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Radiation Control in the Core Shroud Replacement Project of Fukushima-Daiichi NPS Unit #2

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General

At the Fukushima-Daiichi Nuclear Power Station, Tokyo Electric Power Co., core internals have been replaced sequentially as preventive maintenance to prevent stress corrosion cracking of the shrouds. Since this work involves entry into the reactor, reduction of the collective dose equivalent and prevention of excessive exposure have been set as priority control items.

Workers have to enter the reactor for installation of core internals (new shroud, etc.). In order to establish an environment appropriate for workers, various dose reduction measures (chemical internal decontamination, internal shielding, etc.) as well as development and employment of radiation protective equipment for workers have been made.

These measures successfully achieved a work environment, which is observed during ordinary periodical inspection, in the reactor bottom where the great number of workers entered.

From July, 1997, the world’s first shroud replacement work was done at Fukushima-Daiichi Nuclear Power Station Unit #3. The collective dose equivalent was 11.5 persons.Sv.

For the work in Unit #2 of the same station, shroud replacement was done from August, 1998. The collective dose equivalent was 7.7 persons.Sv, about 30% lower than that of Unit #3.

Introduction

In June 1994, a fissure caused by a stress corrosion crack was detected in the shroud main body installed in the reactor pressure vessel in Unit #2 of this station. The structure of shroud is shown in Fig. 1.

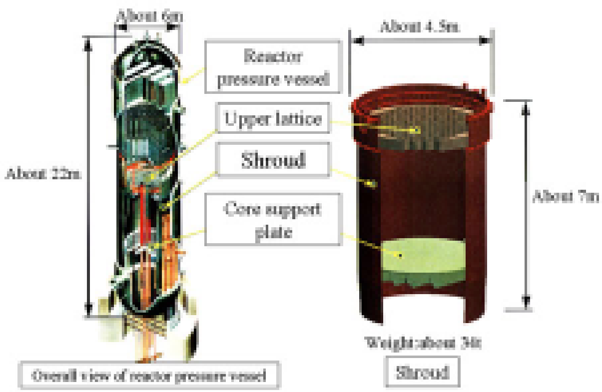

Fig.1 Construction of shroud

Countermeasures in this case included reinforcement of the cracked portion with brackets as well as a visual inspection every two periodical inspections on the weld line where cracks were reported frequently at all six plants. Hydrogen injection was also started sequentially in 1996. Since 1997, hydrogen injection has been done at all plants of the Fukushima-Daiichi Nuclear Power Station.

In addition to these items, preventive maintenance measures to cope with stress corrosion cracking included replacement of SUS304-made shrouds in Units #1, 2, 3, and 5 sequentially with that using the material (SUS316L) that is resistant to stress corrosion cracking. Actual and scheduled replacements are shown in Fig. 2.

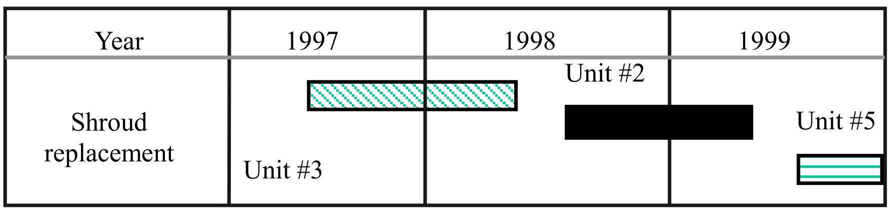

Fig.2 Periodical inspection process and shroud replacement plan

During the 16th periodical inspection at Unit #3 of this Station in 1997, replacement of the shroud and other core internals was achieved for the first time in the world. Though internal operations (welding, etc.) could be executed automatically under remote control, workers must enter the reactor for equipment installation, checking, and inspection. Accordingly, it is necessary to improve the work environment including radiation exposure in the reactor. For this purpose, chemical decontamination in the reactor was carried out before cutting of core internals. After this decontamination, core internals were cut in water, automatically under remote control. Then, the entire reactor inside was mechanically decontaminated. Then, the radioactivated vessel near the effective core was shielded by installing a molded lead shields over the entire core area. After implementation of these measures, including chemical decontamination, the dose equivalent rate in the reactor bottom after drained decreased low enough to allow workers to work in the reactor pressure vessel.

The shroud replacement project was implemented entirely within the dose equivalent limit as set forth in the applicable law (50mSv/year). The collective dose equivalent of shroud replacement work executed in the 17^{th} periodical inspection for Unit #2 of the Station in 1998 was about 7.7 persons.Sv against the expected value of 10 persons. Sv.

Since the shroud replacement project was a large-scale reconstruction over a long period of time and implemented in a high-dose-rate area, major stress was placed on assured safety of work. A radiation control plan, including mainly dose reduction, was drafted and implemented. This paper deals with the state of radiation control and painstaking efforts to reduce the dose during replacement of the shroud at Unit #2 of the Station.

The state of radiation control

Before starting shroud replacement, an overall plan concerning radiation control was drafted for positive checks of individual items before proceeding to the next step.

(1). Collective dose equivalent

The collective dose equivalent for shroud replacement was added to the total dose of 10 persons.Sv by considering the work environment for individual activities and by estimating the dose for each job title from the work period and man-hour.

Concerning the collective dose equivalent of shroud replacement, the actual value of core shroud replacement, feedwater sparger and core spray line replacement, nozzle safe end replacement, and auxiliary works (cutting core internals into pieces) was below the expected level. The collective dose equivalent was 7.7 persons.Sv as compared to the expected value of 10 persons.Sv. We believe that chemical decontamination and internal shield were combined effectively with the painstaking efforts for reduced dose in each activity and contributed to reduction of the dose by about 20%.

(2). Individual workers' dose control

As workers have to enter the reactor for equipment installation, checking, and inspection, thorough dose equivalent control was done for individual workers. Through painstaking dose control of individual workers, the individual dose equivalent of about 2300 workers engaged in shroud replacement was less than one half of the legal limit of annual 50 mSv. We planned the individual dose per day to be maximum of 5 mSv, but the actual dose was less than the planned level.

Implementation of Dose Reduction Measures

Fig.3 shows the status of implementation of major dose reduction measures. The fuel assembly, control rod drive mechanism, dryer, and separator were taken out of the reactor according to the ordinary procedure.

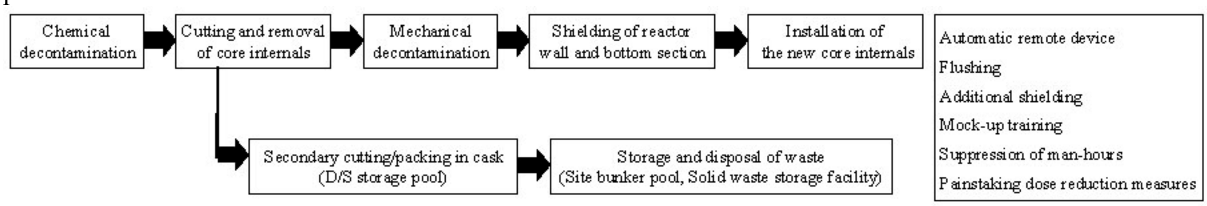

Fig.3 Implementation of principal dose reduction measures

First, chemical decontamination was done to remove radioactive materials accumulated in the reactor, followed by submerged cutting and removal of core internals for disposal. Chips and residual crud left after cutting were removed by mechanical decontamination using brush and water jet in water under remote control. The highly-radioactivated reactor internal wall surface, etc. was shielded in the water. Subsequently, water was drained to establish the atmospheric environment where the workers could be engage in activities. Then, the work with automatic remote devices, flushing, and additional shielding (if necessary) was made. Mock-up training, reduction of work man-hours, and further careful dose reduction measures were implemented.

(1) Chemical decontamination

The CORD/UV method was employed for chemical decontamination, in which oxidization and reduction are repeated with oxalic acid and permanganic acid (decontamination reagents) to dissolve and remove crud produced and adhering to the equipment and piping inside. The CORD/UV method is outlined in Fig.4.

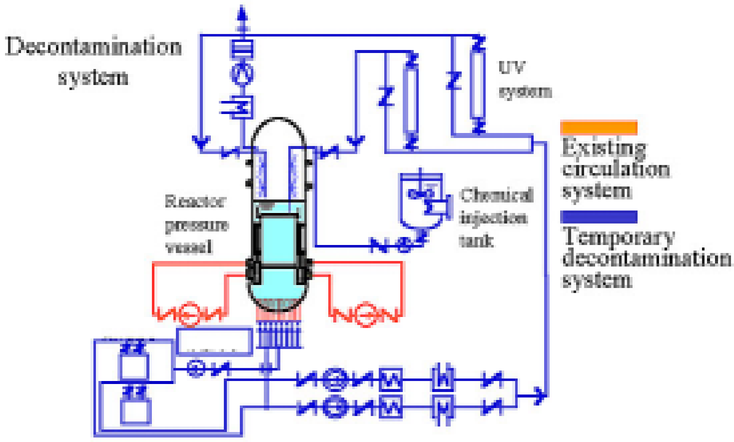

Fig.4 Chemical decontamination system

The water was circulated by temporary equipment and piping and radioactive materials were removed with ion exchange resin. Decontamination steps were taken for three cycles. Before implementation, the cycle progress logic was prepared, with the judgment criteria established to determine if the work could proceed to the next step. In each cycle, various monitoring was conducted to see if the target DF(Decontamination Factor) had been achieved. A high-temperature radiation monitor (NaI(Tl)) was inserted in three locations, periphery, middle point, and center of a housing of the control rod drive mechanism, monitoring continuously the transition of dose equivalent rate below the water line in the reactor bottom. The dose rate on the piping surface of the reactor recirculation system was measured with an ICW survey meter before and after decontamination. Finally, the system water was sampled at the outlet of the resin tower to monitor the radioactivity, metallic oxides, and concentration of decontamination reagents. The monitoring method and results of chemical decontamination is shown in Fig.5.

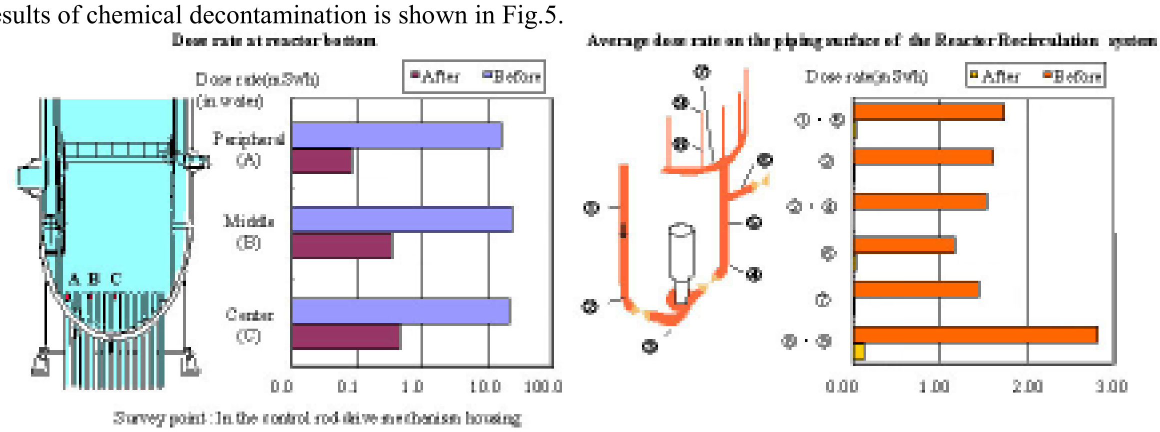

Fig.5 The monitoring method and results of chemical decontamination

Decontamination proved effective, exceeding the target DF20. Namely, the removed radioactivity was about 10 TBq. The average dose rate in the water on the reactor bottom was at a ratio of 108 before and after decontamination, and the average dose rate on the piping surface of the reactor recirculation system was at a ratio of 68 before and after decontamination.

(2) Mechanical decontamination

After the cutting and removal of core internals, mechanical decontamination was conducted through repeated brushing, suction, and water spray in the reactor. The target was set for each step and decontamination method, and the effectiveness was confirmed.

(3) Shielding of the reactor inside the wall

Shielding was provided for the highly-radioactivated reactor wall and for the reactor bottom where radioactive materials tend to accumulate. For the reactor wall, 36 pieces of 7 m high and 3 ton weight shields were provided. Each shield consists of the 80 mm thick lead covered by 5 mm thick stainless steel. The reactor wall shield is shown in Fig. 6.

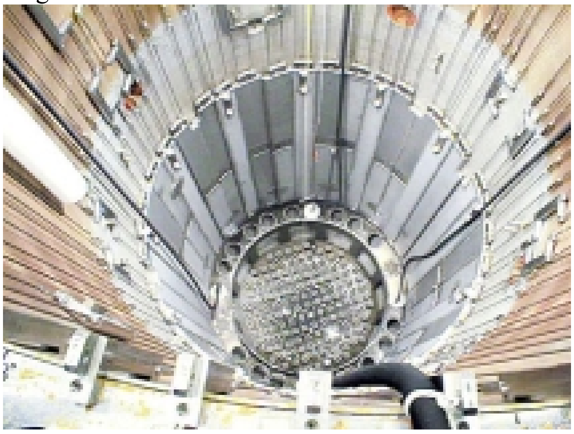

Fig. 6 The reactor wall shield

The reactor bottom was provided with a 25 mm thick stainless steel shield.

With these measures, the dose rate in the air was reduced ensuring the environment where the workers can be engaged in activities.

(4) Flushing

To remove crud accumulated in the piping nozzle thermal sleeve at the recirculation inlet (N2), feedwater (N4) and core spray (N5), water jet cleaning was used, achieving reduction effectively by about 31 – 88%. These measures were to reduce the dose during replacement of the nozzle safe end in the Primary Containment Vessel(PCV).

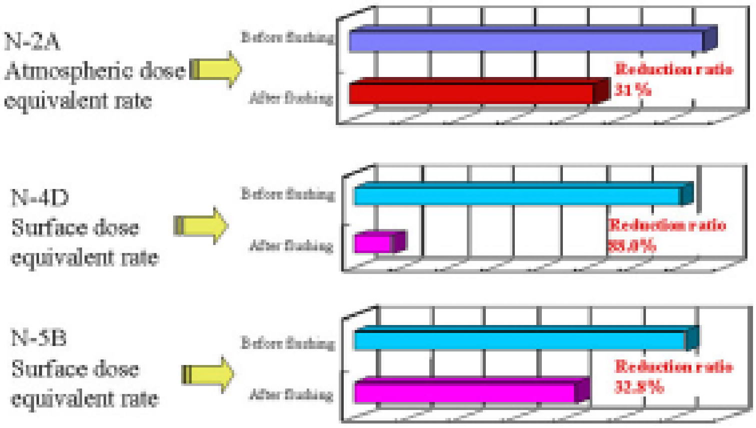

Fig.7 Effects of thermal sleeve jet flushing

(5) Painstaking dose reduction

The radiation control group took a leadership to reduce the dose during shroud replacement. Examples of dose reduction measures and developments appropriate for the site are introduced below.

a. Dryer cleaning and shielding around the dryer

The dryer and separator are stored in water at the D/S storage pool during ordinary periodical inspections. To secure the area for cutting core internals at the D/S storage pool, the dryer and separator are stacked in two stages, allowing a 2.0 m portion of the dryer to be exposed to the air. Though a 50 mm steel plate is provided for entire coverage, it was confirmed that the environmental dose rate of the operation floor(working area) as a whole, including the area for cutting of core internals, increased.

Accordingly, mechanical cleaning was done on the dryer which is partially exposed to the air, reducing successfully the dose rate by about 30%. Moreover, as far as the floor load capacity of steel plate shield allows, lead mats were temporarily installed on the top and on the sides. Dose reduction by about 65% was achieved.

b. Development of nozzle shape shield and lead-clay shield

For replacement of the nozzle (N2) safe end at the recirculation piping inlet, a shield appropriate to the nozzle shape was developed by taking into account flexible shielding, reduction of the installation time, and prevention of displacement after installation. As a result, the installation time was reduced to one-fourth of the conventional time. In addition, the lead-clay shield in which the lead is sandwiched by clays was developed, which was packed into the cut end of N2 piping inside from the PCV side to reduce the effect from the reactor inside.

Implementation of work safety measures

In order to ensure work safety and to suppress the release of radioactivity to the surrounding area, several measures were implemented.

(1) New equipment for workers

Concerning the equipment used by workers, a welding hood mask was developed for activities using fire in the reactor (welding, etc.). In addition, a water-covered hood mask was developed and used for removal of thermal sleeves in the pedestal. And a water-proof permeable protector was developed. These equipment reduce greatly the physical load on workers.

(2) Implementation of work without a mask in the reactor

After installation of the new jet pump, the surface contamination density of the work area was controlled to a level less than that at which the mask must be worn through decontamination and protection of the reactor inside. In consequence, the welding operation, etc. of the sensing line could be done without wearing a mask. Even after installation of the new shroud in the reactor, the workers could operate without wearing the mask. In this way, improved efficiency could be achieved with reduced work time, and we successfully achieved the reactor environment which is observed outside the reactor.

The reduction achieved through these painstaking control measures is estimated to be about 2.3 persons.Sv. As compared to the expected collective dose of 10 persons.Sv, the actual dose equivalent during shroud replacement was 7.7 persons.Sv.

Conclusions

On the basis of knowledge obtained during shroud replacement in Unit #2 of Fukushima-Daiichi Nuclear Power Station, we would like to continue positive implementation and evaluation of chemical decontamination while continuing painstaking radiation control for Unit #5 in progress. Stress continues to be placed on safety against radiation.