

Analysis Cause about Improving Venturi Fouling as making up the Water from Condensate Storage Tank to the Secondary System at H Nuclear Power Plants

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1. Introduction

Mass flow rates are measured using venturis located in feedwater piping in the nuclear power plants. These measurements are used to control nuclear plant output. Because of this reason, it is important that mass flow rate has to be measured accurately by the venturi during the operating of nuclear power plants. But, fouling of these venturis during plant operation by deposition of corrosion products leads to increased pressure drop across the venturis. This abnormally high pressure drop produces erroneously high flow rate indications, i.e. the deposits produce a shift in the venturi calibrations.

Recently, H #5 nuclear power plant has been experienced decreased 5.7 MWe of electric power comparing with COLSS (Core Operating Limit Supervisory System) power output (1,052 MWe) resulting from weekly performance test (Fig. 1).

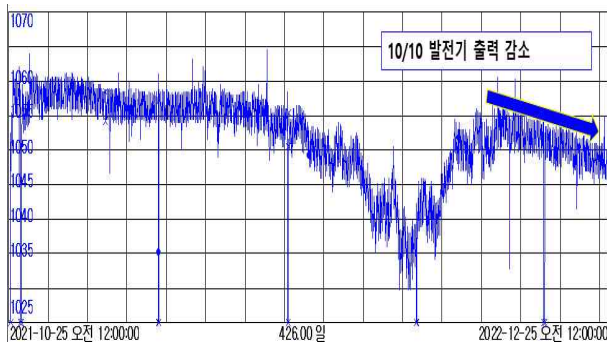


Fig. 1. The decreasing trend of COLSS power output during the normal operation at H nuclear power plant

The cause of decreasing power output resulted fouling of the venturi because corrosion products were deposited on the venturi nozzle tap. So, H nuclear power plant was considered switching flow measurements from FW BSCAL (Basic Secondary Calorimetric) to MS BSCAL. While considering switching from FW BSCAL to MS BSCAL, H plant also supplied auxiliary steam to another plant and made up from auxiliary water of CST (Condensate Storage Tank). And then venturi fouling was been improved after made up the auxiliary water from CST (Fig 2).

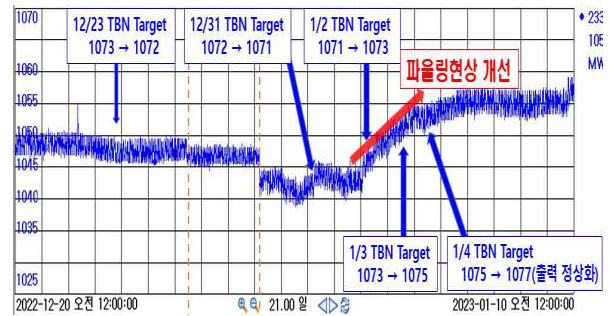


Fig. 2. The recovery trend of COLSS power output after made up from auxiliary water of CST

In this study, it reviewed that making up water from condensate storage tank to the secondary system related with affection improving fouling of venturi.

2. Scope and Methods

In order to find out the correlation between supplement water of secondary system and venturi fouling improvement, reviewing the following as;

- First, reviewing cause creating corrosion oxide in operation environments
- Secondly, reviewing deposition mechanism oxide on venturi nozzle tap
- Finally, water quality changes that contributed to the improvement of venturi fouling were estimated.

3. Results and Discussion

3.1 Cause creating corrosion oxide and specific environmental conditions

A review of domestic and foreign cases revealed that the main component causing venturi fouling was iron oxide. The reason why the main component is iron oxide is that the secondary system constituent material is carbon steel, and the main component of carbon steel is iron. During the operating, main component has been experienced FAC (Flow Accelerated Corrosion) phenomenon. FAC is a phenomenon that affects the normally protective oxide layer formed on carbon or low-alloy steel (Fig. 3).

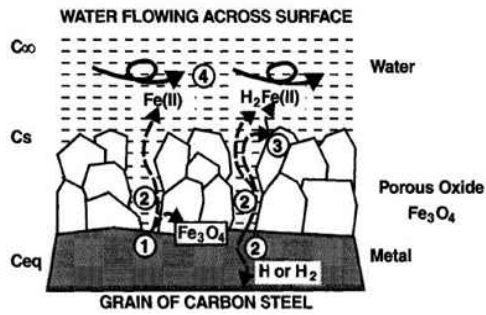


Fig. 3. FAC (Flow Accelerated Corrosion) mechanism schematic [1]

FAC can be anticipated whenever a susceptible metal is exposed to specific environmental conditions. The most important conditions are

- Temperature
- pH
- Oxygen
- Velocity
- Materials

3.2 Oxides deposit mechanism on venturi and zeta potential

Product oxides were deposited in outlet tap of the venturi, and the deposition location varies depending on the heat flux, corrosion product concentration, time, temperature, zeta potential, flow rate, and pressure, etc. In the case of a venturi, corrosion products are likely to be deposited at the downstream outlet tap. This is because of the flow velocity and the zeta potential of the corrosion products.

The location of outlet tap venturi is where the flow velocity decreases relatively. And then oxides have a zeta potential. Insoluble corrosion products such as oxides, hydroxides, and oxyhydroxides in aqueous suspensions develop an electrical charge on the surface as a result of charge transfer processes responsible for maintaining electrochemical equilibrium between the solid surface and the solution. Ions in solution having a charge opposite to that of the solid oxide surface form a Helmholtz layer which is strongly attached to the surface. A diffuse layer consisting of both positive and negative ions extends beyond the Helmholtz; the ions in the diffuse layer remain mobile. The boundary plane between these two layers is called the shear plane, and the difference in electrical potential between the shear plane and the bulk of the solution is called the zeta potential (Fig. 4) [2].

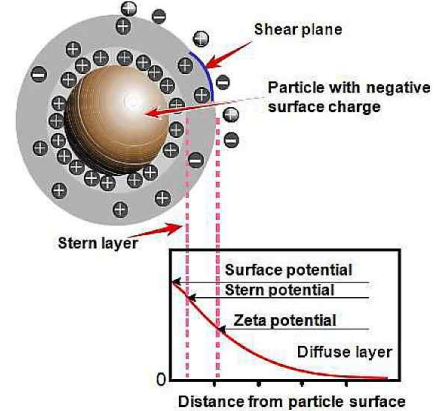


Fig. 4. A simplified model of the electric double layer in stagnant conditions [3]

Clearly, changes in the concentration of acid or base affect the surface on the oxide and hence the magnitude of the zeta potential. This effect indicates that the H^+ and OH^- ions act as potential-determining ions as far as the surface oxides are concerned. The sign and magnitude of the zeta potential of the oxide depend on the pH of the solution in the following manner in the neighborhood of pzc (the pH of zero charge, i.e., the pH where the oxide particles or suspension has zero net charge (equation 1) [4]

$$\xi = k(pzc - pH) \quad (\text{Equation 1})$$

where ξ is the zeta potential of suspension and k is a constant. Following as the equation 1, If the pH is increased and then zeta potential is decreasing that has a negative value finally. It is expected that oxide particles are not deposited if oxides and surface on the venturi have same sign. And magnitude of deposition amount depends also on opposite charge magnitude.

3.3 When improving fouling of venturi, water of secondary system changes trend

H nuclear power plant had been experienced venturi fouling due to the deposition of outlet tap. While considering exchange monitoring method of mass flow rates from FW BSCAL to MS BSCAL, H plant supplied the auxiliary steam to another plant. After made up water from CST (condensate storage tank), H nuclear plant was experienced improving venturi fouling. In order to find out the correlation between venturi fouling and water quality change, the trend of water in the secondary system was investigated. Corrosion of material in system and zeta potential are depending on the dissolved oxygen, pH, etc.

Dissolved oxygen plays a role making the hematite (Fe_2O_3) which prohibit corrosion of materials. So, the change in dissolved oxygen concentration from the occurrence of fouling up to charging water of secondary system period was reviewed. It was confirmed that the

dissolved oxygen concentration increased during the period (Fig 5). Dissolved oxygen tended to increase from an average of 0.358 ppb to 0.377 ppb. From this data, it can be evaluated that the FAC of material has been reduced. Although the dissolved oxygen concentration increased slightly, it is believed to have had a slight effect on reducing corrosion.

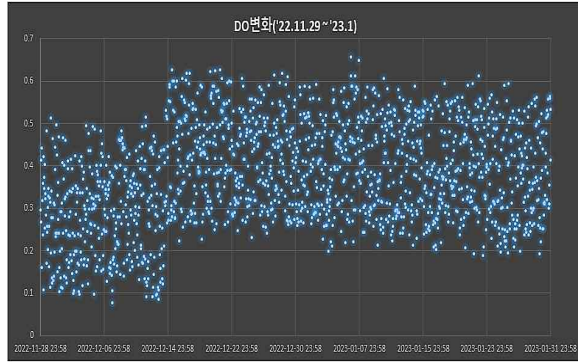


Fig. 5. After making up water, dissolved oxygen trend

pH not only affects material corrosion, but also affects the surface zeta potential of corrosion products. Fig. 6 shows the trend of pH change after making up water from CST. After replenishing water, the pH shows an upward trend slightly (increasing average pH 0.06). When the pH rises, not only corrosion is reduced, but also the negative potential of the surface corrosion product increases. So, it is judged to have an effect on reducing the venturi deposition.

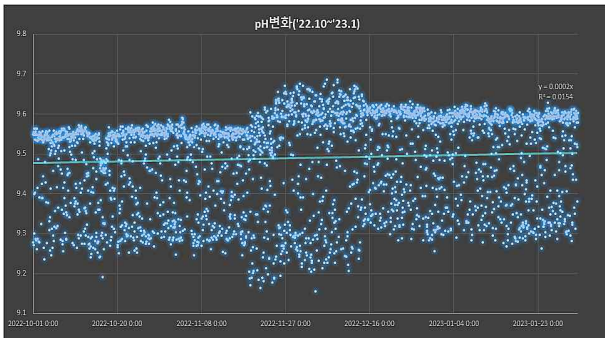


Fig. 6. After making up water, pH trend

4. Conclusions

H nuclear plant had been experienced venturi fouling. While considering exchange monitoring method of mass flow rates from FW BSCAL to MS BSCAL, H plant supplied the auxiliary steam to another plant. After made up water from CST (condensate storage tank), H nuclear plant was experienced improving venturi fouling. In order to find out the correlation between venturi fouling and water quality change, the trend of water in the secondary system was investigated. As a result of the review, dissolved oxygen and pH increased.

It seems that the increased dissolved oxygen contributed to reducing corrosion caused by FAC. The pH also showed a tendency to rise, which is evaluated to have contributed to the reduction of corrosion. Above all, the zeta potential of corrosion products due to the pH increase has a negative charge, which seems to have the effect of inhibiting deposition.

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