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Optimization of Resin Mix Ratio and Column Arrangement of Ion Exchanger on Heavy Water Clean-up System of CANDU-type Nuclear Power Plant

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1. Introduction

In Wolsong Nuclear Power Plant (NPP) 1 and 2 heavy water upgraders are in operation to reuse the recovered heavy water. The corrosion of copper-tin alloy packing inside the upgrader column was detected. The ammoniacal species produced by the decomposition of hydrazine injected into the dousing water, salts coming into the reactor building from outside, and aluminum and silicon produced by the decomposition of the molecular sieve in the heavy water vapor recovery system were suspected as the causes of the corrosion. Al and Si seemed to have indirect effects on the corrosion by accelerating the performance degradation of the heavy water clean-up system. Consequently, the influx of corrosion inducing materials should be prevented by more efficient utilization of the heavy water clean-up system. Currently the heavy water clean-up system of Wolsong NPP1 consists of one activated charcoal filter to remove particulate impurities and 3 ion exchange columns in sequence of mixed-mixed-anion resin columns. The total weight ratio of the cation resin to anion resin in 3 columns is 1:2. Since the performance of the ion exchange resin column removing ionic impurities depends on the quality of incoming water, the sequential order of the mixed and anion columns, and the ratio of cation resin to anion resin in the columns, the effect of these parameters on the break through of the columns were investigated in this study.

2. Heavy Water Management System in Wolsong NPP1

A schematic of heavy water management system in a nuclear power plant is shown in figure 1. The heavy water management system is comprised of three sub systems: heavy water vapor recovery system, heavy water clean-up system and heavy water upgrading system.

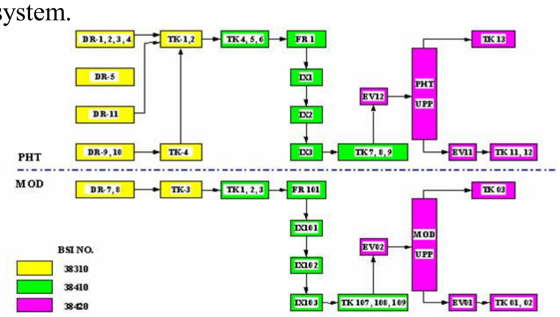


Figure 1. Schematic diagram of heavy water vapor recovery/clean-up/upgrading system

3. Methods and Results

3.1 Materials and apparatus

The ion exchange resins used in experiment were Rohm & Haas IR 120 (cation exchanger) and Rohm & Haas IRA 402 (anion exchanger).

The experiments were performed with an apparatus simulating the heavy water clean-up system of Wolsong NPP1.

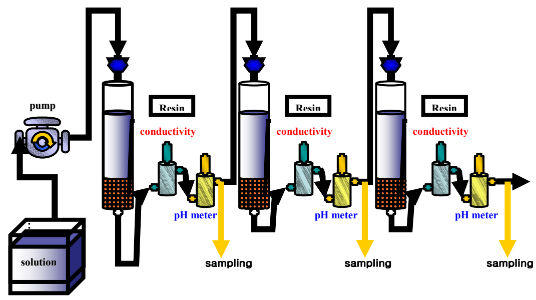
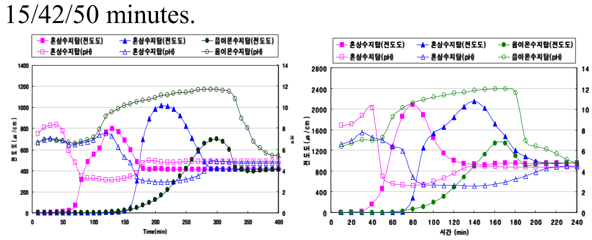


Figure 2. An apparatus simulating three ion exchangers in heavy water clean-up system

3.2 Effect of ionic impurities on break through

The effect of ionic impurities on the ion exchange efficiency was examined. The concentrations of sodium ions and chloride ions were 50, 125, and 250 ppm and 165, 315, and 610 ppm respectively.

The break through time was shortened when the concentrations of the ionic impurities increased as shown in Figure 3. As the concentration of chloride ions increased from 165 to 610 ppm, the break through time of each column was shortened from 55/148/160 minutes to 15/42/50 minutes.



(a) (b)

Figure 3. Changes of pH and Conductivity at the exit of resin column by time (a)Na^{+} 50ppm, Cl^{-} 165ppm, (b) Na^{+} 125ppm, Cl^{-} 315ppm

3.3 Effect of particulate impurities on break through

The effect of particles on the ion exchange efficiency was examined. The concentrations of particles were 0, 50, and 150ppm. By varying the concentrations of particles, conductivities and pH changed as shown in Figure 4. As the concentration of particles varied from 0, 50 and 150 ppm, the break through time of each column changed 12/42/35min, 7/38/29min, and 5/30/23min respectively. The break through time was shortened as the concentrations of the particles increased.

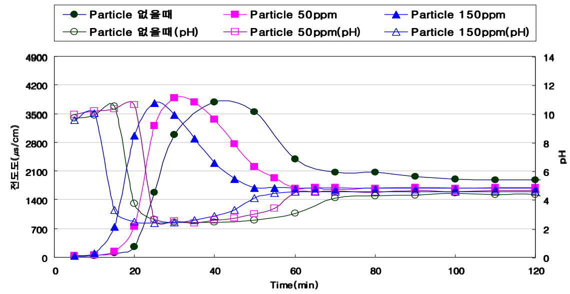
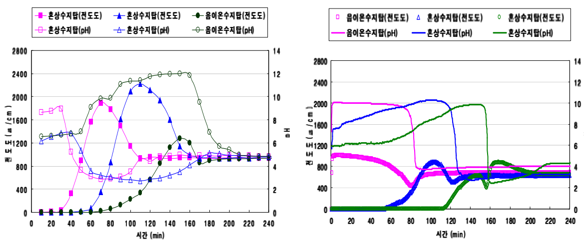


Figure 4. Changes of pH and Conductivity at the exit of the first mixed resin column by time (Na^+ 250ppm, Cl^- 610ppm, Conc. Of Suspended Solids were changed 0, 50, 150ppm)

3.4 Effect of column arrangement on break through

The effect of column arrangement on the ion exchange efficiency was examined. The columns were arranged in three different orders: mixed-mixed-anion, mixed-anion-mixed, and anion-mixed-mixed. When the order was anion-mixed-mixed, break through time was the longest. The break through times of the columns in mixed-mixed-anion order were 32/60/82 min, and the break through times of the columns in anion-mixed-mixed order were 0.5/62.5/125min. The break through times was enhanced about 30%.

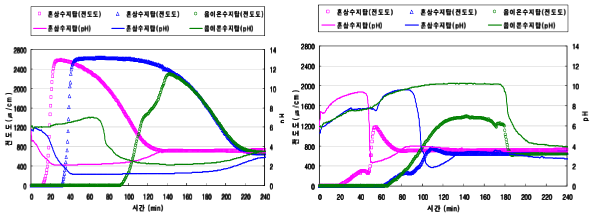


(a) (b)

Figure 5. Changes of pH and Conductivity at the exit of resin columns by time (Na^+ 125ppm, Cl^- 315ppm) (a)mixed-mixed-anion, (b)anion-mixed-mixed

3.5 Effect of cation/anion resin ratio on break through

The effect of resin ratio on the ion exchange efficiency was examined. The ratios of cation resin to anion resin were 1:1, 1:2, 1:3 by wet weight. As the ratio of resin varied 1:1, 1:2, and 1:3, the break through times varied 10/30/101.5min, 28.5/65.5/77.5min, and 32.5/83/84min respectively. At the resin ratio of 1:1, the break through time was enhanced about 30% compared with that at the resin ratio of 1:2.



(a) (b)

Figure 6. Changes of pH and Conductivity at the exit of resin columns by time (Na^+ 125ppm, Cl^- 315ppm) (a)resin ratio 1:1, (b) resin ratio 1:3

4. Conclusion

Currently, the Wolsong NPP1 heavy water clean-up system is operated with mixed-mixed-anion resin columns with the total ratio of cation resin to anion resin 1:2. When the resin ratio is maintained it will be more efficient to change the column sequence to anion-mixed-mixed. The experimental result shows that the break through is 20 minutes longer when the columns were arranged in anion-mixed-mixed order and the resin ratio of 1:2 than when the columns were arranged in mixed-mixed-anion order and the resin ratio of 1:1. Moreover, the latter configuration cannot be adopted since the pH at the exit is less than 2. At that pH the copper alloy packing will corrode. Thus, it would be more efficient to arrange the columns in anion-mixed-mixed order and maintain the resin ratio to 1:2.

Table 1. Summary of experiments

Ratio of resin (cation:anion, by wet weight)		Mixed-mixed-anion	Mixed-anion-mixed	Anion-mixed-mixed
1:1	Break through time(min)	101.5	99	88
	pH at the exit	< 2 (acidic)	< 2 (acidic)	< 2 (acidic)
1:2	Break through time (min)	77.5	114.5	125.5
	pH at the exit	> 9 (basic)	> 9 (basic)	> 8 (basic)
1:3	Break through time (min)	84	85.5	112.5
	pH at the exit	> 9 (basic)	> 9 (basic)	> 8 (basic)

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