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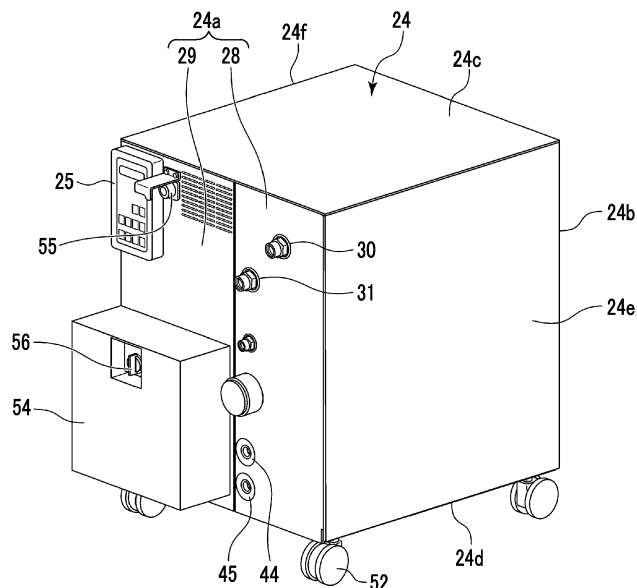
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(54) CRYOCOOLER COMPRESSOR

(57) The task is to facilitate a work of removing a control panel (50) in a cryocooler compressor (12). A compressor (12) for a cryocooler (10) includes a control panel (50), and a compressor casing (24) that includes a front panel (24a) and accommodates the control panel (50). The front panel (24a) includes a first panel portion

(28) that provides a pipe connection, and a second panel portion (29) that is removably connected to the first panel portion (28) and on which the control panel (50) is mounted. The control panel (50) may be able to be extracted forward from the compressor casing (24) together with the second panel portion (29).

FIG. 2

Description**BACKGROUND OF THE INVENTION****Field of the Invention**

[0001] The present invention relates to a cryocooler compressor.

Description of Related Art

[0002] In general, a cryocooler such as a Gifford-McMahon (GM) cryocooler includes a compressor of a refrigerant gas to supply a high-pressure refrigerant gas to a cold head. The compressor includes components such as a compressor main body, an oil separator, an adsorber, a storage tank, and a control device (for example, Japanese Unexamined Patent Publication No. 2001-74326).

SUMMARY OF THE INVENTION

[0003] In an existing cryocooler compressor, a pipe for supplying a refrigerant gas to a cold head and a pipe for collecting the refrigerant gas from the cold head can be connected to a front panel of a compressor casing. In addition, a pipe for supplying a coolant to a heat exchanger installed in the compressor casing to cool the compressor and a pipe for collecting the coolant from the heat exchanger can also be connected to the front panel. A control panel of the compressor can be disposed behind the front panel in the compressor casing.

[0004] In the compressor with such a casing design, when a worker removes the control panel, the worker first removes the front panel from the compressor casing. However, in order to remove the front panel, it is necessary to discharge the refrigerant gas from the pipe for the refrigerant gas and to discharge the coolant from the pipe for the coolant, and then to remove these pipes from the front panel. In addition, another compressor component such as an adsorber may be fastened to the front panel, and in this case, it is necessary to remove the other compressor component beforehand from the front panel. Therefore, in the existing design, the work of removing the control panel from the compressor requires a preliminary process such as disassembling the compressor into individual parts, which is quite laborious.

[0005] An exemplary object of one embodiment of the present invention is to facilitate work of removing a control panel in a cryocooler compressor.

[0006] According to an aspect of the present invention, there is provided a cryocooler compressor including a control panel, and a compressor casing that includes a front panel and accommodates the control panel. The front panel includes a first panel portion that provides a pipe connection, and a second panel portion that is removably connected to the first panel portion and on which the control panel is mounted.

[0007] According to the present invention, it is possible to facilitate work of removing the control panel in the cryocooler compressor.

BRIEF DESCRIPTION OF THE DRAWINGS**[0008]**

Fig. 1 is a diagram schematically showing a cryocooler according to an embodiment.

Fig. 2 is a schematic perspective view showing an appearance of a compressor according to the embodiment.

Fig. 3 is a schematic perspective view showing disposition of devices inside the compressor according to the embodiment.

Fig. 4 is a schematic perspective view showing the disposition of the devices inside the compressor according to the embodiment.

Fig. 5 is a plan view schematically showing a part of a front panel of a compressor casing according to the embodiment.

Fig. 6 is a side view schematically showing a part of the front panel of the compressor casing according to the embodiment.

Fig. 7 is a schematic plan view showing a back surface of a control panel according to the embodiment.

Fig. 8 is a schematic top view showing a passage region of the control panel according to the embodiment.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Hereinafter, an embodiment for carrying out the present invention will be described in detail with reference to the drawings. In the description and the drawings, the same or equivalent components, members, and processes are denoted by the same reference numerals, and overlapping description is omitted as appropriate. The scale and the shape of each of parts shown in the drawings are set for convenience to make the description easy to understand, and are not to be interpreted as limiting unless stated otherwise. The embodiment is merely an example and does not limit the scope of the present invention. All features described in the embodiment or combinations thereof are not necessarily essential to the present invention.

[0010] Fig. 1 is a diagram schematically showing a cryocooler 10 according to the embodiment. The cryocooler 10 is used to provide cryogenic cooling to an object or a medium. For example, the cryocooler 10 may be used as a cooling source for a superconducting magnet device. The superconducting magnet device is mounted on, for example, a high magnetic field using device as a magnetic field source of an accelerator such as a single crystal pulling device, a nuclear magnetic resonance (NMR) system, a magnetic resonance imaging (MRI)

system, and a cyclotron, a high energy physical system such as a nuclear fusion system, or other high magnetic field using devices (not shown) and can generate a high magnetic field required for the devices.

[0011] The cryocooler 10 includes a compressor 12 and a cold head 14. The compressor 12 is configured to collect a refrigerant gas of the cryocooler 10 from the cold head 14, to pressurize the collected refrigerant gas, and to supply the refrigerant gas to the cold head 14 again. The compressor 12 is also referred to as a compressor unit. The cold head 14 is also referred to as an expander and includes a room temperature section 14a and a low-temperature section 14b which is also referred to as a cooling stage. The refrigerant gas is also referred to as a working gas, and other suitable gases may be used although a helium gas is typically used. The compressor 12 and the cold head 14 constitute a refrigeration cycle of the cryocooler 10, whereby the low-temperature section 14b is cooled to a desired cryogenic temperature. The low-temperature section 14b can cool an object to be cooled such as a superconducting magnet.

[0012] Although the cryocooler 10 is, for example, a single-stage or two-stage Gifford-McMahon (GM) cryocooler, the cryocooler 10 may be a pulse tube cryocooler, a Stirling cryocooler, or other types of cryocoolers. Although the cold head 14 has a different configuration depending on the type of the cryocooler 10, the compressor 12 can use a configuration described below regardless of the type of the cryocooler 10.

[0013] In general, both a pressure of a refrigerant gas supplied from the compressor 12 to the cold head 14 and a pressure of a refrigerant gas collected from the cold head 14 to the compressor 12 are considerably higher than the atmospheric pressure, and can be called a first high pressure and a second high pressure, respectively. For convenience of description, the first high pressure and the second high pressure are also simply called a high pressure and a low pressure, respectively. Typically, the high pressure is, for example, 2 to 3 MPa. The low pressure is, for example, 0.5 to 1.5 MPa and is, for example, about 0.8 MPa.

[0014] The compressor 12 is an oil-lubricated cryocooler compressor, and includes a compressor main body 16, a refrigerant gas line 18, and an oil circulation line 20. In Fig. 1, in order to facilitate understanding, the refrigerant gas line 18 is shown by a solid line, and the oil circulation line 20 is shown by a broken line. In addition, the compressor 12 includes a compressor casing 24 that accommodates each component of the compressor 12, such as the compressor main body 16, the refrigerant gas line 18, and the oil circulation line 20.

[0015] The compressor main body 16 is configured to internally compress a refrigerant gas sucked from a suction port of the compressor main body 16 and to discharge the refrigerant gas from a discharge port. An oil is used in the compressor main body 16 for the sake of cooling and lubrication, and the sucked refrigerant gas is directly exposed to the oil in the compressor main body

16. Accordingly, the refrigerant gas is delivered from the discharge port in a state where the oil is slightly mixed.

[0016] The compressor main body 16 may be, for example, a scroll type pump, a rotary type pump, or other pumps that pressurize a refrigerant gas. The compressor main body 16 may be configured to discharge the refrigerant gas at a fixed and constant flow rate. Alternatively, the compressor main body 16 may be configured to vary the flow rate of the refrigerant gas to be discharged. The compressor main body 16 may be called a compression capsule.

[0017] The refrigerant gas line 18 includes a discharge port 30, a suction port 31, a discharge flow path 32, and a suction flow path 33. The discharge port 30 is an outlet of a refrigerant gas that is installed in the compressor casing 24 in order to deliver the refrigerant gas, which is pressurized to a high pressure by the compressor main body 16, from the compressor 12, and the suction port 31 is an inlet of the refrigerant gas that is installed in the compressor casing 24 in order for the compressor 12 to receive a low-pressure refrigerant gas. The compressor casing 24 accommodates the discharge flow path 32 and the suction flow path 33. The discharge port of the compressor main body 16 is connected to the discharge port 30 by the discharge flow path 32, and the suction port 31 is connected to the suction port of the compressor main body 16 by the suction flow path 33.

[0018] The refrigerant gas line 18 is connected to the cold head 14. A high-pressure port 40 and a low-pressure port 41 are provided in the room temperature section 14a of the cold head 14. The high-pressure port 40 is connected to the discharge port 30 by a high-pressure pipe 42, and the low-pressure port 41 is connected to the suction port 31 by a low-pressure pipe 43.

[0019] The oil separator 34 and the adsorber 35 are provided in the discharge flow path 32. The oil separator 34 is provided in order to separate an oil, which is mixed in a refrigerant gas as passing through the compressor main body 16, out from the refrigerant gas. The adsorber 35 is provided in order to remove, for example, a vaporized oil and other contaminants remaining in the refrigerant gas from the refrigerant gas through adsorption. The oil separator 34 and the adsorber 35 are connected in series. In the discharge flow path 32, the oil separator 34 is disposed on the compressor main body 16 side, and the adsorber 35 is disposed on the discharge port 30 side.

[0020] An oil return line 21 that connects the oil separator 34 to the compressor main body 16 is provided. An oil collected by the oil separator 34 can be returned to the compressor main body 16 through the oil return line 21. In the middle of the oil return line 21, a filter that removes dust included in the oil separated out by the oil separator 34 and an orifice that controls the amount of the oil returning to the compressor main body 16 may be provided.

[0021] On the other hand, a storage tank 36 is provided at the suction flow path 33. The storage tank 36 is provided as a volume for removing pulsation included

in a low-pressure refrigerant gas returning from the cold head 14 to the compressor 12.

[0022] In addition, a bypass valve 38 that connects the discharge flow path 32 to the suction flow path 33 to bypass the compressor main body 16 is provided at the refrigerant gas line 18. For example, the bypass valve 38 branches off from the discharge flow path 32 between the oil separator 34 and the adsorber 35 and is connected to the suction flow path 33 between the compressor main body 16 and the storage tank 36. The bypass valve 38 is provided in order to control a flow rate of a refrigerant gas and/or in order to equalize the discharge flow path 32 and the suction flow path 33 when the compressor 12 is stopped.

[0023] The oil circulation line 20 connects an oil outlet to an oil inlet of the compressor main body 16 in order to return the oil flowing out from the compressor main body 16 to the compressor main body 16 again. The oil circulation line 20 may be provided with an orifice that controls a flow rate of an oil flowing therein. In addition, a filter that removes dust included in the oil may be provided at the oil circulation line 20.

[0024] In addition, the compressor 12 further includes a heat exchanger 22 that is accommodated in the compressor casing 24 and cools the compressor 12. The heat exchanger 22 includes a refrigerant gas cooler 22a that cools the refrigerant gas line 18 through heat exchange between the refrigerant gas and a cooling medium, and an oil cooler 22b that cools the oil circulation line 20 through heat exchange between the oil and the cooling medium.

[0025] The refrigerant gas cooler 22a is disposed between the compressor main body 16 and the oil separator 34 in the discharge flow path 32, and cools a high-pressure refrigerant gas heated by compression heat generated with the compression of the refrigerant gas in the compressor main body 16. The refrigerant gas cooler 22a cools the refrigerant gas through heat exchange between the refrigerant gas and the cooling medium. The cooled refrigerant gas is purified by the oil separator 34 and the adsorber 35. In addition, the oil cooler 22b cools the oil through heat exchange between the oil flowing out from the oil outlet of the compressor main body 16 to the oil circulation line 20 and the cooling medium. The cooled oil is returned into the compressor main body 16 from the oil inlet of the compressor main body 16. The cooling medium is supplied from the outside to the compressor 12 through a cooling medium intake 44, and is discharged to the outside of the compressor 12 from a cooling medium discharge port 45 via the refrigerant gas cooler 22a and the oil cooler 22b. The cooling medium may be a coolant, for example, water. In this manner, compression heat generated by the compressor main body 16 is removed to the outside of the compressor 12 together with the cooling medium. The cooling medium may be cooled by, for example, a chiller (not shown) and may be supplied again.

[0026] In this embodiment, the heat exchanger 22 is a

double pipe-type heat exchanger. Therefore, the heat exchanger 22 includes an outer tube and an inner tube inserted into the outer tube. The cooling medium is supplied to one of the outer tube and the inner tube, a fluid to be cooled is supplied to the other. Accordingly, heat exchange between the cooling medium and the target fluid is performed, and the fluid can be cooled. For example, in the refrigerant gas cooler 22a, cooling water may be supplied to the outer tube, and the refrigerant gas may be supplied to the inner tube. In the oil cooler 22b, cooling water may be supplied to the outer tube, and oil may be supplied to the inner tube.

[0027] During an operation of the cryocooler 10, a refrigerant gas is supplied from the compressor 12 to the cold head 14, a refrigeration cycle (for example, a GM cycle) is configured by a periodic volume fluctuation of an expansion space of the refrigerant gas in the cold head 14 and a pressure fluctuation of the refrigerant gas in the expansion space synchronized with the periodic volume fluctuation, and the low-temperature section 14b of the cold head 14 is cooled to a desired cryogenic temperature. In a case where the cold head 14 is, for example, a two-stage type, a first-stage cooling stage is cooled to a first cooling temperature in a range of, for example, about 30 K to about 80 K, and a second-stage cooling stage is cooled to a second cooling temperature lower than the first cooling temperature, for example, 1 K to 20 K. The second cooling temperature may be a liquid helium temperature of about 4.2 K or a temperature lower than the liquid helium temperature.

[0028] A refrigerant gas collected from the cold head 14 to the compressor 12 flows into the suction port 31 of the compressor 12 from the low-pressure port 41 through the low-pressure pipe 43. The refrigerant gas is collected to the suction port of the compressor main body 16 via the storage tank 36 on the suction flow path 33. The refrigerant gas is compressed and pressurized by the compressor main body 16. In this case, a temperature of the refrigerant gas is raised by compression heat. The refrigerant gas delivered from the discharge port of the compressor main body 16 is cooled by the refrigerant gas cooler 22a of the heat exchanger 22, and exits the compressor 12 from the discharge port 30 via the oil separator 34 and the adsorber 35. The refrigerant gas is supplied into the cold head 14 via the high-pressure pipe 42 and the high-pressure port 40.

[0029] Fig. 2 is a schematic perspective view showing an appearance of the compressor 12 according to the embodiment. Figs. 3 and 4 are schematic perspective views showing the disposition of the devices inside the compressor 12 according to the embodiment. Figs. 2 and 3 are perspective views of the compressor 12 seen from a front side, and Fig. 4 is a perspective view of the compressor 12 seen from a rear side. Figs. 3 and 4 show a state in which some panels of the compressor casing 24 are removed in order to show the disposition of the internal devices of the compressor 12.

[0030] As shown in Fig. 2, the compressor casing 24 of

the compressor 12 has a rectangular parallelepiped shape having six surfaces, and includes a front panel 24a, a back panel 24b, an upper panel 24c, a bottom panel 24d, and two side panels 24e and 24f on left and right sides. The back panel 24b faces an opposite side of the front panel 24a. Between the front panel 24a and the back panel 24b, the upper panel 24c is disposed above, the bottom panel 24d is disposed below, and the side panels 24e and 24f are disposed on the left and right sides.

[0031] The front panel 24a includes two panel portions combined with each other to form the front panel 24a, specifically, a first panel portion 28 and a second panel portion 29. The first panel portion 28 provides a pipe connection, and the second panel portion 29 provides a user interface and an electrical connection. As will be described below with reference to Fig. 5, the second panel portion 29 is removably connected to the first panel portion 28.

[0032] The first panel portion 28 and the second panel portion 29 have a vertically elongated shape having a total length corresponding to a height of the compressor 12, and are adjacent to each other in a left-right direction in front view. The first panel portion 28 corresponds to the right half of the front panel 24a, and the second panel portion 29 corresponds to the left half of the front panel 24a. The panel portions are thin plate-shaped members formed of a metal such as stainless steel or other appropriate materials.

[0033] As shown in Figs. 2 and 3, the first panel portion 28 is provided with the discharge port 30, the suction port 31, the cooling medium intake 44, and the cooling medium discharge port 45. In this way, the outlet and the inlet of the fluid such as the refrigerant gas in the compressor 12 are concentrated in the first panel portion 28. The second panel portion 29 is not provided with such outlet and inlet of the fluid.

[0034] An operation panel 25 for receiving an input for controlling the cryocooler 10 from a user of the cryocooler 10 and/or for displaying information regarding the cryocooler 10 is provided on a front surface (surface facing the outside of the compressor casing 24) of the second panel portion 29.

[0035] In addition, a power breaker 54 and a cold head connector 55 are provided on the front surface of the second panel portion 29. The power breaker 54 is connected to an external power source such as a commercial power source, whereby the cryocooler 10 is supplied with power. An electric wire for supplying power from the compressor 12 to the cold head 14 and for controlling the cold head 14 by the control panel 50 is connected to the cold head connector 55. An electrical connection between the compressor 12 and the cold head 14 is established by the electric wire.

[0036] A main switch 56 is provided in the power breaker 54. The main switch 56 is a switch for switching on and off the cryocooler 10. When the main switch 56 is turned on, the compressor 12 and the cold head 14 are oper-

ated, and when the main switch 56 is turned off, the operation of the compressor 12 and the cold head 14 is stopped.

[0037] The control panel 50 is mounted on the second panel portion 29. The control panel 50 is attached to a back surface (surface facing the inside of the compressor casing 24) of the second panel portion 29, and is accommodated in the compressor casing 24. Although details will be described below, as shown by an arrow A in Figs. 3 and 4, the control panel 50 can be extracted forward from the compressor casing 24 together with the second panel portion 29.

[0038] The control panel 50 is a control device that controls the compressor 12. The control panel 50 may include a control circuit configured to receive an output from various sensors provided in the cryocooler 10 and to control various devices of the cryocooler 10 based on the sensor output. A plurality of electric components including sensors such as a temperature sensor and a pressure sensor may be accommodated in the compressor casing 24. Each sensor may be connected to the control panel 50 by a communication cable.

[0039] The temperature sensor may include a refrigerant gas temperature sensor provided in the refrigerant gas line 18, an oil temperature sensor provided in the oil circulation line 20, a coolant temperature sensor provided in a coolant pipe of the heat exchanger 22, a cooling temperature sensor provided in the low-temperature section 14b of the cold head 14, or the like.

[0040] For example, as shown in Fig. 1, a first temperature sensor 46 is provided upstream of the heat exchanger 22 on the discharge flow path 32 of the refrigerant gas line 18, and measures a temperature of the refrigerant gas flowing into the heat exchanger 22 from the compressor main body 16. A second temperature sensor 47 is provided downstream of the heat exchanger 22 on the refrigerant gas line 18, and measures a temperature of the refrigerant gas flowing into the oil separator 34 from the heat exchanger 22. A third temperature sensor 48 is provided upstream of the heat exchanger 22 on the oil circulation line 20, and measures a temperature of the oil flowing into the heat exchanger 22 from the compressor main body 16. A fourth temperature sensor 49 is provided downstream of the heat exchanger 22 on the oil circulation line 20, and measures a temperature of the oil flowing into the compressor main body 16 from the heat exchanger 22. The temperature sensor is configured to output a signal representing the measured temperature to the control panel 50. The temperature sensor may be, for example, a thermistor. The temperature sensor may be mounted on an outer surface of the pipe constituting the refrigerant gas line 18 and the oil circulation line 20.

[0041] In addition, a first pressure sensor 37a may be disposed in the discharge flow path 32 to measure a pressure of the refrigerant gas flowing through the discharge flow path 32. The first pressure sensor 37a is configured to output a first measured pressure signal PH

representing the measured pressure to the control panel 50. A second pressure sensor 37b is disposed in the suction flow path 33 to measure a pressure of the refrigerant gas flowing through the suction flow path 33. The second pressure sensor 37b is configured to output a second measured pressure signal PL indicating the measured pressure to the control panel 50.

[0042] The electric component controlled based on the sensor output may include, for example, a compressor motor that drives the compressor main body 16, the bypass valve 38, and a cold head motor that drives the cold head 14. The control panel 50 may include a compressor inverter for controlling a rotation speed of the compressor motor and/or a cold head inverter for controlling a rotation speed of the cold head motor.

[0043] Referring again to Figs. 2 to 4, casters 52 are attached to the bottom panel 24d in order to facilitate the movement and the transportation of the compressor 12. Four casters 52 are respectively provided at four corners of the bottom panel 24d. As shown in Figs. 3 and 4, in order to fix the casters 52 to the bottom panel 24d, a caster fixation portion 52a is provided at an upper surface end portion of the bottom panel 24d for each of the casters 52. As an example, the caster fixation portion 52a may include a nut for fixing the caster 52 to the bottom panel 24d. The caster 52 is provided with a bolt portion extending upward from the caster 52, and the bolt portion extends above the bottom panel 24d through a receiving hole penetrating the bottom panel 24d and is fixed to the bottom panel 24d by the nut.

[0044] As shown in Figs. 3 and 4, the compressor casing 24 includes a frame structure 26 that supports the above-described panels and is responsible for structural strength. The panels are removably attached to the frame structure 26. In a state where the panels are attached to the frame structure 26, the devices inside the compressor 12 are covered and hidden by the panels as shown in Fig. 2. The panels may be attached to the frame structure 26 by an appropriate method such as screwing. In a state where the panels are removed from the frame structure 26, the user or the worker can easily access the devices inside the compressor 12 from an opening portion of the frame structure 26, and can efficiently perform maintenance work or manufacturing work of the compressor 12.

[0045] For example, on a back surface of the compressor casing 24, a rectangular back outer frame 26a that is provided to surround the back surface and that configures a part of the frame structure 26 is provided. Each of four sides of the rectangular shape of the back panel 24b is removably attached to the back outer frame 26a. Both ends of an upper part of the back outer frame 26a are connected to both ends of an upper edge of the front panel 24a by two side frames 26b, and a lower part of the back outer frame 26a is connected to a rear edge of the bottom panel 24d. In addition, a lower edge of the front panel 24a is connected to a front edge of the bottom panel 24d. Four sides of the upper panel 24c are removably

attached to upper parts of the back outer frame 26a and the front panel 24a and the two side frames 26b. Four sides of the side panel 24e are removably attached to side portions of the back outer frame 26a and the first panel portion 28, the side frame 26b, and the bottom panel 24d. Four sides of the side panel 24f are removably attached to side portions of the back outer frame 26a and the second panel portion 29, the side frame 26b, and the bottom panel 24d.

[0046] In the existing compressor, a design is adopted in which a panel itself forming each surface of the compressor casing is responsible for structural strength, so that a plate thickness of the panel is large, and a weight thereof tends to be large. Therefore, the work of attaching the panel in the manufacturing process or the work of removing the panel in the maintenance work is not easy, which is one of causes of a decrease in workability for the worker. On the other hand, according to the embodiment, the compressor casing 24 includes the frame structure 26 that is responsible for structural strength, so that each panel such as the back panel 24b attached to the frame structure 26 can be thinned and weight-saved. Such a casing structure is also useful in improving workability.

[0047] As described above, the main components of the compressor 12, such as the compressor main body 16, the heat exchanger 22, the oil separator 34, the adsorber 35, the storage tank 36, and the control panel 50, are accommodated in the compressor casing 24. The oil separator 34, the adsorber 35, and the storage tank 36 are installed on the bottom panel 24d close to one side panel 24e, and are disposed in the compressor casing 24. The adsorber 35, the storage tank 36, and the oil separator 34 are arranged in this order from the first panel portion 28 of the front panel 24a toward the back panel 24b. In addition, the compressor main body 16 and the control panel 50 are disposed in the compressor casing 24 close to the other side panel 24f. As described above, the control panel 50 is attached to the second panel portion 29 of the front panel 24a, and the compressor main body 16 is installed on the bottom panel 24d between the control panel 50 and the back panel 24b.

[0048] As shown in Fig. 4, the heat exchanger 22 is disposed in a state of being bent in a spiral shape along the back surface of the compressor casing 24. Accordingly, the double pipe of the heat exchanger 22 having a relatively long total length can be made compact and disposed in a space-saving manner. In addition, the spiral shape of the heat exchanger 22 is formed to leave a space at a center portion of the back surface of the compressor casing 24. That is, an internal access opening portion 62 in which the heat exchanger 22 is not disposed is formed in the center portion of the back surface of the compressor casing 24. In the manufacturing process of the compressor 12 or in maintenance work of the compressor 12 at a site where the compressor 12 is used, the worker can easily access the devices inside the compressor 12 from the internal access opening portion 62. For example, the manufacturing work such as pipe

welding and joint fastening and various kinds of maintenance work (for example, replacement of consumables such as filters and replacement and repair of devices such as failed sensors) can be performed through the internal access opening portion 62.

[0049] Fig. 5 is a plan view schematically showing a part of the front panel 24a according to the embodiment. In addition, Fig. 6 is a side view schematically showing a part of the front panel 24a according to the embodiment.

[0050] As described above, the front panel 24a includes the first panel portion 28 and the second panel portion 29 that are removably connected to each other. Fig. 5 shows a back surface upper part of these two panel portions. Fig. 5 shows a state in which the remaining portions of the compressor casing 24, such as the frame structure 26 and the upper panel 24c, are removed from the front panel 24a, and the control panel 50 is removed from the second panel portion 29.

[0051] The first panel portion 28 and the second panel portion 29 are removably connected to each other by a connecting tool 58. For example, the connecting tool 58 may be a screw, a fastening part such as a bolt and a nut, or other appropriate removable connecting parts. The first panel portion 28 includes a first panel side surface 28a and a second panel side surface 28b, and the second panel portion 29 includes a first panel side surface 29a and a second panel side surface 29b. The first panel side surface 28a of the first panel portion 28 and the first panel side surface 29a of the second panel portion 29 are in contact with each other and are connected to each other by the connecting tool 58. In this embodiment, since the first panel portion 28 and the second panel portion 29 have a vertically elongated shape, the first panel portion 28 and the second panel portion 29 may be connected to each other by a plurality of the connecting tools 58, for example, three connecting tools 58 along a longitudinal direction thereof.

[0052] The second panel side surface 28b of the first panel portion 28 is a side surface on a side opposite to the first panel side surface 28a, and faces the side panel 24e side shown in Fig. 2. The second panel side surface 29b of the second panel portion 29 is a side surface on a side opposite to the first panel side surface 29a, and faces the side panel 24f side shown in Fig. 2.

[0053] The first panel portion 28 includes an opening portion 60 for enabling access to the connecting tool 58 from the outside of the compressor casing 24. Specifically, the opening portion 60 is provided on the second panel side surface 28b of the first panel portion 28. A plurality of the opening portions 60 may be provided on the second panel side surface 28b to correspond to the plurality of connecting tools 58. Since the connecting tool 58 and the opening portion 60 are provided at the same position in the longitudinal direction (that is, a height direction) of the panel, the opening portion 60 functions as a peephole, so to speak.

[0054] Fig. 6 shows the opening portion 60 and the vicinity thereof in the second panel side surface 28b of the

first panel portion 28. When peeping through the opening portion 60 from the outside of the compressor casing 24, as shown in the figure, the connecting tool 58 can be visually recognized in the opening portion 60. In this example, a diameter of the opening portion 60 is slightly larger than a diameter of the connecting tool 58, and the entire head portion of the connecting tool 58 is visible through the opening portion 60.

[0055] Therefore, it is possible to access the connecting tool 58 from the outside of the compressor casing 24 by using the opening portion 60. As shown in Fig. 5, a tool 64 having a length compatible with a width (dimension in the horizontal direction in Fig. 5) of the first panel portion 28 can be inserted from the opening portion 60 into the compressor casing 24 and can reach the connecting tool 58. In a case where the connecting tool 58 is a screw, the tool 64 may be, for example, a driver. In this way, the connecting tool 58 can be operated by using the opening portion 60 and the tool 64 to connect or disconnect the first panel portion 28 and the second panel portion 29.

[0056] As described above, the compressor 12 includes various electric components such as various sensors (for example, the pressure sensors 37a and 37b and the temperature sensors 46 to 49) and the bypass valve 38. The electric component is accommodated in the compressor casing 24 and is connected to the control panel 50. As shown in Figs. 4 and 7, the control panel 50 includes a plurality of connectors 66 in order to electrically connect the electric component and the control panel 50 to each other. A connector of an electric wire (not shown) extending from the electric component is connected to the connectors 66.

[0057] Fig. 7 is a schematic plan view showing a back surface of the control panel 50 according to the embodiment. Referring to Figs. 4 and 7, the plurality of connectors 66 are provided on the back surface of the control panel 50. These connectors may be collectively disposed at a specific location on the back surface of the control panel 50. For example, as shown in the figure, a large number of the connectors 66 may be collectively disposed at a location near the outside of the compressor casing 24 (for example, a location close to the panel of the compressor casing 24) on the back surface of the control panel 50. In this way, the connectors 66 are exposed near the opening portion of the frame structure 26 when the panel (for example, the side panel 24f) is removed from the compressor casing 24. The worker can easily access the connectors 66 from the outside of the compressor casing 24, and can easily perform the work of connecting (or removing) the electric component to (or from) the connectors 66.

[0058] In addition, as shown in the figure, a large number of fasteners 68 (for example, tie anchors) for removably fixing electric wires for connecting the electric component to the connectors 66 to the control panel 50 are provided on the back surface of the control panel 50. The fasteners 68 are provided on the back surface of the control panel 50 to define a wiring route 70 (an example is

shown by a broken line in Fig. 7). By using the fasteners 68, the electric wires can be organized and disposed on the back surface of the control panel 50.

[0059] Fig. 8 is a schematic top view showing a passage region 72 of the control panel 50 according to the embodiment. As described above, the control panel 50 can be extracted forward from the compressor casing 24 together with the second panel portion 29. When the control panel 50 is extracted, the control panel 50 is extracted forward from the compressor casing 24 along an arrow A. In addition, in Fig. 8, the components of the compressor 12 other than the control panel 50 are not shown.

[0060] The caster fixation portion 52a is provided at an upper surface end portion of the bottom panel 24d of the compressor casing 24. In this embodiment, the passage region 72 of the control panel 50 when the control panel 50 is extracted forward from the compressor casing 24 together with the second panel portion 29 is defined inside the caster fixation portion 52a. In other words, a width (dimension in the horizontal direction) W1 of the bottom surface of the control panel 50 is narrower than a width W2 of the second panel portion 29. Accordingly, when the control panel 50 is extracted forward, interference between the control panel 50 and the caster fixation

portion 52a can be avoided, and the control panel 50 can be smoothly extracted.

[0061] An exemplary procedure for removing the compressor 12 from the control panel 50 according to the embodiment is as follows. First, the side panels 24e and 24f and the upper panel 24c are removed from the compressor casing 24. The fastening between the second panel portion 29 of the front panel 24a, and the frame structure 26 and the bottom panel 24d is released. The tool 64, which is long, such as a driver is inserted through the opening portion 60 of the first panel portion 28 of the front panel 24a, the connecting tool 58 is removed, and the fastening between the first panel portion 28 and the second panel portion 29 is released. In this way, the structural connection between the compressor 12 and the control panel 50 is released.

[0062] The main components of the compressor 12, such as the compressor main body 16, the oil separator 34, the adsorber 35, and the storage tank 36, which are installed on the bottom panel 24d, do not need to be removed.

[0063] Next, the electrical connection between the compressor 12 and the control panel 50 is released. The electric wires connected to a large number of the connectors 66 on the back surface of the control panel 50 are removed. The wires are also removed from the fasteners 68 on the back surface of the control panel 50. In addition, an electric cable connecting the compressor main body 16 and the control panel 50 is also removed.

[0064] Then, the second panel portion 29 and the control panel 50 are pulled out from the compressor casing 24 along an arrow A. In this way, the control panel

50 can be removed from the compressor 12 together with the second panel portion 29. The removed control panel 50 can be subjected to the maintenance work such as repair or replacement.

[0065] As described at the beginning of the present specification, typically, in the existing compressor for the cryocooler, a single panel is used on the front surface of the compressor casing. A pipe for supplying the refrigerant gas to the cold head and a pipe for collecting the refrigerant gas from the cold head can be connected to the single front panel. In addition, a pipe for supplying the coolant to the heat exchanger installed in the compressor casing to cool the compressor and a pipe for collecting the coolant from the heat exchanger can also be connected to the front panel. The control panel of the compressor can be disposed behind the front panel in the compressor casing. In the compressor with such a design, when the worker removes the control panel, the worker first removes the front panel from the compressor casing. However, in order to remove the front panel, it is necessary to discharge the refrigerant gas from the pipe for the refrigerant gas and to discharge the coolant from the pipe for the coolant, and then to remove these pipes from the front panel. In addition, another compressor component such as an adsorber may be fastened to the front panel, and in this case, it is necessary to remove the other compressor component beforehand from the front panel. Therefore, in the existing design, the work of removing the control panel from the compressor requires a preliminary process such as disassembling the compressor into individual parts, which is quite laborious.

[0066] On the other hand, according to the embodiment, the first panel portion 28 of the front panel 24a provides the pipe connection, and the control panel 50 is mounted on the second panel portion 29. Accordingly, the second panel portion 29 can be removed without removing the first panel portion 28 from the compressor casing 24 in a state where the pipes for the refrigerant gas and the coolant are connected to the first panel portion 28. It is possible to eliminate the need to remove the pipes in the work of removing the control panel 50. It is possible to facilitate the work of removing the control panel 50 in the compressor 12 for the cryocooler 10.

[0067] In addition, the first panel portion 28 is provided with the opening portion 60 for enabling access to the connecting tool 58 from the outside of the compressor casing 24. Accordingly, without removing various devices such as the adsorber 35 installed in the compressor casing 24, the tool 64 can reach the connecting tool 58 from the outside of the compressor casing 24, and the connection between the first panel portion 28 and the second panel portion 29 can be released. This is also useful to facilitate the work of removing the control panel 50.

[0068] The plurality of connectors 66 connected to the plurality of electric components are provided on the back surface of the control panel 50. Preferably, the plurality of connectors 66 are collectively disposed at a specific

location on the back surface of the control panel 50. Accordingly, the connection between the control panel 50 and the electric component can be released by removing the wires from the connectors 66.

[0069] In addition, the control panel 50 can be extracted forward from the compressor casing 24 together with the second panel portion 29. The passage region 72 of the control panel 50 is defined inside the caster fixation portion 52a. Accordingly, the control panel 50 can be extracted forward without interfering with the caster fixation portion 52a.

[0070] The present invention has been described above based on the examples. It will be understood by those skilled in the art that the present invention is not limited to the embodiment, various modification examples are possible, and such modification examples are also within the scope of the present invention. Various features described concerning a certain embodiment are also applicable to other embodiments. A new embodiment resulting from combinations also has the effects of each of the combined embodiments.

[0071] In the above-described embodiment, the front panel 24a is formed of two panel portions that are adjacent to each other in the left-right direction, but the front panel 24a may have another configuration. For example, the front panel 24a may be formed of two panel portions that are adjacent to each other in an up-down direction. In this case, the first panel portion 28 and the second panel portion 29 may have a horizontally elongated shape having a total length corresponding to a width of the compressor 12, and may be adjacent to each other in the up-down direction in front view. The first panel portion 28 (or the second panel portion 29) may correspond to the upper half of the front panel 24a, and the second panel portion 29 (or the first panel portion 28) may correspond to the lower half of the front panel 24a.

[0072] The front panel 24a may be divided into three or more panel portions including the first panel portion 28 and the second panel portion 29. The panel portions may be connected to each other to form the front panel 24a.

[0073] Although the present invention has been described using specific words and phrases based on the embodiment, the embodiment merely shows one aspect of the principle and application of the present invention, and various modifications and improvements can be made within the scope of the present invention described in claims.

Brief Description of the Reference Symbols

[0074]

10 cryocooler
12 compressor
24 compressor casing
24a front panel
24d bottom panel
28 first panel portion

28a first panel side surface
28b second panel side surface
29 Second panel portion
50 control panel
52 caster
52a caster fixation portion
58 connecting tool

10 **Claims**

1. A cryocooler compressor (12) comprising:

a control panel (50); and
a compressor casing (24) that includes a front panel (24a) and accommodates the control panel (50),
wherein the front panel (24a) includes a first panel portion (28) that provides a pipe connection, and a second panel portion (29) that is removably connected to the first panel portion (28) and on which the control panel (50) is mounted.

25 2. The cryocooler compressor (12) according to claim 1,

wherein the second panel portion (29) is removably connected to the first panel portion (28) by a connecting tool (58), and
the first panel portion (28) includes an opening portion (60) for enabling access to the connecting tool (58) from an outside of the compressor casing (24).

35 3. The cryocooler compressor (12) according to claim 2,

wherein the first panel portion (28) includes a first panel side surface (28a) to which the connecting tool (58) is attached, and a second panel side surface (28b) including the opening portion (60).

45 4. The cryocooler compressor (12) according to claim 1,

wherein the control panel (50) is capable of being extracted forward from the compressor casing (24) together with the second panel portion (29).

50 5. The cryocooler compressor (12) according to claim 4,

wherein the compressor casing (24) includes a bottom panel (24d), and a caster fixation portion (52a) is provided at an upper surface end portion of the bottom panel (24d), and
a passage region (72) of the control panel (50) when the control panel (50) is extracted forward from the compressor casing (24) together with

the second panel portion (29) is defined inside the caster fixation portion (52a) .

6. The cryocooler compressor (12) according to any one of claims 1 to 5, further comprising: 5
- a plurality of electric components accommodated in the compressor casing (24), wherein the control panel (50) includes a plurality of connectors (66) connected to the plurality of electric components on a back surface. 10
7. The cryocooler compressor (12) according to claim 6, wherein the plurality of connectors (66) are collectively disposed at a specific location on the back surface of the control panel (50). 15

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FIG. 1

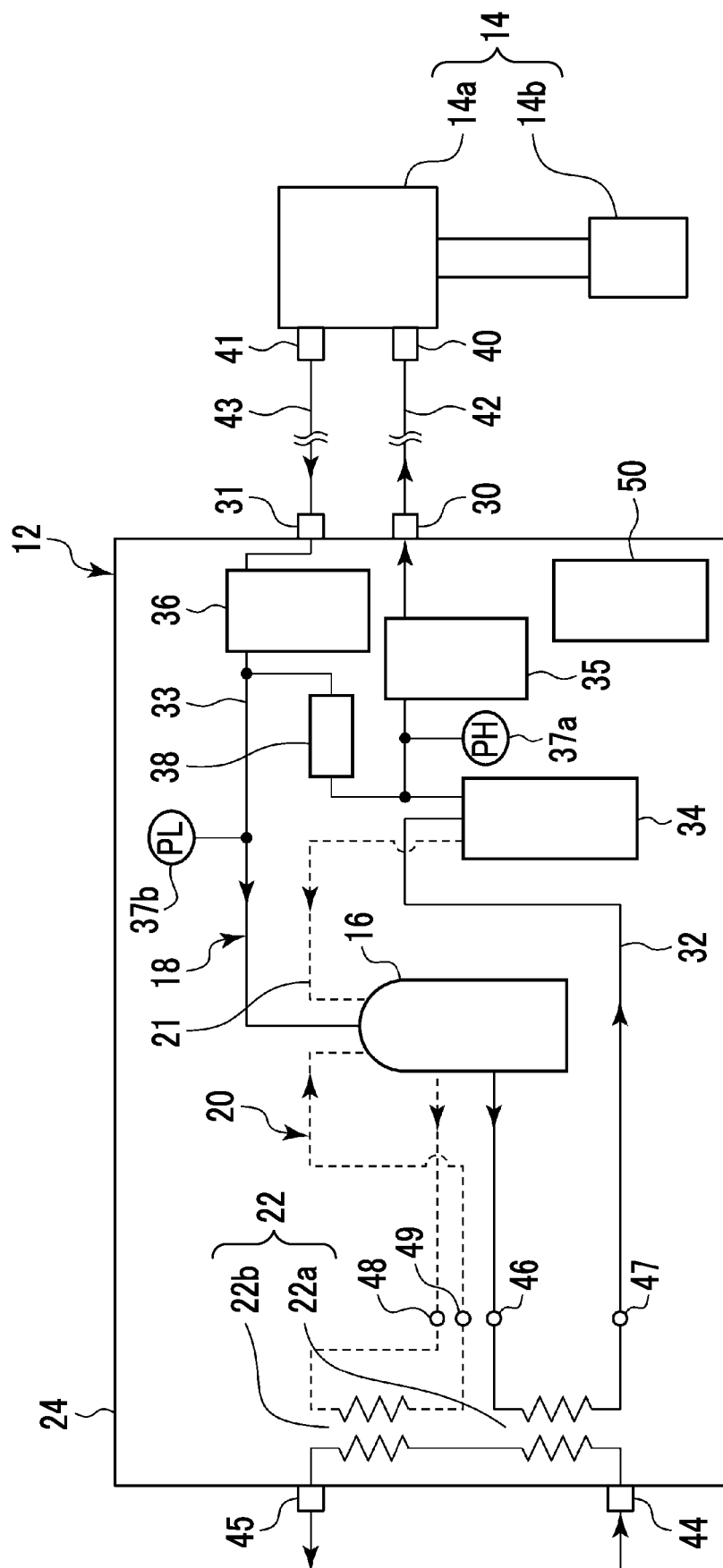
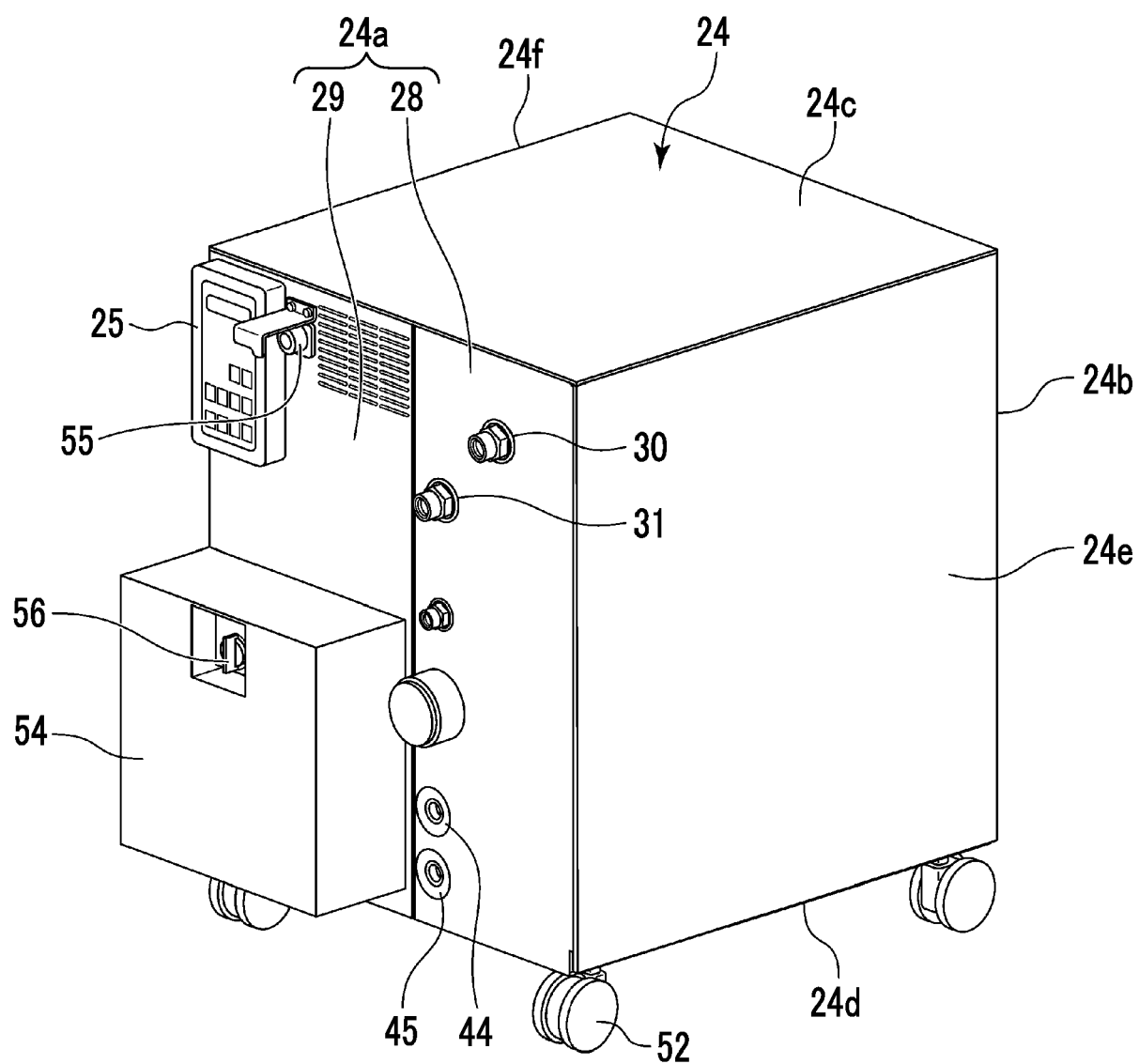
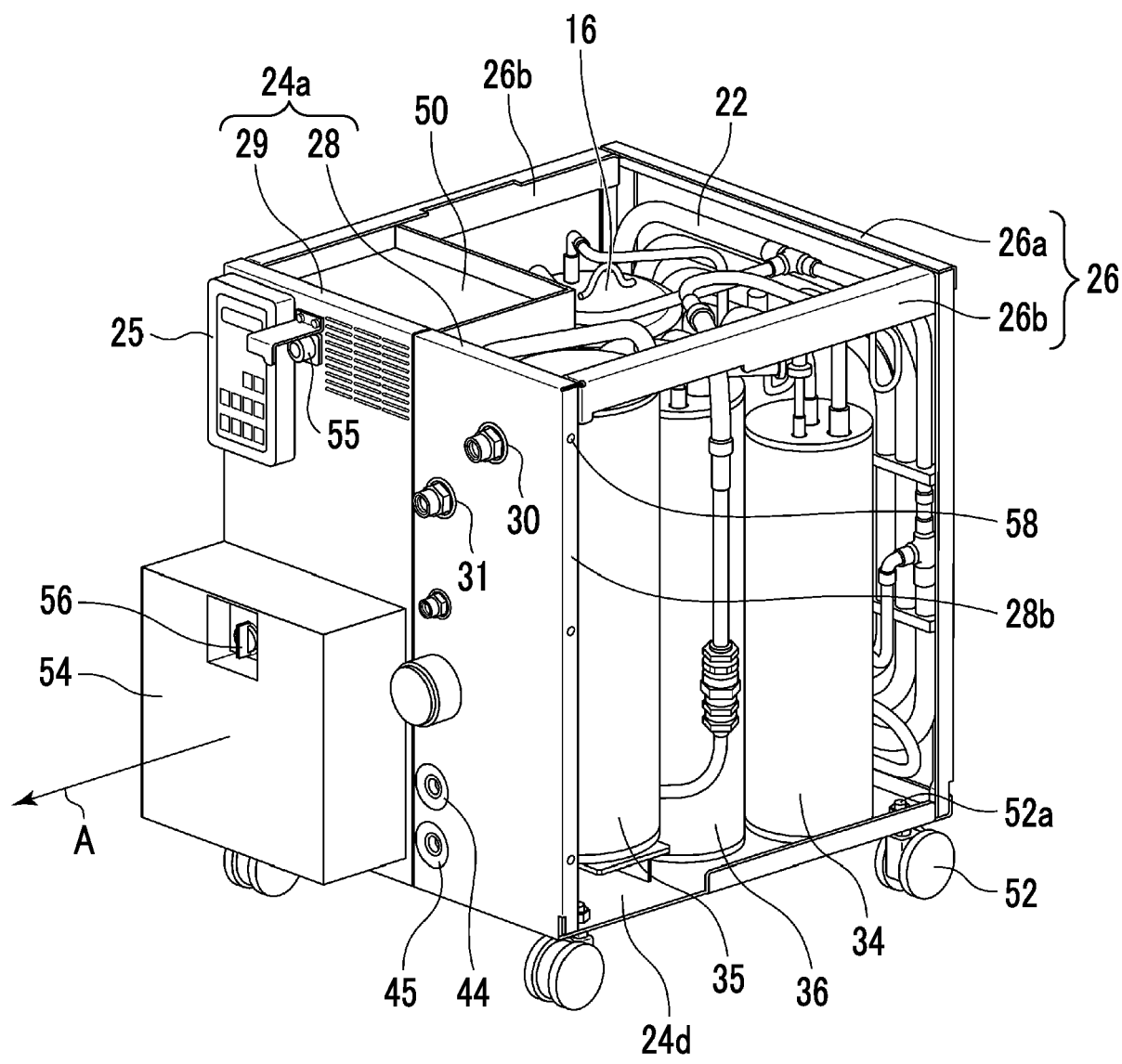


FIG. 2



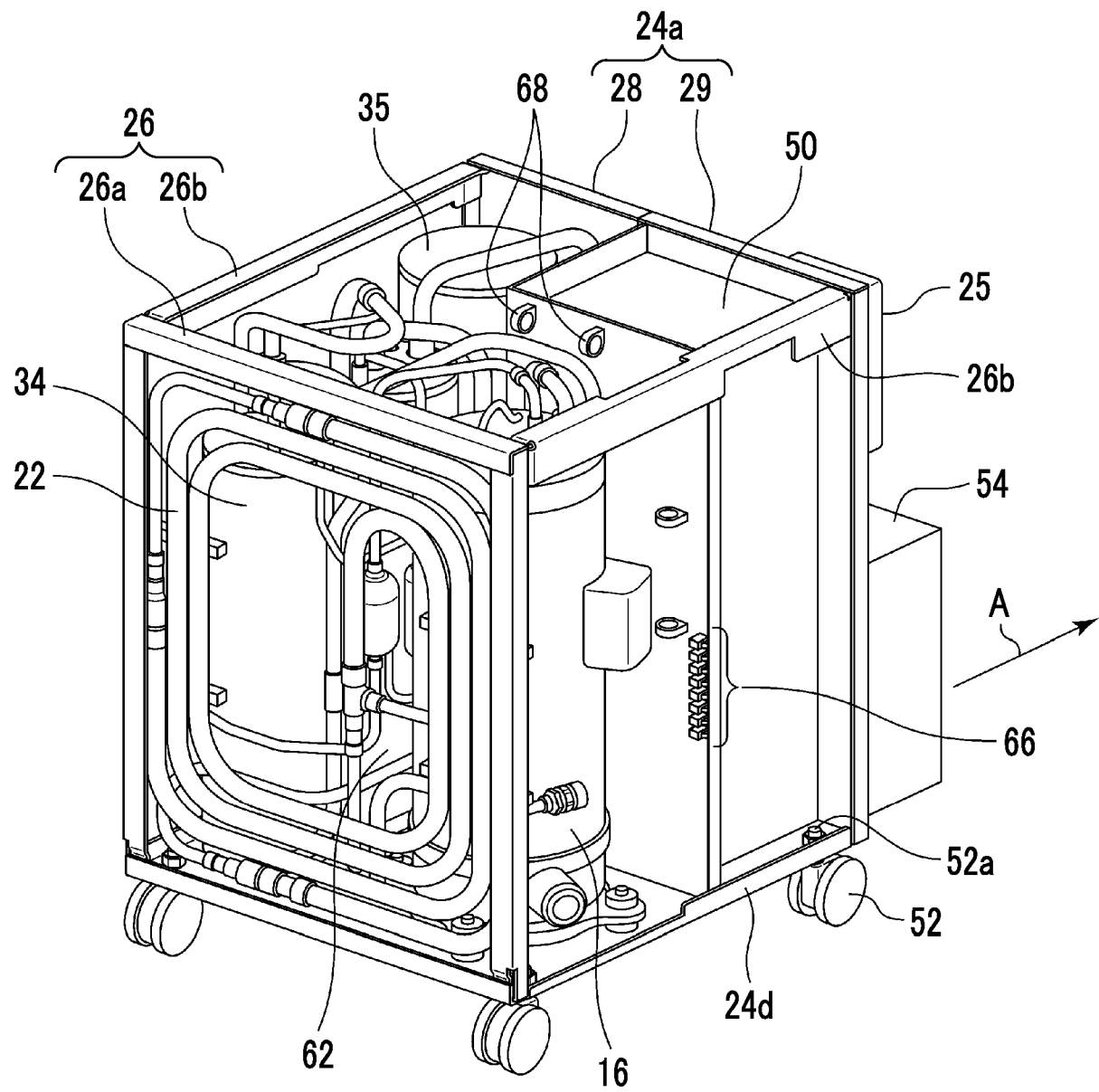
12

FIG. 3



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FIG. 4



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FIG. 5

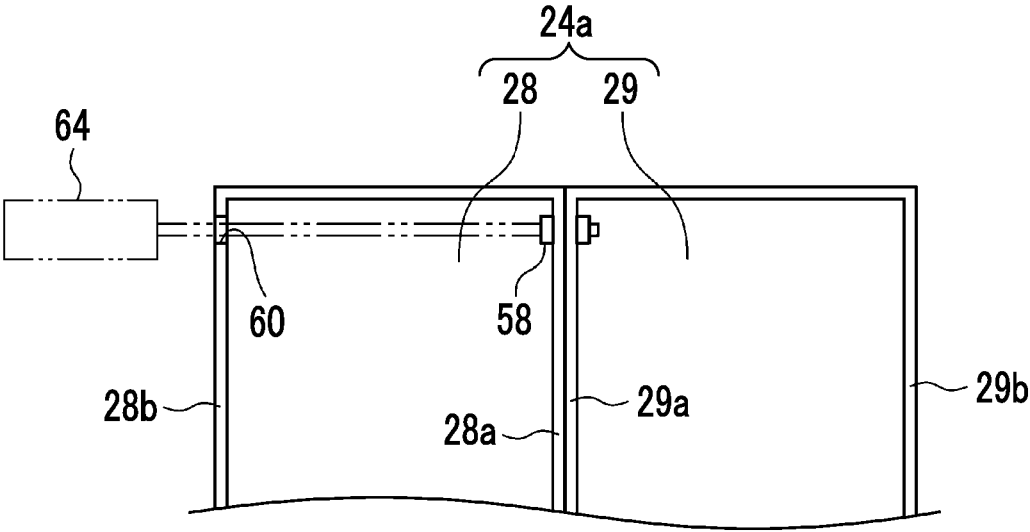
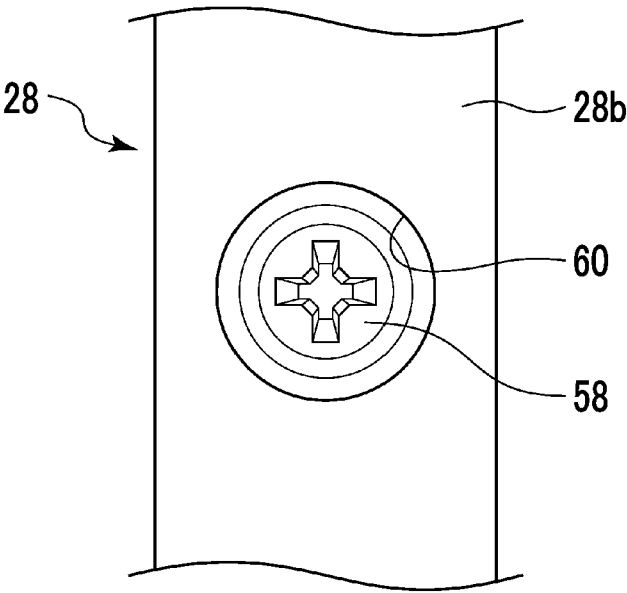
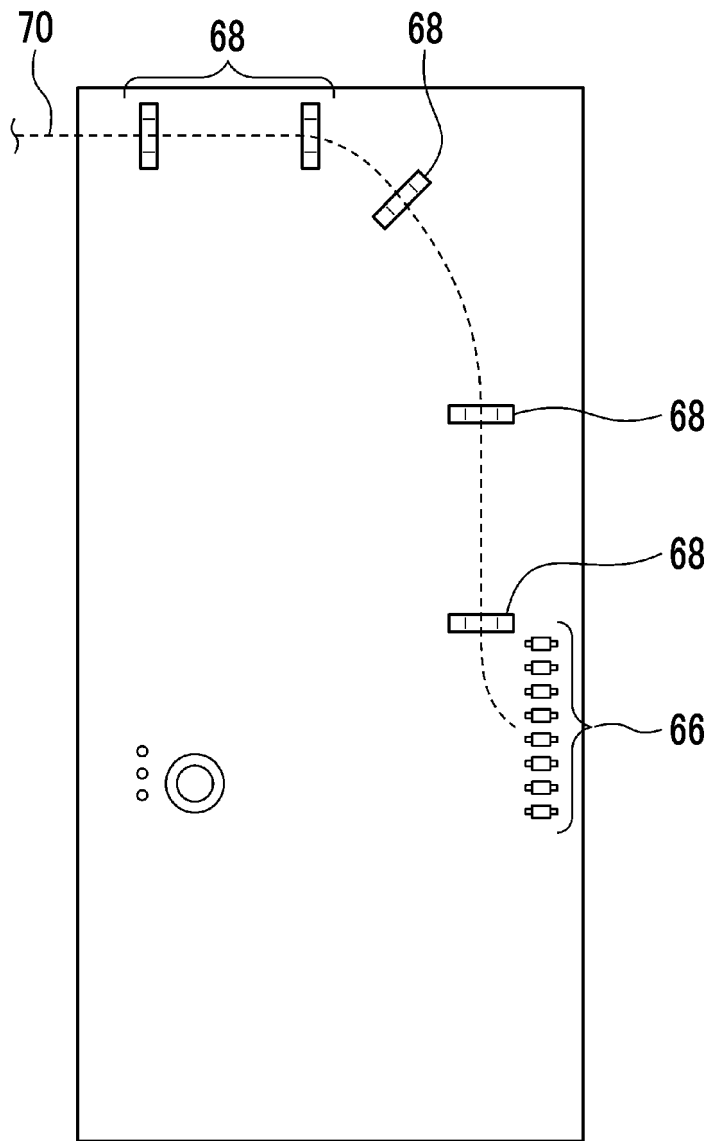


FIG. 6



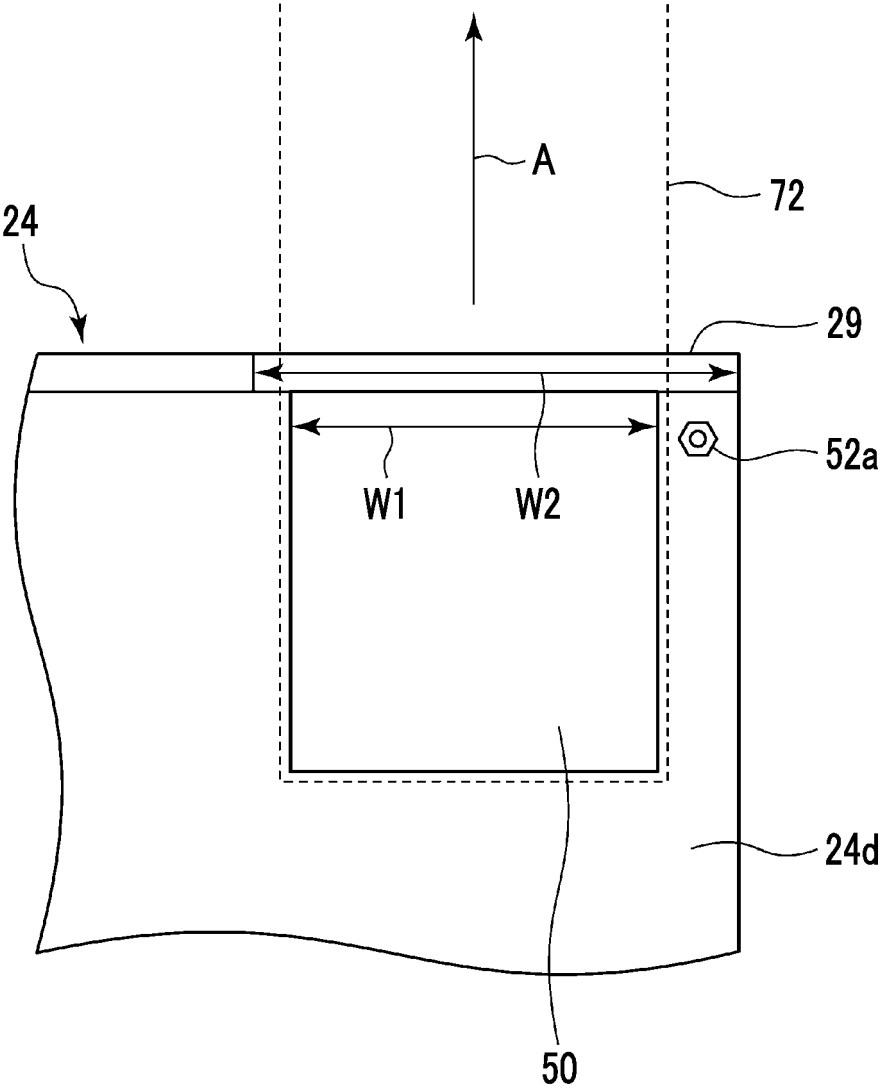
24a

FIG. 7



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FIG. 8





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