

COMPLEX DESALINATION SYSTEM USING SEAWATER DESALINATION PRESSURE RETARDED OSMOSIS TECHNOLOGY

TECHNICAL FIELD

5 The present disclosure relates to a complex desalination system using seawater desalination pressure-retarded osmosis technology.

BACKGROUND

10 As the demand for drinking water or industrial water continues to increase, the importance of seawater desalination technology is increasing. In addition, economically feasible and large-scale seawater desalination technology is particularly important for reasons such as continuous population growth and growth of industries related thereto.

15 A membrane-based desalination process consumes less energy than a thermal desalination process, but still consumes a lot of energy, and the energy consumption rate needs to be lower for eco-friendly and economically feasible desalination processes.

20 Accordingly, as desalination methods with low energy consumption, several methods have been developed, including a technique which applies fluid energy generated in forward osmosis and pressure-retarded osmosis (PRO) processes. The forward osmosis technology theoretically has a mechanism with a small energy consumption, but there are no cases of actually applying it to the desalination process.

 For a continuous and practical process in applying the forward osmosis technology to a desalination process, a technology for separating water from an induction solution and a technology for recovering the induction solution are important, but these technologies still have many problems.

25 Meanwhile, the pressure-retarded osmosis process technology is in the spotlight as a

technology that can recover or produce energy (e.g., Statkraft Osmotic Power Pilot Plant, Norway). However, for commercialization of the pressure-retarded osmosis process technology, the development of innovative technologies for maximizing energy recovery or generation is required.

The driving force of the osmotic process is the difference in osmotic pressure between two aqueous solutions with a semipermeable membrane interposed therebetween. The osmotic pressure of the aqueous solution can be calculated by the Van't Hoff relation equation.

$$\pi = \theta \cdot v \cdot c \cdot R \cdot T$$

where v is the number of ions generated during desalination of the solute, θ is the osmotic coefficient, c is the concentration of all solutes (mole/l), R is the universal gas constant ($0.083145 \text{ l} \cdot \text{bar}/\text{moles} \cdot \text{K}$), and, T is the absolute temperature (K).

The flow rate through the semipermeable membrane due to the difference in osmotic pressure is given by the following equation.

$$J_w = A(\pi_{D,b} - \pi_{F,b})$$

Where J_w is the flow rate passing through the semipermeable membrane, A is the net permeability coefficient of the semipermeable membrane, and $\pi_{D,b}$ and $\pi_{F,b}$ are bulk osmotic pressures during extraction and supply, respectively (see McCutcheon and Elimelech, 2007)

The pressure-retarded osmosis is used to generate or recover energy (power) by using Gibbs free energy of mixing for the difference in salinity of two aqueous solutions.

$$-\Delta G_{\text{mix}} = RT \{ [\sum x_i \ln(\gamma_i x_i)]_M - \theta_A [\sum x_i \ln(\gamma_i x_i)]_A - \theta_B [\sum x_i \ln(\gamma_i x_i)]_B \}$$

where x_i is the mole fraction of the species i in solution, R is the gas constant, T is the

temperature, and γ is the activity coefficient of the species (see Sandler, S. I., 1999, Chemical Engineering Thermodynamics, 3rd ed.; Wiley).

In a pressure-retarded osmosis system, when a constant fluid pressure is applied to a high-salinity aqueous solution, water continues to penetrate from the low-salinity aqueous solution, while the difference in osmotic pressure between the two solutions is higher than the applied fluid pressure. The pressure of the high-salinity aqueous solution is preserved by the additional energy generated from the Gibbs free energy of mixing while the volume flux of the solution increases.

According to Yip and Elimelech (2012), the maximum energy that can be extracted in a constant pressure-retarded osmosis process is 0.75 kWh/m^3 when seawater and rivers are used as extraction and supply solutions, respectively. Accordingly, in terms of pressure and volume, the extracted Gibbs free energy of mixing may be used to generate energy or to recover the pressure for the process.

In a method of producing energy in the pressure-retarded osmosis process, a water turbine may be used to generate power using the pressure and volume flux of an aqueous solution. Even when the efficiency of the latest Pelton turbine can reach 92%, the average efficiency will generally be about 90%, and the overall efficiency, including power generation facilities such as generators, will reach about 80%.

Recently, in the reverse osmosis (RO) seawater desalination process, a pressure-retarded osmosis process technology using a pressure exchanger that can recover the pressure of high-salinity concentrated water through a reverse osmosis membrane by transferring it to raw seawater. By recovering the osmotic energy generated from the pressure-retarded osmosis process as it is and applying it to the existing seawater desalination process, the energy consumption required for seawater desalination can be greatly reduced.

Efficiency of isobaric pressure exchangers applicable to the reverse osmotic seawater

desalination and pressure-retarded osmosis process reaches up to 97%. Accordingly, the complex seawater desalination process, which combines pressure-retarded osmosis processes that can recover and transfer pressure using such a pressure exchanger, is more efficient in energy recovery and can simplify process facilities than the method of producing generated osmotic energy as power through a water turbine.

In addition, as the salinity concentration of the seawater desalination brine increases, the energy recovery amount in the pressure-retarded osmosis process increases, and low-salinity effluent from a sewage treatment plant and low-salinity discharged water from a sewage reuse facility can be used to generate high-salinity concentrated water and osmotic energy. Accordingly, there is a demand for a complex desalination facility for seawater desalination and sewage treatment or sewage reuse that combines pressure-retarded osmosis processes.

SUMMARY

Embodiments of the present disclosure provide a complex desalination system using pressure-retarded osmosis technology capable of complex water treatment of seawater and brackish water reverse osmosis wastewater, by using wastewater (discharged water) generated from a sewage reuse brackish water reverse osmosis (BWRO) process, which additionally treats effluent from a sewage treatment plant, as raw water for a pressure-retarded osmosis process together with reverse osmosis seawater desalination concentrated water.

In accordance with an aspect of the present disclosure, there is provided a complex desalination system using seawater desalination pressure-retarded osmosis technology, the system including: a pre-treatment facility for pre-filtering seawater; a first pressure exchanger for receiving the seawater from the pre-treatment facility to increase a pressure; a second pressure exchanger for receiving at least some of the seawater supplied from the first pressure

exchanger to increase a pressure; a first pressure control device for pressurizing the remaining of the seawater supplied from the first pressure exchanger; a second pressure control device for pressurizing the seawater supplied from the second pressure exchanger; a seawater reverse osmosis facility for producing product water by filtering out salt from the seawater supplied from the first pressure control device and the second pressure control device through a seawater desalination reverse osmosis membrane, and transferring seawater reverse osmosis brine from which salt has not been removed to the second pressure exchanger; a brackish water reverse osmosis facility for receiving effluent from a sewage treatment plant, filtering the effluent through a brackish water desalination reverse osmosis membrane, and discharging brackish water reverse osmosis brine that has not been filtered; and a pressure-retarded osmosis facility for supplying, to the first pressure exchanger, pressure-retarded osmosis product water filtered by performing a pressure-retarded osmosis process on the seawater reverse osmosis brine supplied from the second pressure exchanger and the brackish water reverse osmosis brine supplied from the brackish water reverse osmosis facility, respectively.

A flow rate of the pressure-retarded osmosis product water supplied to the first pressure exchanger and a flow rate of the seawater supplied to the first pressure exchanger may be controlled to be equal.

The complex desalination system may further include: a reverse osmosis facility for receiving the pressure-retarded osmosis product water from the first pressure exchanger and filtering out salt from the received pressure-retarded osmosis product water through a reverse osmosis membrane to produce product water.

The complex desalination system may further include: a first bypass pipe for guiding at least some of the pressure-retarded osmosis product water supplied to an inlet side of the first pressure exchanger to an outlet side of the first pressure exchanger.

The complex desalination system may further include: a second bypass pipe for

guiding at least some of the pressure-retarded osmosis brine discharged from the pressure-retarded osmosis facility to the first pressure exchanger.

The complex desalination system may further include: a third bypass pipe for guiding at least some of the seawater discharged from the pre-treatment facility to the seawater reverse osmosis facility.

The complex desalination system may further include: a fourth bypass pipe for guiding at least some of the pressure-retarded osmosis product water discharged from the first pressure exchanger to the pre-treatment facility

The pressure-retarded osmosis brine discharged from the pressure-retarded osmosis facility may be supplied to the pre-treatment facility.

The pressure-retarded osmosis brine discharged from the pressure-retarded osmosis facility may be supplied to the pre-treatment facility.

According to embodiments of the present disclosure, by applying the brackish water reverse osmosis wastewater generated in the sewage reuse brackish water reverse osmosis process that treats effluent from sewage treatment plant to an osmotic process such as pressure-retarded osmosis in which seawater desalination is performed, the complex desalination treatment for seawater and effluent from the sewage treatment plant is possible.

In addition, according to embodiments of the present disclosure, it is possible to maximize the recovery efficiency of energy recovered during the seawater desalination and the brackish water desalination by connecting the seawater reverse osmosis (SWRO) and the brackish water reverse osmosis (BWRO) to the pressure-retarded osmosis (PRO) facility.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating a complex desalination system according to a first embodiment of the present disclosure.

FIG. 2 is a block diagram illustrating a complex desalination system according to a second embodiment of the present disclosure.

FIG. 3 is a block diagram illustrating a complex desalination system according to a third embodiment of the present disclosure.

5 FIG. 4 is a block diagram illustrating a complex desalination system according to a fourth embodiment of the present disclosure.

FIG. 5 is a block diagram illustrating a complex desalination system according to a fifth embodiment of the present disclosure.

10 FIG. 6 is a block diagram illustrating a complex desalination system according to a sixth embodiment of the present disclosure.

FIG. 7 is a block diagram illustrating a complex desalination system according to a seventh embodiment of the present disclosure.

FIG. 8 is a block diagram illustrating a complex desalination system according to an eighth embodiment of the present disclosure.

15

DETAILED DESCRIPTION

Hereinafter, specific embodiments for implementing a spirit of the present disclosure will be described in detail with reference to the drawings.

20 In describing the present disclosure, detailed descriptions of known configurations or functions may be omitted to clarify the present disclosure.

When an element is referred to as being 'connected' to, 'supported' by, 'accessed' to, 'supplied' to, 'transferred' to, or 'contacted' with another element, it should be understood that the element may be directly connected to, supported by, accessed to, supplied to, transferred to, or contacted with another element, but that other elements may exist in the middle.

25 The terms used in the present disclosure are only used for describing specific

embodiments, and are not intended to limit the present disclosure. Singular expressions include plural expressions unless the context clearly indicates otherwise.

Further, in the present disclosure, it is to be noted that expressions, such as the upper side and the lower side, are described based on the illustration of drawings, but may be modified if directions of corresponding objects are changed. For the same reasons, some components are exaggerated, omitted, or schematically illustrated in the accompanying drawings, and the size of each component does not fully reflect the actual size.

Terms including ordinal numbers, such as first and second, may be used for describing various elements, but the corresponding elements are not limited by these terms. These terms are only used for the purpose of distinguishing one element from another element.

In the present specification, it is to be understood that the terms such as “including” are intended to indicate the existence of the certain features, areas, integers, steps, actions, elements, combinations, and/or groups thereof disclosed in the specification, and are not intended to preclude the possibility that one or more other certain features, areas, integers, steps, actions, elements, combinations, and/or groups thereof may exist or may be added.

Hereinafter, a detailed configuration of a complex desalination system using seawater desalination pressure-retarded osmosis technology according to one embodiment of the present disclosure will be described with reference to FIGS. 1 to 8.

FIG. 1 is a block diagram illustrating a complex desalination system according to a first embodiment of the present disclosure.

Referring to FIG. 1, the complex desalination system 10 according to the first embodiment of the present disclosure receives seawater and sewage treatment plant effluent from Treated WWTE and converts same to fresh water through desalination treatment.

To implement this, the complex desalination system 10 may include a pre-treatment facility 100, a first pressure exchanger 200, a second pressure exchanger 300, a seawater

reverse osmosis (SWRO) facility 400, a brackish water reverse osmosis (BWRO) facility 500, a reverse osmosis (RO) facility 600, and a pressure-retarded osmosis (PRO) facility 900.

The pre-treatment facility 100 can perform pre-filtering (pre-treatment) for desalination of seawater through a dissolved air floating (DAF) device 110 and a seawater ultrafiltration (UF) device 120. The DAF device 110 may be a facility for performing a processing process of separating and removing algae or light specific gravity particles in raw water. The seawater UF device 120 may be a facility for performing a membrane separation process of an ultrafiltration type. The seawater UF device 120 performs a process of primarily removing impurities by filtering raw water through a method of separation depending on the sizes of substances in the solution using a semi-permeable membrane. Since the DAF process and the UF process correspond to well-known common technical knowledge in the art, detailed descriptions of the processes will be omitted.

The seawater from which impurities such as algae are removed through the pre-treatment may be introduced into the first pressure exchanger 200 to be pressurized by pressure application. The seawater pressurized by the first pressure exchanger 200 may be separated by a multi-way valve to be introduced into the second pressure exchanger 300 or into a first pressure control device 810, for example, a high-pressure pump. The seawater pressurized by the second pressure exchanger 300 may be further pressurized by a second pressure control device 820, for example, a booster pump.

The first pressure exchanger 200 refers to a device that transfers pressure from a liquid flow of a higher pressure side to a liquid flow of a lower pressure side while preventing the flows of the two liquids from mixing with each other. Since an example of such a pressure exchanger is disclosed in Korean Patent Application Publication No. 2014-0092836, a detailed description thereof will be omitted.

Some of the seawater pressurized by the first pressure exchanger 200 may be introduced into the SWRO facility 400 after being pressurized through the first pressure control device (high-pressure pump) 810. The remaining of the seawater pressurized by the first pressure exchanger 200 may be introduced into the SWRO facility 400 after being
5 pressurized through the second pressure exchanger 300 and the second pressure control device (booster pump) 820.

The SWRO facility 400 may be understood as a facility for desalination of seawater by reverse osmosis. The SWRO facility 400 includes a seawater desalination reverse osmosis membrane capable of permeating only water while hardly permeating solutes such as
10 salt in the introduced seawater by applying a physical pressure equal to or higher than the osmotic pressure. For example, the SWRO facility 400 may produce product water through the seawater desalination reverse osmosis membrane.

The product water desalinated through the SWRO facility 400 is discharged to the outside in a drinkable state of low salinity, so that the product water can be used for other
15 purposes such as drinking, irrigation, or industrial use through a separately provided post-treatment process.

The SWRO facility 400 may deliver SWRO brine that has not been filtered through the seawater desalination reverse osmosis membrane to the second pressure exchanger 300.

The second pressure exchanger 300 may use the pressure of the SWRO brine received from the SWRO facility 400 and transfer it to the seawater supplied from the first
20 pressure exchanger 200 to reduce the pressure of the SWRO brine. The depressurized SWRO brine may be pressurized to a predetermined pressure in a third pressure control device 830 such as a booster pump. The SWRO brine pressurized by the third pressure control device 830 is a draw solution with high salinity, and may be introduced into the PRO
25 facility 900.

Meanwhile, the BWRO facility 500 may receive the sewage treatment plant effluent from an effluent UF device 510. In the effluent UF device 510, pre-treatment for desalination of the effluent from sewage treatment plant may be performed. The effluent from sewage treatment plant pretreated through the effluent UF device 510 may be
5 pressurized by a fourth pressure control device 840 such as a high-pressure pump and supplied to the BWRO facility 500.

The BWRO facility 500 may filter the sewage treatment plant effluent that has undergone the pre-treatment process through a brackish water desalination reverse osmosis membrane. The sewage treatment plant effluent filtered by the BWRO facility 500 may be
10 sterilized through a UV device 520 and then discharged as drinkable water of low-salinity. The BWRO brine that has not been filtered in the BWRO facility 500 may be provided to the PRO facility 900 as a feed solution.

The PRO facility 900 may perform a pressure-retarded osmosis process on the SWRO brine (draw solution) supplied from the second pressure exchanger 300 and the
15 BWRO brine (feed solution) supplied from the BWRO facility 500. For example, in the PRO facility 900, the draw solution and the feed solution meet each other with a PRO membrane interposed therebetween, and water flows from the feed solution to the draw solution due to the difference in salinity between the draw solution and the feed solution, so that the volume flow rate of the draw solution can be increased.

Accordingly, the extracted water exiting from the BWRO brine through the PRO
20 membrane in the PRO facility 900 has very low salinity, and Gibbs free energy of mixing is generated by the difference in salinity between the two solutions while being mixed with the SWRO brine. The generated Gibbs free energy of mixing maintains the pressure of the SWRO brine.

The volume flow rate of the PRO product water discharged from the PRO facility 900 is increased compared to the SWRO brine, while the pressure thereof is relatively maintained. The PRO product water flows into the first pressure exchanger 200 after being discharged from the PRO facility 900, and transfers the pressure to the seawater supplied from the pre-treatment facility 100 to pressurize the seawater. After transferring the pressure to the seawater, the PRO product water may have a decreased pressure, and may undergo a separate treatment or process after being discharged from the first pressure exchanger 200.

Meanwhile, the brackish water concentrated due to the extracted water exiting from the BWRO brine while the BWRO brine goes through the pressure-retarded osmosis process in the PRO facility 900, may be transported to and stored in an external storage tank as PRO brine, or may be used through a separate post-treatment or process.

In the case of the above-described first embodiment, since the PRO product water discharged from the first pressure exchanger 200 is discharged to the outside of the system, the recovery rate of the product water recovered in the entire system may deteriorate. In order to improve such a problem of the first embodiment, a second embodiment to be described later may be proposed.

FIG. 2 is a block diagram illustrating a complex desalination system according to a second embodiment of the present disclosure.

Referring to FIG. 2, the complex desalination system 10 according to the second embodiment of the present disclosure includes a pre-treatment facility 100, a first pressure exchanger 200, a second pressure exchanger 300, and a SWRO facility 400, a BWRO facility 500, an RO facility 600 and a PRO facility 900. Since the second embodiment is different from the first embodiment in that the PRO product water discharged from the first pressure exchanger 200 is filtered through the RO facility 600, the description will be made mainly on

the difference, and the same description and reference numerals as those in the above-described embodiment are referred to.

The RO facility 600 may receive PRO product water from the first pressure exchanger 200. In this case, the PRO product water may be pressurized through a third pressure exchanger 610 and a fifth pressure control device 850. The third pressure exchanger 610 and the fifth pressure control device 850 may be understood as configurations corresponding to the pressure exchanger and the pressure control device described in the first embodiment.

The RO facility 600 may filter out salt from the supplied PRO product water through a reverse osmosis membrane to produce product water. The RO facility 600 may transfer RO brine that has not been filtered through the reverse osmosis membrane to the third pressure exchange device 610.

As described above, in the second embodiment, by filtering the PRO product water discharged from the first pressure exchanger 200 again through the RO facility 600, it is possible to improve the recovery rate of the product water recovered in the system, and reduce the discharge amount of the PRO product water discharged from the first pressure exchanger 200 to the outside of the system.

In the case of the first embodiment and the second embodiment described above, as the operating time of the PRO facility 900 increases, the filtration performance of the PRO facility 900 may be deteriorated, which decreases the flow rate of the PRO product water. Accordingly, there may occur a difference between the flow rate of PRO product water supplied from the PRO facility 900 to the first pressure exchanger 200 and the flow rate of seawater supplied from the pre-treatment facility 100 to the first pressure exchanger 200. In other words, there may occur a change in flow ratio between the feed solution and the draw solution supplied to the first pressure exchanger 200.

In order to improve such problems of the first and second embodiments, third to eighth embodiments described below may be proposed. When compared to the first and second embodiments, the third to eighth embodiments described later differ in that the flow rate ratio between the feed solution and the draw solution supplied to the first pressure exchanger 200 can be maintained constant by controlling the flow rate through a bypass pipe, and the description will be made mainly on the difference, and the same description and reference numerals as those in the above-described embodiment are referred to.

FIG. 3 is a block diagram illustrating a complex desalination system according to the third embodiment of the present disclosure.

Referring to FIG. 3, in the complex desalination system 10 according to the third embodiment of the present disclosure, an inlet side pipe 711 of the first pressure exchanger 200 and an outlet side pipe 712 of the first pressure exchanger 200 may be connected through a first bypass pipe 710.

For example, when the flow rate of PRO product water supplied to the first pressure exchanger 200 is greater than the flow rate of seawater flowing into the pre-treatment facility 100, the first bypass pipe 710 bypasses at least some of PRO product water supplied to the inlet side of the first pressure exchanger 200 to the outlet side of the first pressure exchanger 200, so that the flow rate of PRO product water supplied to the first pressure exchanger 200 and the flow rate of seawater supplied to the first pressure exchanger 200 can be maintained the same.

As an example, when the flow rate of PRO product water supplied from the PRO facility 900 to the first pressure exchanger 200 is 488 m³/day and the flow rate of seawater supplied from the pre-treatment facility 100 to the first pressure exchanger 200 is 444 m³/day, the first bypass pipe 710 may guide the PRO product water flow rate of 44 m³/day out

of the PRO product water flow rate of 488 m³/day to the outlet side pipe 712 of the first pressure exchanger 200.

In this way, when the flow rate of PRO product water supplied to the first pressure exchanger 200 is greater than the flow rate of seawater flowing into the pre-treatment facility 100, in the third embodiment, by maintaining the flow rate of PRO product water supplied from the PRO facility 900 to the first pressure exchanger 200 and the flow rate of seawater supplied from the pre-treatment facility 100 to the first pressure exchanger 200 to be the same using the first bypass pipe 710, energy change efficiency of the first pressure exchanger 200 can be increased, and energy recovery efficiency of the present disclosure can be maximized.

FIG. 4 is a block diagram illustrating a complex desalination system according to the fourth embodiment of the present disclosure.

Referring to FIG. 4, in the complex desalination system 10 according to the fourth embodiment of the present disclosure, the inlet side pipe 711 of the first pressure exchanger 200 and an outlet side pipe 721 of the PRO facility 900 may be connected through a second bypass pipe 720.

For example, in the fourth embodiment, the second bypass pipe 720 may bypass some of the PRO brine discharged from the PRO facility 900 to the inlet side pipe 711 of the first pressure exchanger 200, so that the flow rate of PRO product water supplied to the first pressure exchanger 200 and the flow rate of seawater supplied to the first pressure exchanger 200 can be maintained the same.

As an example, when the PRO brine discharged from the PRO facility 900 is 73 m³/day, the PRO product water supplied from the PRO facility 900 to the first pressure exchanger 200 is 416 m³/day, and the flow rate of seawater supplied to the first pressure exchanger 200 is 444 m³/day, the second bypass pipe 720 may guide the PRO brine flow rate

of 28 m³/day from the PRO brine flow rate of 73 m³/day to the inlet side pipe 711 of the first pressure exchanger 200.

In this way, in the fourth embodiment, the flow rate of PRO product water supplied from the PRO facility 900 to the first pressure exchanger 200 and the flow rate of seawater supplied from the pre-treatment facility 100 to the first pressure exchanger 200 can be maintained the same using the second bypass pipe 720.

FIG. 5 is a block diagram illustrating a complex desalination system according to the fifth embodiment of the present disclosure.

Referring to FIG. 5, in the complex desalination system 10 according to the fifth embodiment of the present disclosure, an outlet side pipe 731 of the pre-treatment facility 100 and an inlet side pipe 732 of the SWRO facility 400 may be connected through a third bypass pipe 730. The third bypass pipe 730 may be provided with a sixth pressure control device 870, for example, a booster pump.

For example, in the fifth embodiment, the third bypass pipe 730 may bypass some of the seawater treated in the pre-treatment facility 100 to the inlet side of the SWRO facility 400 and pressurize it through the sixth pressure control device 870 (booster pump) and the first pressure control device 810 (high-pressure pump), so that the flow rate of PRO product water supplied to the first pressure exchanger 200 and the flow rate of seawater supplied to the first pressure exchanger 200 can be maintained the same.

As an example, when the flow rate of PRO product water supplied from the PRO facility 900 to the first pressure exchanger 200 is 416 m³/day and the flow rate of seawater discharged from the pre-treatment facility 100 is 444 m³/day, the third bypass pipe 730 may guide the flow rate of 28 m³/day out of the seawater flow rate of 444 m³/day to the inlet side pipe 732 of the SWRO facility 400.

In this way, in the fifth embodiment, the flow rate of PRO product water supplied from the PRO facility 900 to the first pressure exchanger 200 and the flow rate of seawater supplied from the pre-treatment facility 100 to the first pressure exchanger 200 can be maintained the same using the third bypass pipe 730.

5 FIG. 6 is a block diagram illustrating a complex desalination system according to the sixth embodiment of the present disclosure.

Referring to FIG. 6, in the complex desalination system 10 according to the sixth embodiment of the present disclosure, the outlet side pipe 731 of the pre-treatment facility 100 and the inlet side pipe 732 of the SWRO facility 400 may be connected through the third
10 bypass pipe 730, and the outlet side pipe 712 of the first pressure exchanger 200 may be connected to the pre-treatment facility 100. The sixth pressure control device 870 may be provided in the third bypass pipe 730.

For example, by supplying all the PRO product water discharged from the outlet side of the first pressure exchanger 200 to the pre-treatment facility 100, the intake amount of
15 seawater and the discharge amount of concentrated water can be significantly reduced. The third bypass pipe 730 may bypass the mixed water treated in the pre-treatment facility 100 to the inlet side of the SWRO facility 400 and pressurize it, so that the flow rate of PRO product water supplied to the first pressure exchanger 200 and the flow rate of seawater supplied to the first pressure exchanger 200 can be maintained the same.

20 As an example, when the flow rate on the outlet side of the pre-treatment facility 100 is 444 m³/day, all the flow rates (416 m³/day) of PRO product water discharged from the outlet side of the first pressure exchange 200 can flow into the pre-treatment facility 100, so only 28 m³/day of seawater can be taken in, and the discharged concentrated water can be reduced by 416 m³/day. Out of the seawater flow rate (444 m³/day) discharged from the pre-

treatment facility 100, the seawater flow rate of 28 m³/day may be guided to the inlet side pipe 732 of the SWRO facility 400 through the third bypass pipe 730.

In this way, by supplying all the PRO product water discharged from the outlet side of the first pressure exchanger 200 to the pre-treatment facility 100, the intake of seawater can be reduced, and the discharged concentrated water can also be reduced.

FIG. 7 is a block diagram illustrating a complex desalination system according to the seventh embodiment of the present disclosure.

Referring to FIG. 7, in the complex desalination system 10 according to the seventh embodiment of the present disclosure, the outlet side pipe 721 of the PRO facility 900 may be connected to the pre-treatment facility 100.

For example, when the flow rate on the outlet side of the pre-treatment facility 100 is 444 m³/day, all the flow rate (73 m³/day) of the PRO brine discharged from the outlet side of the PRO facility 900 can flow into the pre-treatment facility 100, so only 404 m³/day of seawater can be taken in, and the discharged concentrated water can be reduced by 73 m³/day. In addition, since mixed water has a lower total dissolved solid (TDS) than seawater, the energy consumption of the entire process is reduced.

As an example, when the flow rate on the outlet side of the pre-treatment facility 100 is 444 m³/day, all the flow rates (73 m³/day) of the PRO brine discharged from the outlet side of the PRO facility 900 can flow into the pre-treatment facility 100, so only 404 m³/day of seawater can be taken in, and the discharged concentrated water can be reduced by 416 m³/day.

FIG. 8 is a block diagram illustrating a complex desalination system according to the eighth embodiment of the present disclosure.

Referring to FIG. 8, in the complex desalination system 10, the outlet side pipe 721 of the PRO facility 900 may be connected to the pre-treatment facility 100, the outlet side pipe

712 of the first pressure exchanger 200 and the pre-treatment facility 100 may be connected to each other through a fourth bypass pipe 740, and the outlet side pipe 731 of the pre-treatment facility 100 and the inlet side pipe 732 of the SWRO facility 400 may be connected through the third bypass pipe 730.

5 For example, in the eighth embodiment, all the flow rate of PRO brine discharged from the outlet side of the PRO facility 900 may be guided to the pre-treatment facility 100, and the fourth bypass pipe 740 may bypass some of the PRO product water discharged from the outlet side of the first pressure exchanger 200 to the pre-treatment facility 100.

10 In addition, the third bypass pipe 730 may bypass some of the seawater discharged from the pre-treatment facility 100 to the inlet side of the SWRO facility 400 and pressurize it, so that the flow rate of PRO product water supplied to the first pressure exchanger 200 and the flow rate of the seawater supplied to the first pressure exchanger 200 can be maintained the same.

15 As an example, when the flow rate at the outlet side of the pre-treatment facility 100 is 444 m³/day, all the flow rate (73 m³/day) of the PRO brine from the outlet side of the PRO facility 900 can be guided to the pre-treatment facility 100, and some (220 m³/day) of the flow rate of the PRO product water discharged from the outlet side of the first pressure exchanger 200 can be guided to the pre-treatment facility 100 through the fourth bypass pipe 740. As a result, only 151 m³/day of seawater can be taken in and the discharged concentrated water is reduced by 493 m³/day.

20 In addition, out of the flow rate (444 m³/day) of seawater discharged from the pre-treatment facility 100, 28 m³/day of seawater can be guided to the inlet side pipe 732 of the SWRO facility 400 through the third bypass pipe 730.

25 Although the embodiments of the present disclosure have been described above with reference to the accompanying drawings, those of ordinary skill in the art to which the present

disclosure pertains will understand that the present disclosure can be implemented in other specific forms without changing the technical spirit or essential features thereof. For example, although a person skilled in the art may change the material, size, etc. of each element depending on the field of application, or combine or substitute embodiments to
5 implement it in a form not clearly disclosed in the embodiments of the present disclosure, this also does not depart from the scope of the present disclosure. Therefore, the above-described embodiments are illustrative in all respects and should not be understood as limiting, and it should be said that these modified embodiments are included in the technical idea described in the claims of the present disclosure.

10

WHAT IS CLAIMED IS:

1. A complex desalination system using seawater desalination pressure-retarded osmosis technology, the system comprising:

5 a pre-treatment facility for pre-filtering seawater;

a first pressure exchanger for receiving the seawater from the pre-treatment facility to increase a pressure;

a second pressure exchanger for receiving at least some of the seawater supplied from the first pressure exchanger to increase a pressure;

10 a first pressure control device for pressurizing the remaining of the seawater supplied from the first pressure exchanger;

a second pressure control device for pressurizing the seawater supplied from the second pressure exchanger;

15 a seawater reverse osmosis facility for producing product water by filtering out salt from the seawater supplied from the first pressure control device and the second pressure control device through a seawater desalination reverse osmosis membrane, and transferring seawater reverse osmosis brine from which salt has not been removed to the second pressure exchanger;

20 a brackish water reverse osmosis facility for receiving effluent from a sewage treatment plant, filtering the effluent through a brackish water desalination reverse osmosis membrane, and discharging brackish water reverse osmosis brine that has not been filtered; and

a pressure-retarded osmosis facility for supplying, to the first pressure exchanger, pressure-retarded osmosis product water filtered by performing a pressure-retarded osmosis process on the seawater reverse osmosis brine supplied from the second pressure exchanger

25

and the brackish water reverse osmosis brine supplied from the brackish water reverse osmosis facility, respectively.

2. The complex desalination system of claim 1, wherein a flow rate of the pressure-retarded osmosis product water supplied to the first pressure exchanger and a flow rate of the seawater supplied to the first pressure exchanger are controlled to be equal.

3. The complex desalination system of claim 1, further comprising:
a reverse osmosis facility for receiving the pressure-retarded osmosis product water from the first pressure exchanger and filtering out salt from the received pressure-retarded osmosis product water through a reverse osmosis membrane to produce product water.

4. The complex desalination system of claim 1, further comprising:
a first bypass pipe for guiding at least some of the pressure-retarded osmosis product water supplied to an inlet side of the first pressure exchanger to an outlet side of the first pressure exchanger.

5. The complex desalination system of claim 1, further comprising:
a second bypass pipe for guiding at least some of the pressure-retarded osmosis brine discharged from the pressure-retarded osmosis facility to the first pressure exchanger.

6. The complex desalination system of claim 1, further comprising:
a third bypass pipe for guiding at least some of the seawater discharged from the pre-treatment facility to the seawater reverse osmosis facility.

7. The complex desalination system of claim 6, further comprising:
a fourth bypass pipe for guiding at least some of the pressure-retarded osmosis product water discharged from the first pressure exchanger to the pre-treatment facility

5 8. The complex desalination system of claim 1, wherein the pressure-retarded osmosis brine discharged from the pressure-retarded osmosis facility is supplied to the pre-treatment facility.

10 9. The complex desalination system of claim 7, wherein the pressure-retarded osmosis brine discharged from the pressure-retarded osmosis facility is supplied to the pre-treatment facility.