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(57) A dry vacuum pump apparatus is small in size as it includes a highly efficient cooling unit for cooling, with a coolant such as cooling water, large-current circuit components of high self-heating value, typically switching devices of an inverter. The dry vacuum pump apparatus includes a dry vacuum pump including a pump unit and a motor for actuating the pump unit, an inverter for converting AC power from an AC power supply into AC power having a predetermined frequency and supplying the AC power to the motor, an electric equipment en-

sure accommodating therein a control electronic circuit assembly including the inverter, a pump enclosure accommodating therein the dry vacuum pump and an operation monitoring sensor of the dry vacuum pump, a liquid-cooled partition interposed between the electric equipment enclosure and the pump enclosure, and having a coolant circulating therein, and an external enclosure housing therein the electric equipment enclosure, the pump enclosure, and the liquid-cooled partition as an integral structure.

Description

BACKGROUND OF THE INVENTION

Field of the Invention:

[0001] The present invention relates to a dry vacuum pump apparatus and a method of cooling a dry vacuum pump apparatus, and more particularly to a dry vacuum pump apparatus which is small in size and has a highly effective cooling structure and a method of cooling such a dry vacuum pump apparatus.

Description of the Related Art:

[0002] In recent years, dry vacuum pump apparatus, which can be operated under the atmospheric pressure to produce a clean vacuum environment easily, have been used in a wide range of applications including semiconductor fabrication facilities. The dry vacuum pump apparatus have a pump unit which is actuated by a motor. Power supply apparatus for supplying electric power to the motor for actuating the pump unit of the dry vacuum pump apparatus often incorporate an inverter for various reasons. One of the reasons is that the inverter can make the frequency of the electric power supplied to the motor higher than the commercial frequency thereby to increase the rotational speed of the motor for a higher vacuum pump exhaust capability. A dry vacuum pump apparatus, which is controlled by an inverter, is capable of achieving a desired degree of vacuum with a smaller motor.

[0003] According to another reason, when a chamber or the like has been evacuated to a desired degree of vacuum by operating a dry vacuum pump apparatus and the dry vacuum pump apparatus has come to operate under a very small load, the inverter makes it easy to control its output terminal voltage and also to control the rotational speed of the motor for operating the motor highly efficiently.

[0004] The inverter incorporates semiconductor switching devices therein and is capable of outputting an output voltage at a frequency, which is different from the frequency of an input voltage applied thereto, by an AC/DC/AC converting circuit. The inverter needs to be combined with a suitable cooling apparatus for cooling the semiconductor switching devices which are used to change frequencies as they are heated by an internal loss thereof.

[0005] Conventional dry vacuum pump apparatus, which are combined with a power supply apparatus including an inverter, have an air cooling structure with natural air circulation or forced air circulation for cooling the semiconductor switching devices of the inverter. There has also been proposed a water cooling structure for cooling a dry vacuum pump by circulating a coolant through a coolant pipe mounted in a lower portion of a fixed section of a motor housing of the dry vacuum pump,

so that a substrate in the dry vacuum pump can efficiently be cooled (see Japanese laid-open patent publication No. 2003-269369).

[0006] In vacuum pumps, a pump motor and a pump casing, which incorporate an air cooling structure, are required to have a very large cooling area. Therefore, some vacuum pumps have a water-cooled pump motor and a water-cooled pump casing which incorporate a coolant circulating structure (see PC (WO) 2006-520873 and Japanese laid-open patent publication No. 8-21392).

SUMMARY OF THE INVENTION

[0007] The air cooling structure with natural air circulation or forced air circulation for cooling the semiconductor switching devices of the inverter is necessarily large in size because its cooling efficiency is low, and hence presents itself as an obstacle to efforts to reduce the overall size of the dry vacuum pump apparatus. The water cooling structure cools only a portion of the dry vacuum pump, but fails to efficiently cool the dry vacuum pump apparatus as a whole.

[0008] The present invention has been made in view of the above situation. It is, therefore, an object of the present invention to provide a dry vacuum pump apparatus including an inverter for supplying AC power to a motor for actuating a pump unit, and a highly efficient cooling structure for cooling large-current circuit components of high self heating value, such as switching devices of the inverter, with a coolant such as cooling water, so that the dry vacuum pump apparatus can be reduced in size, and a method of cooling the dry vacuum pump apparatus.

[0009] In order to achieve the above object, the present invention provides a dry vacuum pump apparatus comprising: a dry vacuum pump including a pump unit and a motor for actuating the pump unit; an inverter for converting AC power from an AC power supply into AC power having a predetermined frequency and supplying the AC power to the motor; an electric equipment enclosure accommodating therein a control electronic circuit assembly including the inverter; a pump enclosure accommodating therein the dry vacuum pump and an operation monitoring sensor of the dry vacuum pump; a liquid-cooled partition interposed between the electric equipment enclosure and the pump enclosure, and having a coolant circulating therein; and an external enclosure housing therein the electric equipment enclosure, the pump enclosure, and the liquid-cooled partition as an integral structure.

[0010] In a preferred aspect of the present invention, the external enclosure has a coolant channel defined therein for supplying a coolant initially to the liquid-cooled partition and then from the liquid-cooled partition to the motor and then to the pump unit to cool the liquid-cooled partition, the motor, and the pump unit successively.

[0011] In a preferred aspect of the present invention, the control electronic circuit assembly has electronic

components which generate heat, the electronic components including switching devices of the inverter, and the liquid-cooled partition provides a cooling structure for cooling the electronic components.

[0012] In a preferred aspect of the present invention, the liquid-cooled partition is held out of direct contact with the pump unit of the dry vacuum pump, and is fixed to a frame which extends from an outer wall of the pump unit.

[0013] With the above arrangement, the electric equipment enclosure accommodating therein the control electronic circuit assembly including the inverter, the pump enclosure accommodating therein the dry vacuum pump and the operation monitoring sensor of the dry vacuum pump, and the liquid-cooled partition interposed between the electric equipment enclosure and the pump enclosure and having the coolant circulating therein, are housed in the external enclosure as an integral structure. The coolant circulating in the liquid-cooled partition is effective to absorb heat generated by the control electronic circuit assembly in the electric equipment enclosure, and hence the control electronic circuit assembly in the electric equipment enclosure is highly efficiently cooled. Thus, the dry vacuum pump apparatus can have a small cooling structure and hence can be small in size itself.

[0014] When the external enclosure has the coolant channel defined therein for supplying the coolant initially to the liquid-cooled partition and then from the liquid-cooled partition to the motor and then to the pump unit to cool the liquid-cooled partition, the motor, and the pump unit successively, control electronic circuit assembly including the inverter can be initially cooled by the coolant, and then the motor and the pump unit can be successively cooled by the coolant. This makes it possible to reduce the dry vacuum pump apparatus in size and efficiently to cool as a whole.

[0015] The cooling structure for cooling the electronic components, which generate heat, including switching devices of the inverter housed in the electric equipment enclosure may be provided by the liquid-cooled partition with the coolant circulating therein. The electronic components can thus be efficiently cooled by the coolant circulating in the liquid-cooled partition.

[0016] The liquid-cooled partition may be held out of direct contact with the pump unit of the dry vacuum pump, and be fixed to the frame which extends from the outer wall of the pump unit. This makes it possible to minimize the absorption of heat from the pump unit and to reduce deposits on an inner wall surface of the pump unit of the dry vacuum pump.

[0017] The present invention also provides a dry vacuum pump apparatus comprising: a dry vacuum pump including a pump unit and a motor for actuating the pump unit; an inverter for converting AC power from an AC power supply into AC power having a predetermined frequency and supplying the AC power to the motor; a first electric equipment enclosure accommodating therein the inverter as a heat-generating large-current circuit; a second electric equipment enclosure accommodating there-

in a control circuit including a CPU for controlling the dry vacuum pump in operation; an external enclosure housing therein the first electric equipment enclosure and the second electric equipment enclosure as an integral structure; a cooling unit for cooling the first electric equipment enclosure with a coolant; and an air cooling structure for cooling the second electric equipment enclosure with natural air circulation or forced air circulation.

[0018] In a preferred aspect of the present invention, the dry vacuum pump includes a gear unit, and the cooling unit comprises a cooling unit for cooling the motor or the gear unit of the dry vacuum pump with cooling water as the coolant.

[0019] The present invention further provides a method of cooling a dry vacuum pump apparatus including a dry vacuum pump including a pump unit and a motor for actuating the pump unit, an inverter for converting AC power from an AC power supply into AC power having a predetermined frequency and supplying the AC power to the motor, a first electric equipment enclosure accommodating therein the inverter as a heat-generating large-current circuit of high self-heating value, a second electric equipment enclosure accommodating therein a control circuit including a CPU for controlling the dry vacuum pump in operation, and an external enclosure housing therein the first electric equipment enclosure and the second electric equipment enclosure as an integral structure, the method comprising: cooling the first electric equipment enclosure with a coolant; and cooling the second electric equipment enclosure with natural air circulation or forced air circulation.

[0020] Inasmuch as the first electric equipment enclosure accommodating therein the inverter as the heat-generating large-current circuit of high self-heating value is highly efficiently cooled by the cooling unit with the coolant, the dry vacuum pump apparatus can have a small cooling structure and hence can be small in size itself.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a block diagram of a system arrangement of a dry vacuum pump apparatus according to the present invention;

FIG. 2 is a schematic view of a structural arrangement of a dry vacuum pump apparatus according to an embodiment of the present invention;

FIG. 3A is a side view of a cooling structure for cooling electronic components and devices housed in an electric equipment enclosure of the dry vacuum pump apparatus;

FIG. 3B is a plan view of FIG. 3A;

FIG. 4 is a schematic view of a structural arrangement of a dry vacuum pump apparatus according to another embodiment of the present invention;

FIG. 5 is a schematic view of a structural arrange-

ment of a dry vacuum pump apparatus according to still another embodiment of the present invention; and

FIG. 6 is a schematic view of a structural arrangement of a dry vacuum pump apparatus according to yet another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Preferred embodiments of the present invention will be described in detail below with reference to the drawings. Identical or corresponding parts are denoted by identical or corresponding reference characters throughout views, and their redundant description will be avoided as much as possible for the sake of brevity.

[0023] FIG. 1 is a block diagram of a system arrangement of a dry vacuum pump apparatus according to the present invention. As shown in FIG. 1, the dry vacuum pump apparatus comprises a power supply 10 including a rectifier 13, a DC circuit 15 having a smoothing capacitor 14, a DC/DC converting circuit 16, and an inverter 17, a dry vacuum pump 12 including a motor 12a and a pump unit 12b, and a control circuit 18. The power supply 10 and the control circuit 18 may also be referred to as a control electronic circuit assembly. The rectifier 13 is connected to an AC power supply 19. The AC power supply 19 supplies AC power to the rectifier 13, which converts the AC power into DC power. Under the control of the control circuit 18, the DC/DC converting circuit 16 converts the DC power from the rectifier 13 into DC power having a predetermined voltage, which is supplied to the inverter 17. Under the control of the control circuit 18, the inverter 17 converts the DC power supplied from the DC/DC converting circuit 16 into AC power having a predetermined frequency, which is supplied to the motor 12a of the dry vacuum pump 12. The motor 12a is energized to actuate the pump unit 12b, thereby operating the dry vacuum pump 12.

[0024] In the dry vacuum pump apparatus having the above-described system arrangement, when the dry vacuum pump 12 is in operation, the rectifying devices of the rectifier 13, the smoothing capacitor 14 of the DC circuit 15, the switching devices of the DC/DC converting circuit 16, and the switching devices of the inverter 17 generate heat as they output electric power to energize the motor 12a. The motor 12a and the pump unit 12b of the dry vacuum pump 12 also generate heat. The dry vacuum pump apparatus according to the present invention incorporates a small-size cooling structure for efficiently absorbing the heat generated by the above switching devices, and electronic components and electronic devices of the dry vacuum pump apparatus thereby to cool the dry vacuum pump apparatus. The dry vacuum pump apparatus, which incorporates such a small-size cooling structure, is also small in size.

[0025] FIG. 2 is a schematic view of a structural arrangement of a dry vacuum pump apparatus 20 accord-

ing to an embodiment of the present invention. As shown in FIG. 2, the dry vacuum pump apparatus 20 includes an electric equipment enclosure 21, a pump enclosure 22, and a liquid-cooled partition 23 interposed between the electric equipment enclosure 21 and the pump enclosure 22. The electric equipment enclosure 21, the pump enclosure 22, and the liquid-cooled partition 23 are housed in an external enclosure 24 as an integral structure.

[0026] The electric equipment enclosure 21 accommodates therein various electronic components and electronic devices which generate heat, which include the rectifying devices of the rectifier 13, the smoothing capacitor 14 of the DC circuit 15, the switching devices of the DC/DC converting circuit 16, the switching devices of the inverter 17, and the electronic components of the control circuit 18. The pump enclosure 22 accommodates therein two dry vacuum pumps 12-1, 12-2 and operation monitoring sensors (not shown) of the dry vacuum pumps 12-1, 12-2. Since the electronic components and electronic devices housed in the electric equipment enclosure 21 generate heat, they are disposed above the dry vacuum pumps 12-1, 12-2. The liquid-cooled partition 23 is interposed between the electronic components and electronic devices and the dry vacuum pumps 12-1, 12-2 to isolate heat from the dry vacuum pumps 12-1, 12-2 against transfer to the electronic components and electronic devices in the electric equipment enclosure 21.

[0027] The dry vacuum pump 12-1 comprises a motor 12-1a, a pump unit 12-1b, and a gear unit 12-1c. Similarly, the dry vacuum pump 12-2 comprises a motor 12-2a, a pump unit 12-2b, and a gear unit 12-2c. The motors 12-1a, 12-2a, the pump units 12-1b, 12-2b, and the gear units 12-1c, 12-2c of the dry vacuum pumps 12-1, 12-2 also generate heat when they are in operation. The dry vacuum pump 12-1 has a casing including an intake port 27, and the dry vacuum pump 12-2 has a casing including an exhaust port 28.

[0028] The liquid-cooled partition 23 is held out of direct contact with the pump units 12-1b, 12-2b of the dry vacuum pumps 12-1, 12-2, and is fixed to a frame which extends from outer walls of the pump units 12-1b, 12-2b.

[0029] The external enclosure 24, or more specifically, the liquid-cooled partition 23 and the pump enclosure 22 have a coolant channel 25 defined therein for a coolant such as cooling water, i.e., cold water, to flow therethrough. The coolant channel 25 is arranged to supply cooling water W initially to the liquid-cooled partition 23, then from the liquid-cooled partition 23 to the motors 12-1a, 12-2a of the dry vacuum pumps 12-1, 12-2 and then to the pump units 12-1b, 12-2b thereof to cool the electronic components and electronic devices which generate heat successively as the cooling water W flows.

[0030] As described above, the liquid-cooled partition 23 is interposed between the electric equipment enclosure 21 and the pump enclosure 22, and the coolant channel 25 is arranged to supply cooling water W initially to the liquid-cooled partition 23, then from the liquid-

cooled partition 23 to the motors 12-1a, 12-2a of the dry vacuum pumps 12-1, 12-2 and then to the pump units 12-1b, 12-2b. This can efficiently cool the electronic components and electronic devices which tend to generate an amount of heat that may possibly cause failures, and also of thermally isolate the electric equipment enclosure 21 which houses the rectifier 13, the DC circuit 15, the DC/DC converting circuit 16, the inverter 17, and the control circuit 18 from the pump enclosure 22 which houses the dry vacuum pumps 12-1, 12-2, effectively. Thus, the dry vacuum pump apparatus 20, which incorporates the coolant channel 25, has its overall volume minimized and hence is reduced in size.

[0031] FIG. 3A is a side view of the cooling structure for cooling the rectifying devices of the rectifier 13, the smoothing capacitor 14 of the DC circuit 15, the switching devices of the DC/DC converting circuit 16, the switching devices of the inverter 17, and the electronic components of the control circuit 18 which are housed in the electric equipment enclosure 21. FIG. 3B is a plan view of FIG. 3A. As shown in FIGS. 3A and 3B, the electronic components and electronic devices which generate heat, which belong to the rectifier 13, the DC circuit 15, the DC/DC converting circuit 16, the inverter 17, and the control circuit 18 are mounted on the liquid-cooled partition 23 in which the cooling water W circulates.

[0032] The liquid-cooled partition 23 has the coolant channel 25 defined therein through which cooling water as coolant flows. The cooling water is supplied to the coolant channel 25. The liquid-cooled partition 23 is made of a material of high thermal conductivity such as metal, e.g., aluminum. With this arrangement, the heat generated by the electronic components and electronic devices that are housed in the electric equipment enclosure 21 is transmitted to the liquid-cooled partition 23, and is efficiently absorbed by the cooling water that flows through the coolant channel 25.

[0033] In this embodiment, the pump enclosure 22 accommodates therein two dry vacuum pumps 12-1, 12-2. However, the pump enclosure 22 may accommodate therein a single dry vacuum pump or three or more dry vacuum pumps.

[0034] As described above, the dry vacuum pump apparatus 20 according to this embodiment includes the electric equipment enclosure 21 which houses therein the control electronic circuit assembly, i.e., the rectifier 13, the DC circuit 15, the DC/DC converting circuit 16, the inverter 17, and the control circuit 18, the pump enclosure 22 which houses therein the dry vacuum pumps 12-1, 12-2 and the operation monitoring sensors of the dry vacuum pumps 12-1, 12-2, and the liquid-cooled partition 23 interposed between the electric equipment enclosure 21 and the pump enclosure 22 and having the coolant channel 25 for circulating the coolant there-through, the electric equipment enclosure 21, the pump enclosure 22, and the liquid-cooled partition 23 being housed in the external enclosure 24 as an integral structure. The coolant is circulated through the coolant chan-

nel 25 in the liquid-cooled partition 23 to absorb the heat generated by the electronic components and electronic devices that are housed in the electric equipment enclosure 21 and hence to highly efficiently cool the electronic components and electronic devices that are housed in the electric equipment enclosure 21. The cooling structure, which includes the liquid-cooled partition 23, is small in size, and hence the dry vacuum pump apparatus 20, which incorporates the cooling structure, is also small in size.

[0035] FIG. 4 is a schematic view of a structural arrangement of a dry vacuum pump apparatus 20a according to another embodiment of the present invention. In the dry vacuum pump apparatus 20a, as shown in FIG. 4, the pump unit 12b of the dry vacuum pump 12 is disposed centrally in the external enclosure 24, and the motor 12a and a gear unit 12c are disposed on each side of the pump unit 12b. A first electric equipment enclosure 31 housing therein the inverter 17 (see FIG. 1) and other electronic components and electronic devices is disposed on the side of the motor 12a. A highly efficient cooling unit 30 for cooling the motor 12a and the first electric equipment enclosure 31 with a coolant such as water is interposed between the motor 12a and the first electric equipment enclosure 31. Another highly efficient cooling unit 32 for cooling the gear unit 12c with a coolant such as water is disposed on the side of the gear unit 12c. A second electric equipment enclosure 33 housing therein the control circuit 18 (see FIG. 1) having electronic components which include a pump control CPU is disposed above the pump unit 12b and the motor 12a. The pump unit 12b has a casing including the inlet port 27 and the exhaust port 28.

[0036] The pump unit 12b comprises, e.g., a positive-displacement vacuum pump having two rotatable shafts disposed in a rotor casing and a plurality of sets of a pair of roots-type rotors fixed to the rotatable shafts. The rotors are spaced from each other by small gaps, and also spaced from an inner circumferential surface of the rotor casing by small gaps, so that the rotors fixed to the rotatable shafts can be rotated about the axes thereof out of contact with each other and the rotor casing. The rotor casing has a series of rotor compartments defined therein along the rotatable shafts and housing the respective sets of rotors, for transferring a gas to be pumped through the rotor compartments. The motor 12a has an output shaft coupled to one of the rotatable shafts. When the motor 12a is energized, the output shaft thereof rotates the rotatable shaft coupled thereto, which rotates the other rotatable shaft in synchronism therewith through the gears of the gear unit 12c. The rotors are now rotated to draw in the gas through the intake port 27 and discharge the gas through the exhaust port 28.

[0037] When the motor 12a is energized, its motor stator generates heat. The generated heat is transferred to the motor casing of the motor 12a, increasing its temperature. As the two rotatable shafts rotate, the gears of the gear unit 12c also generate heat. The generated heat is

transferred to the gear casing of the gear unit 12, increasing its temperature. The motor casing is cooled by the coolant, such as water, of the highly efficient cooling unit 30, and the gear casing is cooled by the coolant, such as water, of the highly efficient cooling unit 32.

[0038] As described above, when the dry vacuum pump apparatus 20a is in operation, the motor casing has its temperature raised by the heat from the motor stator of the motor 12a, and the gear casing has its temperature raised by the heat from the rotating gears of the gear unit 12c. According to this embodiment, the highly efficient cooling units (cooling structures) 30, 32, which generally employ a water-cooled system, are provided to cool the motor casing and the gear casing. The inverter 17 (see FIG. 1) which supplies drive power to the motor 12a includes switching devices such as IGBTs. The switching devices of the inverter 17 generate relatively high heat due to currents flowing through the switching devices and switching losses caused by the switching devices. Accordingly, the inverter 17 needs to be cooled. According to this embodiment, the highly efficient cooling unit 30, for cooling the motor casing, serves to cool the inverter 17.

[0039] The control circuit 18 (see FIG. 1) for controlling the operation of the dry vacuum pump apparatus 20a has electronic components. The electronic components of the control circuit 18, which include the pump control CPU, are not of high self-heating value. Insofar as the control circuit 18 is disposed in a location that is normally kept at an ambient temperature at which the electronic components of the control circuit 18 can be used, the control circuit 18 does not need to have a special heat radiating structure, but is combined with an air cooling structure including a forced air cooling system on the assumption that the dry vacuum pump apparatus 20a may be used under conditions outside an ordinary operation range.

[0040] As described above, the highly efficient cooling unit 30 for cooling the motor 12a, which employs, e.g., a cooled-water system, is used as a cooling means for absorbing the heat generated by the switching devices of the inverter 17, and the air cooling structure including a forced air cooling system is used as a cooling means for cooling the electronic components of the control circuit 18 which are not of high self-heating value. Therefore, the dry vacuum pump apparatus 20a has a minimum cooling structure which is simple and effective.

[0041] FIG. 5 is a schematic view of a structural arrangement of a dry vacuum pump apparatus 20b according to still another embodiment of the present invention. The dry vacuum pump apparatus 20b shown in FIG. 5 is different from the dry vacuum pump apparatus 20a shown in FIG. 4 in that the first electric equipment enclosure 31 housing therein the inverter 17 (see FIG. 1) and other electronic components and electronic devices is disposed on the side of the gear unit 12c, and the highly efficient cooling unit 32 for cooling the gear casing of the gear unit 12c is interposed between the gear unit 12c

and the first electric equipment enclosure 31. Other structural details of the dry vacuum pump apparatus 20b shown in FIG. 5 are the same as the dry vacuum pump apparatus 20a shown in FIG. 4.

[0042] As described above, the highly efficient cooling unit 32 for cooling the gear casing of the gear unit 12c is used as a cooling means for absorbing the heat generated by the switching devices of the inverter 17, and the air cooling structure including a forced air cooling system is used as a cooling means for cooling the electronic components of the control circuit 18 which are not of high self-heating value. Therefore, the dry vacuum pump apparatus 20a has a minimum cooling structure which is simple and effective.

[0043] FIG. 6 is a schematic view of a structural arrangement of a dry vacuum pump apparatus 20c according to yet another embodiment of the present invention. The dry vacuum pump apparatus 20c shown in FIG. 6 is different from the dry vacuum pump apparatus 20a shown in FIG. 4 in that a control circuit cooling fan 34 is disposed on the side of the control circuit 18 (see FIG. 1), and the control circuit 18 and the control circuit cooling fan 34 are housed in the second electric equipment enclosure 33, so that the heat generated by the control circuit 18 is forcibly dissipated by air delivered by the control circuit cooling fan 34 to cool the control circuit 18. Other structural details of the dry vacuum pump apparatus 20c shown in FIG. 6 are the same as the dry vacuum pump apparatus 20a shown in FIG. 4.

[0044] As described above, the highly efficient cooling unit 30 for cooling the motor casing of the motor 12a is used as a cooling means for absorbing the heat generated by the switching devices of the inverter 17, and the control circuit cooling fan 34 on the side of the control circuit 18 is used as a cooling means for forced-air cooling the electronic components of the control circuit 18 which are not of high self-heating value. Therefore, the dry vacuum pump apparatus 20c has a minimum cooling structure which is simple and effective.

[0045] In the dry vacuum pump apparatus 20a, 20b, 20c, the power supply 10 (see FIG. 1) and the dry vacuum pump 12, which includes the motor 12a, the pump unit 12b, and the gear unit 12c, are housed in the external enclosure 24 as an integral structure. Each of the dry vacuum pump apparatus 20a, 20b, 20c includes the first electric equipment enclosure 31 housing therein a large-current circuit which is of high self-heating value, typically the inverter 17, and the second electric equipment enclosure 33 housing therein the control circuit 18 having electronic components, typically a pump control CPU, which are not of high self-heating value. Each of the dry vacuum pump apparatus 20a, 20b, 20c may further include a third electric equipment enclosure housing therein operation monitoring sensors of the dry vacuum pump 12. The first electric equipment enclosure 31 housing therein a large-current circuit which is of high self-heating value, typically the inverter 17, is cooled by the highly efficient cooling unit which is used to cool the motor 12a

or the gear unit 12c with the coolant such as water, and the second electric equipment enclosure 33 housing therein the control circuit 18 having electronic components, typically a pump control CPU, is cooled by the air cooling structure with natural air circulation or forced air circulation.

[0046] As described above, the dry vacuum pump apparatus according to the present invention includes the first electric equipment enclosure 31 housing therein a large-current circuit which is of high self-heating value, typically the inverter 17, and the second electric equipment enclosure 33 housing therein the control circuit 18, typically a pump control CPU. The first electric equipment enclosure 31 is cooled by the highly efficient cooling unit with the coolant, and the second electric equipment enclosure 33 is cooled by the air cooling structure with natural air circulation or forced air circulation. The first electric equipment enclosure 31 housing therein a large-current circuit which is of high self-heating value, typically the inverter 17, is highly efficiently cooled, so that the dry vacuum pump apparatus may be reduced in size.

[0047] In the above embodiments, cooling water is used as the coolant that flows through the coolant channel 25. However, any other coolants than cooling water may be used in the coolant channel 25. In addition, any other coolants than cooling water may be used in the highly efficient cooling units 30, 32.

[0048] Although certain preferred embodiments of the present invention have been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.

Claims

1. A dry vacuum pump apparatus comprising:

a dry vacuum pump including a pump unit and a motor for actuating the pump unit;
 an inverter for converting AC power from an AC power supply into AC power having a predetermined frequency and supplying the AC power to the motor;
 an electric equipment enclosure accommodating therein a control electronic circuit assembly including the inverter;
 a pump enclosure accommodating therein the dry vacuum pump and an operation monitoring sensor of the dry vacuum pump;
 a liquid-cooled partition interposed between the electric equipment enclosure and the pump enclosure, and having a coolant circulating therein;
 and
 an external enclosure housing therein the electric equipment enclosure, the pump enclosure, and the liquid-cooled partition as an integral structure.

2. A dry vacuum pump apparatus according to claim 1, wherein the external enclosure has a coolant channel defined therein for supplying a coolant initially to the liquid-cooled partition and then from the liquid-cooled partition to the motor and then to the pump unit to cool the liquid-cooled partition, the motor, and the pump unit successively.

3. A dry vacuum pump apparatus according to claim 1, wherein the control electronic circuit assembly has electronic components which generate heat, the electronic components including switching devices of the inverter, and the liquid-cooled partition provides a cooling structure for cooling the electronic components.

4. A dry vacuum pump apparatus according to claim 1, wherein the liquid-cooled partition is held out of direct contact with the pump unit of the dry vacuum pump, and is fixed to a frame which extends from an outer wall of the pump unit.

5. A dry vacuum pump apparatus comprising:

a dry vacuum pump including a pump unit and a motor for actuating the pump unit;
 an inverter for converting AC power from an AC power supply into AC power having a predetermined frequency and supplying the AC power to the motor;
 a first electric equipment enclosure accommodating therein the inverter as a heat-generating large-current circuit;
 a second electric equipment enclosure accommodating therein a control circuit including a CPU for controlling the dry vacuum pump in operation;
 an external enclosure housing therein the first electric equipment enclosure and the second electric equipment enclosure as an integral structure;
 a cooling unit for cooling the first electric equipment enclosure with a coolant; and
 an air cooling structure for cooling the second electric equipment enclosure with natural air circulation or forced air circulation.

6. A dry vacuum pump apparatus according to claim 5, wherein the dry vacuum pump includes a gear unit, and the cooling unit comprises a cooling unit for cooling the motor or the gear unit of the dry vacuum pump with cooling water as the coolant.

7. A method of cooling a dry vacuum pump apparatus including a dry vacuum pump including a pump unit and a motor for actuating the pump unit, an inverter for converting AC power from an AC power supply into AC power having a predetermined frequency

and supplying the AC power to the motor, a first electric equipment enclosure accommodating therein the inverter as a heat-generating large-current circuit of high self heating value, a second electric equipment enclosure accommodating therein a control circuit including a CPU for controlling the dry vacuum pump in operation, and an external enclosure housing therein the first electric equipment enclosure and the second electric equipment enclosure as an integral structure, the method comprising:

cooling the first electric equipment enclosure with a coolant; and
cooling the second electric equipment enclosure with natural air circulation or forced air circulation.

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FIG. 1

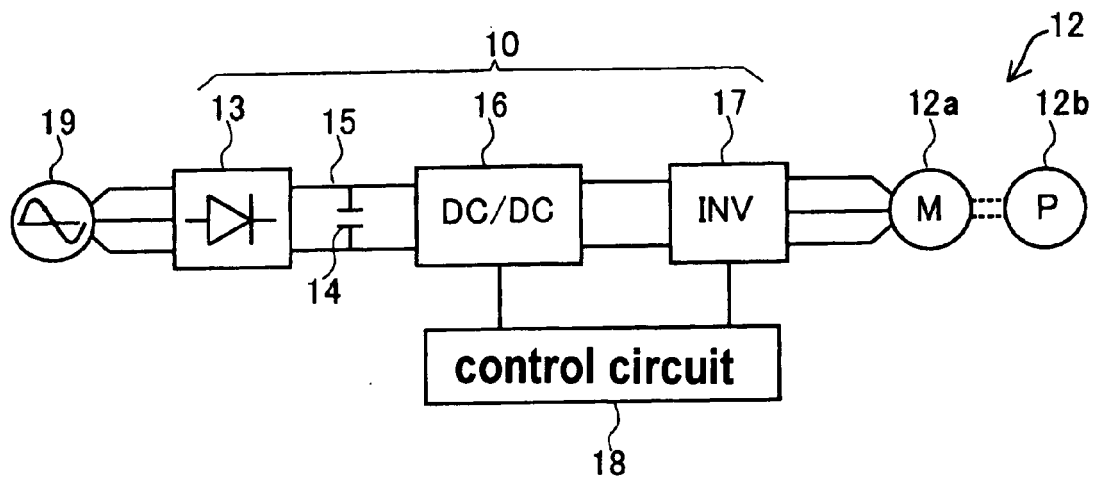


FIG. 2

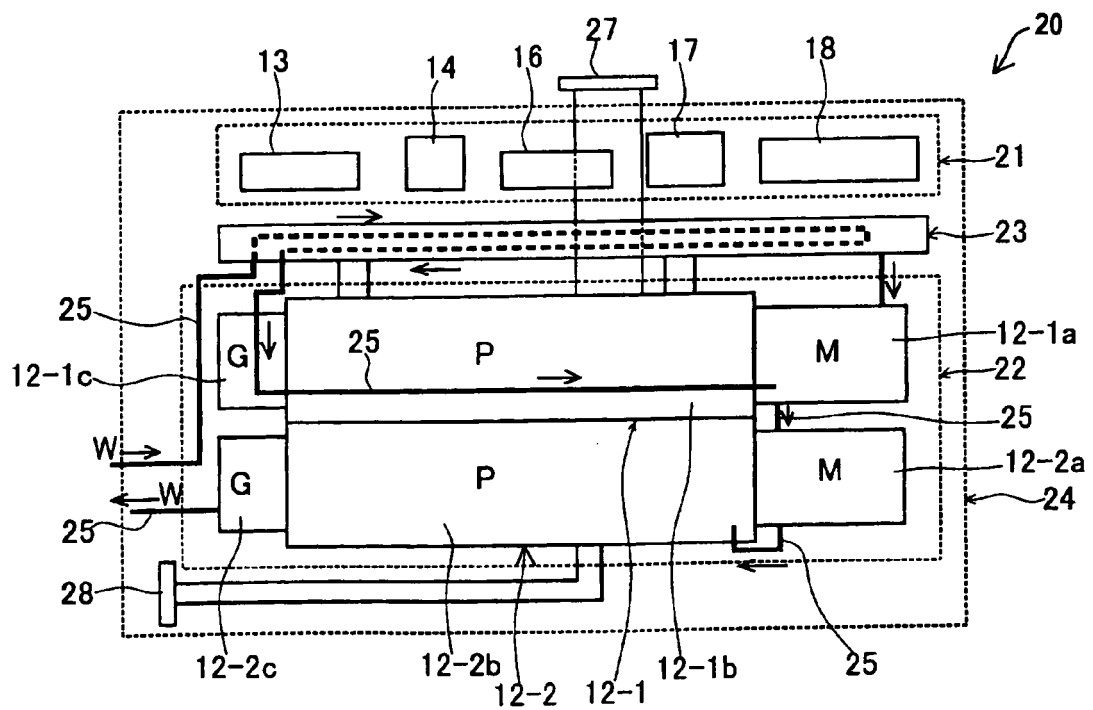


FIG. 3A

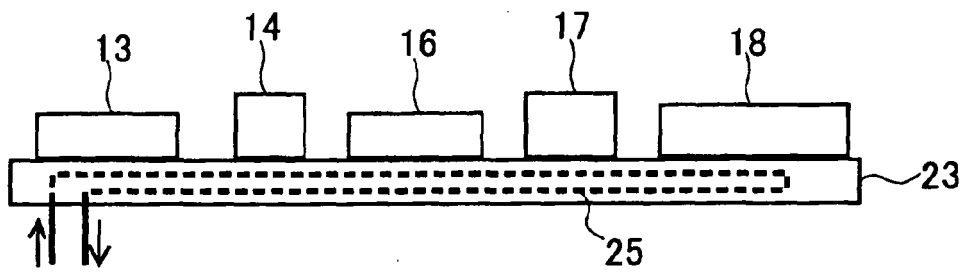


FIG. 3B

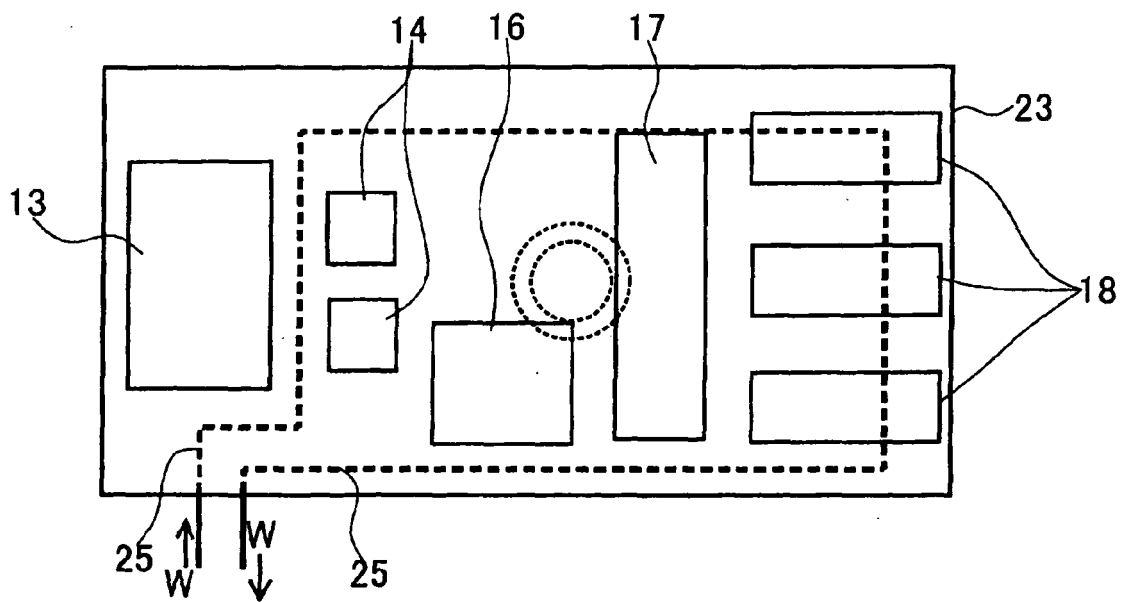


FIG. 4

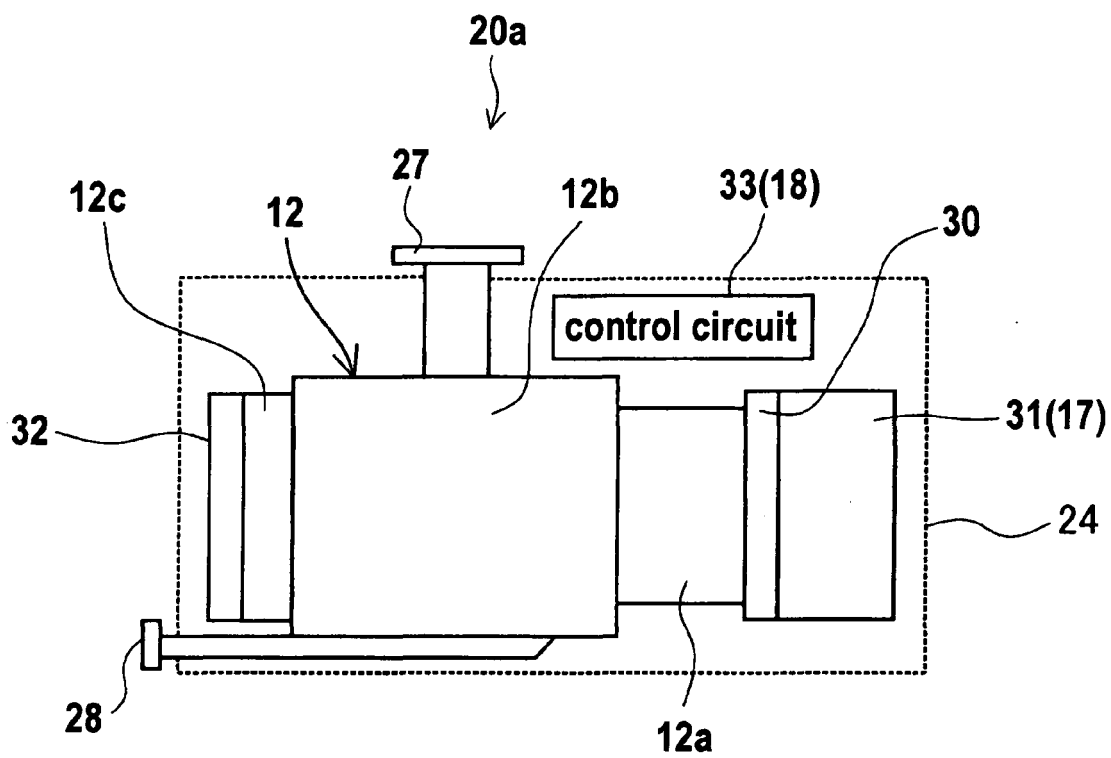


FIG. 5

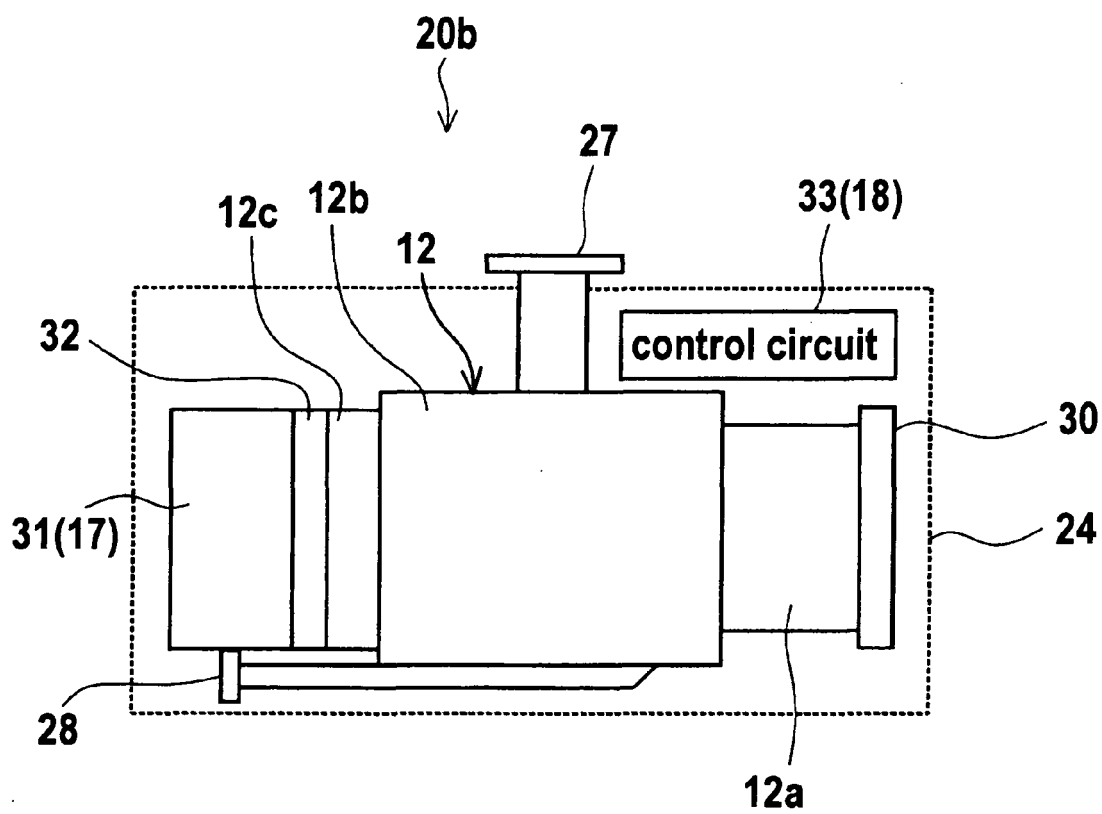
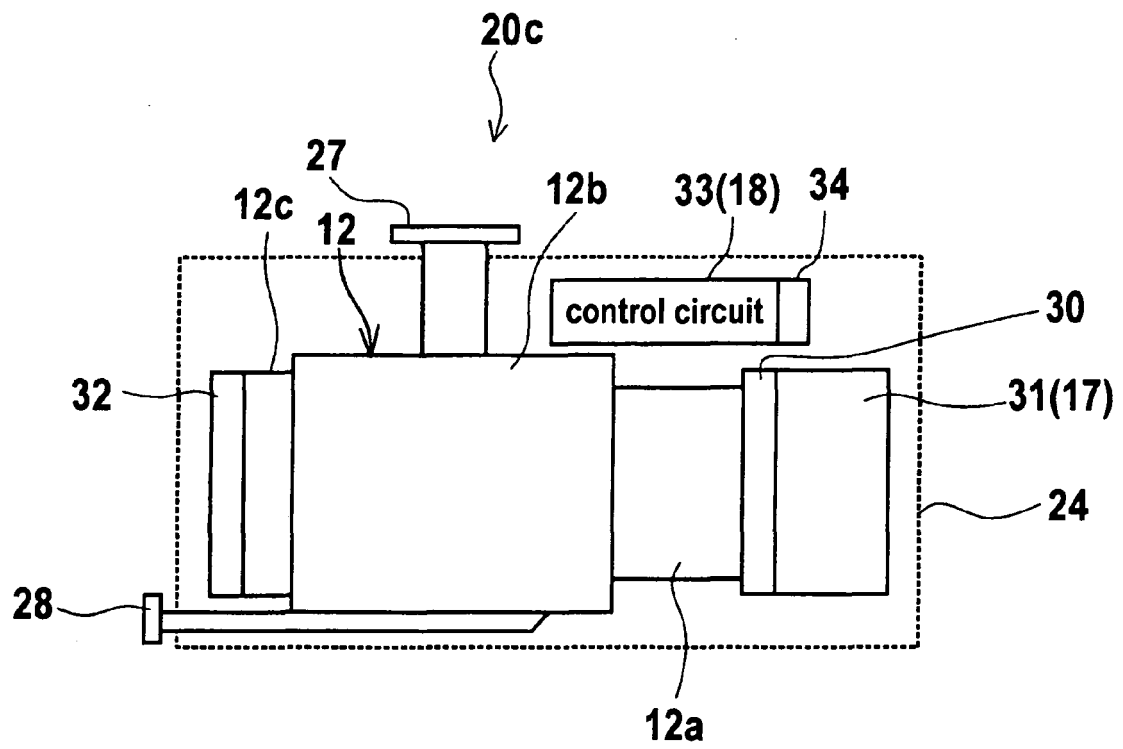


FIG. 6



REFERENCES CITED IN THE DESCRIPTION

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