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Apparatus for Continuous Counter-Current Ion Exchange with Mixed Beds

Aparat do ciągłej przeciwprądowej wymiany jonowej na złożu mieszanym

Аппарат к сплошной противоточной ионной замене на смешанной залежи

In recent years, there has been a number of developments for decreasing the consumption of regenerants of ion exchangers used in water demineralization in order to reduce the quantity of waste effluents and to improve the economics of the process. The developments are along two directions: (1) a new type of equipment for fixed and moving beds for counter-current operation and (2) a greater use of weak type exchangers because of their high regeneration efficiency. In Europe, continuous counter-current ion exchange operation is gaining for wastewater demineralization in the chemical industry because it requires less space, less resin and also has less interrupted service than fixed beds [1-5].

This paper shows the apparatus which we have developed for carrying continuous counter-current ion exchange demineralization. It is illustrated in Figs 1 to 5 inclusive. Figure 1 is a schematic drawing of the equipment and arrangement as indicated below:

1) sorption column containing the mixed bed;
2) cation exchange column;
3) anion exchange column;
4) column for mixing the exchangers;
5) tank for separating the mixed exchangers.

Raw water is introduced during the service cycle through the open valve at 6 and is moved upwards through the mixed bed (1). The demineralized water is discharged through the open valve at 7. As valve at 7 is partially closed, part of the treated water moves upwards through columns 2 and 3 where it rinses the exchangers in the lower part of columns 8 and 9. Most of the rinse waters is discharged through valves 10 and 11, but a part of it moves up, forming a hydraulic barrier to the residual regenerants. The latter part is discharged through valves 12 and 13. Thus regenerant wastes are discharged through valves at 14 and 15.

Water is introduced at the same time through valve 16 into chamber 5 for separating the mixed bed. Valves 17, 19, 20, 21 and 25 are closed and valve 18 is open. After 2 to 5 minutes, valves 16 and 18 are closed and consequently the fluidized bed settles, forming two layers; the lower part being the cation exchager and the upper part being the anion exchanger.

When the service cycle is finished, valves 6, 7, 10, 11, 12, 13, 14 and 15 are closed and the transfer of ion exchangers is started. In the beginning of this cycle, valve 25 is opened and water pressure is introduced into the upper part of the separator 5. Consequently, as the valves 21 and 23 are opened, the anion exchanger layer is transferred from the separator into the upper part of the anion exchanger regeneration column. When a suitable amount of anion exchanger is transferred into column 3, the valves 21 and 23 are closed and valves 20 and 26 are opened resulting in a part of the cation and anion exchangers present within their separating boundary being transferred to a special vessel marked 27. After this operation, valves 20 and 26 are closed and the cation exchanger remaining inside the separator is transferred through open valve 19 into the upper part of the cation exchanger regeneration column, and the transporting water medium is discharged through open valve 24.

Afterwards, valves 19, 24 and 25 are closed, thus, completing the discharge from the separator. The transfer of the regenerated and rinsed cation and anion exchangers from the bottom of the regeneration columns to the upper part of the sorption column takes place through mixer 4.

The exhausted mixed bed is moved from the bottom part of the sorption column into the separator through open valve 17. Simultaneously, the mixed ion exchangers present inside special vessel 27 are moved, via open valve 20, into separator 5 by means of water being introduced through open valve 30.

The movement of the ion exchangers is brought about by means of water under pressure introduced through open valves 28 and 29. Equivalent amounts of water go out of the apparatus through open valve 25. After transferring of suitable amounts of the ion exchangers, valves 20, 28, 29, 30 and 25 are closed and valves 6, 7, 10, 11, 12, 13, 14, 15, 16 and 18 are opened and the service cycle starts again.

A second scheme used was to fill the service column through the bottom as shown in Figure 2, where (C + A) - sorption column containing the mixed bed; C - cation exchanger regenerating and rinsing column; A - anion exchanger regenerating and rinsing column; A - anion exchanger regenerating and rinsing column; M - mixing vessel; S - separation vessel.

During the service cycle raw water is introduced through the inlet with valve 1 open and then it is sent down through the mixed bed contained inside the service column. The main amount of water thus treated is discharged through open valve 5. The outflow of water through the outlet valve 5 partially closed results in a part of the treated water

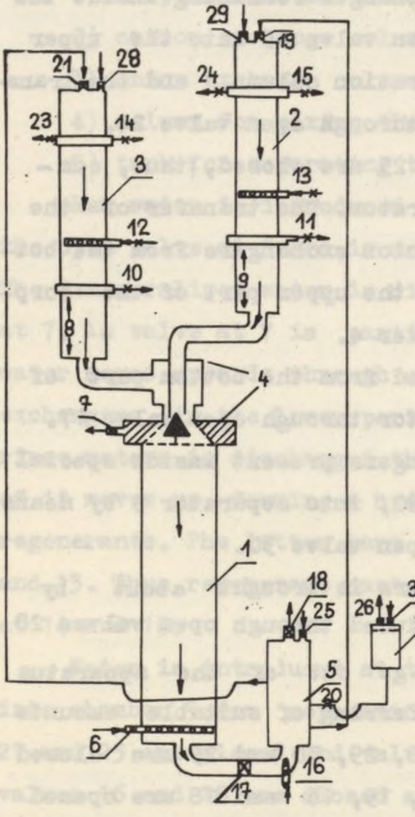

Fig. 1. Schematic drawing of the apparatus with introduction of ion exchangers into the sorption column via top filling

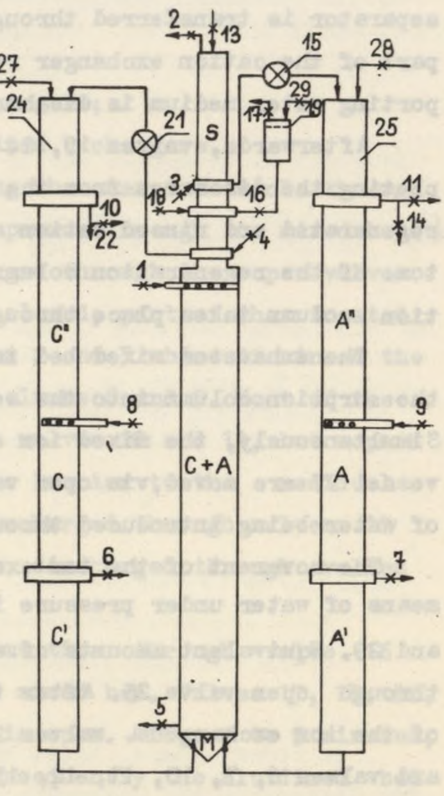

Fig. 2. Schematic drawing of the apparatus with introduction of ion exchangers into sorption column through bottom filling

to be pushed up through columns C and A where it acts as a rinse for the regenerated exchangers.

About 80% of the rinse water is discharged through outlets 6 and 7. But with valves 6 and 7 throttled, a part of the rinse water passes upwards, forming a hydraulic barrier for acid and base that are introduced into the regenerating columns through inlets 8 and 9, after which this portion of the rinse water including some remaining regenerants is returned to the sections of C" and A". The regeneration solutions acid and base are discharged through outlet valves 10 and 11, respectively.

Simultaneously, the part of water introduced into the sorption column via the inlet through open valve 1 is sent upwards through the separation vessel and is discharged via open valve 2. During its flow into the separator, the bed contained inside the separator is fluidized and, consequently, the bed is separated into an upper layer of anion exchanger and a bottom layer of cation exchanger.

When the service cycle is finished, valves 1, 5, 6, 7, 8,9, 10 and 11 are closed and the transfer of the exchangers begins. First, valve 13 is opened and water under pressure is introduced into the upper part of the separation vessel. After that valves 3, 15 and 14 are opened, the anion exchanger layer is transferred into the upper part of the anion-exchanger regeneration column. Afterwards, when suitable amounts of the anion exchanger layer is transferred from the separator into the anion exchanger regeneration column, valves 3, 15 and 14 are closed and valves 16, 17 and 18 are opened, resulting in a part of cation and anion exchangers present within their separating boundary to be transferred to special vessel 19. After this operation, valves 16, 17 and 18 being closed, the cation exchanger remaining inside the separator is transferred via open valve 21 into the upper part of the cation exchanger regeneration column, and the water introduced via open valve 4 is discharged via open valve 22.

Afterwards, valves 4, 21 and 22 are closed, the discharge from the separator is completed. The mixed ion exchangers present inside the special vessel 19 are moved back via open valve 16 into separator S by means of water being introduced via open valve 29. The transfer of regenerated and rinsed ion exchangers takes place from the bottom of the regeneration columns into the sorption column via the mixing tank M. Simultaneously, the exhausted mixed bed is moved from the top of the sorption column into the separator. The movement of the ion exchangers is brought about by means of water under pressure being introduced through open valves 27 and 28. An equivalent amount of water goes out of the apparatus via open valve 2. After a suitable amount of the ion exchangers is transferred, valves 2, 27 and 28 are closed and valves 1, 5, 6, 7, 8, 9, 10 and 11 are opened so that the service cycle begins again.

Figure 3 shows the operation of the valves as the function of time.

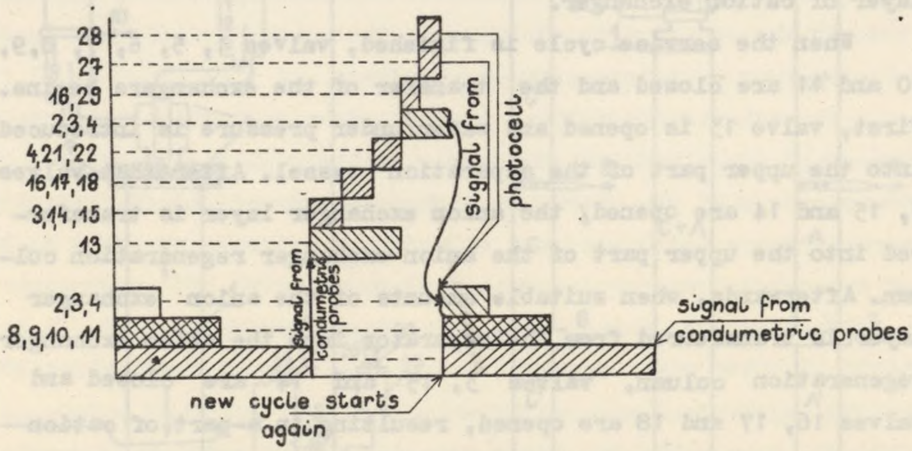

Fig. 3. The operation of the valves of the apparatus in Figure 2 as the function of time

Mixing of the ion exchangers. In the apparatus, as described in the literature, air under pressure is used for mixing of the cation and anion ion exchangers. This has some disadvantages, i.e., as pollutants are introduced from the air and also oxygen content is increased in the demineralized water. In our research, we have investigated special feeders that make possible to design an apparatus, similar to the Higgins loop, for carrying out ion exchange processes in mixed bed.

Figure 4 shows a schematic drawing of such a feeder; where: 1) inlet of raw water, 2) and 3) inlets of cation and exchangers, 4) sorption column, 5) conical metal screen, 6) cross bar for cone, 7) cone, 8) void space for water.

During the tests, we observed that this type of feeder operated quite well.

Figure 5 shows a schematic drawing of another type of feeder; where:

1) inlet of raw water, 2) sorption column, 3) conical metal screen, 4) void space for water, 5) mechanical mixer, 6) driving gear for mixer, 7) and 8) inlets of cation and anion exchangers.

The feeder shown in Figure 5 gives better mixing but the disadvantage is that there is an increase in the amount of broken beads of the ion exchangers through mechanical agitation.

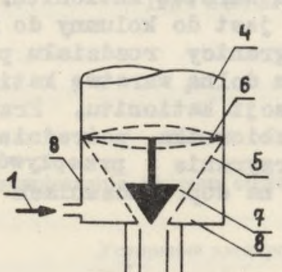

Fig. 4. Mixing of ion exchangers

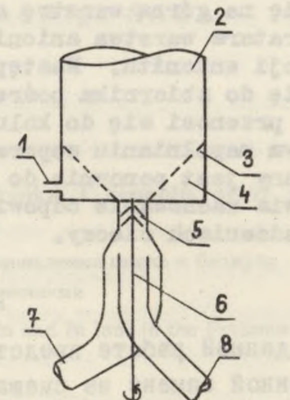

Fig. 5. Mixing of ion exchangers

REFERENCES

1. Ching-Lin Chen R., Miele P.: Wastewater Demineralization by Continuous Counter-Current Ion Exchange Process.Raport EPA-600/2-77-152, September 1977.
2. Pawłowski L., Michalczyk Z.: Gaz, Woda i Technika Sanitarna, Vol. XLIV, No. 11, 377-378 (1970).
3. Pawłowski L.: Inżynieria i Aparatura Chemiczna, No. 1, 1-6 (1971).
4. Pawłowski L.: Ion Exchange and Membranes 1, 113-114 (1972).
5. Pawłowski L.: Gaz, Woda i Technika Sanitarna, Vol. XLVII, No. 7, 239-244 (1973).

STRESZCZENIE

W artykule przedstawiono aparat do ciągłej przeciwprądowej wymiany jonowej w złożu mieszanym. W aparacie tym wyodrębnić można kolumnę do regeneracji kationitu, kolumnę do regeneracji anionitu, kolumnę do demineralizacji wody, mieszalnik jonitów i separator jonitów. Złoża jonitowe przemieszczane są okresowo w ten sposób, że kationit z kolumny do regeneracji przetłaczany jest poprzez mieszalnik do kolumny do demineralizacji wody. Równocześnie anionit jest przemieszczany z kolumny do regeneracji poprzez mieszalnik (w którym miesza się z kationitem) do kolumny do demineralizacji. Wyczerpane złoże przesyłane jest okresowo do separatora, gdzie pod wpływem strumienia wody rozwarstwia się na górną warstwę anionitu i dolną warstwę kationitu. Z separatora warstwa anionitu przenoszona jest do kolumny do regeneracji anionitu. Następnie warstwę z granicy rozdziału przenosi się do zbiornika pośredniego, po czym dolną warstwę kationitową przenosi się do kolumny do regeneracji kationitu. Przy ponownym napełnianiu separatora jonit ze zbiornika pośredniego zawracany jest ponownie do separatora. Utrzymanie przepływów umożliwia zachowanie odpowiednich ciśnień na doprowadzeniach i odprowadzeniach cieczy.

РЕЗЮМЕ

В данной работе представлено аппарат к сплошной противоточной ионной замене на смешанной залежи. В этом аппарате можно выделить колонку для регенерации катионита, колонку для регенерации анионита, колонку для обезсоливания воды, растворитель ионитов и сепаратор ионитов. Ионитовая залежь перемещается периодически таким образом, что катионит из колонки для регенерации перекачивается растворителем в колонку для обезсоливания воды. Одновременно анионит перекачивается из колонки для регенерации через растворитель, в котором смешивается с катионитом, в колонку для обезсоливания. Истощенная залежь периодически подается в сепаратор, где под влиянием водяной струи расслаивается на верхний слой анионита и нижний слой катионита. Из сепараторе слой анионита перемещается в колонку для регенерации анионита, а потом слой из границы раздела перемещается в промежуточный сборник, а также нижний катионитный слой переносится в колонку для регенерации катионита. При вторичной зарядке сепаратора, ионит из промежуточного сборника поворачивается снова в сепаратор. Поддерживание переносов дает возможность сохранить соответствующие давления на подведениях и спусках жидкости.