

DESCRIPTION

Title of Invention

METHOD FOR OPERATING DEMINERALIZATION
APPARATUS

Technical Field

[0001]

The present invention relates to a method for operating a desalting apparatus, and particularly to a method for operating a desalting apparatus having a plurality of series of desalting lines.

Background Art

[0002]

In a desalting apparatus such as a reverse osmosis membrane, precipitation of scale of calcium carbonate, silica, calcium fluoride, etc. and membrane clogging caused by organic substances occur due to long-term operation, resulting in performance degradation such as decrease in salt rejection rate and decrease in permeated water volume. In the case of scale clogging, in order to prevent the performance degradation of the desalting apparatus, an operation method including measuring the ion concentration of the raw water not to exceed the saturation index of the concentrated water in the desalting apparatus is employed. Here, the saturation index generally refers to a logarithmic value of a value obtained by dividing the product of the concentration and ionic strength of each ion species involved in scale generation by the solubility product. Operation of the desalting apparatus is performed such that the

saturation index does not exceed zero. Further, in the case where the saturation index exceeds zero, the desalting apparatus is operated with suppression of the generation of scale, for example, by adding a scale preventing agent.

[0003]

In the case where the water quality greatly exceeds the saturation index, which is uncontrollable even by adding a scale preventing agent, chemical cleaning such as acid cleaning and alkaline cleaning has been conventionally performed to remove the scale. However, since the general cleaning includes steps of stopping the apparatus, cleaning after preparing a cleaning liquid, collecting the cleaning liquid, and then starting passing water, there is a problem that the cleaning cost increases. Therefore, it has been desired to operate a desalting apparatus which causes no performance degradation even after long-term operation and requires no chemical cleaning.

[0004]

One of the methods for operating a desalting apparatus is a flushing method. Here, flushing refers to an operation of discharging the feed water from a concentrated water discharge pipe to the outside of the system. By passing water at a higher flow velocity than during normal operation, fouling substances on the membrane surface can be effectively washed away. Flushing is generally performed at a frequency of 1 to 10 times/day for 30 to 120 seconds/time. However, the flushing for several minutes/time is not sufficient to recover a desalting apparatus with deteriorated performance, and the problem is that cleaning is required after all. Further, since the on-off valve of the concentrated water pipe is opened for flushing, the permeated water cannot be

produced during flushing, resulting in lowered recovery ratio of the desalting apparatus.

[0005]

Another method includes reversing the flow direction of the water to be treated of a module. According to the method, suspended substances accumulated in a raw water spacer can be easily peeled off, so that the stability of the desalting apparatus can be improved. However, the problem is that the number of valves required to reverse the flow is greatly increased, resulting in great increase in the initial cost. Further, in case of breakdown of a valve, the valve cannot be switched, so that the stability of the apparatus is greatly impaired. Furthermore, the peeling effect on scale substances caused by flow reversal has not been described.

Citation List

Patent Literature

[0006]

PTL1: JP 2004-141846 A

PTL2: JP 2004-261724 A

Summary of Invention

Technical Problem

[0007]

In view of the problem described above, an object of the present invention is to provide a method for operating a desalting apparatus having a plurality of series of desalting line, capable of recovering the deteriorated desalting performance of the series of desalting series

without stopping operation of the desalting apparatus, with less usage of dilute water.

Solution to Problem

[0008]

The method for operating a desalting apparatus of the present invention is a method for operating a desalting apparatus provided with a plurality of desalting series having a desalting unit in parallel, in which while producing a desalted water by passing water to be treated through a part of the desalting series, dilute water is passed through other desalting series from a dilute water tank to perform cleaning, and cleaning drainage water is returned to the dilute water tank, the method comprising, in a case where the water quality of the dilute water has a higher salt concentration than a predetermined value, discharging a part of the dilute water to be merged with the water to be treated and replenishing new dilute water.

[0009]

In an aspect of the present invention, the dilute water for use in cleaning is controlled to have a pH of 3.2 or less.

[0010]

In an aspect of the present invention, a desalted water of the desalting apparatus or an unsaturated solution having a saturation index of scale species of less than zero is used as the dilute water.

[0011]

In an aspect of the present invention, a scale preventing agent is added to the dilute water.

[0012]

In an aspect of the present invention, the desalting apparatus is a reverse osmosis membrane apparatus.

Advantageous Effects of Invention

[0013]

According to the method for operating a desalting apparatus of the present invention, while water to be treated is passed through a part of desalting series to produce desalted water, dilute water is passed through other desalting series, so that the desalting performance of the desalting series can be recovered.

[0014]

In the present invention, cleaning with dilute water can be performed for a long time before the decrease in flux proceeds. Further, when the salt concentration increases in a dilute water circulation system due to dissolution of scale, a part of the dilute water is discharged and new dilute water is replenished, so that the concentration in the dilute water can be kept low.

Brief Description of Drawings

[0015]

[Fig. 1] Fig. 1 is a flow chart illustrating a method for operating a desalting apparatus in an embodiment.

[Fig. 2] Fig. 2 is a flow chart illustrating a method for operating a desalting apparatus in an embodiment.

[Fig. 3] Fig. 3 is a cross sectional view of a test cell.

Description of Embodiments

[0016]

Hereinafter, embodiments will be described with reference to drawings. In the embodiment, a reverse osmosis membrane apparatus (RO apparatus) is described as an example of desalting apparatus, though the present invention is not limited thereto. Examples of the desalting apparatus other than the reverse osmosis membrane apparatus include a nanofiltration membrane apparatus, a forward osmosis membrane apparatus, a membrane distillation apparatus, an electrodialysis apparatus, and an electrodeionization apparatus.

[0017]

In Figs. 1 and 2, the structure of a desalting apparatus used in the method for operating the desalting apparatus according to the embodiment is shown. Note that in Fig. 1, the water flow in a first pattern of water passing is shown by a thick solid line, and in Fig. 2, the water flow in a second pattern of water passing is shown by a thick solid line. In the drawings, PI indicates a pressure sensor and FI indicates a flow rate sensor.

[0018]

The desalting apparatus has a first desalting series having first and second RO apparatuses 7 and 10, and a second desalting series having third and fourth RO apparatuses 37 and 40. While the RO treatment is performed in one desalting series, cleaning with dilute water is performed in another desalting series.

[0019]

[First pattern of water passing]

In the first pattern of water passing, as shown in Fig. 1, raw water is desalted in the first desalting series, and each RO apparatus is cleaned with dilute water in the second desalting series.

[0020]

<First desalting series>

In the first desalting series of the first pattern of water passing, the raw water (water to be treated) in a raw water tank 1 is supplied to the concentrated water chamber of the first RO apparatus 7 through a pump 2, a pipe 3, a valve 4, and pipes 5 and 6, and the concentrated water supplied from the first RO apparatus 7 is supplied to the concentrated water chamber of each second RO apparatus 10 through pipes 8 and 9. The concentrated water of each second RO apparatus 10 is taken out as concentrated water through pipes 11 and 12, a valve 13, a pipe 14, a valve 15, and a pipe 16.

[0021]

The permeated water of each of the first RO apparatus 7 and the second RO apparatus 10 is taken out as permeated water through pipes 18 and 19, a valve 20, a pipe 21, a valve 21a, and a pipe 22.

[0022]

<Second desalting series>

In the second desalting series of the first pattern of water passing, the dilute water in a dilute water tank 31 is supplied to concentrated water chambers of a plurality of the third RO apparatuses 37 through a pump 32, a pipe 33, a valve 34, and pipes 35 and 36, and the water flowing out of the concentrated water chamber is supplied to a concentrated water chamber of the fourth RO apparatus 40 through pipes 38 and 39. The water that has passed through the concentrated water

chamber of each fourth RO apparatus 40 is returned to a dilute water tank 31 through pipes 41 and 42, a valve 43, pipes 44 and 47, a valve 48, and a pipe 28b.

[0023]

The permeated water of each of the third RO apparatus 37 and the fourth RO apparatus 40 is returned to the dilute water tank 31 through pipes 50 and 51, a valve 52, pipes 53 and 56, valves 57, and pipes 58 and 25b.

[0024]

In the case of the first pattern of water passing, the valves 4, 13, 15, 20 and 21a are opened and valves 61, 24 and 27 are closed in order to make the water flow as described above. Further, the valves 34, 43, 48, 52 and 57 are opened and valves 45, 54, 65 and 68 are closed.

[0025]

It is preferable that either an acid such as hydrochloric acid and sulfuric acid be added from a pH adjusting unit 31a so that the pH of the dilute water in the dilute water tank 31 is controlled to 3.2 or less, or a scale preventing agent be added from a scale preventing agent adding unit 31c so that the saturation solubility of an insoluble component such as calcium fluoride scale is increased.

[0026]

An RO-treated water of raw water is suitable as the dilute water, though not limited thereto.

[0027]

[Second pattern of water passing]

In the second pattern of water passing, as shown in Fig. 2, the raw water is desalted in the second desalting series, and each RO apparatus is cleaned with dilute water in the first desalting series.

[0028]

<First desalting series>

In the first desalting series of the second pattern of water passing, the dilute water in the dilute water tank 31 is supplied to concentrated water chambers of the plurality of first RO apparatuses 7 through a pump 32, pipes 63 and 62, a valve 61, and pipes 60, 5 and 6, and water that has passed through the concentrated water chamber is supplied to a concentrated water chamber of a second RO apparatus 10 through pipes 8 and 9. The water that has passed through the concentrated water chamber of each second RO apparatus 40 is returned to a dilute water tank 31 through pipes 11 and 12, a valve 13, pipes 14 and 26, a valve 27, and pipes 28a and 28b.

[0029]

The permeated water of each of the first RO apparatus 7 and the second RO apparatus 10 is returned to a dilute water tank 31 through pipes 18 and 19, a valve 20, pipes 21 and 23, a valve 24, and pipes 25a and 25b.

[0030]

<Second desalting series>

In the second desalting series of the second pattern of water passing, the raw water (water to be treated) in a raw water tank 1 is supplied to a concentrated water chamber of a third RO apparatus 37 through a pump 2, pipes 3 and 67, a valve 68, and pipes 35 and 36, and the concentrated water from the third RO apparatus 37 is supplied to a

concentrated water chamber of each fourth RO apparatus 40 through pipes 38 and 39. The concentrated water of each fourth RO apparatus 40 is taken out as concentrated water through pipes 41 and 42, a valve 43, a pipe 44, a valve 45, and a pipe 46.

[0031]

The permeated water of each of the third RO apparatus 37 and the fourth RO apparatus 40 is taken out as permeated water through pipes 50 and 51, a valve 52, a pipe 53, a valve 54, and a pipe 55.

[0032]

In the case of the second pattern of water passing, the valves 4, 15, 21a and 65 are closed and the valves 13, 20, 24, 27 and 61 are opened in order to make the water flow as described above. Further, the valves 34, 48 and 57 are closed and the valves 43, 45, 52, 54 and 68 are opened.

[0033]

[Pattern of water passing in the case of securing water quality of dilute water]

When circularly passing dilute water, the pressure of passing water is basically controlled to a not-so-high level, and the entire volume of the treated water and concentrated water is returned to the dilute water tank 31, so that the dilute water is not concentrated and circularly passed while maintaining a dilute concentration.

[0034]

However, in both Figs. 1 and 2, since the cleaning drainage water resulting from cleaning the RO apparatus with dilute water is returned to the dilute water tank 31, the solute concentration of the dilute water in the dilute water tank 31 gradually increases. Accordingly, when the water quality detection value detected by a water quality monitor 31b

exceeds a predetermined value, the valve 65 is opened to discharge at least a part of the dilute water sent from the pump 32 into the raw water tank 1 through the pipes 63 and 64, the valve 65 and the pipe 66. Into the dilute water tank 31, a new dilute water with a volume corresponding to the volume of discharged water is introduced from a replenishment line 30 by using a ball tap or the like. As the water quality monitor 31b, an electrical conductivity meter, a colorimetric analysis, an ion electrode and the like are suitable.

[0035]

In the method for operating the desalting apparatus, while continuing the operation of producing permeated water in one desalting series, the operation of passing dilute water maintained at a low concentration through another desalting series is performed. As a result, the flux of the desalting series is recovered, so that decrease in recovery ratio can be prevented without stopping the desalting apparatus. Further, since the entire amount of the dilute water used for cleaning is returned to the dilute water tank 31, the consumption of the dilute water is low.

[0036]

[Timing for switching from normal operation to recovery operation]

In the present invention, although it is possible to switch to the recovery operation when the normal operation is performed for a predetermined time, it is preferable to switch to the recovery operation at the timing when the scale is generated in the second desalting apparatus. For example, in the case of Fig. 1 where a reverse osmosis membrane is used as the desalting apparatus, switching is performed when the permeation flux of the second RO apparatus 10 decreases by a set ratio

from the initial stage of operation, for example, by 5%. It should be noted that 5% is an example, and the set ratio may be a value selected from 1 to 20%, particularly 1 to 10%. In particular, it is preferable to measure the change in the permeation flux of a terminal RO, which is most concentrated in the second RO apparatus.

[0037]

Since the actual permeation flux is affected by the operating pressure, water temperature, and salt concentration in the feed water, it is preferred to specify a corrected permeation flux as data indicating the performance of the RO apparatus.

[0038]

Here, the corrected permeation flux is generally calculated by a method described in the method for standardizing permeated water volume performance data of reverse osmosis membrane element and module as shown in JIS K 3805: 1990.

[0039]

That is, the permeated water volume performance data is calculated as corrected permeation flux F_{ps} through correction by the following formula (1).

[0040]

$$F_{ps} = (Q_{pa}) \times \frac{\left[P_{fa} - \frac{\Delta P_{fba}}{2} - P_{pa} - \pi_{fba} + \pi_{pa} \right]}{\left[P_{fs} - \frac{\Delta P_{fbs}}{2} - P_{ps} - \pi_{fbs} + \pi_{ps} \right]} \times \frac{(TCF_a)}{(TCF_s)} \quad (1)$$

[0041]

wherein

Q_{pa} : Permeated water volume under actual operating conditions
(m³/d)

P_{fa} : Operating pressure under actual operating conditions (kPa)

ΔP_{fba} : Differential pressure of module under actual operating
conditions (kPa)

P_{pa} : Pressure on the permeated water side under actual operating
conditions (kPa)

Π_{fba} : Osmotic pressure of the average solute concentration on the
supply side and concentration side under actual operating conditions
(kPa)

TCF_a : Temperature conversion coefficient under actual operating
conditions

P_{fs} : Operating pressure under standard operating conditions (kPa)

ΔP_{fbs} : Differential pressure of module under standard operating
conditions (kPa)

P_{ps} : Pressure on the permeated water side under standard
operating conditions (kPa)

Π_{fbs} : Osmotic pressure of average solute concentration on the
supply side and concentration side under standard operating conditions
(kPa)

TCF_s : Temperature conversion coefficient under standard operating
conditions.

[0042]

[Direction of passing of dilute water]

As shown in Fig. 1, it is preferable that the dilute water is passed
from the feed water side of the second RO apparatus. However, in the

case of using a dilute water having good water quality, the dilute water may be passed from the concentrated water outlet side.

[0043]

Although the RO apparatus is installed in two stages in the embodiment described above, it may be installed in one stage or three or more stages. Further, although the desalting series is provided in two rows in the embodiment described above, it may be provided in three or more rows.

Example

[0044]

<Purpose of test>

A simulated raw water made of a calcium fluoride fine particle dispersion was prepared, and the water was passed through an RO apparatus for testing alternately with pure water to measure the flux recovery characteristics.

[0045]

<Testing method>

Through a flat membrane type RO apparatus 200 in Fig. 3 provided with a rectangular RO membrane having a membrane surface size of 95 mm × 146 mm, the following simulated raw water and simulated dilute water (except for Test Example 1, simulated dilute water with addition of scale preventing agent) were passed in the following three steps in order. The RO apparatus 200 has a lower cell 201, an upper cell 202, a mesh spacer 203 between the cells, an RO membrane 204, and a spacer 205 on the permeated water side.

[0046]

<Sequence of water passing>

Step of passing first simulated raw water: The simulated raw water was passed so as to have an initial flux of 0.45 m/D and a water passing flow rate of 0.1 m/s, and a water passing test was performed at a constant volume of permeated water. (Accordingly, the corrected permeation flux gradually decreased over time.) The feed water pressure was set constant. (Accordingly, the flux gradually decreased over time.)

[0047]

Step of passing dilute water: After the corrected permeation flux decreased by 10 to 15% from the initial value, dilute water was passed at a water passing flow rate of 0.1 m/s for 45 minutes.

[0048]

Step of passing second simulated raw water: Simulated raw water was passed at the same feed water pressure and the same permeated water volume as in the step of passing first simulated raw water.

[0049]

<Simulated raw water>

Calcium chloride dihydrate and sodium hydrogen carbonate were dissolved in pure water to prepare so as to have a Ca concentration of 650 mg/L and an F concentration of 70 mg/L.

[0050]

pH: 5.5

Water temperature: 22 to 23°C

[0051]

<Simulated dilute water>

The water having Ca and Na concentrations and pH shown in Table 1 prepared in the same manner as with the simulated raw water was used.

[0052]

<Simulated dilute water with addition of scale preventing agent>

To the simulated dilute water, 2-phosphonobutane-1,2,4-tricarboxylic acid was added as a scale preventing agent so as to have the concentration shown in Table 1 for use.

[0053]

[Results]

The ratio between the corrected permeation flux F immediately before the end of the step of passing the first simulated raw water and the initial corrected permeation flux F_0 , i.e. F/F_0 , is shown as "Flux ratio before passing dilute water" in Table 1.

[0054]

The ratio between the corrected permeation flux F' immediately after the start of the step of passing the second simulated raw water and the initial corrected permeation flux F_0 , i.e. F'/F_0 , is shown as "Flux ratio after passing dilute water" in Table 1.

[0055]

The value $[\text{Flux ratio after passing dilute water}]/[\text{Flux ratio before passing dilute water}]$ is shown in Table 1 as "Recovery ratio".

[0056]

[Table 1]

—	Water quality of dilute water				[1] Flux ratio before passing dilute water	[2] Flux ratio after passing dilute water	Recovery ratio ([2]/[1])
	Ca	F	pH	Scale preventing agent			
	mg/L	mg/L	-	mg/L			
Test Example 1	<0.1	<0.1	5.5	0	94.80%	99.80%	1.05
Test Example 2	<0.1	<0.1	5.5	10	95.20%	99.80%	1.05
Test Example 3	3.2	0.8	5.5	10	95.60%	98.80%	1.03
Test Example 4	32	8	3.2	10	94.80%	99.80%	1.05
Test Example 5	25	16	3	10	93.30%	94.20%	1.01
Test Example 6	32	8	5.5	500	94.50%	96.40%	1.02
Test Example 7	32	8	5.5	50	94.50%	95.80%	1.01
Test Example 8	32	8	5.5	10	94.30%	94.50%	1
Test Example 9	32	8	3.5	10	96.00%	95.30%	0.99
Test Example 10	64	40	3	10	95.80%	95.50%	1
Test Example 11	32	20	3	10	93.40%	93.80%	1

[0057]

[Discussion]

- (1) As shown in Table 1, the flux is recovered (increased) by performing the step of passing dilute water.
- (2) From the comparison of Test Examples 2, 3 and 8, it is confirmed that the more dilute the water quality of the dilute water, the higher the recovery ratio is achieved.
- (3) As shown in Test Example 1, a sufficiently dilute dilute water allows a high recovery ratio to be achieved even without addition of a scale preventing agent.
- (4) As shown in Test Examples 6, 7 and 8, a dilute water having poor water quality hardly allows a high recovery ratio to be achieved even with addition of a scale preventing agent.
- (5) As shown in Test Examples 4, 7 and 8, even a dilute water having poor quality allows a high recovery ratio to be achieved in the case where the pH of the dilute water is 3.2 or less.

(6) As shown in Test Examples 5, 10 and 11, a dilute water having an excessively high F concentration (≥ 20 mg/L) allows a high recovery ratio not to be achieved even at a low pH.

[0058]

Among the following conditions (i) the water quality of dilute water is dilute, (ii) the pH of the dilute water is 3.2 or less, and (iii) a scale preventing agent is added, satisfying conditions (i) and (ii) or (iii) allows the effect of improving Flux to be higher in comparison with satisfying condition (i) alone. Further, lowering the pH of a dilute water, even the dilute water having poor water quality allows the effect of improving Flux to be maintained.

[0059]

Although the present invention has been described in detail with reference to specific embodiments, it will be apparent to those skilled in the art that various modifications can be made without departing from the intent and scope of the present invention.

The present application is based on JP 2020-153862 filed on September 14, 2020, which is incorporated by reference in its entirety.

Reference Signs List

[0060]

1: Raw water tank

7, 10, 37 and 40: RO apparatus

31: Dilute water tank

CLAIMS

[Claim 1]

A method for operating a desalting apparatus provided with a plurality of desalting series having a desalting unit in parallel,

the desalting apparatus is a reverse osmosis membrane apparatus, a nanofiltration membrane apparatus, a forward osmosis membrane apparatus, a membrane distillation apparatus, an electrodialysis apparatus, or an electrodeionization apparatus,

in which while producing a desalted water by passing water to be treated through a part of the desalting series, dilute water is passed through the desalting apparatus of other desalting series from a dilute water tank to dissolve a scale and perform cleaning, and cleaning drainage water containing the dissolved scale flowed out from the desalting apparatus is returned to the dilute water tank, the method comprising,

in a case where the water quality of the dilute water has a higher salt concentration than a predetermined value, discharging a part of the dilute water to be merged with the water to be treated and replenishing new dilute water,

the dilute water dissolves the scale of the desalting apparatus and having a lower salt concentration than the predetermined value.

[Claim 2]

The method for operating a desalting apparatus according to claim 1, wherein the dilute water for use in cleaning is controlled to have a pH of 3.2 or less.

[Claim 3]

The method for operating a desalting apparatus according to claim 1 or 2, wherein a desalted water of the desalting apparatus is used as the dilute water.

[Claim 4]

The method for operating a desalting apparatus according to any one of claims 1 to 3, wherein a scale preventing agent is added to the dilute water.

[Claim 5]

The method for operating a desalting apparatus according to any one of claims 1 to 4, wherein the desalting apparatus is the reverse osmosis membrane apparatus.