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(71) Applicant: **Taiyo Nippon Sanso Corporation**
Tokyo 142-8558 (JP)

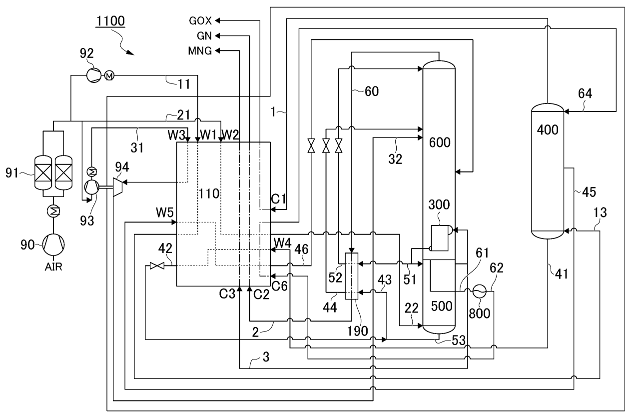
(72) Inventor: **EGOSHI, Nobuaki**
Tokyo 142-8558 (JP)

(74) Representative: **HGF**
HGF Limited
1 City Walk
Leeds LS11 9DX (GB)

(54) HEAT EXCHANGER

(57) An object of the present invention is to provide a heat exchanger that can be used in an air separation unit including a low-pressure column, a high-pressure column, and a mixing column, and that can suppress increases in equipment costs. The present invention provides a heat exchanger used in an air separation unit (1100) including a low-pressure column (600), a high-pressure column (500), and a mixing column (400), wherein the heat exchanger is composed of plates and fins, and wherein a warm gas which is at least a part (at least one of W1, W2, W3) of a feed air and at least one warm liquid (at least one of W4 and W5) which is led out from the mixing column (400) are cooled by at least one cold gas (at least one of C2 and C3) which is led out from the low-pressure column (600) and a cold gas (C1) which is led out from the mixing column (400), and a cold liquid (C6) which is led out from the low-pressure column (600) through a pressure boosting pump (800) and supplied to the mixing column (400) is heated.

FIG. 1



EP 4 560 235 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a heat exchanger used in an air separation unit including a low-pressure column, a high-pressure column, and a mixing column, for cooling feed air and heating liquid supplied from the low-pressure column to the mixing column.

BACKGROUND ART

[0002] Some air separation unit include a mixing column in addition to a low-pressure column and a high-pressure column. In air separation unit that generally use a mixing column, low-purity oxygen with an oxygen concentration of about 97% or less is produced as product oxygen gas. In the mixing column, liquid oxygen from the top of the column is directly contacted with gaseous air from the bottom of the column to change the liquid oxygen into low-purity oxygen gas, and the low-purity oxygen gas is taken out from the top of the column as product oxygen gas.

[0003] The liquid oxygen supplied to the top of the mixing column is obtained by pressurizing the liquid oxygen at the bottom of the low-pressure column by a pump, and the temperature thereof is lower than a boiling point thereof at the increased pressure. Therefore, if the liquid oxygen is supplied to the mixing column in this state, the flow rate of the product oxygen gas from the top of the mixing column will decrease and the flow rate of liquid air from the bottom of the column will increase, causing a decrease in the oxygen yield of the air separation unit.

[0004] Accordingly, a process has been disclosed in which in a heater for heating the liquid oxygen pressurized by the pump, the liquid oxygen at the bottom of the low-pressure column is heat exchanged with a side-cut liquid and a bottom liquid from the mixing column, and then in the auxiliary heat exchanger, it is further heat exchanged with gas air to heat it up to near saturation temperature and then supplied into the mixing column. (see, for example, Patent Document 1).

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0005] Patent Document 1: Japanese Unexamined Patent Application, First Publication No. 2004-28572

SUMMARY OF INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0006] However, in order to heat the liquid oxygen pressurized by the pump, it is necessary to install a heater and an auxiliary heat exchanger, as well as pipes to these devices. Furthermore, a cold box must be large to accommodate these devices and pipes, which increases the cost of the equipment.

[0007] The present invention has been made to solve such problems, and has an object to provide a heat exchanger that can be used in an air separation unit including a low-pressure column, a high-pressure column, and a mixing column, and that can suppress increases in equipment costs.

MEANS FOR SOLVING THE PROBLEM

[0008]

(1) The heat exchanger of the present invention is a heat exchanger used in an air separation unit including a low-pressure column, a high-pressure column, and a mixing column,

> wherein the heat exchanger is composed of plates and fins, and
> wherein a warm gas which is at least a part of a feed air and at least one warm liquid which is led out from the mixing column are cooled by at least one cold gas which is led out from the low-pressure column and a cold gas which is led out from the mixing column, and a cold liquid which is led out from the low-pressure column through a pressure boosting pump and supplied to the mixing column is heated.

(2) The heat exchanger according to (1), wherein at least one warm liquid which is led out from the high-pressure column is cooled.

(3) The heat exchanger according to (1) or (2),

> wherein the heat exchanger further includes a cold liquid passage through which the cold liquid flows, a cold gas passage through which the cold gas flows, a warm liquid passage through which the warm liquid flows, and a warm gas passage through which the warm gas flows, and wherein the warm gas passage is arranged so that the warm gas flows in a counter-flow to the cold liquid and the cold gas, and the warm liquid passage is arranged so that the warm liquid flows in a cross-flow to the cold liquid and the cold gas.

EFFECTS OF THE INVENTION

[0009] According to the present invention, the number of devices can be reduced and the cold box can be made compact, thereby reducing equipment costs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

[FIG. 1] FIG. 1 is an explanatory diagram of an air separation unit equipped with a heat exchanger according to the first embodiment.
[FIG. 2] FIG. 2 is an explanatory diagram of the internal structure of the heat exchanger according to the first embodiment.
[FIG. 3] FIG. 3 is an explanatory diagram of an air separation unit equipped with a heat exchanger according to the second embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First embodiment]

[0011] FIG. 1 shows an example of an air separation unit using the heat exchanger according to the present embodiment.
[0012] The heat exchanger 110 according to the present embodiment is a heat exchanger used in an air separation unit 1100 including a low-pressure column 600, a high-pressure column 500, and a mixing column 400, as shown in FIG. 1.
[0013] The heat exchanger 110 of the present embodiment is a heat exchanger that is composed of plates and fins, and that a warm gas (at least one of W1, W2, and W3) which is at least a part of the feed air and at least one warm liquid (at least one of W4 and W5) which is led out from the mixing column 400 are cooled by at least one cold gas (at least one of C2 and C3) which is led out from the low-pressure column 600 and cold gas (C1) which is led out from the mixing column 400, and a cold liquid (C6) which is led out from the low-pressure column 600 through a pressure boosting pump 800 and supplied to the mixing column 400 is heated.
[0014] First, the overall configuration of the air separation unit 1100 including the heat exchanger 110 will be described with reference to FIG. 1, and then the internal structure of the heat exchanger 110 will be described.
[0015] In the present description, a fluid marked with "C" (the initial of "cold") is a cold fluid, and a fluid marked with "W" (the initial of "warm") is a warm fluid.

<Explanation of the configuration of the air separation unit>

[0016] The air separation unit 1100 includes a high-pressure column 500, a low-pressure column 600, a mixing column 400, a subcooler 190, and a heat exchanger 110.
[0017] A part (W2) of a feed air (W1, W2, W3) which has compressed by the compressor 90 and purified by the purifier 91 is supplied to the heat exchanger 110 through a pipe 21. In the heat exchanger 110, a part (W2) of the feed air is cooled by heat exchange with a product oxygen gas (C1) which is supplied from the top of the mixing column 400 through a line 1, a nitrogen gas (C2) which is supplied from the top of the low-pressure column 600 through the subcooler 190 and a line 2, a medium-pressure nitrogen gas (C3) which is supplied from the top of the high-pressure column 500 through a line 3, and a liquid oxygen (C6) which is supplied from the bottom of the low-pressure column 600 and pressurized by a pressure boosting pump 800, and then is supplied to the bottom of the high-pressure column 500 through a line 22.
[0018] Another part (W1) of the feed air is pressurized in a recompressor 92 and then supplied to the heat exchanger 110 through a line 11. In the heat exchanger 110, the other part (W1) of the feed air is cooled by heat exchange with cold fluids, namely the product oxygen gas (C1), the nitrogen gas (C2), the medium-pressure nitrogen gas (C3), and the liquid oxygen (C6), and then supplied to the bottom of the mixing column 400 through a line 13.
[0019] Furthermore, still another part (W3) of the feed air is pressurized by the recompressor 93 and then supplied to the heat exchanger 110 through a line 31. In the heat exchanger 110, the another part (W3) of the feed air is cooled by heat exchange between the product oxygen gas (C1), the nitrogen gas (C2), and the medium-pressure nitrogen gas (C3), which are cold fluids, and is further expanded by the expansion turbine 94, after which it is supplied to the low-pressure column 600 through a line 32.
[0020] A part (W2) of the feed air which has supplied to the high-pressure column 500 through a pipe 22 ascends while coming into gas-liquid contact with a reflux liquid descending inside the high-pressure column 500, and nitrogen, which is a low boiling point component, is concentrated, producing nitrogen gas at the top of the high-pressure column 500.
[0021] In addition, an oxygen-enriched liquid air, which is enriched in oxygen, which is a high boiling point component, is produced at the bottom of the high-pressure column 500 and is led out through a line 53.
[0022] The nitrogen gas which has produced in the high-pressure column is liquefied in the main condenser 300, and a part of it is supplied to the subcooler 190 where it is cooled through a line51, reduced in pressure through a line 52, and then supplied as reflux to the top of the low-pressure column 600.
[0023] In addition, an oxygen-enriched liquid air which is led out from the bottom of the high-pressure column 500 through a line 53, and supplied to the subcooler 190 through a line 43 together with a liquid air which has led out from the mixing column 400 through a line 41, the heat exchanger 110, and a line 42, cooled, decompressed through a line 44, and then supplied as reflux to the low-pressure column 600.
[0024] The cooling source for these liquids in the subcooler 190 is a nitrogen gas supplied through a line 60

from the top of the low-pressure column 600.

[0025] The reflux liquid which has supplied to the low-pressure column 600 descends due to gas-liquid contact with the ascending gas in the low-pressure column 600, and oxygen, which is a high boiling point component, is concentrated as it flows down, producing liquid oxygen at the bottom of the low-pressure column 600. Meanwhile, nitrogen, which is a low boiling point component, is concentrated in the ascending gas as it rises, producing nitrogen gas at the top of the low-pressure column 600.

[0026] The liquid oxygen (C6) which has produced at the bottom of the low-pressure column 600 is led out through a line 61, pressurized by a pressure boosting pump 800, and then introduced to the heat exchanger 110 through a line 62. In the heat exchanger 110, the pressurized liquid oxygen (C6) exchanges heat with the liquid which is side-cut from the mixing column 400 (hereinafter referred to as "side-cut liquid") through a line 45, the bottom liquid (W4) from a line 41, and a part of the feed air (W1, W2), and is heated. After that, it is led out through a line 64 and supplied to the top of the mixing column 400.

[0027] In the mixing column 400, the liquid oxygen supplied and the gaseous air introduced through a line 13 come into direct contact with each other, and a product oxygen (C1) with low-purity is produced and led out from the top of the mixing column 400 through a line 1.

<Explanation of heat exchanger>

[0028] The heat exchanger 110 can be a plate-fin heat exchanger in which layers composed of plates and fins are stacked. FIG. 2 shows each layer of the heat exchanger 110 separated into flow paths.

[0029] As shown in FIG. 2, the heat exchanger 110 has three warm fluid passages A1 to A3 and three cold fluid passages B1 to B3.

[0030] The warm fluid passage A1 has a warm gas passage a1 through which a warm gas W1 flows between the warm end and the cold end.

[0031] The warm fluid passage A2 is divided into two flow areas between the warm end and the cold end, with the warm end section having a warm gas passage a2 through which a warm gas W2 flows, and the cold end section having a warm liquid passage a4 through which a warm liquid W4 flows.

[0032] The warm fluid passage A3 is divided into two flow areas between the warm end and the cold end, with the warm end section having a warm gas passage a3 through which a warm gas W3 flows, and the cold end section having a warm liquid passage a5 through which a warm liquid W5 flows.

[0033] Furthermore, the cold fluid passage B1 is divided into two flow areas between the warm end and the cold end, with the warm end section having a cold gas passage b1 through which a cold gas C1 flows, and the cold end section having a cold liquid passage b6 through which a cold liquid C6 flows.

[0034] The cold fluid passage B2 has a cold gas passage b2 through which a cold gas C2 flows between the warm end and the cold end.

[0035] The cold fluid passage B3 has a cold gas passage b3 through which a cold gas C3 flows between the warm end and the cold end.

[0036] The warm gas passages a1, a2, a3 (see FIGS. 2(a), (b), and (c)), through which the feed air (W1, W2, W3), which is a warm gas, flows, are arranged so that the warm gases flow in a counter-flow to the cold gases in the cold gas passages b1, b2, b3 (see FIGS. 2(d),(e), and (f)), through which the product oxygen gas (C1), the nitrogen gas (C2), and the medium-pressure nitrogen gas (C3), which are the cold gases, flow, and to the cold liquid passage b6 (see FIG. 2(d)), through which the liquid oxygen (C6), which is a cold liquid, flows.

[0037] In addition, the warm liquid passages a4, a5 (see FIGS. 2(b) and (c)), through which the bottom liquid (W4) and side-cut liquid (W5), which are warm liquids led out from the mixing column 400 through the lines 41 and 45, flow, are arranged so that the warm liquids flow in a cross-flow to the cold gases in the cold gas passages b2, b3 (see FIGS. 2(e) and 2(f)), through which the nitrogen gas (C2) and the medium-pressure nitrogen gas (C3), which are the cold gases, flow, and to the cold liquid passage b6 (see FIG. 2(d)), through which the liquid oxygen (C6), which is a cold liquid, flows.

[0038] The passage for the bottom liquid (W4) (see FIG. 2 (b)) consists of five paths, and the passage for the side-cut liquid (W5) (see FIG. 2 (c)) consists of seven paths.

[0039] As shown in FIG. 2 (b), the bottom liquid (W4) of the mixing column 400 which is led out through the line 41 flows into the inlet (in) of the passage and flows in a cross-flow to the nitrogen gas (C2), the medium-pressure nitrogen gas (C3), and the liquid oxygen (C6), then flows in the opposite direction through the path located in a direction of the cold end, passing through a total of five paths before being led out from the outlet (out).

[0040] As shown in FIG. 2 (c), the side-cut liquid (W5) of the mixing column 400 led out through line 45 flows in from the inlet (in) of the passage and flows crosswise against the nitrogen gas (C2), the medium-pressure nitrogen gas (C3) and the liquid oxygen (C6), then flows in the opposite direction through the path located in a direction of the cold end, passing through a total of seven paths before being led out from the outlet (out). The inlets (in) of the bottom liquid (W4) and the side-cut liquid (W5) are provided closer to the warm end than the respective outlets (out), and are connected to the mixing column 400 by the lines 41 and 45.

[0041] In the present embodiment, as shown in FIGS. 2(b) and (c), the passages for the bottom liquid (W4) and the side-cut liquid (W5) are separated and arranged below the passages for the feed air (W2, W3), but they may also be arranged below the passages for the feed air (W1) and the product oxygen gas (C1).

[0042] In addition, the outlet (out) for the liquid oxygen (C6) connected to the top of the mixing column 400 and the inlet (in) for the side-cut liquid (W5) connected to the side-cut of the mixing column 400 are provided closer to the warm end than the outlet (out) for the feed air (W1, W2). The outlet (out) and inlet (in) are arranged so that the efficiency of heat exchange is high, taking into account the temperature of each fluid. This arrangement is possible because of the integrated heat exchanger 110. The heat exchanger 110 of the present embodiment is not a simple combination of an auxiliary heat exchanger, a heater that was provided separately in the conventional example, and a main heat exchanger. However, depending on the pressure of the mixing column 400, the outlet (out) for the liquid oxygen (C6) and the inlet (in) for the side-cut liquid (W5) may be placed toward the cold end.

[0043] As described above, since the heat exchanger 110 has the above functions, it is not necessary to install a heater or an auxiliary heat exchanger, which were separately provided in the conventional example. Furthermore, the cold box space for storing these devices can be reduced, and the equipment costs can be reduced.

[Second embodiment]

[0044] FIG. 3 shows an air separation unit 1200 using a heat exchanger 120 according to a second embodiment, which includes a high-pressure column 500, a low-pressure column 600, a mixing column 400, and a heat exchanger 120. In FIG. 3, the same parts as in FIG. 1 are denoted by the same reference numerals.

[0045] The heat exchanger 120 is the heat exchanger 110 shown in FIGS. 1 and 2, to which a passage for cooling liquid including an oxygen-enriched liquid air (hereinafter simply referred to as "oxygen-enriched liquid air") (W6) from the bottom of the high-pressure column 500 through the line 43, and a passage for cooling liquid nitrogen (W7) from the main condenser 300 through the line 51 are added.

[0046] The cooling sources for the oxygen-enriched liquid air (W6) and the liquid nitrogen (W7) are nitrogen gas (C2) which is introduced into the heat exchanger 120 from the top of the low-pressure column 600 through the line 60, and the medium-pressure nitrogen gas (C3) which is introduced into the heat exchanger 120 from the top of high-pressure column 500 through the line 3.

[0047] The oxygen-enriched liquid air (W6) and the liquid nitrogen (W7) cooled in the heat exchanger 120 are led out from the lines 44 and 52, and supplied to the low-pressure column 600 after being depressurized.

[0048] As described above, according to the heat exchanger 120, it is possible to eliminates the conventional heater, the auxiliary heat exchanger, and the subcooler 190 that were installed in the first embodiment, and further reduces the cold box space for storing these devices, thereby reducing equipment costs.

EXPLANATION OF SYMBOLS

[0049]

1100, 1200 air separation unit
800 pressure boosting pump
500 high-pressure column
600 low-pressure column
400 mixing column
300 main condenser
190 subcooler
110, 120 heat exchanger
90 compressor
91 purifier
92, 93 recompressor
94 expansion turbine
1, 2, 3, 11, 13, 21, 22, 31, 32, 41, 42, 43, 44, 45, 51, 52, 53, 60, 61, 62, 64 line
A1-A3 warm fluid passage
B1-B3 cold fluid passage
a1, a2, a3 warm gas passage
a4, a5 warm liquid passage
b1-b3 cold gas passage
b6 cold liquid passage
C1 product oxygen gas
C2 nitrogen gas
C3 medium-pressure nitrogen gas
C6 liquid oxygen
W1, W2, W3 feed air
W4 bottom liquid
W5 side-cut liquid
W6 oxygen-enriched liquid air
W7 liquid nitrogen

Claims

1. A heat exchanger used in an air separation unit including a low-pressure column, a high-pressure column, and a mixing column,

wherein the heat exchanger is composed of plates and fins, and
wherein a warm gas which is at least a part of a feed air and at least one warm liquid which is led out from the mixing column are cooled by at least one cold gas which is led out from the low-pressure column and a cold gas which is led out from the mixing column, and a cold liquid which is led out from the low-pressure column through a pressure boosting pump and supplied to the mixing column is heated.

2. The heat exchanger according to Claim 1, wherein at least one warm liquid which is led out from the high-pressure column is cooled.

3. The heat exchanger according to Claim 1 or 2,

wherein the heat exchanger further includes a cold liquid passage through which the cold liquid flows, a cold gas passage through which the cold gas flows, a warm liquid passage through which the warm liquid flows, and a warm gas passage through which the warm gas flows, and wherein the warm gas passage is arranged so that the warm gas flows in a counter-flow to the cold liquid and the cold gas, and the warm liquid passage is arranged so that the warm liquid flows in a cross-flow to the cold liquid and the cold gas.

FIG. 1

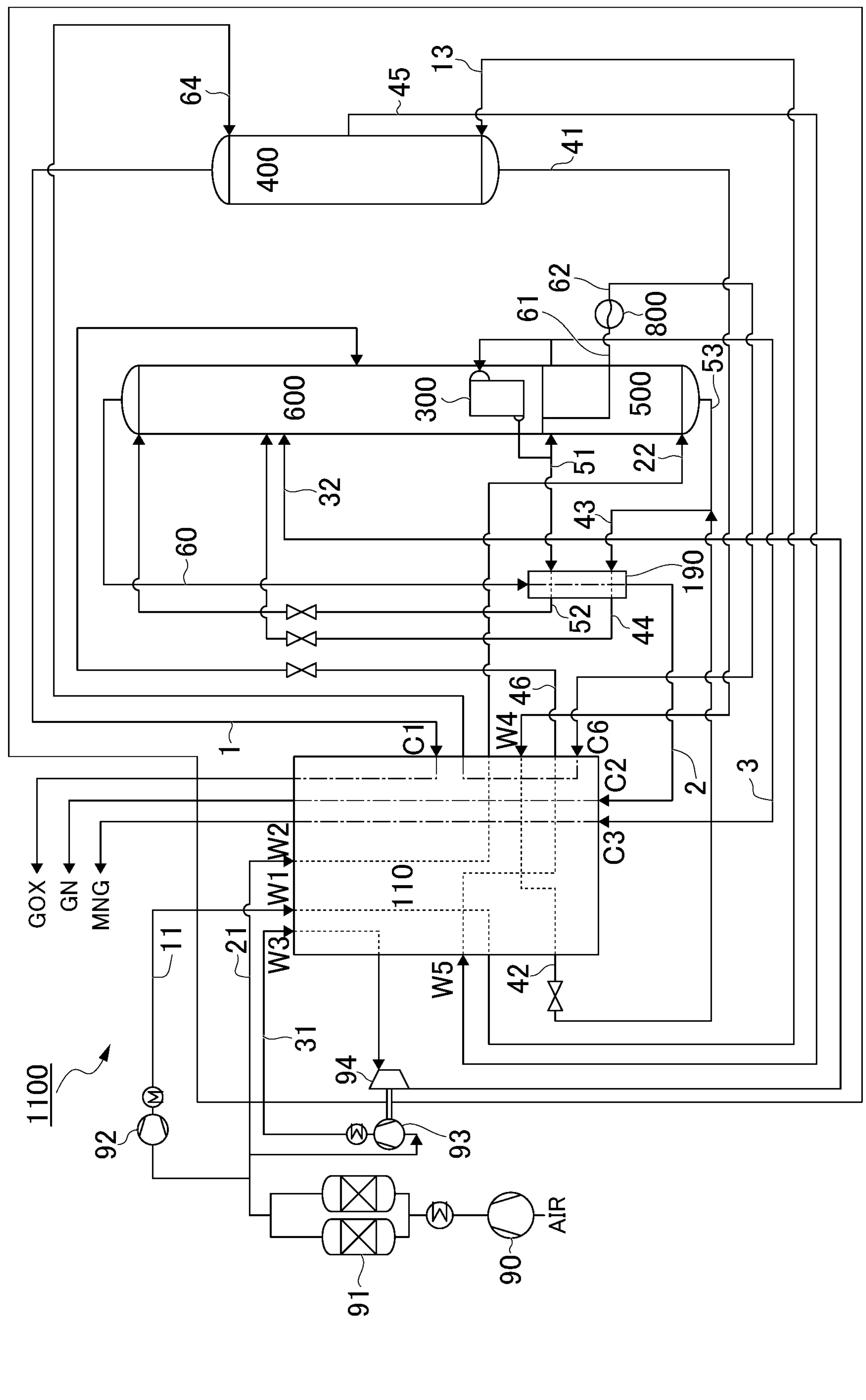

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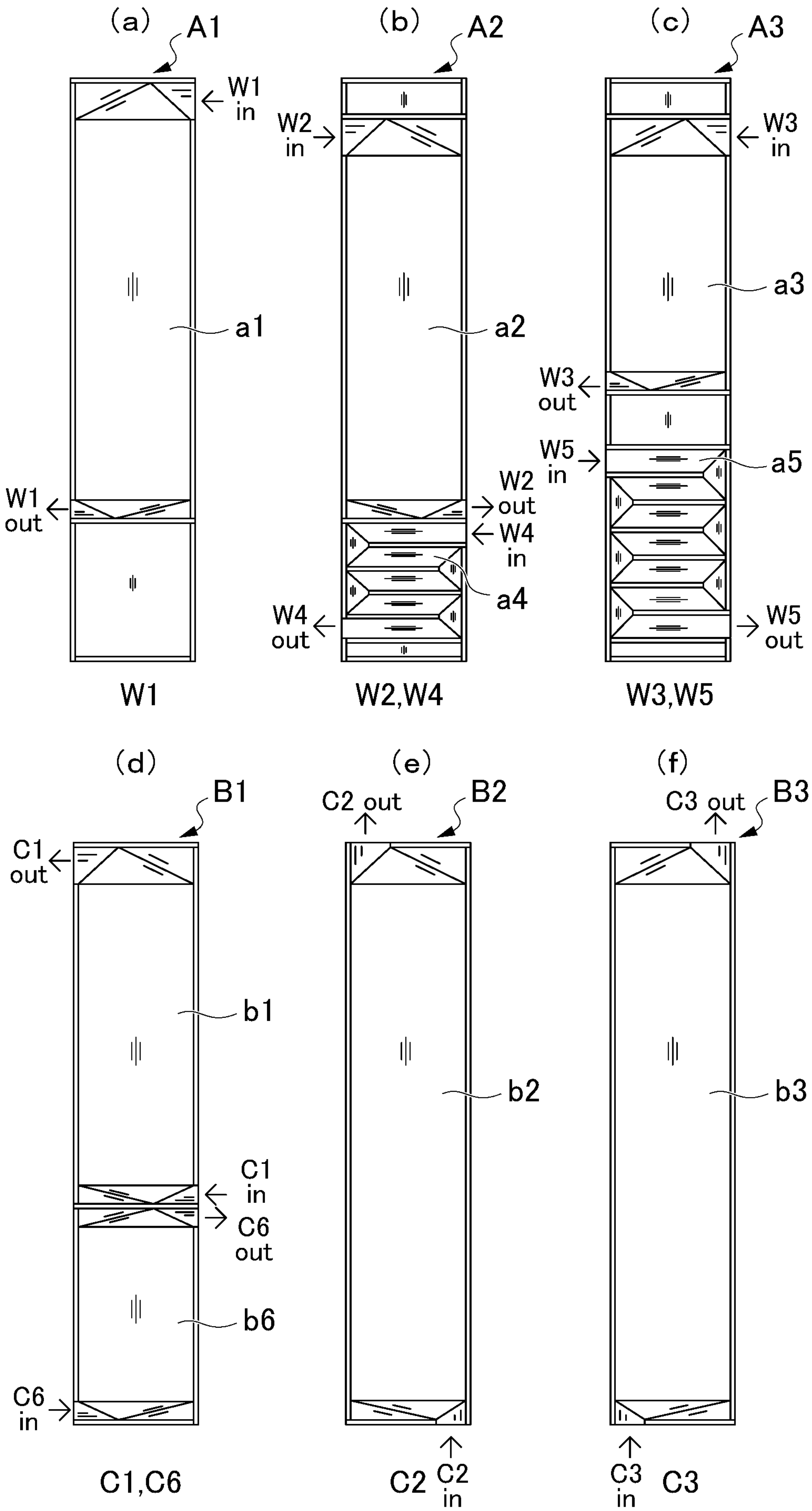
FIG. 2


(a)
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W1 in
a1
W1 out
W1
(b)
A2
W2 in
a2
W2 out
W4 in
a4
W4 out
W2,W4
(c)
A3
W3 in
a3
W3 out
W5 in
a5
W5 out
W3,W5
(d)
B1
C1 out
b1
C1 in
C6 out
b6
C6 in
C1,C6
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(f)
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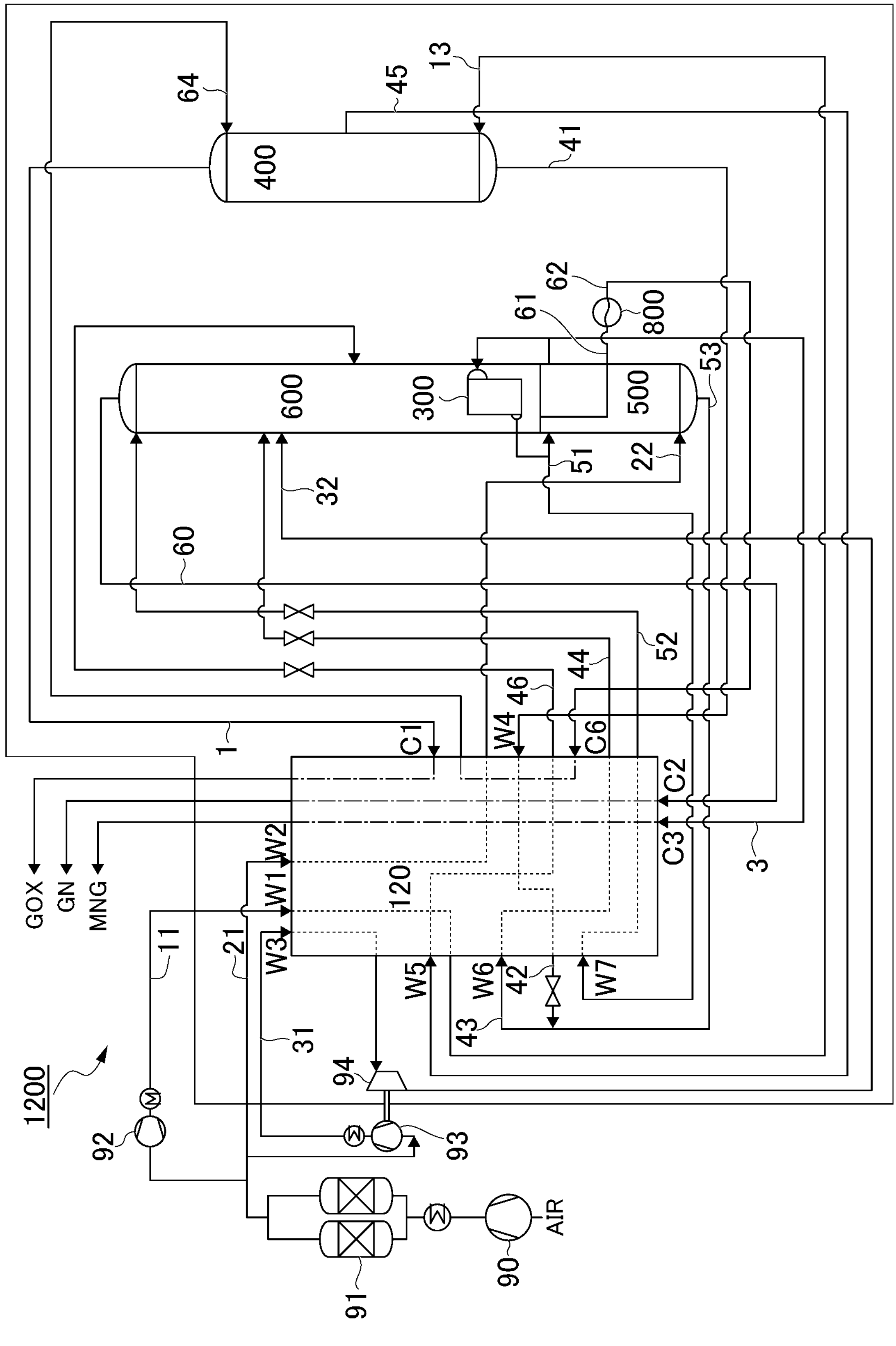
FIG. 3



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/018452

A. CLASSIFICATION OF SUBJECT MATTER

F25J 5/00(2006.01)i; ***F25J 3/04***(2006.01)i; ***F28D 9/00***(2006.01)i; ***F28F 3/08***(2006.01)i
FI: F25J5/00; F25J3/04 102; F28F3/08 301A; F28D9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25J5/00; F25J3/04; F28D9/00; F28F3/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 3179186 A1 (LINDE AKTIENGESELLSCHAFT) 14 June 2017 (2017-06-14)	1-3
A	US 2019/0321772 A1 (LINDE AKTIENGESELLSCHAFT) 24 October 2019 (2019-10-24)	1-3

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 July 2023	**18 July 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/018452

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REFERENCES CITED IN THE DESCRIPTION

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