Evaluation of RCS Zinc Injection in the Hanbit Unit 3

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1. Introduction

The principle of zinc injection is to continuously inject a small amount of zinc solution into the Reactor Coolant System (RCS), and the Co-58 generated by Ni from materials of steam generators and main piping is replaced by zinc. As Co-58 releases from the oxide layers, radiation fields are reduced. Moreover, zinc injection improves the corrosion resistance of the primary system materials.

Hanbit Unit 3 performed first zinc injection into the reactor coolants during 17 cycle, the 2nd injection at 18 cycle, and 3rd injection at the 19 cycle. The radiation doses during the period of zinc application were analyzed to determine how effectively zinc incorporates into oxide layers and reduces radiation doses in the primary system.

2. Method and Results

2.1 Zinc Injection Location, Amount and Period

The zinc injection point is between the Volume Control Tank (VCT) and Chemical and Volume Control System (CVCS) charging pump suction (Figure 1).

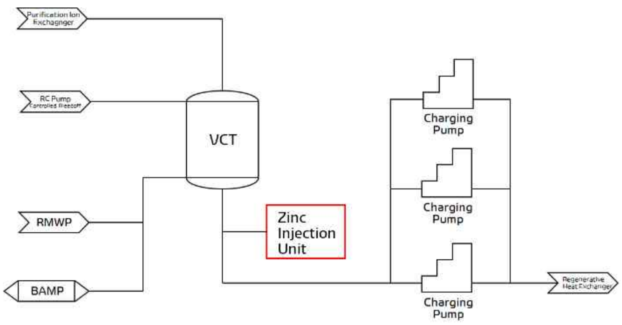

Figure 1. Zinc injection location

In order to prevent the possibility of occurrence Axial Offset Anomaly (AOA), the time of zinc injection is followed by continuous operation of about 5~7ml for 24 hours through a core evaluation.

The period of Hanbit Unit 3 18th cycle is from November 14, 2020 to March 22, 2022. After core evaluation, zinc injection was started on July 23, 2021 which is 200 Effective Full Power Days (EFPD), and stopped on March 18, 2022.

The effect was evaluated by identifying the behavior of radionuclides in the pipe surface area before and after zinc injection, the behavior RCS liquid radioactivity, and the exposure dose of workers during refueling outage (RFO).

2.2 Pipe surface area radionuclide behavior

In order to determine how effective zinc injection is by identifying the nuclide behaviors of the pipe oxide layers, CdZnTe Quasi-Hemispherical Detector (CZT) was used. It was installed at the front of the CVCS purification filter of the Hanbit Unit 3 as shown in the figure 2.

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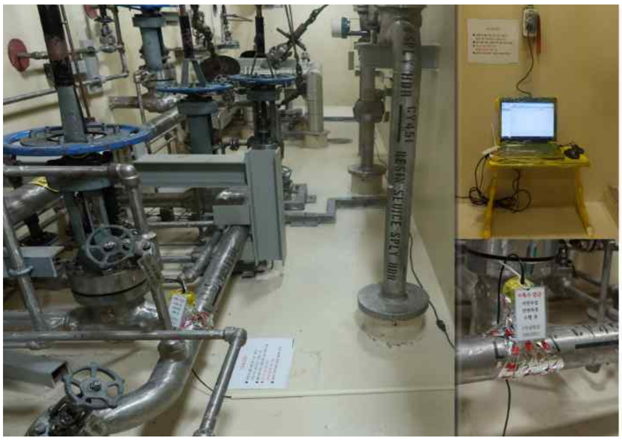

Figure 2. CZT install at the front of the CVCS filter

The CZT was installed before zinc injection, and measurements were performed for 600 seconds, once a week from April 20, 2021 to March 15, 2022, to examine nuclide behavior of piping oxide layers before and after zinc injection. The five major corrosive nuclides in pipes were selected and evaluated, and changes were identified.

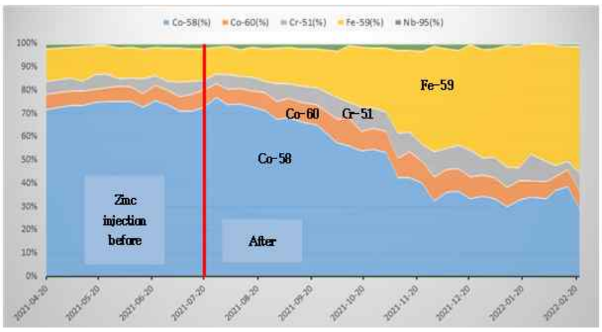

Figure 3 The behaviour radionuclides in the pipe

As shown in the figure 3, the behaviour was evaluated by the fraction of each nuclides, and the change by nuclides was identified by calculating the average value of the specific activity concentration before and after zinc injection. As a result of the analysis, the specific radioactivity values of Co-58 and Co-60 were reduced by 48.9% and 11.7%, and the radioactive fraction of Co-58 and Co-60 in the pipe was also reduced from 73.7% to 52.4%. Fe-59 was released from oxides present in the core crud and moved to the pipe, resulting in a 59.4% increase in the CVCS pipe. The specific radioactivity according to the zinc injection in the oxide film of the CVCS pipe showed a 44.9%, 27.2% reduction effect considering Co-58 and Co-60, which are the main nuclides for zinc injection evaluation. The total amount of five radionuclides reduced by 27.2%.

2.3 Radionuclide behaviour in RCS

According to the principle of zinc injection, oxide layers are formed with zinc oxides, and the substituted Co-58 releases through the RCS and is removed by the ion exchange and filters. The behaviour of radionuclides was identified through a gamma nuclide analysis.

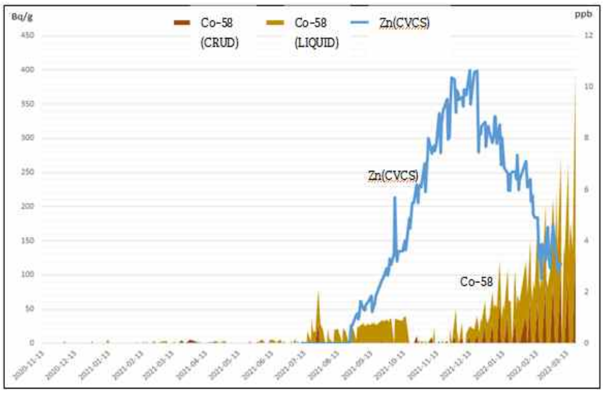

Figure 4. Co-58 in RCS during Zinc injection

As shown in the figure 4, the trends before and after zinc injection of Co-58, the main radionuclide in RCS liquid radioactivity and released into RCS by zinc, continuously increased. It was confirmed that it increased up to 9.86 times after zinc injection, and it can be seen that the substitution effect according to zinc injection is large.

Moreover, it was confirmed that corrosion products, also continuously increased as the substitution reaction of zinc into oxide layers. The increased radionuclides in the RCS were removed through the ion exchange resin along the flow path, showing the effect of reducing radioactivity.

2.4 Worker exposure dose reduction

Another indicator to evaluate the effect of zinc injection is the radiation doses of exposure to workers. After the zinc injection was completed, the radiation exposure of workers in the radiation control area during RFO was evaluated and the effect was compared with the data during RFO before zinc injection.

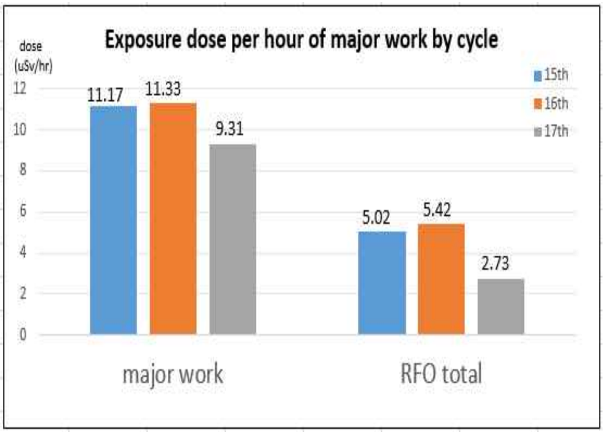

Figure 5. Exposure dose per hour of major work

The radiation exposure doses per working hour for major works during RFO was 17.8% compared to the previous RFO. About 50% of radiation exposure decreased for the total works (Figure 5). The dose rates of Steam Generator (SG) channel head also decreased by 36%, and the radiation exposure to workers also decreased accordingly.

3. Conclusion

The zinc injection is very important role to reduce the radioactive concentration. As mentioned above, it was confirmed that the radionuclides of pipe oxide layers were reduced effectively through the zinc injection. It is also very important to analyse the effect of zinc injection by identifying the trends of radionuclides in the pipe oxide surface area by using CZT equipment. It is also very useful to determine the effect of zinc injection by the trends of radionuclides in the RCS using a gamma spectroscopy.

In conclusion, the radiation dose rates and radioactive corrosion products of primary system were improved by performing the zinc injection, and there was also an effect of reducing the radiation exposure of workers during RFO. This study will be used for further zinc application in domestic nuclear power plants.

4. REFERENCES

[1]EPRI, Pressurized Water Reactor Primary Zinc Application Sourcebook, Revision 1(TR-1025316), 2012.

[2]EPRI, Pressurized Water Reactor Primary Water Chemistry Guidelines, 2014.