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(71) Applicants:
- **Mitsubishi Electric Corporation**
  Chiyoda-ku
  Tokyo 100-8310 (JP)
- **Asahi Glass Company, Limited**
  Tokyo 100-8405 (JP)

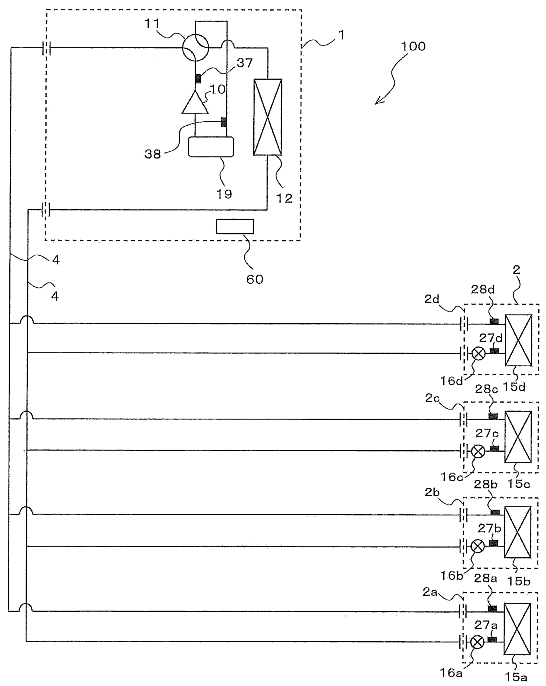
(72) Inventor: **YAMASHITA, Koji**
Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(54) REFRIGERATION CYCLE APPARATUS

(57) A refrigeration cycle apparatus includes a refrigeration cycle in which a compressor 10, a heat source-side heat exchanger 12, an expansion device 16, and a load-side heat exchanger 15 are connected by refrigerant pipes to circulate refrigerant. The refrigerant is a single-component refrigerant composed of 1,1,2-trifluoroethylene or a refrigerant mixture containing 1,1,2-trifluoroethylene. The compressor 10 has a compression chamber 47 and a motor 44 in a compressor shell 45. A resin material is used as an insulating material for the motor 44.

FIG. 2



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Description

Technical Field

[0001] The present invention relates to refrigeration cycle apparatuses, such as air-conditioning apparatuses, which are applied to, for example, multi-air-conditioning systems for buildings.

Background Art

[0002] Refrigeration cycle apparatuses include a refrigerant circuit through which refrigerant circulates and perform air conditioning and other operations as in, for example, multi-air-conditioning systems for buildings. Refrigeration cycle apparatuses normally use, as a refrigerant, substances containing hydrogen and carbon, such as R410A being nonflammable, R32 being less flammable, and propane being highly flammable. Although these substances differ in their lifetime until decomposing into different substances when released into the air, these substances are highly stable in refrigeration cycle apparatuses and can be used as a refrigerant for long periods such as several tens of years.

[0003] Unfortunately, some of substances containing hydrogen and carbon are unstable in refrigeration cycle apparatuses and are difficult to use as a refrigerant. Some of these unstable substances may, for example, undergo a disproportionation reaction. Disproportionation is a reaction in which the same substance reacts with itself to form different substances. For example, the application of some high energy to refrigerant that is in a liquid state or another state where adjacent substance molecules are very close to each other causes a disproportionation reaction, in which adjacent substance molecules react with each other to form different substances. The disproportionation reaction involves heat generation and leads to a rapid increase in temperature, which may result in a rapid increase in pressure. For example, when a substance that undergoes disproportionation is used as a refrigerant for a refrigeration cycle apparatus and enclosed in pipes made of copper or other materials, the pipes cannot withstand an increase in pressure of the refrigerant therein and an accident such as a pipe burst may occur. Examples of the substance that undergoes disproportionation include 1,1,2-trifluoroethylene (HFO-1123) and acetylene.

[0004] There is a heat cycle system (refrigeration cycle apparatus) in which 1,1,2-trifluoroethylene (HFO-1123) is used as a working medium for a heat cycle (e.g.,

[0005] Patent Literature 1).

Citation List

Patent Literature

[0006] Patent Literature 1: WO12/157764 (e.g., page 3, page 12, and Fig. 1)

Summary of Invention

Technical Problem

[0007] In a refrigeration cycle apparatus, such as a heat cycle system described in Patent Literature 1,1,1,2-trifluoroethylene (HFO-1123) is used as a working medium for the heat cycle. 1,1,2-Trifluoroethylene (HFO-1123) is a substance that undergoes disproportionation. When this substance is used as a refrigerant as is, some energy causes adjacent substance molecules to react with each other to form different substances. As a result, the substance not only fails to function as a refrigerant but also may cause an accident such as a pipe burst because of a rapid increase in pressure. For use as a refrigerant, there is a challenge to use 1,1,2-trifluoroethylene (HFO-1123) without this disproportionation reaction occurring. Therefore, measures against this disproportionation reaction need to be taken, but none of documents including Patent Literature 1 describes methods for realizing apparatuses or other systems in which no disproportionation reaction occurs.

[0008] The present invention has been made to overcome the above-mentioned problems. An object of the present invention is to provide a refrigeration cycle apparatus in which a substance that undergoes disproportionation is safely used as a refrigerant by reducing the energy that the refrigerant externally receives. Solution to Problem

[0009] A refrigeration cycle apparatus according to an embodiment of the present invention is a refrigeration cycle apparatus comprising a refrigeration cycle in which a compressor, a first heat exchanger, an expansion device, and a second heat exchanger are connected by refrigerant pipes to circulate refrigerant, the refrigerant being a single-component refrigerant composed of a substance that undergoes disproportionation or a refrigerant mixture containing a substance that undergoes disproportionation and another substance, the compressor having, in a sealed container thereof, a compression chamber and a motor, the motor being insulated with a resin material serving as an insulating material. Advantageous Effects of Invention

[0010] A refrigeration cycle apparatus according to an embodiment of the present invention overcomes the following disadvantage of a substance that undergoes disproportionation, such as 1,1,2-trifluoroethylene (HFO-1123): the substance fails to function as a refrigerant or causes an accident such as a pipe burst because of the disproportionation reaction. As a result, the substance that undergoes disproportionation, such as 1,1,2-trifluoroethylene (HFO-1123), can be safely used as a refrigerant.

Brief Description of Drawings

[0011]

[Fig. 1] Fig. 1 is a schematic diagram illustrating an installation example of a refrigeration cycle apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a circuit diagram of the refrigeration cycle apparatus according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a circuit diagram of the refrigeration cycle apparatus in cooling operation according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a circuit diagram of the refrigeration cycle apparatus in heating operation according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a schematic diagram illustrating the structure of a compressor in the refrigeration cycle apparatus according to Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a schematic diagram illustrating the structure of an accumulator in the refrigeration cycle apparatus according to Embodiment 1 of the present invention.

Description of Embodiments

[0012] A refrigeration cycle apparatus according to an embodiment of the present invention will be described below with reference to, for example, the drawings. In the following drawings including Fig. 1, the same components or their equivalent components are denoted by the same reference numerals and are common to all sentences in embodiments described below. The configuration of components described in the entire specification is illustrative only, and the configuration of components should not be limited to that described in the specification. In particular, combinations of components are not limited only to the combinations in each of the embodiments, and components described in one embodiment can be used in other embodiments. Same devices or components may be distinguished by subscripts, but may not be subscripted when no such distinction is needed. In the drawings, the relationships in size between components may be different from the actual ones. The level of temperature, pressure, or other conditions is not determined particularly by the relationship with an absolute value, but determined relatively by the state, operation, or the like of, for example, the system or apparatus.

Embodiment 1

[0013] Embodiment 1 of the present invention will be described based on the drawings. Fig. 1 is a schematic diagram illustrating an installation example of a refrigeration cycle apparatus according to Embodiment 1 of the present invention. In the refrigeration cycle apparatus illustrated in Fig. 1, any of cooling mode and heating mode can be selected as an operation mode by employing a refrigeration cycle using refrigerant and including a refrigerant circuit through which the refrigerant circulates. The refrigeration cycle apparatus of Embodiment 1 will be described by providing, as an example, an air-conditioning apparatus that air-conditions a target space (indoor space 7).

[0014] In Fig. 1, the refrigeration cycle apparatus according to Embodiment 1 has one outdoor unit 1, which is a heat source unit, and multiple indoor units 2. The outdoor unit 1 and the indoor units 2 are connected by extension pipes (refrigerant pipes) 4 that establish fluid communication of the refrigerant, and cooling energy or heating energy generated by the outdoor unit 1 is delivered to the indoor units 2.

[0015] The outdoor unit 1 is normally placed in an outdoor space 6, which is a space outside a structure 9 such as a building (e.g., space on a roof), and supplies cooling energy or heating energy to the indoor units 2. The indoor units 2 are installed at positions at which temperature-controlled air can be supplied to the indoor space 7, which is a space (e.g., living room) inside the structure 9, and supplies cooling air or heating air to the indoor space 7, which is a target space.

[0016] As illustrated in Fig. 1, in the refrigeration cycle apparatus according to Embodiment 1, the outdoor unit 1 is connected to each of the indoor units 2 by two extension pipes 4.

[0017] Fig. 1 illustrates a case where the indoor units 2 are ceiling cassette units, however, the indoor units 2 are not limited to this type. Any type of indoor unit, such as those of a ceiling concealed type or a ceiling suspended type, are applicable as long as the indoor unit allows heating air or cooling air to blow into the indoor space 7 directly or through a duct or other devices.

[0018] Fig. 1 illustrates a case where the outdoor unit 1 is placed in the outdoor space 6. However, the outdoor unit 1 is not necessarily placed in the outdoor space 6. For example, the outdoor unit 1 may be placed in an enclosed space, such as a machine room having a ventilation opening. The outdoor unit 1 may be placed inside the structure 9 as long as waste heat can be exhausted from the structure 9 through an exhaust duct. Furthermore, the outdoor unit 1 may be placed inside the structure 9 when the outdoor unit 1 is of a water-cooled type. The outdoor unit 1 can be placed in any location without any particular problem.

[0019] The numbers of connected outdoor units 1 and indoor units 2 are not limited to those illustrated in Fig. 1 and may be determined in accordance with the structure 9 to be provided with the refrigeration cycle apparatus according to Embodiment 1.

[0020] Fig. 2 is a circuit diagram illustrating an example circuit configuration of the refrigeration cycle apparatus according to Embodiment 1 (hereinafter referred to as a refrigeration cycle apparatus 100). With reference to Fig. 2, a detailed structure of the refrigeration cycle apparatus 100 will be described. As illustrated in Fig. 2, the outdoor unit 1 and the indoor units 2 are connected by the extension pipes (refrigerant pipes) 4 in which the refrigerant flows.

[Outdoor Unit 1]

[0021] The outdoor unit 1 includes a compressor 10, a first refrigerant flow switching device 11, such as a four-way valve, a heat source-side heat exchanger 12, and an accumulator 19, which are connected in series by the refrigerant pipes.

[0022] The compressor 10 sucks refrigerant and compresses the refrigerant into a high temperature, high pressure state. The compressor 10 may be composed of, for example, a capacity-controllable inverter compressor. The first refrigerant flow switching device 11 switches between the flow of the refrigerant in heating operation and the flow of the refrigerant in cooling operation. The heat source-side heat exchanger 12 serves as an evaporator in heating operation and serves as a condenser (or radiator) in cooling operation. The heat source-side heat exchanger 12, which is a first heat exchanger, exchanges heat between the refrigerant and the air supplied from a fan (not illustrated) to evaporate and gasify the refrigerant or to condense and liquefy the refrigerant. The heat source-side heat exchanger 12, when operating to cool the indoor space 7, serves as a condenser. The heat source-side heat exchanger 12, when operating to heat the indoor space 7, serves as an evaporator. The accumulator 19 is disposed on the suction side of the compressor 10 and stores the refrigerant excess in the refrigerant circuit due to a change in operation mode or other causes.

[0023] The outdoor unit 1 includes the compressor 10, the first refrigerant flow switching device 11, the heat source-side heat exchanger 12, the accumulator 19, a high-pressure detecting device 37, a low-pressure detecting device 38, and a controller 60. The compressor 10 has, for example, a compression chamber in a sealed container thereof. The compressor 10 may have a low-pressure shell structure in which the sealed container is allowed to contain a low-refrigerant-pressure atmosphere and low-pressure refrigerant in the sealed container is sucked and compressed, or may have a high-pressure shell structure in which the sealed container is allowed to contain a high-refrigerant-pressure atmosphere and high-pressure refrigerant compressed in the compression chamber is discharged into the sealed container. The outdoor unit 1 includes the controller 60, which controls devices based on information detected by various detecting devices, instructions from a remote controller, or other information and instructions. The controller 60 controls, for example, the driving frequency of the compressor 10, the rotation speed (including ON/OFF) of the fan, switching of the first refrigerant flow switching device 11, and other conditions, and runs each operation mode described below. The controller 60 of Embodiment 1 is composed of, for example, a microcomputer having a control processing unit, such as a CPU (central processing unit). The controller 60 has a storage unit (not illustrated), which has data including programs of procedures for controls and other operations. The control processing unit achieves control by performing processing based on the data of the programs.

[Indoor Unit 2]

[0024] The indoor units 2 each include a load-side heat exchanger 15, which is a second heat exchanger. The load-side heat exchanger 15 is connected to the outdoor unit 1 by the extension pipes 4. The load-side heat exchanger 15 exchanges heat between the refrigerant and the air supplied from a fan (not illustrated) and generates heating air or cooling air to be supplied to the indoor space 7. The load-side heat exchanger 15, when operating to heat the indoor space 7, serves as a condenser. The load-side heat exchanger 15, when operating to cool the indoor space 7, serves as an evaporator.

[0025] Fig. 2 illustrates a case where four indoor units 2 are connected to the outdoor unit 1. The indoor units 2 are illustrated as an indoor unit 2a, an indoor unit 2b, an indoor unit 2c, and an indoor unit 2d from the bottom of the drawing. Corresponding to the indoor unit 2a to the indoor unit 2d, the load-side heat exchangers 15 are also illustrated as a load-side heat exchanger 15a, a load-side heat exchanger 15b, a load-side heat exchanger 15c, and a load-side heat exchanger 15d from the bottom side of the drawing. As in Fig. 1, the number of the connected indoor units 2 is not limited to four illustrated in Fig. 2.

[0026] The operation modes to be run by the refrigeration cycle apparatus 100 will be described. The refrigeration cycle apparatus 100 determines whether the operation mode of the outdoor unit 1 is the cooling operation mode or the heating operation mode based on instructions from the indoor units 2. That is, the refrigeration cycle apparatus 100 allows all the indoor units 2 to perform the same operation (cooling operation or heating operation) and controls room temperature. Each indoor unit 2 can be freely switched on and off in both the cooling operation mode and the heating operation mode.

[0027] The operation modes to be run by the refrigeration cycle apparatus 100 include the cooling operation mode in which all the running indoor units 2 perform cooling operation (including off mode), and the heating operation mode in which all the running indoor units 2 perform heating operation (including off mode). Each operation mode will be described below along with the flow of the refrigerant.

[Cooling Operation Mode]

[0028] Fig. 3 illustrates a refrigerant circuit diagram indicating the flow of the refrigerant in the cooling operation mode when the refrigeration cycle apparatus 100 has a low discharge temperature. Fig. 3 describes the cooling operation mode by providing, as an example, a case where a cooling load is generated in all the load-side heat exchangers 15. In Fig. 3, pipes denoted by the thick lines correspond to pipes in which the refrigerant flows, and the flow direction of the refrigerant is indicated by the solid arrows.

[0029] For the cooling operation mode illustrated in Fig. 3, in the outdoor unit 1, the first refrigerant flow switching device 11 performs switching such that the refrigerant discharged from the compressor 10 flows into the heat source-side heat exchanger 12. The low-temperature, low-pressure refrigerant is compressed by the compressor 10 and discharged as high-temperature, high-pressure gas refrigerant. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows into the heat source-side heat exchanger 12 through the first refrigerant flow switching device 11. In the heat source-side heat exchanger 12, the refrigerant condenses and liquefies into high-pressure liquid refrigerant while rejecting heat into the outdoor air. The liquid refrigerant then flows out of the outdoor unit 1.

[0030] The high-pressure liquid refrigerant flowing out of the outdoor unit 1 flows into the indoor units 2 (2a to 2d) through the extension pipes 4. The high-pressure liquid refrigerant flowing into the indoor units 2 (2a to 2d) enters the expansion devices 16 (16a to 16d). The high-pressure liquid refrigerant is expanded by the expansion devices 16 (16a to 16d) and decompressed into low-temperature, low-pressure two-phase refrigerant. Furthermore, the two-phase refrigerant flows into the load-side heat exchangers 15 (15a to 15d), which function as evaporators, and absorbs heat from the air flowing around the load-side heat exchangers 15 to form low-temperature, low-pressure gas refrigerant. The low-temperature, low-pressure gas refrigerant flows out of the indoor units 2 (2a to 2d) and flows into the outdoor unit 1 through the extension pipes 4 again. The low-temperature, low-pressure gas passes through the first refrigerant flow switching device 11 and the accumulator 19 and is sucked into the compressor 10 again.

[0031] The opening degree (opening area) of the expansion devices 16a to 16d is controlled such that a difference in temperature (degree of superheat) between the temperature detected by a load-side-heat-exchanger gas refrigerant temperature detecting device 28 and the evaporating temperature transmitted via communication from the controller 60 in the outdoor unit 1 to a controller (not illustrated) in each indoor unit 2 is close to a target value.

[0032] In running the cooling operation mode, the refrigerant does not need to flow into the load-side heat exchanger 15 with no heat load (including thermo-off), and thus the indoor unit 2 is switched off. The expansion device 16 in the switched-off indoor unit 2 is either fully closed or opened only slightly so as not to permit flow of the refrigerant.

[Heating Operation Mode]

[0033] Fig. 4 illustrates a refrigerant circuit diagram indicating the flow of the refrigerant when the refrigeration cycle apparatus 100 runs in the heating operation mode. Fig. 4 describes the heating operation mode by providing, as an example, a case where a heating load is generated in all the load-side heat exchangers 15. In Fig. 4, pipes denoted by the thick lines correspond to pipes in which the refrigerant flows, and the flow direction of the refrigerant is indicated by the solid arrows.

[0034] For the heating operation mode illustrated in Fig. 4, in the outdoor unit 1, the first refrigerant flow switching device 11 performs switching such that the refrigerant discharged from the compressor 10 flows into the indoor units 2 without passing through the heat source-side heat exchanger 12. The low-temperature, low-pressure refrigerant is compressed by the compressor 10 and discharged as high-temperature, high-pressure gas refrigerant. The high-temperature, high-pressure gas refrigerant passes through the first refrigerant flow switching device 11 and flows out of the outdoor unit 1. The high-temperature, high-pressure gas refrigerant flowing out of the outdoor unit 1 flows into the indoor units 2 (2a to 2d) through the extension pipes 4. The high-temperature, high-pressure gas refrigerant flowing into the indoor units 2 (2a to 2d) enters the load-side heat exchangers 15 (15a to 15d). The gas refrigerant condenses and liquefies into high-temperature, high-pressure liquid refrigerant while rejecting heat into the air flowing around the load-side heat exchangers 15 (15a to 15d). The high-temperature, high-pressure liquid refrigerant that has flowed out of the load-side heat exchangers 15 (15a to 15d) enters the expansion devices 16 (16a to 16d). The liquid refrigerant is expanded by the expansion devices 16 (16a to 16d) and decompressed into low-temperature, low-pressure two-phase refrigerant. The two-phase refrigerant then flows out of the indoor units 2 (2a to 2d). The low-temperature, low-pressure two-phase refrigerant flowing out of the indoor unit 2 flows into the outdoor unit 1 through the extension pipes 4 again.

[0035] The opening degree (opening area) of the expansion devices 16a to 16d is controlled such that a difference in temperature (degree of subcooling) between the condensing temperature transmitted via communication from the controller 60 in the outdoor unit 1 to a controller (not illustrated) in each indoor unit 2 and the temperature detected by a load-side-heat-exchanger liquid refrigerant temperature detecting device 27 is close to a target value.

[0036] The low-temperature, low-pressure two-phase refrigerant flowing into the outdoor unit 1 enters the heat source-side heat exchanger 12 and absorbs heat from the air flowing around the heat source-side heat exchanger 12. The refrigerant evaporates into low-temperature, low-pressure gas refrigerant or low-temperature, low-pressure two-phase refrigerant with a large quality. The low-temperature, low-pressure gas refrigerant or two-phase refrigerant passes through the first refrigerant flow switching device 11 and the accumulator 19 and is sucked into the compressor 10 again.

[0037] In running the heating operation mode, the refrigerant does not need to flow into the load-side heat exchanger 15 with no heat load (including thermo-off). However, when the expansion device 16 for the load-side heat exchanger 15 with no heating load is either fully closed or opened only slightly so as not to permit flow of the refrigerant in the heating operation mode, the refrigerant condenses by being cooled by the ambient air and is accumulated in the load-side heat exchanger 15 out of operation, which may result in a shortage of the refrigerant in the entire refrigerant circuit. Therefore, in heating operation, stagnation of the refrigerant is avoided by increasing the opening degree (opening area) of the expansion device 16 for the load-side heat exchanger 15 with no heat load, for example, by fully opening the expansion device 16.

[0038] The first refrigerant flow switching device 11 is typically, but not necessarily, a four-way valve. The first refrigerant flow switching device 11 may include plural two-way passage switching valves or three-way passage switching valves so that the refrigerant flows similarly.

[Type of Refrigerant]

[0039] When a substance ordinary used as a refrigerant, such as R32 or R410A, is used as a refrigerant in the refrigeration cycle apparatus 100, the substance can be normally used as is without taking measures for improving the stability of the refrigerant in the refrigerant circuit. It is noted that the refrigerant used herein is a single-component refrigerant composed of a substance that undergoes disproportionation, such as 1,1,2-trifluoroethylene (HFO-1123) having one double bond in the molecular structure represented by $C_2H_1F_3$, or a refrigerant mixture containing a substance that undergoes disproportionation and another substance.

[0040] Examples of the substance to be mixed with the substance that undergoes disproportionation to produce a refrigerant mixture include tetrafluoropropene represented by $C_3H_2F_4$ (e.g., HFO-1234yf, which is 2,3,3,3-tetrafluoropropene represented by $CF_3CF=CH_2$, and HFO-1234ze, which is 1,3,3,3-tetrafluoro-1-propene represented by $CF_3CH=CHF$) and difluoromethane (HFC-32) represented by the chemical formula of CH_2F_2. However, the substance to be mixed with the substance that undergoes disproportionation is not limited to these substances, and HC-290 (propane) or other substances may be mixed. Any substance that has thermal performance usable as a refrigerant for the refrigeration cycle apparatus 100 can be used. These substances can be mixed at any mixing ratio.

[0041] When the substance that undergoes disproportionation is used as a refrigerant as is, adjacent substance molecules may react with each other to form different substances caused by some high external energy. Therefore, when the substance that undergoes disproportionation is used as a refrigerant without taking measures in the refrigerant circuit, the substance changes into different substances. As a result, the substance not only fails to function as a refrigerant and but also may cause an accident such as a pipe burst because of a rapid increase in pressure due to heat generation. The disproportionation reaction is likely to occur particularly at a place where a substance in a liquid state is present, namely, where adjacent substance molecules are very close to each other, as for substances in a liquid state, a two-phase state, or other states. However, substances in a gaseous state also undergo a disproportionation reaction when receiving high energy. For use as a refrigerant, measures need to be taken to suppress the disproportionation reaction. The disproportionation reaction of the refrigerant is cause by external energy, such as by collision of the refrigerant with a structure or flow of current in the refrigerant.

[Compressor 10]

[0042] A hermetic compressor is used as the compressor 10. For example, a high pressure shell-type or low pressure shell-type rotary compressor or scroll compressor is used. Fig. 5 is a schematic diagram illustrating the structure of the compressor 10 according to Embodiment 1 of the present invention. Fig. 5 is a side view of the compressor 10 as viewed from the lateral side. The compressor 10 illustrated in Fig. 5 is a high pressure shell-type rotary compressor. The compressor 10 includes an inflow pipe 41 through which the refrigerant flows into the compressor 10, an outflow pipe 42 through which the refrigerant flows out of the compressor 10, a compression unit 43 that compresses the refrigerant, a motor 44 that is a driving source for the compressor 10, and a compressor shell 45 that is a sealed container enclosing the compression unit 43 and the motor 44. The motor 44 is disposed above the compression unit 43.

[0043] The motor 44 includes a stator 48 and a rotor 49. The stator 48 is fixed to the compressor shell 45. The rotor 49 is disposed inside the stator 48 and connected to a shaft 50. The compression unit 43 includes a rolling piston 51. The rolling piston 51 is fixed to the shaft 50 that is the same as that for the rotor 49, and rotation of the rotor 49 is transmitted to the rolling piston 51. The rolling piston 51 is eccentrically attached to the shaft 50.

[0044] In Fig. 5, the solid arrows indicate the flow direction of the refrigerant.

[0045] The refrigerant flows into the compressor 10 through the inflow pipe 41, passes through a suction port 46, and flows into the compression chamber 47 in the compression unit 43. The volume of the compression chamber 47 changes in accordance with rotation of the rolling piston 51 by way of the action of the rolling piston 51 eccentrically attached to the shaft 50, and the inflow refrigerant is compressed accordingly. The high-temperature, high-pressure gas refrigerant whose pressure has been increased by compression is ejected into the compressor shell 45 from the compression chamber 47. The gas refrigerant then flows around the motor 44 and flows out of the compressor 10 through the outflow pipe 42.

[0046] There are the following types of hermetic compressors: the high pressure shell-type described above and a low pressure shell-type. A low pressure shell-type compressor 10 includes a compression unit 43 and a motor 44 in a compressor shell 45 that is a sealed container. Refrigerant sucked into the low pressure shell-type compressor 10 flows into the compressor shell 45, so that the compressor shell 45 contains a low-pressure refrigerant atmosphere. The refrigerant in the compressor shell 45 is sucked and compressed in the compression chamber 47 in the compression unit 43. After compression is complete, the refrigerant is discharged out of the compressor shell 45 from the compression unit 43. In the low pressure shell-type compressor 10, for example, the compression unit 43 is disposed in the upper part, and the motor 44 is disposed in the lower part. For the low pressure shell-type compressor 10, when two-phase refrigerant flows into the compressor 10, a liquid component in the two-phase refrigerant is separated at the time when the refrigerant is allowed to flow into the compressor shell 45 before being sucked into the compression chamber 47. The liquid component flows around the motor 44 disposed below the compression unit 43 and drops into the lower part of the compressor 10. Since the liquid refrigerant, which has a small intermolecular distance, flows around the motor 44, a disproportionation reaction tends to occur. Thus, in the compressor shell 45 of the low pressure shell-type compressor 10, the disproportionation reaction of the refrigerant is likely to occur.

[0047] The high pressure shell-type compressor 10 has the above-described structure. Therefore, the gas refrigerant whose temperature has been increased by compression in the compression chamber 47 is discharged into the compressor shell 45 that is a space in which the motor 44 is exposed. The disproportionation reaction of the refrigerant tends to occur when the refrigerant is in a liquid state or in a two-phase state where the intermolecular distance is small. The disproportionation reaction is a chemical reaction. The higher the temperature, the faster the chemical reaction progresses (the reaction rate increases with increasing temperature) as widely known. Consequently, even if the refrigerant is in a gaseous state, the refrigerant tends to undergo a disproportionation reaction at high temperature, and the disproportionation reaction of the refrigerant is likely to occur in the compressor shell 45 of the high pressure shell-type compressor 10 (though not as likely to occur in the low pressure shell-type compressor).

[0048] As described above, in the compressor shell 45 of the low pressure shell-type compressor 10, liquid refrigerant, which has a small intermolecular distance, flows around the motor 44. The compressor shell 45 of the high pressure shell-type compressor 10 is filled with high-temperature gas refrigerant. Therefore, in any type of the compressor 10, the refrigerant tends to undergo a disproportionation reaction in the compressor shell 45.

[0049] In the compressor 10, which is a hermetic compressor, the motor 44 is exposed to a low-pressure refrigerant atmosphere or a high-pressure refrigerant atmosphere. Since current flows in the stator 48 and the rotor 49 in the motor 44, an insulation process is needed. Unless the motor 44 is insulated, current flows in the surrounding refrigerant, which not only may lead to a risk of electric leakage but also may cause a disproportionation reaction of the refrigerant by way of the energy of current.

[0050] As insulating materials for the motor 44, substances that are not physically or chemically modified by the refrigerant and especially have solvent resistance, extraction resistance, thermal and chemical stability, and blister resistance are preferably used. Insulating materials for the motor 44 are, for example, an insulating coating material for windings of the stator 48, an insulating film, an insulator for holding the windings, and an insulating tube. For all of these insulating materials, resin materials are used.

[0051] Specifically, as the insulating coating material for windings of the stator 48, at least one substance selected from polyvinyl formal, polyester, THEIC-modified polyester, polyamide, polyamide imide, polyester imide, and polyester amide imide is used. In addition, an enamel coating having a glass transition temperature of 120 degrees C or higher may be used.

[0052] For the insulating film for the stator 48, at least one substance selected from polyethylene terephthalate (PET), polyethylene naphthalate, polyphenylene sulfide (PPS), and polybutylene terephthalate (PBT) is used. As the insulating material for holding the windings, such as an insulator, at least one substance selected from polyether ether ketone (PEEK) and liquid-crystal polymer (LCP) is used. An epoxy resin is used as varnish. Furthermore, for the insulating tube for the stator 48, at least one substance selected from polytetrafluoroethylene (PTFE) and tetrafluoroethylene hexafluoropropylene copolymer resin (FEP) is used.

[0053] As described above, even if the refrigerant is in a gaseous state, the refrigerant tends to undergo a disproportionation reaction at high temperature in the compressor shell 45. The higher the temperature, the faster the disproportionation reaction progresses (the reaction rate increases with increasing temperature). In particular, the disproportionation reaction, which is a chemical reaction, is more likely to occur at a temperature of 50 degrees C or higher. In the refrigeration cycle apparatus including the high pressure shell-type compressor 10, the temperature of the refrigerant in the compressor shell 45 in the compressor 10 is 50 degrees C or higher in most of the time except starting time or other times at which the refrigerant is in a transient state. However, even in this state, the disproportionation reaction of the refrigerant can be suppressed if the motor 44 in the compressor 10 is insulated as described above. At a temperature of 80 degrees C, the disproportionation reaction is still more likely to occur.

[0054] Here, a discussion is made on the use of a refrigerating machine oil miscible with the refrigerant in the refrigeration cycle. The solubility of the refrigerant with respect to a miscible refrigerating machine oil increases with decreasing temperature under the same pressure condition and increases with increasing pressure under the same temperature condition. When the refrigerant is dissolved in the refrigerating machine oil, refrigerating machine oil molecules are present so as to be incorporated between refrigerant molecules. That is, when the solubility of the refrigerant with respect to the refrigerating machine oil is large, the refrigerating machine oil is present between a large amount of refrigerant molecules. The disproportionation reaction of the refrigerant is a phenomenon in which adjacent refrigerant molecules react with each other. If the refrigerating machine oil miscible with the refrigerant is used, refrigerating machine oil molecules are present between refrigerant molecules, and the refrigerant is less likely to undergo a disproportionation reaction.

[0055] To suppress the disproportionation reaction of the refrigerant, a larger solubility of the refrigerant with respect to the refrigerating machine oil is more effective. Practically, as long as the solubility of the refrigerant with respect to the refrigerating machine oil is 50 wt% or more in the case where the refrigerant is a liquid state or a two-phase state, a large amount of the refrigerant is dissolved in the refrigerating machine oil, which suppresses the disproportionation reaction. Therefore, when the low pressure shell-type compressor 10 is used as the compressor 10, and the solubility of the refrigerant with respect to the refrigerating machine oil is 50 wt% or more in a state where, for example, the temperature of the refrigerant in the compressor shell 45 is 0 degrees C and the pressure of the refrigerant is a saturation pressure at a refrigerant temperature of 0 degrees C, the disproportionation reaction of the refrigerant can be sufficiently suppressed even if the two-phase refrigerant flows in.

[0056] As described above, the refrigerant in a liquid state or a two-phase state is most likely to undergo a disproportionation reaction. The refrigerant that is even in a gaseous state but has a high temperature, particularly a temperature of 50 degrees C or higher, and further 80 degrees C or higher, is likely to undergo a disproportionation reaction, which is a chemical reaction. However, the refrigerant in a liquid state or a two-phase state is more likely to undergo a disproportionation reaction than the refrigerant in a gaseous state. Although the refrigerant in a gaseous state is also dissolved in the miscible refrigerating machine oil, the solubility needed to suppress the disproportionation reaction of the refrigerant in a high-temperature gaseous state is smaller than that for the refrigerant in a liquid state or a two-phase state. Practically, as long as the solubility of the refrigerant in a gaseous state is 10 wt% or more, the disproportionation reaction of the refrigerant in a rather high temperature gaseous state can be suppressed. Therefore, when the high pressure shell-type compressor 10 is used as the compressor 10, and the solubility of the refrigerant with respect to the refrigerating machine oil is 10 wt% or more in a state where, for example, the temperature of the refrigerant in the compressor shell 45 is 80 degrees C, and the pressure of the refrigerant is a saturation pressure at a refrigerant temperature of 50 degrees C, the disproportionation reaction of the refrigerant can be sufficiently suppressed.

[0057] As the refrigerating machine oil of Embodiment 1, a refrigerating machine oil having a relatively large volume resistivity is used. For example, the volume resistivity of the refrigerating machine oil is $2 \times 10^{10}\ \Omega\cdot m$ or higher at 20 degrees C. Therefore, when a miscible oil is used as the refrigerating machine oil, the volume resistivity of a fluid mixture composed of the refrigerant and the refrigerating machine oil in the compressor shell 45 of the compressor 10 is relatively large. Therefore, in the compressor 10, the current leaked from the motor 44 is relatively low, and furthermore the refrigerant is unlikely to undergo a disproportionation reaction.

[0058] As the refrigerating machine oil, an oil containing one selected from polyol ester and polyvinyl ether as a main component is used. Polyol ester and polyvinyl ether are both refrigerating machine oils having a relatively high volume resistivity and miscibility with and solubility with respect to a refrigerant having one double bond in the molecular structure.

[0059] In Embodiment 1, an example case in which the compression unit 43 is disposed in the lower part and the motor 44 is disposed in the upper part in the compressor shell 45 of the compressor 10 is described. The configuration is not limited to this, and the compression unit 43 may be disposed in the upper part and the motor 44 may be disposed in the lower part. This configuration applies to both a high pressure shell-type compressor and a low pressure shell-type compressor.

[0060] The compressor 10 is described by providing a rotary compressor as an example. However, the compressor 10 is not limited to this type. Any type of compressor, such as a scroll compressor or a screw compressor, may be used, and the same advantageous effects are obtained.

[Accumulator 19]

[0061] Fig. 6 is a schematic diagram illustrating the structure of an accumulator 19 according to Embodiment 1 of the present invention. Fig. 6 is a side view of the accumulator 19 as viewed from the lateral side. The accumulator 19 includes an inflow pipe 52, an outflow pipe 53, an oil return port 54 provided on the outflow pipe 53, and an accumulator shell 55 for the accumulator 19. The accumulator 19 has a structure in which the inflow pipe 52 and the outflow pipe 53 are inserted into the accumulator shell 55. In Fig. 6, the solid arrows indicate the flow direction of the refrigerant. The refrigerant flows in through the inflow pipe 52 and is released into the accumulator shell 55, so that the volume of the refrigerant increases. The refrigerant then flows out through the outflow pipe 53. The inlet of the outflow pipe 53 is located higher than the outlet of the inflow pipe 52 and positioned such that the refrigerant that has flowed in through the inflow pipe 52 does not directly enter the outflow pipe 53 by way of inertia force and gravity.

[0062] The inflow pipe 52 is inserted into the accumulator shell 55 from above and laterally bents in the accumulator shell 55. The outlet of the inflow pipe 52 is located slightly apart from the inner wall surface of the accumulator shell 55 and without contact with the inner wall surface of the accumulator shell 55. The outlet of the inflow pipe 52 is directed toward the inner wall surface of the accumulator shell 55. Directing the inflow pipe 52 toward the inner wall surface of the accumulator shell 55 has the following function: the refrigerant that has flowed in through the inflow pipe 52 collides with the inner wall surface of the accumulator shell 55 to separate a liquid component in the two-phase refrigerant and the refrigerating machine oil in the accumulator shell 55, and the liquid component and the refrigerating machine oil are stored in the lower part of the accumulator shell 55 by way of gravity.

[0063] The oil return port 54 provided on the outflow pipe 53 has the following function: a refrigerant solution in which the refrigerating machine oil is dissolved and that is stored in the lower part of the accumulator shell 55 is allowed to flow into the outflow pipe 53, and the refrigerating machine oil is returned to the compressor 10. Since the refrigerant is dissolved in the refrigerating machine oil at this time, the refrigerant also flows out together with the refrigerating machine oil through the oil return port 54, and is sucked into the compressor 10. Thus, the refrigerant in a two-phase state having a quality of more than 0 and less than 1 is sucked into the compressor 10. Therefore, when the low pressure shell-type compressor is used and excess refrigerant is generated in the refrigeration cycle, the refrigerant in a two-phase state having a quality of more than 0 and less than 1 flows into the compressor shell 45 and this refrigerant flows around the motor 44. That is, when the oil return port 54 is provided in the accumulator 19, the refrigerant in a two-phase state having a quality of more than 0 and less than 1 flows into the compressor 10.

[0064] In the accumulator 19, low-temperature, low-pressure gas refrigerant flows in in cooling operation, and excess refrigerant is generated in the refrigerant circuit in heating operation. Thus, two-phase refrigerant including gas refrigerant and liquid refrigerant flows into the accumulator 19. In a refrigeration cycle apparatus, such as a multi-air-conditioning apparatus having multiple indoor units 2, excess refrigerant is generated even in cooling operation depending on, for example, the number of the indoor units 2 in operation, and two-phase refrigerant may flow into the accumulator 19.

[0065] In Embodiment 1, the accumulator 19 including the accumulator shell 55 having a longitudinal (vertically long) shape is illustrated. However, the accumulator shell 55 may have any shape, such as a horizontally long shape.

[0066] In Embodiment 1, the case where the accumulator 19 that stores excess refrigerant is provided in the refrigerant circuit is described. When the amount of excess refrigerant is small, such as in the case where the extension pipes 4 are short or when the number of the indoor unit 2 is one, the accumulator 19 is not necessarily provided. When the accumulator 19 is not provided, two-phase refrigerant directly flows into the compressor 10 depending on the operational state.

[Extension Pipe 4]

[0067] As described above, the refrigeration cycle apparatus 100 according to Embodiment 1 has several operation modes. In these operation modes, the refrigerant flows in the extension pipes 4 by which the outdoor unit 1 is connected to the indoor units 2.

[0068] The high-pressure detecting device 37 and the low-pressure detecting device 38 are provided to control the high pressure and the low pressure of the refrigeration cycle at target values, but a temperature detecting device that detects a saturation temperature may be disposed.

[0069] The first refrigerant flow switching device 11 is described like a four-way valve, but is not limited to this. The first refrigerant flow switching device 11 may include multiple two-way passage switching valves or multiple three-way passage switching valves so that the refrigerant flows similarly.

[0070] Typically, the heat source-side heat exchanger 12 and the load-side heat exchangers 15a to 15d may be often provided with a fan so that condensation or evaporation is accelerated by air blowing. The heat source-side heat exchanger 12 and the load-side heat exchangers 15a to 15d are not limited to this type. For example, a device such as a panel heater using radiation can be also used as the load-side heat exchangers 15a to 15d, and a water-cooled device that transfers heat with water or an antifreeze can be used as the heat source-side heat exchanger 12. Any heat exchanger having a structure capable of rejecting heat and absorbing heat can be used.

[0071] The case where there are four load-side heat exchangers 15a to 15d is described here as an example, but any number of load-side heat exchangers may be connected. Furthermore, multiple outdoor units 1 may be connected to form one refrigeration cycle.

[0072] The cooling/heating switching-type refrigeration cycle apparatus 100 in which the indoor units 2 perform only either cooling operation or heating operation is described as an example, but the refrigeration cycle apparatus 100 is not limited to this type. The refrigeration cycle apparatus may, for example, allow the operation of the indoor units 2 to be freely selected from the cooling operation and the heating operation and may perform, as the entire system, mixed operation of the cooling operation by indoor units 2 and the heating operation by indoor units 2. As a result, the refrigeration cycle apparatus provides the same advantageous effects.

[0073] In addition, the refrigeration cycle apparatus may be an air-conditioning apparatus, such as a room air-conditioning apparatus including only one indoor unit 2 connected, a refrigeration cycle apparatus including a showcase or a unit cooler connected, or other apparatuses. Any refrigeration cycle apparatus using a refrigeration cycle provides the same advantageous effects.

[0074] The refrigeration cycle apparatus may have a structure in which, for example, plate heat exchangers that exchange heat with water or an antifreeze or the like are used as the load-side heat exchangers 15 and water or the antifreeze or the like subjected to heat exchange is circulated in the indoor units 2 to supply temperature-controlled air to a target space.

Reference Signs List

[0075]

1 heat source unit (outdoor unit) 2a, 2b, 2c, 2d indoor unit 4 extension pipe (refrigerant pipe)6 outdoor space 7 indoor space 8 outdoor space such as space above ceiling, and space different from indoor space 9 structure such as building 10 compressor 11 first refrigerant flow switching device (four-way valve) 12 heat source-side heat exchanger 15, 15a, 15b, 15c, 15d load-side heat exchanger 16, 16a, 16b, 16c, 16d expansion device 19 accumulator 27 load-side-heat-exchanger liquid refrigerant temperature detecting device 28 load-side-heat-exchanger gas refrigerant temperature detecting device 37 high-pressure detecting device 38 low-pressure detecting device 41 inflow pipe 42 outflow pipe 43 compression unit 44 motor 45 compressor shell 46 suction port 47 compression chamber 48 stator 49 rotor 50 shaft 51 rolling piston52 inflow pipe 53 outflow pipe 54 oil return port 55 accumulator shell 60 controller 100 refrigeration cycle apparatus

Claims

1. A refrigeration cycle apparatus comprising a refrigeration cycle in which a compressor, a first heat exchanger, an expansion device, and a second heat exchanger are connected by refrigerant pipes to circulate refrigerant,
the refrigerant being a single-component refrigerant composed of a substance that undergoes disproportionation or a refrigerant mixture containing a substance that undergoes disproportionation and another substance,
the compressor having, in a sealed container thereof, a compression chamber and a motor,
the motor being insulated with a resin material serving as an insulating material.

2. The refrigeration cycle apparatus of claim 1, wherein the substance that undergoes disproportionation is 1,1,2-trifluoroethylene.

3. The refrigeration cycle apparatus of claim 1 or 2, wherein the insulating material for the motor is at least one substance of a group comprising polyvinyl formal, polyester, THEIC-modified polyester, polyamide, polyamide imide, polyester imide, polyester amide imide, polyethylene terephthalate, polyethylene naphthalate, polyphenylene sulfide, polybutylene terephthalate, polyether ether ketone, liquid-crystal polymer, epoxy resin, polytetrafluoroethylene, and tetrafluoroethylene hexafluoropropylene copolymer resin.

4. The refrigeration cycle apparatus of any one of claims 1 to 3, wherein
the compressor is a low pressure shell-type compressor configured to cause the refrigerant to flow into the sealed container, compress the refrigerant in the sealed container by using the compression chamber, and discharge the compressed refrigerant out of the sealed container, and
the refrigeration cycle apparatus is operable at an operational state in which the refrigerant in a two-phase state having a quality of more than 0 and less than 1 is allowed to flow into the sealed container of the compressor.

5. The refrigeration cycle apparatus of any one of claims 1 to 3, wherein
the compressor is a high pressure shell-type compressor configured to cause the refrigerant to flow into the compression chamber, compress the refrigerant flowing into the compression chamber by using the compression chamber, discharge the compressed refrigerant into the sealed container, and discharge the refrigerant in the sealed container to outside the sealed container, and
the refrigeration cycle apparatus is operable at an operational state in which the refrigerant at 50 degrees C or higher is discharged into the sealed container from the compression chamber in the compressor.

6. The refrigeration cycle apparatus of any one of claims 1 to 5, wherein the refrigeration cycle circulates a refrigerating machine oil miscible with the refrigerant.

7. The refrigeration cycle apparatus of claim 6, wherein the refrigerating machine oil contains either of polyol ester and polyvinyl ether as a main component.

8. The refrigeration cycle apparatus of claim 6 or 7, wherein the refrigerating machine oil has a volume resistivity of 2×10^{10} $\Omega \cdot m$ or higher at 20 degrees C.

9. The refrigeration cycle apparatus of any one of claim 4, claim 6 as dependent on claim 4, and claim 7 as dependent on claim 4, wherein the refrigerating machine oil has a solubility of 50 wt% or more with respect to the refrigerant when a temperature of the refrigerant is 0 degrees C and a pressure of the refrigerant is a saturation pressure at a refrigerant temperature of 0 degrees C.

10. The refrigeration cycle apparatus of any one of claim 5, claim 6 as dependent on claim 5, and claim 7 as dependent on claim 5, wherein the refrigerating machine oil has a solubility of 10 wt% or more with respect to the refrigerant when a temperature of the refrigerant is 80 degrees C and a pressure of the refrigerant is a saturation pressure at a refrigerant temperature of 50 degrees C.

FIG. 1

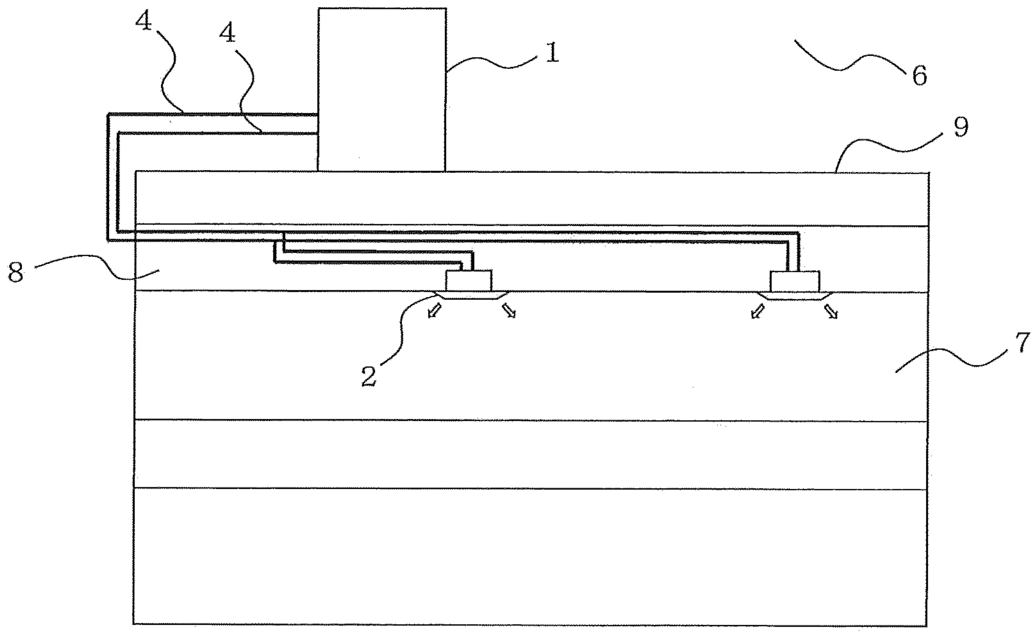

FIG. 2

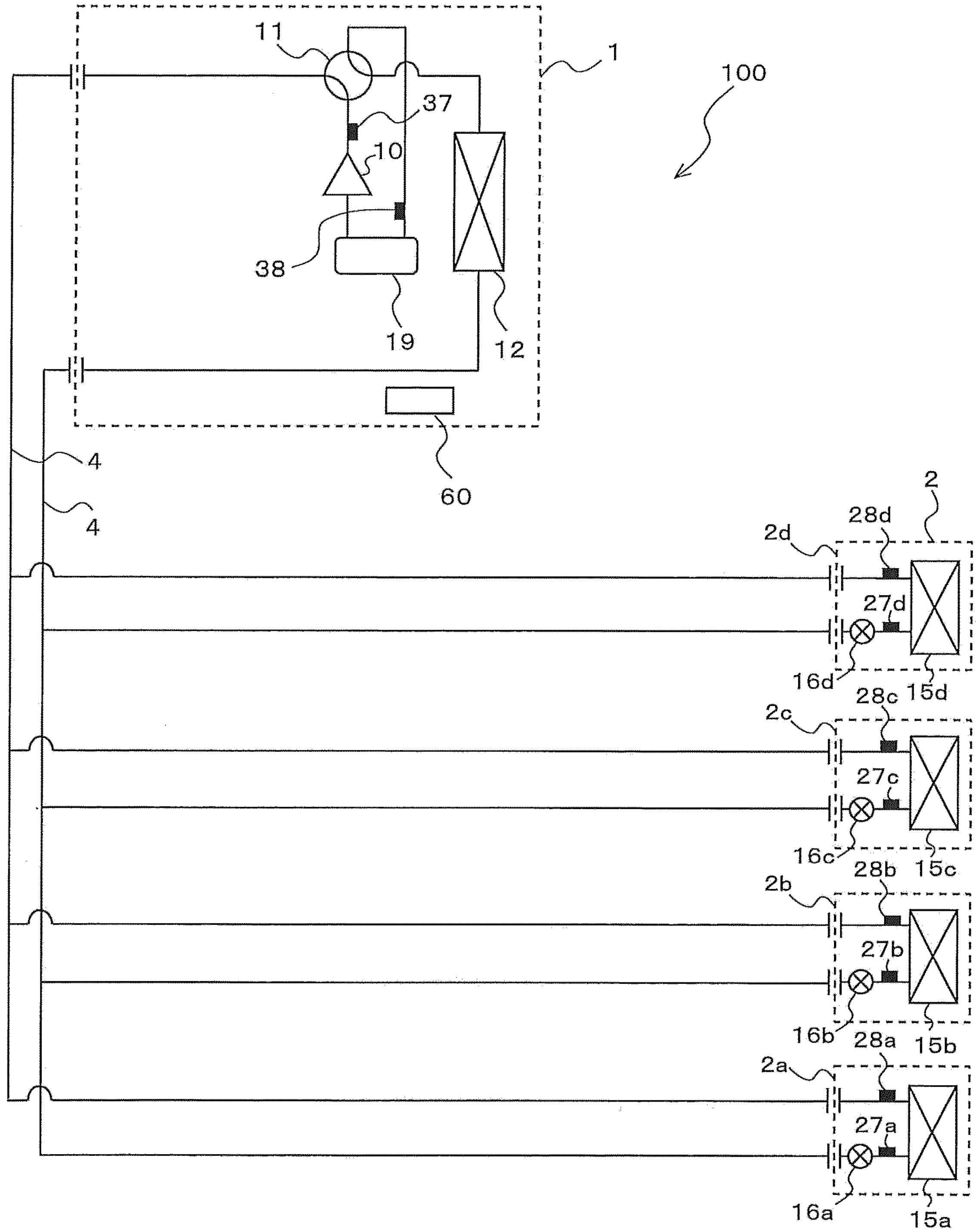
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FIG. 3

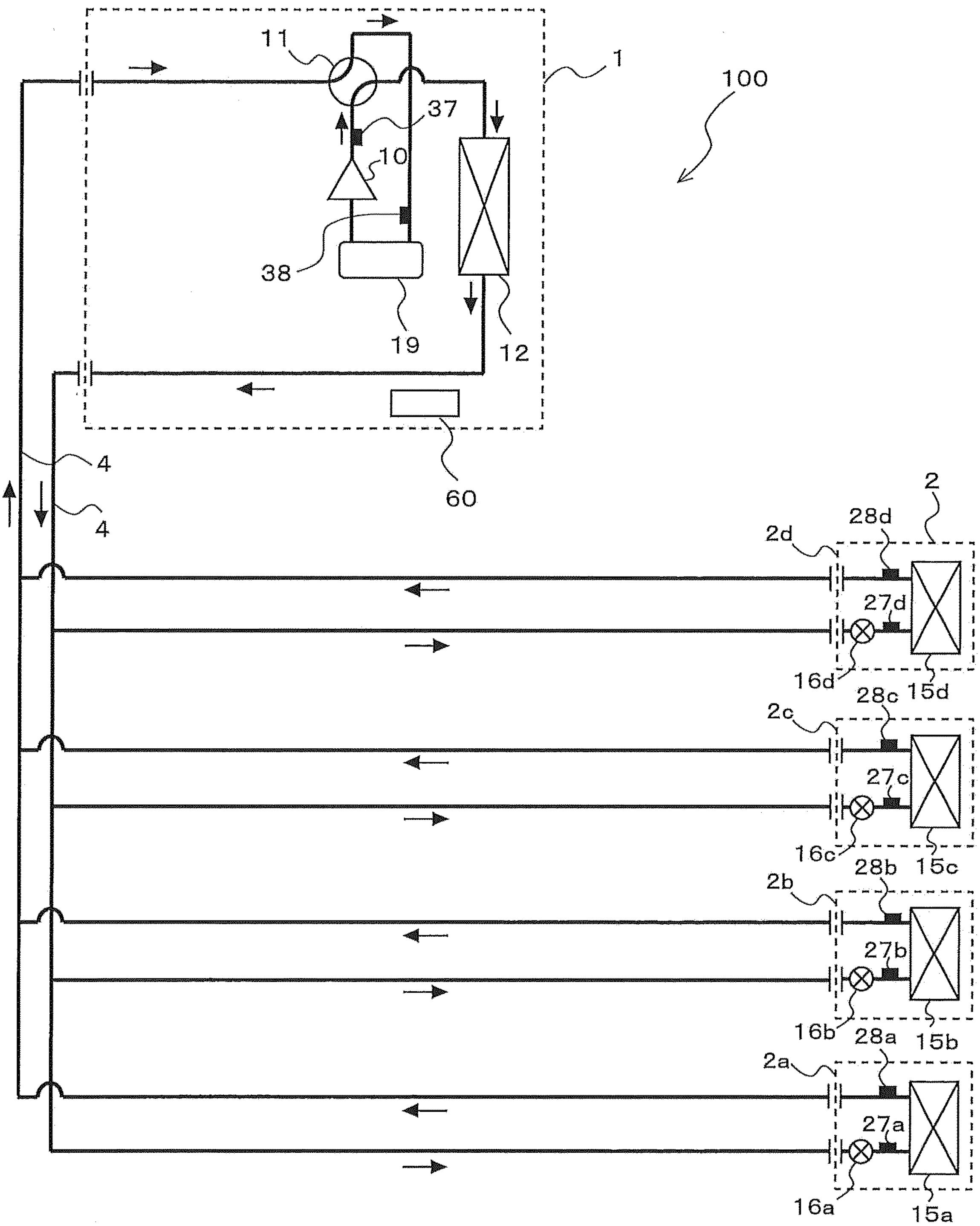
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FIG. 4

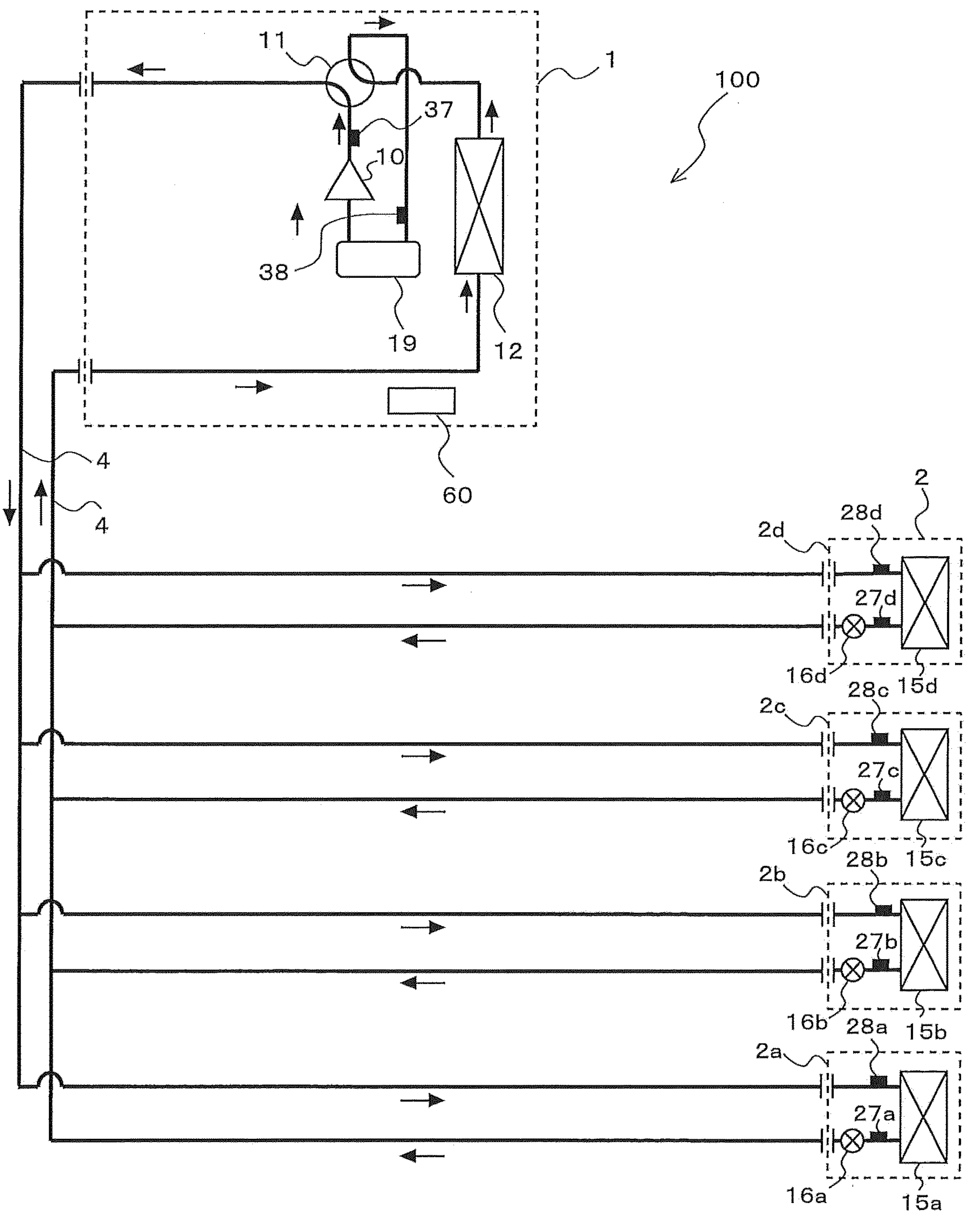
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FIG. 5

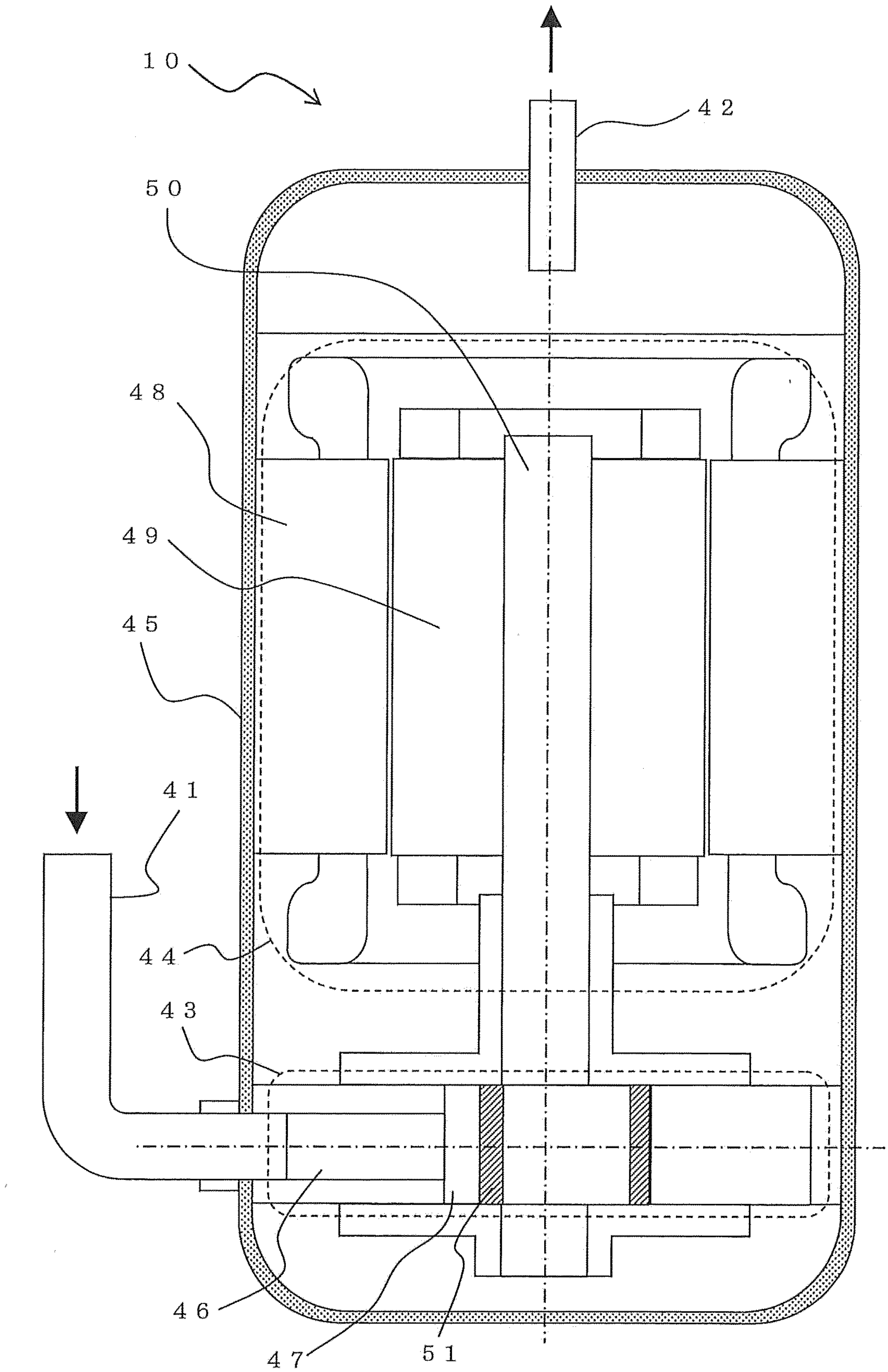
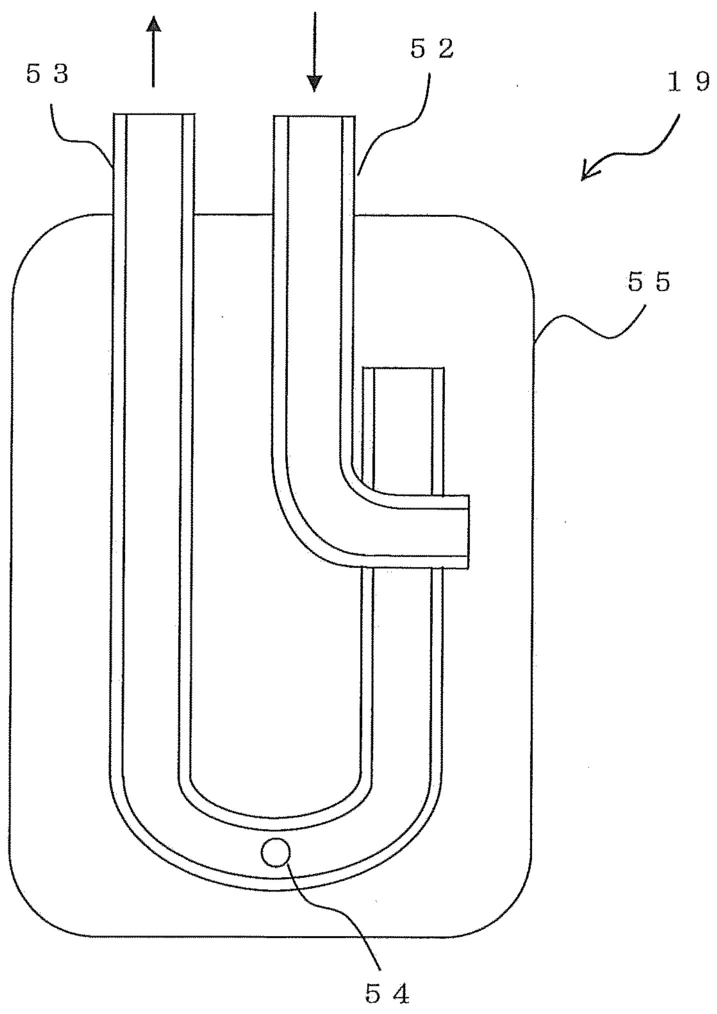


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/057041

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(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)
F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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 Y	JP 2012-131994 A (JX Nippon Oil & Energy Corp.), 12 July 2012 (12.07.2012), paragraphs [0018] to [0142] & US 2012/0132848 A1 & CN 102533392 A	1-3,6-7 1-10
Y	WO 2012/157764 A1 (Asahi Glass Co., Ltd.), 22 November 2012 (22.11.2012), paragraphs [0001] to [0036] (Family: none)	1-10
Y	JP 2010-156524 A (Mitsubishi Electric Corp.), 15 July 2010 (15.07.2010), paragraphs [0004], [0023] to [0034] (Family: none)	4-5,8-10

☒ 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	Date of mailing of the international search report
29 May, 2014 (29.05.14)	10 June, 2014 (10.06.14)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2013-124800 A (Panasonic Corp.), 24 June 2013 (24.06.2013), paragraphs [0002] to [0003], [0034] to [0050] & WO 2013/088638 A1	4-5,8-10
Y	JP 2013-11391 A (Panasonic Corp.), 17 January 2013 (17.01.2013), paragraphs [0009] to [0025] (Family: none)	4-5,8-10

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REFERENCES CITED IN THE DESCRIPTION

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