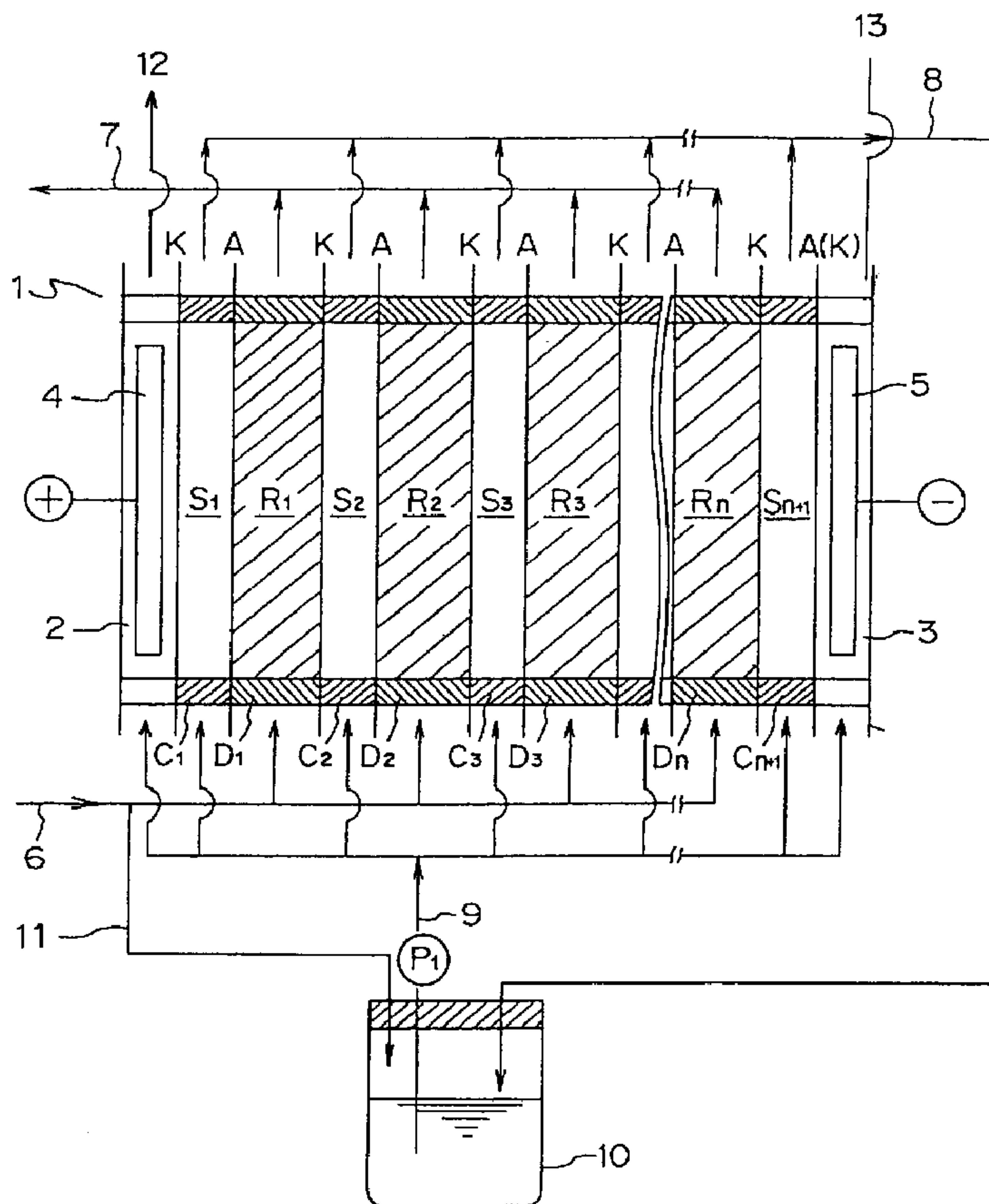




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(54) Titre : METHODE DE PRODUCTION D'EAU DESIONISEE  
 (54) Title: METHOD FOR PRODUCING DEIONIZED WATER



(57) Abrégé/Abstract:  
 A method for producing deionized water by self-regenerating type electrodesionization, which comprises (i) using a deionized water-producing apparatus containing an electrodesionizer comprising cation exchange membranes and anion exchange

(57) **Abrégé(suite)/Abstract(continued):**

membranes alternately arranged between an anode compartment provided with an anode and a cathode compartment provided with a cathode, demineralizing compartments compartmentalized with anion exchange membranes on the anode side and compartmentalized with cation exchange membranes on the cathode side, and concentrating compartments compartmentalized with cation exchange membranes on the anode side and compartmentalized with anion exchange membranes on the cathode side, the electro dialyzer having ion exchangers accommodated in the demineralizing compartments, and (ii) applying a voltage while supplying water to be treated to the demineralizing compartments to remove impurity ions in the water to be treated, wherein at least a part of the untreated water or already treated water is withdrawn to be added to a concentrating water for recycle, a flow amount of untreated water to be introduced into the demineralizing compartments being from 2 to 5.5 to a flow amount of a concentrating water to be introduced into the concentrating compartments, a linear velocity of untreated water in the demineralizing compartments being from 0.5 to 7.0 cm/sec, and a linear velocity of a concentrating water in the concentrating compartments being from 1.2 to 20 times to the linear velocity in the demineralizing compartments.

## ABSTRACT

A method for producing deionized water by self-regenerating type electrodialysis deionization, which comprises (i) using a deionized water-producing apparatus  
5 containing an electrodialyzer comprising cation exchange membranes and anion exchange membranes alternately arranged between an anode compartment provided with an anode and a cathode compartment provided with a cathode, demineralizing compartments compartmentalized with anion  
10 exchange membranes on the anode side and compartmentalized with cation exchange membranes on the cathode side, and concentrating compartments compartmentalized with cation exchange membranes on the anode side and compartmentalized with anion exchange  
15 membranes on the cathode side, the electrodialyzer having ion exchangers accommodated in the demineralizing compartments, and (ii) applying a voltage while supplying water to be treated to the demineralizing compartments to remove impurity ions in the water to be treated, wherein  
20 at least a part of the untreated water or already treated water is withdrawn to be added to a concentrating water for recycle, a flow amount of untreated water to be introduced into the demineralizing compartments being from 2 to 5.5 to a flow amount of a concentrating water  
25 to be introduced into the concentrating compartments, a linear velocity of untreated water in the demineralizing compartments being from 0.5 to 7.0 cm/sec, and a linear

velocity of a concentrating water in the concentrating compartments being from 1.2 to 20 times to the linear velocity in the demineralizing compartments.

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METHOD FOR PRODUCING DEIONIZED WATER

The present invention relates to a method for producing pure water or ultra-pure water by self-regenerating type electrodialysis deionization, which is used for pharmaceutical-manufacturing industries, semiconductor-manufacturing industries, food industries or boiler water and other laboratory facilities.

Heretofore, as a method for producing deionized water, it is common to obtain deionized water by passing water to be treated through a bed packed with an ion exchange resin so that impurity ions are removed as adsorbed on the ion exchange resin. Here, it is common to employ a method of regenerating the ion exchange resin having its ion-exchanging and adsorbing abilities lowered, by means of an acid or alkali. However, this method has problems that a troublesome operation is required and that a waste liquid of the acid or alkali used for the regeneration, is discharged.

Therefore, a method for producing deionized water which requires no such regeneration, is desired. From

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such a viewpoint, a self-regenerating type  
electrodialysis deionizing method has been recently  
developed and practically used. This method employs an  
electrodialyzer having anion exchange membranes and  
5 cation exchange membranes alternately arranged to form  
demineralizing compartments and having a mixture of  
anion-exchange resin and cation-exchange resin  
accommodated in the demineralizing compartments, and is  
designed to apply a voltage while supplying water to be  
10 treated to the demineralizing compartments and supplying  
concentrating water to concentrating compartments  
arranged alternately to the demineralizing compartments  
to carry out electrodialysis to produce deionized water.

Thus, a conventional method for producing deionized  
15 water by self-regenerating type electrodialysis  
deionization, employs a deionized water-producing  
apparatus containing an electrodialyzer comprising cation  
exchange membranes and anion exchange membranes  
alternately arranged between an anode compartment  
20 provided with an anode and a cathode compartment provided  
with a cathode, demineralizing compartments  
compartmentalized with anion exchange membranes on the  
anode side and compartmentalized with cation exchange  
membranes on the cathode side, and concentrating  
25 compartments compartmentalized with cation exchange  
membranes on the anode side and compartmentalized with  
anion exchange membranes on the cathode side, the

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electrodialyzer having an anion exchange resin and a cation exchange resin accommodated in the demineralizing compartments, and impurity ions in water to be treated are removed by applying a voltage while supplying the water to be treated to the demineralizing compartments and supplying a part of the water to be treated (untreated water) or already treated water as a concentrating water to the concentrating compartments.

According to this method, an ion exchanger is continuously regenerated, and it therefore has an advantage that regeneration by a chemical reagent such as an acid or alkali is not necessary. However, since this method generally requires a high voltage to be applied, it raises a problem of high power cost or high accessory rectifier cost. Accordingly, it is an important subject to lower a voltage to be applied. An amount of waste water to be disposed is largely reduced in comparison with the case of using a bed packed with an ion exchange resin, but from a viewpoint of recent environmental problems, it is required to further reduce an amount of waste water such as a concentrating water or the like to be disposed. Thus, it is strongly demanded to positively improve a rate of using the starting water efficiently.

Among the above mentioned problems, to reduce a voltage means to lower an electric resistance in demineralizing compartments and/or concentrating compartments, but since an anion exchange resin and a

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cation exchange resin accommodated in the demineralizing compartments are electroconductive materials, it is considered that an important factor to lower the electric resistance resides in the concentrating compartments.

5           As a method for lowering the electric resistance in the concentrating compartments, it is proposed to minimize a thickness of the concentrating compartments. However, since an electrodialyzer generally comprises plural pairs of concentrating compartments, and demineralizing  
10 compartments, the amounts of water flowing through these compartments become extremely different between the compartments of each pair when the thickness of the concentrating compartment is made extremely small. Further, there is a fear of causing a local voltage rise. Also, from  
15 a viewpoint of accuracy for designing the concentrating compartment, there is a restriction, and a practically allowable thickness of the concentrating compartment is restricted.

          On the other hand, when a water-flowing system on  
20 the concentrating compartment is not a recycling system, a practical amount of water to be treated flowing in a conventional electrodialyzer is from 3 to 5 times that of a concentrating water, and when the water to be treated is demineralized to pure water, impurity ions in the  
25 concentrating water are concentrated to 4 - 6 times. However, at this degree of concentration rate, a satisfactory reduction in electric resistance can not be achieved even when a thickness of the compartment frame is made extremely small. On the contrary, a problem of a water  
30 flow distribution is raised, and a voltage to be applied may have to be raised.

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As another method for lowering the electric resistance in the concentrating compartments, it is proposed to elevate a concentration of a concentrating water. This method can be considered to be effected by reducing a flow amount of the concentrating water (i.e., the amount of the concentrating water flowing through the concentrating compartments). That is, a concentration rate is elevated by reducing the flow amount of the concentrating water, whereby an electroconductivity is raised to reduce a voltage to be applied. However, in order to prevent occurrence of the ion concentration gradient in a concentrating compartment and also to prevent scale precipitation due to the presence of hardness components in water such as Ca ion, Mg ion and the like, it is necessary to cause a turbulent flow by flowing the concentrating water in an amount larger than a certain value. On the other hand, to reduce the flow amount of the concentrating water as mentioned above, means to reduce or to prohibit occurrence of a required turbulent flow.

It is therefore proposed to raise a flow amount ratio (water to be treated/concentrating water ratio) of water to be treated and a concentrating water and to raise a linear velocity of water in the concentrating compartment. However, when a water flow system on the concentrating compartment side is not a recycling system, the above mentioned problem concerning a frame thickness arises, and the amount of water to be treated or already treated water to be supplied as a concentrating water is increased, which reduces the amount of water actually treated and increases the amount of waste water to be disposed.

Further, as other method to reduce the electric resistance in the concentrating compartment, it is proposed to pack an ion exchange resin also into the concentrating compartment. However, since the concentrating compartment

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originally has a small thickness, it is difficult to pack an ion exchange resin therein, and therefore this method is not realistic. Also, even when the compartment frame is made so thick as to be able to pack the ion exchange resin, pressure loss becomes high, and it becomes difficult to achieve a good pressure balance between the concentrating compartment and the demineralizing compartment. Further, in proportion to the thickness of the compartment frame, the size of the electro dialyzer becomes large. As mentioned above, there are some methods to lower the electric resistance in the concentrating compartment, but when the water flow system on the concentrating compartment side is not a recycling system, the above mentioned various disadvantages are raised, and a basic solution could not be achieved up to now.

The present invention has been made in order to

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solve the above mentioned various problems. Thus, an object of the present invention is to provide a method for producing deionized water by self-regenerating type electro dialysis deionization, which comprises applying  
5 accurately controlled operation conditions to an apparatus for producing deionized water, comprising an electro dialyzer having cation exchange membranes and anion exchange membranes alternately arranged between a cathode and an anode to form demineralizing compartments  
10 and concentrating compartments and having ion exchangers accommodated in the demineralizing compartments, thereby solving the above mentioned conventional problems.

That is, the present invention provides a method for producing deionized water by self-regenerating type  
15 electro dialysis deionization, which comprises (i) using a deionized water-producing apparatus containing an electro dialyzer comprising cation exchange membranes and anion exchange membranes alternately arranged between an anode compartment provided with an anode and a cathode  
20 compartment provided with a cathode, demineralizing compartments compartmentalized with anion exchange membranes on the anode side and compartmentalized with cation exchange membranes on the cathode side, and concentrating compartments compartmentalized with cation  
25 exchange membranes on the anode side and compartmentalized with anion exchange membranes on the cathode side, the electro dialyzer having ion exchangers

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accommodated in the demineralizing compartments, and (ii) applying a voltage while supplying water to be treated to the demineralizing compartments to remove impurity ions in the water to be treated, wherein at least a part of the untreated water or already treated water is withdrawn to be added to a concentrating water for recycle, a ratio of a flow amount of untreated water to be introduced into the demineralizing compartments/a flow amount of a concentrating water to be introduced into the concentrating compartments being 2 - 5.5/1, a linear velocity of untreated water in the demineralizing compartments being 0.5 - 7.0 cm/sec, and a linear velocity of a concentrating water in the concentrating compartments being 1.2 - 20 times to the linear velocity in the demineralizing compartments.

The present invention employs a deionized water-producing apparatus containing an electro dialyzer comprising cation exchange membranes and anion exchange membranes alternately arranged between an anode compartment provided with an anode and a cathode compartment provided with a cathode, demineralizing compartments compartmentalized with anion exchange membranes on the anode side and compartmentalized with cation exchange membranes on the cathode side, and concentrating compartments compartmentalized with cation exchange membranes on the anode side and compartmentalized with anion exchange membranes on the

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cathode side, the electro dialyzer having ion exchangers accommodated in the demineralizing compartments. A concentrating water to be introduced into the concentrating compartments is preferably reused by recycling to a tank other than the concentrating compartments, and a part of untreated water or already treated water is added in a predetermined amount to the recycling system to maintain a concentration of concentrating water constant. The amount of the untreated water or treated water thus added is not specially limited, but is preferably in the range of from 0.2 to 9.5 wt% based on the total water to be treated, for practical use.

In this invention, a term "concentrating water" means a water to be passed through a concentrating compartment, and a term "untreated water" means a water to be introduced into a deionizing compartment.

Figure 1 illustrates an embodiment of the self-regenerating type electro dialysis deionization apparatus usable in the present invention. In Figure 1, A represents anion exchange membranes and K represents cation exchange membranes. As illustrated in the Figure, these anion exchange membranes A and cation exchange membranes K are arranged at predetermined distances by means of demineralizing compartment frames  $D_1, D_2, D_3 \dots D_n$  and concentrating compartment frames  $C_1, C_2, C_3 \dots C_{n+1}$  in an electro dialyzer 1, thereby forming an anode

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compartment 2, concentrating compartments  $S_1, S_2 \dots S_{n+1}$ ,  
demineralizing compartments  $R_1, R_2 \dots R_n$  and a cathode  
compartment 3. In the demineralizing compartments  $R_1, R_2$   
 $\dots R_n$ , anion and cation exchange resin are accommodated  
5 and packed. In the concentrating compartments, spacers  
of mesh-like structures are inserted.

In Figure 1, numeral 4 represents an anode and  
numeral 5 represents a cathode, and a predetermined  
amount of voltage is applied between the two electrodes  
10 during operation. Water to be treated is introduced  
through a conduit 6 into demineralizing compartments  $R_1,$   
 $R_2 \dots R_n$  and anion components in the water to be treated  
are permeated and transferred through anion exchange  
membranes A to concentrating compartments on the anode  
15 side. On the other hand, cation components in the water  
to be treated in the demineralizing compartments are  
permeated and transferred through cation exchange  
membranes K to concentrating compartments on the cathode  
side. In this manner, the water to be treated is  
20 deionized, and discharged through a conduit 7 to be  
utilized. Further, a concentrating water is introduced  
through a conduit 9 into each concentrating compartment  
 $S_1, S_2 \dots S_{n+1}$ , wherein the above mentioned permeated and  
transferred anions and cations are gathered and recycled  
25 through a conduit 8. Figure 1 illustrates the case in  
which the flow direction of the water to be treated and  
the flow direction of the concentrating water are co-

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current each other, but as a matter of fact, they may be counter-current.

In Figure 1, a part of concentrating water is withdrawn from the conduit 9 to be introduced into the anode compartment 2 and the cathode compartment 3. The water introduced into the anode compartment 2 is disposed through conduit 12. The water introduced into the cathode compartment 3 is disposed through conduit 13.

In each demineralizing compartment  $R_1, R_2 \dots R_n$ , cations in the water to be treated trapped by a cation exchanger are driven by an electric field through a cation exchanger in contact with the cation exchanger trapping cations into a cation exchange membrane, and are permeated through the membranes and transferred to each concentrating compartment  $S_1, S_2 \dots S_{n+1}$ . In the same manner as above, anions in the water to be treated trapped by an anion exchanger are driven through an anion exchanger and an anion exchange membrane in contact therewith and are transferred to each concentrating compartment  $S_1, S_2 \dots S_{n+1}$ .

As mentioned above, in the present invention, a concentrating water withdrawn from each concentrating compartment is preferably reused for recycling between each concentrating compartment and a tank other than the concentrating compartment, and a part of untreated water or already treated water is added in a predetermined amount to the recycling system to maintain a

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concentration constant. In Figure 1, 10 represents a tank, a concentrating water withdrawn from each concentrating compartment  $S_1, S_2 \dots S_{n+1}$  is introduced through a conduit 8 into a tank 10, and is reused for recycling through a conduit 9. P1 represents a pump for recycling. In the present invention, flow amounts of water to be treated and concentrating water are adjusted to be a predetermined ratio by controlling an amount of water to be treated newly added to a concentrating water recycle system, and a required amount of water to be treated is separated from a conduit 6 by a separative conduit 11, and is introduced into a tank 10 through a control valve (not shown), and is then added to a recycled concentrating water. In the present invention, a treated water may be used in place of the water to be treated (untreated water), but in such a case, the treated water is separated from a treated water conduit 7.

In the present invention, the amount of the water to be treated flowing through the demineralizing compartments is adjusted to be from 2 to 5.5 times that of the concentrating water flowing through the concentrating compartments. If the amount of the water to be treated is less than 2 times that of the concentrating water, the concentrating water does not provide a satisfactory electroconductivity when recycled for reuse. On the other hand, if the amount of the water to be treated is more than 5.5 times that of the concentrating water, the efficiency of deionization is lowered and consequently the water quality of the deionized water thus obtained is lowered. Particularly, it is preferable that the amount of the water to be treated is from 3 to 5 times that of the concentrating water.

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However, even when the abovementioned flow amount ratio of the water to be treated to the concentrating water is satisfied, a satisfactory result can not be obtained unless linear velocities of respective flowing waters in the demineralizing compartment and the concentrating compartment are adjusted so as to satisfy predetermined conditions. For the purpose of demineralization, it is usual to conduct operation under an excessive pressure condition on the demineralizing compartment side so that the water to be treated may not be contaminated with the concentrating water even if an internal leakage occurs. If the linear velocity of the water to be treated is less than 0.5 cm/sec, it becomes difficult to obtain an appropriate pressure loss and an absolute pressure in the concentrating compartment becomes higher. On the contrary, if the linear velocity of the water to be treated is higher than 7.0 cm/sec, a pressure loss becomes too large, and a contact time between the water and the resin becomes shorter, whereby the efficiency of deionization is lowered and the water quality of the deionized water thus obtained tends to be lowered. Thus, the linear velocity of the water to be treated in demineralizing compartments is adjusted to be in the range of from 0.5 to 7.0 cm/sec, preferably from 1.0 to 5.5 cm/sec.

On the other hand, it is necessary to adjust the linear velocity of the concentrating water in the concentrating compartment at least 1.2 times that of the water to be treated in the demineralizing compartment. In the concentrating compartment, it is usual to use such a structure as to prevent deformation and to secure a flow path, preferably a mesh-like structure, and this structure

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provides a pressure loss smaller than an ion exchange packing material in the demineralizing compartment. Therefore, if the linear velocity of water flowing in the concentrating compartment is less than 1.2 times that of water flowing in the demineralizing compartment, the pressure in the concentrating compartment becomes too small relative to that in the demineralizing compartment, and the ion exchange membrane is intruded into openings of such a structure as a mesh-like structure, whereby it becomes difficult to secure an appropriate flow amount.

Also, such a low linear velocity hardly causes an effective turbulent flow in the concentrating compartment, whereby a scale due to the presence of hardness components in water such as Ca ion and Mg ion is likely to be precipitated. On the other hand, if the linear velocity of water flowing in the concentrating compartment is more than 20 times that of water flowing in the demineralizing compartment, the demineralizing compartment can not be maintained under an excessive pressure condition higher than the concentrating compartment, and consequently the water quality of treated water becomes lowered. It is therefore necessary to adjust the linear velocity of the concentrating water in the concentrating compartment in the range of from 1.2 to 20 times, preferably from 1.5 to 15 times that of water flowing in the demineralizing compartment.

In the present invention, in order to provide the abovementioned specific flow ratio and linear velocity, it is preferable to adjust the thickness of the demineralizing compartment in the range of from 0.3 to 30 cm and also to adjust the thickness of the concentrating compartment in the

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range of from 0.01 to 3.7 cm. Thus, if the thickness of the demineralizing compartment is smaller than 0.3 cm, the number of constituting parts becomes large to a predetermined load amount, which leads to a high cost. On the other hand, if the thickness of the demineralizing compartment exceeds 30 cm, a possibility of bringing a cation exchange resin and an anion exchange resin in continuous contact with each other between the cation exchange membrane and the anion exchange membrane constituting the demineralizing compartment becomes extremely low, and consequently, the efficiency of deionization becomes unfavorably low. On the other hand, if the thickness of the concentrating compartment is less than 0.01 cm, it becomes very difficult to prevent water from soaking into each compartment frame, and on the contrary, if the thickness of the concentrating compartment exceeds 3.7 cm, the electrodialyzer becomes too large in size, which leads to a high cost. Particularly, the thickness of the demineralizing compartment is preferably from 0.7 to 15 cm, and the thickness of the concentrating compartment is preferably from 0.04 to 2 cm.

Also, it is possible to raise a concentration of the concentrating water by adding a salt or an acid to the concentrating water to be recycled and reused. The addition of a salt or an acid to the recycling system is helpful for optionally controlling a concentration and a pH value of the concentrating water in combination with the addition amount of untreated water or treated water supplied separately, whereby a voltage applied can be reduced and precipitation of a salt of hard water components in a concentrating compartment, particularly Ca salt, can be effectively

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prevented. For a practical operation, an electroconductivity of the concentrating water is preferably in the range of from 5 to 3000  $\mu$  S/cm when considering unit requirements of water to be treated or treated water and  
5 salt or acid.

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## EXAMPLES

Hereinafter, the present invention is further illustrated by the following Examples, but it should be noted that the present invention is not limited to these 5 Examples. In the Examples, a self-regenerating type electro dialyzer apparatus as shown in Figure 1 was used, and an example of flowing water to be treated and concentrating water as upward co-current was employed. In Comparative Example 1, water flowing out of the 10 concentrating compartment was not recycled but was made one path. In Comparative Example 1, a conduit 8 was not connected to the tank 10, and an embodiment of introducing water to be treated through a conduit 9 and disposing through a conduit 8 was employed as the 15 concentrating water. Further, in Comparative Example 2, the thickness of a concentrating compartment was made 0.38 cm unlike other Examples, and in Example 2 and in Comparative Example 2, 1 ppm of  $Mg^{2+}$  ion was added as a promoting factor of scale precipitation in a 20 concentrating compartment.

## EXAMPLES 1 to 2 and COMPARATIVE EXAMPLES 1 to 2

An electro dialyzer (effective area  $507 \text{ cm}^2$  [width (= compartment frame width) 13 cm, length (= demineralizing compartment length) 39 cm]  $\times$  3 pairs) 25 comprising a filter press type dialyzer (a polypropylene-made net is inserted into a concentrating compartment) having a cation exchange membrane (strong acid type

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heterogeneous membrane, thickness 500  $\mu\text{m}$ , ion exchange capacity 4.5 meq/g-dry resin) and an anion exchange membrane (strong base type heterogeneous membrane, thickness 500  $\mu\text{m}$ , ion exchange capacity 3.5 meq/g-dry resin) arranged and fixed by way of a demineralizing compartment frame (made of polypropylene) and a concentrating compartment frame (made of polypropylene) was formed. In Examples 1 to 2 and Comparative Example 1, the thickness of a demineralizing compartment was made 0.8 cm, and the thickness of a concentrating compartment was made 0.19 cm, but in Comparative Example 2, the thickness of a concentrating compartment was made 0.38 cm.

A demineralizing compartment was packed with a sheet-like molded product of a mixture of a cation exchange resin, an anion exchange resin and a binder in dry state, and a spacer made of a synthetic resin was placed in a concentrating compartment to secure a flowing path. The above two ion exchange resins employed were an acid (sulfonic acid) type (H type) cation exchange resin (trademark: Diaion SK-1B manufactured by Mitsubishi Chemical Corporation) having a particle diameter of 400 to 600  $\mu\text{m}$  and an ion exchange capacity of 4.5 meq/g dry resin and a quaternary ammonium salt type (OH type) anion exchange resin (trademark: Diaion SA-10A manufactured by Mitsubishi Chemical Corporation) having a particle diameter of 400 to 600  $\mu\text{m}$  and an ion exchange capacity

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of 3.5 meq/g dry resin, and an ion exchange capacity ratio of the two resins was made 50/50.

By using this electro dialyzer, a test for producing deionized water was carried out in the following manner.

5 Industrial water was filtrated, and treated by a reverse osmosis apparatus to prepare "water to be treated". The industrial water employed and the water to be treated thus prepared were measured with regard to electroconductivity, pH value and composition of  
10 constituents, and the results are shown in the following Table 1. The water to be treated was introduced upward as water to be treated and concentrating water, and was regenerated under predetermined electric regeneration conditions, and operation was carried out under flow  
15 amount conditions as shown in the following Table 2.

The voltage and D.C. electric current conditions employed during this operation are shown in the following Table 3. Applied voltages shown in Table 3 are voltages required to obtain satisfactory deionized water having  
20 a specific resistance value of at least 10 MΩ·cm. In Comparative Example 1, flowing water on the concentrating compartment side was not recycled, and was made one path. In each of Examples 1 to 2 and Comparative Examples 1 to 2, operation was carried out  
25 continuously for 750 hours under conditions as shown in the following Tables 2 and 3. After finishing the operation, the electro dialyzer used was disassembled to

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check occurrence of scale precipitation on the concentrating compartment side. These results are shown in the following Tables 2 and 3.

Table 1

	Electro- conductivity ( $\mu$ S/cm)	pH	Na ( $\mu$ g/L)	Ca ( $\mu$ g/L)	Mg ( $\mu$ g/L)
Industrial water	309	6.5	15600	29900	9200
Water to be treated	6.6	5.9	1300	61	22

Table 2

	Example 1	Example 2	Compar- ative Example 1	Compar- ative Example 2
Flow amount of water to be treated (L/H/compartment)	90	90	90	90
Linear velocity of water to be treated (cm/sec)	2.4	2.4	2.4	2.4
Recycled flow amount of concentrating water (L/H/compartment)	30	30	30	30
Linear velocity of concentrating water (cm/sec)	3.4	3.4	3.4	1.7
Flow amount ratio (water to be treated/concentrating water)	3/1	3/1	3/1	3/1
Mg concentration (ppm as Mg)	0	1	0	1
Utilization ratio of starting water (%)	95	95	75	95

Table 3

	Electro-conductivity of concentrating water ( $\mu S/cm$ )	Applied voltage (V)	D.C. electric current (A)	Presence or absence of scales after 750 hours
Example 1	152	45	2.0	absence
Example 2	302	35	2.0	absence
Comparative Example 1	25	100	2.0	absence
Comparative Example 2	298	60	2.0	presence

As evident from Tables 2 and 3, in Comparative Example 1 wherein a flowing water on the concentrating compartment side was made one path, the electroconductivity of concentrating water was extremely low (i.e. low concentration) and the applied voltage is high, as compared with Example 1 employing the same flow amount ratio and flowing velocity conditions. Also, the rate of using starting water in Comparative Example 1 was lower by 20% than in Example 1. Further, when comparing Example 2 and Comparative Example 2, both of which contain 1 ppm of  $Mg^{2+}$  ion as a promoting factor of scale precipitation in a concentrating compartment, a scale did not precipitate in Example 2, whereas a scale clearly precipitated in Comparative Example 2. It is evident

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from this fact that a scale of hard water components precipitates when a linear velocity on the concentrating compartment side is low even if a flow amount ratio of water to be treated and concentrating water is equivalent  
5 to each other.

According to the present invention, by controlling a flow amount of water to be treated or treated water newly added to the concentrating water recycle system to make a flow amount ratio of the water to be treated and  
10 the concentrating water in the specific predetermined range and by adjusting each linear velocity in the specific predetermined range, a high electroconductivity can be secured in a concentrating compartment, and also by causing an effective turbulent flow by a high linear  
15 velocity, precipitation of a scale in a concentrating compartment can be prevented while being operatable under a low voltage. By this manner, it is possible to reduce electric power unit requirements. Further, since a high rate of using starting water can be easily achieved, an  
20 amount of water to be disposed outside the system can be reduced, whereby an operation cost can be reduced and a cost per unit production amount of deionized water can be further reduced.

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CLAIMS:

1. A method for producing deionized water from untreated water containing impurity ions, by self-regenerating type electrodialysis deionization, which  
5 comprises:

(i) providing a deionized water-producing apparatus containing an electrodialyzer comprising a plurality of pairs of a cation exchange membrane and an anion exchange membrane alternately arranged between an  
10 anode compartment provided with an anode and a cathode compartment provided with a cathode, a plurality of demineralizing compartments each compartmentalized with the anion exchange membrane on the anode side and the cation exchange membrane on the cathode side, and a plurality of  
15 concentrating compartments each compartmentalized with the cation exchange membrane on the anode side and the anion exchange membrane on the cathode side, the electrodialyzer having anion and cation ion exchange resins accommodated in the demineralizing compartments, and

20 (ii) applying a voltage between the anode and the cathode, while supplying the untreated water through a conduit to the demineralizing compartments to remove the impurity ions contained in the untreated water and discharging the thus-produced deionized water from the demineralizing compartments, and supplying concentrating  
25 water to the concentrating compartments and discharging ion-concentrated water from the concentrating compartments,

wherein:

(I) (a) a part of the untreated water is withdrawn  
30 from the conduit before being introduced into the demineralizing compartments and is added to the

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concentrating water, (b) a part or whole of the ion-concentrated water discharged from the concentrating compartments is added to the concentrating water, thereby recycling the ion-concentrated water, or (c) a part of the untreated water is withdrawn from the conduit before being introduced into the demineralizing compartments and is added to the concentrating water and a part or whole of the ion-concentrated water discharged from the concentrating compartments is added to the concentrating water, thereby recycling the ion-concentrated water;

(II) the untreated water introduced into the demineralizing compartments is in an amount of from 2 to 5.5 times that of the concentrating water introduced into the concentrating compartments;

(III) a linear velocity of the untreated water in the demineralizing compartments is from 0.5 to 7.0 cm/sec; and

(IV) a linear velocity of the concentrating water in the concentrating compartments is from 1.2 to 20 times the linear velocity of the untreated water in the demineralizing compartments.

2. The method according to claim 1, wherein the untreated water or the ion concentrated water added to the concentrating water or both are in an amount of from 0.2 to 9.5 wt% based on the total untreated water.

3. The method according to claim 1 or 2, wherein the demineralizing compartments have a thickness of from 0.3 to 30 cm and the concentrating compartments have a thickness of from 0.01 to 3.7 cm.

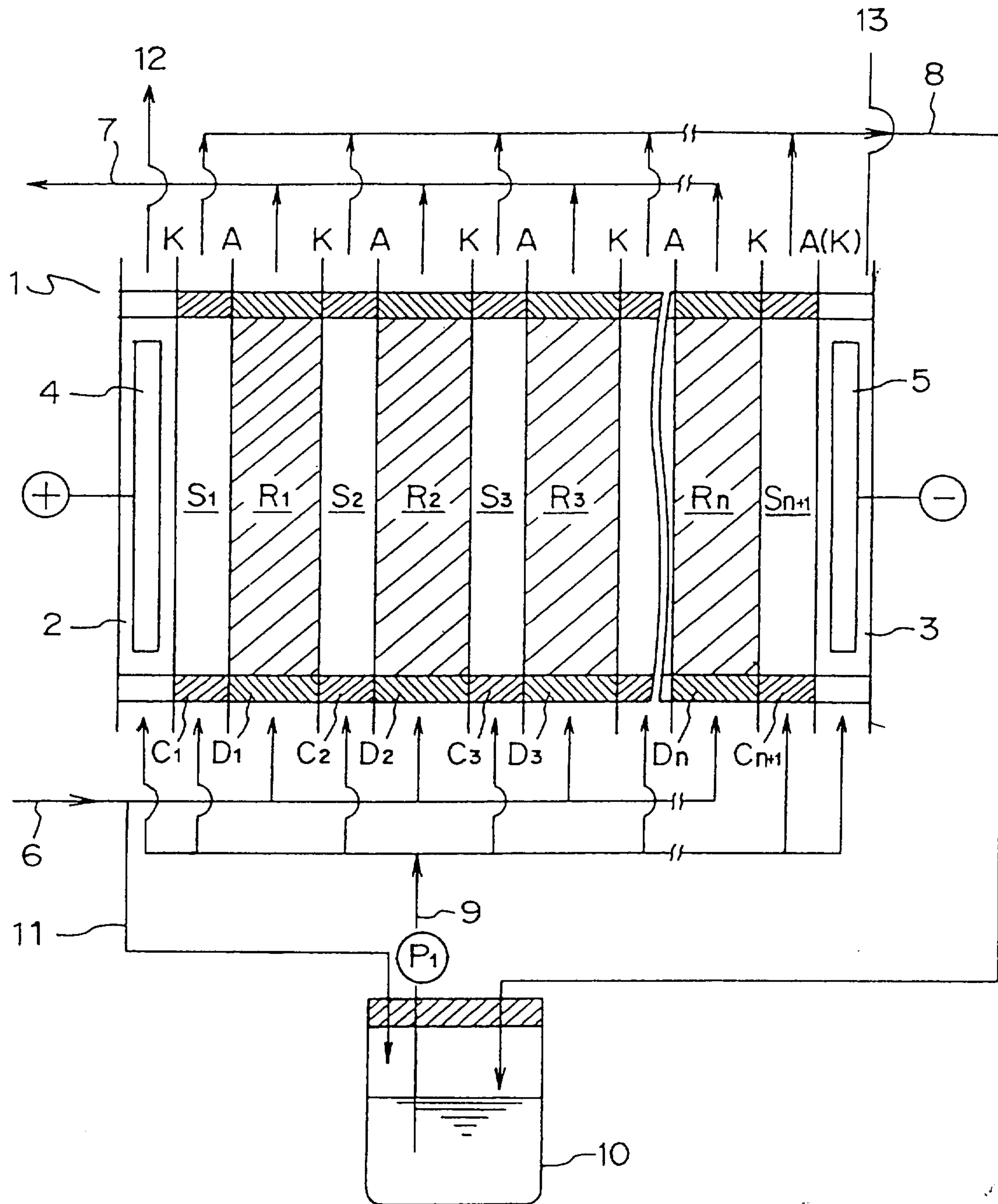
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4. The method according to any one of claims 1 to 3, wherein an acid or a salt is added to the concentrating water.
5. The method according to any one of claims 1 to 4, choice (a) in item (I) is selected.

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FIGURE 1



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