

DESCRIPTION

Title of Invention

DISTILLATION APPARATUS

Technical Field

[0001] The present invention relates to a distillation apparatus, and particularly to a distillation apparatus configured to heat a liquid to be distilled using a heat exchanger. In particular, the present invention relates to a distillation apparatus suitably used for the purpose of separating a volatile acidic gas from an aqueous solution of the volatile acidic gas.

Background Art

[0002] One example of distillation apparatuses configured to heat a liquid to be distilled using a heat exchanger is shown in Fig. 2.

[0003] Raw water (a liquid to be distilled) having been introduced into a feed-water tank 1 through a feed line (not shown) is sent from the feed-water tank 1 to a heat exchanger 4 through a pump 2 and a pipe 3 and heated in the heat exchanger 4, and is 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 18.

[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 9b through a pipe (steam pipe) 6, a cooled-side passage of a heat exchanger (cooler) 7, a pipe 8, a condensate water tank 9, and a pipe 9a, and the secondary side 17 is depressurized by the pressure reduction device 9b.

[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 6, and is cooled in the heat exchanger 7 to form condensate water. The condensate water is stored in the condensate water tank 9. The condensate water accumulated inside the condensate water tank 9 is taken out of a lower part of the condensate water tank 9 through a take-out line (not shown). An upper part of the condensate water tank 9 is connected to the pressure reduction device 9b through the pipe 9a.

[0010] High-temperature water from a heat pump system 19 is passed through a heat source fluid passage 4a of the heat exchanger 4, and low-temperature water from the heat pump system 19 is passed through a heat source fluid passage 7a of the heat exchanger 7.

[0011] A heat pump 20 of the heat pump system 19 has a commonly known configuration and is configured such that a heat medium from an evaporator 21, such as a substitute for chlorofluorocarbon, is heated to a high temperature by adiabatic compression in a compressor 22 and introduced into a condenser 23, and that the heat medium from the condenser 23 is introduced into the evaporator 21 through an expansion valve 24 and undergoes adiabatic expansion so as to be reduced in temperature.

[0012] Water inside a warm-water tank 30 is passed to a heat transfer tube 23a provided inside the condenser 23 through a pump 31 and a pipe 32, and is heated by exchanging heat with a high-temperature heat medium. The water having been heated and turned into high-temperature water is returned to the warm-water tank 30 through a pipe 33.

[0013] This high-temperature water inside the warm-water tank 30 is passed to the heat source fluid passage 4a of the heat exchanger 4 through a pump 34 and a pipe 35, and heats the raw water by exchanging heat therewith. The water having been reduced in temperature by exchanging heat with the raw water is returned to the warm-water tank 30 through a pipe 36.

[0014] Water inside a cold-water tank 40 is passed to a heat transfer tube 21a provided inside the evaporator 21 through a pump 41 and a pipe 42, and is cooled by exchanging heat with a low-temperature heat

medium. The water having been cooled and turned into low-temperature water is returned to the cold-water tank 40 through a pipe 43.

[0015] This low-temperature water inside the tank 40 is passed to the heat source fluid passage 7a of the heat exchanger 7 through a pump 44 and a pipe 45, and cools steam by exchanging heat therewith. The water having been increased in temperature by exchanging heat with the steam is returned to the cold-water tank 40 through a pipe 46.

Citation List

Patent Literature

[0016] PTL1: JPH 03-52627 A

PTL2: JP 2019-158173 A

Summary of Invention

Technical Problem

[0017] In the case where water to be distilled (raw water) is an aqueous solution of a volatile acidic gas, such as hydrochloric acid or hydrofluoric acid, and this volatile acidic gas is to be collected through membrane permeation in a membrane module, the heat exchanger 7 comes into contact with highly concentrated corrosive acid. For this reason, a heat exchanger made of synthetic resin (e.g., fluorine resin) excellent in corrosion resistance is used as the heat exchanger 7. However, since synthetic resin has low heat conductivity, it is necessary to use a large-sized heat exchanger with a large heat exchange area as the heat exchanger 7. In addition, a heat exchanger made of synthetic resin is costly.

[0018] An object of the present invention is to provide a distillation apparatus that allows a heat exchanger made of highly heat-conductive metal to be used as a heat exchanger even when raw water contains a volatile acidic gas.

Solution to Problem

[0019] The gist of the present invention is as follows.

[0020] [1] A distillation apparatus having: a distiller into which a liquid to be distilled is introduced; an aspirator or an ejector that suctions steam generated inside the distiller; a tank into which water flowing out of the aspirator or the ejector flows; a path through which water inside the tank is sent to a working fluid inflow part of the aspirator or the ejector; and a heat exchanger for cooling provided in the path.

[0021] [2] The distillation apparatus of [1], including water quality measurement means for water inside the tank or water circulating between the tank and the aspirator or the ejector, and discharge means for discharging part of the water when a water quality measured by the water quality measurement means has exceeded a specified value.

[0022] [3] The distillation apparatus of [2], wherein the water is a solution of acid and the water quality is electrical conductivity or specific resistance.

[0023] [4] The distillation apparatus of any one of [1] to [3], wherein the heat exchanger is made of highly corrosion-resistant metal.

[0024] [5] The distillation apparatus of [4], wherein the highly corrosion-resistant metal is titanium, titanium alloy, or hastelloy.

[0025] [6] The distillation apparatus of any one of [1] to [5], wherein the distiller is a membrane distiller.

[0026] [7] The distillation apparatus of any one of [1] to [6], having means for replenishing the tank with water.

Advantageous Effects of Invention

[0027] In the distillation apparatus of the present invention, steam generated inside the distiller is suctioned by the aspirator or the ejector. As the steam dissolves in water flowing out of the aspirator or the ejector, this outflow water has a low acid concentration even when the steam contains an acidic gas. Thus, even when a heat exchanger provided in a path through which this outflow water is sent from the tank to the aspirator or the ejector as a working fluid is made of metal, corrosion is prevented for a long period of time. This metal heat exchanger has favorable heat exchange characteristics and is significantly small in size compared with a synthetic resin heat exchanger.

[0028] In one aspect of the present invention, when the acid concentration of water as a working fluid has become higher than a predetermined value, part of the water is discharged and fresh water is added.

Brief Description of Drawings

[0029] [Fig. 1] Fig. 1 is a configuration diagram of a distillation apparatus according to an embodiment.

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

Description of Embodiments

[0030] An embodiment will be described below with reference to Fig. 1.

[0031] Raw water (a liquid to be distilled) having been introduced into a feed-water tank 1 through a feed line 1F is sent from the feed-water tank 1 to a heat exchanger 4 through a pump 2 and a pipe 3 and heated in the heat exchanger 4, and is then sent to a membrane module 10 through a pipe 5.

[0032] 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.

[0033] 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.

[0034] 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 18.

[0035] 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.

[0036] The secondary side 17 communicates with a suction part 50a of an aspirator 50 through a pipe (steam pipe) 6, and the secondary side 17 is depressurized by the aspirator 50.

[0037] While the liquid-being-processed is flowing inside the hollow fibers 17 (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 aspirator 50 through the pipe 6, and an absorbing liquid having absorbed the steam is generated.

[0038] An absorbing liquid inside an absorbing liquid tank 90 is introduced into a working fluid inflow opening 50b of the aspirator 50 through a pump 51, a pipe 52, a fluid passage 71 for a fluid to be cooled in a heat exchanger 70 made of highly corrosion-resistant metal, and a pipe 54. Water flowing out of an outflow opening 50c of the aspirator 50 returns to the absorbing liquid tank 90 through a pipe 55.

[0039] A pipe 57 branches from the pipe 52, and a valve 58 is provided on the pipe 57. An electrical conductivity meter 59 is provided in the absorbing liquid tank 90.

[0040] High-temperature water from a warm-water tank 30 of a heat pump system 19 is circulated passed to a heat source fluid passage 4a of the heat exchanger 4 through pipes 35, 36, and low-temperature water from a cold-water tank 40 of the heat pump system 19 is circulated and passed to a heat source fluid passage 72 of the heat exchanger 70 through pipes 45, 46.

[0041] A heat pump 20 of the heat pump system 19 is configured such that a heat medium from an evaporator 21, such as a substitute for chlorofluorocarbon, is heated to a high temperature by adiabatic compression in a compressor 22 and introduced into a condenser 23, and that the heat medium from the condenser 23 is introduced into the evaporator 21 through an expansion valve 24 and undergoes adiabatic expansion so as to be reduced in temperature.

[0042] Water inside the warm-water tank 30 is passed to a heat transfer tube 23a provided inside the condenser 23 through a pump 31

and a pipe 32, and is heated by exchanging heat with a high-temperature heat medium. The water having been heated and turned into high-temperature water is returned to the warm-water tank 30 through a pipe 33.

[0043] This high-temperature water inside the warm-water tank 30 is passed to the heat source fluid passage 4a of the heat exchanger 4 through a pump 34 and the pipe 35, and heats the raw water by exchanging heat therewith. The water having been reduced in temperature by exchanging heat with the raw water is returned to the warm-water tank 30 through the pipe 36.

[0044] Water inside the cold-water tank 40 is passed to a heat-transfer tube 21a provided inside the evaporator 21 through a pump 41 and a pipe 42, and is cooled by exchanging heat with a low-temperature heat medium. The water having been cooled and turned into low-temperature water is returned to the cold-water tank 40 through a pipe 43.

[0045] This low-temperature water inside the tank 40 is passed to the heat source fluid passage 72 of the heat exchanger 70 through a pump 44 and the pipe 45, and cools an absorbing liquid flowing through the fluid passage 71 by exchanging heat therewith. The water having been increased in temperature by exchanging heat with the absorbing liquid is returned to the cold-water tank 40 through the pipe 46.

[0046] Makeup water can be introduced into the absorbing liquid tank 90 through a makeup water line 56. Before the distillation apparatus starts operation, a predetermined amount of water is supplied to the absorbing liquid tank 90 through the makeup water line 56 and stored therein.

[0047] As described above, a terminal end of the pipe 6 for suctioning the secondary side 17 of the membrane module 10 is connected to the suction part 50a of the aspirator 50. The absorbing liquid inside the absorbing liquid tank 90 is circulated and passed to the aspirator 50 through the pump 51, the pipe 52, the metal heat exchanger 70, and the pipes 54, 55.

[0048] In the case where the water inside the feed-water tank 1 is an aqueous solution of a volatile acidic gas, such as hydrochloric acid or hydrofluoric acid, the acidic gas is suctioned from the secondary side 17 of the membrane module 10 to the pipe 6 due to a negative pressure resulting from operating the pump 51 and passing water through the aspirator 50. This acidic gas dissolves in water flowing through the aspirator 50, and flows into the absorbing liquid tank 90 as an acidic aqueous solution. Thus, as the operation continues, the acid concentration of the aqueous solution inside the absorbing liquid tank 90 rises gradually.

[0049] When electrical conductivity detected by the electrical conductivity meter 59 provided in the absorbing liquid tank 90 becomes higher than a predetermined value, the valve 58 is opened to discharge part of the absorbing liquid to an outside of the system through the pipe 57, and instead makeup water is supplied to the absorbing liquid tank 90 through the makeup water line 56.

[0050] In this embodiment, as described above, since the acidic aqueous solution inside the absorbing liquid tank 90 flows through the fluid passage 71 of the heat exchanger 70, a heat exchanger made of highly corrosion-resistant metal is used as the heat exchanger 70. When the electrical conductivity of the liquid inside the absorbing liquid tank 90

becomes higher than a predetermined value, the valve 58 is opened to discharge the highly concentrated acidic aqueous solution to the outside of the system through the pipe 57, and instead makeup water is introduced into the absorbing liquid tank 90 through the makeup water line 56. In this way, stable operation can be performed without the heat exchanger 70 corroding for a long period of time.

[0051] As the highly corrosion-resistant metal to compose the heat exchanger 70, highly corrosion-resistant metal or alloy such as titanium, titanium alloy, or hastelloy is suitable.

[0052] One example of the heat conductivity of each of titanium, hastelloy C, and polytetrafluoroethylene is shown below.

titanium: 21.9 w/(m·k)

hastelloy C: 11.1 w/(m·k)

polytetrafluoroethylene: 0.24 w/(m·k)

[0053] Thus, titanium and hastelloy have significantly higher heat conductivity compared with polytetrafluoroethylene, so that a small-sized heat exchanger with a small heat exchange area can be used as the heat exchanger 70.

[0054] While the aspirator is used in Fig. 1, an ejector may instead be used.

[0055] The above-described embodiment is one example of the present invention, and an embodiment of the present invention other than the above-described one may be adopted. For example, while an electrical conductivity meter is used in the above-described embodiment, various sensors that can detect acid concentration of water such as a specific resistance meter or a pH meter can be used.

[0056] While the electrical conductivity meter is provided in the absorbing liquid tank 90 in the above-described embodiment, it may be installed at another location, such as the pipe 52 or 54.

[0057] While a membrane distiller having the membrane module 10 and the feed-water tank 1 is installed in the above-described embodiment, other distillers may be used.

[0058] 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. 2020-157300 filed on September 18, 2020, which is entirely incorporated herein by citation.

Reference Signs List

- [0059] 1 Feed-water tank
4, 7, 70 Heat exchanger
9 Condensate water tank
19 Heat pump system
20 Heat pump
21 Evaporator
22 Compressor
23 Condenser
24 Expansion valve
30 Warm-water tank
40 Cold-water tank
50 Aspirator

- 59 Electrical conductivity meter
- 90 Absorbing liquid tank

CLAIMS

[Claim 1]

A distillation apparatus comprising:

a distiller into which a liquid to be distilled is introduced;

an aspirator or an ejector that suctions steam generated inside the distiller;

a tank into which water flowing out of the aspirator or the ejector flows;

a path through which water inside the tank is sent to a working fluid inflow part of the aspirator or the ejector; and

a heat exchanger for cooling provided in the path.

[Claim 2]

The distillation apparatus according to claim 1, comprising water quality measurement means for water inside the tank or water circulating between the tank and the aspirator or the ejector, and discharge means for discharging part of the water when a water quality measured by the water quality measurement means has exceeded a specified value.

[Claim 3]

The distillation apparatus according to claim 2, wherein the water is a solution of acid and the water quality is electrical conductivity or specific resistance.

[Claim 4]

The distillation apparatus according to any one of claims 1 to 3, wherein the heat exchanger is made of highly corrosion-resistant metal.

[Claim 5]

The distillation apparatus according to claim 4, wherein the highly corrosion-resistant metal is titanium, titanium alloy, or hastelloy.

[Claim 6]

The distillation apparatus according to any one of claims 1 to 5, wherein the distiller is a membrane distiller.

[Claim 7]

The distillation apparatus according to any one of claims 1 to 6, comprising means for replenishing the tank with water.