

DESCRIPTION

Title of Invention

MEMBRANE DISTILLATION DEVICE AND METHOD FOR
OPERATING SAME

Technical Field

[0001] The present invention relates to a membrane distillation device and a method for operating the same.

Background Art

[0002] A membrane distillation device 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 through 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 device, a membrane distillation device has an advantage in that the evaporation surface area is increased and the size of the device is reduced owing to the use of a membrane.

[0003] One example of conventional examples of membrane distillation devices 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 and vaporizes to become steam. The steam is discharged from the secondary side 17 to the pipe 20 by suction,

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, 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.

[0011] Pressure sensors P1, P2, P3 are installed so as to detect pressures inside the gas phase part 1a of the feed-water tank 1, the pipe 20, and the pipe 5.

Citation List

Patent Literature

[0012] PTL1: JPH 03-52627 A

[0013] In the above-described membrane distillation device, a negative pressure of the pressure reduction device 25 is transmitted from the secondary side 17 to the inside of the feed-water tank 1 through the pipe 7. Accordingly, the pressure inside the pipe 3 on the suction side of the feed-water pump 2 decreases, which may result in cavitation. To prevent such cavitation, a water head (water level) H inside the feed-water tank 1 needs to be raised, and then the feed-water tank 1 needs to be designed to have an increased height.

Summary of Invention

Technical Problem

[0014] An object of the present invention is to provide a membrane distillation device in which cavitation of a feed-water pump can be prevented without the feed-water tank being increased in height, and a method for operating this membrane distillation device.

Solution to Problem

[0015] A membrane distillation device of the present invention is a membrane distillation device having: a membrane module having a casing, an inside of the casing being divided into a primary side and a secondary side by a hydrophobic membrane; liquid-being-processed circulation and supply means that has a feed-water tank and a feed-water pump and serves to circulate and supply a liquid-being-processed to the primary side of the membrane module; a pressure reduction device that depressurizes the secondary side of the membrane module; and communication means that allows communication between the secondary side of the membrane module and a gas phase part of the feed-water tank, wherein a differential pressure between the gas phase part of the feed-water tank and the secondary side of the membrane module is 20 to 90 kPa.

[0016] In one aspect of the present invention, the communication means has differential pressure adjustment means for adjusting the differential pressure.

[0017] In one aspect of the present invention, the communication means having the differential pressure adjustment means is a pipe provided with a valve.

[0018] In one aspect of the present invention, the communication means is a pipe, and an inside diameter of the pipe is equal to or smaller than a quarter of an inside diameter of a steam pipe that is connected to the secondary side so as to suction and discharge steam by depressurizing the secondary side.

[0019] A method for operating a membrane distillation device of the present invention is a method for operating this membrane distillation device of the present invention, wherein a degree of opening of the valve is adjusted such that the differential pressure becomes 20 to 90 kPa.

Advantageous Effects of Invention

[0020] According to the present invention, adjusting the differential pressure between the secondary side and the gas phase part inside the feed-water tank to 20 to 90 kPa can secure a pressure on the suction side of a feed-water pump and thereby prevent cavitation.

Brief Description of Drawings

[0021] [Fig. 1] Fig. 1 is a configuration diagram of a membrane distillation device according to an embodiment.

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

[Fig. 3] Fig. 3 is a graph showing a relationship between a boiling point and a gauge pressure.

Description of Embodiments

[0022] Fig. 1 shows the configuration of a membrane distillation device according to an embodiment.

[0023] In this embodiment, a valve 8 for adjusting a differential pressure between a secondary side 17 of a membrane module 10 and a gas phase part 1a of a feed-water tank 1 is provided on a pipe 7 that allows communication between the secondary side 17 and the gas phase part 1a. The differential pressure between the secondary side 17 and

the gas phase part 1a may be adjusted by reducing the diameter of the pipe 7 instead of providing the valve 8, or by both reducing the diameter of the pipe 7 and providing the valve 8. Alternatively, the diameter of part of the pipe 7 may be reduced.

[0024] In the case of reducing the diameter of the pipe 7, the inside diameter of the pipe 7 should be equal to or smaller than a quarter (25%) of the inside diameter of the steam pipe 20, preferably 0.5 to 25% and particularly preferably 1 to 20% thereof. The pipe 7 is installed for the purpose of discharging a condensate or a precipitate that remains in a secondary side of the membrane module 10 before restart after shutdown of the membrane distillation device or during operation thereof, and a small inside diameter of the pipe 7 hardly affects the operation management of the membrane distillation device. On the other hand, when the inside diameter of the pipe 7 is large, stably adjusting the differential pressure to a predetermined value involves frequently opening and closing the valve 8, thus making the operation management difficult. When the valve 8 is closed, a condensate or a precipitate may remain in the secondary side of the membrane module 10, which poses a problem for stable operation of the membrane distillation device. It is preferable that the length of the pipe 7 is 0.2 to 4 m, particularly 0.5 to 2 m.

[0025] In the present invention, the degree of opening of the valve 8 (or the pipe diameter of the pipe 7) is set such that a difference $P_1 - P_2$ between a pressure P_1 in the gas phase part 1a of the feed-water tank detected by the pressure sensor P1 and the pressure P_2 on the secondary side 17 inside the casing 14 detected by the pressure sensor P2 becomes 20 to 90 kPa, preferably 20 to 70 kPa.

[0026] Thus, an excessive pressure decrease in the gas phase part 1a is prevented, so that cavitation on the suction side of the feed-water pump 2 can be prevented without the water head H of the feed-water tank 1 being raised.

[0027] It is preferable that a gauge pressure (a difference from an atmospheric pressure) of P_2 is about -100 to -40 kPa, particularly about -100 to -60 kPa.

[0028] The configuration of Fig. 1 is otherwise the same as that of Fig. 2, and the same reference sign denotes the same part.

[0029] A hydrophobic hollow fiber membrane is suitable as the hollow fibers 11. It is preferable that the inside diameter (diameter) of the hollow fiber is 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.

[0030] While hollow fibers are used in the above description, a hydrophobic flat membrane may instead be used.

[0031] 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 speed (linear speed) 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.

[0032] The above-described suitable conditions represent suitable examples and the present invention is not limited to the above-described conditions.

Example

[0033] [Comparative Example 1]

<Experimental Device and Conditions>

The device shown in Fig. 2 was operated under the following conditions, and a value of the pressure P_1 inside the feed-water tank and a value of the pressure P_2 on the secondary side of the membrane were measured. The test conditions are as follows.

[0034] 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_3 : -80 kPa (gauge pressure)

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

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

Inside diameter of steam pipe 20: 6 mm

Inside diameter of pipe 7: 6 mm

Length of pipe 7: 1 m

Liquid level H: 50 cm

[0035] <Result and Review>

At the same time as the secondary side of the membrane was depressurized, the pressure inside the feed-water tank 1 also decreased rapidly. Cavitation occurred at a stage where the feed-water tank pressure P_1 reached -70 kPa, and boiling started at a stage where it reached -80 kPa.

[0036] Fig. 3 shows a relationship between the pressure and the boiling point of this aqueous solution. From this relationship, it is considered that when the feed water temperature is 60°C , boiling occurs at -80 kPa.

[0037] In this Comparative Example 1, since cavitation occurred at the stage of -70 kPa, it is considered that preventing cavitation even at a stage where -90 kPa is reached requires a liquid level as high as at least 3 m.

[0038] [Example 1]

<Experimental Device and Conditions>

The membrane distillation device shown in Fig. 1 was used that had the same configuration as in Comparative Example 1 except that the pipe 7 had an inside diameter of 0.75 mm and that the valve 8 of which the degree of opening was adjustable was provided on the pipe 7. (The inside diameter of the pipe 7 was 12.5% of the inside diameter of the steam pipe 20). A distillation test was conducted under the same conditions as in Comparative Example 1 except that the degree of

opening of the valve 8 was adjusted such that the membrane module inlet pressure P_3 became -40 kPa (gauge pressure).

[0039] <Result and Review>

In this example, the degree of opening of the valve 8 was adjusted such that the membrane module inlet pressure P_3 became -40 kPa, so that $P_1 - P_2$ became 50 kPa and operation was possible without the pump 2 experiencing cavitation.

[0040] Moreover, since the inside diameter of the pipe 7 in Example 1 is sufficiently small compared with that in Comparative Example 1, the speed with which the inside of the feed-water tank 1 was depressurized was low compared with that on the secondary side 17, which made the pressure adjustment easy.

[0041] Thus, it was confirmed that adjusting the feed-water tank pressure to 20 to 90 kPa allows operation without causing cavitation even with a liquid level of 50 cm.

[0042] 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. 2020-134727 filed on August 7, 2020, which is entirely incorporated herein by citation.

Reference Signs List

[0043] 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 membrane distillation device comprising:

a membrane module having a casing, an inside of the casing being divided into a primary side and a secondary side by a hydrophobic membrane;

liquid-being-processed circulation and supply means that has a feed-water tank and a feed-water pump and serves to circulate and supply a liquid-being-processed to the primary side of the membrane module;

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

communication means that allows communication between the secondary side of the membrane module and a gas phase part of the feed-water tank,

wherein the communication means is configured such that a differential pressure between the gas phase part of the feed-water tank and the secondary side of the membrane module is 20 to 90 kPa.

[Claim 2]

The membrane distillation device according to claim 1, wherein the communication means is a pipe, and an inside diameter of the pipe is equal to or smaller than a quarter of an inside diameter of a steam pipe that is connected to the secondary side so as to suction and discharge steam towards the pressure reduction device thereby depressurizing the secondary side.

[Claim 3]

A membrane distillation device comprising:

a membrane module having a casing, an inside of the casing being divided into a primary side and a secondary side by a hydrophobic membrane;

liquid-being-processed circulation and supply means that has a feed-water tank and a feed-water pump and serves to circulate and supply a liquid-being-processed to the primary side of the membrane module;

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

communication means that allows communication between the secondary side of the membrane module and a gas phase part of the feed-water tank,

wherein the communication means comprises differential pressure adjustment means for adjusting a differential pressure between the gas phase part of the feed-water tank and the secondary side of the membrane module to 20 to 90 kPa.

[Claim 4]

The membrane distillation device according to claim 3, wherein the communication means comprising the differential pressure adjustment means is a pipe provided with a valve.

[Claim 5]

A method for operating the membrane distillation device of claim 4, wherein a degree of opening of the valve is adjusted such that the differential pressure becomes 20 to 90 kPa.