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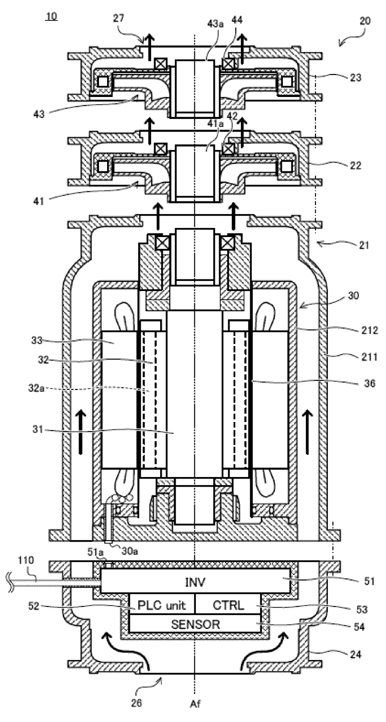
(54) PUMP DEVICE

(57) A pump apparatus which can save space and is easy to handle is proposed. The pump apparatus includes a pipe-shaped casing including a suction port and a discharge port arranged in the same straight line and defining a flow channel that connects the suction port and the discharge port; a motor disposed inside the casing, the motor including a rotating shaft extending along a flow channel direction directing from the suction port to the discharge port, a rotor rotating integrally with the rotating shaft, a stator provided on an outer peripheral side of the rotor, and a can for isolating a rotor chamber and a stator chamber, the rotor chamber having the rotor disposed therein and the stator chamber having the stator disposed therein; and an inverter disposed in the interior of the casing for exercising variable speed control over the motor.

Fig. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a pump apparatus.

BACKGROUND ART

[0002] In the related art, an inline pump including a suction port and a discharge port arranged in the same straight line is known (for example, see PTL 1). The inline pump described in PTL 1 includes a pump casing including an outer cylinder configured to connect the suction port and the discharge port, and a motor provided in the pump casing. The inline pump achieves a high lift without increasing the outer diameter of the pump by using a variable frequency inverter and driving the motor at a higher speed than a commercial frequency of 50 to 60 Hz.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laid-Open No. 5-332282

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] In general, the pump apparatus is disposed adjacent to a building or disposed in a pump room in the building, when used, for example, for supplying water to the building. However, to dispose the pump apparatus adjacent to the building, a space is needed outdoors. In addition, to dispose the pump apparatus in the building, a pump room for disposing the pump apparatus is needed, which may occupy an available space in the building. In particular, in the case of a high-building with many levels, if the pump apparatus is disposed on a middle level for pumping water to higher levels, a useful space on the middle level is occupied for disposing the pump apparatus.

[0005] The present invention is made in view of such circumstances, and it is one of objects of the present invention to propose a pump apparatus that can save space and is easy to handle.

SOLUTION TO PROBLEM

[0006] An embodiment of the present invention proposes a pump apparatus. The pump apparatus includes: a pipe-shaped casing including a suction port and a discharge port arranged in the same straight line and defining a flow channel that connects the suction port and the discharge port; a motor disposed inside the casing, the motor including: a rotating shaft extending along a flow channel direction directing from the suction port to the discharge port; a rotor rotating integrally with the rotating shaft; a stator provided on an outer peripheral side of the rotor; and a can for isolating a rotor chamber and a stator chamber, the rotor chamber having the rotor disposed therein and the stator chamber having the stator disposed therein; and an inverter disposed in the interior of the casing for exercising variable speed control over the motor.

BRIEF DESCRIPTION OF DRAWINGS

[0007]

[Fig. 1] Fig. 1 is a drawing illustrating a schematic configuration of a pump apparatus according to an embodiment of the present invention.
[Fig. 2] Fig. 2 is a pattern diagram illustrating schematic functions of the pump apparatus according to the embodiment.
[Fig. 3] Fig. 3 is a drawing illustrating a schematic configuration of a pressure tank according to the embodiment.
[Fig. 4] Fig. 4 is a drawing illustrating an example of a water supply system using the pump apparatus of the embodiment.
[Fig. 5] Fig. 5 is a drawing illustrating a power line communication in the embodiment.
[Fig. 6] Fig. 6 is a drawing illustrating a schematic configuration of a water supply system according to a modification.
[Fig. 7] Fig. 7 is a drawing illustrating a schematic configuration of a water supply system according to another modification.
[Fig. 8] Fig. 8 is a drawing illustrating a schematic configuration of a water supply system according to still another modification.
[Fig. 9] Fig. 9 is a drawing illustrating another application of the pump apparatus.
[Fig. 10] Fig. 10 is a drawing illustrating a schematic configuration of a pump apparatus according to a modification.

DESCRIPTION OF EMBODIMENT

[0008] Referring now to the drawings, an embodiment of the present invention will be described. The drawings used here, however, are pattern diagrams. Therefore, the size, location, and shape of illustrated parts may differ from the size, location, and shape of those in an actual apparatus. In the following description and the drawings used in the following description, the parts having the same configuration are denoted by the same reference signs, and redundant explanations are omitted.

(Pump Apparatus)

[0009] Fig. 1 is a drawing illustrating a schematic configuration of a pump apparatus according to an embodiment of the present invention. For example, a pump apparatus 10 of the embodiment may be used as a water supply apparatus for supplying tap water to a water supply target such as a building or a fire-extinguishing apparatus in the fire-extinguishing system. The pump apparatus 10 of the embodiment includes a plurality of casing members (first to fourth casing members 21 to 24) in each of which components of the pump apparatus 10 are separately housed and supported. The plurality of casing members and the components are connected to each other. In Fig. 1, the first to fourth casing members 21 to 24 and the components housed in the interior thereof are illustrated as an exploded diagram. However, the configuration is not limited to the described example, and the pump apparatus may be configured to be supported generally by a single casing member.

[0010] The pump apparatus 10 illustrated in Fig. 1 includes a casing 20 configured to define an outline of the apparatus. The casing 20 generally has a cylindrical pipe shape as a whole. One end (a lower end in Fig. 1) of the casing 20 defines a suction port 26 of the pump apparatus 10, and the other end (an upper end in Fig. 1) of the casing 20 defines a discharge port 27 of the pump apparatus 10. Note that the pump apparatus 10 may further include components connected respectively to the upstream (lower side in Fig. 1) and the downstream (upper side in Fig. 1) of the configuration illustrated in Fig. 1. When the additional component is connected to the upstream side, the upstream end of the component may be configured as the suction port 26. When the additional component is connected to the downstream side, the downstream end of the component may be configured as the discharge port 27. The casing 20 defines a flow channel that connects the suction port 26 and the discharge port 27 in the interior thereof. Although not limiting, bold arrows in Fig. 1 indicates a flow of a carrier liquid. In Fig. 1, the carrier liquid flows upward from the bottom of the pump apparatus 10. The direction of the flow of the carrier liquid connecting the suction port 26 and the discharge port 27 (vertical direction in Fig. 1) is referred to as a "flow channel direction Af". Note that although the pump apparatus 10 illustrated in Fig. 1 is indicated such that the flow channel direction Af extends along an up-down direction, the pump apparatus 10 may be disposed at any angle. For example, the pump apparatus 10 may be disposed so that the flow channel direction Af extends along the vertical direction or the flow channel direction Af extends along the horizontal direction.

[0011] In the embodiment, the casing 20 includes four casing members (first to fourth casing members 21 to 24). The first to fourth casing members 21 to 24 are arranged in line in the flow channel direction, and define flow channels, respectively, for the carrier liquid. In the example illustrated in Fig. 1, from the upstream (primary side) to the downstream (secondary side) in the flow channel direction Af, the fourth casing member 24, the first casing member 21, the second casing member 22, and the third casing member 23 are arranged in this order. The first to fourth casing members 21 to 24 may be connected to each other with fasteners such as bolts.

[0012] A motor 30 is housed in the interior of the first casing member 21. The first casing member 21 includes a piping frame 211 that defines an outside surface of the pump apparatus 10 and a motor frame 212 located in the interior of the piping frame 211 and having the motor 30 housed therein. In the example illustrated in Fig. 1, the piping frame 211 and the motor frame 212 have a cylindrical shape, respectively, and are arranged concentrically about the rotating shaft of the motor 30. The piping frame 211 and the motor frame 212 are fixed to each other or are configured as a unitary member, and the flow channel is defined between the piping frame 211 and the motor frame 212. In other words, in the embodiment the flow channel for the carrier liquid is defined on the outer periphery of the motor 30.

[0013] The motor 30 includes a rotating shaft 31 extending along the flow channel direction Af, a rotor 32 rotating integrally with the rotating shaft 31, and a stator 33 provided on the outer peripheral side of the rotor 32. In the embodiment an IPM motor in which a permanent magnet 32a is embedded in the interior of the rotor 32 is employed as the motor 30. However, an SPM motor having the permanent magnet 32a on the surface of the rotor 32 may also be employed as the motor 30. The motor 30 is not limited to those having the rotor 32 provided with the permanent magnet 32a and may be an induction motor or an SR (Switched Reluctance motor), and the like. The stator 33 is fixed to an inner peripheral side of the motor frame 212. A thin cylindrical shaped can 36 is disposed on an inner peripheral side of the stator 33. The material that can be used for the can 36 may be a metal material such as stainless steel, or a resin material such as PPS. The motor frame 212 and the can 36 are disposed concentrically about the rotating shaft 31. Disposed between the can 36 and the motor frame 212 is a frame side plate 214. Note that the frame side plate 214 is disposed only on one end side (the lower side in Fig. 1) of the stator 33 in the example illustrated in Fig. 1, but the frame side plate 214 may also be disposed on the other end side (the upper side in Fig. 1) of the stator 33. The motor frame 212, the can 36, and the frame side plate 214 define a stator chamber in which the stator 33 is disposed.

[0014] A first impeller 41 and a bearing 42 for axially supporting the first impeller 41 are housed in the interior of the second casing member 22. The first impeller 41 includes a first impeller rotating shaft 41a configured to be connectable to the rotating shaft 31 of the motor 30. The first impeller rotating shaft 41a and the rotating shaft 31 of the motor 30 may respectively have a convex and a concave, for example, to be fitted to each other, so as to rotate integrally when connected to each other. The first impeller rotating shaft 41a and the rotating shaft 31 of the motor 30 may be connected to each other via a shaft coupling. The second casing member 22 supports the bearing 42 and supports the first impeller 41 via the bearing 42. The second casing member 22 may be formed to have an interior having a shape in conformity with the shape of the first impeller 41 so that the carrier liquid is pumped from the suction port 26 toward the discharge port 27 by the rotation of the first impeller 41. For example, the second casing member 22 may have a diffuser, a guide vane, or the like.

[0015] A second impeller 43 and a bearing 44 for axially supporting the second impeller 43 are housed in the interior of the third casing member 23. The second impeller 43 includes a second impeller rotating shaft 43a configured to be connectable to the first impeller rotating shaft 41a. The second impeller rotating shaft 43a and the first impeller rotating shaft 41a may respectively have a convex and a concave, for example, to be fitted to each other, so as to rotate integrally when connected to each other. The second impeller rotating shaft 43a and the first impeller rotating shaft 41a may be connected to each other via a shaft coupling. The third casing member 23 supports the bearing 44 and supports the second impeller 43 via the bearing 44. The third casing member 23 may be formed to have an interior having a shape in conformity with the shape of the second impeller 43 so that the carrier liquid is pumped from the suction port 26 toward the discharge port 27 by the rotation of the second impeller 43. For example, the third casing member 23 may have a diffuser, a guide vane, or the like.

[0016] As described above, in the example illustrated in Fig. 1, the second casing member 22 in which the first impeller 41 is housed and the third casing member 23 in which the second impeller 43 is housed are connected to the first casing member 21 in which the motor 30 is housed, so that the pump apparatus 10 having the two-stage impeller is achieved. The pump apparatus 10 here may be configured as the pump apparatus 10 not including the third casing member 23 and the second impeller 43 but including a single-stage impeller. The pump apparatus 10 may also be configured as a pump apparatus having a plurality of, three or more stages by connecting a casing member in which still another impeller is housed. In the pump apparatus 10 of the embodiment, a single impeller is housed in a single casing member, and a pump apparatus having a desired number of impellers may be configured by connecting a plurality of casing members corresponding to the desired lifting height of the pump apparatus 10. Note that although it is described that a single impeller is housed in a single casing in the embodiment, two or more impellers may be housed in the single casing member.

[0017] The fourth casing member 24 includes an inverter 51, a controller 53, a power line communication unit (PLC unit) 52, and a sensor 54 housed in the interior thereof. The fourth casing member 24 supports these components. However, at least one of the inverter 51, the controller 53, the PLC unit 52, and the sensor 54 may be housed in another casing member or may be divided and housed in a plurality of casing members. Note that in the example illustrated in Fig. 1, the fourth casing member 24 includes a first frame 241 that defines an outside surface of the pump apparatus 10, and a second frame 242 located in the interior of the first frame 241 and configured to house the inverter 51 or the like. In the example illustrated in Fig. 1, the first frame 241 and the second frame 242 have a cylindrical shape, respectively, and are arranged concentrically about the rotating shaft of the motor 30. The piping frame 211 and the motor frame 212 are fixed to each other or are configured as a unitary member, and the flow channel is defined between the first frame 241 and the second frame 242. In other words, in the embodiment the flow channel for the carrier liquid is defined on the outer periphery of the inverter 51 or the like. However, the configuration is not limited to the example described above, and such a configuration is also applicable that the inverter 51 or the like is formed into an annular shape and is disposed on the outer peripheral side in the interior of the fourth casing member 24 to allow the carrier liquid to flow inside the inverter 51 or the like.

[0018] The inverter 51 is provided for exercising variable speed control over the motor 30. The inverter 51 and the motor 30 are electrically connected to each other by a connection between a connector 51a connected to the inverter 51 and a connector 30a connected to the motor 30 (stator 33). The connectors 30a and 51a may employ various known mechanisms. Accordingly, assembling and disassembling of the first casing member 21 and the motor 30 to and from the fourth casing member 24 and the inverter 51 can be achieved easily. The controller 53 is provided to control the entire pump apparatus 10. The PLC unit 52 can communicate with the controller 53 and is configured to be capable of performing communication using a power line 110 for supplying power to the pump apparatus 10 as a communication line. Examples of the communication destinations by the PLC unit 52 include a control panel provided outside the pump apparatus 10, a monitoring device, or a PLC unit provided in another pump apparatus.

[0019] The sensor 54 is provided for detecting various types of operation information of the pump apparatus 10. In the embodiment, the sensor 54 includes pressure sensors 63 and 64 and a flow switch 66, described later. However, the configuration is not limited to the described example, and only a sensor for monitoring the status of the pump apparatus 10 needs to be included as the sensor 54. For example, the sensor 54 may include a temperature sensor for detecting the temperature of at least one of the components of the pump apparatus 10, such as the temperature of the motor 30, the temperature of the inverter 51, and the temperature of the controller 53. The sensor 54 may also include a vibration sensor for detecting the vibration of at least one of the components of the pump apparatus 10, such as the vibration of the casing 20, the vibration of the bearings 42 and 44, and the vibration of the rotating shaft 31. The sensor 54 may further include a flow rate sensor for detecting the flow rate of the carrier liquid. The sensor 54 may also include a current sensor for detecting the current flowing in the pump apparatus 10 or the motor 30. Furthermore, the sensor 54 may include a sensor for monitoring the magnitude of the noise generated by the pump apparatus 10.

[0020] Fig. 2 is a pattern diagram illustrating schematic functions of the pump apparatus 10 according to the embodiment. Note that in Fig. 2, the configurations corresponding to those illustrated in Fig. 1 are denoted by the same reference signs and redundant description is omitted. In Fig. 2, the configuration not illustrated in Fig. 1 is partly added in illustration. As illustrated in Fig. 2, the pump apparatus 10 is configured to be capable of pumping the carrier liquid from the suction port 26 to the discharge port 27 by a pump 40 having impellers (the first impeller 41 and the second impeller 43 in the example illustrated in Fig. 1). Here, the suction port 26 may be connected to a supply source of the carrier liquid, not illustrated, such as a water main or a water receiving tank, and the discharge port 27 may be connected to an object to be supplied with the carrier liquid, not illustrated, such as a water outlet of the building.

[0021] Check valves 62a and 62b are provided on the upstream side and the downstream side of the pump 40. The check valves 62a and 62b prevent the backflow of water when the pump 40 is stopped. A pressure sensor 63 is provided upstream of the check valve 62a. The pressure sensor 63 is a pressure measuring device for measuring the suction pressure of the pump 40. Note that the check valve 62a and the pressure sensor 63 provided upstream of the pump 40 may be omitted in the case where a water receiving tank is connected to the suction port 26 of the pump apparatus 10. A flow switch 66 is provided downstream of the check valve 62b. The flow switch 66 is a flow rate detector configured to detect the fact that the flow rate of the carrier liquid to be discharged from the pump 40 is lowered to a predetermined value, that is, the underquantity of water (small quantity of water). Provided further downstream of the flow switch 66 are a pressure sensor 64 and a pressure tank 70. The pressure sensor 64 is a pressure measuring device for measuring the discharge pressure of the pump 40. The pressure tank 70 is a pressure retainer for retaining the discharge pressure while the pump 40 is stopped.

[0022] Note that in the example illustrated in Fig. 2, the pump apparatus 10 includes the check valves 62a and 62b, the pressure sensors 63 and 64, the flow switch 66, and the pressure tank 70. However, the pump apparatus 10 may not include some of these, and some of these may be installed externally of the pump apparatus 10. For example, such configuration is also applicable that the check valve 62a is connected to a primary side of the suction port 26 of the pump apparatus 10, and the check valve 62b is connected to a secondary side of the discharge port 27 of the pump apparatus 10, so that the pump apparatus 10 may be configured to be detachable from the flow channel of the carrier liquid. In addition, the pump apparatus 10 may include other components in addition to the components illustrated in Fig. 2. For example, the pump apparatus 10 may include a manual valve configured such that the flow channel of the carrier liquid can be manually opened and closed instead of, or in addition to the check valves 62a and 62b.

[0023] The pump apparatus 10 includes the controller 53 for controlling the pump apparatus 10 entirely. Note that in the example illustrated in Fig. 1, the controller 53 is housed in the fourth casing member 24. However, the configuration is not limited to the described example, and the controller 53 may be housed in another casing member and may be provided outside the casing 20. As the controller 53, a known microprocessor centered on a CPU may be employed, and a dedicated circuit board may also be employed. As illustrated in Fig. 2, the controller 53 of the embodiment includes a memory 531, an arithmetic part 532, an I/O part 533, and a communication part 534.

[0024] Examples of the memory 531 include a nonvolatile memory such as ROM, HDD, EEPROM, FeRAM, and a flash memory, and a volatile memory such as RAM. The memory 531 stores a control program for controlling the pump apparatus 10, and various data relating to the pump apparatus 10 such as apparatus information, set value information, maintenance information, history information, abnormality information, and operation information. Note that when the memory 531 includes a nonvolatile memory area, these may be stored in the nonvolatile memory area.

[0025] As the arithmetic part 532, used here is a CPU. The arithmetic part 532 performs an arithmetic operation or the like for controlling the various devices which constitute the pump apparatus 10 based on the control program and various data stored in the memory 531 and signals input from the I/O part 533. The arithmetic part 532 also performs communication control in the I/O part 533, the communication part 534 and the like. The results of the arithmetic operation performed by the arithmetic part 532 are stored in the memory 531 and are output to the I/O part 533 and the communication part 534.

[0026] Examples of the I/O part 533 include ports and terminals. The I/O part 533 receives detection signals from the various sensors such as the pressure sensors 63 and 64 and the flow switch 66 and transmits these signals to the arithmetic part 532. Note that the pressure sensors 63 and 64 and the flow switch 66 are examples of the sensor 54 illustrated in Fig. 1. As other examples of the sensor 54, the detection signals from the sensor for detecting the temperature of the inverter 51, the detection signals from the sensor for detecting the number of rotations of the motor 30 may be input to the I/O part 533. The I/O part 533 is mutually connected to the inverter 51 and to the PLC unit 52. For the connection of the I/O part 533 to the inverter 51 or the PLC unit 52, communication means such as the RSs 422, 232C, and 485 may be employed.

[0027] The communication part 534 transmits various types of information relating to the pump apparatus 10 stored in the memory 531, receives change of setting of the set value information or a control command of the pump apparatus 10 from the outside, and reflects the changes or the command in the control. As the wireless communication in the communication part 534, for example, near field communication (NFC) technology may be used. In addition, wireless communication of any scheme, such as Bluetooth (registered trademark) and the Wi-Fi (registered trademark) may be used. However, the NFC is advantageous in that the communication may be completed only by bringing an external device close to the communication part 534 in the casing 20. As the wired communication, for example, an external connection terminal such as USB (Universal Serial Bus) may be provided on the outer surface of the casing 20 so that communication by the communication part 534 is achieved by connecting the external device to the external connection terminal, or a serial communication such as RS 422, RS 232C, RS 485 or the like may be used.

[0028] The controller 53 of the embodiment is assumed to exchange signals with an external device 80 via the communication part 534 or the PLC unit 52, and the pump apparatus 10 itself does not include a control panel that functions as a user interface. Assumed examples of the external device 80 that communicates with the controller 53 include, for example, general-purpose terminal devices such as smartphones, mobile phones, personal computers, and tablets, or a dedicated terminal device for the pump apparatus 10. However, the configuration is not limited to the described example, and the pump apparatus 10 may be configured to include a control panel configured to be able to communicate via a wire or wirelessly with the controller 53, so that various data stored in the memory 531 can be displayed or changed by the control panel via the arithmetic part 532.

[0029] An example of control of the pump apparatus 10 by the controller 53 will be described. When the discharge pressure drops to a predetermined starting pressure in a state in which the pump 40 is stopped, the controller 53 starts the pump 40. Specifically, the controller 53 issues a command to the inverter 51 to start driving the pump 40. During the operation of the pump 40, control such as estimated end pressure constant control or target pressure constant control is performed with the set pressure (set pressure PA). Specifically, in the case of the estimated end pressure constant control, the controller 53 sets a target pressure SV with respect to the discharge pressure of the pump 40 using the number of rotations of the pump 40 and a target pressure control curve so that the pressure at the end of the water supply destination becomes constant at the minimum pressure "PB-actual lifting height". In the case of the target pressure constant control, the controller 53 set the set pressure PA to the target pressure SV so that the pressure on the discharge side of the pump 40 becomes the set pressure PA. In both cases of the estimated end pressure constant control and the target pressure constant control, the controller 53 sets the discharge pressure detected by the pressure sensor 64 as a current pressure PV. Then, a PID calculation is performed based on the deviation between the target pressure SV and the current pressure PV, whereby a command rotation speed of the pump 40 is set. Note that in the estimated end pressure constant control, the set pressure PA is a pressure value at the maximum flow rate, and the minimum pressure PB is a pressure value at the zero flow rate.

[0030] When the amount of use of water in the water supply target is reduced during the operation of the pump 40, the flow switch 66 detects the fact that the discharge flow rate from the pump 40 reaches the amount below the underquantity of water and sends the detection signal to the controller 53 via the I/O part 533. Upon reception of the detection signal, the controller 53 performs pressure accumulation operation, which is an operation to control the number of rotations of the pump 40 until the discharge pressure reaches a stop pressure in a predetermined time. When the discharge pressure reaches the predetermined stop pressure, it is determined that the pressure is accumulated in the pressure tank 70 and the pressure accumulation operation is ended and the pump 40 is stopped (stop due to small quantity of water). When water is used again in the water supply target and the discharge pressure drops to or below a starting pressure after the pump 40 is stopped due to small quantity of water, the pump 40 is restarted. Other means such as loading by a current value of the inverter 51 or shut-off head may be used as a method of detecting the small quantity of water without using the flow switch 66.

[0031] Fig. 3 is a drawing illustrating a schematic configuration of the pressure tank 70 according to the embodiment. The pressure tank 70 is connected to downstream (secondary side) of the pump 40 (the first and second impellers 41 and 43 in Fig. 1) and configured to retain the discharge pressure while the pump 40 is stopped. The pressure tank 70 defines part of the flow channel of the carrier liquid carried by the pump apparatus 10. The pressure tank 70 includes a pipe-shaped pressure tank casing 72, which is opened at both ends (the upper end and the lower end in Fig. 3), and an annular-shaped bladder 74. The pressure tank casing 72 includes an enlarged diameter portion 721, and the annular-shaped bladder 74 is disposed in the enlarged diameter portion 721 which has enlarged diameter. The bladder 74 is provided with an air-supply valve 741 for supplying working fluid such as nitrogen gas, for example, and the working fluid is enclosed in the bladder 74 through the air-supply valve 741. In this manner, in the embodiment since the outline of the pressure tank 70 has a pipe shape, the outer shape of the pump apparatus 10 entirely including the pressure tank 70 may be formed into a pipe shape, so that the apparatus can save space.

[0032] Note that in the embodiment the pump apparatus 10 is described to have the pressure tank 70 having the pipe-shaped outline but is not limited thereto. The pump apparatus 10 may be provided with a conventional pressure tank branched and connected to the flow channel of the carrier liquid instead of, or in addition to the pressure tank 70 illustrated in Fig. 3. Alternately, the pressure tank as illustrated in Fig. 3 or the conventional pressure tank may be connected to the secondary side of the discharge port 27 of the pump apparatus 10. In addition, the pump apparatus 10 may not be provided with the pressure tank, for example, when the discharge port 27 is connected to the water receiving tank (see a pump apparatus 10A in Fig. 7).

[0033] According to the pump apparatus 10 of the embodiment described above, the motor 30 and the inverter 51 are housed in the interior of the pipe-shaped casing 20. Accordingly, the apparatus can save space. In addition, since the motor 30 and the inverter 51 are disposed in the vicinity of the flow channel of the carrier liquid, the heat dissipation of the motor 30 and the inverter 51 may be accelerated. Furthermore, transmission of the noise generated by driving of the motor 30 and the inverter 51 to the outside, that is, the noise of the pump apparatus 10 may be reduced. The casing 20 includes the first to fourth casing members 21 to 24 connected to each other, and the motor 30, the first impeller 41, the second impeller 43, and the inverter 51 are housed in the interior of each of the first to fourth casing members 21 to 24. In this manner, since the components of the pump apparatus 10 is housed in the respective casing members, maintenance work can be facilitated and customization of the pump apparatus 10 such as changing the number of stages of the impellers to one, or three or more according to the application of the user can also be facilitated.

(Modification of Pump Apparatus)

[0034] In the pump apparatus 10 illustrated in Fig. 1, the casing 20 includes four casing members (first to fourth casing members 21 to 24). However, the configuration is not limited to the example described above, and the casing 20 may include one to three casing members or may include five or more casing members. Also, in the example illustrated in Fig. 1, from the upstream (primary side) to the downstream (secondary side) in the flow channel direction Af, the fourth casing member 24, the first casing member 21, the second casing member 22, and the third casing member 23 are arranged in this order, but the configuration is not limited in the example in Fig. 1. For example, such a configuration is also applicable that at least one of the second casing member 22 and the third casing member 23 is connected to a primary side of the first casing member 21, and the impeller is disposed upstream of the motor 30. The pump apparatus 10 may also be configured to have the impellers on both upstream and downstream of the motor 30.

[0035] Fig. 10 is a drawing illustrating a schematic configuration of a pump apparatus 10X according to a modification. In the pump apparatus 10X illustrated in Fig. 10, the same components as those in the pump apparatus 10 illustrated in Fig. 1 are denoted by the same reference signs, and substantially the same components are denoted by reference signs added with X. In the description below, the description of parts overlapping those of the pump apparatus 10 illustrated in Fig. 1 will be omitted. A casing 20X of the pump apparatus 10X illustrated in Fig. 10 includes first to fourth casing members 21X to 24X. The first casing member 21X houses the motor 30, and the fourth casing member 24X houses an inverter 51X. Also, the second and third casing members 22X and 23X house first and second impellers 41X and 43X, respectively. In the pump apparatus 10X illustrated in Fig. 10, as an example, the second casing member 22X, the fourth casing member 24X, the first casing member 21X, and the third casing member 23X are arranged in this order in the flow channel direction Af of the carrier liquid. The pump apparatus 10X is configured such that when a rotating shaft 30X of the motor 30 rotates, the first impeller 41X in the second casing member 22X and the second impeller 43X in the third casing member 23X rotate integrally with the rotating shaft 30X of the motor 30, and the carrier liquid is pumped from the suction port 26 to the discharge port 27. In other words, in the pump apparatus 10X, the impellers are disposed on both upstream and downstream of the motor 30. Note that although one each of the impellers is provided upstream and downstream of the motor 30 in the example illustrated in Fig. 10, the configuration is not limited to the described example, and two or more stages of the impellers may be provided on at least one of the upstream and the downstream of the motor 30.

[0036] In addition, in the pump apparatus 10X illustrated in Fig. 10, as an example, the first impeller 41X and the second impeller 43X are provided to pump the carrier liquid in the opposite directions. In other words, the pump apparatus 10X is configured such that the first impeller 41X pumps the carrier liquid upward from the bottom, and the second impeller 43X pumps the carrier liquid downward from the top. In this configuration, a thrust force acting on the first impeller 41X and a thrust force acting on the second impeller 43X may be cancelled out, and thus a force acting on the respective rotating shafts of the pump apparatus 10X and the bearing can be reduced. Note that although the impellers configured to pump the carrier liquid in the opposite directions are provided both upstream and downstream of the motor 30 in the pump apparatus 10X illustrated in Fig. 10, the configuration is not limited to the described example, and in the pump apparatus 10 illustrated in Fig. 1, for example, one of the first impeller 41 and the second impeller 43 may be configured to pump the carrier liquid to a direction opposite to the other.

[0037] Note that in the pump apparatus 10X, a rotating shaft 31Xa for connecting the rotating shaft 31X of the motor 30 and a rotating shaft 41Xa of the first impeller 41X is axially supported in the fourth casing 24X. However, the configuration is not limited to the described example. For example, the rotating shaft 31X of the motor 30 may be configured to extend beyond the fourth casing 24X and be connected to the rotating shaft 41Xa of the first impeller 41X.

(Example of Application to Water Supply System)

[0038] Next, an example of the water supply system using the pump apparatus 10 of the embodiment will be described. Note that the pump apparatus 10X of the modification may be employed instead of the pump apparatus 10 in the following description. Fig. 4 is a drawing illustrating an example of a water supply system using the pump apparatus 10 of the embodiment. As illustrated in Fig. 4, the water supply system includes a first pump apparatus 10A coupled to a water pipe (water main) 102 and a second pump apparatus 10B coupled in series to a discharge side of the first pump apparatus 10A. Here, the pump apparatus 10 described above is used as the first pump apparatus 10A and the second pump apparatus 10B. The components of the first and second pump apparatuses 10A and 10B corresponding to those of the pump apparatus 10 described above will be described with "A" and "B" suffixed to the respective signs. In the embodiment, the first pump apparatus 10A is installed on the ground or underground, and the second pump apparatus 10B is installed in the middle level of a building 106.

[0039] A suction port of the first pump apparatus 10A is connected to the water pipe 102 via an introduction pipe 103. A discharge port of the first pump apparatus 10A and a suction port of the second pump apparatus 10B are coupled by a first water distribution pipe 104a. The first water distribution pipe 104a is coupled to respective water supply plugs (first water supply targets) 108a of lower levels in the building 106 via branch pipes 107a. A second water distribution pipe 104b is connected to a discharge port of the second pump apparatus 10B, and the second water distribution pipe 104b is coupled to respective water supply plugs (second water supply target) 108b on the higher levels of the building via branch pipes 107b. In this configuration, the first pump apparatus 10A is configured to boost the pressure of water from the water pipe 102 and supply the water to the respective water supply plugs 108a on the lower levels of the building 106. Then, the second pump apparatus 10B further boosts the pressure of the water from the first pump apparatus 10A and supplies the water to respective water supply plugs 108b on the higher levels of the building 106.

[0040] A controller 53A of the first pump apparatus 10A and a controller 53B of the second pump apparatus 10B are configured to communicate operation information with each other via so-called power line communication (PLC) using the power line 110 as a communication line. Fig. 5 is a drawing illustrating a power line communication in the embodiment. As illustrated, the power line 110 is connected from a distribution board 112 to each of the pump apparatuses 10A and 10B so that power from the commercial power supply (system power supply 114), not illustrated, is supplied. The power from the system power supply 114 is supplied to pumps 40A and 40B of the respective pump apparatuses 10A and 10B via the power line 110. The power line 110 from the distribution board 112 is connected to PLC units 52A and 52B of the respective pump apparatuses 10A and 10B. The respective PLC units 52A and 52B are configured to be capable of performing communication through the power line 110 (see broken line), so that mutual exchange of information between the controllers 53A and 53B is performed by the communication between the controllers 53A and 53B and the PLC units 52A and 52B.

[0041] The operation information including operation and stop of the pumps 40A and 40B, the measurement values (discharge pressure) of pressure sensors 64A and 64B, failure information of the pump apparatuses 10A and 10B, and operation commands to the pumps 40A and 40B is transmitted in both direction between the controller 53A and the controller 53B through the power line 110. Such a communication function enables a coordinated operation between the first pump apparatus 10A and the second pump apparatus 10B.

[0042] When only the pump 40B of the second pump apparatus 10B is operated in a state in which the pump 40A of the first pump apparatus 10A is stopped, negative pressure may be generated within the first water distribution pipe 104a. If the water supply plugs 108a on the lower levels are opened in this state, air may be sucked from the water supply plugs 108a. Therefore, in order to prevent such suction of air, the pump 40B is started after the pump 40A is started.

[0043] As described above, the pumps 40A and 40B are started when the respective discharge pressures drop to a predetermined starting pressure. Therefore, the controllers 53A and 53B each have a preset starting pressure that triggers the pumps 40A and 40B, respectively, to start. In addition, the controller 53A has a second starting pressure set for starting the pump 40A. The second starting pressure is a second threshold value for a start based on the discharge pressure of the second pump apparatus 10B (measurement value of the pressure sensor 64B). The second starting pressure is set to be larger than the starting pressure of the pump 40B of the second pump apparatus 10B. This is for starting the pump 40A before the pump 40B is started as described above.

[0044] The controller 53A starts the pump 40A based on two triggers: when the measurement value of the pressure sensor 64A drops to the first starting pressure, and when the measurement value of the pressure sensor 64B acquired via the power line communication drops to the second starting pressure. When the discharge pressure of the pump 40B drops, it will fall below the second starting pressure of the first pump apparatus 10A before the starting pressure of the second pump apparatus 10B. The controller 53A of the first pump apparatus 10A starts the pump 40A when the measurement value of the pressure sensor 64A acquired through the power line 110 (that is the discharge pressure of the pump 40B) reaches the second starting pressure.

[0045] If water is used in the lower levels in a state in which the pump 40A is stopped, the discharge pressure of the pump 40A drops. Then, the discharge pressure drops to the first starting pressure, the pump 40A starts. In this manner, the pump 40A is started based on the measurement values of the two pressure sensors 64A and 64B.

[0046] The controller 53B of the second pump apparatus 10B preferably starts the pump 40B after confirming the fact that the pump 40A is started. The controller 53B may determine whether or not the pump 40A is started based on the fact that the number of rotations of the pump 40A exceeds a predetermined number of rotations (for example, 30% or 40% of the rated number of rotations).

[0047] When the water supply operation is stopped from the state in which both the pump 40A and the pump 40B are operated, the pump 40B is first stopped, and then the pump 40A is stopped. Such a coordinated operation is performed based on the operation information transmitted between the controllers 53A and 53B. The controller 53A may determine whether or not the pump 40B is stopped based on the fact that the number of rotations of the pump 40B is below the predetermined number of rotations (for example, 30% or 40% of the rated number of rotations). Such a coordinated operation can prevent the pump 40A from stopping before the pump 40B is stopped, so that negative pressure can be prevented from being generated in the first water distribution pipe 104a.

(Modification of Water Supply System)

[0048] In the example illustrated in Fig. 4, two pump apparatuses 10A and 10B are provided in the water supply system. However, the configuration is not limited to the described example, and three or more pump apparatuses may be provided. Fig. 6 is a drawing illustrating a schematic configuration of a water supply system according to a modification. The water supply system illustrated in Fig. 6 includes three pump apparatuses 10A to 10C. The pump apparatus 10 described above may be employed as the pump apparatuses 10A to 10C. The first pump apparatus 10A is connected to the water pipe 102 via the introduction pipe 103 in the same manner as the water supply system illustrated in Fig. 4. The second pump apparatus 10B is provided on the discharge side of the first pump apparatus 10A and is connected to the first pump apparatus 10A via the first water distribution pipe 104a. Likewise, the third pump apparatus 10C is provided on the discharge side of the second pump apparatus 10B and is connected to the second pump apparatus 10B via the second water distribution pipe 104b. Then, the first pump apparatus 10A is configured to boost the pressure of water from the water pipe 102 and supply the water to the respective water supply plugs 108a on the lower levels of the building 106 connected to the first water distribution pipe 104a. Likewise, the second pump apparatus 10B is configured to further boost the pressure of water from the first pump apparatus 10A and supply the water to the respective water supply plugs 108b on the middle levels of the building connected to the second water distribution pipe 104b. Furthermore, the third pump apparatus 10C is configured to further boost the pressure of water from the second pump apparatus 10B and supply the water to respective water supply plugs 108c on the higher levels of the building connected to a third water distribution pipe 104c. The first to third pump apparatuses 10A to 10C are respectively configured to be able to communicate with each other by the power line communication through the power line 110 of the building 106.

[0049] In the water supply system as described above, the same control as the water supply system illustrated in Fig. 4 can be executed. In other words, regarding the first pump apparatus 10A and the second pump apparatus 10B, by performing the same control as for the first pump apparatus 10A and the second pump apparatus 10B in the water supply system illustrated in Fig. 4 described above, the pressure in the first water distribution pipe 104a is prevented from unintentionally dropping to a lower pressure and the respective pump apparatuses 10A and 10B can be properly controlled. Likewise, regarding the second pump apparatus 10B and the third pump apparatus 10C, by performing the same control as for the first pump apparatus 10A and the second pump apparatus 10B in the water supply system illustrated in Fig. 4 described above, the pressure in the second water distribution pipe 104b is prevented from unintentionally dropping to a lower pressure and the respective pump apparatuses 10B and 10C can be properly controlled. In other words, the same control as for the first pump apparatus 10A and the second pump apparatus 10B in the water supply system illustrated in Fig. 4 described above may be performed with the pump apparatus on the primary side (upstream) defined as the "first pump apparatus" and the pump apparatus on the secondary side (downstream) defined as the "second pump apparatus".

[0050] In the water supply system illustrated in Fig. 4, the first pump apparatus 10A is based on a direct water supply system connected to the water pipe 102 via the introduction pipe 103, and the second pump apparatus 10B is directly connected to the first pump apparatus 10A via the first water distribution pipe 104a. However, the configuration is not limited to the described example, and at least some of the plurality of pump apparatuses in the water supply system may be based on a water receiving tank system in which the water receiving tank is connected to the suction side.

[0051] Fig. 7 is a drawing illustrating a schematic configuration of a water supply system according to another modification. The water supply system illustrated in Fig. 7 is the same as the water supply system illustrated in Fig. 4 described above except that the respective pump apparatuses 10A and 10B are based on a water receiving tank system. In the water supply system illustrated in Fig. 7, water from the water pipe 102 is accumulated in a water receiving tank 112A, and the primary side (suction side) of the first pump apparatus 10A is connected to the water receiving tank 112A via the introduction pipe 103. Likewise, water from the first pump apparatus 10A is accumulated in a water receiving tank 112B provided in the building 106, and the primary side (suction side) of the second pump apparatus 10B is connected to the water receiving tank 112B via a second introduction pipe 103b. The introduction pipes 103 and 103b are provided with inlet valves (for example, solenoid valves) 105a and 105b that can block the flow channels to the water receiving tanks 112A and 112B. Note that opening and closing of the inlet valves 105a and 105b may be controlled by the controllers 53A and 53B of the pump apparatus 10A and 10B, or may be controlled by the external controller, not illustrated.

[0052] In the water supply system illustrated in Fig. 4 described above, the first pump apparatus 10A is installed on the ground or underground, and the second pump apparatus 10B is installed in the middle level of the building 106. However, the water supply system is not limited to the configuration in which the second pump apparatus 10B is disposed at a higher position than the first pump apparatus 10A. The second pump apparatus 10B may be disposed at the same height level as the first pump apparatus 10A, or the second pump apparatus 10B may be disposed at a lower position than the first pump apparatus 10A.

[0053] Furthermore, in the water supply system illustrated in Fig. 4 described above, the first pump apparatus 10A and the second pump apparatus 10B are connected in series. However, the configuration is not limited to the described example, and a plurality of pump apparatuses 10 may be connected in parallel. In the example illustrated in Fig. 8, the first pump apparatus 10A and the second pump apparatus 10B are connected in parallel. Likewise, in the water supply system illustrated in Fig. 4, Fig. 6 and Fig. 7, a plurality of the pump apparatuses 10 may be connected in parallel to the introduction pipe 103 and the first water distribution pipe 104a as illustrated in Fig. 8, or the plurality of pump apparatuses 10 may be connected in parallel to the first water distribution pipe 104a and the second water distribution pipe 104b as illustrated in Fig. 8. Furthermore, in the water supply system illustrated in Fig. 7, the plurality of pump apparatuses 10 may be connected in parallel to a second drain pipe 104b and a third drain pipe 104c as illustrated in Fig. 8. In other words, an arbitrary pump apparatus 10 may be connected to another pump apparatus 10 in parallel. Here, the pump apparatuses 10 connected in parallel may be provided on the same level or on the same floor. In addition, in the pump apparatuses 10 connected in parallel, at least part of the sensors 54 in the plurality of pump apparatuses 10 may be grouped, for example, by providing the pressure sensors 63 and 64 shared by the plurality of pump apparatuses 10 in an integrated pipe connected to the suction port 27 of the respective pump apparatuses 10. In this configuration, the number of the sensors in the water supply system is reduce, so that the costs can be lowered and management of the system can be facilitated.

(Example of Other Application)

[0054] The description given above is directed to the application of the pump apparatus 10 to the water supply system. However, the application is not limited thereto. The pump apparatus 10 described above may be used for various applications. For example, in a facility in which cold and hot water are circulated in the heat exchanger for air-conditioning, a pump is generally used in many cases. The pump apparatus 10 of the embodiment may be applied for example to a facility in which a liquid is circulated by the pump.

[0055] Fig. 9 is a drawing illustrating another application of the pump apparatus. As illustrated in Fig. 9, an air conditioning facility 1000 includes a pump apparatus 1100, a heat exchanger 1200, and a check valve 1300, and a pipe 1400 that couples the pump apparatus 1100, the heat exchanger 1200, and the check valve 1300 for circulation. Note that in the example illustrated in Fig. 9, the pump apparatus 10 illustrated in Fig. 1 is employed as the pump apparatus 1100, and the pump apparatus 1100 includes the pump 40, the motor 30 and the inverter 51. However, the configuration is not limited to the described example, and a configuration in which a plurality of the pump apparatuses 10 illustrated in Fig. 1 are connected in parallel and/or in series may be employed as the pump apparatus 1100. In addition, although illustration is omitted in Fig. 9, the air conditioning facility 1000 is also provided with a controller configured to control the operation of the pump apparatus 1100, such as the controller 53, for driving the pump apparatus.

[0056] The liquid discharged from the pump apparatus 1100 passes through the pipe 1400 and is heat-exchanged by the heat exchanger 1200, and then is sucked by the pump 1100 via the check valve 1300. By the provision of the check valve 1300, the liquid circulates in one direction, and backflow is prevented. In the circulation path of liquid in the air conditioning facility 1000, the fluid never flows to the outside in the normal use, and always circulates in a predetermined direction. Note that the check valve 1300 corresponds to the check valve 62a described above.

[0057] As described above, in the pump apparatus 10 of the embodiment, the motor 30 and the inverter 51 are housed in the interior of the pipe-shaped casing 20 and thus the pump apparatus 10 (the pump apparatus 1100) can save space. Therefore, the air conditioning facility provided with such a pump apparatus 10 (pump apparatus 1100) can save space for the air conditioning facility in whole. In addition, since the pump apparatus 10 described above can reduce the noise, the noise of the air conditioning facility provided with the pump apparatus 10 in whole (pump apparatus 1100) can be reduced.

[0058] The embodiment described thus far may be described in the following mode.

[Mode 1] According to Mode 1, a pump apparatus is provided, and the pump apparatus includes a pipe-shaped casing including a suction port and a discharge port arranged in the same straight line and defining a flow channel that connects the suction port and the discharge port; a motor disposed inside the casing, the motor including a rotating shaft extending along a flow channel direction directing from the suction port to the discharge port, a rotor rotating integrally with the rotating shaft, a stator provided on an outer peripheral side of the rotor, and a can for isolating a rotor chamber and a stator chamber, the rotor chamber having the rotor disposed therein and the stator chamber having the stator disposed therein; and an inverter disposed in the interior of the casing for exercising variable speed control over the motor. According to Mode 1, the pump apparatus which can save space and is easy to handle can be provided.

[Mode 2] According to Mode 2, the pump apparatus of Mode 1 further includes a controller disposed in the interior of the casing. According to Mode 2, since the controller is disposed in the interior of the pipe-shaped casing, the pump apparatus can save more space.

[Mode 3] According to Mode 3, the pump apparatus of Mode 1 or 2 further includes a communication part configured to perform at least one of transmission of information relating to the pump apparatus to the outside, reception of a set change command for the pump apparatus from the outside, and reception of a control command for the pump apparatus from the outside.

[Mode 4] According to Mode 4, the pump apparatus of Modes 1 to 3 further includes a power line communication unit configured to be able to communicate with the controller and is configured to be capable of performing communication using a power line for supplying power to the pump apparatus as a communication line. According to Mode 4, the power line communication unit allows the pump apparatus to communicate with an external control panel, a monitoring device, or other pump apparatus. By utilizing the power line as the communication line, the pump apparatus can save space.

[Mode 5] According to Mode 5, the pump apparatus of Modes 1 to 4 further includes a sensor disposed in the interior of the casing, the sensor being for detecting at least one of the discharge pressure of the pump apparatus and the suction pressure of the pump apparatus. According to Mode 5, the sensor is disposed in the interior of the casing, and the pump apparatus can save space.

[Mode 6] According to Mode 6, the pump apparatus of Modes 1 to 5 further includes a pressure tank, and the pressure tank includes a pipe-shaped pressure tank casing having an enlarged diameter portion which has enlarged diameter, and an annular bladder disposed in the enlarged diameter portion. According to Mode 6, since the pressure tank is configured to have a pipe shape, the pump apparatus can be configured to have a pipe shape as a whole, so that the pump apparatus can save space.

[Mode 7] According to Mode 7, the pump apparatus of Modes 1 to 6 includes two or more impellers fixed to the rotating shaft. According to Mode 7, the high-lift pump apparatus can be achieved.

[Mode 8] According to Mode 8, in the pump apparatus of Modes 1 to 7, the casing includes a first casing member that houses at least the motor, and a second casing member connected to the first casing member, the second casing member including a first impeller having a first impeller rotating shaft configured to be connectable to the rotating shaft of the motor, and a bearing that axially supports the first impeller housed therein. According to Mode 8, assembly, maintenance, and the like of the pump apparatus can be facilitated.

[Mode 9] According to Mode 9, in the pump apparatus of Mode 8, the casing further includes a third casing member connected to the second casing member, the third casing member in which a second impeller having a second impeller rotating shaft configured to be connectable to the rotating shaft of the motor via the first impeller rotating shaft and a bearing that axially supports the second impeller are housed. According to Mode 9, the pump apparatus having two impellers can be achieved by combining the second casing member in which the first impeller is housed, and the third casing member in which the second impeller is housed. Furthermore, by combining a casing member in which still another impeller is housed, the pump apparatus having the impellers of a desired number of stages can be achieved.

[Mode 9] According to Mode 10, in the pump apparatus of Modes 1 to 9, the casing includes the first casing member in which at least the motor is housed, and a fourth casing member connected to the first casing member and including the inverter housed therein. According to Mode 10, assembly, maintenance, and the like of the pump apparatus can be facilitated.

[0059] Although the embodiment of the present invention has been described thus far, the embodiment of the present invention described above is presented for facilitating the understanding of the present invention, and not for limiting the present invention. The present invention may be modified and improved without departing from its gist, and as a matter of course, the present invention includes equivalents thereof. In addition, to the extent that at least some of the problems described above can be solved or at least some of the effects can be achieved, any combination of the embodiments and variations is possible, and any combination or omission of each of the components described in the claims and the specification is possible.

[0060] This application claims its priority based on Japanese Patent Application No. 2019-153911 filed on August 26, 2019. The entire disclosure of Japanese Patent Application No. 2019-153911 including the specification, claims, drawings, and abstract is incorporated by reference in this application in its entirety. All disclosures in Japanese Patent Laid-Open No. 5-332282 (Patent Document 1) are hereby incorporated by reference in their entirety.

REFERENCE SIGNS LIST

[0061]

Af	flow channel direction
10	pump apparatus
20	casing
21	first casing member
22	second casing member
23	third casing member
24	fourth casing member
26	suction port
27	discharge port
30	motor
31	rotating shaft
32	rotor
33	stator
36	can
40	pump
41	first impeller
41a	first impeller rotating shaft
42	bearing
43	second impeller
43a	second impeller rotating shaft
44	bearing
51	inverter
52	PLC unit (power line communication unit)
53	controller
54	sensor
70	pressure tank
72	pressure tank casing
721	enlarged diameter portion
74	bladder
110	power line

Claims

1. A pump apparatus comprising:

    a pipe-shaped casing including a suction port and a discharge port arranged in the same straight line and defining a flow channel that connects the suction port and the discharge port;
    a motor disposed inside the casing, the motor including:

        a rotating shaft extending along a flow channel direction directing from the suction port to the discharge port;
        a rotor rotating integrally with the rotating shaft;
        a stator provided on an outer peripheral side of the rotor; and
        a can for isolating a rotor chamber and a stator chamber, the rotor chamber having the rotor disposed therein and the stator chamber having the stator disposed therein; and

    an inverter disposed in the interior of the casing for exercising variable speed control over the motor.

2. The pump apparatus according to claim 1, further comprising a controller disposed in the interior of the casing.

3. The pump apparatus according to claim 1 or 2, further comprising a communication part configured to perform at least one of transmission of information relating to the pump apparatus to the outside, reception of a set change command for the pump apparatus from the outside, and reception of a control command for the pump apparatus from the outside.

4. The pump apparatus according to any one of claims 1 to 3 further comprising a power line communication unit configured to be capable of performing communication using a power line for supplying power to the pump apparatus as a communication line.

5. The pump apparatus according to any one of claims 1 to 4, further comprising a sensor disposed in the interior of the casing, the sensor being for detecting at least one of a discharge pressure of the pump apparatus and a suction pressure of the pump apparatus.

6. The pump apparatus according to any one of claims 1 to 5, further comprising:
    a pressure tank, the pressure tank including:

        a pipe-shaped pressure tank casing having an enlarged diameter portion which has enlarged diameter, and
        an annular bladder disposed in the enlarged diameter portion.

7. The pump apparatus according to any one of claims 1 to 6, comprising two or more impellers fixed to the rotating shaft.

8. The pump apparatus according to any one of claims 1 to 7, wherein the casing comprises:

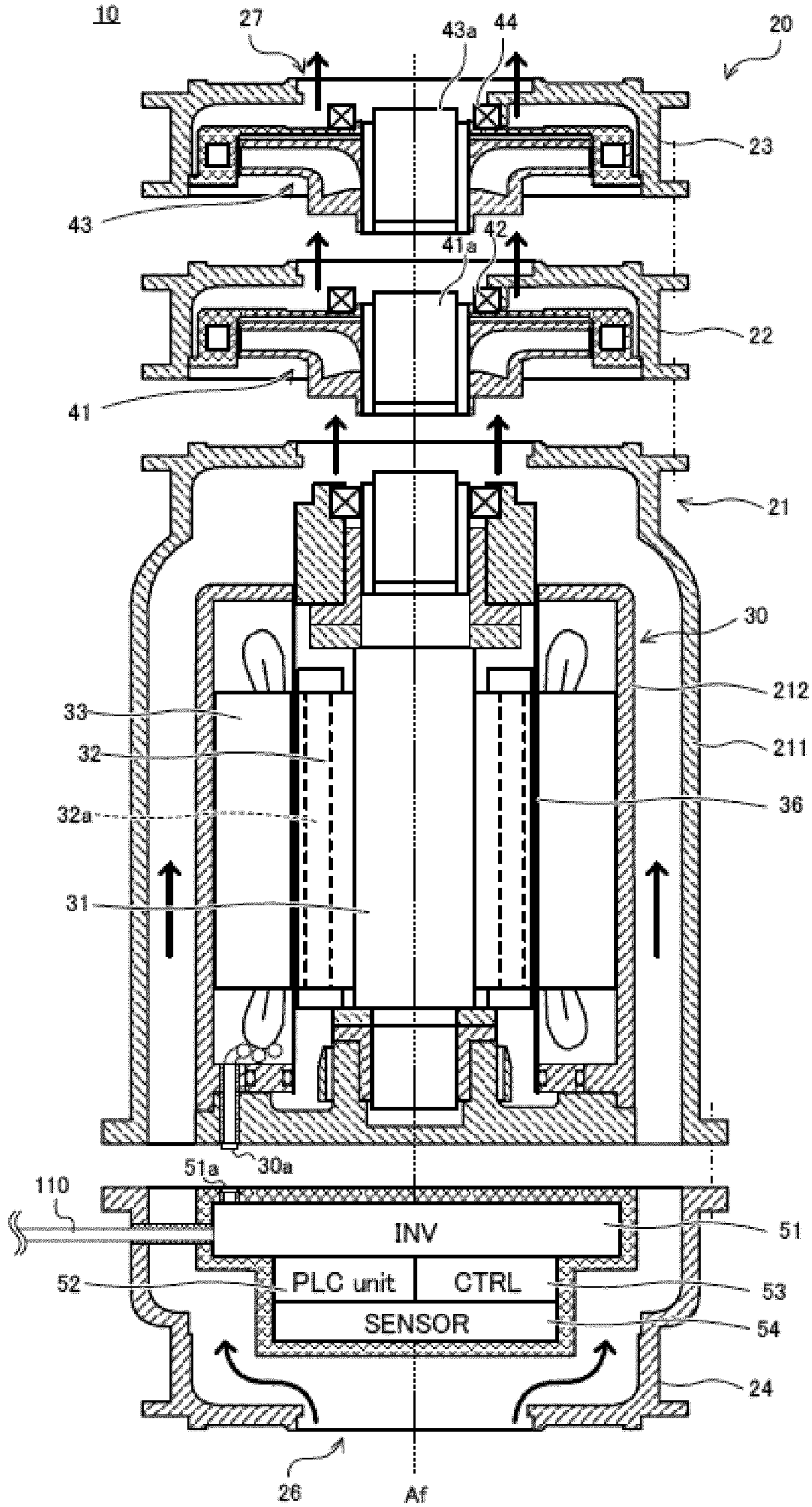
a first casing member that houses at least the motor; and
a second casing member connected to the first casing member, the second casing member including a first impeller having a first impeller rotating shaft configured to be connectable to the rotating shaft of the motor, and a bearing that axially supports the first impeller housed therein.

9. The pump apparatus according to claim 8, wherein the casing further comprises: a third casing member connected to the second casing member, the third casing member including: a second impeller having a second impeller rotating shaft configured to be connectable to the rotating shaft of the motor via the first impeller rotating shaft; and a bearing that axially supports the second impeller housed therein.

10. The pump apparatus according to any one of claims 1 to 9, wherein the casing comprises:

the first casing member in which at least the motor is housed, and
a fourth casing member connected to the first casing member and including the inverter housed therein.

Fig. 1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53
SENSOR
54
24
26
Af

Fig. 2

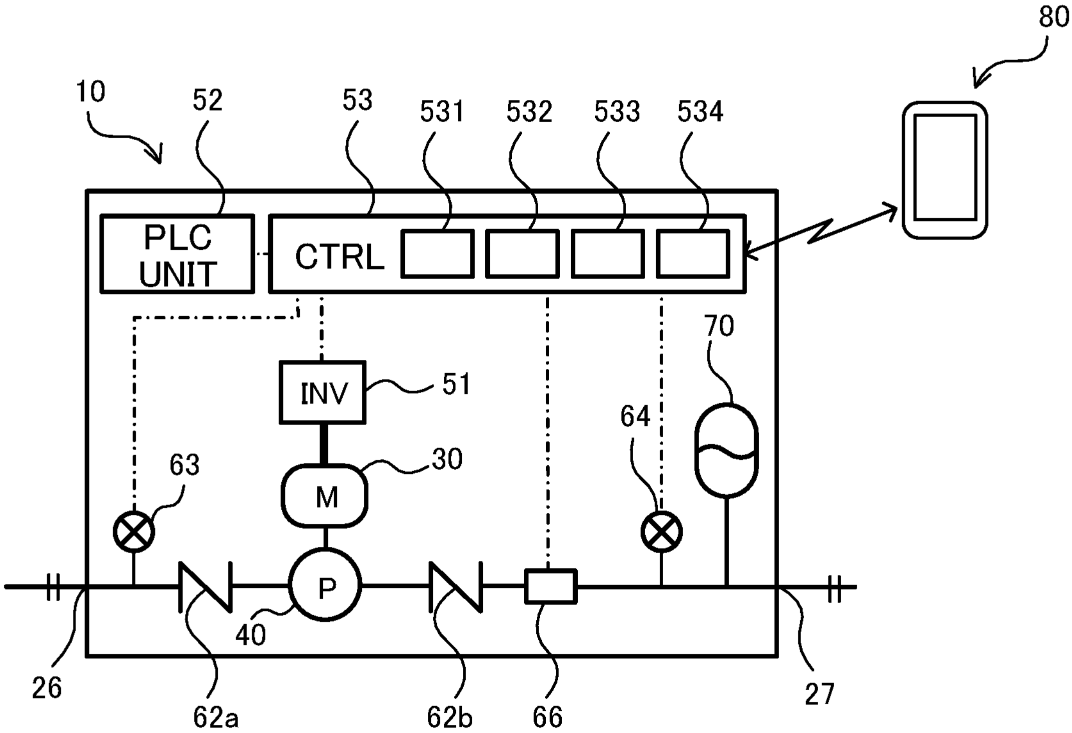
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Fig. 3

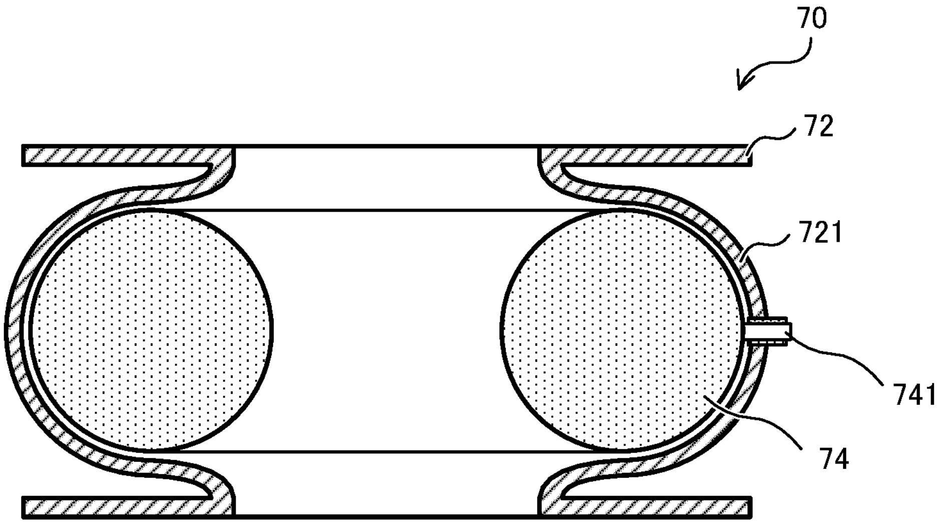
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Fig. 4

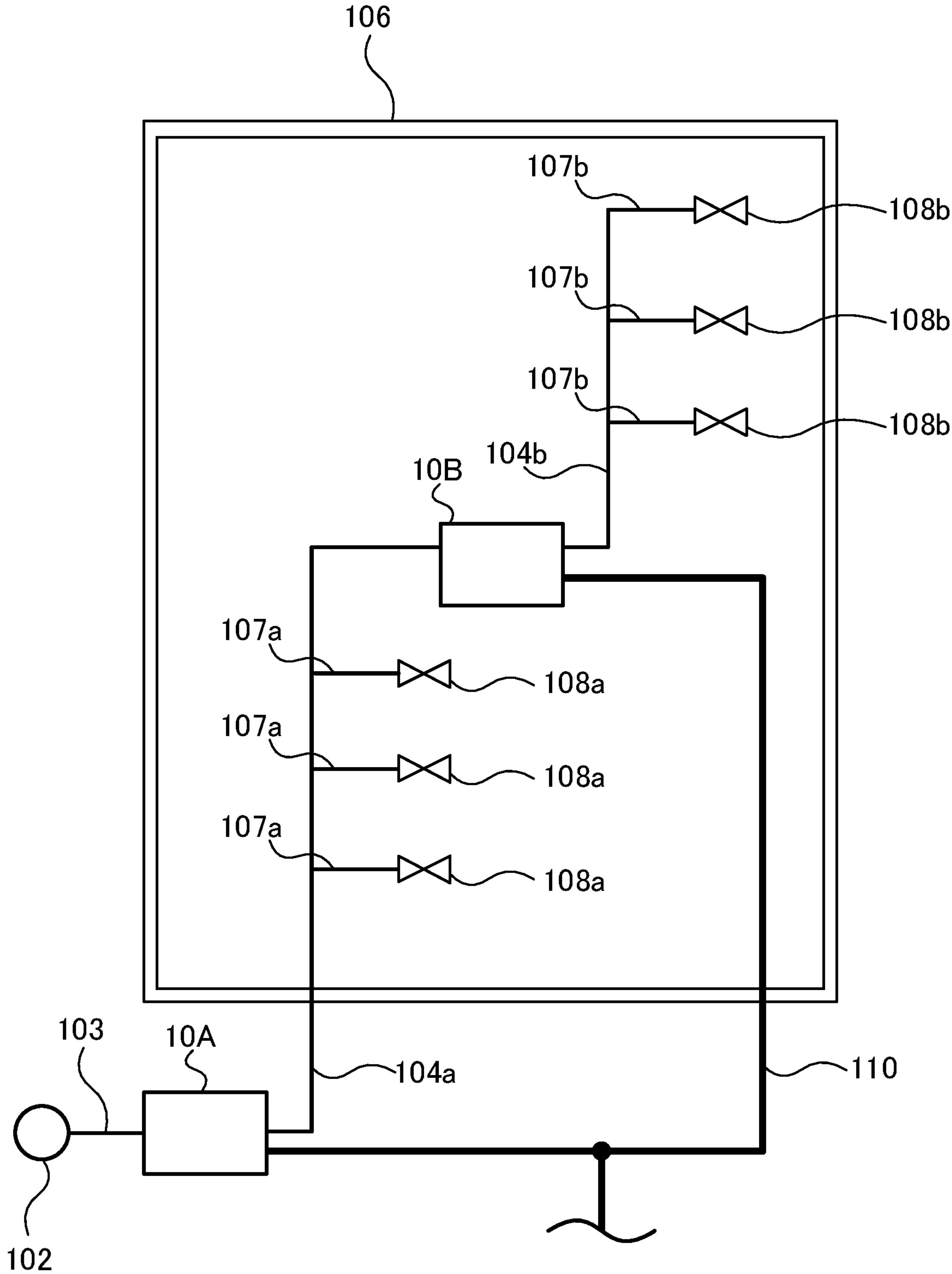
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Fig. 5

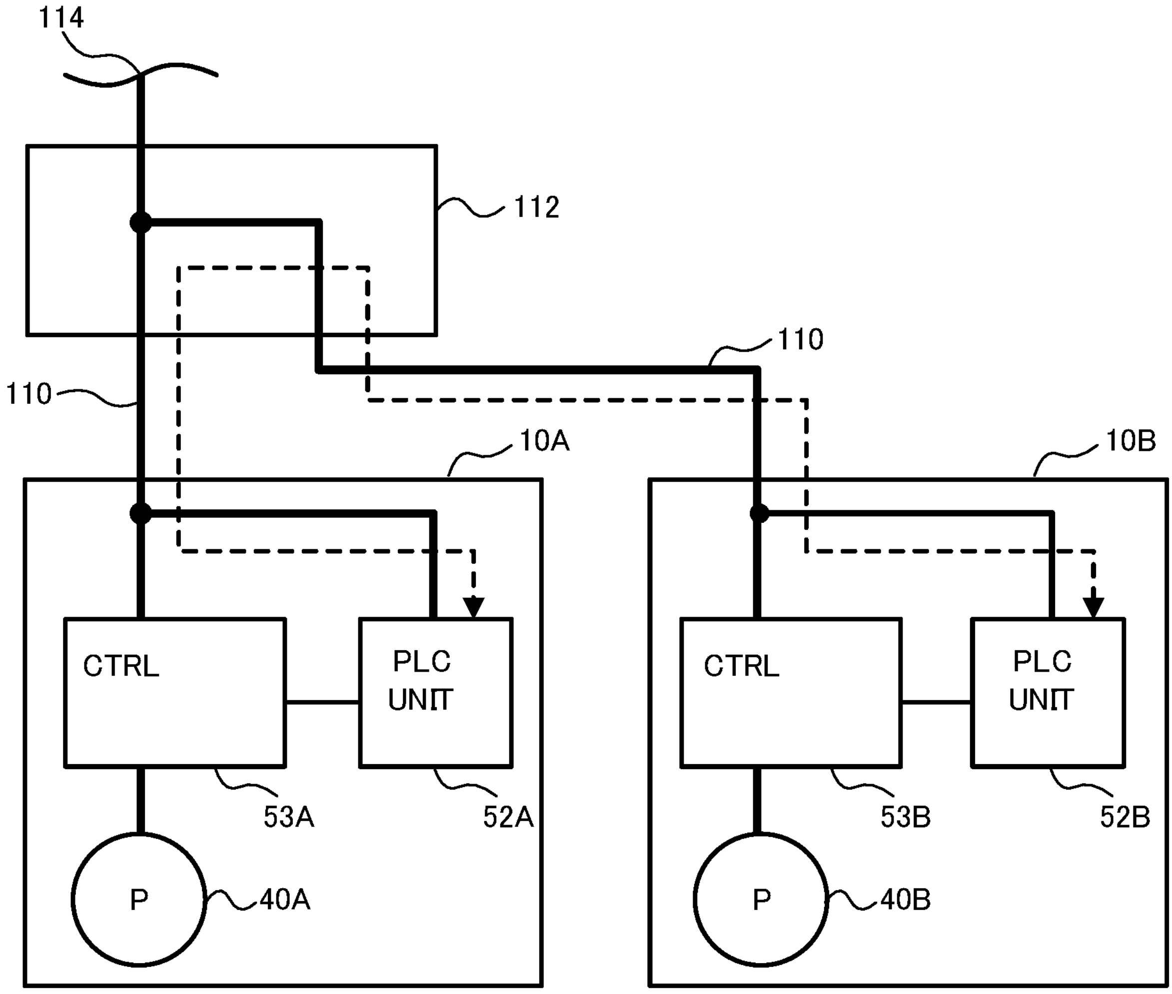
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Fig. 6

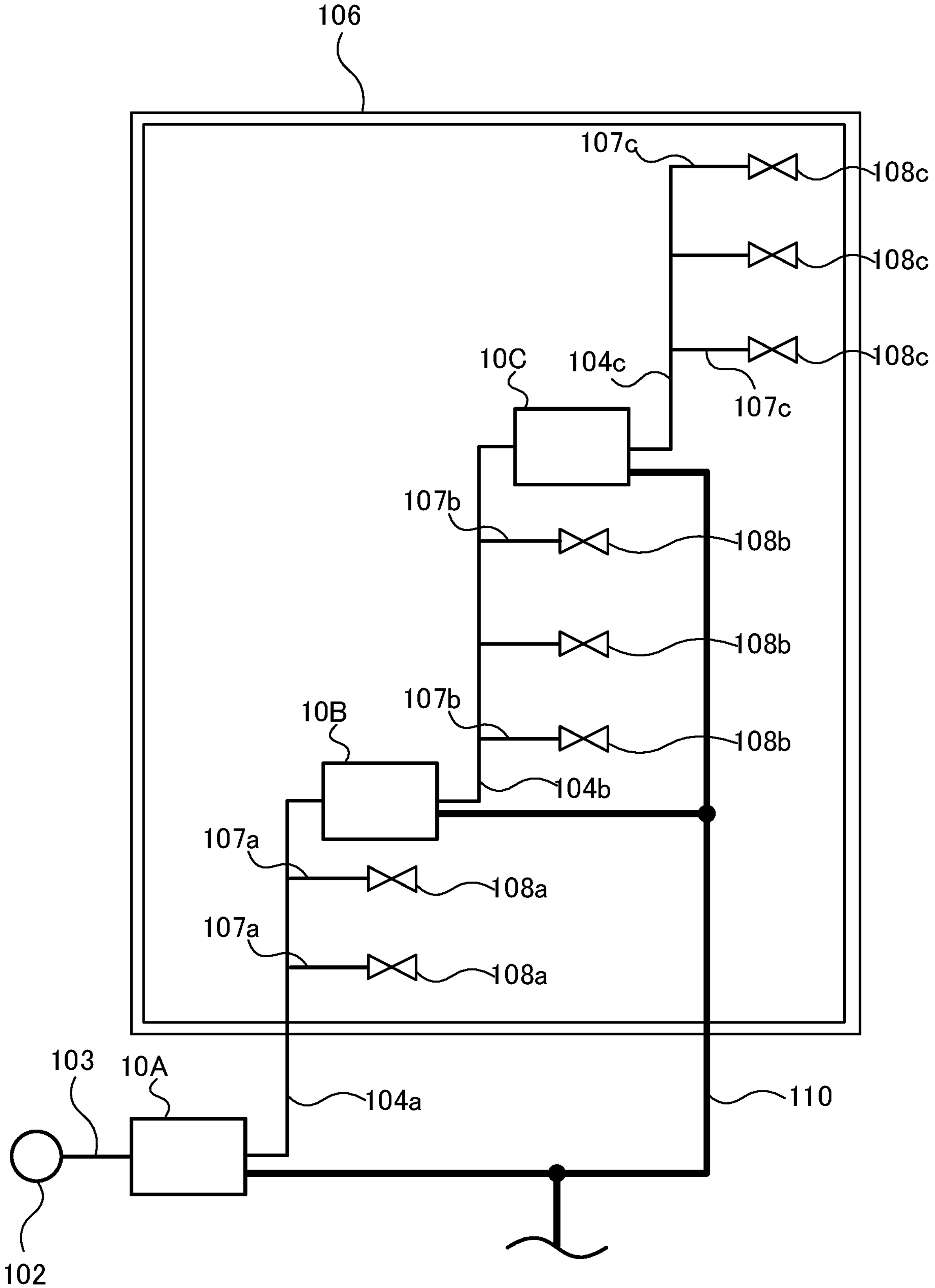
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Fig. 7

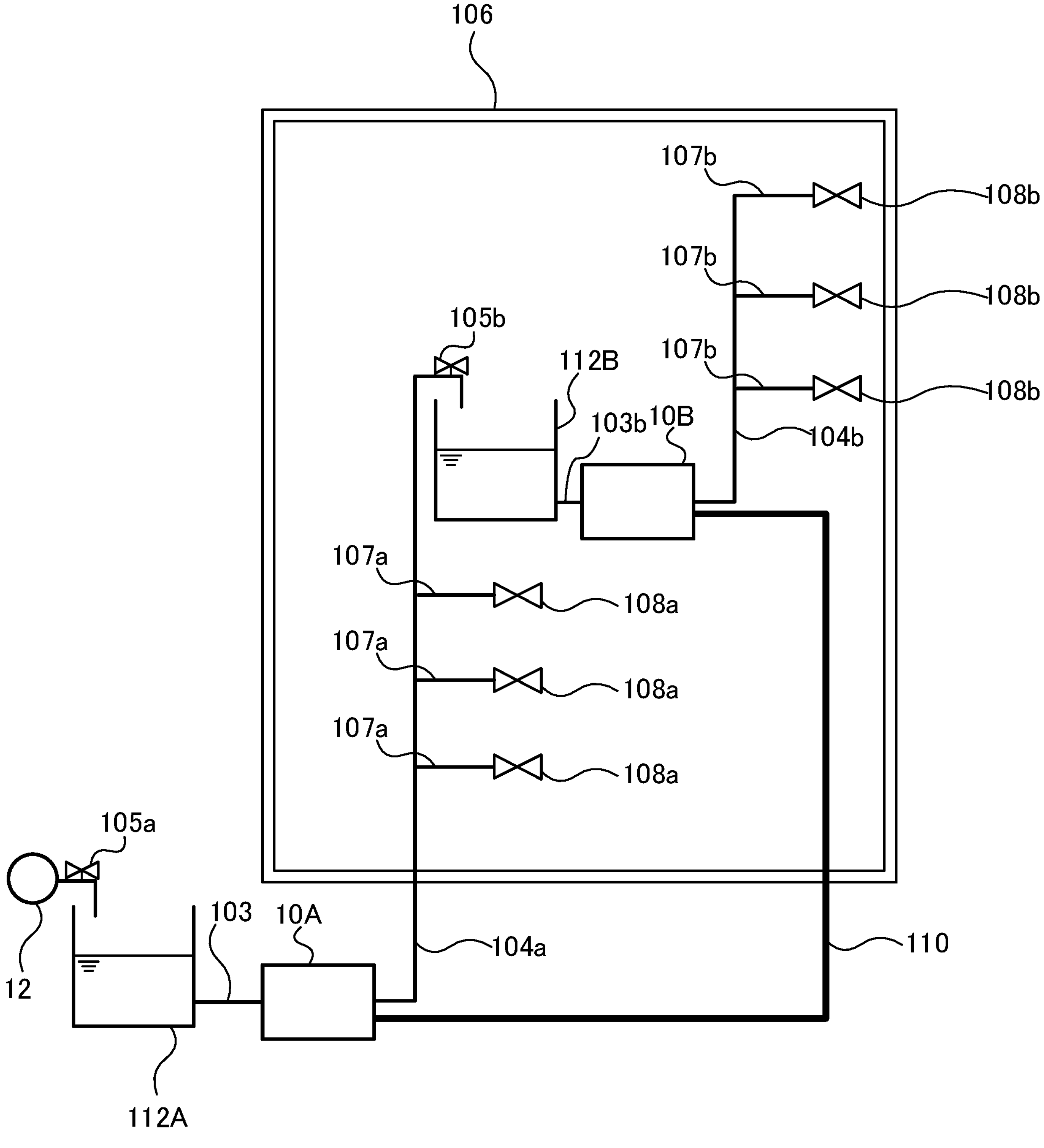
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Fig. 8

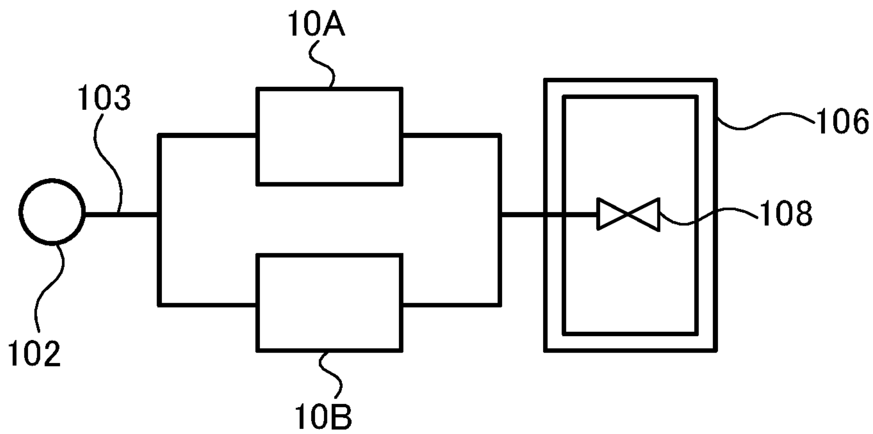


Fig. 9

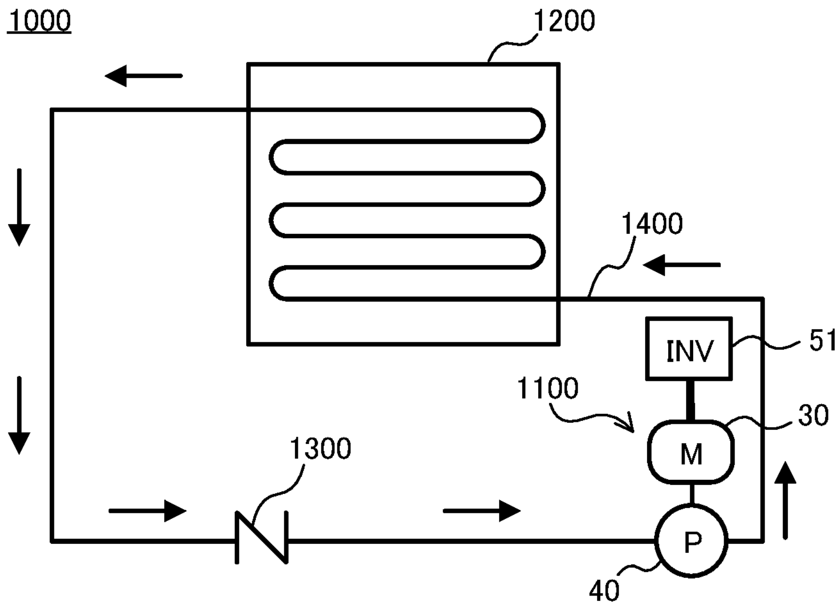
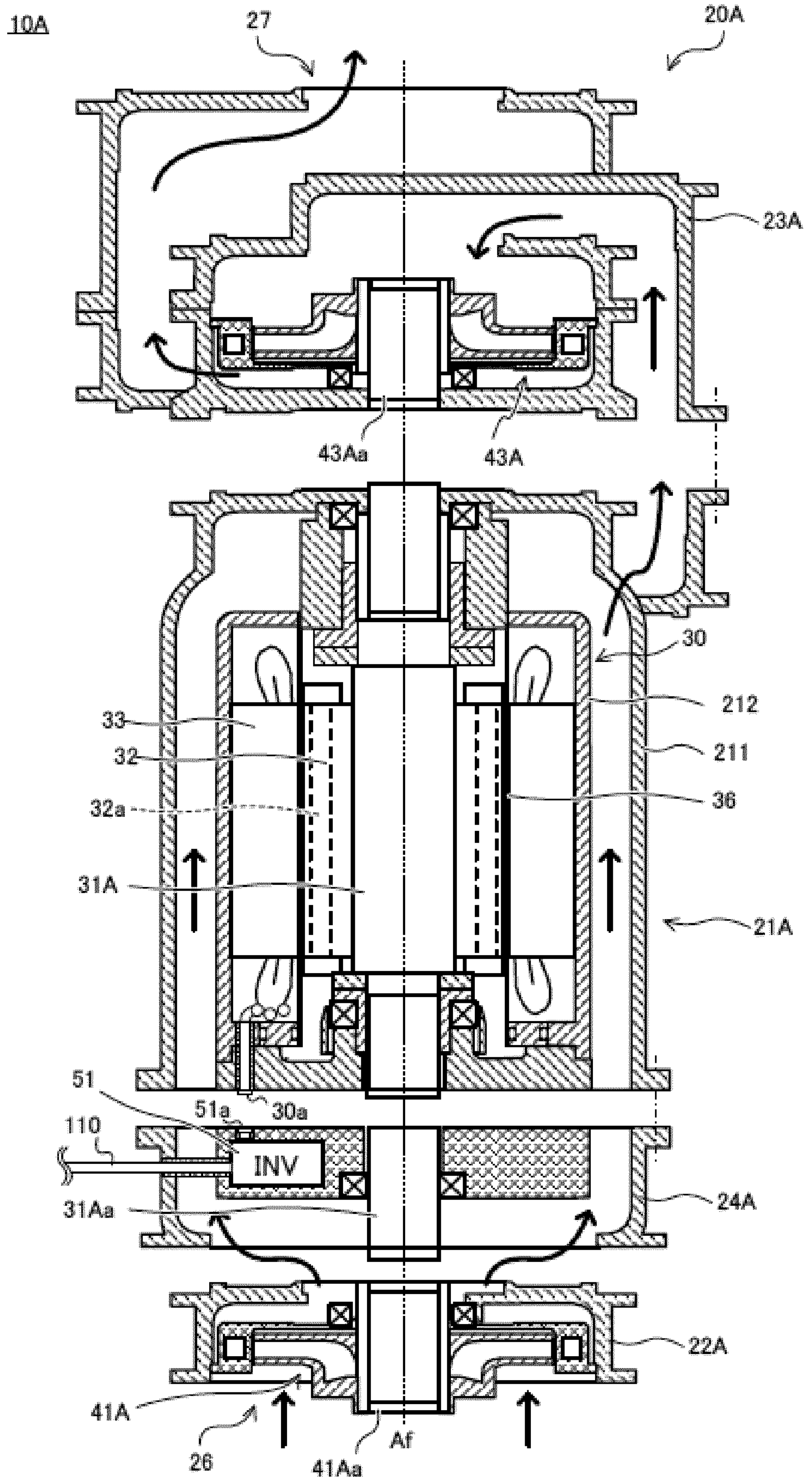


Fig. 10


10A
27
20A
23A
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43A
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211
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32a
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31A
21A
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51a
30a
110
INV
31Aa
24A
22A
41A
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Af
41Aa

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/032112

A. CLASSIFICATION OF SUBJECT MATTER
F04D 13/06(2006.01)i; F04D 13/14(2006.01)i
FI: F04D13/06 E; F04D13/14

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)
F04D13/06; F04D13/14

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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.
Y	JP 2009-41500 A (EBARA CORPORATION) 26.02.2009 (2009-02-26) paragraphs [0013], [0016]-[0018], [0021]-[0023], fig. 1	1-10
Y	JP 7-139492 A (HITACHI, LTD.) 30.05.1995 (1995-05-30) paragraphs [0007]-[0009], fig. 1-4	1-10
Y	JP 2005-171880 A (SHINMAYWA INDUSTRIES, LTD.) 30.06.2005 (2005-06-30) paragraphs [0042]-[0044]	4-10
Y	JP 2013-199894 A (KUBOTA CORP.) 03.10.2013 (2013-10-03) paragraphs [0081]-[0090], fig. 5	8-10

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 September 2020 (18.09.2020)	06 October 2020 (06.10.2020)

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

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/032112

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2009-41500 A	26 Feb. 2009	(Family: none)	
JP 7-319492 A	30 May 1995	(Family: none)	
JP 2005-171880 A	30 Jun. 2005	(Family: none)	
JP 2013-199894 A	03 Oct. 2013	CN 203201821 U	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5332282 A **[0003] [0060]**
- JP 2019153911 A **[0060]**