Measures for containing an increase in pipes' dose-equivalent rate in the hydrogen-injected environment at the Shimane Nuclear Power Station Unit 1

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Introduction

It is an important task for nuclear power stations to reduce the dose of radiation exposure on plant operators and maintenance workers. A range of measures is implemented from the perspectives of facilities, operations and water quality management. In terms of water quality management, plants are required to keep the concentration of radioactive materials in reactor water low, and contain the amount of radioactive deposits on the inside of piping systems around reactors, so as to reduce the amount of radioactive material generation and accumulation.

In an effort to reduce radiation dose, the Shimane Nuclear Power Station has adopted the filtration and desalination devices to the condensate purification and reactor purification systems, increased the capacity of the reactor purification system, introduced hydrogen injection to the condensate system, and implemented various other dose reduction measures in the plant's design and operation stages in terms of water quality control.

In addition in February 1998, Shimane Unit 1 began oxygen injection into the feed-water system to counter stress corrosion cracking (SCC).

Today, we introduce hydrogen injection and other measures that have been implemented to date to contain an increase in piping dose-equivalent rate and control the water quality.

1. Outline of Shimane Nuclear Power Station

The Shimane Nuclear Power Station is situated at the center of Shimane Peninsula in eastern Shimane Prefecture. The picturesque site, facing the Sea of Japan, is in Shimane's prefectural capital, Matsue City. (Figures 1 and 2)

The plant has Unit 1 and Unit 2. Unit 1 is a BWR plant with the power output of 460,000kW. Since the commercial operation launch in March 1974, it has sustained stable operations for over 30 years and is currently undergoing the 26th outage. Unit 2 is an 820,000kW BWR plant, which started its commercial operations in February 1989 and is now in the 14th cycle of operations.

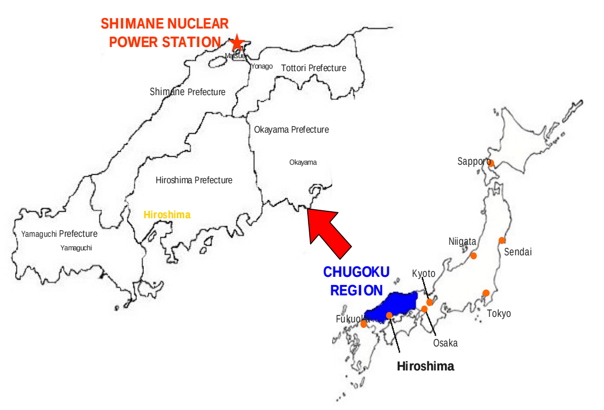
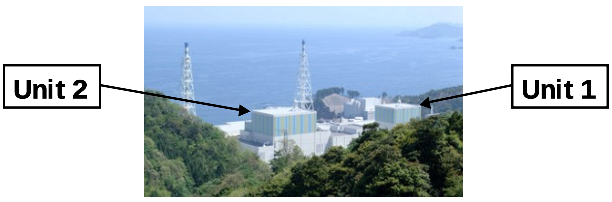


Fig.1 Outline of Shimane NPS(1/2)



Unit No.	Capacity (MW)	Reactor Type	Commercial Operation
1	460	BWR	Mar.1974
2	820	BWR	Feb.1989

Fig.2 Outline of Shimane NPS(2/2)

2. Hydrogen injection performance

Shimane Unit 1 introduced a hydrogen injection facility in January 1998. After trial injection at the concentration of 0 to 0.7ppm in stages, continuous injection at 0.5ppm started in February 1998.

The feed-water hydrogen concentration has since been changed from the initial 0.50ppm to 0.45ppm and 0.40ppm in view of influence on the main steam (MS) monitor.

3. Transition of primary piping dose-equivalent rate after hydrogen injection

Figures 3 and 4 shows the amount of nuclide deposits and dose-equivalent rate for the Primary Loop Recirculation (PLR) system piping, measured at the 21st outage after the first cycle beginning hydrogen injection.

The PLR piping A was recording around 0.4mSv/h of dose-equivalent rate, well below 1mSv/h, before hydrogen injection. At the 21st outage, the figure was around the same on the PLR pump inlet, but climbed to 2mSv/h on the outlet.

The piping B showed similar results to piping A, showing no major changes in dose-equivalent rate before and after hydrogen injection on the pump inlet, but increasing to around 4mSv/h on the outlet.

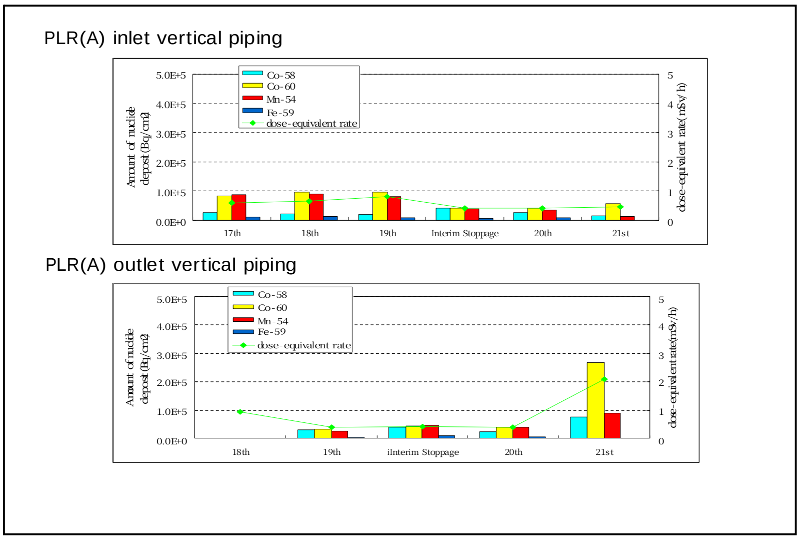


Fig.3 Transition of PLR piping dose - equivalent rate(Pump A(21st outage))

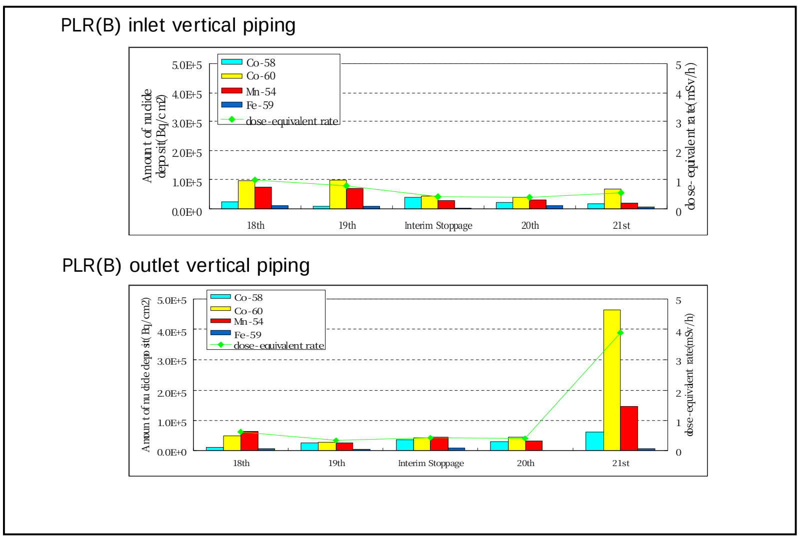


Fig.4 Transition of PLR piping dose - equivalent rate(Pump B(21st outage))

4. Management of gradual hydrogen injection termination

(1) Cause of the dose-equivalent rate increase

The dose-equivalent rate increase at the PLR pump outlet piping in the 21st outage may have been caused by hydrogen injection in the 21st cycle. Figure 5 shows the pattern of hydrogen injection in the 21st cycle. In the 21st cycle, hydrogen injection operations continued for around 300 days before the injection was terminated.

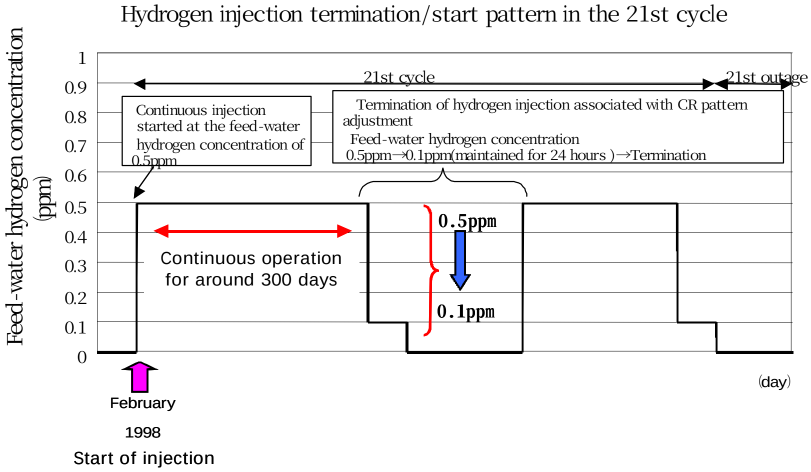


Fig.5 Hydrogen injection termination/start pattern (21st cycle)

After 300 days of hydrogen injection operations, piping internal surfaces were heavily coated with chromium oxide. Sudden termination of hydrogen injection in this state changed the reactor water environment from a reductive to an oxidative atmosphere, thereby dissolving the chromium on piping internal surfaces and increasing the reactor water's conductivity.

Figure 6 shows the transition of reactor water conductivity and chromic acid concentration upon the termination of hydrogen injection.

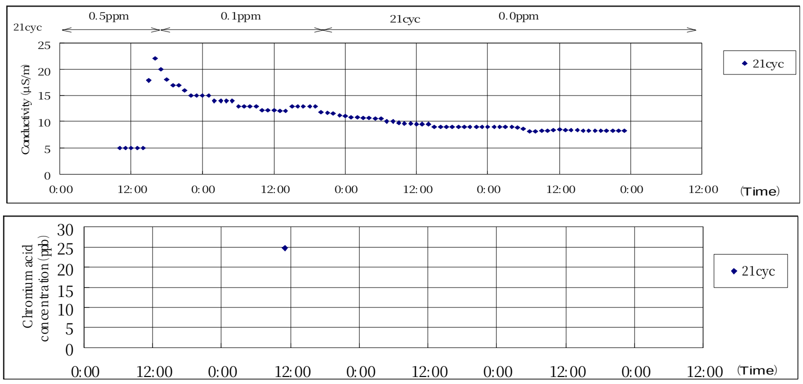


Fig.6 Transition of reactor – water conductivity and chromium acid concentration (21st cycle)

The dose-equivalent rate of the PLR pump outlet piping is believed to have increased due to the facts that swirls on the outlet side significantly disturbed the flow, and that chromium elution upon hydrogen injection termination and chromium oxide buildup upon injection resumption aggravated the unevenness of piping internal surfaces, which led to localized deposition of Co-60 and other radioactive material (cladding)..

(2) Implementation of improvement measures

a. Gradual hydrogen injection

Hydrogen injection is conducted gradually to alleviate the changes in reactor water environment from HWC to NWC.

(HWC: Hydrogen Water Chemistry

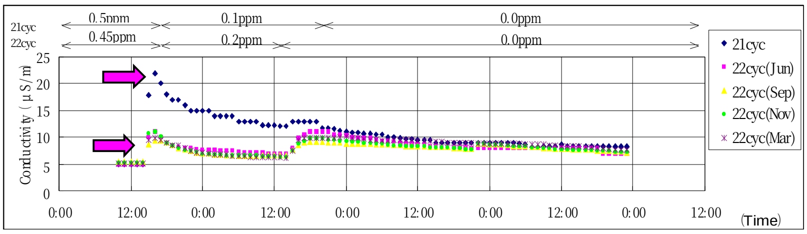
NWC: Normal Water Chemistry)

More specifically, the amount of hydrogen injection was reduced from 0.45ppm to 0.2ppm on Day 1, and brought down to 0ppm after a 24-hour hold. When hydrogen injection was resumed, the amount was gradually increased from 0ppm to 0.2ppm and 0.45ppm to contain major changes.

b. Chromium discharge operation

Once every three months, chromium discharge operation was conducted to contain the buildup of chromium oxides in long-term hydrogen injection.

Figure 7 shows the transition in reactor water conductivity and chromium acid concentration upon the termination of hydrogen injection in the 21st and 22nd cycles.



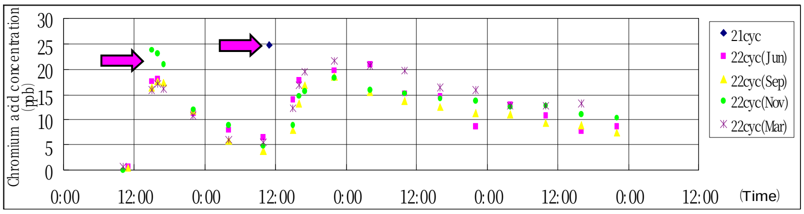


Fig.7 Transition of reactor – water conductivity and chromium acid concentration (21st and 22nd cycle)

In the 22nd cycle, hydrogen injection was stopped once every three months and four times during the cycle for chromium discharge.

Reactor water's conductivity increased to coincide with changes in hydrogen concentration, and reached 23μS/m in the 21st cycle. However, the figure was as low as 10μS/m in the 22nd cycle, demonstrating the effect of gradual termination.

The effect of gradual termination is also seen in the concentration of chromium acid, which was kept low in correlation with conductivity.

Figures 8 and 9 shows PLR piping dose-equivalent rate and the amount of nuclide deposits in the 22nd outage. The dose-equivalent rate of the PLR pump outlet, which recorded an increase in the previous outage (21st), showed a decrease as a result of the three-monthly gradual termination / resumption of hydrogen injection, i.e. repeated oxidative and reductive operations, which eluted chromium oxide deposits and consequently separated radioactive cladding (Co-60, etc.).

Similarly to the PLR piping A, the piping B showed a dramatic drop in dose-equivalent rate on the PLR pump outlet, with no major changes from the previous outage on the inlet side.

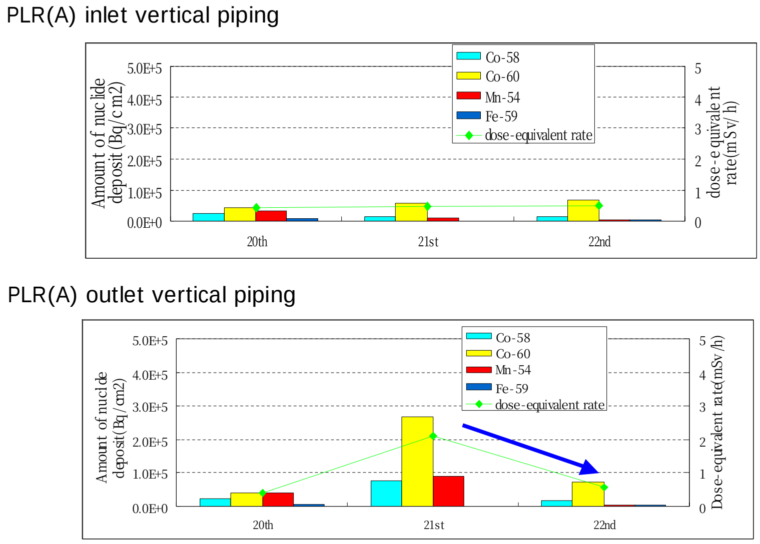


Fig.8 Transition of PLR piping dose-equivalent rate (Pump A (22nd outage))

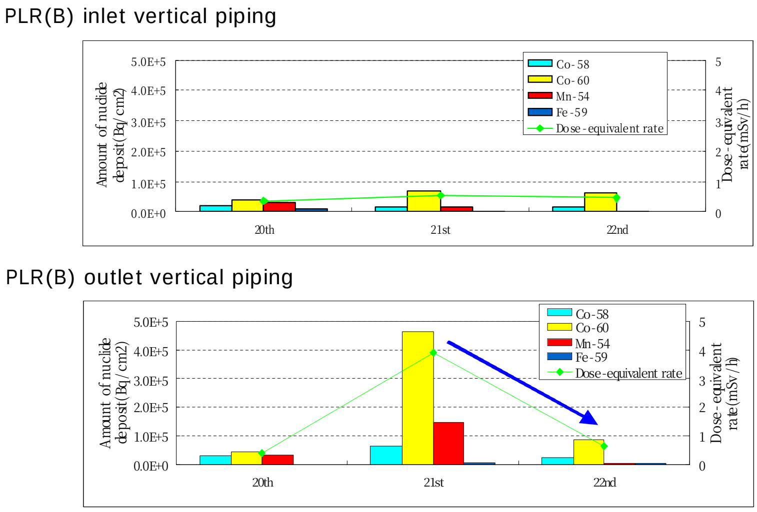


Fig.9 Transition of PLR piping dose-equivalent rate (Pump B (22nd outage))

(3) Piping dose-equivalent rate after improvement

Following the implementation of measures to contain the increase of piping dose-equivalent rate, including gradual hydrogen injection / termination, the current piping dose-equivalent rate registers no marked increase, and no difference between PLR pump inlet and outlet sides. Figures 10 and 11 shows the current PLR piping dose-equivalent rate and the amount of nuclide deposits.

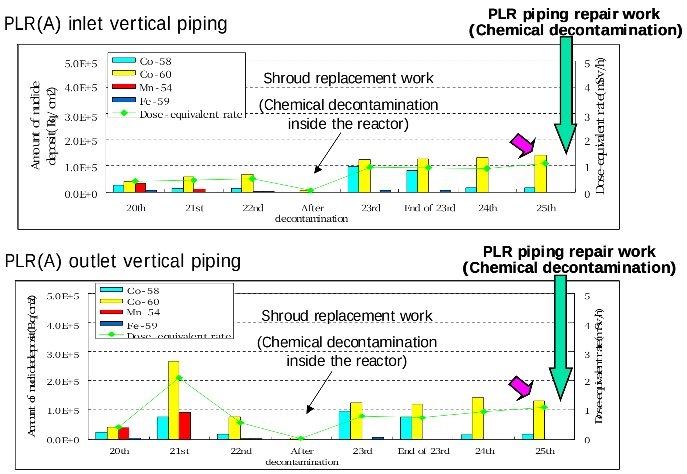


Fig.10 Current PLR piping dose-equivalent rate (Pump A (25th outage))

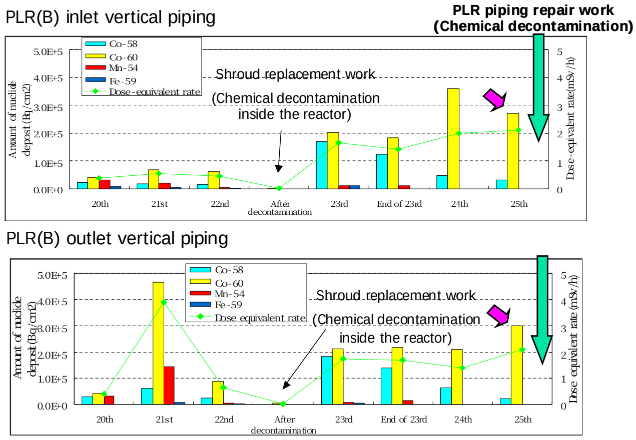


Fig.11 Current PLR piping dose-equivalent rate (Pump B (25th outage))

5. Measures to contain piping dose-equivalent rate increase after chemical decontamination

Shimane Unit 1 has conducted chemical decontamination inside the reactor following shroud replacement. The piping dose-equivalent rate ratio between before chemical decontamination and after one cycle of operation (rebound rate) has been high at no less than "2". Since the reactor water's radiation concentration remains low, the high rebound rate is attributed to an increase in Co-60 piping deposit speed factor.

In order to keep the post-decontamination piping deposit speed factor low, it has been decided to conduct a preliminary oxidative operation for forming fine film on piping internal surfaces (operation that ensures a set period of NWC). At the 25th outage, Shimane Unit 1 undertook chemical decontamination to reduce exposure, in relation to the PLR piping replacement work. The effect of this preliminary oxidative operation will be examined in this outage.

6. Application to Unit 2

A hydrogen injection facility was introduced to Shimane Unit 2 in May 2006. The method for controlling hydrogen injection is to be determined based on experiences at Unit 1 and other Japanese BWR plants, in an effort to reduce piping dose-equivalent rate.

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