Analysis of Sludge Deposition in Steam Generator during Operation of Domestic NPPs

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1. Introduction

During nuclear power plant operation, corrosion products (mainly iron oxides) are continuously generated due to corrosion of secondary system piping and equipment. Most of this flows into the Steam Generators (SGs) and is accumulated and hardened, which causes various problems such as inhibiting heat transfer from tubes and causing Stress Corrosion Cracking (SCC). So domestic nuclear power plants are managing limit 5 ppb of iron (Fe) in the feedwater, and it is very important monitoring parameter. In this study, the amount of iron oxides flowed into and deposited in SG during normal operation was evaluated for Domestic PWR NPPs.

2. Methods and Results

The evaluation method for calculating the amount of sludge deposited in SG and the results for domestic PWR NPPs are as follows.

2.1 Analysis of Iron Concentration in System Water

In order to evaluate the amount of sludge deposited in SG, the iron concentration in system water must be identified. The iron concentration analysis method currently applied to power plants is according to ASTM D6301. Using the equipment of the configuration shown in Fig. 1 [1], the system water is continuously passed through a filter to collect corrosion products. The filter is dissolved in acids and then the liquid sample is analyzed by Atomic Absorption Spectrometry (AAS) or Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES).

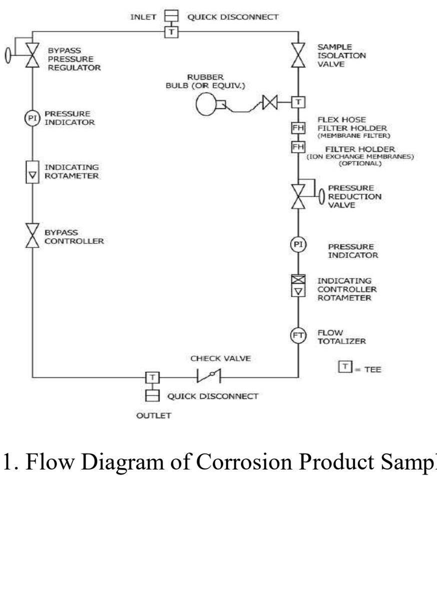

Fig. 1. Flow Diagram of Corrosion Product Sampler

2.2 Calculation of Sludge Deposition in SG

The amount of sludge deposition in SG during plant operation can be calculated through the following Eq. (1) [2,3].

$$M = (F_{FW} \times C_{FW} - F_{BD} \times C_{BD} - F_{MS} \times C_{MS}) \times t \times 1.38 \quad (1)$$

Where, M: accumulated mass in SG (kg, as Fe_3O_4)
F : mass flow rate (kg/hr)
C : iron (Fe) concentration (kg/kg)
FW : final feedwater
BD : steam generator blowdown
MS : main steam
t : operating hours
1.38 : conversion factor ($Fe_3O_4 \div Fe_3$)

In Eq. (1), iron particles are difficult to carry over to the steam, and iron ions contained in moisture present in less than 0.25% are extremely small, so the iron concentration of Main Steam (MS) can be assumed to be 0 ($C_{MS} = 0$).

2.3 Calculation Results of SG Sludge Deposit during Cycle Operation

The amount of sludge deposited inside the SG during normal operation was calculated for 21 units of domestic PWR NPPs. This was calculated through the results of one cycle operation that was completed for each unit from 2015 to 2021, and was calculated through the cycle average iron concentration and the flow rate for each system per unit.

In the case of the final feedwater iron concentration (C_{FW}), it is the result of sampling and analysis using a Corrosion Product Sampler (CPS) according to ASTM D6301. On the other hand, in the case of the SG blowdown iron concentration (C_{BD}), the concentration was calculated assuming 5 ppb because no CPS was installed on site.

The results of the evaluation of 21 units of domestic PWR NPPs are shown in Fig. 2. During the recent operation, an average iron concentration in feedwater was 2.2 ppb. The amount of sludge deposited in the steam generator, calculated considering the inflow through the feedwater and discharge through the SG blowdown, was an average of 204 kg as Fe_3O_4 (sum of total SGs).

From the results, although there is a difference in the flow rate of feedwater by unit, as a matter of course, the higher the iron concentration in feedwater, the higher the amount of sludge deposited in SG. In general, recently constructed power plants are expected to have lower feedwater iron concentrations due to improved water chemistry control and material. However, in this result, there was a large deviation in the iron concentration of feedwater by unit without such a tendency. From this, it seems that the amount of corrosion in the secondary system is affected by complex factors such as design differences (pipe geometry, flow speed, etc.), changes in water chemistry management, etc., rather than the operating period of the plant.

This result is calculated for the amount of sludge deposited in the SG during power operation. The actual amount of sludge inventory inside the SG will differ to not only inflow during power operation, but also temporary large inflow when the plant starts up, and outflow through sludge removal works during outage.

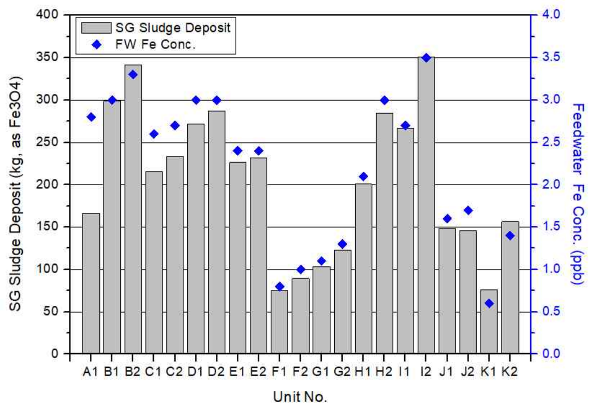

Fig. 2. Amount of SG Sludge Deposit per Unit (per 1 cycle)

3. Conclusions

In this study, the amount of iron oxides flowing into the steam generator during the NPP's cycle operation was evaluated. The amount of accumulated corrosion products in the SG for domestic nuclear plants is depending on the composited of materials and environment of water chemistry. This results can be used as up-to-date data to check the sludge deposition environment inside the steam generator of domestic NPPs.

REFERENCES

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