



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
16.09.2020 Bulletin 2020/38

(51) Int Cl.:
F25B 1/10 (2006.01) F25B 5/02 (2006.01)

(21) Application number: **18877202.4**

(86) International application number:
PCT/JP2018/041487

(22) Date of filing: **08.11.2018**

(87) International publication number:
WO 2019/093420 (16.05.2019 Gazette 2019/20)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(30) Priority: **08.11.2017 JP 2017215660**

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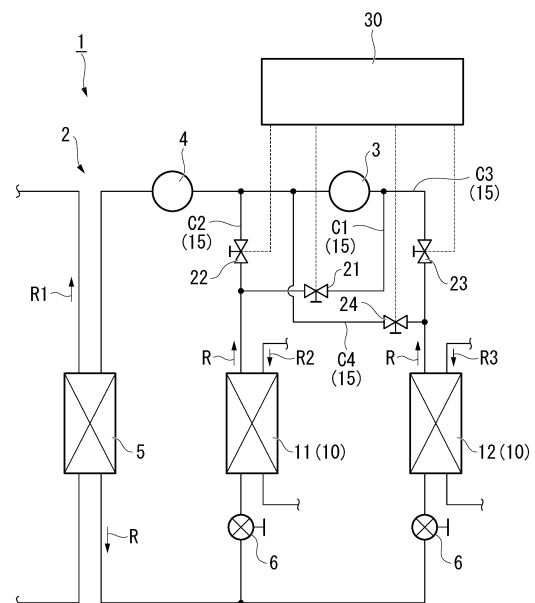
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(54) **HEAT PUMP**

(57) A refrigerant circuit (2) includes a first flow path (C1) through which a downstream side of a first evaporator (11) and an upstream side of a low-stage side compressor (3) are connected to each other, a first valve (21) which opens or closes the first flow path (C1), a second flow path (C2) through which the downstream side of the first evaporator (11) and an upstream side of a high-stage side compressor (4) are connected to each other, a second valve (22) which opens or closes the second flow path (C2), a third flow path (C3) through which a downstream side of a second evaporator (12) and the upstream side of the low-stage side compressor (3) are connected to each other, a third valve (23) which opens or closes the third flow path (C3), a fourth flow path (C4) through which the downstream side of the second evaporator (12) and the upstream side of the high-stage side compressor (4) are connected to each other, and a fourth valve (24) which opens or closes the fourth flow path (C4).

FIG. 1



Description

[Technical Field]

[0001] The present invention relates to a heat pump including a refrigerant circuit.

[0002] Priority is claimed on Japanese Patent Application No. 2017-215660, filed November 8, 2017, the content of which is incorporated herein by reference.

[Background Art]

[0003] In the related art, a refrigeration cycle including a refrigerant circuit through which a refrigerant circulates while being repeatedly compressed and expanded, that is, a heat pump is known. In this heat pump, for example, as described in Patent Document 1, a refrigerant may be compressed in two stages by a low-stage side compressor which compresses a refrigerant and a high-stage side compressor which further compresses the refrigerant discharged from the low-stage side compressor.

[0004] Moreover, the heat pump includes an evaporator which evaporates the refrigerant on an upstream side of the low-stage side compressor. For example, the evaporator is a heat exchanger which exchanges heat between the refrigerant and a heating medium such as water or air.

[Citation List]

[Patent Document]

[0005] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2016-90102

[Summary of Invention]

[Technical Problem]

[0006] Here, in a heat pump of Patent Document 1, a refrigerant from an evaporator is introduced into a low-stage side compressor, and thereafter is introduced into a high-stage side compressor.

[0007] However, a heat exchange amount in the evaporator is not always constant, and may fluctuate due to an environmental factor or the like. Accordingly, a temperature of a refrigerant introduced from a heat exchanger into the low-stage side compressor is not constant, and the refrigerant introduced into the low-stage side compressor may not be in a state optimum for compression in the low-stage side compressor. In some cases, efficient operation of the entire heat pump cannot be performed.

[0008] Therefore, the present invention provides a heat pump which can introduce a refrigerant in a state optimum for compression into a low-stage side compressor and a high-stage side compressor and can perform an efficient operation.

[Solution to Problem]

[0009] According to a first aspect of the present invention, there is provided a heat pump including: a low-stage side compressor; a high-stage side compressor which is connected to a downstream side of the low-stage side compressor in series, a condenser which is connected to a downstream side of the high-stage side compressor; an expansion mechanism which is connected to a downstream side of the condenser; a first evaporator and a second evaporator which are connected to a downstream side of the expansion mechanism in parallel; a first flow path through which a downstream side of the first evaporator and an upstream side of the low-stage side compressor are connected to each other; a first valve which opens or closes the first flow path; a second flow path through which the downstream side of the first evaporator and an upstream side of the high-stage side compressor are connected to each other; a second valve which opens or closes the second flow path; a third flow path through which a downstream side of the second evaporator and the upstream side of the low-stage side compressor are connected to each other; a third valve which opens or closes the third flow path; a fourth flow path through which the downstream side of the second evaporator and the upstream side of the high-stage side compressor are connected to each other; and a fourth valve which opens or closes the fourth flow path.

[0010] Accordingly, the heat pump includes the first evaporator and the second evaporator. That is, the heat pump has a multi-source type refrigerant circuit including a plurality of heat exchangers having different heat exchange amounts or installation environments.

[0011] Here, in each evaporator, a heat exchange amount fluctuates and a temperature of the refrigerant is changed. Accordingly, in some cases, the state of the refrigerant directed toward the low-stage side compressor and the high-stage side compressor may not be optimum for compression in the low-stage side compressor and the high-stage side compressor. Here, by opening or closing the first flow path, the second flow path, the third flow path, and the fourth flow path by the first valve, the second valve, the third valve, and the fourth valve, not only can the refrigerant be introduced from the first evaporator into the low-stage side compressor, but also the refrigerant can be directly introduced into the high-stage side compressor by bypassing the low-stage side compressor. Further, at the same time as switching of an introduction path of the refrigerant from the first evaporator to the compressor, an introduction path of the refrigerant from the second evaporator to the compressor can be switched. That is, not only can the refrigerant be introduced from the second evaporator into the low-stage side compressor, but also the refrigerant can be directly introduced into the high-stage side compressor by bypassing the low-stage side compressor.

[0012] Therefore, it is possible to switch the introduction path of the refrigerant to a compressor capable of

performing optimum compression according to the state of the refrigerant flowing out from each evaporator.

[0013] In the heat pump according to a second aspect of the present invention, in the first aspect, the heat pump may further include a control unit which controls opening or closing operations of the first valve, the second valve, the third valve, and the fourth valve according to loads on the first evaporator and the second evaporator.

[0014] By providing the control unit, the introduction path of the refrigerant can be automatically switched so that the refrigerant is introduced into the compressor capable of performing optimum compression according to the state of the refrigerant flowing out from each evaporator.

[0015] In the heat pump according to a third aspect of the present invention, in the second aspect, the control unit may control the opening or closing operations of the first valve, the second valve, the third valve, and the fourth valve so that a first state where a refrigerant from the first evaporator is introduced into the low-stage side compressor and a refrigerant from the second evaporator is directly introduced into the high-stage side compressor and a second state where the refrigerant from the first evaporator is directly introduced into the high-stage side compressor and the refrigerant from the second evaporator is introduced into the low-stage side compressor are switchable to each other.

[0016] According to this heat pump, since the flow of the refrigerant can be switched between the first state and the second state, the flow of the refrigerant from the first evaporator and the flow of the refrigerant from the second evaporator do not interfere with each other, the refrigerant circulates so that the flow of the refrigerant from the first evaporator and the flow of the refrigerant from the second evaporator cross each other, and the refrigerant can be introduced into an optimum compressor. Therefore, a degree of freedom of an operation increases, and an efficient operation can be performed.

[Advantageous Effects of Invention]

[0017] According to the above-described heat pump, the refrigerant in the state optimum for compression can be introduced into the low-stage side compressor and the high-stage side compressor, and an efficient operation can be performed.

[Brief Description of Drawings]

[0018]

Fig. 1 is an overall configuration diagram of a heat pump according to an embodiment of the present invention.

Fig. 2 is an overall configuration diagram of the heat pump according to the embodiment of the present invention and illustrates a case where a refrigerant circulates in an A mode. Further, a location through

which the refrigerant does not flow is indicated by a broken line.

Fig. 3 is an overall configuration diagram of the heat pump according to the embodiment of the present invention and illustrates a case where a refrigerant circulates in a B mode. Further, a location through which the refrigerant does not flow is indicated by a broken line.

Fig. 4 is an overall configuration diagram of the heat pump according to the embodiment of the present invention and illustrates a case where a refrigerant circulates in a C mode. Further, a location through which the refrigerant does not flow is indicated by a broken line.

Fig. 5 is an overall configuration diagram of the heat pump according to the embodiment of the present invention and illustrates a case where a refrigerant circulates in a D mode. Further, a location through which the refrigerant does not flow is indicated by a broken line.

[Description of Embodiments]

[0019] Hereinafter, a heat pump 1 according to the embodiment of the present invention will be described.

[0020] As illustrated in Fig. 1, the heat pump 1 according to the present embodiment has a refrigerant circuit 2 which is operated in a two-stage compression cycle. The refrigerant circuit 2 has a low-stage side compressor 3, a high-stage side compressor 4, a condenser 5, an expansion valve (expansion mechanism) 6, and an evaporator 10, and the components are connected by a pipe 15 in this order. Then, for example, a refrigerant R such as carbon dioxide circulates through the refrigerant circuit 2. Here, the refrigerant R is not particularly limited to carbon dioxide.

[0021] The low-stage side compressor 3 sucks the refrigerant R and compresses the refrigerant R.

[0022] The high-stage side compressor 4 is connected in series to the low-stage side compressor 3, and compresses the refrigerant R discharged from the low-stage side compressor 3 to a higher pressure.

[0023] The condenser 5 exchanges heat between the high-temperature and high-pressure refrigerant R discharged from the high-stage side compressor 4 and a heating medium R1 such as air or water to cool and condense the refrigerant R.

[0024] The expansion valve 6 adiabatically expands the refrigerant R from the condenser 5 and decompresses the refrigerant R. A plurality (two in this embodiment) of expansion valves 6 are provided on an upstream side (inlet side) of the evaporator 10 in correspondence with a first evaporator 11 and a second evaporator 12 described later.

[0025] In the present embodiment, the first evaporator 11 and the second evaporator 12 are provided as the evaporator 10. The first evaporator 11 and the second evaporator 12 are provided in parallel.

[0026] The first evaporator 11 is an air heat exchanger which performs heat exchange between the refrigerant R which has passed through the expansion valve 6 and air serving as the heating medium R2, for example.

[0027] The pipe 15 between the first evaporator 11 and an upstream side (suction side) of the low-stage side compressor 3 forms a first flow path C1. The first flow path C1 includes a first valve 21 which opens or closes the first flow path C1 so that the refrigerant R can flow through the first flow path C1 or cannot flow through the first flow path C1.

[0028] The pipe 15 between the first evaporator 11 and an upstream side (a suction side of the high-stage side compressor 4 and a discharge side of the low-stage side compressor 3) of the high-stage side compressor 4 forms a second flow path C2. The second flow path C2 includes a second valve 22 which opens or closes the second flow path C2 so that the refrigerant R can flow through the second flow path C2 or cannot flow through the second flow path C2. In the present embodiment, the first flow path C1 is provided so as to branch from the second flow path C2 on an upstream side of a position where the second valve 22 is provided, that is, on a side closer to the first evaporator 11.

[0029] The second evaporator 12 is a water heat exchanger which performs heat exchange between the refrigerant R which has passed through the expansion valve 6 and water serving as the heating medium R3, for example.

[0030] The pipe 15 between the second evaporator 12 and the upstream side (suction side) of the low-stage side compressor 3 forms a third flow path C3. The third flow path C3 includes a third valve 23 which opens or closes the third flow path C3 so that the refrigerant R can flow through the third flow path C3 or cannot flow through the third flow path C3. In the present embodiment, the first flow path C1 is connected to the third flow path C3 on a downstream side of a position where the third valve 23 is provided, that is, at a position closer to the low-stage side compressor 3.

[0031] The pipe 15 between the second evaporator 12 and the upstream side (the suction side of the high-stage side compressor 4 and the discharge side of the low-stage side compressor 3) of the high-stage side compressor 4 forms a fourth flow path C4. The fourth flow path C4 includes a fourth valve 24 which opens or closes the fourth flow path C4 so that the refrigerant R can flow through the fourth flow path C4 or cannot flow through the fourth flow path C4. In the present embodiment, the fourth flow path C4 is provided so as to branch from the third flow path C3 on an upstream side of a position where the third valve 23 is provided, that is, on a side closer to the second evaporator 12.

[0032] Further, in this embodiment, a control unit 30 such as a MICRO-PROCESSING UNIT (MPU) for opening or closing the first valve 21, the second valve 22, the third valve 23, and the fourth valve 24 is provided.

[0033] The control unit 30 opens or closes the first

valve 21, the second valve 22, the third valve 23, and the fourth valve 24 according to loads (heat exchange amounts) on the first evaporator 11 and the second evaporator 12.

[0034] Next, a control method of the opening or closing operation of each valve in the control unit 30 will be described.

[0035] Hereinafter, a temperature of the refrigerant R flowing out from the first evaporator 11 is defined as T1, and a temperature of the refrigerant R flowing out from the second evaporator 12 is defined as T2.

[A mode]

[0036] A case where $T1 < T2$ is satisfied is an A mode (first state). In this mode, as illustrated in Fig. 2, the control unit 30 closes the second valve 22 and opens the first valve 21 so that the refrigerant R from the first evaporator 11 is introduced into the low-stage side compressor 3. Therefore, the refrigerant R from the first evaporator 11 is compressed by the low-stage side compressor 3, and thereafter, is compressed by the high-stage side compressor 4.

[0037] Further, in this mode, the control unit 30 closes the third valve 23 and opens the fourth valve 24 so that the refrigerant R from the second evaporator 12 is introduced only into the high-stage side compressor 4 without passing through the low-stage side compressor 3. Therefore, the refrigerant R from the second evaporator 12 is compressed only by the high-stage side compressor 4.

[B mode]

[0038] A case where $T1 > T2$ is a B mode (second state). In the present mode, as illustrated in Fig. 3, the control unit 30 closes the first valve 21 and opens the second valve 22 so that the refrigerant R from the first evaporator 11 is introduced only into the high-stage side compressor 4 without passing through the low-stage side compressor 3. Therefore, the refrigerant R from the first evaporator 11 is compressed only by the high-stage side compressor 4 without passing through the low-stage side compressor 3.

[0039] In addition, in this mode, the control unit 30 closes the fourth valve 24 and opens the third valve 23 so that the refrigerant R from the second evaporator 12 is introduced into the low-stage side compressor 3. Therefore, the refrigerant R from the second evaporator 12 is compressed by the low-stage side compressor 3, and thereafter, is compressed by the high-stage side compressor 4.

[C mode]

[0040] A C mode is when $T1 \cong T2$ is satisfied and the temperature of the refrigerant R flowing out from the condenser 5 is equal to T1 and T2. In this mode, as illustrated in Fig 4, the control unit 30 stops an operation of the low-

stage side compressor 3. Further, the control unit 30 closes the first valve 21 and the third valve 23 and opens the second valve 22 and the fourth valve 24 so that the refrigerant R flowing out from the first evaporator 11 and the second evaporator 12 is introduced only into the high-stage side compressor 4 without passing through the low-stage side compressor 3. Therefore, both the refrigerant R from the first evaporator 11 and the refrigerant R from the second evaporator 12 are compressed by the high-stage side compressor 4 without passing through the low-stage side compressor 3.

[D mode]

[0041] A D mode is when $T1 \approx T2$ is satisfied and a temperature difference between the temperature of the refrigerant R flowing out from the condenser 5 and $T1$ and $T2$ is large. In this mode, as illustrated in Fig. 5, the control unit 30 closes the second valve 22 and the fourth valve 24 and opens the first valve 21 and the third valve 23 so that the refrigerant R flowing out from the first evaporator 11 and the second evaporator 12 is introduced into the low-stage side compressor 3. Therefore, both the refrigerant R from the first evaporator 11 and the refrigerant R from the second evaporator 12 are compressed by the low-stage side compressor 3, and thereafter, are compressed by the high-stage side compressor 4.

[0042] The heat pump 1 according to the present embodiment described above includes the first evaporator 11 and the second evaporator 12. That is, the heat pump 1 has a multi-source type refrigerant circuit 2 including a plurality of heat exchangers having different heat exchange amounts or installation environments, that is, the first evaporator 11 and the second evaporator 12.

[0043] Here, in each evaporator 10, the load (heat exchange amount) fluctuates and the temperature of the refrigerant R is changed. Accordingly, in some cases, the state of the refrigerant R directed toward the low-stage side compressor 3 and the high-stage side compressor 4 may not be optimum for compression in the low-stage side compressor 3 and the high-stage side compressor 4. In the present embodiment, the control unit 30 opens or closes the first flow path C1, the second flow path C2, the third flow path C3, and the fourth flow path C4 by the first valve 21, the second valve 22, the third valve 23, and the fourth valve 24 so that not only can the refrigerant R be introduced from the first evaporator 11 into the low-stage side compressor 3, but also the refrigerant R can be directly introduced into the high-stage side compressor 4 by bypassing the low-stage side compressor 3.

[0044] Further, at the same time as switching of a circulation path of the refrigerant R from the first evaporator 11, a circulation path of the refrigerant R from the second evaporator 12 can be switched. That is, not only can the refrigerant R be introduced from the second evaporator 12 into the low-stage side compressor 3, but also the

refrigerant R can be directly introduced into the high-stage side compressor 4 by bypassing the low-stage side compressor 3.

[0045] Specifically, by operating the first valve 21, the second valve 22, the third valve 23, and the fourth valve 24 from the A mode to the D mode, according to the state of the refrigerant R flowing out from each evaporator 10 (11, 12), an introduction path of the refrigerant R can be switched to the compressor capable of performing optimum compression of the low-stage side compressor 3 and the high-stage side compressor 4. Therefore, the refrigerant R in a state optimum for compression can be introduced into the low-stage side compressor 3 and the high-stage side compressor 4, and an efficient operation can be performed.

[0046] Further, by providing the control unit 30, the introduction path of the refrigerant R can be automatically switched to the compressor capable of performing optimum compression of the low-stage side compressor 3 and the high-stage side compressor 4 according to the state of the refrigerant R flowing out from each of the first evaporator 11 and the second evaporator 12.

[0047] Further, since the flow of the refrigerant R can be switched between the A mode and the B mode, the refrigerant R from the first evaporator 11 can be introduced into any one of the low-stage side compressor 3 and the high-stage side compressor 4, and the refrigerant R from the second evaporator 12 can be introduced into any one of the low-stage side compressor 3 and the high-stage side compressor 4.

[0048] That is, the flow of the refrigerant R from the first evaporator 11 and the flow of the refrigerant R from the second evaporator 12 do not interfere with each other, the refrigerant R circulates so that the flow of the refrigerant R from the first evaporator 11 and the flow of the refrigerant R from the second evaporator 12 cross each other, and can flow into the low-stage side compressor 3 and the high-stage side compressor 4. Therefore, a degree of freedom of an operation increases.

[0049] Hereinbefore, the embodiment of the present invention is described in detail with reference to the drawings. However, respective configurations in the embodiment and a combination thereof are merely examples, and addition, omission, substitution, and other modifications of configurations can be made within a scope which does not depart from the gist of the present invention. In addition, the present invention is not limited by the embodiment, but is limited only by claims.

[0050] For example, the control unit 30 does not necessarily have to be provided. In this case, the first valve 21, the second valve 22, the third valve 23, and the fourth valve 24 may be manually opened or closed.

[0051] Further, three or more evaporators 10 may be provided, and the number of the evaporators 10 is not limited to the above-described case.

[Industrial Applicability]

[0052] According to the above-described heat pump, the refrigerant in the state optimum for compression can be introduced into the low-stage side compressor and the high-stage side compressor, and an efficient operation can be performed.

[Reference Signs List]

[0053]

1 Heat pump
2 Refrigerant circuit
3 Low-stage side compressor
4 High-stage side compressor
5 Condenser
6 Expansion valve (expansion mechanism)
10 Evaporator
11 First evaporator
12 Second evaporator
15 Pipe
21 First valve
22 Second valve
23 Third valve
24 Fourth valve
30 Control unit
R Refrigerant
R1, R2, R3 Heating medium
C1 First flow path
C2 Second flow path
C3 Third flow path
C4 Fourth flow path

Claims

1. A heat pump comprising:

a low-stage side compressor;
a high-stage side compressor which is connected to a downstream side of the low-stage side compressor in series,
a condenser which is connected to a downstream side of the high-stage side compressor;
an expansion mechanism which is connected to a downstream side of the condenser;
a first evaporator and a second evaporator which are connected to a downstream side of the expansion mechanism in parallel;
a first flow path through which a downstream side of the first evaporator and an upstream side of the low-stage side compressor are connected to each other;
a first valve which opens or closes the first flow path;
a second flow path through which the downstream side of the first evaporator and an up-

stream side of the high-stage side compressor are connected to each other;
a second valve which opens or closes the second flow path;
a third flow path through which a downstream side of the second evaporator and the upstream side of the low-stage side compressor are connected to each other;
a third valve which opens or closes the third flow path;
a fourth flow path through which the downstream side of the second evaporator and the upstream side of the high-stage side compressor are connected to each other; and
a fourth valve which opens or closes the fourth flow path.

2. The heat pump according to claim 1, further comprising:

a control unit which controls opening or closing operations of the first valve, the second valve, the third valve, and the fourth valve based on loads on the first evaporator and the second evaporator.

3. The heat pump according to claim 2, wherein the control unit controls the opening or closing operations of the first valve, the second valve, the third valve, and the fourth valve so that a first state where a refrigerant from the first evaporator is introduced into the low-stage side compressor and a refrigerant from the second evaporator is directly introduced into the high-stage side compressor and a second state where the refrigerant from the first evaporator is directly introduced into the high-stage side compressor and the refrigerant from the second evaporator is introduced into the low-stage side compressor are switchable to each other.

FIG. 1

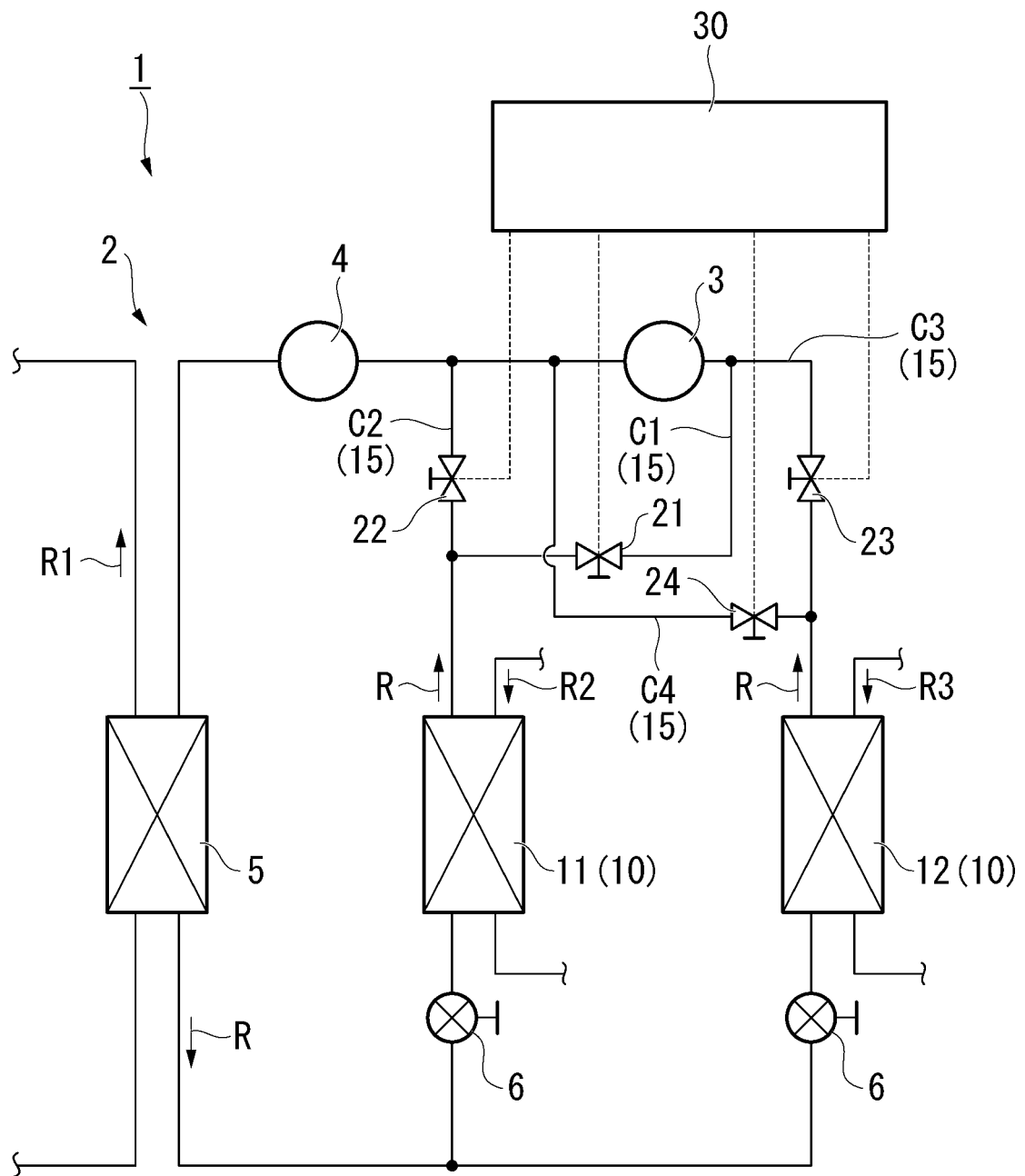


FIG. 2

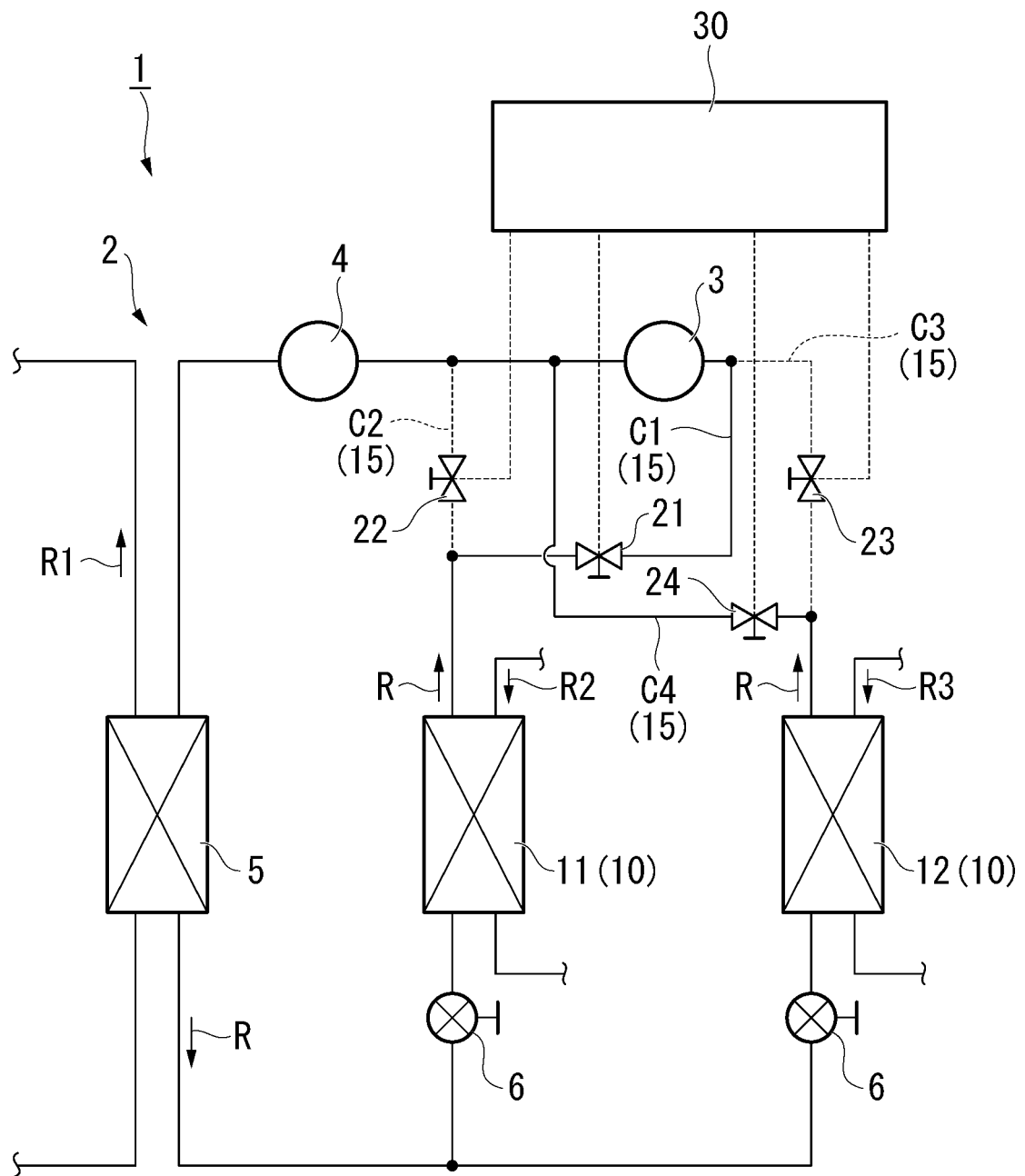


FIG. 3

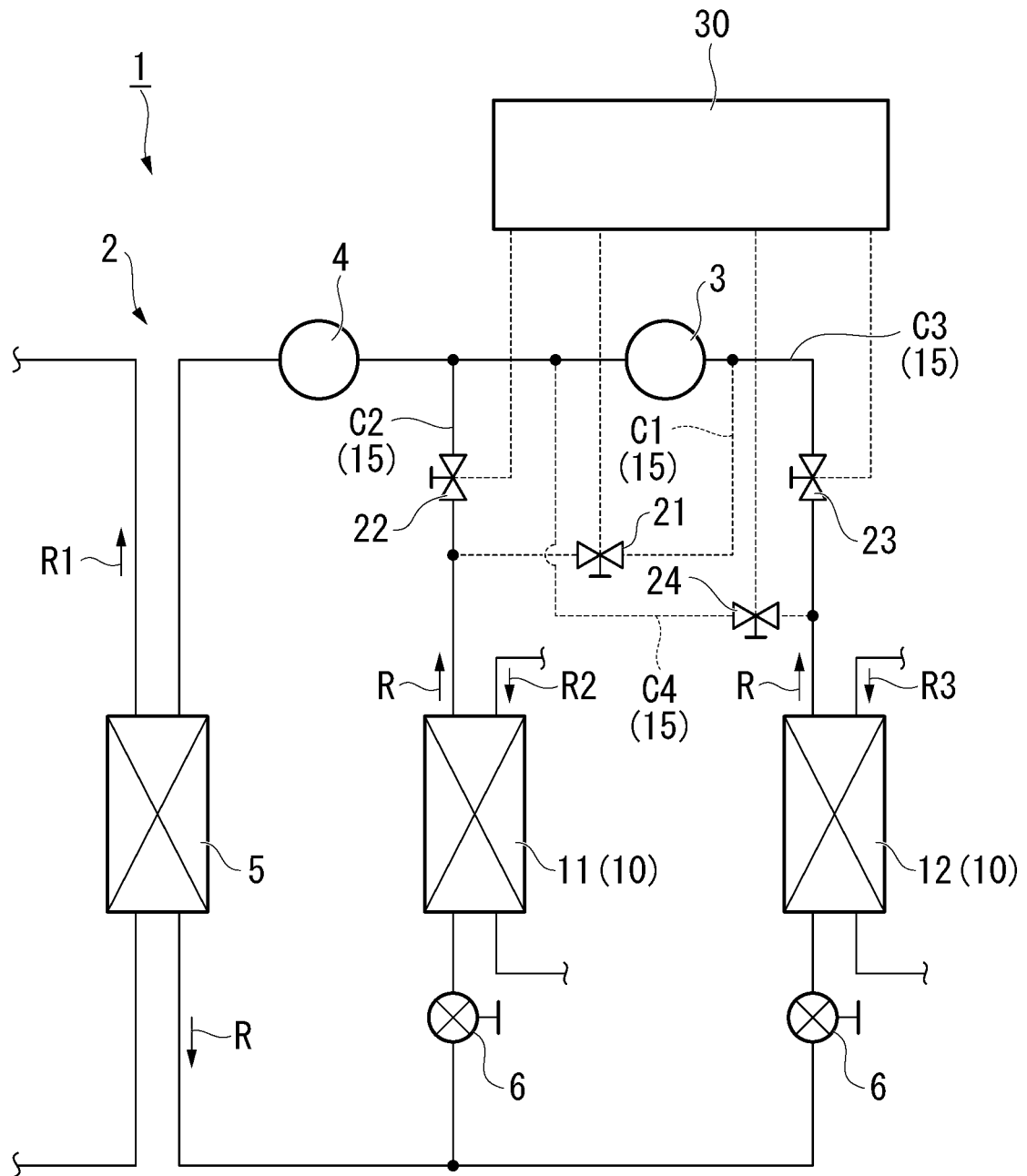


FIG. 4

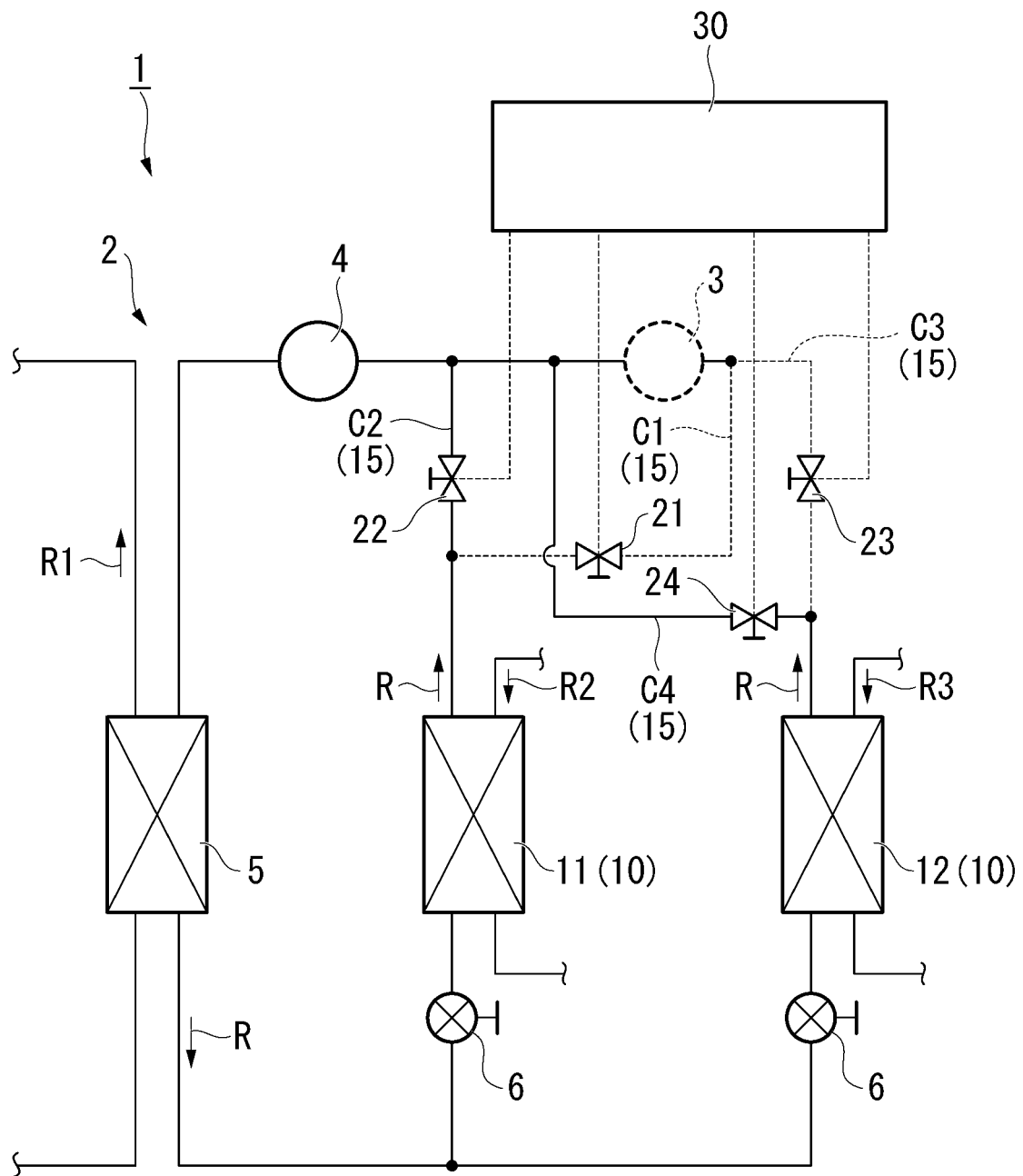
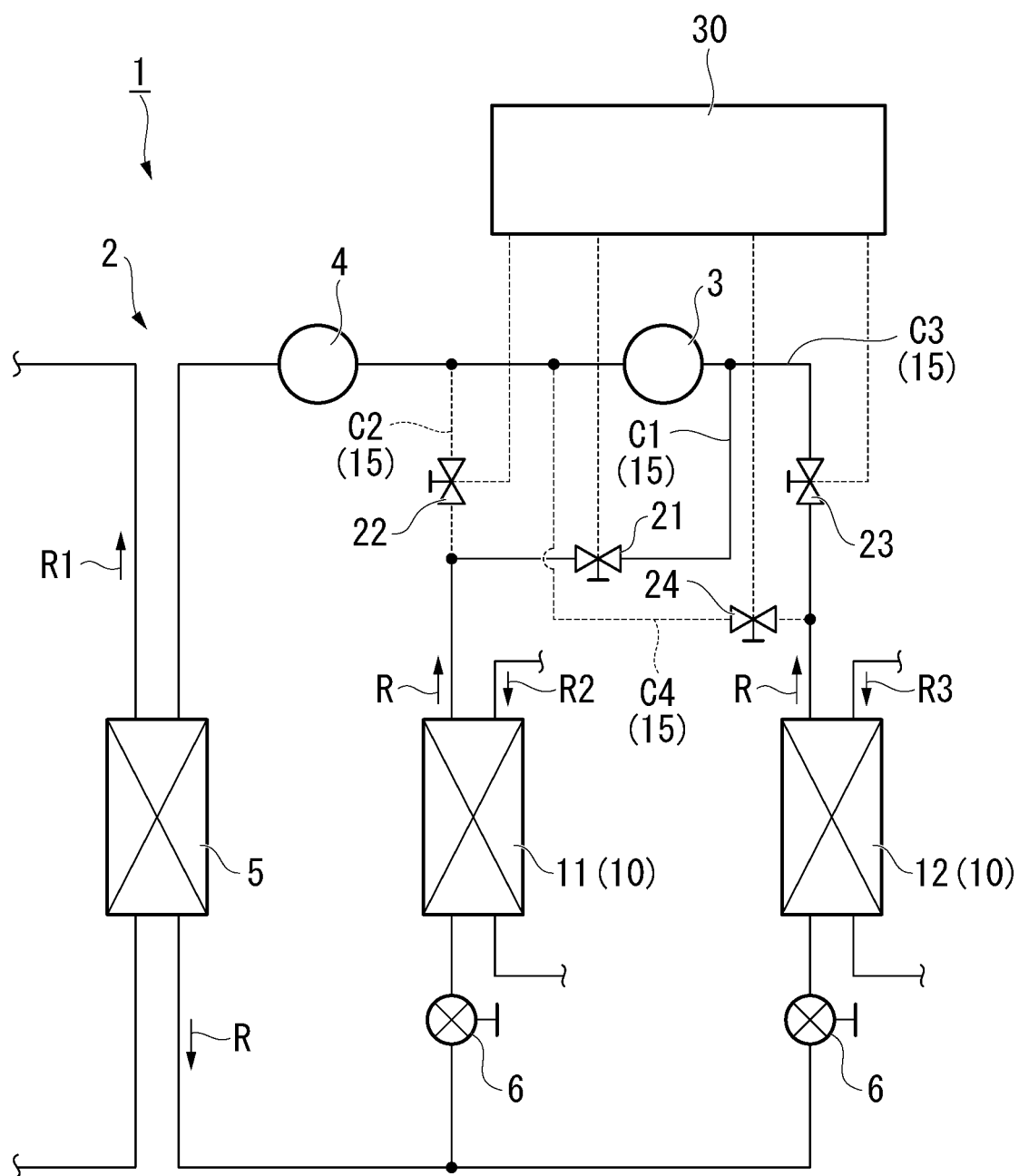


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/041487

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F25B1/10 (2006.01) i, F25B5/02 (2006.01) i

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)

Int.Cl. F25B1/10, F25B5/02

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 1971-2019

Registered utility model specifications of Japan 1996-2019

Published registered utility model applications of Japan 1994-2019

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.
X	JP 06-257889 A (MITSUBISHI ELECTRIC CORP.) 16 September 1994, paragraphs [0049], [0167]-[0179], fig. 46, 53-54 (Family: none)	1-3
A	JP 2009-210138 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 17 September 2009, entire text, all drawings (Family: none)	1-3
A	JP 2009-079863 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 16 April 2009, entire text, all drawings (Family: none)	1-3



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search
23 January 2019 (23.01.2019)Date of mailing of the international search report
05 February 2019 (05.02.2019)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/041487

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2007-178120 A (MITSUBISHI ELECTRIC CORP.) 12 July 2007, entire text, all drawings (Family: none)	1-3
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REFERENCES CITED IN THE DESCRIPTION

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