

DESCRIPTION

Title of Invention

METHOD FOR OPERATING MEMBRANE DISTILLATION APPARATUS

Technical Field

[0001] The present invention relates to a method for operating a membrane distillation apparatus, and particularly to a method for operating a membrane distillation apparatus having a process of removing a precipitate generated on a secondary side of a membrane.

Background Art

[0002] A membrane distillation apparatus is configured to collect only steam from a liquid-being-processed and concentrate the liquid-being-processed as the liquid-being-processed having been warmed is passed to a primary side of a hydrophobic flat membrane or a hydrophobic hollow fiber membrane and a secondary side of the membrane is subjected to a pressure equal to or lower than a steam pressure on the primary side.

Unlike a common distillation apparatus, a membrane distillation apparatus has an advantage in that the evaporation surface area is increased and the size of the apparatus is reduced owing to the use of a membrane.

[0003] One example of conventional examples of membrane distillation apparatuses is shown in Fig. 2. A liquid-being-processed stored inside a feed-water tank 1 is sent to a heat exchanger (warmer) 4 through a pipe 3 having a feed-water pump 2, warmed by exchanging heat with a high-

temperature fluid, and then sent to a membrane module 10 through a pipe 5.

[0004] In this conventional example, the membrane module 10 is a hollow fiber membrane module. In the membrane module 10, a large number of hollow fibers 11 are arranged in parallel to form a bundle of hollow fibers and disposed in an up-down direction. An upper end side and a lower end side of the bundle of hollow fibers are bound by potting materials 12, 13.

[0005] The bundle of hollow fibers is disposed inside a casing 14 of the membrane module 10, and an inflow chamber 15 is formed on an upper side of the upper-side potting material 12 and an outflow chamber 16 is formed on a lower side of the lower-side potting material 13. The inside of each hollow fiber 11 communicates with the inside of each of the inflow chamber 15 and the outflow chamber 16.

[0006] The liquid-being-processed from the pipe 5 flows from the inflow chamber 15 into each hollow fiber 11 (primary side), passes through the hollow fiber 11, flows to the outflow chamber 16, and returns from the outflow chamber 16 to the feed-water tank 1 through a pipe 6.

[0007] A part inside the casing 14 that is outside the hollow fibers 11 and between the potting materials 12, 13 constitutes a secondary side 17.

[0008] The secondary side 17 communicates with a pressure reduction device 25 through a pipe (steam pipe) 20, a heat exchanger (cooler) 21, a pipe 22, a condensate water tank 23, and a pipe 24, and the secondary side 17 is depressurized by the pressure reduction device 25.

[0009] While the liquid-being-processed is flowing inside the hollow fibers 11 (primary side), water inside the liquid-being-processed permeates the hollow fibers 11, turns into steam, is suctioned and

discharged from the secondary side 17 to the pipe 20, and is cooled in the heat exchanger 21 to form condensate water. The condensate water is stored in the condensate water tank 23.

[0010] In this conventional example, a lower part of the secondary side 17 inside the casing 14 and an upper part (gas phase part 1a) inside the feed-water tank 1 communicate with each other through a pipe 7.

Pressure sensors P1, P2 are installed so as to detect pressures inside the pipes 5, 20.

Citation List

Patent Literature

[0011] PTL1: JPH 03-52627 A

[0012] In the above-described membrane distillation apparatus, a precipitate composed of salt and the like can be deposited on the secondary side of the membrane. When a precipitate is generated, the membrane surface area decreases and the distillation performance degrades.

[0013] To remove such precipitate, conventionally, the membrane is removed from the membrane distillation apparatus and washed with pure water, which, however, takes time and effort as well as generates washing wastewater.

Summary of Invention

Technical Problem

[0014] An object of the present invention is to provide a method for operating a membrane distillation apparatus that makes it possible to remove a precipitate without removing the membrane from the

membrane distillation apparatus and also to avoid generating washing wastewater.

Solution to Problem

[0015] A method for operating a membrane distillation apparatus of the present invention is a method for operating a membrane distillation apparatus that distills a liquid-being-processed using a membrane distillation apparatus comprising: a membrane module of which an inside of a casing is divided into a primary side and a secondary side by a membrane; a feed-water tank and a feed-water pump for supplying a liquid-being-processed to the primary side of the membrane module; and a pressure reduction device that depressurizes the secondary side of the membrane module, wherein a precipitate removal process is performed in which a gas is introduced to the secondary side of the membrane module to generate condensate water on the secondary side and a precipitate on the secondary side is removed by being dissolved in the condensate water.

[0016] In one aspect of the present invention, the precipitate removal process is performed by stopping the pressure reduction device in a state where the feed-water pump is operating, and thus creating a positive pressure on the secondary side.

[0017] In one aspect of the present invention, a pipe branches from a path connecting the secondary side and the pressure reduction device to each other and a valve is provided on this branch pipe, and a positive pressure is created on the secondary side by opening this valve.

[0018] In one aspect of the present invention, the precipitate removal process is performed on a regular basis or when distillation performance has degraded below a predetermined value.

[0019] In one aspect of the present invention, the distillation performance is obtained based on a pressure on the secondary side or generation speed of condensate water.

[0020] In one aspect of the present invention, a communication part that allows communication between the secondary side of the membrane module and the feed-water tank is provided, and in the precipitate removal process, a solution in which the precipitate has dissolved flows into the feed-water tank through the communication part.

Advantageous Effects of Invention

[0021] According to the present invention, performing the precipitate removal process can remove a precipitate on the secondary side of the membrane by dissolving it in condensate water, without removing the membrane from the membrane distillation apparatus. In one aspect of the present invention, the membrane is not washed with pure water, so that washing wastewater is not generated.

Brief Description of Drawings

[0022]

[Fig. 1] Fig. 1 is a configuration diagram of a membrane distillation apparatus according to an embodiment.

[Fig. 2] Fig. 2 is a configuration diagram of a membrane distillation apparatus according to a conventional example.

Description of Embodiments

[0023] Fig. 1 shows the configuration of a membrane distillation apparatus according to an embodiment.

[0024] In this embodiment, a pipe 30 for suctioning air branches from a pipe 24 that allows communication between a condensate water tank 23 and a pressure reduction device 25, and a valve 31 is provided on this pipe 30. The pipe 30 is either opened to the atmosphere or connected to a gas source (not shown), such as nitrogen. A valve 8 is provided on a pipe 7 that allows communication between a secondary side 17 of the membrane module 10 and a gas phase part 1a of a feed-water tank 1.

[0025] The configuration of this membrane distillation apparatus is otherwise the same as the membrane distillation apparatus of Fig. 2, and the same reference sign denotes the same part.

[0026] When performing a distillation process by this membrane distillation apparatus, the valves 8, 31 are closed and the pressure reduction device 25 and the feed-water pump 2 are operated. As in the case of Fig. 2, a liquid-being-processed inside the feed-water tank 1 flows from the inflow chamber 15 into each hollow fiber 11 (primary side) through the pipe 3, the heat exchanger 4, and the pipe 5, passes through the hollow fiber 11, flows to the outflow chamber 16, and returns from the outflow chamber 16 to the feed-water tank 1 through the pipe 6.

[0027] Since the secondary side 17 is depressurized by the pressure reduction device 25, while the liquid-being-processed is flowing inside the hollow fibers 11 (primary side), water in the liquid-being-processed permeates the hollow fibers 11, turns into steam, is suctioned and discharged from the secondary side 17 to the pipe 20, and is cooled in the heat exchanger 21 to form condensate water. The condensate water is stored in the condensate water tank 23.

[0028] When this distillation operation is continued, a precipitate, such as salt and the like, deposits on the secondary side of the hollow fibers 11.

Therefore, a precipitate removal process of removing a precipitate on the secondary side of the hollow fibers 11 by dissolution is performed on a regular basis or when the distillation performance has degraded below a predetermined value.

[0029] To perform this precipitate removal process, the pressure reduction device 25 is stopped and the valve 31 is opened with the feed-water pump 2 operating, and thereby a positive pressure is created on the secondary side of the hollow fibers 11. It is preferable that the valve 8 be opened when the valve 31 is opened.

[0030] When thus the pressure reduction device 25 is stopped and the valve 31 is opened so as not to depressurize the secondary side of the hollow fibers 11, the secondary side of the hollow fibers 11 is filled with saturated steam and a sufficient amount of condensate water is generated on the secondary side of the hollow fibers 11, so that a precipitate on the secondary side of the hollow fibers 11 is removed by dissolving in this condensate water. The condensate water in which the precipitate has dissolved flows into the feed-water tank 1 through the pipe 7.

[0031] After the precipitate removal process is performed in this way, the valves 8, 31 are closed and the pressure reduction device 25 is operated to resume the distillation process.

[0032] As mentioned above, the precipitate removal process may be performed on a regular basis or when the distillation performance has degraded. Degradation of the distillation performance can be detected, for example, as the rising speed of the level of the condensate water inside the condensate water tank 23 decreases to or below a

predetermined speed, or as the pressure detected by the pressure sensor P2 decreases to or below a specified value.

[0033] A hydrophobic hollow fiber membrane is suitable as the hollow fibers 11. It is preferable that the inside diameter (diameter) of the hollow fiber be 0.1 to 3.0 mm, particularly 0.5 to 2.0 mm, and that the thickness, i.e., the difference between the outside diameter (radius) and the inside diameter (radius) of the hollow fiber be 0.01 to 1.0 mm, particularly 0.1 to 0.5 mm. The length of the hollow fiber is preferably 200 to 2000 mm, particularly 300 to 1000 mm. The packing ratio of the hollow fibers (the sum of the cross-sectional areas of the hollow fibers/the cross-sectional area of the casing) is preferably 5% to 50%, particularly 15% to 35%. Examples of the material of the hollow fibers include polysulfone, polyether sulfone, polyethylene, polypropylene, polyvinylidene fluoride, and polytetrafluoroethylene, but are not limited thereto.

[0034] While hollow fibers are used in the above description, a hydrophobic flat membrane may instead be used.

[0035] As the liquid-being-processed, an acidic solution such as common salt, phosphoric acid, hydrochloric acid, hydrofluoric acid, or sulfuric acid, alkaline wastewater such as ammonia water, or an aqueous solution such as plating wastewater is suitable. A water passage velocity (linear velocity) of the liquid-being-processed inside the hollow fiber is suitably about 400 to 2000 mm/sec, particularly about 700 to 1500 mm/sec. The temperature of the liquid-being-processed when it flows into the membrane module 10 is suitably about 45 to 150°C, particularly about 50 to 80°C.

[0036] The above-described suitable conditions represent suitable examples and the present invention is not limited to the above-described conditions.

Example

[0037] [Example 1]

With the valves 8, 31 closed, the apparatus shown in Fig. 1 was operated under the following conditions. The casing 14 was a transparent column, and a status of deposition of a precipitate on an outer surface of the hollow fiber 11 was visually observed.

[0038] <Test Conditions>

Hollow fiber 11: made of polytetrafluoroethylene, 1.0 mm in inside diameter, 0.3 mm in thickness, 600 mm in length, one fiber

Casing 14 of membrane module 10: 10 mm in inside diameter, 690 mm in height

Feed-water: 1% NaCl aqueous solution

Feed-water temperature: 60°C

Membrane module inlet pressure P_1 : -80 kPa (gauge pressure)

Feed-water amount: 40 mL/min (linear velocity inside hollow fiber: 850 mm/sec)

Secondary-side pressure P_2 : -90 kPa (gauge pressure)

[0039] As a result of about 50 hours of operation, deposition of a white precipitate on the outer surface of the hollow fiber 11 was recognized.

[0040] Therefore, the pressure reduction device 25 was stopped and the valves 8, 31 were opened with the feed-water pump 2 operating, and this state was maintained for 15 minutes. As a result, a sufficient amount of condensate water was generated on the secondary side of the hollow fiber

11, and the precipitate dissolved in the condensate water. The solution flowed to the feed-water tank 1 through the pipe 7, and 15 minutes later, near disappearance of the precipitate was recognized.

[0041] While the present invention has been described in detail using specific aspects, it is obvious to those skilled in the art that various changes can be made without departing from the intention and the scope of the present invention.

This application is based on Japanese Patent Application No. 2020-157308 filed on September 18, 2020, which is entirely incorporated herein by citation.

Reference Signs List

[0042]

- 1 Feed-water tank
- 2 Feed-water pump
- 4, 21 Heat exchanger
- 8 Valve
- 10 Membrane module
- 11 Hollow fiber
- 12, 13 Potting material
- 14 Casing
- 15 Inflow chamber
- 16 Outflow chamber
- 17 Secondary side
- 25 Pressure reduction device

CLAIMS

[Claim 1]

A method for operating a membrane distillation apparatus that distills a liquid-being-processed using a membrane distillation apparatus comprising:

a membrane module of which an inside of a casing is divided into a primary side and a secondary side by a membrane;

a feed-water tank and a feed-water pump for supplying a liquid-being-processed to the primary side of the membrane module; and

a pressure reduction device that depressurizes the secondary side of the membrane module,

wherein a precipitate removal process is performed in which a gas is introduced to the secondary side of the membrane module to generate condensate water on the secondary side and a precipitate on the secondary side is removed by being dissolved in the condensate water, and

wherein the precipitate removal process is performed by stopping the pressure reduction device in a state where the feed-water pump is operating, and thus creating a positive pressure on the secondary side.

[Claim 2]

The method for operating a membrane distillation apparatus according to claim 1, wherein a pipe branches from a path connecting the secondary side and the pressure reduction device to each other and a valve is provided on this branch pipe, and a positive pressure is created on the secondary side by opening this valve.

[Claim 3]

The method for operating a membrane distillation apparatus according to claim 1 or 2, wherein the precipitate removal process is performed on a regular basis or when distillation performance has degraded below a predetermined value.

[Claim 4]

The method for operating a membrane distillation apparatus according to claim 3, wherein the distillation performance is obtained based on a pressure on the secondary side or generation speed of condensate water.

[Claim 5]

The method for operating a membrane distillation apparatus according to any one of claims 1 to 4, wherein a communication part that allows communication between the secondary side of the membrane module and the feed-water tank is provided, and in the precipitate removal process, a solution in which the precipitate has dissolved flows into the feed-water tank through the communication part.