

## DESCRIPTION

### SEPARATION MEMBRANE MODULE AND OPERATING METHOD OF SEPARATION MEMBRANE MODULE

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#### TECHNICAL FIELD

The present invention relates to a separation membrane module for efficiently eliminating turbid materials accumulated in a feed water spacer wound around a spiral  
10 membrane element and to a method for operating the separation membrane module.

#### BACKGROUND ART

Conventionally, as a method for desalinating seawater  
15 or for obtaining high purity water and process water for various manufacturing processes, a method of separating ion components and low molecular weight components from feed water using a spiral membrane element in which a reverse osmosis membrane (RO membrane) or a nanofiltration membrane (NF membrane) is used  
20 as a permeable membrane has been known. The spiral membrane element is also used in a ultrafiltration method for separating low molecular weight components and high molecular weight components or for removing only high molecular weight components from the mixture of high molecular weight components  
25 and low molecular weight components or in a microfiltration method for separating fine particles. As shown in Figure 8, an embodiment of the conventional spiral membrane element has

a enveloped membrane 83 formed from a sheet of permeate water spacer 82 having reverse osmosis membranes 81 layered on both surfaces thereof, by closing off three sides of the permeate water spacer 82, thereby forming a enveloped membrane 83. The open side of the enveloped membranes 83 is attached to a permeate water collecting pipe 84 and the enveloped membrane is spirally wound around the external circumference of the permeate water collecting pipe 84 together with a net consisting of feed water spacer 85. Feed water 86 is supplied from one end 89a of a spiral membrane element 80, flows along the feed water spacer 85, and is discharged from the other end 89b of the spiral membrane element 80 as concentrate water 88. While flowing along the feed water spacer 85, the feed water 86 permeates through the reverse osmosis membrane 81. The permeate water 87 flows along the permeate water spacer 82 into the permeate water collecting pipe 84 and is discharged from the other end of the permeate water collecting pipe 84. In this manner, a feed water passage is formed by the feed water spacer 85 provided between the wound enveloped membranes 83.

20 A multi-stage separation membrane apparatus having two or more stages of separation membrane units, each unit consisting of one or more separation membrane modules, arranged in parallel when the number of modules are two or more, having the above mentioned spiral membrane element, have  
25 conventionally been used to increase the recovery ratio of water and the throughput capacity. For example, as shown in a multi-stage separation membrane apparatus 90 in Figure 9, the

feed water supplied from pump 91 is sent via a feed water supply main pipe 92 and branched feed water pipes 93a, 93b to first stage separation membrane modules 94a, 94b arranged in parallel, wherein the feed water is separated into permeate water to be discharged from permeate water discharge pipes 96a, 96b and concentrate water to be discharged from concentrate water discharge pipes 95a, 95b. The concentrated water discharged from the separation membrane modules 94a, 94b is collected in concentrate water collecting pipes 97a, 97b and sent to a second stage separation membrane module 99 via an interstage concentrate water supply main pipe (a second stage feed water supply main pipe) 98. The permeate water is discharged from a permeate water discharge pipe 101 and the concentrate water is discharged from a concentrate water discharge pipe 100. In this manner, treating the interstage concentrate water obtained in the front stage in the separation membrane module in the rear stage can increase the recovery ratio of water. In addition, arranging two or more separation membrane modules in one stage in parallel can increase the throughput capacity.

When desalinating seawater or producing high purity water or process water for various manufacturing processes using such a reverse osmosis membrane spiral element, feed water is pretreated for the purpose of eliminating turbid materials and the like. The feed water spacer in the reverse osmosis membrane spiral element has a small thickness (usually 1 mm or less) to provide the feed water with as large a contact area with the reverse osmosis membrane as possible, while ensuring

the required feed water passage. This design allows turbid materials in the feed water to be accumulated in the feed water spacer, giving rise to clogging of the feed water passage. The pretreatment is performed in order to remove the turbid

5 materials in the feed water to ensure a safe and long-term operation by avoiding a water flow pressure drop and a decrease in the amount and quality of the permeate water due to accumulated turbid materials. A pretreatment apparatus used for eliminating such turbid materials includes various process  
10 units such as a coagulation and sedimentation, filtration and membrane separation, which not only increase installation and operation costs, but also require a large installation area.

If the pretreatment apparatus for the separation membrane module having a spiral membrane element can be omitted,  
15 industrial water and tap water can be treated without pretreatment, thereby enabling system simplification, minimization of the installation area, and reduction of operating cost. Such a system has an extremely high industrial value. Therefore, a feed water spacer having a structure less  
20 liable to accumulate ion of turbid materials or a technology that can eliminate turbid materials that may accumulate in the feed water spacer by alteration of the operating method or by means of flushing is very useful. The technology capable of eliminating turbid materials by altering the operating method  
25 or by flushing is particularly preferable, since such a technology may allow use of the conventional spiral membrane element as is.

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discloses a method of flushing a reverse osmosis membrane module by backwashing the membrane module by supplying a pressurized gas-liquid two-phase flow in the direction opposite to the normal flow direction of feed water. The flushing by backwashing, however, is to eliminate turbid materials deposited on the surface of hollow fiber membranes of a hollow fiber reverse osmosis membrane module, but not to eliminate turbid materials deposited on a feed water spacer of a spiral reverse osmosis membrane module.

An object of the present invention is therefore to provide a separation membrane module that can efficiently eliminate turbid materials accumulated in a feed water spacer wound around a spiral-type membrane element and a method for operating the separation membrane module.

#### DISCLOSURE OF THE INVENTION

Such being the case, the inventors of the present invention have conducted extensive studies. As a result, the inventors have found that, in a separation membrane module having a spiral membrane element of the type in which an enveloped separation membrane and a feed water spacer are wound around the external circumference of a permeate water collecting pipe, turbid materials in feed water accumulate mainly in intersection areas at which wires of the feed water spacer intersect, that turbid materials accumulated in the feed water spacer can be easily eliminated if the separation membrane

module is operated while regularly or irregularly changing the flow of feed water to reverse directions, that the efficiency of turbid material elimination increases if flushing operation is carried out two or more times when the feed water flow direction is changed, and that much more turbid materials can be eliminated if flushing is carried out from time to time during operation of the separation membrane module, and if a first flushing operation among consecutive flushing operations is carried out in the direction reverse to the direction of feed water immediately before the flushing operation. These findings have led to the completion of the present invention.

Specifically, the present invention provides in a method for operating a separation membrane module having a spiral membrane element of the type in which an enveloped separation membrane and a feed water spacer are wound around the external circumference of a permeate water collecting pipe (hereinafter referred to as "separation membrane module operating method (I)") or a method for operating a multi-stage separation membrane module comprising a front separation membrane module(s) having one spiral membrane element or two or more spiral membrane elements arranged in parallel and a rear separation membrane module(s) having one spiral membrane element or two or more spiral membrane elements arranged in parallel, wherein interstage concentrate water from the front separation membrane module(s) is sequentially supplied to the rear separation membrane module(s) (hereinafter referred to as "separation membrane module operating method (II)"), a method

characterized by operating the separation membrane modules while regularly or irregularly changing the flow of feed water to reverse directions. This configuration ensures easy dislodgment and elimination of turbid materials accumulated in intersection areas of the feed water spacer.

The present invention also provides the separation membrane module operating method (I) or (II), wherein a flushing operation is carried out two or more times alternately in either of the flow directions when altering the feed water flow direction. This configuration ensures elimination of turbid materials accumulated in intersection areas of the feed water spacer without fail.

The present invention further provides the separation membrane module operating method (I) or (II), wherein a first flushing operation is carried out in the direction reverse to the direction of feed water immediately before the flushing operation. This configuration ensures efficient dislodgment of turbid materials accumulated in intersection areas of the feed water spacer, whereby the elimination operation can be carried out easily.

The present invention further provides the separation membrane module operating method (I) or (II), wherein the separation membrane module comprises a spiral membrane element of the type in which an enveloped separation membrane and a feed water spacer are wound around the external circumference of a permeate water collecting pipe, the operating method comprising one or more flushing operations, in which the first flushing

operation is carried out in the direction reverse to the direction of feed water immediately before the flushing operation. This configuration ensures the same effect as in the invention mentioned above.

5           The present invention also provides the separation membrane module operating method (I) or (II), wherein valves on the permeate water side are entirely closed during the flushing operation. Feed water used for flushing operation does not permeate through a separation membrane module for high  
10 pressure operation with a flushing pressure even if the valves on the permeate water side are open. However, the feed water permeates through a separation membrane module for low pressure operation if the valves on the permeate water side are open, giving rise to a decrease in a flushing water flow rate and  
15 permeation of water with a low quality. Closure of the valves on the permeate water side brings about another effect of causing foulants deposited on the membrane surface to be suspended due to a back pressure created immediately after closure of the valves, thereby increasing the effect of flushing  
20 operation.

          The present invention also provides the separation membrane module operating method (I) or (II), wherein the pressure on the feed water supply side is released before the flushing operation. Releasing the pressure on the feed water  
25 supply side decreases the pressure that presses the membrane and causes the membrane slightly to rise, whereby turbid materials accumulated on the membrane surface and feed water

spacer are caused to float.

The present invention further provides a method of operating a multi-stage separation membrane modules, wherein the flushing operation of the multi-stage separation membrane modules is carried out for the separation membrane modules in each stage or for each group of the separation membrane modules. This configuration prevents turbid materials dislodged from the front spiral membrane elements from flowing in and fouling the rear spiral membrane elements.

The present invention further provides a separation membrane apparatus having a first feed water supply pipe connecting a feed water supply pump with a first valve, a second feed water supply pipe connecting the first valve with a separation membrane module, the separation membrane module, a permeate water discharge pipe joined to the permeate water side of the separation membrane module, a flow direction conversion pipe having a second valve and a first branched pipe for discharging concentrate water connecting the first feed water supply pipe with the concentrate water discharge side of the separation membrane module, and a second branched pipe for discharging concentrate water branched from the second feed water supply pipe for discharging concentrate water when the flow direction of feed water is reversed. This configuration enables the separation membrane module operating method (I) to be carried out in a simple apparatus.

The present invention further provides a multi-stage separation membrane apparatus, wherein interstage concentrate

water from a separation membrane module of a front separation membrane apparatus or a front separation membrane apparatus group is sequentially supplied to the rear separation membrane module of a rear separation membrane apparatus or a rear separation membrane apparatus group, wherein the separation membrane apparatuses or the separation membrane apparatuses forming the separation membrane apparatus group have a first feed water supply pipe connected to a first valve, a second feed water supply pipe connecting the first valve with a separation membrane module, the separation membrane module, a permeate water discharge pipe joined to the permeate water side of the separation membrane module, a flow direction conversion pipe having a second valve and joined to the first feed water supply pipe on the concentrate water discharge side of the separation membrane module, a first concentrate water discharge pipe joined to the flow direction conversion pipe and having a third valve, and a second concentrate water discharge pipe branched from the second feed water supply pipe and having a third valve. This configuration enables the separation membrane module operating method (II) to be carried out in a simple apparatus.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a flow diagram of the apparatus for carrying out the operating method of the separation membrane module in one embodiment of the present invention. Figure 2 is a flow diagram of the apparatus for carrying out the operating method of the separation membrane module in another embodiment of the

present invention. Figure 3 is a flow diagram of the apparatus for carrying out the operating method of the separation membrane module in still another embodiment of the present invention. Figure 4 is a drawing showing a structure of the separation membrane module in one embodiment of the present invention. Figure 5 is a flow diagram of the multi-stage separation membrane apparatus in one embodiment of the present invention. Figure 6 is a flow diagram of the multi-stage separation membrane apparatus in another embodiment of the present invention. Figure 7 is a flow diagram of the multi-stage separation membrane apparatus for carrying out the experiments of Examples 7-11. Figure 8 shows an outline of a conventional reverse osmosis membrane module. Figure 9 is a flow diagram of a conventional multi-stage separation membrane apparatus.

#### BEST MODE FOR CARRYING OUT THE INVENTION

The operating method for the separation membrane module in a first embodiment of the present invention will be explained with reference to Figure 1. Figure 1 is a flow diagram of a reverse osmosis membrane apparatus for carrying out the operating method of this embodiment. In Figure 1, a reverse osmosis membrane apparatus 10 has a first feed water supply pipe 12 connecting a feed water supply pump 11 with a first valve a, a second feed water supply pipe 13 connecting the first valve a with a reverse osmosis membrane module 10A, a permeate water discharge pipe 14 having a valve e joined to the permeate water side of the separation membrane module 10A, a flow direction

conversion pipe 15 having a second valve b and a first branched pipe 151 for discharging concentrate water connecting the first feed water supply pipe 12 with the concentrate water discharge side of the reverse osmosis membrane module 10A, and a second  
5 branched pipe 121 for discharging concentrate water branched from the second feed water supply pipe 13 and having a valve d for discharging concentrate water when the flow direction of feed water is reversed. A valve c is installed in the first branched pipe 151 for discharging concentrate water.

10 In the reverse osmosis membrane apparatus 10, the second valve b and the valve d are first closed, the valve c is opened so as to adjust the pressure in the module to a prescribed one, and the first valve a and the valve e are open. Feed water is supplied to the reverse osmosis membrane module 10A by the feed  
15 water supply pump 11. The feed water is treated in the reverse osmosis membrane module 10A and separated into concentrate water that is discharged via the first branched pipe 151 for discharging the concentrate water and permeate water that is discharged via the permeate water discharge pipe 14. Suspended  
20 substances such as turbid materials in the feed water accumulate in the feed water spacer wound around the element with a progress of operating hours, although the extent of accumulation depends on turbidity of the feed water.

Accumulation of turbid materials in the feed water spacer  
25 increases the differential pressure for water permeation. The feed water flow direction is reversed in such a case. Specifically, the first valve a and the valve c are closed, the

valve d is opened so as to adjust the pressure in the module to a prescribed one, and the second valve b is open. This valve operation causes the feed water to enter from the concentrate water discharge side of the reverse osmosis membrane module 10A and to be separated into concentrate water that is discharged via the second branched pipe 121 for discharging concentrate water and permeate water that is discharged via the permeate water discharge pipe 14. Turbid materials accumulated in intersection areas of the feed water spacer can be easily dislodged and eliminated by reversing the flow direction of feed water. Since suspended substances such as turbid materials in the feed water again accumulate in the feed water spacer installed in the element with a further progress of operating hours, the feed water flow direction is again reversed. This procedure is repeated thereafter. The timing for reversing the feed water flow direction may be either regular or irregular, usually at intervals of 1-24 hours, and preferably of 1-12 hours. If the interval is less than one hour, the valves must be switched frequently, whereby the life of the valves is shortened. If the interval is more than 24 hours, it is difficult to remove accumulated turbid materials. The feed water flow direction may be reversed when the water permeating differential pressure reaches a prescribed level. This manner of operation is preferable since turbid materials can be removed without frequently reversing the feed water flow direction. The method of reversing the flow direction after an elapse of a prescribed period of time can be combined with the method of reversing the

flow direction when a prescribed water permeation differential pressure has been reached.

Since the reverse osmosis membrane apparatus 10 of this embodiment can suppress accumulation of turbid materials by reversing the flow direction of feed water, a conventional pretreatment means for removing turbid materials in feed water such as coagulation / sedimentation, filtration or membrane separation can be omitted. Therefore, the system is simplified, the installation area is minimized, and cost can be reduced. The effect of the reverse osmosis membrane apparatus is thus innovative.

Next, a second embodiment of the operating method for the separation membrane module of the present invention will be explained with reference to Figure 1. In the second embodiment of the operating method for the reverse osmosis membrane module, a flushing operation is carried out several times alternately from either of the flow directions when altering the feed water flow direction in the operating method of the first embodiment. The flushing operation can ensure elimination of turbid materials accumulated in the intersection areas of the feed water spacer. As the method for flushing alternately from both directions of the reverse osmosis membrane module, a method of carrying out first flushing from the direction reverse to the direction of feed water immediately before the flushing operation (hereinafter from time to time referred to as "reverse direction flushing") and a method of flushing from the same direction as the direction of feed water

immediately before the flushing operation may be employed. Of the two methods, the reverse direction flushing is more preferable to efficiently dislodge turbid materials accumulated in intersection areas of the feed water spacer in a first flushing operation. Although a part of turbid materials can be eliminated by a first flushing in the same direction as the feed water flow immediately before the flushing operation, turbid materials accumulated in the retention areas of the feed water spacer are excessively pressed, giving rise to solid accumulation of turbid materials over time. The first valve a and the valve c are closed and the second valve b and the valve d are opened to initiate the reverse direction flushing. Then, feed water in an amount three times the feed water feed rate in the permeation process is jetted to the reverse osmosis membrane module from the concentrate water discharge side and discharged from the second feed water supply pipe 13 and the second branched pipe 121 for discharging concentrate water on the feed water feeding side. After completing the reverse direction flushing, a flushing operation in the direction opposite to the reverse direction flushing operation is carried out. Specifically, the second valve b and the valve d are closed and the first valve a and the valve c are opened. Then, feed water in the same feed rate in the reverse direction flushing is jetted to the reverse osmosis membrane module from the feed water supply side and discharged from the first branched pipe 151 on the concentrate water discharge side. Next, a flushing operation in the direction reverse to the direction of this

flushing is carried out. The same procedure is repeated several times alternately from the both sides.

If the first flushing is carried out in the same direction of the feed water flow immediately before the flushing operation, the second procedure in the above-described reverse direction flushing is first carried out. Turbid materials accumulated in intersections areas of the feed water spacer can be dislodged and discharged outside the element without fail by carrying out the flushing operation alternately in the both directions in this manner. When carrying out such a flushing operation, the pressure is released by opening the valve c or d for pressure control on the concentrate water discharge side in the embodiment shown in Figure 1. The method for pressure release is by no means limited to the method of this embodiment. A separate valve for the pressure release may be provided. In this instance, a concentrate water discharge pipe with a larger diameter than that of the pipe in which the pressure control valve is installed is preferably used to increase the amount of discharged water. In addition, it is possible to install an air chamber (not shown) both in the first branched pipe 151 for discharging concentrate water and the second branched pipe 121 for discharging concentrate water to perform the flushing operation using water accumulated during operation. The air chamber herein indicates an apparatus for discharging water accumulated in the chamber due to the air pressurized by the concentrate water.

In the case where the flushing operation is carried out

two or more times when the feed water flow direction is changed, it is preferable that the pressure that has pressed the membrane surface is released by releasing the pressure on the feed water supply side before the flushing operation, whereby the membrane is caused slightly to rise and float. Releasing the pressure on the feed water supply side is preferable because releasing the pressure causes turbid materials accumulated on the membrane surface and in the feed water spacer to be suspended. One method for releasing the pressure on the feed water supply side is to provide a blowdown pipe (not shown) on the first feed water supply pipe 12 on the discharge side of the feed water supply pipe 11, install a valve (not shown) in the blowdown pipe, and open the valve. Another method is to open the valve d installed in the second concentrate water discharge branched pipe 121 during the operation in which the first valve a, valve c, and valve e are open. Although there are no specific limitations to the speed of opening the valve, fully opening the valve instantaneously or within one second is preferable. Instantaneous pressure release is more advantageous for causing the membrane to float and for obtaining turbid material removing effect due to a striking action of water. In this instance, the valve e on the permeate water side is preferably opened. If the valve e is closed, there is no differential pressure through the membrane and there is no pressure exerted on the membrane. Therefore, the membrane is not caused to rise or float even if the pressure on the feed water supply side is released.

In addition, the valve e installed on the permeate water discharge pipe 14 is preferably fully closed during the flushing operation. Feed water used for flushing operation does not permeate through a reverse osmosis membrane module for high pressure operation with a flushing pressure even if the valve e installed on the permeate water discharge pipe 14 is open. However, the feed water permeates through a reverse osmosis membrane module for low pressure or super-low pressure operation if this valve is open, giving rise to a decrease in a flushing water flow rate and permeation of water with a low quality. Closing of the valve e installed on the permeate water discharge pipe brings about another effect of causing foulants deposited on the membrane to be suspended due to a back pressure created immediately after the closing of the valves, thereby increasing the effect of flushing operation.

Two to five flushing operations alternately from each direction is preferably carried out. One flushing in only one direction cannot achieve satisfactory flushing effect, causing turbid materials to accumulate over time. The amount of waste water increases and the recovery rate decreases if the flushing operation is carried out six or more times. Although the time per one flushing operation is not specifically restricted, 30-120 seconds is preferable. If less than 30 seconds, the effect of washing is insufficient; if more than 120 seconds, the blowdown quantity increases, resulting in a significant decrease in the recovery rate. Pressurized air may be injected into feed water during the flushing operation. The effect of

washing increases by injecting pressurized air into feed water. Although the amount of the pressurized air is not specifically restricted, the amount of air making the volume ratio of feed water to air 2:1-1:2 is preferable.

5           Feed water is treated again after a flushing operation for a prescribed period of time. In this instance, the flow direction of feed water should be reverse to the feed water flow direction immediately before the first flushing operation. Specifically, the first valve a and the valve c are closed, the  
10 valve d is opened so as to adjust the pressure in the module to a prescribed one, the second valve b and the valve e are opened, and the feed water is treated by the reverse osmosis membrane module 10A. The procedure of feed water treatment -> flushing  
-> feed water treatment -> flushing is repeated. The feed water  
15 treatment time is usually 1-24 hours, and preferably 1-12 hours. If the feed water treatment time is less than one hour, not only the valves must be switched frequently so that the life of the valves is shortened, but also the recovery ratio is decreased. If the feed water treatment continues for more than  
20 24 hours, the effect of removing accumulated turbid materials may be decreased. As the method for switching the operation from feed water treatment to flushing, a method of reversing the flow direction after an elapse of a prescribed period of time, a method of reversing the flow direction when a prescribed  
25 water permeation pressure difference is reached, or a combination of these methods can be utilized.

Next, a third embodiment of the operating method for the

separation membrane module of the present invention will be explained with reference to Figure 1. This is a method of operating a separation membrane module in which a spiral membrane element is installed. A flushing operation is included in the course of the separation membrane module operation. The first flushing is carried out in the direction reverse to the direction of feed water immediately before the flushing operation. The feed water flow direction after flushing is either the same as or reverse to the direction of feed water flow immediately before the flushing in this third embodiment. Otherwise the third embodiment is the same as the second embodiment. Therefore, the preferable form of feed water during treatment, manner of operating valves during flushing, method of flushing, and the like are the same as in the second embodiment. Since turbid materials are sufficiently removed by flowing the flushing fluid in the reverse direction in the third embodiment, the same effect as in the second embodiment can be achieved by operation of the third embodiment.

Next, a fourth embodiment of the operating method for the separation membrane module of the present invention will be explained with reference to Figure 2. In Figure 2, the same symbols are given to the same components as in Figure 1, for which the description is omitted, focusing the description on the components having different features. The embodiment shown in Figure 2 differs from that shown in Figure 1 in that a rear reverse osmosis membrane module 10B is installed in the

downstream side of the reverse osmosis membrane module 10A. The front reverse osmosis membrane module 10A is linked to the rear reverse osmosis membrane module 10B by a primary permeate water discharge pipe 14 for supplying permeate water from the reverse osmosis membrane module 10A to the rear module as feed water to be treated there. The rear reverse osmosis membrane module 10B is equipped with a permeate water discharge pipe 16 and a return pipe 18 for returning concentrate water to a point before the feed water pump. The rear reverse osmosis membrane module 10B is further equipped with a concentrate water discharge pipe 17. The front reverse osmosis membrane module 10A uses the reverse osmosis membrane apparatus of the present invention, whereas a conventional reverse osmosis membrane apparatus is used as the rear reverse osmosis membrane module 10B.

Specifically, in the reverse osmosis membrane apparatus 10a, feed water is supplied to the front reverse osmosis membrane module 10A by a feed water supply pump 11. The feed water is treated in the front reverse osmosis membrane module 10A and separated into primary concentrate water that is discharged via the concentrate water discharge pipe 15 and primary permeate water that is discharged via the primary permeate water discharge pipe 14. The primary permeate water is treated in the rear reverse osmosis membrane module 10B and separated into secondary permeate water that is discharged via the permeate water discharge pipe 16 and secondary concentrate water that is returned to the point before the feed water feed pump via the return pipe 18. The secondary concentrate water, obtained

by concentrating the permeate water that has already been desalinated in the front reverse osmosis membrane module 10A using the rear reverse osmosis membrane module 10B, has a lower conductivity than feed water. For this reason, the entire  
5 secondary concentrate water can be recycled, whereby the water recovery ratio can be increased. In this manner the operating method of the present invention is applied to the front reverse osmosis membrane module 10A in the reverse osmosis membrane apparatus 10a. Since the reverse osmosis membrane apparatus  
10 10a employs the reverse osmosis membrane module utilizing the reverse osmosis membrane module to which the operating method of the present invention can be applied in the front end instead of a conventional pretreatment apparatus of which the target is only removing turbid materials, the apparatus 10a  
15 substantially utilizes reverse osmosis membranes in two steps. The reverse osmosis membrane apparatus 10a produces permeate water of remarkably excellent quality as compared with permeate water from a conventional reverse osmosis membrane apparatus that is not equipped with a pretreatment unit having a  
20 desalination function.

Next, a fifth embodiment of the operating method for the separation membrane module of the present invention will be explained with reference to Figure 3. Figure 3 is a flow diagram of a multi-stage separation membrane apparatus for carrying out  
25 the operating method of this embodiment. The multi-stage separation membrane apparatus is a two-step separation membrane apparatus, wherein interstage concentrate water obtained in

each of separation membrane modules 30a, 30b of a front separation membrane apparatus group 29a is supplied to a rear separation membrane module 48 of a rear separation membrane apparatus group 29b. Specifically, a separation membrane apparatus 31a having the separation membrane module 30a and a separation membrane apparatus 31b having the separation membrane module 30b are arranged in parallel to form the separation membrane apparatus group 29a for the front stage. The separation membrane apparatus group 29b is arranged in the rear end of the front separation membrane apparatus group 29a to form a two-stage separation membrane apparatus.

In Figure 3, the separation membrane apparatus 31a has a first feed water supply pipe 32a connected with a valve a1, a second feed water supply pipe 33a connecting the valve a1 with the separation membrane module 30a, the separation membrane module 30a, a permeate water discharge pipe 34a having a valve e1 joined to the permeate water side of the separation membrane module 30a, a flow direction conversion pipe 35a having a valve b1 and connecting the first feed water supply pipe 32a with the concentrate water discharge side of the separation membrane module 30a, a first concentrate water discharge pipe 36a joined to the flow direction conversion pipe 35a and provided with a valve c1, and a second concentrate water discharge pipe 37a branched from the second feed water supply pipe 33a and having a valve d1 for discharging concentrate water when the flow direction of feed water is reversed. The separation membrane apparatuses 31b, 31c have the same configuration as the

separation membrane apparatus 31a. The separation membrane apparatus group 29a is provided with a feed water supply main pipe 38 joined to a first feed water discharge pipe 39 in which a first valve f for discharging feed water is installed, feed  
5 water supply branched pipes 40a, 40b branched from the feed water supply main pipe 38 and joined to first feed water supply pipes 32a, 32b for the separation membrane apparatuses 31a, 31b, respectively. The rear separation membrane apparatus group 29b is provided with a rear stage first concentrate water supply  
10 main pipe (feed water supply main pipe) 41 joined to a second feed water discharge pipe (feed water discharge pipe) 47 in which a second feed water discharge valve (rear stage feed water discharge valve) m is installed and a separation membrane apparatus 31c. The multi-stage separation membrane apparatus  
15 28 is further provided with a pump 50 in front of the front stage separation membrane apparatus groups 29a, 29b and a concentrate water collecting pipe 51 branched from the first concentrate water supply main pipe (feed water supply main pipe) 41 of the separation membrane apparatus group 29b and joined to first  
20 concentrate water discharge pipes 36a, 36b and second concentrate water discharge pipes 37a, 37b.

In the multi-stage separation membrane apparatus 28, the valves b1, b2, d1, d2, f, h, j, and m are closed, openings of the valves c1, c2, and i are adjusted to prescribe the pressure  
25 in the modules, and the valves a1, a2, e1, e2, g, and k are opened. Feed water is supplied to the separation membrane modules 30a, 30b by the feed water supply pump 50. The feed water is treated

in the separation membrane modules 30a, 30b and separated into first concentrate water that is discharged via the first concentrate water discharge pipes 36a, 36b and permeate water that is discharged via the permeate water discharge pipes 34a, 34b. The first concentrate water (hereinafter referred to as "interstage concentrate water") discharged from the separation membrane modules 30a, 30b is collected in the concentrate water collecting pipe 51 and sent to a rear separation membrane module 48. The second concentrate water is discharged via a first concentrate water discharge pipe 45 and permeate water is discharged via a permeate water discharge pipe 43. Suspended substances such as turbid materials in the feed water accumulate in the feed water spacer wound around the element with a progress of operating hours, although the extent of accumulation depends on turbidity of the feed water.

Accumulation of turbid materials in the feed water spacer increases the differential pressure for water permeation. The water flow direction is reversed in such a case. Specifically, the valves a1, a2, c1, c2, g, and i are closed, openings of the valves d1, d2, and j are adjusted to prescribe the pressure in the module, and the valves b1, b2, and h are opened. In this manner, the feed water enters from the concentrate water discharge side of the separation membrane modules 30a, 30b and is treated there and separated into first concentrate water that is discharged via the second concentrate water discharge pipes 37a, 37b and permeate water that is discharged via the permeate water discharge pipes 34a, 34b. The first concentrate water

discharged from each separation membrane module is collected in a concentrate water collecting pipe 51, sent to the concentrate water discharge side of the rear separation membrane module 48, and processed there. The second

5 concentrate water is discharged via the second concentrate water discharge pipe 46 and permeate water is discharged via the permeate water discharge pipe 43. Turbid materials accumulated in intersection areas of the feed water spacer can be easily dislodged and eliminated by reversing the flow

10 direction of feed water. Since suspended substances such as turbid materials in the feed water again accumulate in the feed water spacer inserted in the element with a further progress of operating hours, the feed water flow direction is again reversed. The procedure is repeated thereafter. The timing

15 for reversing the feed water flow direction may be either regular or irregular, usually at intervals of 1-24 hours, and preferably of 1-12 hours. If the intervals are less than one hour, the valves must be switched frequently, whereby the life of the valves is shortened. If the intervals are at more than

20 24 hours, it is difficult to remove accumulated turbid materials. The feed water flow direction may be reversed when the water permeating differential pressure reaches a prescribed level. This manner of operation is preferable since turbid materials can be removed without frequently reversing the feed water flow

25 direction. The method of reversing the flow direction after elapsing a prescribed period of time can be combined with the method of reversing the flow direction when a prescribed water

permeation differential pressure has been reached.

Since the multi-stage separation membrane apparatus 28 of this embodiment can suppress accumulation of turbid materials by reversing the flow direction of feed water, a conventional pretreatment means for removing turbid materials in feed water such as coagulation / sedimentation, filtration or membrane separation can be omitted. Therefore, the system is simplified, the installation area is minimized, and cost can be reduced. The effect of the reverse osmosis membrane apparatus is thus innovative.

Next, a sixth embodiment of the operating method for the separation membrane module of the present invention will be explained with reference to Figure 3. In the sixth embodiment of the operating method for the separation membrane module, a flushing operation is carried out several times alternately in either of the flow directions when altering the feed water flow direction in the operating method of the fifth embodiment. The flushing operation can ensure elimination of turbid materials accumulated in the intersection areas of the feed water spacer. As the method for flushing alternately in the opposite directions of the separation membrane module, a method of flushing from the direction reverse to the direction of feed water immediately before the flushing operation (hereinafter referred to as "reverse direction flushing") and a method of flushing in the same direction as the direction of feed water immediately before the flushing operation can be employed. Of the two methods, the reverse direction flushing is more

preferable to efficiently dislodge turbid materials accumulated in intersection areas of the feed water spacer in a first flushing operation. Although a part of turbid materials can be eliminated by a first flushing in the same direction as the feed water flow immediately before the flushing operation, turbid materials accumulated in the retention areas of the feed water spacer are excessively pressed, giving rise to accumulation of turbid materials over time. The valves a1, a2, c1, c2, f, g, I, and m are closed and the valves b1, b2, d1, d2, h, and j are opened to initiate the flush operation in the reverse direction. Then, feed water in an amount three times the feed water feed rate in the permeation process operation is jetted from the concentrate water discharge side to the separation membrane modules 30a, 30b and discharged from the second feed water supply pipes 33a, 33b and the second concentrate water discharge pipes 37a, 37b on the feed water feeding side. The feed water discharged from the separation membrane modules 30a, 30b is sent to the rear separation membrane module 48 from the concentrate water discharge side via the concentrate water collecting pipe 51, and discharged from the second feed water supply pipe 42 and second concentrate water discharge pipe 46. After completing the reverse flushing, a flushing operation in the direction reverse to the reverse flushing operation is carried out. The valves b1, b2, d1, d2, f, h, j, and m are closed and the valves a1, a2, c1, c2, g, and i are opened. Then, feed water in the same feed rate in the reverse flushing operation is jetted to the separation membrane

modules 30a, 30b from the feed water feeding side and discharged from the first concentrate water discharge pipes 36a, 36b on the concentrate water discharge side. The feed water discharged from the separation membrane modules 30a, 30b is sent to the separation membrane module 48 from the feed water feeding side via the concentrate water collecting pipe 51, and discharged from the first concentrate water discharge pipe 45 on the concentrate water discharge side. Next, a flushing operation in the direction reverse to the direction of this flushing is carried out. The same procedure is repeated several times alternately from the both sides.

Flushing operation is preferably carried out separately for each separation membrane module group in each stage. For instance, in the above flushing operation in the reverse direction, the front separation membrane modules 30a, 30b are first flushed by opening the valve m that has been closed and closing the valves h and j that have been opened. Then, feed water is discharged from the second feed water discharge pipe 47 and, after a certain period of time, the rear separation membrane module 48 is reversibly flushed by closing the valves d1, d2, and m and opening the valves c1, c2, h, and j. This method ensures a rapid flushing operation since turbid materials dislodged from the feed water spacer of the front separation membrane modules 30a, 30b do not enter the rear separation membrane module 48 and, therefore, the rear separation membrane module 48 is prevented from being fouled by the turbid materials from the feed water spacer of the front

separation membrane modules. When the flushing operation is carried out in the reverse direction, the front separation membrane modules 30a, 30b are first flushed by opening the valves a1, a2, and m and closing the valves b1, b2, h, and j.

5 The feed water is discharged from the second feed water discharge pipe 47 and, after a certain period of time, the rear separation membrane module 48 is flushed by closing the valves c1, c2, and m and opening the valves d1, d2, g, and i. In this manner, the flushing operation is preferably carried out  
10 separately for each separation membrane module group of each stage. In the case of a multi-stage separation membrane module having three or more stages, the flushing operation is also preferably carried out separately for each separation membrane module group in each stage.

15 If the first flushing is carried out in the same direction of the feed water flow immediately before the flushing operation, the second procedure in the above-described reverse direction flushing is first carried out. Turbid materials accumulated in intersections areas of the feed water spacer can be dislodged  
20 and discharged outside the element without fail by carrying out the flushing operation alternately in the both directions in this manner. When carrying out such a flushing operation, the pressure is released by opening the valves c1, c2, d1, d2, i, and j for pressure control on the concentrate water discharge  
25 side in the embodiment shown in Figure 3. The method of pressure release is by no means limited to the method of this embodiment. A separate valve for the pressure release may be provided. In

this instance, a concentrate water discharge pipe with a larger diameter than the pipe in which the pressure control valve is installed is preferably used to increase the amount of discharged water. In addition, it is possible to install one or more air chambers (not shown) at any point or points in the first concentrate water discharge pipes 36a, 36b, 45, and the second concentrate water discharge pipes 37a, 37b, and 46 to perform the flushing operation using water accumulated during operation. The air chamber herein indicates an apparatus for discharging water accumulated in the chamber due to the air pressurized by the concentrate water.

In the case where the flushing operation is carried out two or more times alternately in either direction when the feed water flow direction is changed, the pressure that has pressed the membrane surface is released by releasing the pressure on the feed water supply side before the flushing operation, whereby the membrane is caused slightly to become loosened. Releasing the pressure on the feed water supply side is preferable because releasing the pressure causes turbid materials accumulated on the membrane surface and in the feed water spacer to become loosened. One method for releasing the pressure on the feed water supply side is to open the first feed water discharge pipe f installed in the first feed water discharge pipe 39 joined to the feed water supply main pipe 38 on the injection side of the feed water supply pump 50. Another method is to open the valves d1, d2, and m during the operation in which the first valves a1, a2, c1, c2, e1, e2, g, i, and k

are opened. Although there are no specific limitations to the speed of opening the valve, fully opening the valve instantaneously or within one second is preferable. The instantaneous pressure release is more advantageous for causing the membrane to become loosen and for obtaining a turbid material removing effect due to a striking action of water. In this instance, the valves e1, e2, and k on the permeate water side are preferably opened. If the valves e1, e2, and k are closed, there is no differential pressure between both sides of the membrane and there is no pressure pressing the membrane. Therefore, the membrane is not caused to become loosened even if the pressure on the feed water supply side is released.

In addition, the valves e1, e2, and k installed in the permeate water discharge pipe 34a, 34b, and 43 are preferably fully closed during the flushing operation. Feed water used for flushing operation does not permeate through a reverse osmosis membrane module for high pressure operation with a flushing pressure even if the valves e1, e2, and k installed on the permeate water discharge pipes 34a, 34b, and 43 are opened. However, the feed water permeates through a reverse osmosis membrane module for low pressure or ultra-low pressure operation if this valve is open, giving rise to a decrease in a flushing water flow rate and permeation of water with a low quality. Closure of the valve installed on the permeate water discharge pipe brings about another effect of causing foulants deposited on the membrane surface to become loosened due to a back pressure created immediately after closure of the valves,

thereby further increasing the effect of flushing operation.

Two to five flushing operations alternately in opposite directions are preferable carried out. One flushing in only one direction cannot achieve a satisfactory flushing effect, causing turbid materials to accumulate over time. The amount of waste water increases and the recovery ratio decreases if the flushing operation is carried out six or more times. Although the time per flushing operation is not specifically restricted, 30-120 seconds are preferable. If the flushing time is less than 30 seconds, the effect of washing is insufficient; if the flushing time is more than 120 seconds, the blowdown volume increases, resulting in a significant decrease in the recovery ratio. Pressurized air may be injected into feed water during the flushing operation. The washing efficiency further increases by injecting pressurized air into feed water. Although the amount of the pressurized air is not specifically restricted, the amount of air making the volume ratio of feed water to air 2:1-1:2 is preferable.

Feed water is treated again after the flushing operation for a prescribed period of time. In this instance, the flow direction of feed water should be reverse to the flow direction immediately before the first flushing operation. Specifically, the valves a1, a2, c1, c2, f, g, i, and m are closed, openings of the valves d1, d2, and j are adjusted to prescribe the pressure in the module, and the valves b1, b2, e1, e2, and k are opened to treat feed water in the separation membrane modules 30a, 30b, and 48. The procedure of feed water processing -> flushing ->

feed water processing -> flushing is repeated. The feed water processing time is usually 1-24 hours, and preferably 1-12 hours. If the feed water processing time is less than one hour, not only must the valves be switched frequently so that the life of the valves is shortened, but also the recovery ratio is decreased. If more than 24 hours, the effect of removing accumulated turbid materials may be decreased. As the method for switching the operation from feed water treatment to flushing, a method of reversing the flow direction after an elapse of a prescribed period of time, a method of reversing the flow direction when a prescribed water permeation differential pressure has been reached, or a combination of these methods can be utilized.

Next, a seventh embodiment of the operating method for the separation membrane module of the present invention will be explained with reference to Figure 3. This is a method of operating a multi-stage separation membrane module in which a spiral membrane element is installed. A flushing operation is included in the course of the separation membrane module operation. The first flushing is carried out in the direction reverse to the direction of feed water immediately before the flushing operation. The feed water flow direction after flushing is either the same as or reverse to the direction of feed water flow immediately before the flushing in this seventh embodiment. Otherwise the seventh embodiment is the same as the sixth embodiment. Therefore, the preferable form of feed water during treatment, manner of operating valves during

flushing, method for flushing, and the like are the same as in the sixth embodiment. Since turbid materials are sufficiently removed by flowing the flushing fluid in the reverse direction in the seventh embodiment, the same effect as in the sixth  
5 embodiment can be achieved.

As the feed water directly supplied to the reverse osmosis membrane apparatus 10 or the multi-stage separation membrane apparatus 28 of this embodiment, industrial water, tap water, and recovery water can be given. Although the turbidity of feed  
10 water is not specifically limited, turbid feed water with a turbidity of about 2, which is rather high to be treated in a spiral membrane element, can be treated without a problem such as a rise in water flow differential pressure during a long run due to the regular or irregular reversing of the flow direction  
15 of feed water. Feed water is preferably supplied after heating to 40-60°C since it is possible to prevent formation of slime on the membrane surface and to remove slime if heated feed water is supplied. If the feed water temperature is less than 40°C, almost no slime removing effect can be achieved. A feed water  
20 temperature exceeding 60°C is above the heat resistant temperature of the water treatment apparatus, even if the temperature exceeding 60°C is effective for removing slime. Feed water heated to 40-60°C may be supplied either continuously or intermittently. When heated feed water is intermittently  
25 supplied, the interval is preferably from one hour to one week for ensuring efficient slime removal from the membrane surface without wasting energy. If the interval is less than one hour,

involved unnecessary heating results in an energy loss. If the interval is longer than one week, on the other hand, slime is easily formed and the effect of the present invention is impaired. Feed water is preferably supplied at a pH of 2.0-7.0

5 since an acidic feed water exhibits an excellent sterilization effect, prevents production of slime on the membrane surface, and reduces accumulation of turbid materials on the membrane surface. Feed water with a pH of less than 2.0 has a problem of chemical resistance of the water treatment apparatus, whereas  
10 feed water with a pH of more than 7.0 cannot be expected to exhibit the effect of slime prevention. Feed water includes water pretreated with a coarse filter to remove large particles such as sand grains and water containing a dispersant for preventing scale and fouling. The addition of a dispersant  
15 increases the effect of suppressing accumulation of turbid materials in the feed water spacer and membrane surface. As the dispersant, commercially available products, Hypersperse MSI300 and Hypersperse MDC200 (both manufactured by Argo Scientific), for example, can be cited.

20 There are no specific limitations to the spiral membrane element installed in the separation membrane module of the present invention inasmuch as such a spiral membrane element is made by winding a enveloped separation membrane and a feed water spacer around the external circumference of a permeate  
25 water collecting pipe. There are several types of feed water spacer: (i) a feed water spacer formed from first wires and second wires, each meandering with a gentle curve from a feed

water inlet side toward a feed water outlet side, the first wires running along one of the opposing surfaces of the separation membrane, one first wire and another adjacent first wire forming one of the feed water passages, the second wires running along

5 the other membrane surface of the separation membrane, one second wire and another adjacent second wire forming the other feed water passage, and the first wires and second wires partly overlapping and being bonded at the overlapping points, (ii) a feed water spacer secured to the end of feed water discharge

10 side of the separation membrane or secured to the end of feed water discharge side and the end of concentrate water discharge side, (iii) a feed water spacer folded into two parts to secure the end of feed water discharge side of the separation membrane or the end of feed water discharge side and the end of concentrate

15 water discharge side by sandwiching these ends from both sides, (iv) a feed water spacer made from wires with the number of intersecting points of 500-10,000 per 1 m<sup>2</sup> in average, (v) a feed water spacer made from wires with intersecting points of which the number gradually or intermittently decreases along

20 the feed water flow direction, and (vi) a feed water spacer made from wires with intersecting points of which the number gradually or intermittently increases along the feed water flow direction. Of the type (i) feed water spacers, those in which the meandering shape with a gentle curve has a regular pattern

25 without a bending point and in which the pattern has a ratio of amplitude H to wavelength L (H/L) of 0.02-2 and the number of wavelength of 1-100/m per wire are preferable since that such

a feed water spacer has intersecting points of an adequate number and allows feed water to flow in the feed water flow passage from the inlet side to the outlet side almost straight while gently meandering, thereby preventing turbid materials from being accumulated in the feed water flow passage. In the type (ii) or type (iii) feed water spacer, the length of the end of feed water discharge side of the separation membrane and the end of concentrate water discharge side from the permeate water collecting pipe are respectively 1-10% of the length of the permeate water collecting pipe of the separation membrane in the longitudinal direction measured from each end to the inside.

In the operating method of the separation membrane module of the present invention, the separation membrane modules equipped with a spiral membrane element having a feed water spacer of the type (i), (ii) or (iii) can be applied to any one of the first to seventh embodiments. Since the number of intersection points in the feed water spacer is restricted according to the flow direction of feed water in the separation membrane modules equipped with a spiral membrane element having the feed water spacer of the type (v) or (vi), these separation membrane modules cannot be applied to the first, second, fifth, and sixth embodiments in which the feed water flow direction is reversed. It is essential for the separation membrane modules equipped with a spiral membrane element having a feed water spacer of the type (v) to use the reverse-direction flushing of the third and seventh embodiments, since these

separation membrane modules employ a structure in which turbid materials are accumulated near the entrance of the feed water spacer. The separation membrane module equipped with a spiral membrane element having the feed water spacer of the type (vi) can be applied to the third and seventh embodiments.

As the feed water spacers of the type (ii) to type (vi), network spacers formed from multiple first wires and multiple second wires, for example, can be given. The network configuration includes, but is not limited to, a rhomboid, quadrangle, and waveform. The manner of wire intersection is not specifically limited and includes nonwoven, plain fabric, twilled fabric, and the like. The intersection point indicates a point at which the first wire intersects with the second wire, but may include the case in which the first and wires partly overlap, for example, the case in which the first and wires have waveform configurations. There are no specific limitations to the cross-sectional configuration of the first and second wires. A circle, triangle, and quadrangle can be given as examples. Wires with the same dimension and same cross-sectional configuration can be used for the first and second wires. The thickness of the feed water spacer is equivalent to or slightly smaller than the sum of the diameters of the first wire and the second wire, which is in the range of 0.4-3.0 mm. Although there are no specific limitations to the material for the feed water spacer, polypropylene and polyethylene are preferable from the viewpoint of formability and cost. Methods known in the art can be used with no specific limitations for manufacturing the

feed water spacer. Extrusion molding is preferable from the viewpoint of cost and fabrication precision.

The spiral membrane element is made by winding one or two or more enveloped separation membranes around the external circumference of a permeate water collecting pipe together with the feed water spacer. As the separation membrane, a microfiltration membrane, ultrafiltration membrane, reverse osmosis membrane, and the like can be given. Of these, the reverse osmosis membrane, which has been used for separating ionic components and low molecular weight components from feed water and conventionally requires a pretreatment as an essential treatment, can exhibit a better effect. As the reverse osmosis membrane, a common reverse osmosis membrane capable of eliminating 90% or more sodium chloride from a brine and a nanofiltration membrane or loose reverse osmosis membrane with a lower desalinating capacity can be cited. The nanofiltration membrane and loose reverse osmosis membrane have a desalinating capacity lower than common reverse osmosis membranes, but can separate out hard components particularly such as calcium and magnesium. The nanofiltration membrane and loose reverse osmosis membrane are also referred to as an NF membrane.

Any reverse osmosis membrane module that is equipped with the above-described spiral membrane element may be used without any specific limitations. For example, a reverse osmosis membrane module having the structure shown in Figure 4 can be cited. As shown in Figure 4, a enveloped reverse osmosis

membrane 61 is spirally wound around the external circumference of a permeate water collecting pipe 60 together with the feed water spacer. The surface is then covered with a cover 62. A telescope stopper 64 having several radial ribs 63 is secured at both ends to prevent the spirally wound reverse osmosis membrane 61 from being pushed out. One spiral membrane element 65 is formed from the permeate water collecting pipes 60, reverse osmosis membrane 61, cover 62, and telescope stopper 64. Several spiral membrane elements 65 are connected by connecting the permeate water collecting pipe 60 in each spiral membrane element 65 using a connector (not shown in the Drawing) and are packed in a housing 66. A clearance 67 between the external circumference of the spiral membrane element 65 and the internal circumference of the housing 66 is sealed with a brine seal 68. A feed water feed pipe (not shown) for feeding feed water to the housing 66 is installed at one end of the housing 66. At the other end of the housing 66, a processed water pipe (not shown) connected with the permeate water collecting pipe 60 and a non-permeating water pipe (not shown) is installed. The reverse osmosis membrane module 69 is formed from the housing 66, its internal components, pipes (nozzles), and the like.

When treating feed water using the reverse osmosis membrane module 69 of this type of structure, the feed water is introduced under pressure using a pump at one end of the housing 66. As shown by the arrows in Figure 4, the feed water passes through the spaces of radial ribs 63 of the telescope

stopper 64 and is introduced into the first spiral membrane element 65. A part of the feed water passes through a feed water passage partitioned by a feed water spacer between the membranes of the first spiral membrane element 65 and is introduced into the next spiral membrane element 65. The other part of the feed water permeates through the reverse osmosis membrane 61 and is collected in the permeate water collecting pipe 60 as permeate water. Feed water passes through the spiral membrane elements 65 continuously. The feed water not permeated through the reverse osmosis membrane is removed from the other end of the housing 66 as a condensed waste containing turbid materials and ionic impurities at a high concentration. Water permeated through the reverse osmosis membrane is removed from the housing 66 via the permeate water collecting pipe 60 as permeate water. The reverse osmosis membrane module of the present invention includes, in addition to the module equipped with a plurality of spiral membrane elements as shown in Figure 4, a module equipped with one spiral membrane element, for example.

The multi-stage separation membrane apparatus of this embodiment has the two or more stages, wherein interstage concentrate water from separation membrane modules of a front stage separation membrane apparatus or separation membrane apparatus group is sequentially supplied to separation membrane modules of a rear stage separation membrane apparatus or separation membrane apparatus group. For example, a 4->2->1 type three stage separation membrane apparatus consisting of a front separation membrane apparatus group 72a having four

separation membrane modules 71a-71d arranged in parallel, an interstage separation membrane apparatus group 72b having two separation membrane modules 71e-71f arranged in parallel, and a rear separation membrane apparatus 72c having one separation membrane module 71g (Figure 5), a 3->2 type two stage separation membrane apparatus consisting of a front separation membrane apparatus group 73a having three separation membrane modules 74a-74c arranged in parallel and a rear separation membrane apparatus 73b having two separation membrane modules 74d, 74e (Figure 6(A)), a 2->1 type two stage separation membrane apparatus consisting of a front separation membrane apparatus group 75a having two separation membrane modules 76a, 76b and a rear separation membrane apparatus 75b having one separation membrane module 76c (Figure 6(B)), and a 1->1 type two stage separation membrane apparatus consisting of a front separation membrane apparatus 77a having one separation membrane module 78a and a rear separation membrane apparatus 77b having one separation membrane modules 78b (Figure 6(C)) can be given. The apparatus of Figure 6(B) employs the same arrangement as the apparatus of Figure 3. Figures 5 and 6 are schematic views, wherein two discharge lines from a separation membrane module indicates a first concentrate water discharge pipe and a second concentrate water pipe. The locations are different from those of an actual arrangement. These multi-stage separation membrane apparatuses have an appropriate form according to a required recovery rate and throughput of water. The multi-stage separation membrane apparatus of the present

invention can ensure the operating method of multi-stage separation membrane module of the present invention in a simple apparatus.

## 5 EXAMPLES

The present invention will be described in more detail by examples, which should not be construed as limiting the present invention.

### Example 1

10 Industrial water with a turbidity of 2 and conductivity of 20 mS/m was treated in a 2,000 hour permanent run under the following operating conditions using a reverse osmosis membrane apparatus with a flow arrangement shown in Figure 1. A reverse osmosis membrane module having an 8-inch element ES-10  
15 (manufactured by Nitto Denko Corp.) with a network feed water spacer wound therearound was used as the reverse osmosis membrane apparatus. Performance of the reverse osmosis membrane module was evaluated by measuring the differential pressure (MPa), the amount of permeate water (l/min), and the  
20 conductivity of the permeate water (mS/m) at the initial stage of operation and at 2,000 hours thereafter. After the 2,000 hour operation, the reverse osmosis membrane module was dismantled to observe conditions of turbid material adhesion to the feed water passage. The results of measurement are shown  
25 in Table 1 and the results of naked eye observation of the feed water passage are shown in Table 2.

(Operating conditions)

As shown in the above second embodiment, three flushing operations were carried out alternately from both directions when the feed water flow direction is changed, wherein the first flushing was carried out in the direction reverse to the feed water flow direction immediately before the flushing operation. Specifically, a cycle operation, one cycle consisting of feed water treatment (8 hours) -> flushing in the reverse direction (60 seconds) -> flushing in the forward direction (60 seconds) -> flushing in the reverse direction (60 seconds), was repeated. The flushing in the forward direction herein indicates a flushing operation carried out in the direction of feed water flow immediately before the flushing in the reverse direction.

Permeation process operation was carried out under the following conditions: pressure: 0.75 MPa, concentrate water flow rate: 2.7 m<sup>3</sup>/hour, water temperature: 25°C, and pH of feed water: 7.0.

Flushing was carried out under the following conditions: valves c or d: full open, flushing water flow rate: 8.0 m<sup>3</sup>/hour, and water temperature: 25°C.

#### Example 2

The same 2,000 hour permanent run as in Example 1 was carried out under the same conditions as in Example 1, except that air was injected during each flushing operation at a rate to make the ratio of feed water to air 1:1. The results of performance evaluations of the reverse osmosis membrane module are shown in Tables 1 and 2.

#### Example 3

The same 2,000 hour permanent run as in Example 1 was carried out under the same conditions as in Example 1, except that feed water at 50°C was intermittently supplied once a day for one hour instead of continuously supplying feed water at 25°C. Feed water at 50°C was obtained by heating the feed water at 25°C in a heater. The results of performance evaluations of the reverse osmosis membrane module are shown in Tables 1 and 2.

#### Example 4

The same 2,000 hour permanent run as in Example 1 was carried out under the same conditions as in Example 1, except that feed water at a pH of 4.0 was supplied instead of feed water at a pH of 7.0. Feed water at a pH of 4.0 was obtained by adding hydrochloric acid to the feed water. The results of performance evaluations of the reverse osmosis membrane module are shown in Tables 1 and 2.

#### Example 5

The same 2,000 hour permanent run as in Example 1 was carried out under the same conditions as in Example 1, except that 5 mg/l of a dispersant (Hypersperse MSI300 manufactured by Argoscientific Co.) was added to industrial water with a turbidity of 2 and conductivity of 20 mS/m. The results of performance evaluations of the reverse osmosis membrane module are shown in Tables 1 and 2.

#### Example 6

Industrial water with a turbidity of 2 and conductivity of 20 mS/m was processed in a 2,000 hour permanent run under

the following operating conditions using a reverse osmosis membrane apparatus with a flow arrangement shown in Figure 2. A reverse osmosis membrane module having an 8-inch element ES-10 (manufacture by Nitto Denko Co., Ltd.) with a network feed water spacer wound therearound was used as a front reverse osmotic membrane module 10A and a rear reverse osmosis membrane module 10B. One front reverse osmotic membrane module 10A and one rear reverse osmosis membrane module 10B were used for the reverse osmosis membrane apparatus. Performance of the reverse osmosis membrane module was evaluated in the same manner as in Example 1.

(Operating conditions)

Pressure: 0.75 Mpa, concentrate water flow rate: 2.7 m<sup>3</sup>/hour, water temperature: 25°C, pH: 7.0 (for both the front reverse osmosis membrane module 10A and the rear reverse osmosis membrane module 10B), flushing operation (for the front reverse osmosis membrane module 10A): the same flushing as in Example 1 for every 8 hours. The flow direction of feed water was changed for only the front reverse osmosis membrane module, but not for the rear reverse osmosis membrane module. Table 1 shows the results for the rear reverse osmosis membrane module.

Comparative Example 1

Industrial water was treated in the same manner as in Example 1, except that a known membrane separation pretreatment was installed in the front end, the flow direction of feed water was not changed, and flushing was omitted. Specifically, industrial water with a turbidity of 2 and conductivity of 20

mS/m was treated in the pretreatment unit and the treated water was further treated by a conventional method using a commercially available conventional reverse osmosis membrane module. The results are shown in Tables 1 and 2.

#### 5 Comparative Example 2

Industrial water was treated in the same manner as in Example 1 except that the following operating conditions were applied. Specifically, industrial water with a turbidity of 2 and conductivity of 20 mS/m was directly treated by a  
10 conventional method using a commercially available conventional reverse osmosis membrane module without using pretreatment. The results are shown in Tables 1 and 2. In the experiment of Comparative Example 2, since the differential pressure reached too high a level to obtain permeate water, the  
15 operation was stopped at about 800 hours after initiation of operation.

(Operating conditions)

Pressure: 0.75 Mpa, concentrate water flow rate: 2.7 m<sup>3</sup>/hour, water temperature: 25°C, pH of feed water: 7.0.

20 Flushing operation in the forward direction was carried out every 8 hours by suspending feed water treatment, fully opening valve c installed in the first branched pipe 151 for concentrate water discharge, jetting feed water to the reverse osmosis membrane module in an amount three times the feed water feed  
25 rate in the permeation processing, and discharging flushing waste water from the concentrate water discharge pipe.

TABLE 1

|                       | Permeating water pressure difference [MPa] |         | Amount of permeating water [l/min] |         | Conductivity of permeating water [mS/m] |         |
|-----------------------|--------------------------------------------|---------|------------------------------------|---------|-----------------------------------------|---------|
|                       | Initial                                    | 2000 hr | Initial                            | 2000 hr | Initial                                 | 2000 hr |
| Example 1             | 0.020                                      | 0.035   | 20                                 | 15      | 0.30                                    | 0.45    |
| Example 2             | 0.020                                      | 0.031   | 20                                 | 16      | 0.30                                    | 0.42    |
| Example 3             | 0.020                                      | 0.035   | 20                                 | 17      | 0.30                                    | 0.39    |
| Example 4             | 0.020                                      | 0.035   | 20                                 | 17      | 0.30                                    | 0.39    |
| Example 5             | 0.020                                      | 0.033   | 20                                 | 18      | 0.30                                    | 0.38    |
| Example 6             | 0.020                                      | 0.020   | 20                                 | 20      | 0.30                                    | 0.03    |
| Comparative Example 1 | 0.020                                      | 0.022   | 20                                 | 20      | 0.30                                    | 0.30    |
| Comparative Example 2 | 0.020                                      | -       | 20                                 | -       | 0.30                                    | -       |

TABLE 2

5

|                       | Results of naked eye observation of feed water passage after 2,000 hours |
|-----------------------|--------------------------------------------------------------------------|
| Example 1             | Turbid materials are slightly attached.                                  |
| Example 2             | Turbid materials are slightly attached.                                  |
| Example 3             | Turbid materials are very slightly attached.                             |
| Example 4             | Turbid materials are very slightly attached.                             |
| Example 5             | Turbid materials are very slightly attached.                             |
| Example 6 (front RO)  | Almost no turbid materials are attached.                                 |
| Example 6 (rear RO)   | No turbid materials are attached.                                        |
| Comparative Example 1 | Almost no turbid materials are attached.                                 |
| Comparative Example 2 | Turbid materials entirely blocks the feed water passage.                 |

## Example 7

Industrial water with a turbidity of 2 and conductivity of 20 mS/m was treated in a 2,000 hour permanent run under the

following operating conditions using a multi-stage separation membrane apparatus of which the flow diagram is shown in Figure 7. A separation membrane module having one 8-inch element ES-10 (manufacture by Nitto Denko Corp.) with a network feed water spacer wound therearound was used in the multi-stage separation membrane apparatus. Performance of the separation membrane module was evaluated by measuring the differential pressure (MPa), the amount of permeate water (l/min), and the conductivity of the permeate water (mS/m) at the initial stage of operation and at 2,000 hours thereafter of the first stage separation membrane module. After the 2,000 hour operation, the first stage separation membrane module was dismantled to observe conditions of turbid material adhesion to the feed water passage. The results of measurements in the first stage separation membrane module are shown in Tables 8. The results of naked eye observation of the feed water passage (the part in which the feed water spacer exists in the separation membrane element) in the first stage separation membrane module are shown in Tables 9. These remarks also apply to results of Examples 8-12 and Comparative Examples 3-5 in Tables 8 and 9.

(Operating conditions)

Valves were opened and closed according to the process steps shown in Table 3, wherein steps No. 1 to No. 16 making up one cycle to be repeated are shown. Permeation operation (water collections A and B) was carried out under the conditions of pressure of 0.75 Mpa, concentrate water flow rate of 2.7 m<sup>3</sup>/hour (in the first stage), water temperature of 25°C, and

feed water pH of 7.0. Flushing operations (flushing A1, A2, B1, and B2) were carried out under the conditions of the flushing water flow rate of 8.0 m<sup>3</sup>/hour and water temperature of 25°C.

5

TABLE 3

| No | Process step       | Holding time | a3 | b3 | c3 | d3 | e3 | f | g | h | i | j | k | m |
|----|--------------------|--------------|----|----|----|----|----|---|---|---|---|---|---|---|
| 1  | Water collection A | 12 hr        | ■  |    | ▲  |    | ■  |   | ■ |   | ▲ |   | ■ |   |
| 2  | Pressure release A | 10 sec       | ■  |    | ▲  |    | ■  | ■ | ■ |   | ▲ |   | ■ |   |
| 3  | Flushing B1        | 60 sec       |    | ■  |    | ■  |    |   |   |   |   |   |   | ■ |
| 4  | Flushing B2        | 60 sec       |    | ■  | ■  |    |    |   |   | ■ |   | ■ |   |   |
| 5  | Flushing A1        | 60 sec       | ■  |    | ■  |    |    |   |   |   |   |   |   | ■ |
| 6  | Flushing A2        | 60 sec       | ■  |    |    | ■  |    |   | ■ |   | ■ |   |   |   |
| 7  | Flushing B1        | 30 sec       |    | ■  |    | ■  |    |   |   |   |   |   |   | ■ |
| 8  | Flushing B2        | 30 sec       |    | ■  | ■  |    |    |   |   |   |   | ■ |   |   |
| 9  | Water collection B | 12 hr        |    | ■  |    | ▲  | ■  |   |   | ■ |   | ▲ | ■ |   |
| 10 | Pressure release B | 10 sec       |    | ■  |    | ▲  | ■  | ■ |   | ■ |   | ▲ | ■ |   |
| 11 | Flushing A1        | 60 sec       | ■  |    | ■  |    |    |   |   | ■ |   |   |   | ■ |
| 12 | Flushing A2        | 60 sec       | ■  |    |    | ■  |    |   | ■ |   | ■ |   |   |   |
| 13 | Flushing B1        | 60 sec       |    | ■  |    | ■  |    |   |   |   |   |   |   | ■ |
| 14 | Flushing B2        | 60 sec       |    | ■  | ■  |    |    |   |   | ■ |   | ■ |   |   |
| 15 | Flushing A1        | 30 sec       | ■  |    | ■  |    |    |   |   |   |   |   |   | ■ |
| 16 | Flushing A2        | 30 sec       | ■  |    |    | ■  |    |   | ■ |   | ■ |   |   |   |

(Note) Blank: valve closed, ■: valve full open, ▲: valve open to prescribe an appropriate pressure

10

#### Example 8

A 2,000 hour long-range run was carried out under the same operating conditions as in Example 7, except that air was jetted to make the volume ratio of air to water 1:1 during each flushing A1, A2, B1, or B2. The results of performance evaluations of the separation membrane module are shown in Tables 8 and 9.

15

#### Example 9

A 2,000 hour permanent run was carried out under the same

operating conditions as in Example 7, except that feed water was intermittently supplied, i.e. a combination of feed water supply at 25°C for 23 hours and feed water supply at 50°C was repeated, instead of the continuous supply of feed water at 25°C.

5 The feed water at 50°C was obtained by heating feed water at 25°C using a heater. The results of performance evaluations of the separation membrane module are shown in Tables 8 and 9.

#### Example 10

10 The same 2,000 hour long-range run was carried out under the same conditions as in Example 7, except that feed water at a pH of 4.0 was supplied instead of feed water at a pH of 7.0. Feed water at a pH of 4.0 was obtained by adding hydrochloric acid to the feed water. The results of performance evaluations of the separation membrane module are shown in Tables 8 and 9.

#### 15 Example 11

The same 2,000 hour long-range run as in Example 1 was carried out under the same conditions as in Example 7, except that 50 mg/l of a dispersant (Hypersperse MSI300 manufactured by Argo Scientific Co.) was added to industrial water with a  
20 turbidity of 2 and conductivity of 20 mS/m. The results of performance evaluations of the separation membrane module are shown in Tables 8 and 9.

#### Comparative Example 3

25 Industrial water was treated in the same manner as in Example 7, except that a known ultrafiltration membrane apparatus for pretreatment was installed in the front end and only the water collection step of Table 4 was carried out.

Specifically, industrial water with a turbidity of 2 and conductivity of 20 mS/m was treated in a pretreatment unit and the pretreated water was further treated by a conventional method using a multi-stage separation membrane apparatus in which commercially available conventional separation membrane modules are layered in two stages. The results are shown in Tables 8 and 9.

TABLE 4

| No | Process step     | Holding time | a3 | b3 | c3 | d3 | e3 | f | g | h | i | j | k | m |
|----|------------------|--------------|----|----|----|----|----|---|---|---|---|---|---|---|
| 1  | Water collection | 2000 hr      | ■  |    | ▲  |    | ■  |   | ■ |   | ▲ |   | ■ |   |

(Note) Blank: valve closed, ■: valve full open, ▲: valve open to prescribe an appropriate pressure

#### Comparative Example 4

Industrial water was treated in the same manner as in Example 7 except that the following operating conditions were applied. Specifically, industrial water with a turbidity of 2 and conductivity of 20 mS/m was directly treated by a conventional method without pretreatment, but using a multi-stage separation membrane apparatus in which commercially available conventional separation membrane modules are layered in two stages. The results are shown in Tables 8 and 9. In the experiment of Comparative Example 4, since the differential pressure reached too high a level to obtain permeate water at about 800 hours after initiation of operation, the operation was stopped.

(Operating conditions)

Pressure: 0.75 Mpa, concentrate water flow rate: 2.7 m<sup>3</sup>/hour, water temperature: 25°C, pH of feed water: 7.0. Valves were opened and closed according to the process steps shown in Table 5, wherein steps No. 1 and No. 2 making up one cycle to be repeated are shown.

TABLE 5

| No | Process step     | Holding time | a3 | b3 | c3 | d3 | e3 | f | g | h | i | j | k | m |
|----|------------------|--------------|----|----|----|----|----|---|---|---|---|---|---|---|
| 1  | Water collection | 8 hr         | ■  |    | ▲  |    | ■  |   | ■ |   | ▲ |   | ■ |   |
| 2  | Flushing         | 60 sec       | ■  |    | ■  |    |    |   | ■ |   | ■ |   |   |   |

(Note) Blank: valve closed, ■: valve full open, ▲: valve open to prescribe an appropriate pressure

#### Example 12

Industrial water with a turbidity of 2 and conductivity of 20 mS/m was treated in a 2,000 hour long-range run under the following operating conditions using a multi-stage separation membrane apparatus of which the flow diagram is shown in Figure 3. Performance of the separation membrane module 20a was evaluated by measuring the differential pressure (MPa), the amount of permeate water (l/min), and the conductivity of the permeate water (mS/m) at the initial stage of operation and at 2,000 hours thereafter of the first stage separation membrane module. After the 2,000 hour operation, the first stage separation membrane module 20a was dismantled to observe conditions of turbid material adhesion to the feed water passage. The results of measurement are shown in Table 8 and the results of naked eye observation of the feed water passage are shown

in Table 9.

(Operating conditions)

Valves were opened and closed according to the process steps shown in Table 6, wherein steps No. 1 to No. 16 making up one cycle to be repeated are shown. Permeation operations (water collection A and B) were carried out under the conditions of pressure of 0.75 Mpa, a concentrate water flow rate (at the final stage) of 4.4 m<sup>3</sup>/hour, water temperature of 25°C, and feed water pH of 7.0. Flushing operations (flushing A1, A2, B1, and B2) were carried out under the conditions of the flushing water flow rate of 8.0 m<sup>3</sup>/hour and water temperature of 25°C.

TABLE 6

| No | Process step       | Holding time | a1 | a2 | b1 | b2 | c1 | c2 | d1 | d2 | e1 | e2 | f | g | h | i | j | k | m |
|----|--------------------|--------------|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|
| 1  | Water collection A | 12 hr        | ■  | ■  |    |    | ▲  | ▲  |    |    | ■  | ■  |   | ■ |   | ▲ |   | ■ |   |
| 2  | Pressure release A | 10 sec       | ■  | ■  |    |    | ▲  | ▲  |    |    | ■  | ■  | ■ | ■ |   | ▲ |   | ■ |   |
| 3  | Flushing B1        | 60 sec       |    |    | ■  | ■  |    |    | ■  | ■  |    |    |   |   |   |   |   |   | ■ |
| 4  | Flushing B2        | 60 sec       |    |    | ■  | ■  | ■  | ■  |    |    |    |    |   |   | ■ |   | ■ |   |   |
| 5  | Flushing A1        | 60 sec       | ■  | ■  |    |    | ■  | ■  |    |    |    |    |   |   |   |   |   |   | ■ |
| 6  | Flushing A2        | 60 sec       | ■  | ■  |    |    |    |    | ■  | ■  |    |    |   | ■ |   | ■ |   |   |   |
| 7  | Flushing B1        | 30 sec       |    |    | ■  | ■  |    |    | ■  | ■  |    |    |   |   |   |   |   |   | ■ |
| 8  | Flushing B2        | 30 sec       |    |    | ■  | ■  | ■  | ■  |    |    |    |    |   |   | ■ |   | ■ |   |   |
| 9  | Water collection B | 12 hr        |    |    | ■  | ■  |    |    | ▲  | ▲  | ■  | ■  |   |   | ■ |   | ▲ | ■ |   |
| 10 | Pressure release B | 10 sec       |    |    | ■  | ■  |    |    | ▲  | ▲  | ■  | ■  | ■ | ■ | ■ |   | ▲ | ■ |   |
| 11 | Flushing A1        | 60 sec       | ■  | ■  |    |    | ■  | ■  |    |    |    |    |   |   |   |   |   |   | ■ |
| 12 | Flushing A2        | 60 sec       | ■  | ■  |    |    |    |    | ■  | ■  |    |    |   | ■ |   | ■ |   |   |   |
| 13 | Flushing B1        | 60 sec       |    |    | ■  | ■  |    |    | ■  | ■  |    |    |   |   |   |   |   |   | ■ |
| 14 | Flushing B2        | 60 sec       |    |    | ■  | ■  | ■  | ■  |    |    |    |    |   |   | ■ |   | ■ |   |   |
| 15 | Flushing A1        | 30 sec       | ■  | ■  |    |    | ■  | ■  |    |    |    |    |   |   |   |   |   |   | ■ |
| 16 | Flushing A2        | 30 sec       | ■  | ■  |    |    |    |    | ■  | ■  |    |    |   | ■ |   | ■ |   |   |   |

(Note) Blank: valve closed, ■: valve full open, ▲: valve open to prescribe an appropriate pressure

### Comparative Example 5

Industrial water was treated in the same manner as in Example 12 except that the following operating conditions were applied. Specifically, industrial water with a turbidity of 2 and conductivity of 20 mS/m was directly processed by a conventional method without pretreatment, but using a multi-stage separation membrane apparatus provided with three commercially available conventional separation membrane modules, two in a front stage and one in a rear stage. The results are shown in Tables 8 and 9. In the experiment of Comparative Example 5, since the differential pressure reached too high a level to obtain permeate water, the operation was stopped at about 800 hours after initiation of operation.

(Operating conditions)

Pressure: 0.75 Mpa, concentrate water flow rate: 4.4 m<sup>3</sup>/hour, water temperature: 25°C, pH of feed water: 7.0. Valves were opened and closed according to the process steps shown in Table 7, wherein steps No. 1 and No. 2 making up one cycle to be repeated are shown.

TABLE 7

| No | Process step     | Holding time | a1 | a2 | b1 | b2 | c1 | c2 | d1 | d2 | e1 | e2 | f | g | h | i | j | k | m |
|----|------------------|--------------|----|----|----|----|----|----|----|----|----|----|---|---|---|---|---|---|---|
| 1  | Water collection | 8 hr         | ■  | ■  |    |    | ▲  | ▲  |    |    | ■  | ■  |   | ■ |   | ▲ |   | ■ |   |
| 2  | Flushing         | 60 sec       | ■  | ■  |    |    | ■  | ■  |    |    |    |    |   | ■ |   | ■ |   |   |   |

(Note) Blank: valve closed, ■: valve full open, ▲: valve open to prescribe an appropriate pressure

TABLE 8

|                       | Permeating water pressure difference [MPa] |         | Amount of permeating water [l/min] |         | Conductivity of permeating water [mS/m] |         |
|-----------------------|--------------------------------------------|---------|------------------------------------|---------|-----------------------------------------|---------|
|                       | Initial                                    | 2000 hr | Initial                            | 2000 hr | Initial                                 | 2000 hr |
| Example 7             | 0.020                                      | 0.035   | 20                                 | 15      | 0.30                                    | 0.45    |
| Example 8             | 0.020                                      | 0.031   | 20                                 | 16      | 0.30                                    | 0.42    |
| Example 9             | 0.020                                      | 0.035   | 20                                 | 17      | 0.30                                    | 0.39    |
| Example 10            | 0.020                                      | 0.035   | 20                                 | 17      | 0.30                                    | 0.39    |
| Example 11            | 0.020                                      | 0.033   | 20                                 | 18      | 0.30                                    | 0.38    |
| Example 12            | 0.020                                      | 0.035   | 20                                 | 15      | 0.30                                    | 0.45    |
| Comparative Example 3 | 0.020                                      | 0.022   | 20                                 | 20      | 0.30                                    | 0.30    |
| Comparative Example 4 | 0.020                                      | -       | 20                                 | -       | 0.30                                    | -       |
| Comparative Example 5 | 0.020                                      | -       | 20                                 | -       | 0.30                                    | -       |

TABLE 9

|                       | Results of naked eye observation of feed water passage after 2,000 hours |
|-----------------------|--------------------------------------------------------------------------|
| Example 7             | Turbid materials are slightly attached.                                  |
| Example 8             | Turbid materials are slightly attached.                                  |
| Example 9             | Turbid materials are very slightly attached.                             |
| Example 10            | Turbid materials are very slightly attached.                             |
| Example 11            | Turbid materials are very slightly attached.                             |
| Example 12            | Turbid materials are slightly attached.                                  |
| Comparative Example 3 | Almost no turbid materials are attached.                                 |
| Comparative Example 4 | Turbid materials entirely blocks the feed water passage                  |
| Comparative Example 5 | Turbid materials entirely blocks the feed water passage                  |

In Examples 1-6 using a single-stage separation membrane apparatus and Examples 7-12 using a multi-stage separation membrane apparatus, there was almost no increase in the differential pressure and no decrease in the amount of water permeated, and quality of the permeate water was high. Although the results of performance evaluation after 2,000 hours using the apparatus of Comparative Example 1 and Comparative 3 were comparative respectively to the results of Examples 1-6 and Example 7-12, these apparatuses were provided with a pretreatment unit that requires an extra installation area and installation cost. The apparatus of Comparative Example 2 to be compared with the apparatuses of Examples 1-5, the apparatus of Comparative Example 4 to be compared with the apparatuses of Examples 7-11, and the apparatus of Comparative Example 5 to be compared with the apparatus of Example 12 suffered from so serious attachment of turbid materials that the rate of water permeation dropped to zero in about 800 hours. The apparatus of Example 6 to be compared with the apparatus of Comparative Example 1 exhibited excellent performance and operated at a low cost.

#### INDUSTRIAL APPLICABILITY

The operating method of the separation membrane module of the present invention ensures easy dislodgment and complete elimination of turbid materials accumulated in intersection areas of the feed water spacer, without a problem of a decrease in the flushing flow rate that can occur in a low pressure or

ultra-low pressure reverse osmosis membrane module. In addition, closure of the valves on the permeate water side brings about an effect of causing the compaction of foulants deposited on the membrane surface to be released due to a back  
5 pressure created immediately after the closure of the valves, thereby increasing the effect of flushing operation.

Releasing the pressure on the feed water supply side decreases the pressure that presses the membrane surface and causes the membrane slightly to become loosened, whereby turbid materials  
10 accumulated on the membrane surface and feed water spacer are caused to float. The separation membrane apparatus of the present invention ensures the above operating method using a simple apparatus.

## CLAIMS

1. A method for operating a separation membrane module comprising a spiral membrane element of the type in which a  
5 enveloped separation membrane and a feed water spacer are wound around the external circumference of a permeate water collecting pipe, the method comprising regularly or irregularly reversing the flow direction of feed water in the separation membrane module.

10

2. The method according to claim 1, wherein a flushing operation is carried out two or more times alternately in either of the flow directions when the feed water flow direction is reversed.

15

3. The method according to claim 2, wherein a first flushing operation is carried out in the direction reverse to the direction of feed water immediately before the flushing operation.

20

4. A method for operating a separation membrane module comprising a spiral membrane element of the type in which a  
enveloped separation membrane and a feed water spacer are wound around the external circumference of a permeate water  
25 collecting pipe, the method comprising one or more flushing operations, in which the first flushing operation is carried out in the direction reverse to the direction of feed water

immediately before the flushing operation.

5        5. The method according to any one of claims 2 to 4,  
wherein valves on the permeate water side are entirely closed  
during the flushing operation.

6. The method according to any one of claims 2 to 5,  
wherein the pressure on the feed water supply side is released  
during the flushing operation.

10

7. A method for operating a multi-stage separation  
membrane module comprising a front separation membrane module  
or a group of front separation membrane modules, each separation  
membrane module having one spiral membrane element or two or  
15 more spiral membrane elements arranged in parallel and a rear  
separation membrane module or a group of rear separation  
membrane modules, each separation membrane module having one  
spiral membrane element or two or more spiral membrane elements  
arranged in parallel, wherein interstage concentrate water from  
20 the front separation membrane module or the group of front  
separation membrane modules is sequentially supplied to the  
rear separation membrane module of the group of rear separation  
membrane modules, the method comprising operating the  
separation membrane modules while regularly or irregularly  
25 reversing the feed water flow direction.

8. The method according to claim 7, wherein a flushing

operation is carried out two or more times alternately in either of the flow directions when the feed water flow direction is reversed.

5           9. The method according to claim 8, wherein a first flushing operation is carried out in the direction reverse to the direction of feed water immediately before the flushing operation.

10           10. A method for operating a multi-stage separation membrane module comprising a front separation membrane module or a group of front separation membrane modules, each front separation membrane module having one spiral membrane element or two or more spiral membrane elements arranged in parallel  
15 and a rear separation membrane module or a group of rear separation membrane modules, each rear separation membrane module having one spiral membrane element or two or more spiral membrane elements arranged in parallel, wherein interstage concentrate water from the front separation membrane module or  
20 the group of front separation membrane modules is sequentially supplied to the rear separation membrane module or the group of rear separation membrane modules, the method comprising one or more flushing operations, in which the first flushing operation is carried out in the direction reverse to the  
25 direction of feed water immediately before the flushing operation.

11. The method according to any one of claims 8 to 10, wherein valves on the permeate water side are entirely closed during the flushing operation.

5        12. The method according to any one of claims 8 to 11, wherein the pressure on the feed water supply side is released during the flushing operation.

10       13. The method according to any one of claims 8 to 12, wherein the flushing operation is carried out for the separation membrane module in each stage or for each group of the separation membrane modules.

15       14. A separation membrane apparatus having a first feed water supply pipe connecting a feed water supply pump with a first valve, a second feed water supply pipe connecting the first valve with a separation membrane module, the separation membrane module, a permeate water discharge pipe joined to the permeate water side of the separation membrane module, a flow  
20       direction conversion pipe having a second valve and a first branched pipe for discharging concentrate water connecting the first feed water supply pipe with the concentrate water discharge side of the separation membrane module, and a second branched pipe for discharging concentrate water branched from  
25       the second feed water supply pipe for discharging concentrate water when the flow direction of feed water is reversed.

15. A multi-stage separation membrane apparatus, wherein interstage concentrate water from a separation membrane module of a front separation membrane apparatus or a front separation membrane apparatus group is sequentially supplied to the  
5 separation membrane module of a rear separation membrane apparatus or a rear separation membrane apparatus group, wherein the separation membrane apparatus or the separation membrane apparatuses forming the separation membrane apparatus group have a first feed water supply pipe connected to a first  
10 valve, a second feed water supply pipe connecting the first valve with a separation membrane module, the separation membrane module, a permeate water discharge pipe joined to the permeate water side of the separation membrane module, a flow direction conversion pipe having a second valve and joined to  
15 the first feed water supply pipe on the concentrate water discharge side of the separation membrane module, a first concentrate water discharge pipe joined to the flow direction conversion pipe and having a third valve, and a second concentrate water discharge pipe branched from the second feed  
20 water supply pipe and having a fourth valve.