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Review of the Impact of pH and Conductivity due to Dissolution of Carbon Dioxide in Air of System Water Storage Tanks for Nuclear Power Plants

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1. Introduction

Nuclear power plants operate water storage tanks for various purposes, and water quality management is implemented in accordance with the characteristics of the system where water is used. Some major tanks store demineralized and degassed water and strictly control water quality. At this time, if some air enters the tank, changes in pH and conductivity of the stored water may occur due to the dissolution of carbon dioxide in the air. In this study, the current management status of water storage tanks in NPPs was examined, and it was confirmed whether the previously set pH and conductivity management limits could be satisfied under air inlet conditions.

2. Methods and Results

2.1 System Water Storage Tanks in NPP

The main tanks of NPPs, their functions, and water storage environments are as follows.

Table 1. Main Tanks and Water Storage Conditions

Tank	Main function	Storage condition
Primary Makeup Water storage Tank(PMWT)	Water supply to primary system	Demineralized /Degassed water & Air blocking condition
Refueling Water Storage Tank (RWST)	Water supply and storage during fuel reload	Borated water & Air inflow condition
Condensate water Storage Tank (CST)	Water supply to secondary system	Demineralized /Degassed water & Air blocking condition
Auxiliary Feedwater storage Tank (AFT)	Water supply in case of loss of main feedwater	Demineralized /Degassed water & Air blocking condition
Demineralized water Storage Tank (DST)	Storage of demineralized water produced in Pure water production facility	Demineralized water & Air inflow condition
Raw Water storage Tank (RWT)	Storage of raw water and supply to fire-fighting water in case of emergency	Raw water & Air inflow condition

In the above table, in case of Primary Makeup Water storage Tank(PMWT) and Condensate water Storage Tank(CST) that supply water to primary and secondary systems, degassed water is stored and supplied to prevent the accumulation of radionuclides in the system and corrosion of components/pipes.

In domestic NPPs, the pH and conductivity limits are generally set as follows for tanks that store degassed pure water.

- pH(25℃) : 6.0~8.0
- Conductivity : < 0.1μS/cm or < 0.2μS/cm

2.2 Changes in pH and Conductivity of Water due to Carbon Dioxide Dissolution

In general, pure water has pH of 7.0 and conductivity of 0.055 μS/cm at 25℃. However, when it comes into contact with air, the pH decreases and the conductivity increases due to dissolution of carbon dioxide. (In addition to carbon dioxide, major components of air such as nitrogen, oxygen, and argon do not form ionic species, so they do not affect the pH and conductivity of water.) [1]

The dissolution reaction of carbon dioxide can be expressed by the following formulas.[2]

<Dissolution of gaseous CO_2>

$$CO_2\ (g) \Leftrightarrow CO_2\ (aq)$$

<Ionization of dissolved CO_2>

$$CO_2\ (aq) + H_2O \Leftrightarrow H_2CO_3$$
$$H_2CO_3 \Leftrightarrow H^+ + HCO_3^-$$
$$HCO_3 \Leftrightarrow H^+ + CO_3^{2-}$$

Through the above formulas, it is possible to calculate the pH and conductivity change of water due to the dissolution of carbon dioxide. At this time, in the gas dissolution reaction and the ionization reaction in water, the concentration of CO_2 in the air, Henry's law, ionization equilibrium, and steam pressure act as variables, and in particular, the equilibrium state depends on the temperature. [2]

Fig. 1 shows the results of calculating the pH and conductivity change of water due to dissolution of CO_2 in the air by temperature. As a result, in the case of water exposed to air, the pH decreases to 5.64(weak acidity) and the conductivity increases to 0.91 μS/cm under 25°C when CO_2 is saturated.

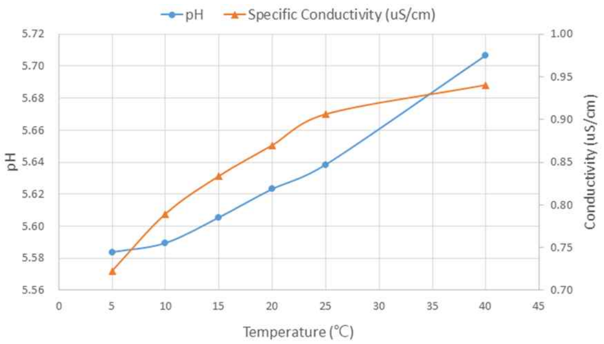

Fig 1. pH and conductivity change of water due to dissolution of CO_2 in the air by temperature

2.3 Review of Air Inflow Blocking Methods and Control Limits

In case of PMWT, CST, etc. that stored degassed water, the basic design is applied to block air inflow. In general, the air inflow blocking method applied to the tank is as follows.

- Floatable Diaphragm
- Nitrogen Blanket

In case of a Floatable Diaphragm, it is a diaphragm that moves fluidly depending on the tank water level and covers the contact area between air and water. It is possible to block air contact simply, but it is difficult to completely block it, and once air is introduced, the air inside cannot be removed.

In case of Nitrogen Blanket, it may be most effective in blocking air inflow. In domestic NPPs, Nitrogen Blanket is applied to PMWT and CST after KSNP type reactors. However, when applied to PMWT, there is a concern that it increases the dissolved nitrogen concentration and increases the C-14 inventory of RCS.

The pH and conductivity limit values currently applied to PMWT and CST in domestic NPPs (pH : 6.0~8.0, Conductivity : <0.1 or <0.2 μS/cm) are values based on degassed pure water. According to the results calculated in paragraph 2.2, it may be difficult to satisfy the existing pH and conductivity limits due to the dissolution of CO_2 in case of some air inflow.

Therefore, if the effect of CO_2 on the supplied system is insignificant, the limit values can be relaxed and applied by reflecting the CO_2 dissolution conditions as follows.

- pH(25°C) : N/A
- Conductivity : Set the upper limit to at least 1 μS/cm

If degassed water must be supplied, a water purification facility equipped with a vacuum filtration device should be installed in the tank to periodically degassing the stored water.

3. Conclusions

In this study, the pH and conductivity limit values of water storage tanks that store and supply demineralized & degassed water in NPPs were reviewed. These tanks apply a design that block air inflow, but it seems difficult to satisfy the pH and conductivity limit values if there is some air inflow. In this case, it is necessary to relax and apply the pH and conductivity limit values in consideration of the dissolution of carbon dioxide, or to manage degassing conditions by installing an additional degassing facility in the tank.

REFERENCES

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[2] Vernon L. Snoeyink, David Jenkins, Water Chemistry, John Wiley & Sons, 1980, p. 156-161.