Experimental studies on the Continuous Operation of Mixed-bed Ion-Exchange tower : A case of production of deionized water

Experimental Studies on the Continuous Operation of Mixed-Bed Ion-Exchange Tower
——A case of production of deionized water——

Takeo YANO*, Takeshi KATAOKA* and Yoshiki SANO*

(Received September 30, 1959)

The purposes of this work were to examine the possibility and utility of continuous mixed-bed ion exchange operation in separating and refining processes of Uranium and Thorium. Experiments were cırried out in the case of simple deionization process of city water instead of the purification of Uranium and Thorium.

In the continuous co-current operation, the tower showed the nearly typical performance of mono-bed type. But in the continuous counter current operation, the promising results did not obtained owing to the separation of anion and cation resins in the tower.

1. Introduction

The object of this research is the achievement of the continuous operation in separating and refining process of Uranium and Thorium. In this paper the development research of the continuous operation in mixed-bed ion exchange process have been started. The possibility and utility of continuous mixed-bed ion exchange operation were examined by the simple deionization process of city water instead of the purification of Uranium, and then some progressive results were obtained.

2. Apparatus and Procedure

The schematic diagram of continuous mixed-bed ion exchange tower employed was shown in **Fig. 1.** The tower was made from meta-acrylate resin. The tower dimensions were tabulated in **Table 1.** The resins used were Duolite C-20 (strongly acidic resin) and Duolite A-41 (strongly basic resin). The particle size distribution, the condition of regeneration and washing were also shown in **Table 1.**

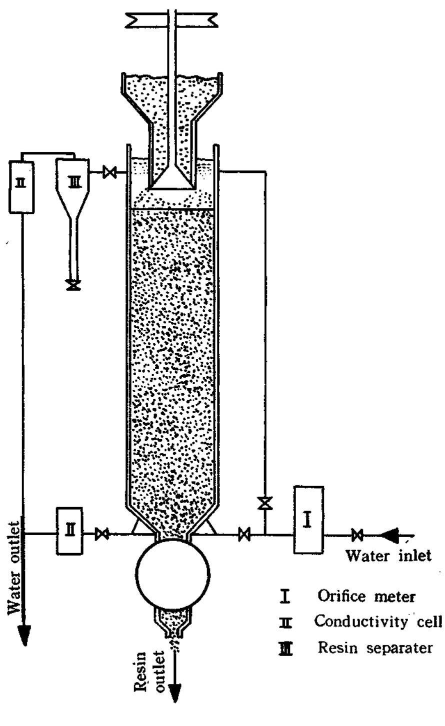

Fig. 1. Experimental Apparatus

The resins were feed from the hopper in-

*Department of Chemical Engineering, College of Engineering.

stalled at the top of tower, and discharged through the roater at the bottom. For the feed water, the city water of our college was used and its purity was 4,000~6,000Ωc.m. in specific resistance. The flow rates of water were measured by the orifice meter. In counter current operation, the feed water was charged to the bottom of the tower, run up-ward through the bed of resin, and the deionized water was flown into the resin separator at the top of tower and then measured the specific resistance (purity) before discharged out from the system.

In co-current operation, on the other hand, the feed water was charged to the top of tower, flown downward through the bed, and then the deionized water was withdrawn from the bottom of the tower.

The apparatus employed in batch operation was the same one used in continuous operation, and in batch operation the bed of resin was fixed, while the feed water was charged up- or down-ward according to up-flow or down-flow type operations as usual.

3. Experimental Results

1. Batch Operation

In order to examine the influence of mixing ratio of resins upon the purity of

	resin size	regeneration			washing
	[mesh]	concentration	volume [l/lofusin]	rate [m³/m². hr]	[lwater/l resin]
Duolite A 41	20~35	4% NaOH	1.7	0.35	15
Duolite C 20	12~32	5% HCl	2.0	0.42	10

tower dia, 7.8 [cm], towerheight, 110[cm]

Table. 1 Operational Conditions

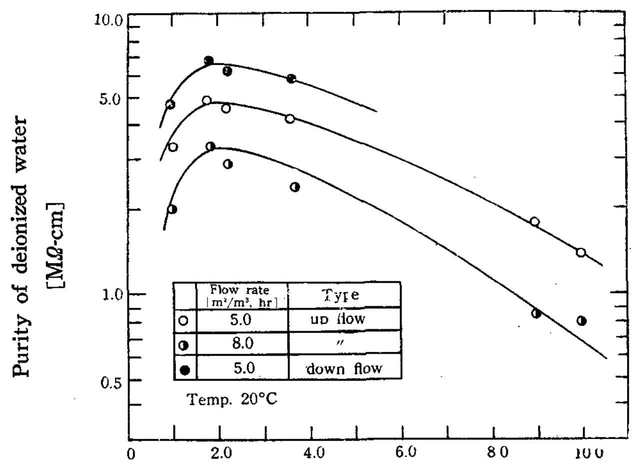

Fig. 2. Influence of mixing ratio of resin on the purity of deionized water

deionized water in batch operation, the experiments were carried out varing the mixing ratio (volume ratio of anion exchange resin to cation exchange resin) in the range of 1/1~10/1, at the fixed condition of packed height 52.5 [cm], and the flow rates of the feed water 5.0 and 8.0 [m³/m².hr] in up-flow type, and 5.0 [m³/m².hr] down-flow type, respectively. The results obtained were shown in **Fig. 2.** The purities of deionized water changed depending on the mixing ratios. When the mixing ratio was about 1.8/1, the purity had the highest value in all flow rates. The purity was lower as the ratio was larger than 1.8/1.

The influence of flow rate upon the purity of deionized water under the conditions of the resin ratio 1.8/1 and the packed height 52.5 [cm], in up-flow or down-flow type was shown in **Fig. 3.** As shown in **Fig. 3,** the purity obtained in the down-flow type was higher than that in the up-flow type in whole range of flow rate. Moreover, both up-and down-flow type the maximun value of purity showed in the flow rate of about 5.0 [m^3/m^2. hr], and about 7.2 [m^3/m^2.hr], respectively. Furthermore, the increasing gradient of purity to the flow rate in the down-flow type was larger than that of the up-flow type in the left side of the curves, but in the other side of the curve the decreasing degree of the latter was larger than the former. This discrepancy might be resulted from the separation of anion resin and cation resin. The patterns of resin separation due to the increase of

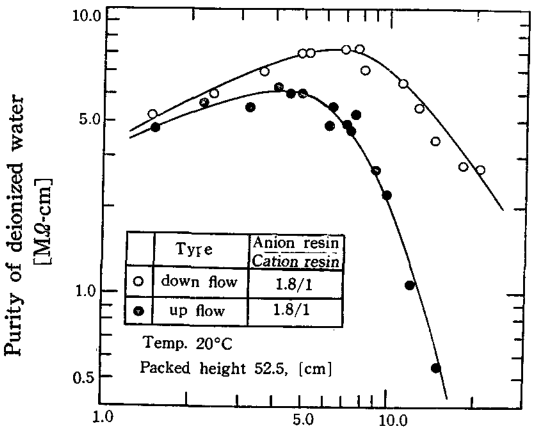

Fig. 3. Influence of water flow rate on the purity of deionized water

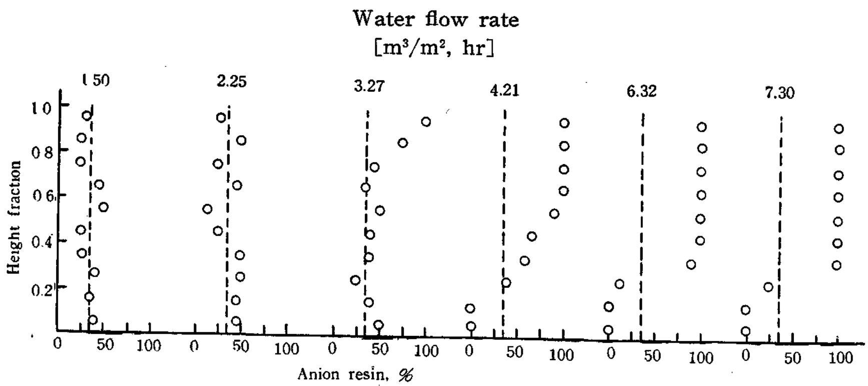

Fig. 4. The separation states of resin with the increase of water flow rate

flow rate were shown in **Fig. 4.** After the run's period, the resin bed was divided into ten equal parts in height, and in each part the mixing ratio of both resins were measured by the hydraulic elutriation. In this Figure, the optimum resin ratio 1.8/1 were shown by the chain lines. As shown in this Figure, the mixing patterns were good under the flow rate about 2.25 [m^3/m^2. hr], but as the flow rate was increased about 3.27 [m^3/m^2. hr], the separation of resins occured at the top of bed and finally separated in two layers over about 6.32 [m^3/m^2. hr].

The relation between the packed height and purity of deionized water at the fixed flow rate in down-flow type were shown in **Fig. 5.** The purity was increased and

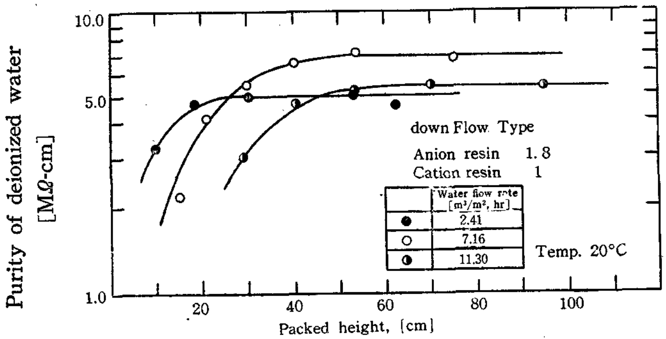

Fig. 5 The relation between the packed height and the purity of deionized water

saturated as the packed height was increased. The logarithmic plots of this height vs. flow rate at saturation points was show in **Fig. 6.** The plots were linear and its inclination was 0.46.

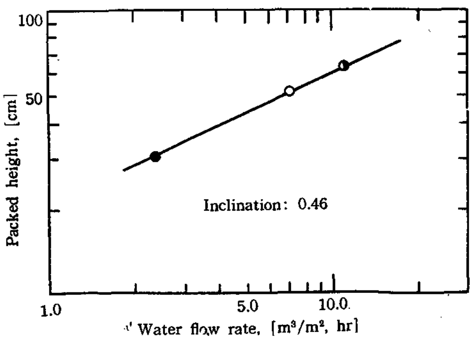

Fig. 6. Influence of water rate on packed height

The relation between the packed height and the purity of deionzed water at the fixed flow rate in up-flow type were also shown in **Fig. 7.** The packed heights of up-flow type were measured

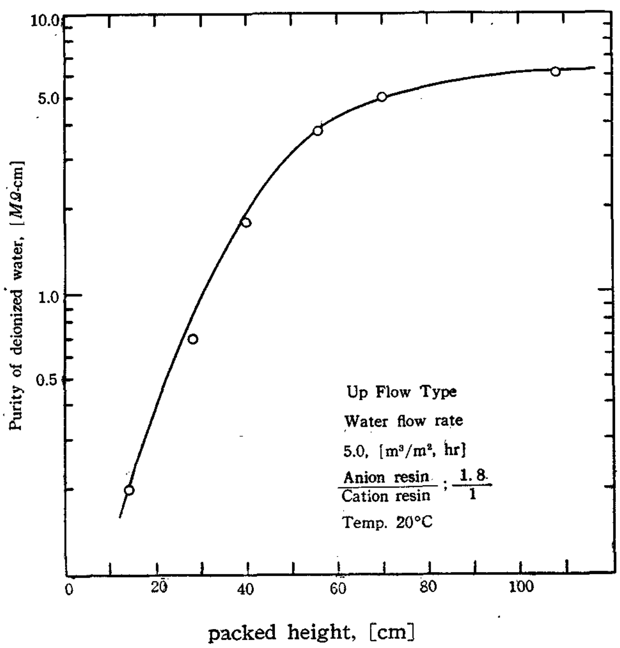

Fig. 7. The relation between the packed height and the purity of deionized water

under the expanded state of bed. The purity of deionized water was increased and saturated with the increase of packed height.

2. Continuous Operation

To investigate the relation between flow rate and the purity of deionized water in continuous counter current operation, the experiments were carried out at the fixing conditions of packed height 52.5 [cm], feed resin composition 1.8/1 (volume ratio of anion resin to cation resin), and resin rate 1.58, 0.92 and 0.52 [$m^3/m^2.hr$], respectively. As shown in **Fig. 8**, the purity of deionized water obtained were increased along the upward convex curves. And in the range of a low liquid flow rate, the gradients of the curve were nearly same even though the resin rate changed. On the other hand, in the range of a high flow rate of water, the inclinations were decreased as the resin rate increased. The maximum purities increased as the resin rate decreased, but the flow rate of water corresponding to the maximum values decreased inversely. This reason might be thought that in a constant resin rate the separation of the anion and cation resins occured with the increase of liquid rate, and further the mixing ratio of resin were over the optimum mixing ratio of 1.8/1.

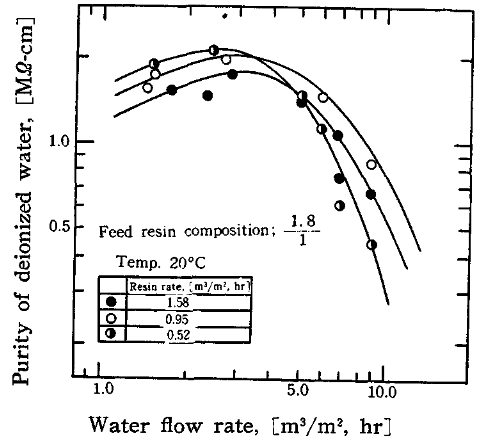

Fig. 8. The relation between the water flow rate and the purity of deionized water

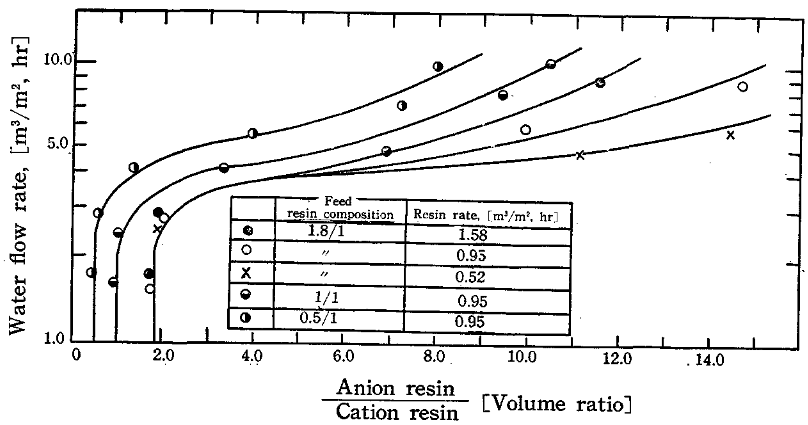

Fig. 9-a The Variation of mixing ratio of resin with the water flow rate

Fig. 9-a shows the relation between the change of the mixing ratio and the water flow rate from the experiments shown in Fig. 8. The mixing ratio was nearly constant in a low water rate, and then the separation of resins occured rapidly as the liquid rate increased. This tendency increased as the resin rate increased. The pattern of

separation which was tested at constant liquid rate of 9.4 and 6.0 [$m^3/m^2.hr$], were shown in **Fig. 9-b,** respectively. The upper parts of the tower was occupied by the anion resin and the smaller zone of the lower parts was only formed the typical mono-bed.

Accordingly, in order to keep the mixing ratio of resin in the tower constant, the feed of resin from the top of tower was varied from 1.8/1 to 1/1 and 0.5 /1, respectively. This results were shown in **Fig. 10.** The maximum values in purity of the deionized water were nearly independent to the resin composition, but the water flow rate of this value increased inversely as the resin composition decreased. The variation of mixing ratio of resin with the increase of flow rate were also shown in **Fig. 9-a.** In the region of a high liquid flow rate the mixing ratio of resin increased with the decrease of resin rate, but were smaller than 1.8/1 of optimum mixing ratio.

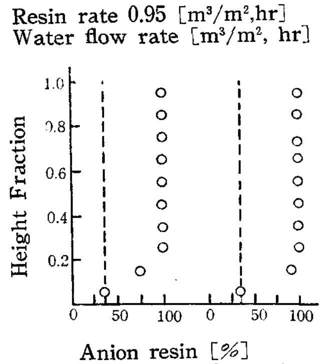

Fig. 9-b The separation states of resin with the water flow rate

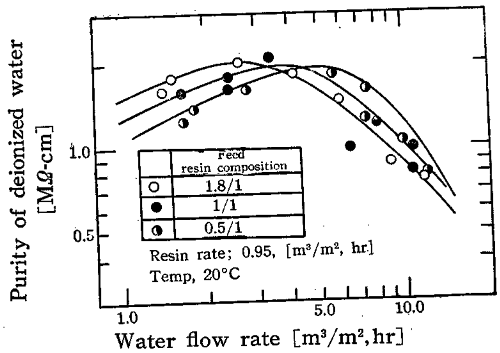

Fig. 10 Influence of water flow rate on the purity of deionized water

In conclusion for the counter current operation, the mixing ratio of resin in the tower deviated from the optimum value of 1.8/1 as the liquid flow rate increased, and the results obtained did not show the typical performance of mono-bed tower.

Accordingly, the co-current operation were examined at the condition of the packed height 52.5 [cm], resin composion 1.8/1 and the resin rates 0.18, 0.52 and 1.58 [m^3/m^2. hr], respectively. The influence of liquid flow rate upon the purity of deionized water in the co-current operation was shown in **Fig. 11.** All purity curves of deionized water at the constant resin rate showed similarly upward convex ones, and as the ersin rate increased the purities on the curve became lower. The water flow rates of the maximum point were constant 7.0 [$m^3/m^2.hr$] independent of the resin rate, and also

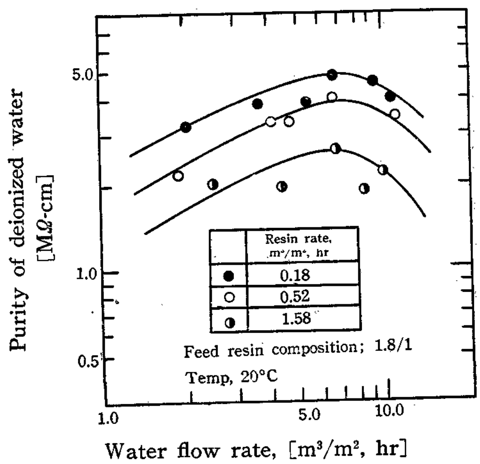

Fig. 11. Influence of water flow rate on the purity of deionized water

this values were nearly equal to those values in the down-flow type in batch operation as shown in Fig. 4.

Fig. 12 shows the influence of water flow rate upon the purity of deionized water at the conditions of packed height 52.5, 125. and 2.7 [cm], and resin rate 0.18 [m^3/m^2.hr], respectively. The curves obtained were nearly similar even if the packed height varied. In order to clear the relation between the packed height and the purity of deionized water, semi-log plot was shown in **Fig. 13.** The purity of deionized water increased with the increase of packed height and approached asymptotically to the fixed value at the constant liquid flow rate of 7.0 [m^3/m^2,hr].

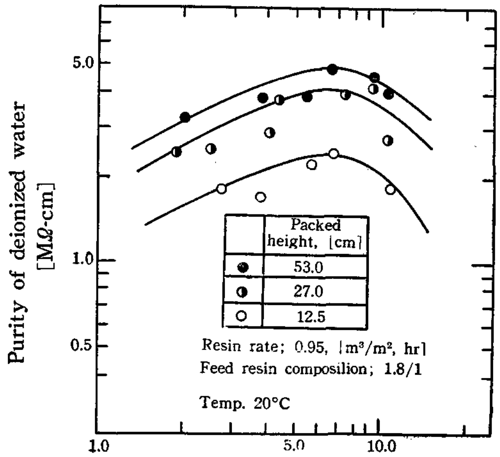

Fig. 12. Influence of water flow rate on the purity of deionized water

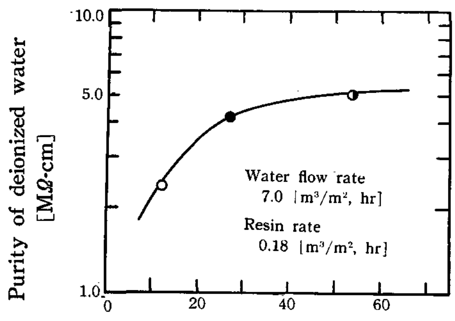

Fig. 13. The relation between the packed height and the purity of deionized water

4. Conclusion

In counter current operation, the continuous mixed bed ion-exchange tower did not play the performance of mono-bed type, owing to the separation of anion and cation resins in the tower. If the plate tower was used, the good results would be obtained even in the counter current operation.

On the other hand, in the co-current operation the tower showed the nearly typical performance of mono-bed type, and obtained the promising results.