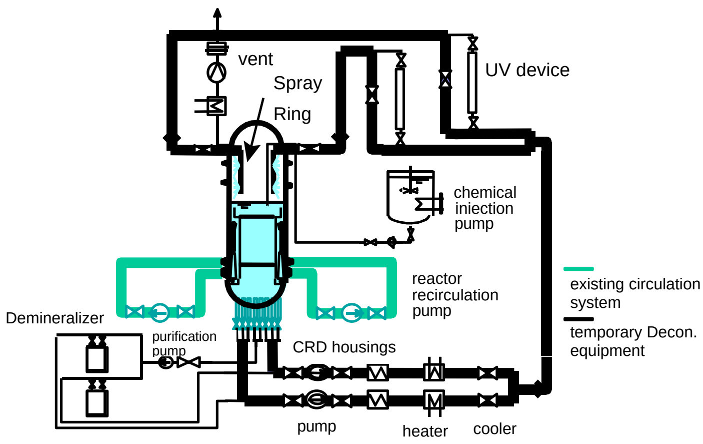

Fig.3 1F-3 Full System Decontamination Flow Diagram

(5) Decontamination Operation and Monitoring
By external heater and joule energy of the RRS, the decontamination system was heated and maintained to 95℃ in advance. The decontamination chemicals were added to the decontamination loop until attaining the demanded concentration at each cycles. UV light skid was running for decomposing oxalic acid and oxalates. After the third cycle, the decontamination chemicals and impurities in the RPV was purified and absence of residual chemicals was confirmed. Cation and anion resins bed were in operation during the decontamination cycles, and the mixed resins bed were used for the final purification. The used resins were discharged at the end of the decontamination cycles respectively, and transferred to a spent resin tank. During the decontamination, process, the schedule was controlled by measuring the concentration of radioactivity, metals and the decontamination chemicals at the inlet /outlet of ion exchange columns. The effect on each decontamination cycles was evaluated by monitoring the trend of dose rate at the RPV bottom and surface on RRS pipings, calculating the removed amount of radioactivity. Total decontamination was conducted during June 29 to July 6 in 1997.

3.2. Chemical Decontamination Results

(1) Dose Rate
Three dose rate sensors (NaI) were installed in the top of CRD housings and continuously measured during the FSD. Figure 4 shows positions of these sensors and the measurements results before and after the FSD. The average decontamination factor (DF) at the RPV bottom was 43. This value was higher than the target value of 20. Additionally, the outer surface dose rate on the recirculation piping was measured by an ion chamber in the end of each cycle. These dose rate results are shown in Fig.5. Comparing with the target value of 20, the average DF of 46 was higher. Furthermore adherent radioactivity nuclides at inner RRS vertical piping was measured by gamma-scanning detector. The DF was obtained 72 as Co-60. As these results of decontamination, the remarkable effect of dose rate reduction in the drywell was also achieved as well as in the RPV.

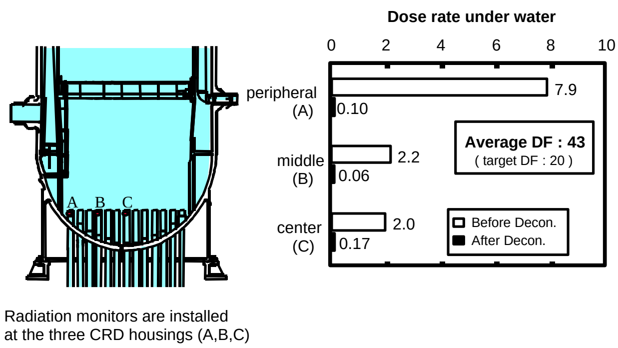

Fig.4 1F-3 Dose Rate at the RPV Bottom

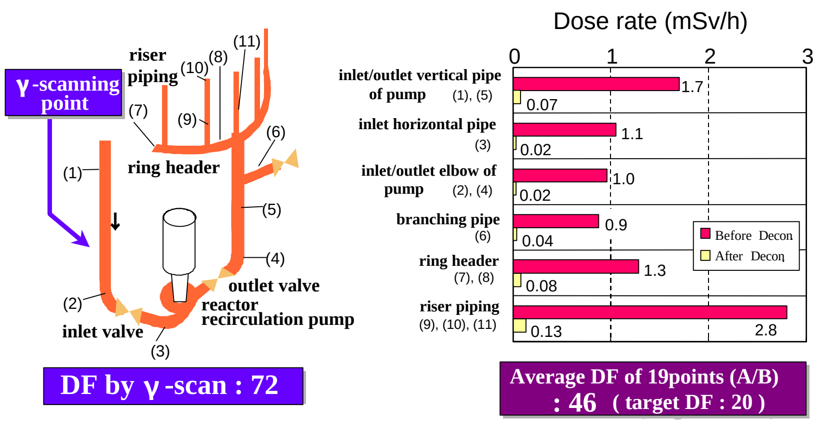

Fig.5 Contact Dose Rate of Reactor Recirculation Piping

(2) Radioactivity and Metals

The decontamination solution was sampled and nalyzed every hour at the inlet/outlet of ion exchange columns. Amount of radioactivity and metals released from contaminated surface were evaluated as trapped in ion exchange columns. Radioactivity removed by the FSD was approximately 10TBq as shown in Fig.6. The dominant removed radioactivity nuclide was Co-60 for each cycle respectively and almost 90% of activity was removed in the first cycle. Corrosion products removed as metals were 72 kg as shown in Fig.7. Iron was the main metal removed by decontamination and Iron amount in the first cycle accounts for 71% in the whole cycles. Consequently, the FSD using CORD/UV method in 1F-3 enabled to obtain good results on the whole.

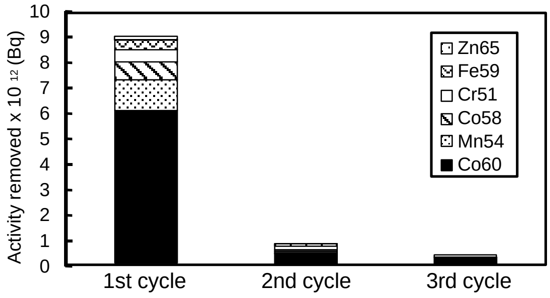

Fig.6 1F-3 FSD Release of Activity

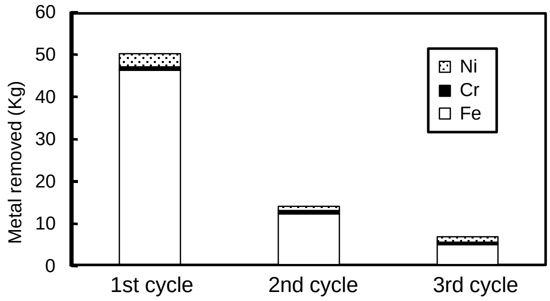

Fig.7 1F-3 FSD Release of Metal

(3) Wastes and Occupational Exposure

In order to remove radioactivity and metal ions dissolved in the decontamination solution, resins were in service during the each decontamination cycle and final purification step. These resins waste were generated 5.4 m^3 in total. Total occupational exposure was approximately 0.2 person-Sv for the FSD.

3.3. Mechanical Cleaning and Shieldings

Because of cutting the reactor internals in the water after the FSD, the residual insoluble crud and cutting particles were existing in the RPV. To improve the working conditions in the RPV, mechanical cleaning method was applied for the removal of these activity solids. This cleaning process consists of brushing, suction cleaning and water jet cleaning. Then RPV wall and bottom shieldings were installed before the operation of installation in the RPV. Figures 8 shows the dose rate results after mechanical cleaning and installing shieldings. The dose rate at the RPV bottom 0.1 mSv/h after the FSD was decreased to 0.03 mSv/h in the water. After draining the reactor water, the dose rate at the RPV bottom in the air was 0.2 mSv/h. This value of dose rate was possible to work inside the RPV.

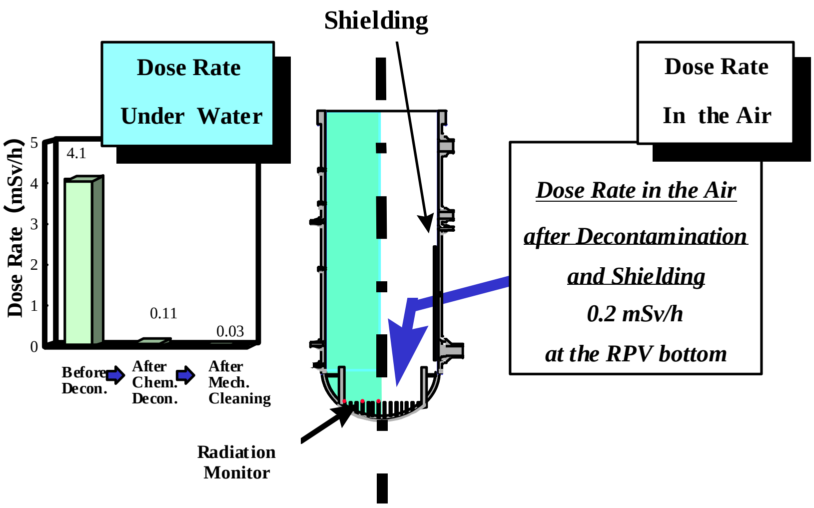

Fig.8 After FSD and Mechanical Cleaning Dose Rate at the RPV Bottom

4. Replacement schedule

The period of this outage, including the core internals replacement, was initially expected to be 300 days. Actually, however, the whole period took about 420 days. It was partly because the removal of the internal components was delayed and operations were detained due to irregularities initially unexpected, such as cracking inside the ICM housing. The main reason of delay is that, considering the core shroud and jet pumps replacement was the first experience, a cautious attitude was taken in carrying out replacement work to secure safety and reliability. The initial plan imposed rather stringent requirement. All these factors combined to result in a longer-than-expected period for the outage.

5. Exposure Results

The total collective dose for the replacement of the shroud and other equipments was 11.5 person-Sv. This was below originally estimated values of 12.6 person-Sv owing to the effects of radiation reduction measures taken place such as full system chemical decontamination, mechanical cleaning and various shields etc.