Dose Reduction Experience of Permanent Shielding Installation on Tokai-II Power Station

Hiroshi Hujii[1], Toshiyuki Satou[1], Kazuhumi Taniguchi[1],
Yoshinori Chiba[2], Kazuhiro Yoshinari[2] and Youichi Shimizu[3]

1 The Japan Atomic Power Company, 1-6-1 Ohtemachi, Chiyoda-ku, Tokyou 100-0004 Japan
2 Hitachi Engineering Co., Ltd., 3-2-1 Saiwaichou, Hitachi-shi, Ibaraki 317-0073 Japan
3 Nuclear Fuel Machinery Co., Ltd., 1-13 Ienomae, Obuchi, Rokkasho-mura, Kamikita-gun, Aomori 039-3212 Japan

ABSTRACT

Tokai-II power station started commercial operation in 1978, which was the first large scale Boiling Water Reactor (BWR) type nuclear power station in Japan. This power station recorded the largest cumulative electricity per unit among the BWR in the world at the period of March. 1999.

In construction of Tokai-II, several dose reduction measures were adopted based on the experience of the former plant Tsuruga-1 power station. We have applied the various dose reduction measures since the start point of the commercial operation. In spite of these efforts, the occupational radiation exposure of annual outage work in Tokai-II increased and showed higher value than the average of 28 units of Japanese BWR in the 6th annual outage (1984). Now, we have got a large dose reduction as a result of the whole organization effort to reduce the occupational radiation exposure. It recorded 1.45 person-Sv in the 15th annual outage (1996).

This paper describes the experience of the installation of permanent shielding to the piping with high dose rate in the Reactor Containment Vessel (PCV), that is the most effective dose reduction measurement in our experiences.

1. INTRODUCTION

Tokai-II power station started construction in 1973 and started commercial operation in 1978, which was the first large scale BWR in Japan. Specifications for this plant are 1100MWe electric power, 50Hz frequency, about 131 ton of fuel inventory. Tokai-II shows the experience of 148.4 billion Kwh, 75.7% of capacity factor, 77.0% of operation factor at the end of March in 1999.

Figure 1 shows the comparison of the occupational radiation exposure between Tokai-II and the average of Japanese BWR. The occupational radiation exposure of 6th outage (1984) showed the highest value of 4.89 person-Sv. And the 4.89 person-Sv was higher value than the average radiation exposure of Japanese BWR in the year.

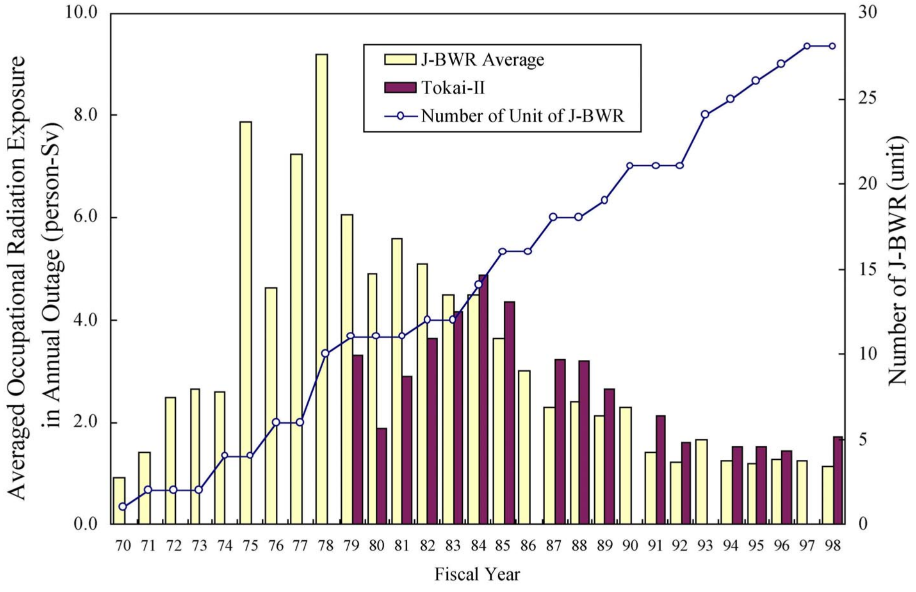


Fig.1 Occupational Radiation Exposure of Japanese BWR in Annual Outage

Therefore we started the study on dose reduction measurements and we set the target, "reduce the exposure half in five years" that is, reduce the exposure from 4.89 person-Sv to 2.5 person-Sv.

Following action items were applied to meet the dose reduction target.

(1) Reduction of radiation sources
 a. Reduce the concentration of iron in the feed-water
 b. Clean the inside of the Reactor Primary Vessel (RPV)

(2) Improvement of workability and Remote operation
 a. Apply the improved type of remote Control Rod Drive (CRD) handling machine
 b. Use the RPV well cleaning machine

(3) Organization of ALARA control
 Establish a new organization named "the ALARA review team"

(4) Installation of permanent shielding
 Install the permanent shielding for piping in the PCV

Figure 2 shows the trend of occupational radiation exposure of Tokai-II in each annual outage and the dose reduction experiences. The occupational radiation exposure in Tokai-II power station has reduced to a level of 1.5 person-Sv in recent year.

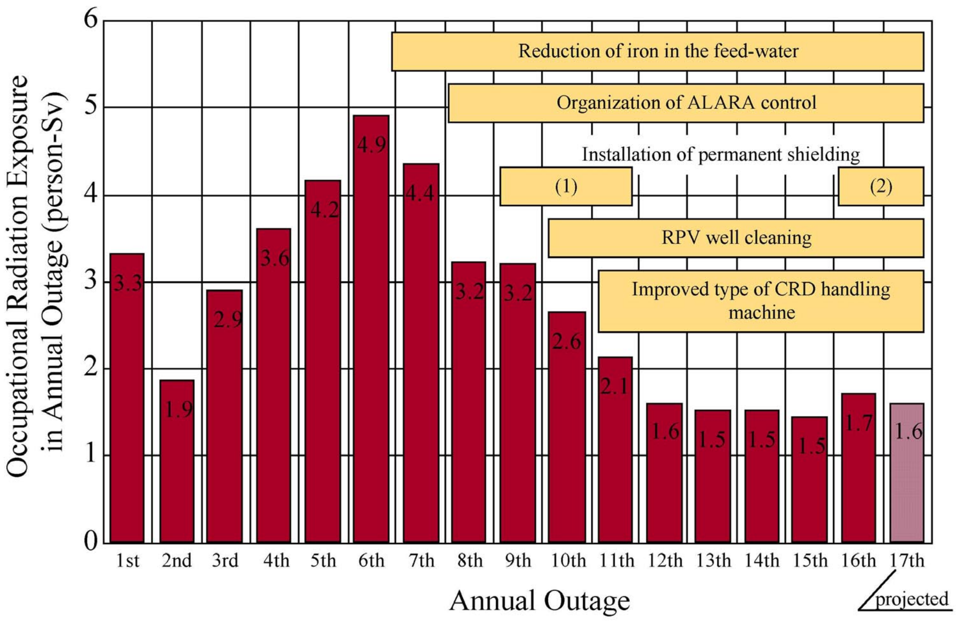


Fig.2 Occupational Radiation Exposure of Tokai-II in Annual Outage

2. EXPERIENCES OF DOSE REDUCTION

2.1 REDUCTION OF RADIATION SOURCES

The iron concentration in the feed-water has been controlled to reduce the radioactivity concentration in the reactor water of BWR. The feed water iron concentration control is a technique to suppress the dissolution of Co-60 and Co-58 from the fuel deposits by allowing the nickel and cobalt on the fuel surface to chemically react with the iron to form the insoluble complex oxides.

The soak regeneration of the small particle size resin was applied to the Condensate Purification system in the 7th fuel cycles (1). The concentration of iron in the feed-water was reduced to less than 1 ppb after the 9th fuel cycles.

Another measurement was the mechanical cleaning of the inside of the RPV, the RPV well bellows and the reactor internals. Brushing the inner surface of the RPV, the internals, sucking the crud from the bottom of the RPV and the high-pressure water jet were applied for the removal of the radioactivity in the RPV. Figure 3 shows the RPV well cleaning machine.

We assume that approximately 0.2 person-Sv has been reduced with applying the remove of radiation sources.

2.2 IMPROVEMENT OF WAKABILITY AND REMOTE OPERATION

The about 20% of CRD are overhauled in each annual outage. The CRD is removed from the bottom of the RPV and the overhauled CRD is re-installed to the RPV again.

The former type remote CRD handling machine was operated with the attendance of supervisor in the pedestal. The supervisor had to confirm the connection the bottom of the CRD were removed and the head of the CRD handling machine, and had to confirm the transportation of the CRD to the out side of the pedestal. The improved type remote CRD handling machine dose not need the attendance of supervisor in the pedestal.

Another sample of the remote operation is the reactor well cleaning machine. The spent fuels are removed from the RPV core and transported to the spent fuel pool through the reactor well after opening the RPV head in each annual outage. After the refueling, the radiation source on the surface of wall and floor of reactor well increased the radiation exposure of internals handling job at the reactor well. The reactor well cleaning step has been required to remove the radiation source on the surface of reactor well after draining off reactor well water. Figure 3 shows the RPV well cleaning machine. RPV well cleaning machine moves from the top of wall to the lower side of the wall, in according to drain off the water in the RPV well. This remote operation machine reduces the decontamination work and the radiation exposure in the reactor well after draining off the reactor well water.

We assume that approximately 0.3 person-Sv has been reduced with applying the remote operation machines.

Fig.3 Reactor Primary Vessel Well Cleaning Machine in Tokai-II

2.3 ORGANIZATION OF ALARA CONTROL

A new organization named "the ALARA review team" was established for the optimization of radiation exposure reduction in each maintenance work during the annual outage. The team consists of maintenance section people, health physics section people and technical control section people of JAPCO and all the company related to the annual outage maintenance work.

The first job of the team was to make a list of the work item, which was projected to be over 0.5 person-Sv, to review the person-hour, the occupational radiation exposure reduction measurements and the projected person-Sv in each maintenance work at the six month before the annual outage.

The second action of the team was to operate the occupational radiation exposure reduction measurements and to review the experiences in each work items. Finally, the team fed the experiences and the lessons learned to the projection of next annual outage.

The ALARA review team action has succeeded in every annual outage. We assume that approximately 1 person-Sv has been reduced with applying the ALARA review team action.

2.4 INSTALLATION OF PERMANENT SHIELDING

The installation of permanent shielding has been taken for a long time. The first permanent shielding works were performed in three annual outages, from 1988 to 1991. The Primary Loop Recirculation (PLR) system pipe, the Reactor Water Clean-Up System (RWCU) pipe and the Residual Heat Removal System (RHR)

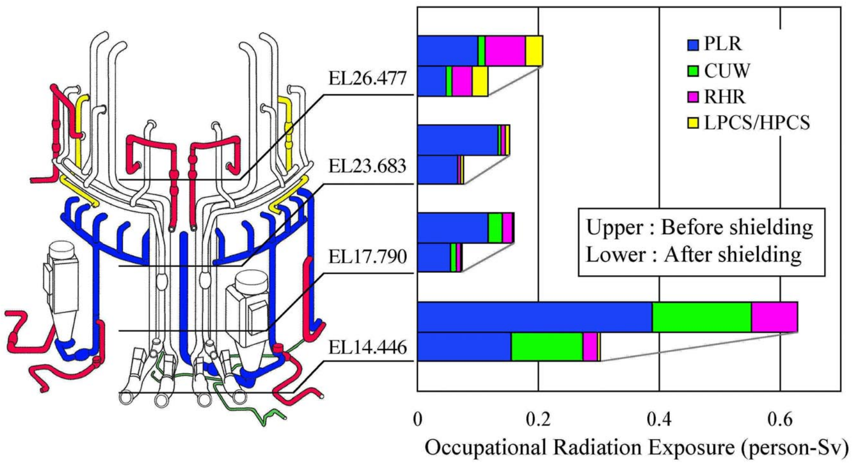


Fig.4 Analized and Projected Occupational Radiation Exposure in the PCV of Tokai-II

pipe were shielded. We assume that approximately 1.2 person-Sv has been reduced with applying the 89 tons of iron and lead shielding.

For the purpose of further dose reduction, added permanent shielding works were performed in two annual outages, from 1998 to 1999. The remaining piping in the PCV and the high dose rate pipe along the passage in reactor building was shielded at the 16th and 17th annual outage. We assume that approximately 0.3 person-Sv has been reduced with applying the 21 tons of iron and lead shielding.

3. EXPERIENCES OF PERMANENT SHIELDING INSTALATION IN PCV

3.1 STRATEGY OF PERMANENT SHIELDING

The occupational radiation exposure experience of the 8th annual outage showed that the about 60% of occupational radiation exposure was related to the work in the drywell. The major radiation sources in the drywell were the pipe of the PLR, RWCU and the RHR system. The occupational radiation exposure data was reviewed by the aid of calculation of the dose distribution on each system pipe. Figure 4 shows the reviewed and projected occupational radiation exposure in PCV of Tokai-II.

The study of radiation exposure and the radiation source in the drywell showed

1. Approximately 60% of the occupational radiation exposure in the drywell due to the PLR system
2. Approximately 20% due to the RWCU system
3. Approximately 15% due to the RHR system.

The study of radiation exposure and work area in the drywell showed

(1) Approximately 50% of the occupational radiation exposure due to the work in the E.L.14.446 floor of drywell
(2) Approximately 13% due to the work in the E.L.17.790 floor
(3) Approximately 12% due to the work in the E.L.23.683 floor
(4) Approximately 14% due to the work in the E.L.26.477 floor

The lower area of PLR system was selected as the first target of dose reduction based on the analysis.

3.2 SCOPE OF PERMANENT SHIELDING

Figure 5 shows the scope of permanent shielding in each annual outage. The first permanent shielding works were performed in three annual outages, from 1987 to 1989. The pipe for the PLR (A) system excluding the suction pipe and the discharge pipe of the PLR (A) pump was shielded in the 9th annual outage (1987). The piping for the suction pipe, the discharge pipe of the PLR (A) (B) pump, the RWCU System and the RHR

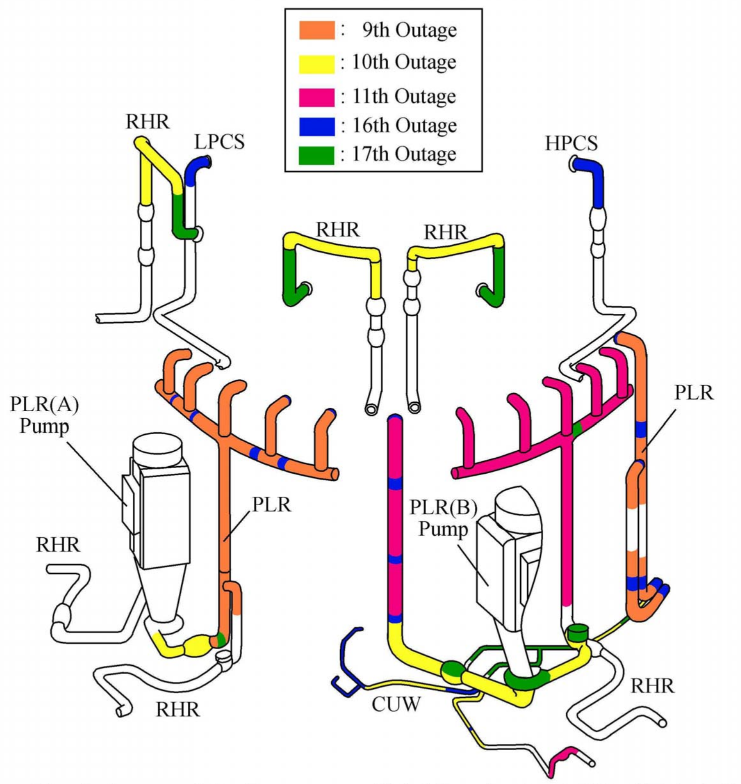
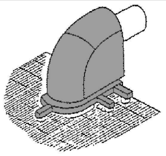
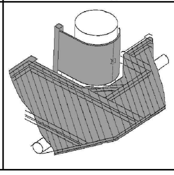
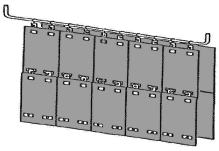
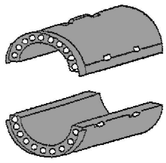


Fig.5 Scope of the Permanent Shielding in the PCV of Tokai-II

System were shielded in the 10th annual outage (1988). And the pipe for the PLR (B) system excluding the suction pipe and the discharge pipe of the PLR (B) pump was shielded in the 11th annual outage (1989).

For the purpose of further dose reduction, added permanent shielding works were performed in two

Type	Sample of Type		Scope of Shielding			
	9th~11th Outage	16th~17th Outage	PLR	CUW	RHR	LPCS HPCS
Iron Plate Type			○	○	○	-
Mattress Type (Including the lead fiber)			○	○	○	-
Thermal Insulation Type (Including the lead plate)			-	○	○	○

○ : Applied

Fig.6 Type and Scope of Permanent Shielding in the PCV of Tokai-II

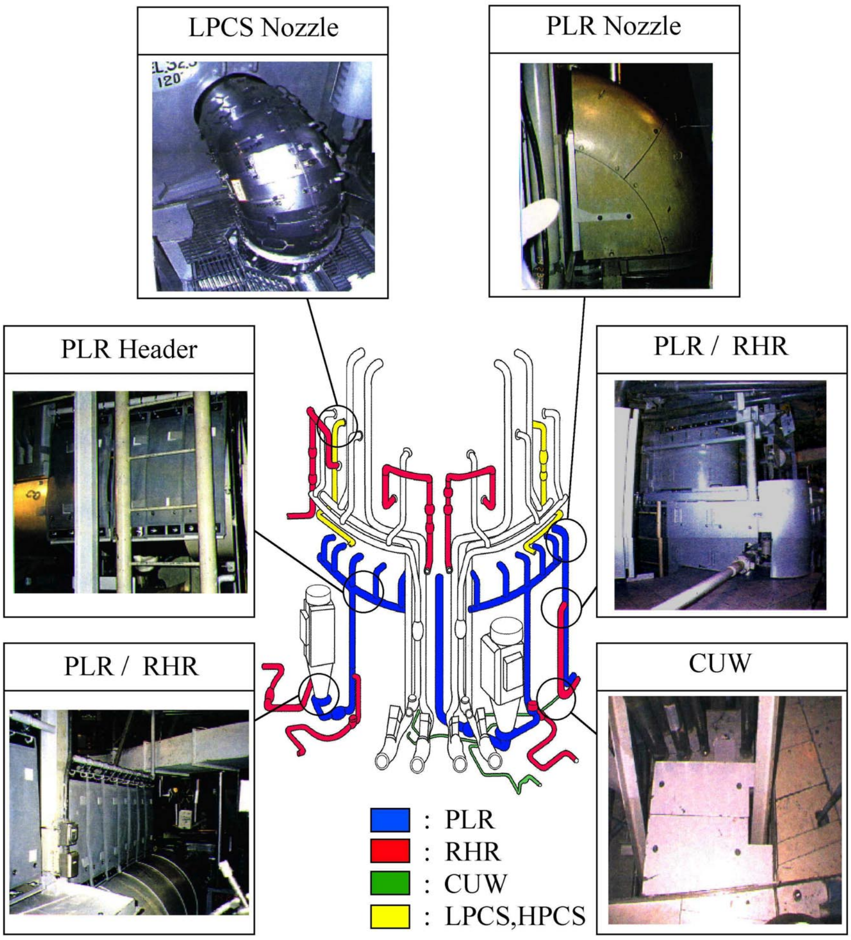


Fig.7 Sample Pictures of Permanent Shielding in the PCV of Tokai-II

annual outages, from 1998 to 1999. The remaining piping in the PCV, which could not be shielded in the former dose reduction, was shielded in the 16th and 17th annual outage. The pipe outside of the PCV in reactor building, which has high dose rate at the passage, was shielded. And the pipe for the PLR (B) system was shielded in the 9th annual outage.

3.3 TYPE OF SHIELDING

Figure 6 shows the type of permanent shielding. Three types of shielding were applied, the iron plate type, the mattress type including the lead fiber and the thermal insulation type including the lead plate.

Most part of the PLR pipe was shielded by the 25 mm thickness of iron plate and the RWCU pipe was shielded by the 60 - 70 mm thickness of iron plate. A kind of access door was installed on this type of shielding for the In-service Inspection (ISI) of pipe and valve overhaul.

The mattress type including the lead fiber was applied for the shielding of the suction pipe, the discharge pipe of the PLR pump and the piping which has a gap should be shielded.

The thermal insulation type including the lead plate was applied for the pipe, which has no place to install the iron plate type or the mattress type including the lead fiber. A part of the RWCU pipe, the RHR pipe, the Low Pressure Core Spray (LPCS) system pipe and the High Pressure Core Spray (HPCS) system pipe were shielded by the thermal insulation type shielding. The 20mm thickness of lead plate was installed in the thermal insulation.

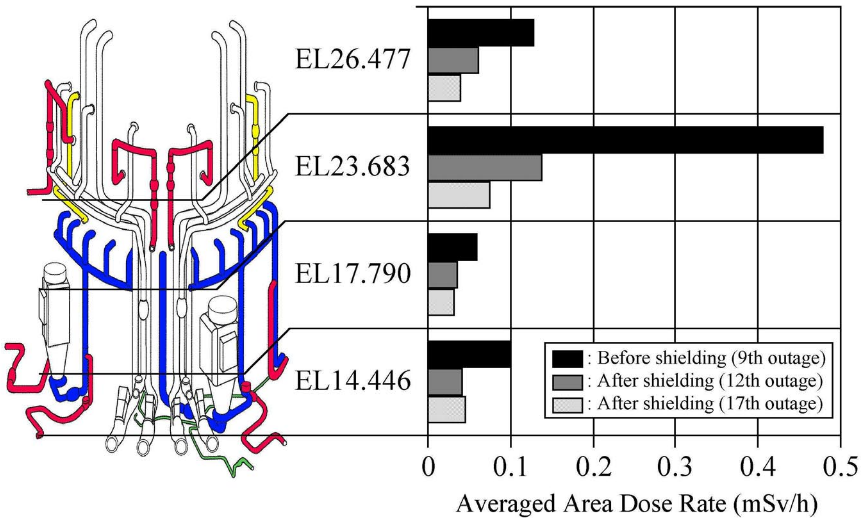


Fig.8 Averaged Area Dose Rate in the PCV of Tokai-II

3.4 PERMANENT SHIELDING RESULTS

Figure 7 shows the result of the pipe shielding. Figure 8 shows the averaged area dose rate in PCV in the 9th outage, the 12th outage and the 17th outage and Figure 9 shows the measured area dose rate in PCV in the 9th outage, the 12th outage and the 17th outage.

The averaged area dose rate of the EL 14.446 floor was 0.1 mSv/h before shielding in the 9th outage and 0.044 mSv/h after shielding in the 17th outage. The averaged area dose rate of the EL 17.790 floor was 0.061 mSv/h before shielding in the 9th outage and 0.038 mSv/h after shielding in the 17th outage. The 25 mm thickness of iron plate for the PLR pipe and the 60 - 70 mm thickness of iron plate for the RWCU pipe reduced the area dose rate of the EL 14.446 and the EL 17.790 floor.

The averaged area dose rate of the EL 23.683 floor was 0.48 mSv/h before shielding in the 9th outage and 0.14 mSv/h after shielding in the 17th outage. The 25mm thickness of iron plate for the PLR pipe reduced the area dose rate of the EL 23.683 floor.

The averaged area dose rate of the EL 26.477 floor was 0.13 mSv/h before shielding in the 9th outage and 0.042 mSv/h after shielding in the 17th outage. The thermal insulation type shield for the RHR pipe, the LPCS pipe and the HPCS pipe reduced the area dose rate of the EL 26.477 floor.

The first permanent shielding is assumed that approx. 1.2 person-Sv has been reduced with applying the 89 tons of iron and lead shielding. We assume that approx. 0.3 person-Sv has been reduced with applying the 21 tons of iron and lead shielding.

4. SUMMARY

The occupational radiation exposure of the 6th outage (1984) showed the highest value of 4.89 person-Sv. We started the study on dose reduction measurements and we set the target, "reduce the occupational

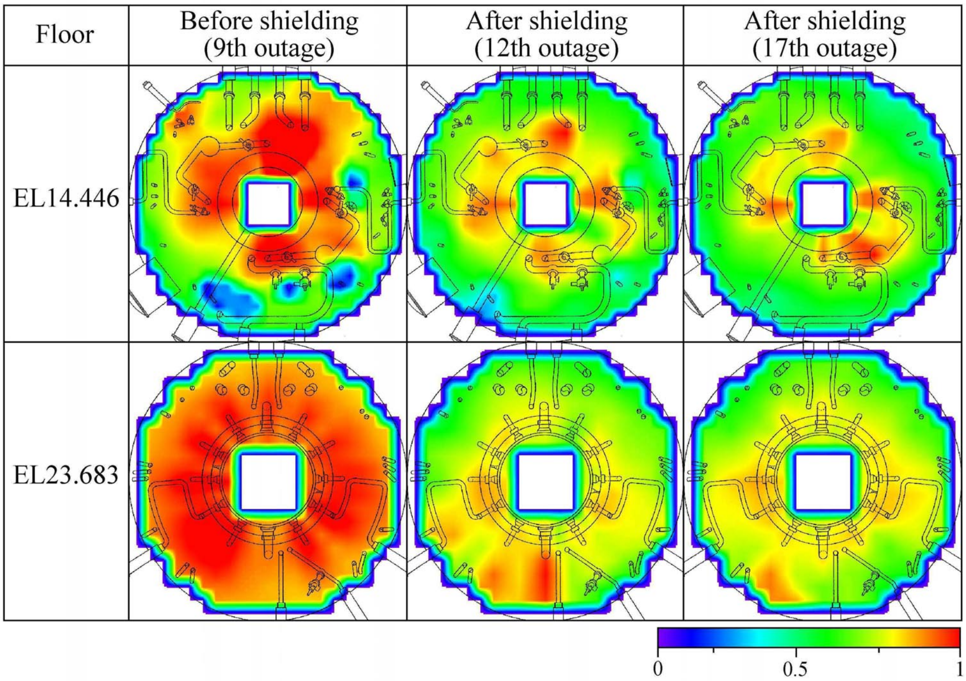


Fig.9 Measured Area Dose Rate in the PCV of Tokai-II

radiation exposure half in five years" that is, reduce the exposure from 4.89 person-Sv to 2.5 person-Sv.

Following action items were applied to meet the dose reduction target.

(1) Reduction of radiation sources
(2) Improvement of workability and Remote operation
(3) Organization of ALARA control
(4) Installation of permanent shielding

The occupational radiation exposure has reduced to 1.6 person-Sv in recent year. We assume that the following value has been reduced with applying the dose reduction items.

(1) 0.2 person-Sv due to the reduction of radiation sources
(2) 0.3 person-Sv due to the improvement of workability and remote operation
(3) 1 person-Sv due to the organization of ALARA control action
(4) 1.5 person-Sv due to the installation of permanent shielding

5. CLOSURE

JAPCO people and all the company people related to the annual outage maintenance work, and all of the sections, maintenance section, chemical section and health physics section co-operated to study the dose reduction procedure for a long time.

An attempt was made to reduce the occupational radiation exposure using the measurement combining the radiation source reduction, the remote operation, the ALARA review team and the permanent shielding. The results revealed very effective to reduce the occupational radiation exposure.

6. REFERENCES

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2. K.Hisamune, et al., *Characterization of Fuel and Pipe Surface Deposit in Tokai-2*, Proceedings of 1991 JAIF International Conference, pp.444-449 (1991)