Dose Rate Reduction Methods at Shimane Nuclear Power Station

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Abstract

The Chugoku Electric Power Company has been wrestling with dose rate reduction systematically, because the dose rate increase of RRS piping increased after adopting the hydrogen injection to prevent SCC and the radiation exposure reduction became the urgent problem at Shimane Nuclear Power Station Unit 1.

As a result of adopting the countermeasures such as Hi-F Coat*1 [1][2], NWC pre-oxidation operation*2 and so on, the dose rate could be reduced. We continue to wrestle with the further dose rate reduction in future.

1. Introduction

Shimane Nuclear Power Station Unit 1 continues operating smoothly since commercial operation started in 1974. However, an increasing trend of the dose rate has been observed since the hydrogen injection was applied as a countermeasure to prevent SCC at 21st operating cycle (1998) and the dose reduction became the urgent problem.

So, the headquarters and the power station in the nuclear division are cooperatively wrestling with the dose rate reduction.

2. Radiation exposure of the 27th outage at Shimane Nuclear Power Station Unit 1

An increasing trend of the atmospheric dose rate in the pressure containment vessel (PCV) has been observed since the hydrogen injection was applied at the 21st operating cycle and the total radiation exposure of the 27th outage became 4.12 person・Sv as shown in Fig. 1. Especially radiation exposure of the regular outage works became 3.03 person・Sv. This is the highest value after the 21st cycle and the 2nd highest one among the past 27 times outage. It is also the highest level among the total radiation exposure of the outage works in recent Japanese BWR plants.

The cause of radiation exposure increase was due to the increase of piping and equipments surface dose rate. The RRS piping was the representative one. The dose rate of the RRS piping was stable about 0.5 mSv/h before hydrogen injection as shown in Fig. 2. But, it began to increase after the hydrogen injection and the average dose rate was about 1.4 mSv/h at the 27th outage. Especially, rapid dose rate increase after 1 cycle operation was observed when chemical decontamination was applied in the outage. This was a big problem to deal with.

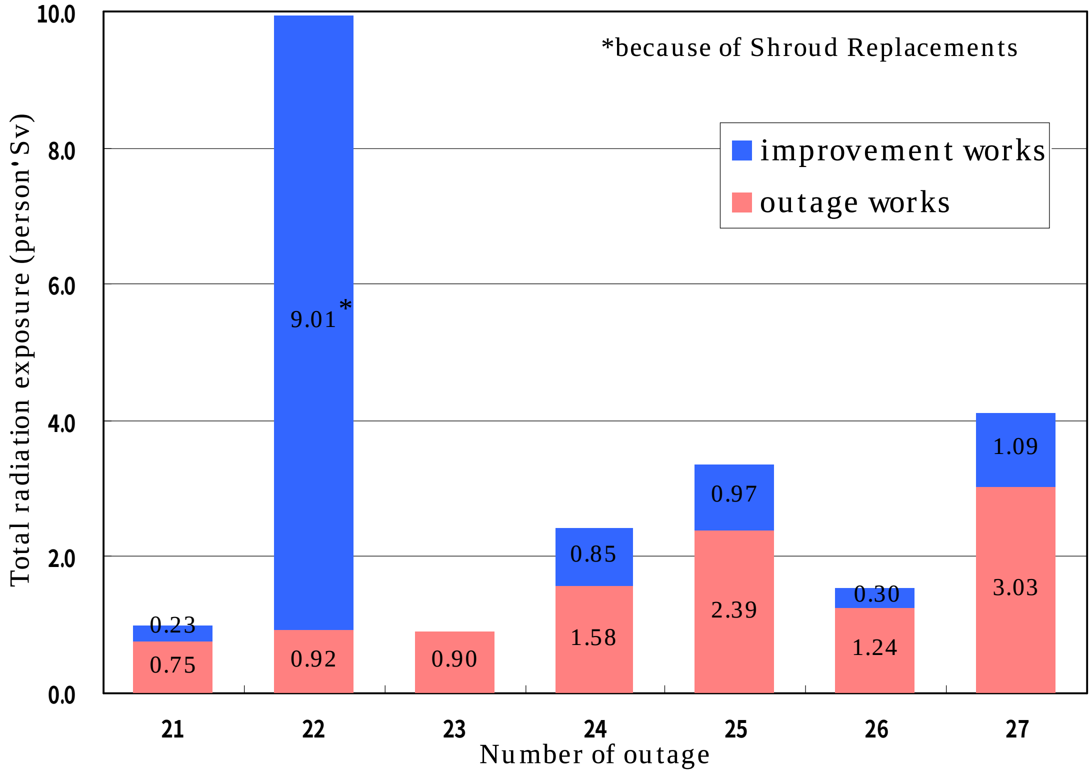

Figure 1 Radiation exposure at Shimane Nuclear Power Station Unit 1 after hydrogen injection

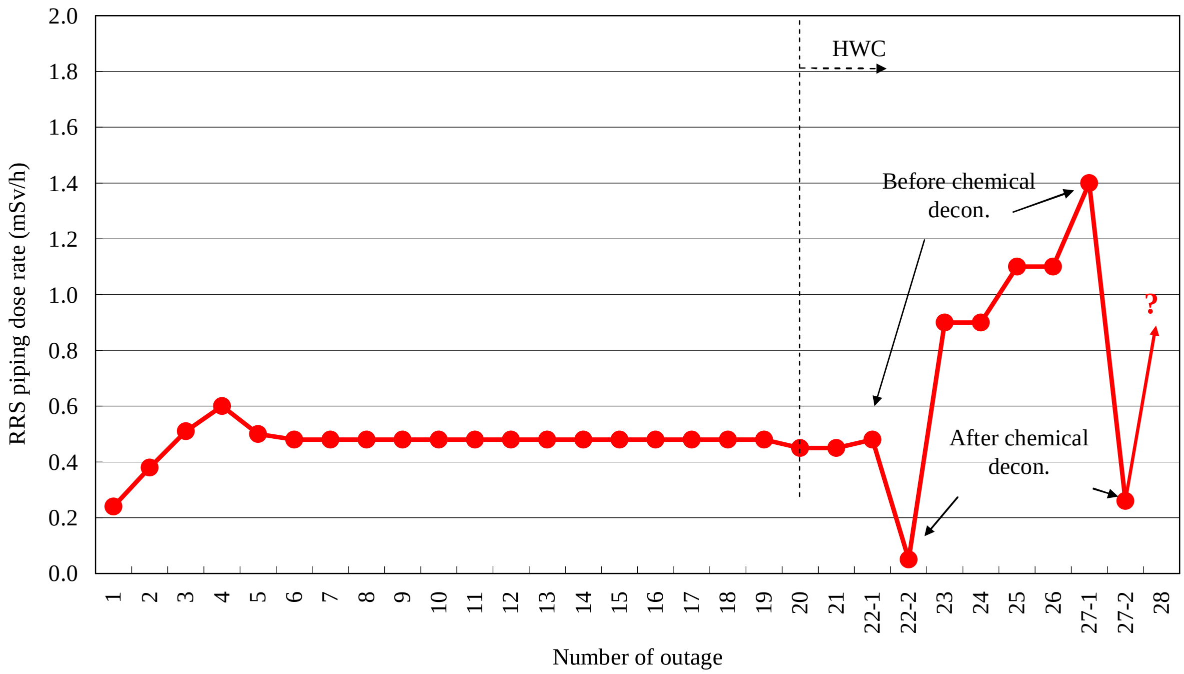

Figure 2 RRS dose rate trend at Unit 1

3. Dose rate reduction committee

Countermeasures to reduce dose rate of RRS piping have been studied mainly by radiation control staff at Shimane Nuclear Power Station. However, not only radiation control staff, but also maintenance staff and chemistry control staff were assigned to wrestle with the dose rate reduction cooperatively based on the present dose rate and the future company needs.

The dose rate reduction committee, which has been operated based on the necessity, reinforced its functions. New chemistry control WG, equipment management WG and radiation control WG were settled under the committee to study the detail countermeasures to reduce dose rate as shown in Fig. 3.

Furthermore, headquarter persons were added to the committee members and they began to wrestle with the dose rate reduction all in one body with the power station staff.

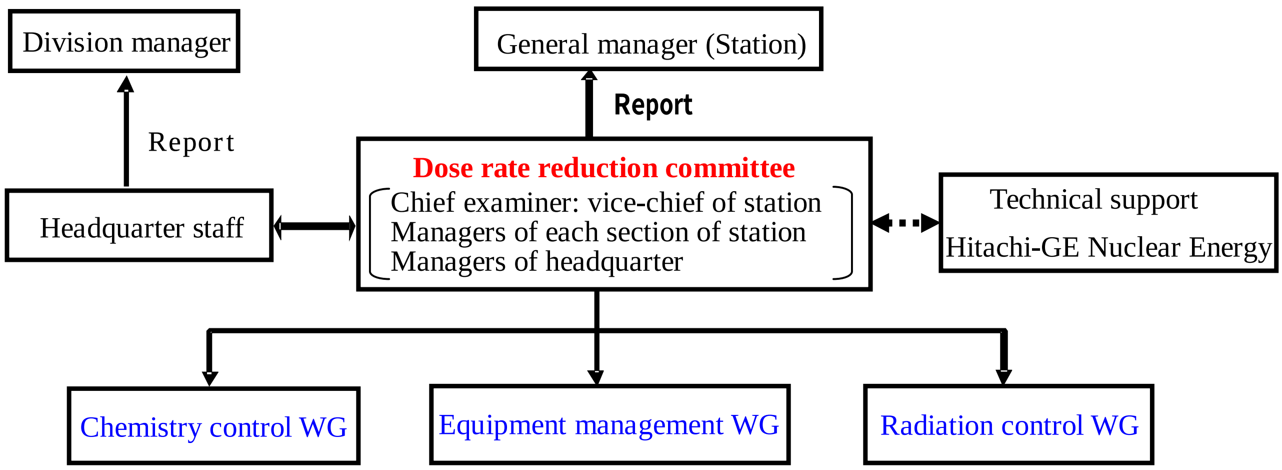

Figure 3 Structure of dose rate reduction committee

4. Examination items of dose rate reduction committee

Although there is a fact that higher feedwater hydrogen concentration results in larger incorporation of Co-60 into the oxide film and higher dose rate of RRS piping in the previous knowledge, there is an another company need of higher hydrogen concentration and higher availability from the viewpoint of SCC suppression in order to operate the plant smoothly.

Then, the countermeasures to reduce radiation exposure have been studied the predetermined items from the viewpoint of chemistry control, equipment management and radiation control in each WG.

Figure 4 shows the examination items at dose rate reduction committee. Short term target was to lessen the dose rate of 28th outage at Unit 1. Countermeasures to need a long time were placed in the middle and long term items and adopted as permanent ones.

Item	Chemistry control WG	Equipment management WG	Radiation control WG
Objectives	Dose rate reduction in PCV	Improvement of work methods and work environment	Improvement of radiation control
Matters	NWC pre-oxidation operation, CF bypass operation, Hi-F Coat, etc	Survey of remote automatic equipments, Additional permanent shielding, Enlargement of chemical decontamination area, Improvement of work procedure, etc	Piping dose rate prediction method, Temporary shielding, Survey of good practice, etc

Extension to middle and long term

Middle and long term matters	Zinc injection, Improvement of water chemistry control, etc	Application of remote automatic equipments and permanent shielding, etc	Establishment of piping dose rate prediction method and temporary shielding, etc

Figure 4 Examination items at dose rate reduction committee

5. Applied countermeasures until 28th outage and their results

Hi-F Coat*[1], which is a technique to form the oxide film compulsorily, was applied after chemical decontamination at the 27th outage. And NWC pre-oxidation operation*[2] of 90 days was conducted at the beginning of the 28th operating cycle to form a fine oxide structure under NWC conditions.

As a result of above countermeasures, dose rate of RRS piping was about 0.5 mSv/h at the 28th outage at Unit 1 and became much lower than that at the 27th outage as shown in Fig. 5. It was confirmed that applied Hi-F Coat and NWC pre-oxidation operation were effective to reduce dose rate of RRS piping. The reason to be able to realize low dose rate was considered due to the protective film formed by Hi-F Coat and NWC pre-oxidation operation, which suppressed the Co-60 accumulation into the oxide film.

According to this low dose rate, total radiation exposure during the 28th outage could be suppressed to about 55% of the planned value. So, planned total radiation exposure was changed from 4.2 person • Sv to 2.3 person • Sv. The result of total radiation exposure during the 28th outage is shown in Fig. 6. Addition to this radiation exposure reduction, term of the 28th outage could be cut for 45 days compared to the original plan because of smooth works under the low dose rate circumstances, which also contributed to improve the plant availability.

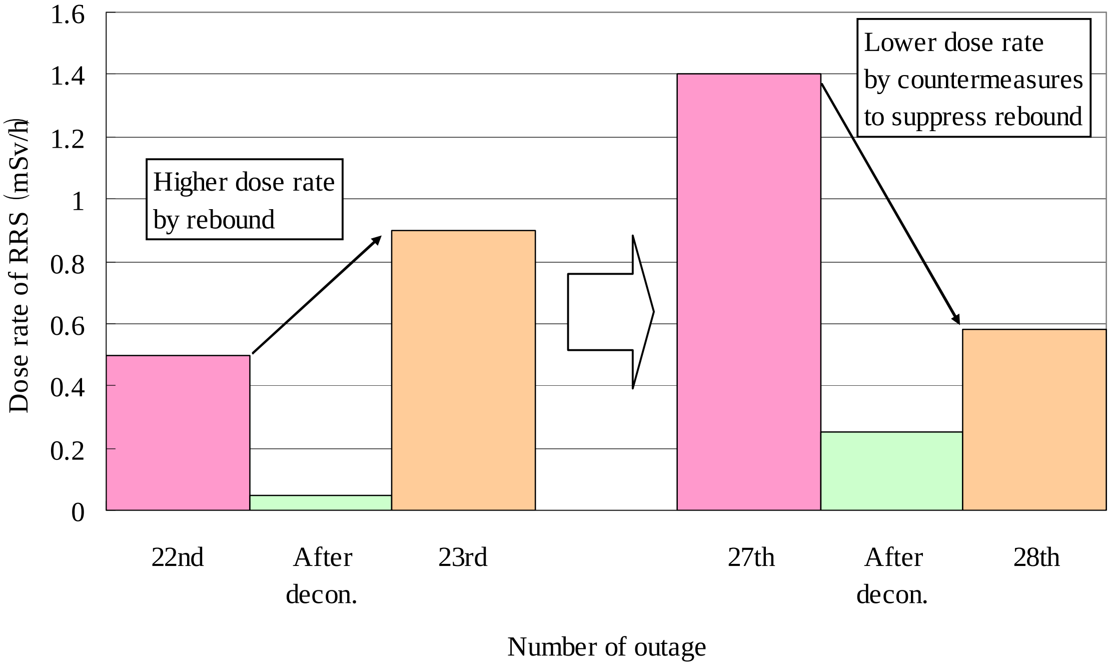

Figure 5 Dose rate change of RRS piping after the 27th outage

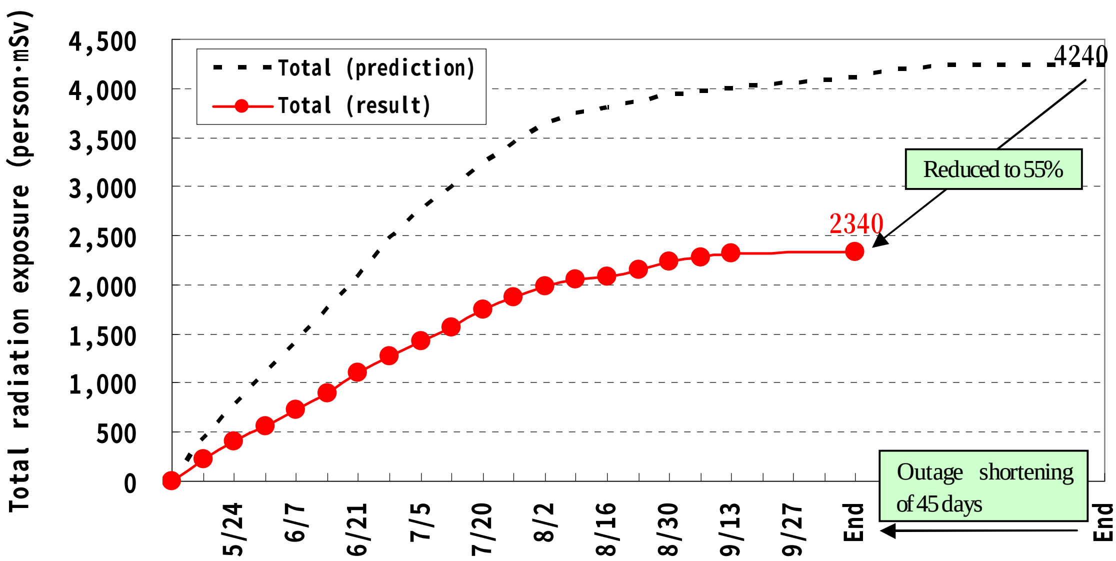

Figure 6 Trend of total radiation exposure during the 28th outage

6. Future activities

This time countermeasures were confirmed to be effective as dose rate reduction methods. We are now evaluating the contribution and durability of Hi-F Coat and NWC pre-oxidation operation and also examine the effectiveness as a permanent countermeasure.

As further countermeasures, an on-line monitor, zinc injection and temporary shielding will be examined by the dose rate reduction committee.

(1) On-line monitor

If a real time dose rate of RRS piping during plant operation can be measured, it is considered to be effective for water chemistry control such as hydrogen injection rate and outage planning such as a judgment to do chemical decontamination in order to realize low dose rate at the following outage systematically. So, we decided to develop an on-line monitor and set up the experimental equipments to gather basic data such as energy distribution of gamma ray and atmospheric dose rate under the operating condition in the PCV during the 28th outage. These data were obtained during the 29th operation cycle and used to design an actual on-line monitor.

(2) Zinc injection

Zinc injection is widely known as an effective method to reduce piping dose rate. It has been examined as a permanent countermeasure to reduce dose rate to meet the company need to continue hydrogen injection. Survey of zinc injection practices in worldwide and laboratory experiments were conducted and its effectiveness was confirmed to Shimane Nuclear Power Station last year. Its applicability to the plants is being examined further in detail.

References

[1] H. Hosokawa, et.al., “Development of a Suppression Method for Deposition of Radioactive Cobalt after Chemical Decontamination: (I) Effect of the Ferrite Film Coating on Suppression of Cobalt Deposition”, J. Nucl. Sci. Technol., Vol. 47, No. 6, p. 531–537 (2010)

[2] T. Ito, et.al., “Development of a Suppression Method for Deposition of Radioactive Cobalt after Chemical Decontamination: (II) Consideration of Fe_3O_4 Plating Mechanism on Stainless Steel in Aqueous Solution at 363K”, J. Nucl. Sci. Technol., Vol. 47, No. 8, p. 698–704 (2010)

*1：Hi-F Coat is an abbreviation of Hitachi Ferrite Coating and it forms the magnetite film which is one of chemical forms formed under normal water chemistry conditions (no hydrogen injection). It is done by circulating iron formate solution in the system at the final step of chemical decontamination. This oxide film suppresses to form the inner oxide layer which is easy to incorporate cobalt.

*2：Under normal water chemistry (NWC) conditions, a fine oxide film which is not easy to incorporate cobalt is formed compared to the hydrogen injection conditions. By using this feature, hydrogen injection is stopped for a certain period such as about 50 days and it is started after that.