EFFORTS FOR OPTIMIZATION OF BWR CORE INTERNALS REPLACEMENT

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Abstract

The core internal components replacement of a BWR was successfully completed at Fukushima-Daiichi Unit #3 (1F3) of the Tokyo Electric Power Company (TEPCO) in 1998. The core shroud and the majority of the internal components made by type 304 stainless steel (SS) were replaced with the ones made of low carbon type 316L SS to improve Intergranular Stress Corrosion Cracking (IGSCC) resistance. Although this core internals replacement project was completed, several factors combined to result in a longer-than-expected period for the outage. It was partly because the removal work of the internal components was delayed. Learning a lesson from whole experience in this project, some methods were adopted for the next replacement project at Fukushima-Daiichi Unit #2 (1F2) to shorten the outage and reduce the total radiation exposure. Those are new removal processes and new welding machine and so on. The core internals replacement work was ended at 1F2 in 1999, and both the period of outage and the total radiation exposure were the same degree as expected previous to starting of this project. This result shows that the methods adopted in this project are basically applicable for the core internals replacement work and the whole works about the BWR core internals replacement were optimized. The outline of the core internals replacement project and applied technologies at 1F3 and 1F2 are discussed in this paper.

1. INTRODUCTION

Since the core shroud cracking was found [1], the Japanese BWR owners and the plant manufacturers have conducted several R&D programs to establish the countermeasures for core shroud cracking. Based on the evaluation of the effect and applicability of them, TEPCO decided to replace the core shroud made of 304SS which has relatively higher possibility of IGSCC. Among 17 BWR plants owned by TEPCO, four plants have the core shrouds made of 304SS. In accordance with the long term outage schedule, 1F3 was selected as the first plant to replace the core shroud with the one made of 316L SS which has much less possibility of IGSCC [2].

In addition to the core shroud, the majority of the internal components made of 304SS are replaced at the same outage. These are (1) core shroud, (2) top guide, (3) core plate, (4) core spray spargers, (5) feed water spargers, (6) jet pumps, (7) differential pressure and liquid control system (DP/LC) pipe, (8) in core monitor (ICM) guide tubes, and internal pipes and nozzle safe ends connected to these components as illustrated in Figure 1.

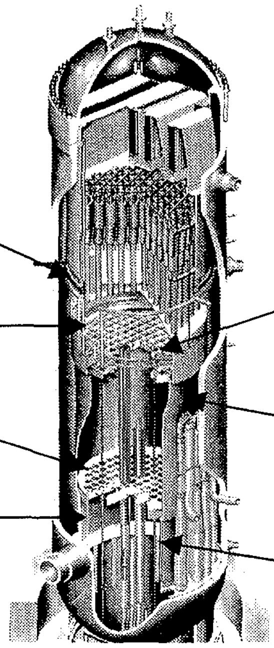

FIG. 1. Replaced components.

2. CORE INTERNALS REPLACEMENT AT 1F3

During the 16th outage of 1F3 started in May 1997 the core internals replacement project had been carried out, and 1F3 was back on line in July 1998.

Reduction of radiation dose level is one of the key elements through the core internals replacement work because of the workers to be able to enter inside the reactor pressure vessel (RPV) for installation work of new components. Prior to the removal work the chemical decontamination was conducted to reduce the radiation from the radioactive metal oxide deposited on the components, and the in-vessel shielding panels were set after the removal work to reduce the radiation from the irradiated RPV. As a result of them, the in-vessel dose level decreased generally below 1.0mSv/h, and it was nearly 0.2mSv/h at the bottom of RPV where operations were performed for many hours [3].

The Removal of the core shroud and most of other internals was conducted by means of Electrical Discharge Machining (EDM) process underwater [5]. Subsequently, the removed core shroud and other internals were sliced into small pieces, and put in the containers in the Dryer Separator Pool (DSP). The underwater plasma slicing was employed for the slicing process because of its slicing speed. The stuffed containers were decontaminated and transferred to the site bunker pool and the dry storage facility in the site.

The period of this outage, including the core internals replacement, was initially expected to be 300 days, but the actual period of outage was 423 days. It was partly because the removal work of the internal components was delayed. 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.

3. IMPROVEMENT FOR THE REPLACEMENT WORK AT 1F2

As the 1F3 core internals replacement work ended, an experience to implement the world's first welded core shroud and jet pumps replacement was acquired. Hence, many examinations for shortening a shutdown period had been conducted to gain economical efficiency in next replacement work at 1F2. Reflect on a delay in replacement work at 1F3, the schedules of all works were corrected adequately ,considering about the results at 1F3.

And at the same time, for some works, conspicuous about delay and radiation exposure, the new methods were adopted. Those works are removal work and slicing work and jet pumps installation work.

3.1. Improvement for removal work

3.1.1. Appropriation for removal process

At 1F3 removal work of core internal components was conducted by the EDM process and the mechanical cutting process. And most of the components were removed by means of the EDM process for its technological reliability. The EDM process allows a very high degree of precision and complicated operation remotely. So the EDM process is suitable to cut the components precisely underwater as previously planned. However the cutting speed is low and it takes long time to set the machine to the right position.

To shorten the schedule of removal work, it was took into consideration to enlarge the scope of adoption of the mechanical cutting process at 1F2. The mechanical cutting process, using some conventional tools, is appropriate for cutting the small component rapidly which has simple shape.

Therefore considering the acquired conditions of each components after cutting, adequate process were selected for each components. The EDM process was adopted basically to the part of component which is to be prepared for welding with new components. And the mechanical cutting process are adopted to the part no need to be cut precisely. The core spray pipings and guide rods are cut by sawing. DP/LC pipe and ICM stabilizers are cut by hydraulic cutting. The bolts of top guide and core plate are removed by pliers.

As the result of these improvement, the total schedule of removal work was shortened compared to 1F3's by 30 days approximately.

3.1.2. Adoption of mechanical cutting tool for core shroud

The mechanical cutting process was adopted to core shroud too. The core shroud is cut at an upper and lower location to be sliced underwater in the DSP. As an alternative to the

EDM process, it is interested in using a mechanical roll cutting technique to sever the upper core shroud section to shorten the cutting time. The roll cutting tool, as illustrated in Figure 2, consists of 10 cutting modules and a support structure. Each module has one cutting blade. The blades are pressed by and rotated inside core shroud by hydraulic and electric motors. After the mock-up test, this tool was adopted at 1F2. As the result of the adoption of this tool, the schedule of cutting the upper core shroud were shortened compared to 1F3's by 10 days approximately.

3.2. Improvement for slicing work

3.2.1. Appropriation of sequence for removal and slicing work

The internal components removed from RPV are sliced into small pieces in the DSP and stuffed in the containers to be transported. To store dryer and steam separator in the DSP, only a half of the whole space in the DSP is available for slicing work. So when the slicing work is delayed, sliced components cannot be transported from the DSP, and then the components removed from RPV cannot be carried into the DSP.

That is to say, the removal work and the slicing work are closely related each other. Actually the removal work was detained by delay of the slicing work at 1F3. So it is very important to examine the whole sequence considering many factors other than cutting and slicing speed. Those are the time for setting tools, the order of slicing, the arrangement of components and tools in the DSP, and utilities available at refuel floor for instance. Additionally a new process of slicing was adopted at 1F2 to shorten the schedule of slicing work.

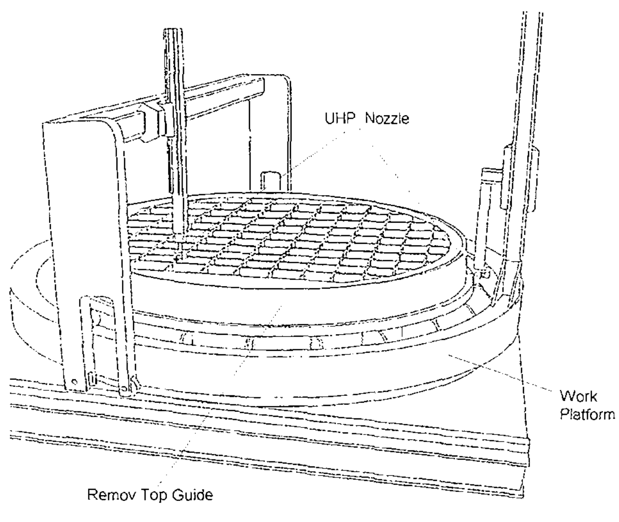

FIG. 2. UHP slicing tool.

3.2.2. Adoption of new slicing process

At 1F3 the plasma slicing process was adopted because of its slicing speed. But the slicing work took time longer-then-expected. Mainly because the sensitivity in setting the plasma torch to the right position. As an alternative to the plasma slicing process, a new slicing process was examined. The ultra high pressure abrasive water jet (UHP-AWJ) slicing process was adopted at 1F2. The UHP-AWJ process mechanically cuts off components by throwing a stream of abrasive-containing high pressure water to them. It is a practical method that has been used lately in the bolt-type core shroud replacement work at the Oskarshamn Nuclear Power Station in Sweden as illustrated in Figure 3.

3.3. Improvements for the installation works at 1F2

The installation works of new internal components start with jet pumps installation work and then continues to core shroud installation work. After that, the other components are installed, those are core plate, top guide, ICM guide tubes, DP/LC pipe and so on. Most of installation works were made good progress at 1F3. But as concerns about jet pumps installation work, the schedule was longer than previously expected. And the radiation exposure of this work is relative large compare to another works. So the examination was conducted to shorten the schedule and reduce the radiation exposure of this work.

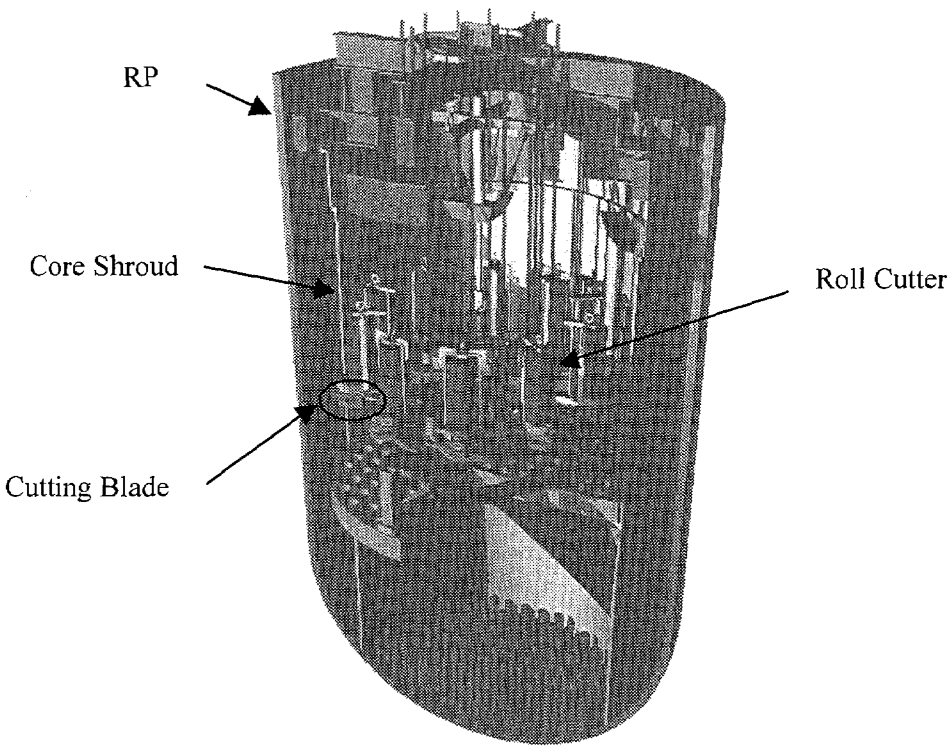

FIG. 3. Roll cutting tool.

3.3.1. Improvement for jet pump raiser brace installation work

There are 20 jet pumps in the RPV and one jet pump is mainly consists of three assemblies, those are raiser assembly and inlet-mixer assembly and diffuser assembly. As the result of estimation for works to install those tree assemblies, the raiser brace installation work was focused to be improved. Raiser brace is one of the parts of raiser assembly to join raiser pipe with RPV by welding. A raiser brace has four thin plates, called raiser brace leaves, and the tip of them are directly attached to the cladding pad inside RPV at core region. Therefore to install raiser brace, the in-vessel shield panels must be opened partially for welding. The automatic welding machine was adopted to decrease the radiation exposure at 1F3. But setting and testing operation previous to welding could not be done remotely. So workers operated closely to the welding point. Therefore the radiation exposure of these operations was relative large compared to the other operations.

To reduce the radiation exposure, a new welding machine was adopted at 1F2. This machine, as illustrated in Figure 4, has two manipulators which has six axis to move independently. With the large degrees of freedom, setting and testing operation can be done remotely. Therefore the time of those operations became shorter and the radiation exposure was reduced.

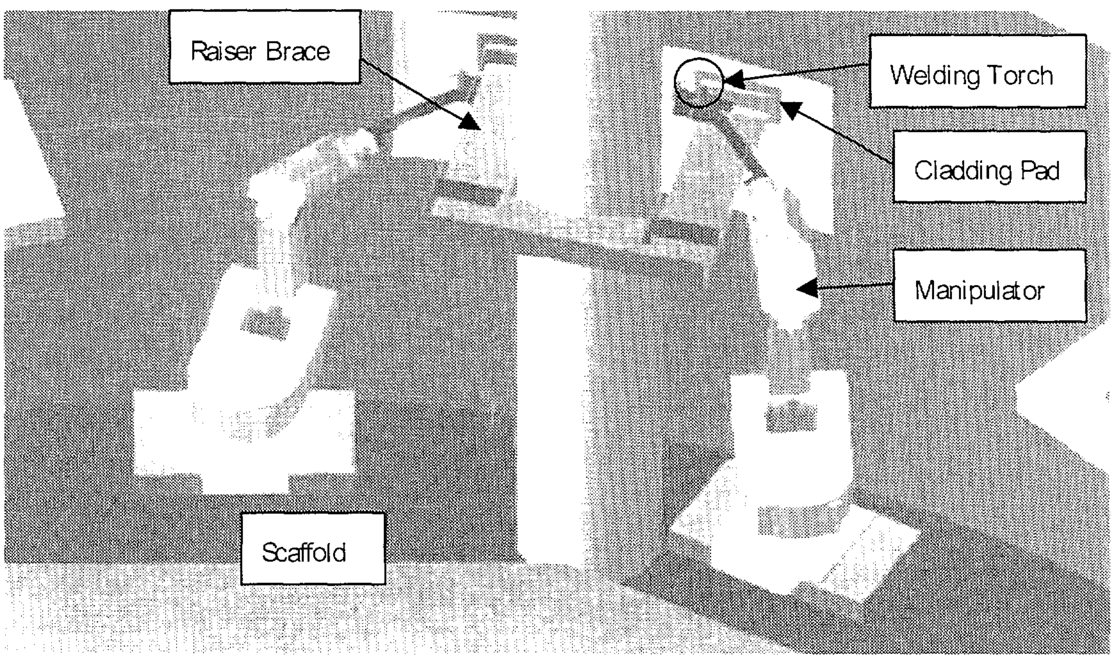

FIG. 4. Raiser brace welding machine.

3.3.2. Result of improvement

In addition to the improvement for the raiser brace installation work, some examination were planned to reduce the total radiation exposure. As the way to access to working area in RPV, an elevator was attached to reduce the burden of workers and the radiation exposure at

1F3. But the station of the elevator was located on the top floor of the scaffold where existed at the core region in RPV and relative high dose level. So the location of the station was changed to the top of scaffold, as illustrated in Figure 5, to reduce the radiation exposure.
As the result of those improvements, as mentioned above, the schedule of jet pumps installation work was shortened compared to 1F3's by 30 days approximately. And the radiation exposure of this work was reduced compared to 1F3's

3.4. Result of core internals replacement work at 1F3

The 17th outage of 1F2, including the core internals replacement work, was carried out and back on line in July 1999. The period of outage and the total exposure at 1F3 and 1F2 are shown in the Table I. Considering about them, many kinds of improvements, as mentioned above, were functioned effectively and resulted in shortening the period of outage and reduction of total radiation exposure.

At the same time, the period of the outage was planned to be 334 days, and actual period was 331 days. There is no significant difference between the planning and actual period, so it seems that the schedule and sequence of core internals replacement work were almost optimized.

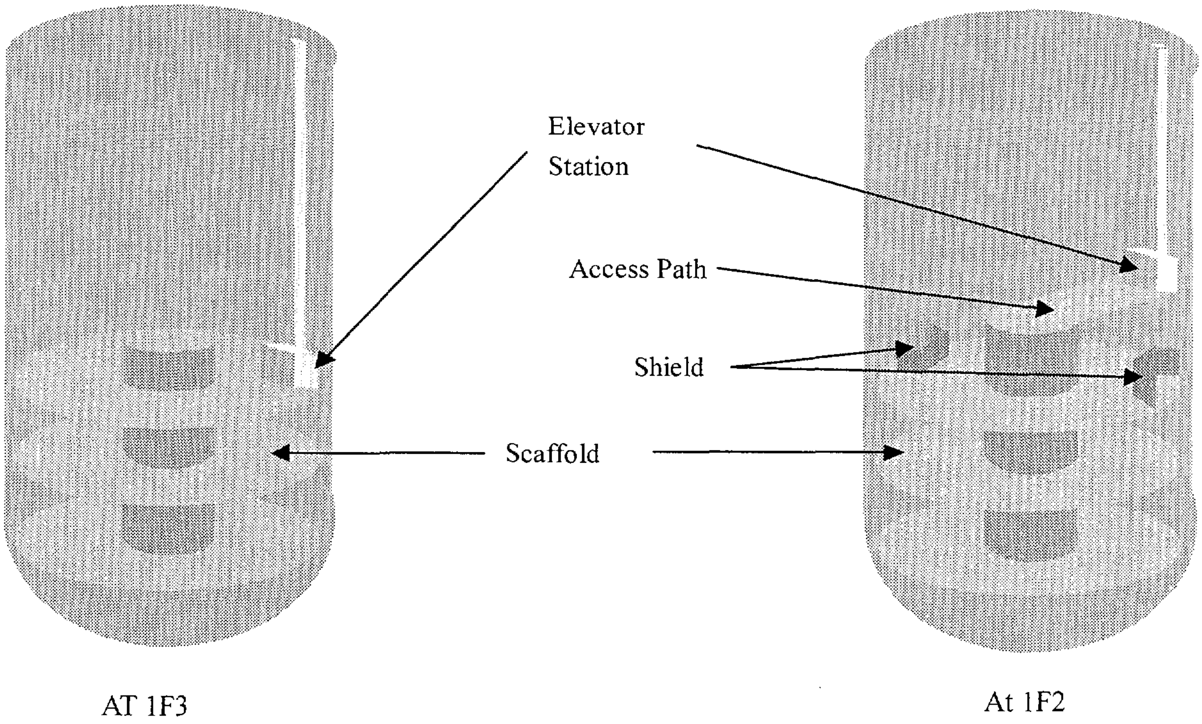

FIG. 5. Circumstances in RPV.

TABLE I. COMPARISON OF CORE INTERNALS REPLACEMENT WORK AT 1F3 AND 1F2

Unit	Period of outage (days)	Total radiation exposure (person Sv)	Points of improvements
1F3	423	11.5	-
1F2	331	7.7	• Enlargement of the scope of mechanical cutting • Adoption of water jet slicing • Adoption of new welding machine for jet pumps Installation

4. CONCLUSION

The core internals replacement project at 1F3 were successfully completed. Because of the several factors, the period of outage at 1F3, including the core internals replacement, was longer-than-expected. To shorten the schedule, some works were focused to be improved. Those were removal work, slicing work and jet pumps installation work. So some examinations about work sequence and new processes were conducted prior to the internals replacement work at 1F2.

As the result of adoption, the period of outage at 1F2 was 331 days, almost as long as expected, and the total radiation exposure was reduced. Therefore the core internals replacement work is seemed to be optimized and the methods, those were adopted at 1F2, are basically applicable for core internals replacement work.

And now TEPCO is planning the core internals replacement work at Fukushima-Daiichi Unit#5. The period of outage and the total radiation exposure are expected to the same degree as 1F2's approximately.

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