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(71) Applicant: **Ebara Corporation**
Tokyo 144-8510 (JP)

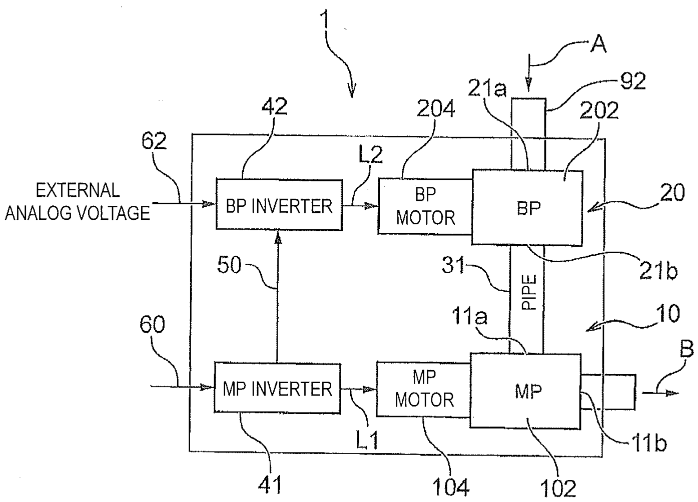
(72) Inventors:
- **LIN, Jie Yuan**
  Tokyo, 144-8510 (JP)
- **IWASAKI, Koichi**
  Tokyo, 144-8510 (JP)
- **OSUGA, Toru**
  Tokyo, 144-8510 (JP)
- **ISHII, Yuji**
  Tokyo, 144-8510 (JP)
- **KAWASHIMA, Hiroyasu**
  Tokyo, 144-8510 (JP)
- **SHIMADA, Seiji**
  Tokyo, 144-8510 (JP)

(74) Representative: **Klang, Alexander H.**
Wagner & Geyer
Gewürzmühlstrasse 5
80538 München (DE)

(54) OPERATION CONTROL DEVICE AND OPERATION CONTROL METHOD FOR VACUUM PUMP ASSEMBLY

(57) A vacuum pump that is more compact and lower in cost as compared with prior arts is provided. A vacuum pump assembly 1 includes a main pump 10 and a booster pump 20. Each of the pumps has an intake port 11a, 21a and an exhaust port 11b, 21b. The intake port 1 la of the main pump 10 intercommunicates with the exhaust port 21b of the booster pump 20. A switch receives a start instruction for starting the main pump 10. When the switch receives the start instruction and the main pump 10 starts, it is determined based on the start instruction whether the booster pump 20 is started, and the booster pump 20 is started.

Fig. 1



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Description

[0001] The present invention relates an operation control device and an operation control method for a vacuum pump assembly having a main pump and a booster pump.

[0002] In recent years, dry vacuum pumps that can operate from atmospheric pressure and easily obtain a clean vacuum environment have been used as components of semiconductor manufacturing facilities and as liquid crystal manufacturing facilities, etc. in a wide range of fields. A pump controller, a pressure sensor, a main pump inverter, and a booster pump inverter have been conventionally used for the operation of a dry vacuum pump having a main pump (MP) and a booster pump (BP) incorporated therein. A pressure sensor is required for starting the booster pump. The reason for this is as follows.

[0003] Each of the main pump and the booster pump has an intake port and an exhaust port, and the intake port of the main pump intercommunicates with the exhaust port of the booster pump. The intake port of the booster pump is functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is functioned as an exhaust side of the vacuum pump assembly. A pressure sensor is arranged in a pipe for connecting the exhaust port of the booster pump and the intake port of the main pump. The pressure sensor detects the pressure in this pipe. With respect to the timing for starting the booster pump, a pump controller determines whether a pressure value measured by the pressure sensor is proper or not, and the pump controller outputs a start signal to the booster pump inverter when the measured pressure value is proper.

[0004] The reason why the main pump and the booster pump are not simultaneously started is as follows. This is because when the pressure in the pipe between the booster pump and the main pump is not a vacuum of a predetermined pressure or less, the load of the booster pump is large, so that it is impossible to stably operate the booster pump. Therefore, the booster pump is started after the pipe between the main pump and the booster pump is evacuated by the operation of the main pump.

[0005] The start and stop of the dry vacuum pump have been conventionally performed as follows. Upon a user's operation of a start switch, the main pump is started. The pump controller determines whether the pressure in the pipe between the main pump and the booster pump becomes a vacuum of a predetermined pressure or less. When determining that the pressure has become a vacuum of the predetermined pressure or less, the pump controller transmits an instruction to the booster pump inverter, and the booster pump starts.

[0006] When the main pump is stopped by the user's operation of a stop switch or due to occurrence of an alarm in the main pump, the pump controller transmits an instruction to the booster pump inverter, and the booster pump stops. On the other hand, when the booster pump stops due to occurrence of an alarm in the booster pump, the pump controller determines whether the main pump should be stopped or not, and does not stop the main pump when determining that it is unnecessary to stop the main pump. The reason for this is as follows. When the main pump operates in spite of stop of the booster pump, the speed of increase of the pressure in a container to be evacuated can be suppressed. Furthermore, when the stop of the booster pump is caused for a reason particular to the booster pump, the main pump is considered to be normal. Accordingly, whether the operation of the main pump is continued or not is dependent on a design concept of the user or a designer of a vacuum system.

[0007] PTL 1: Japanese Patent No. 4218756

[0008] In order to properly start the booster pump, a pressure sensor and a signal processing circuit for the pressure sensor have been required for the conventional dry vacuum pump having the main pump and the booster pump incorporated therein. Therefore, an installation space for the pressure sensor has been required, so that the vacuum pump has increased in size. Furthermore, the price of the vacuum pump has been high because of the costs for the pressure sensor and the signal processing circuit for the pressure sensor.

[0009] A mode of the present invention has been implemented to solve the problem as described above, and has an object to provide a vacuum pump which is more compact and lower in cost as compared with prior arts.

[0010] In order to solve the foregoing problem, in a first mode, an operation control device for a vacuum pump assembly including a main pump and a booster pump is configured so that each of the pumps has an intake port and an exhaust port, the intake port of the main pump intercommunicates with the exhaust port of the booster pump, the intake port of the booster pump is functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is functioned as an exhaust side of the vacuum pump assembly, and the operation control device includes a start instruction receiving unit for receiving a start instruction for starting the main pump, and a booster pump starting unit for determining based on the start instruction whether the booster pump should be started when the start instruction receiving unit receives the start instruction and the main pump starts, and starting the booster pump.

[0011] In this embodiment, a pressure sensor and a signal processing circuit for the pressure sensor are omitted, and the main pump and the booster pump can be started by using no pressure sensor. Therefore, when the start instruction receiving unit receives the start instruction and the main pump starts, the booster pump starting unit determines based on the start instruction whether the booster pump should be started, and starts the booster pump. Since the pressure sensor and the signal processing circuit for the pressure sensor are not provided, a vacuum pump that is more compact and lower in cost as compared with prior arts can be provided.

[0012] The reason why the operation can be performed without any pressure sensor is as follows. The reason why the main pump and the booster pump have not been conventionally started simultaneously with each other resides in that the load of the booster pump increases and thus the booster pump cannot stably operate unless the pressure in the pipe between the booster pump and the main pump is a vacuum of a predetermined pressure or less. Conventionally, after the pipe between the main pump and the booster pump is evacuated by the operation of the main pump, the booster pump is started.

[0013] When the number of revolutions of the main pump exceeds a predetermined value and a predetermined time elapses after the main pump is started, it is estimated that the pressure between the main pump and the booster pump becomes a pressure level which enables the booster pump to start. This is because the volume of the intake side (upstream-side) of the main pump is not infinite. A container to be evacuated is installed on the intake side of the vacuum pump assembly. The dry vacuum pump exhausts gas in the container to evacuate the inside of the container. Since the volume of the container is finite, the volume of the intake side (upstream-side) of the main pump is not infinite. From the foregoing, when it is known only that a predetermined time has elapsed after start of the main pump, the booster pump can be safely started. Furthermore, when only a short time has elapsed after stop of the main pump, the degree of vacuum in the pipe decreases hardly. Therefore, after start of the main pump, the booster pump can be immediately safely started.

[0014] The time in which the booster pump can be started or the number of revolutions of the main pump at which the booster pump can be started can be determined by an experiment or the like. When an unintended situation occurs, that is, when the volume of the container is remarkably larger than an intended volume under pump design, when the container is not hermetically sealed due to a mistake or the like, or when external gas flows into the container due to damage or the like, there is the following countermeasure method. In such a case, there is case where the number of revolutions of the main pump is equal to a certain number of revolutions, and the pressure between the main pump and the booster pump does not reach a vacuum enough to stably activate the booster pump even when a predetermined time has elapsed. In this case, since current flowing in a motor for the booster pump increases, the current of the motor for the booster pump is detected by an inverter device of the booster pump, and a booster pump overcurrent alarm is generated. When the booster pump overcurrent alarm is detected, the booster pump is stopped. Furthermore, a signal representing stop of the booster pump is transmitted from the digital output unit of the inverter device for the booster pump to the digital input unit of a main pump inverter device, whereby the main pump is stopped and the pump system is safely stopped.

[0015] In a second mode, the operation control device is configured so that the booster pump starting unit determines that the booster pump can be started when the start instruction receiving unit receives the start instruction, and starts the booster pump.

[0016] In a third mode, the operation control device is configured so that the booster pump starting unit determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when a predetermined time has elapsed, and starts the booster pump.

[0017] In a fourth mode, the operation control device is configured so that the booster pump starting unit determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and the number of revolutions of the main pump has been equal to a predetermined number or more over the predetermined time, and starts the booster pump.

[0018] In a fifth mode, the operation control device is configured so that the booster pump starting unit determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when the number of revolutions of the main pump has been equal to a predetermined number or more and a current value of a motor for driving the main pump has been equal to a predetermined value or less over the predetermined time, and starts the booster pump.

[0019] In the present embodiment, the reason why it is determined that the booster pump can be started when the current value of the motor for driving the main pump is equal to a predetermined value or less is as follows. Since the pressure between the main pump and the booster pump cannot be actually measured because there is no pressure sensor, it is estimated based on a result of an experiment or the like whether the pressure reaches a pressure required for stable activation of the booster pump. A method of enhancing the precision of this estimation is a method of this embodiment. In this embodiment, after the number of revolutions of the main pump reaches a predetermined number of revolutions, the current of the main pump is monitored. When a predetermined time has elapsed after the current of the main pump decreases to a predetermined value, the booster pump is started.

[0020] The current flowing in the main pump motor is proportional to the flow rate of gas introduced into the main pump. That is, when the pressure in the container is high in a short time after the operation is started, the current of the main pump is high. When the gas in the container is exhausted and the pressure on the upstream side of the main pump decreases, the current of the main pump decreases. From this fact, the pressure on the upstream side of the main pump can be estimated with higher precision by an estimation based on the number of revolutions, the current and the time as compared with an estimation based on the number of revolutions and the time. Therefore, it can be surely grasped that a condition for stating the rotation of the booster pump is satisfied, and the probability of occurrence of an alarm when the booster pump is started can be reduced.

[0021] In a sixth mode, the operation control device is configured to further include a stop instruction receiving unit for receiving a stop instruction for stopping the main pump, and a booster pump stopping unit for determining based on the stop instruction whether the booster pump should be stopped when the stop instruction receiving unit receives the stop instruction and the main pump stops, and stops the booster pump.

[0022] In a seventh mode, the operation control device is configured to further include a main pump abnormality detector for detecting abnormality of the main pump, and an abnormal stopping unit for stopping the main pump and the booster pump when the main pump abnormality detector detects abnormality of the main pump.

[0023] In an eighth mode, the operation control device is configured to further include a booster pump abnormality detector for detecting abnormality of the booster pump, and a booster pump abnormal stopping unit for causing the booster pump to stop and causing the main pump not to stop when the booster pump abnormality detector detects abnormality of the booster pump.

[0024] In the present embodiment, the main pump is not stopped when the booster pump stops. The reason for this resides in that the main pump is not necessarily required to be stopped when the booster pump stops. Irrespective of stop of the booster pump, the increase speed of the pressure in the container is suppressed when the main pump operates. Accordingly, when the booster pump stops for a reason particular to the booster pump, it is based on a design concept of the vacuum system whether the main pump is stopped or the main pump is continuously operated. When a user, etc. wishes to continuously operate the main pump, a signal for stopping the booster pump may not be transmitted from the digital output unit for the booster pump to the digital input unit for the main pump. Furthermore, even when the signal is transmitted, the main pump may not stop even when receiving the signal for stopping the booster pump.

[0025] In a ninth mode, the operation control device is configured to further include a signal input unit to which a signal for controlling the number of revolutions of the main pump and/or the booster pump is input from the outside.

[0026] In a tenth mode, an operation control method for a vacuum pump assembly including a main pump and a booster pump is configured so that each pump has an intake port and an exhaust port, the intake port of the main pump intercommunicates with the exhaust port of the booster pump, the intake port of the booster pump is functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is functioned as an exhaust side of the vacuum pump assembly, and the operation control method includes a step of receiving a start instruction for starting the main pump, and a step of determining based on the start instruction whether the booster pump should be started when the start instruction is received and the main pump starts, and starting the booster pump.

Fig. 1 is a block diagram showing a schematic configuration of a vacuum pump assembly having an operation control device according to an embodiment of the present invention;

Fig. 2 is a block diagram showing a schematic configuration of a vacuum pump assembly having an operation control device according to a comparative example;

Fig. 3 is a block diagram showing a configuration of a main pump inverter 41;

Fig. 4 is a block diagram showing flow of a signal in an inverter control circuit 66;

Fig. 5 is a block diagram showing signal communication between an inverter control circuit 66 of a main pump 10 and an inverter control circuit 66 of a booster pump 20;

Fig. 6 is a diagram showing the relationship of starting and stopping timings of the main pump 10 and the booster pump 20; and

Fig. 7 is a diagram showing the relationship of starting and stopping timings of the main pump 10 and the booster pump 20.

[0027] Embodiments according to the present invention will be described hereunder with reference to the drawings. In each of the embodiments described below, the same or corresponding members are represented by the same reference signs, and duplicated description thereof is omitted.

[0028] Fig. 1 is a block diagram showing a schematic configuration of a vacuum pump assembly having an operation control device according to an embodiment of the present invention. As shown in Fig. 1, the vacuum pump assembly 1 includes a main pump 10 and a booster pump 20 which are biaxial positive-displacement type dry vacuum pumps. The main pump 10 has a pump unit 102 and a motor unit (pump driving electric motor) 104. The pump unit 102 has an intake port 11a and an exhaust port 11b. The booster pump 20 has a pump unit 202 and a motor unit (pump driving electric motor) 204. The pump unit 202 has an intake port 21a and an exhaust port 21b.

[0029] The intake port 11a of the main pump 10 is connected to and made to intercommunicate with the exhaust port 21b of the booster pump 20 via a connecting pipe 31, and the intake port 21a of the booster pump 20 is connected to and made to intercommunicate with an exhaust port (not shown) of a container (not shown) via a connecting tube 92, thereby configuring the vacuum pump assembly 1. The intake port 11a of the booster pump 20 is set as an intake side of the vacuum pump assembly 1, and the exhaust port 11b of the main pump 10 is set as an exhaust side of the vacuum pump assembly 1. By operating the motor units 104, 204 and the pump units 102, 202 of the main pump 10 and the booster pump 20, gas in the container is sucked from the intake port 21a of the booster pump 20 as indicated by an arrow A.

The sucked gas is sucked from the exhaust port 21b of the booster pump 20 to the intake port 11a of the main pump 10, and exhausted from the exhaust port 11b as indicated by an arrow B.

[0030] The main pump inverter 41 supplies a driving current to the motor unit 104 (pump driving electric motor) via a power supply line L1. The booster pump inverter 42 supplies a driving current to the motor unit 204 (pump driving electric motor) via a power supply line L2. The main pump inverter 41 and the booster pump inverter 42 transmit a signal for start or stop via a signal line 50. The signal for start or stop will be described in detail later.

[0031] The start and stop of the vacuum pump assembly 1 are roughly performed as follows. Upon a user's operation of a start/stop switch, a start/stop instruction 60 is input to the main pump inverter 41, and the pump unit 102 starts. The main pump inverter 41 transmits a signal for starting the pump unit 202 via the signal line 50. This signal causes the pump unit 202 to start.

[0032] With respect to the stop, it is performed as follows. When an alarm occurs in the pump unit 102 of the main pump 10 and the pump unit 102 stops, the main pump inverter 41 transmits a signal for stopping the pump unit 202 via the signal line 50. This signal causes the pump unit 202 to stop.

[0033] When an alarm occurs in the pump unit 202 of the booster pump 20 and the booster pump stops, the main pump 10 does not stop. At this time, the booster pump 20 starts again by a retry function of the booster pump inverter 42.

[0034] When the main pump 10 stops upon the user's operation of the start/stop switch, the main pump inverter 41 transmits a signal for stopping the pump unit 202 via the signal line 50. This signal causes the pump unit 202 to stop. The booster pump inverter 42 has a number-of-revolutions control function of the booster pump by an external analog voltage 62.

[0035] Here, for comparison with the present embodiment, a vacuum pump assembly 52 in which a pressure sensor is required to start the booster pump is shown in Fig. 2. Fig. 2 is a block diagram showing a schematic configuration of the vacuum pump assembly 52 having an operation control device according to a comparative example. A pressure sensor 54 is arranged in a connecting pipe 31 for connecting the exhaust port 21b of the pump unit 202 of the booster pump 20 and the intake port 11a of the pump unit 102 of the main pump 10. The pressure sensor 54 detects the pressure in the connecting pipe 31. The pressure detected by the pressure sensor 54 is transmitted to a pump controller 56. In order to detect a timing at which the pump unit 202 of the booster pump 20 is started, the pump controller 56 determines whether the pressure value measured by the pressure sensor 54 is a proper value. When the pressure value is proper, the pump controller 56 outputs a start signal 58 to the booster pump inverter 421.

[0036] The main pump inverter 41 in the present embodiment will be described with reference to Fig. 3. Fig. 3 is a block diagram showing a configuration of the main pump inverter 41. The booster pump inverter 42 has substantially the same configuration as the main pump inverter 41. Different points will be referred to in the following description on the main pump inverter 41. With respect to portions of the main pump inverter 41 with which no reference is made to the booster pump inverter 42, the main pump inverter 41 and the booster pump inverter 42 have the same configurations and operations.

[0037] The main pump inverter 41 includes an inverter main circuit 64 for supplying an AC current to the motor unit 104 to drive the motor unit 104, an inverter control circuit 66 for controlling the inverter main circuit 64 along various signals input from the outside, and indirectly operating the motor unit 104, and a control circuit power source 70 for generating a DC power source of a low voltage required to drive the inverter control circuit 66 from a power source 68 input to the main pump inverter 41. In general, 100V, 200V, 400V, etc. of AC are input to the main pump inverter 41. On the other hand, the inverter control circuit 66 is driven with 3.3V, 5V, 12V, etc, of DC. The inverter control circuit 66 performs alarm detection based on an input signal to the inverter control circuit 66, display, recording of a target number of revolutions, etc. and recording of an operation history of the inverter. The inverter control circuit 66 of the main pump 10, the inverter control circuit 66 of the booster pump 20 and a switch 86 constitute the operation control device.

[0038] The main pump inverter 41 further includes an alarm detector 72, a temperature detector 74, a current detector 76 and a number-of-revolutions detector 78. When the motor unit 104 exceeds a predetermined current, temperature or number of revolutions, or when the motor unit 104 has not yet reached a specified number of revolutions even after a predetermined time has elapsed from start of the pump unit 102, the alarm detector 72 outputs an alarm detection signal 108 to a digital signal detector 80. The processing of the alarm detection signal 108 in the digital signal detector 80 will be described later.

[0039] The detections of the current, the temperature and the number of revolutions are performed by the current detector 76, the temperature detector 74 and the number-of-revolutions detector 78 described below. The current detector 76, the temperature detector 74 and the number-of-revolutions detector 78 output respective detection results to the alarm detector 72 as shown in Fig. 4. Fig. 4 is a block diagram showing signal flow in the inverter control circuit 66.

[0040] A temperature signal from a temperature sensor installed outside the main pump inverter 41 is input to the temperature detector 74, and the temperature detector 74 converts the input temperature signal to temperature information of a predetermined format, and transmits the converted information to the alarm detector 72. The temperature detector 74 is an analog circuit or CPU having an A/D conversion function. The load of the pump can be estimated by measuring the temperature of each part of the main pump 10. The temperature sensor is installed in, for example, the main body of the pump unit 102 or the motor unit 104. The temperature sensor may be installed at a front stage of the intake port 21a of the booster pump 20, between the main pump 10 and the booster pump 20 or in a pipe 94 at a rear stage of the exhaust port 11b of the main pump 10.

[0041] A signal from a current sensor is input to the current detector 76, and the current detector 76 converts the input signal to current information of a predetermined format, and transmits the converted information to the alarm detector 72. The current detector 76 is an analog circuit or CPU having an A/D conversion function. The current sensor is installed in, for example, an output unit or an input unit of the main pump inverter 41, and the motor unit 104. The current sensor is, for example, a Hall current detector. The Hall current detector measures the current by measuring a magnetic flux occurring in proportion to the current in a contactless manner with a combination of a magnetic iron core and a magnetic sensor (Hall element).

[0042] The number-of-revolutions detector 78 obtains the number of revolutions of the motor from the motor current obtained by the current detector 76. The number-of-revolutions detector 78 estimates the position of the magnetic pole of the motor from distortion of the waveform of the motor current, and obtains the number of revolutions of the motor by continuously estimating the position of the magnetic pole of the motor. In place of use of the motor current, a magnetic pole sensor or a number-of-revolutions sensor may be installed in the motor to capture sensor signals from these sensors into the number-of-revolutions detector to detect the number of revolutions of the motor. In this case, since the phase of the motor can be easily grasped with higher precision as compared with the estimation of the number of revolutions from the current, so that the motor can be more stably controlled.

[0043] The main pump inverter 41 further includes a voltage frequency controller 100, a digital signal detector 80, a digital signal output unit 82, and an analog signal detector 84. The voltage frequency controller 100 controls the inverter main circuit 64 to apply an electrical signal having predetermined frequency and voltage to the motor unit 104. The voltage frequency controller 100 controls the inverter main circuit 64 to start or stop the motor unit 104.

[0044] The digital signal detector 80 detects a switch signal 88 (analog signal or digital signal) from the switch 86 for starting and stopping the vacuum pump assembly 1, a start/stop signal as a digital signal from an upstream-side (downstream-side) device and digital signals (TH temperature signal, alarm occurrence signal, etc.) from the upstream-side (downstream-side) device. The digital signal detector 80 has a function of a booster pump starting unit, etc. of determining based on a start instruction whether the booster pump 20 is started or not when the main pump 10 is started, and starting the booster pump 20. This point will be described later.

[0045] The switch 86 serving as a start instruction receiving unit for receiving a start instruction for starting the main pump 10 outputs a switch signal 88. The start instruction is input upon an operation of the switch 86 by a user of the vacuum pump assembly 1. The switch 86 is used for the user to instruct start and stop of the main pump 10. That is, the switch 86 serves as a stop instruction receiving unit for receiving a stop instruction for stopping the main pump. The stop instruction is input upon operation of the switch 86 by the user of the vacuum pump assembly 1. Whether the instruction is the start instruction or the stop instruction is identified, for example, based on whether the voltage of the switch signal 88 has a high level or a low level.

[0046] The digital signal detector 80 of the main pump inverter 41 identifies whether the switch signal 88 from the switch 86 has a high level or a low level. Based on an identification result, the digital signal detector 80 outputs a start signal or a stop signal as a signal 106 to the voltage frequency controller 100. Whether the signal 106 indicates the start instruction or the stop instruction is identified, for example, based on whether the voltage of the signal 106 has a high level or a low level. The voltage frequency controller 100 receiving the signal 106 controls the inverter main circuit 64 to start or stop the main pump 10. Furthermore, the digital signal detector 80 outputs the identification result to the digital signal output unit 82.

[0047] The digital signal detector 80 of the booster pump inverter 42 detects a start/stop signal which is a digital signal to be output by the digital signal output unit 82 of the main pump inverter 41. The digital signal detector 80 of the booster pump inverter 42 receiving the start/stop signal which is a digital signal to be output from the digital signal output unit 82 of the main pump inverter 41 identifies whether the start/stop signal is the start signal or the stop signal. Based on this identification result, the digital signal detector 80 outputs the start signal or the stop signal to the voltage frequency controller 100 of the booster pump inverter 42. The voltage frequency controller 100 receiving these signals controls the inverter main circuit 64 to start or stop the booster pump 20.

[0048] The digital signal detector 80 is capable of receiving the signal from the switch 86 and also receiving the start signal/stop signal based on the digital signal. As to whether start/stop is performed according to the switch 86 (in the case of the main pump inverter 41) or start/stop is performed based on the digital signal (in the case of the booster pump inverter 42), there are a) a method of setting it in the inverter device in advance, and b) a method of inputting, as a digital signal from the outside, which instruction should be followed.

[0049] The digital signal detectors 80 of the main pump inverter 41 and the booster pump inverter 42 detect the TH temperature signal, the alarm occurrence signal, etc. The TH (thermal protector) is a temperature sensor which prevents overheat of the motor, and in which the internal contact of the temperature sensor is opened when the temperature of the motor reaches a predetermined temperature. The digital signal detectors 80 detect from the TH temperature signal that the internal contact of the temperature sensor is opened. As a method of detecting the opening of the internal contact, there is a method of configuring a circuit so that the TH temperature signal changes from a low level to a high level when the internal contact is opened.

[0050] The digital signal output unit 82 is supplied with the start/stop signal from the digital signal detector 80, and outputs a digital signal (start (stop) signal 96) to an upstream-side (downstream-side) device. That is, as shown in Fig. 5, the digital signal output unit 82 of the main pump inverter 41 outputs the start (stop) signal 96 to the digital signal detector 80 of the booster pump inverter 42. The digital signal output unit 82 of the booster pump inverter 42 outputs the alarm occurrence signal to the digital signal output unit 82 of the booster pump inverter 42. Fig. 5 is a block diagram showing signal communication between the inverter control circuit 66 of the main pump 10 and the inverter control circuit 66 of the booster pump 20.

[0051] The digital signal detector 80 of the main pump inverter 41 is a booster pump starting unit for determining based on the start instruction whether the pump unit 202 of the booster pump inverter 42 should be started or not when the start instruction receiving unit (switch 86) receives the start instruction and the pump unit 102 of the main pump inverter 41 starts, and starting the pump unit 202. There are various determining methods depending on the application, state and characteristic of the vacuum pump assembly 1.

[0052] For example, as shown in Fig. 6, if the switch 86 receives the start instruction and a predetermined time 90 (delayed time width for booster pump start) has elapsed thereafter, the digital signal detector 80 of the main pump inverter 41 determines that the booster pump 20 can be started, and starts the booster pump 20. At this time, the digital signal detector 80 transmits a signal for starting the booster pump 20 to the digital signal output unit 82. The digital signal output unit 82 transmits a start signal to the digital signal detector 80 of the booster pump 20. Fig. 6 is a diagram showing the relationship of the start and stop timings of the main pump 10 and the booster pump 20.

[0053] Here, there is a case where the predetermined time 90 is set to 0 second. That is, there is a case where the digital signal detector 80 of the main pump inverter 41 determines that the booster pump 20 can be started at the time when the switch 86 receives the start instruction, and starts the booster pump 20. When the lapse time after stop of the booster pump 20 is short, the degree of vacuum in the connecting pipe 31 does not decrease, so that the booster pump 20 can be immediately started.

[0054] After the switch 86 receives the start instruction and when the number of revolutions of the main pump 10 has been equal to a predetermined number or more over a predetermined time, the digital signal detector 80 of the main pump inverter 41 may determine that the booster pump 20 can be started, and start the booster pump 20. The number of revolutions is transmitted as a signal 110 from the number-of-revolutions detector 78 to the digital signal detector 80. By considering the number of revolutions, it is estimated that the degree of vacuum in the connecting pipe 31 surely decreases.

[0055] After the switch 86 receives the start instruction and when the rotation number of the main pump 10 has been equal to a predetermined number or more and a current value of the motor for driving the main pump has been equal to a predetermined value or less over a predetermined time, the digital signal detector 80 of the main pump inverter 41 may determine that the booster pump 20 can be started, and start the booster pump 20 if so determined. The current value is transmitted as a signal 112 from the current detector 76 to the digital signal detector 80. By considering the current value and the number of revolutions of the motor, it is estimated that the degree of vacuum in the connecting pipe 31 decreases more surely.

[0056] The inverter control circuit 66 of the main pump inverter 41 has a stop instruction receiving unit (switch 86) for receiving the stop instruction for stopping the main pump 10, and a booster pump stopping unit (digital signal detector 80) for determining based on a stop instruction whether the booster pump 20 should be stopped or not when the switch 86 receives the stop instruction and the main pump 10 stops, and stops the booster pump 20 if so determined. In this case, as indicated as a time 114 in Fig. 6, the booster pump 20 also stops simultaneously with the stop of the main pump 10.

[0057] At this time, the digital signal detector 80 transmits a stop signal to the voltage frequency controller 100 to stop the main pump 10, and transmits a stop signal to the digital signal output unit 82 to stop the booster pump 20.

[0058] The operation control device includes a main pump abnormality detector (the alarm detector 72 of the main pump 10) for detecting abnormality of the main pump 10, and an abnormal stopping unit (the digital signal detectors 80 of the main pump 10 and the booster pump 20) for stopping the main pump 10 and the booster pump 20 when the alarm detector 72 detects abnormality of the main pump 10. That is, the digital signal detectors 80 of the main pump 10 and the booster pump 20 respectively stop the inverter main circuits 64 of the main pump 10 and the booster pump 20 via the voltage frequency controllers 100.

[0059] As signal flow, with respect to the stop of the main pump 10, signals flow from the alarm detector 72 of the main pump 10 to the digital signal detector 80, and from the digital signal detector 80 to the voltage frequency controller 100, and the main pump 10 stops. Furthermore, with respect to the stop of the booster pump 20, signals flows from the alarm detector 72 of the main pump 10 to the digital signal detector 80, from the digital signal detector 80 to the digital signal output unit 82, from the digital signal output unit 82 to the digital signal detector 80 of the booster pump 20 and from the digital signal detector 80 to the voltage frequency controller 100, and the booster pump 20 stops.

[0060] The operation control device may include a booster pump abnormality detector (the alarm detector 72 of the booster pump 20) for detecting abnormality of the booster pump 20, and a booster pump abnormal stopping unit (the digital signal output unit 82 of the booster pump 20) for causing the booster pump to stop, but causing the main pump not to stop when the booster pump abnormality detector detects abnormality of the booster pump 20.

[0061] At this time, in order to stop the booster pump 20, signals flow from the alarm detector 72 of the booster pump 20 to the digital signal detector 80, and from the digital signal detector 80 to the voltage frequency controller 100, and the booster pump 20 stops. No stop signal flows from the booster pump 20 to the main pump 10. Whether the main pump is caused to stop or not to stop is based on the design concept of the vacuum pump assembly 1 as described above.

[0062] The operation control device includes a signal input unit (analog signal detector 84) to which a signal for controlling the number of revolutions of the main pump 10 and/or the booster pump 20 is input from the outside. This will be described hereunder. A signal is input in an analog manner from the outside to the analog signal detector 84 shown in Fig. 3. The signal may be, for example, such a current signal as ranging from 4 to 20 mA. Furthermore, the signal may be such a voltage signal as ranging from 0 to 5V, from 1 to 10V. A target number of revolutions of the motor unit 104 or the motor unit 204 is changed by the input signal. For example, when the target number of revolutions is changed by the signal of 4 to 20 mA, the pump target number of revolutions is reduced upon input of 4 mA. The target number of revolutions is increased in proportion to the input current, and set to a rated number of revolutions at 20 mA. In a situation where pump exhaust performance is not required, the user of the pump can realize reduction of the power consumption of the pump by reducing the number of revolutions of the pump.

[0063] The number of revolutions may be changed by a digital signal in place of the analog signal. In this case, it is determined based on the digital signal which one of a target number of revolutions A and a target number of revolutions B preset in the inverter device is used. By inputting digital signals of plural systems, the number of number-of-revolutions patterns can be increased. For example, when three systems are set, the cube of 2, that is, 8 patterns can be selected. The number of revolutions is selected from eight target numbers of revolutions from the target number of revolutions A to a target number of revolutions H to control the motor unit 104 or the motor unit 204. By inputting digital signals of plural systems, the configuration can be established more inexpensively as compared with a case where an external number of revolutions instructing circuit is an analog circuit.

[0064] According to the present embodiment, an operation control method for the vacuum pump assembly 1 having the main pump 10 and the booster pump 20 can be implemented. In this method, as described above, each pump has an intake port and an exhaust port, the intake port of the main pump intercommunicates with the exhaust port of the booster pump, the intake port of the booster pump is functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is functioned as an exhaust side of the vacuum pump assembly.

[0065] As shown in Fig. 7, the operation control method receives a start instruction for starting the main pump 10 (step 1). It is determined based on the start instruction whether the booster pump 20 should be started when the start instruction is received to start the main pump 10, and the booster pump 20 is started (step 2). After the booster pump 20 is started, the number of revolutions of the booster pump 20 is controlled upon input of an analog voltage from the outside to the booster pump 20 (step 3). Fig. 7 is a diagram showing the relationship of starting and stopping timings of the main pump 10 and the booster pump 20.

[0066] With respect to the stop of the booster pump 20, the stop instruction receiving unit receives the stop instruction, and the main pump stops (step 4). The digital signal detector 80 determines based on the stop instruction whether the booster pump 20 should be stopped or not, and stops the booster pump 20 when determining to stop the booster pump 20 as described above (step 5). When the main pump abnormality detector detects abnormality of the main pump 10, the main pump 10 and the booster pump 20 can be stopped (step 6).

[0067] The examples of the embodiment of the present invention have been described above. However, the foregoing embodiment of the present invention is presented to facilitate understanding of the present invention, and does not limit the present invention. It is needless to say that the present invention may be modified and improved without departing from the subject matter thereof, and contain equivalents thereof. Furthermore, it is possible to perform any combination or omission of the respective constituent elements described in claims and the specification in a range where at least a part of the foregoing problem can be solved or a range in which at least a part of the effect can be obtained.

[0068] As described above, the present invention has the following modes.

[Mode 1]

[0069] An operation control device for a vacuum pump assembly including a main pump and a booster pump, wherein each pump has an intake port and an exhaust port, the intake port of the main pump intercommunicates with the exhaust port of the booster pump, the intake port of the booster pump is functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is functioned as an exhaust side of the vacuum pump assembly, and the operation control device includes a start instruction receiving unit for receiving a start instruction for starting the main pump, and a booster pump starting unit for determining based on the start instruction whether the booster pump should be started when the start instruction receiving unit receives the start instruction and the main pump starts, and starting the booster pump.

[Mode 2]

[0070] The operation control device according to the mode 1, wherein the booster pump starting unit determines that the booster pump can be started when the start instruction receiving unit receives the start instruction, and starts the booster pump.

[Mode 3]

[0071] The operation control device according to the mode 1, wherein the booster pump starting unit determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when a predetermined time has elapsed, and starts the booster pump.

[Mode 4]

[0072] The operation control device according to the mode 3, wherein the booster pump starting unit determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when the number of revolutions of the main pump has been equal to a predetermined number or more over the predetermined time, and starts the booster pump.

[Mode 5]

[0073] The operation control device according to the mode 4, wherein the booster pump starting unit determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when the number of revolutions of the main pump has been equal to a predetermined number or more and a current value of the motor for driving the main pump has been equal to a predetermined value or less over the predetermined time, and starts the booster pump.

[Mode 6]

[0074] The operation control device according to any one of the modes 1 to 5, further including a stop instruction receiving unit for receiving a stop instruction for stopping the main pump, and a booster pump stopping unit for determining based on the stop instruction whether the booster pump should be stopped when the stop instruction receiving unit receives the stop instruction and the main pump stops, and stopping the booster pump.

[Mode 7]

[0075] The operation control device according to any one of the modes 1 to 6, further including a main pump abnormality detector for detecting abnormality of the main pump, and an abnormal stopping unit for stopping the main pump and the booster pump when the main pump abnormality detector detects abnormality of the main pump.

[Mode 8]

[0076] The operation control device according to any one of the modes 1 to 7, further including a booster pump abnormality detector for detecting abnormality of the booster pump, and a booster pump abnormal stopping unit for causing the booster pump to stop and causing the main pump not to stop when the booster pump abnormality detector detects abnormality of the booster pump.

[Mode 9]

[0077] The operation control device according to any one of the modes 1 to 8, further including a signal input unit to which a signal for controlling the number of revolutions of the main pump and/or the booster pump is input from the outside.

[Mode 10]

[0078] An operation control method for a vacuum pump assembly including a main pump and a booster pump, wherein each pump has an intake port and an exhaust port, the intake port of the main pump intercommunicates with the exhaust port of the booster pump, the intake port of the booster pump is functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is functioned as an exhaust side of the vacuum pump assembly, and the operation control method includes a step of receiving a start instruction for starting the main pump, and a step of determining based on the start instruction whether the booster pump should be started when the start instruction is received and the main pump starts, and starting the booster pump.

REFERENCE SIGNS LIST:

[0079]

1 vacuum pump assembly
41 main pump inverter
42 booster pump inverter
64 inverter main circuit
66 inverter control circuit

72 alarm detector
74 temperature detector
76 current detector
78 number-of-revolutions detector
80 digital signal detector
82 digital signal output unit
84 analog signal detector
86 switch

Claims

1. A vacuum pump assembly including a main pump and a booster pump, wherein each of the pumps has an intake port and an exhaust port, the intake port of the main pump intercommunicates with the exhaust port of the booster pump, the intake port of the booster pump is functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is functioned as an exhaust side of the vacuum pump assembly, and
the vacuum pump assembly comprises:

    an instruction receiving unit for receiving a start instruction for starting the main pump or a stop instruction for stopping the main pump, and outputting a switch signal;
    a main pump inverter for receiving the output switch signal to start or stop the main pump, and outputting a start/stop signal for instructing start/stop of the booster pump; and
    a booster pump inverter for detecting the start/stop signal output from the main pump inverter, and to start or stop the booster pump.

2. The vacuum pump assembly according to claim 1, wherein the main pump inverter is configured to be capable of outputting a start signal for instructing start of the booster pump after the main pump starts, and the booster pump inverter is configured to determine based on the start signal output from the main pump inverter whether the booster pump should be started, and start the booster pump if so determined.

3. A vacuum pump assembly including a main pump and a booster pump, comprising:

    a main pump inverter for controlling an operation of the main pump;
    a booster pump inverter for controlling an operation of the booster pump;
    a booster pump abnormality detector for detecting abnormality during the operation of the booster pump; and
    a booster pump abnormal stopping unit for causing the booster pump to stop while the main pump keeps in operation when the booster pump abnormality detector detects abnormality of the booster pump.

4. The vacuum pump assembly according to claim 1 or 3, wherein the booster pump inverter determines that the booster pump can be started when the start instruction receiving unit receives the start instruction, and starts the booster pump if so determined.

5. The vacuum pump assembly according to claim 1 or 3, wherein the booster pump inverter determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when a predetermined time has elapsed, and starts the booster pump if so determined.

6. The vacuum pump assembly according to claim 5, wherein the booster pump inverter determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when a number of revolutions of the main pump has been equal to a predetermined number or more over the predetermined time, and start the booster pump if so determined.

7. The vacuum pump assembly according to claim 6, wherein the booster pump inverter determines that the booster pump can be started after the start instruction receiving unit receives the start instruction and when the number of revolutions of the main pump has been equal to the predetermined number or more and a current value of a motor for driving the main pump has been equal to a predetermined value or less over the predetermined time, and starts the booster pump if so determined.

8. The vacuum pump assembly according to any one of claims 3 to 7, further comprising a booster pump stopping unit for determining based on the stop instruction whether the booster pump should be stopped when the stop instruction receiving unit receives the stop instruction and the main pump stops, and stopping the booster pump if so determined.

9. The vacuum pump assembly according to any one of claims 1 to 8, further comprising:

    a main pump abnormality detector for detecting abnormality of the main pump; and
    an abnormal stopping unit for stopping the main pump and the booster pump when the main pump abnormality detector detects abnormality of the main pump.

10. The vacuum pump assembly according to claim 1 or 2, further comprising:

    a booster pump abnormality detector for detect-

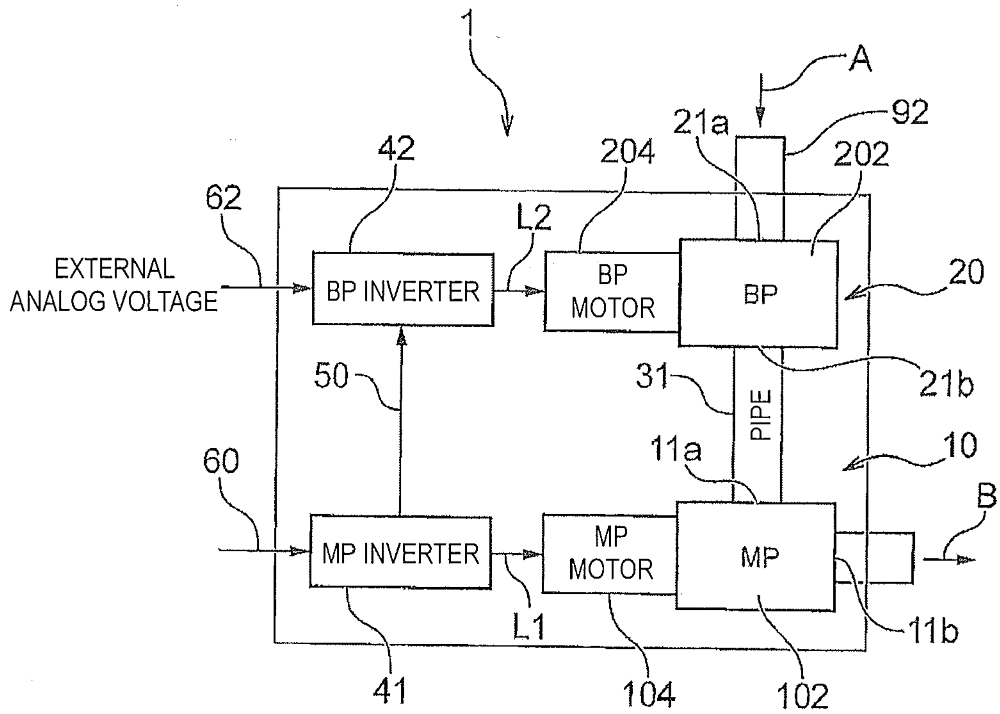
ing abnormality of the booster pump; and
a booster pump abnormal stopping unit for causing the booster pump to stop and causing the main pump to keep in operation when the booster pump abnormality detector detects abnormality of the booster pump.

11. The vacuum pump assembly according to any one of claims 1 to 10, further comprising a signal input unit to which a signal for controlling the number of revolutions of the main pump and/or the booster pump is input from an outside.

12. An operation control method for a vacuum pump assembly including a main pump and a booster pump, wherein each of the pumps has an intake port and an exhaust port, the intake port of the main pump intercommunicates with the exhaust port of the booster pump, the intake port of the booster pump is-functioned as an intake side of the vacuum pump assembly, and the exhaust port of the main pump is-functioned as an exhaust side of the vacuum pump assembly,
the operation control method comprising:

a step of receiving a start instruction for starting the main pump; and
after the start instruction is received, a step of determining based on the start instruction whether the booster pump should be started, and if so determined starting the booster pump concurrently when the main pump starts.

Fig. 1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L1
11b
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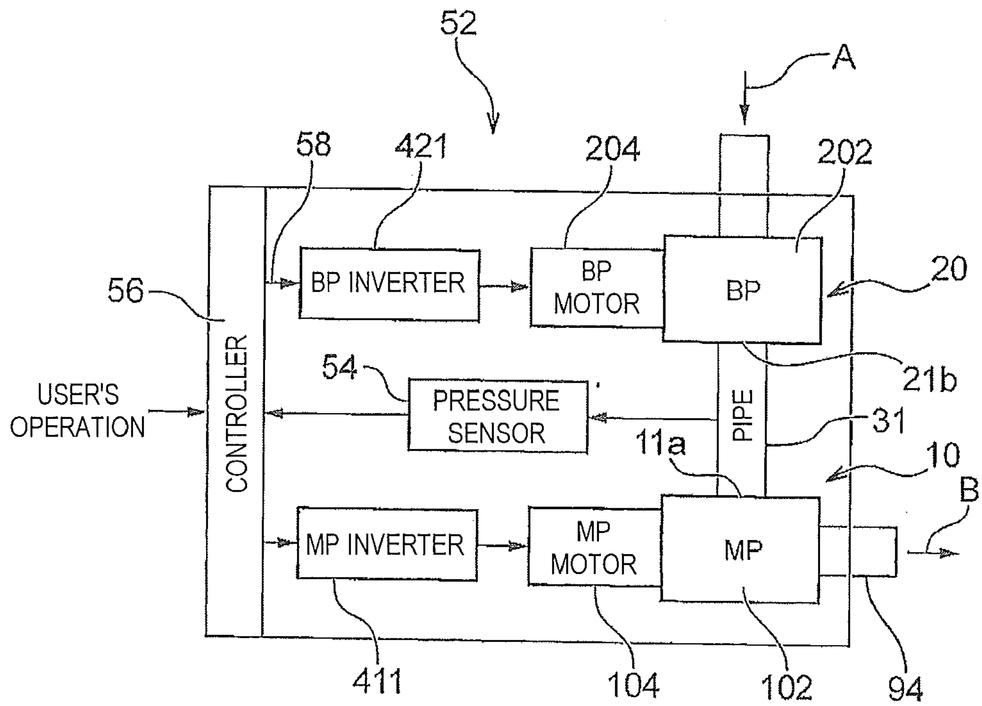
104
102

Fig. 2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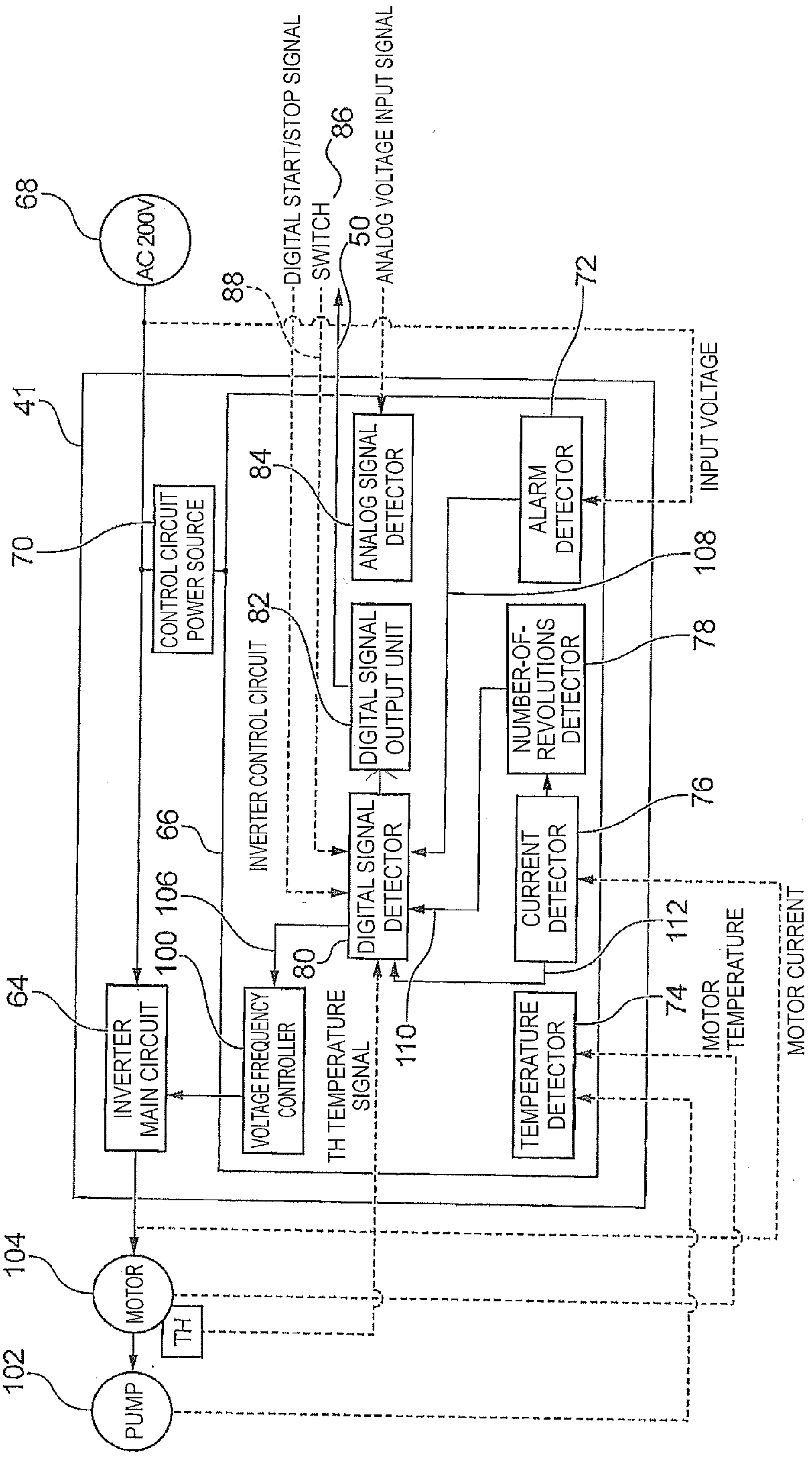
94

Fig. 3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SWITCH
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50
ANALOG VOLTAGE INPUT SIGNAL
88
41
70
CONTROL CIRCUIT POWER SOURCE
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ANALOG SIGNAL DETECTOR
72
ALARM DETECTOR
INPUT VOLTAGE
108
INVERTER CONTROL CIRCUIT
82
DIGITAL SIGNAL OUTPUT UNIT
NUMBER-OF-REVOLUTIONS DETECTOR
78
66
DIGITAL SIGNAL DETECTOR
76
CURRENT DETECTOR
106
100
80
112
64
INVERTER MAIN CIRCUIT
VOLTAGE FREQUENCY CONTROLLER
TH TEMPERATURE SIGNAL
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TEMPERATURE DETECTOR
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MOTOR TEMPERATURE
MOTOR CURRENT
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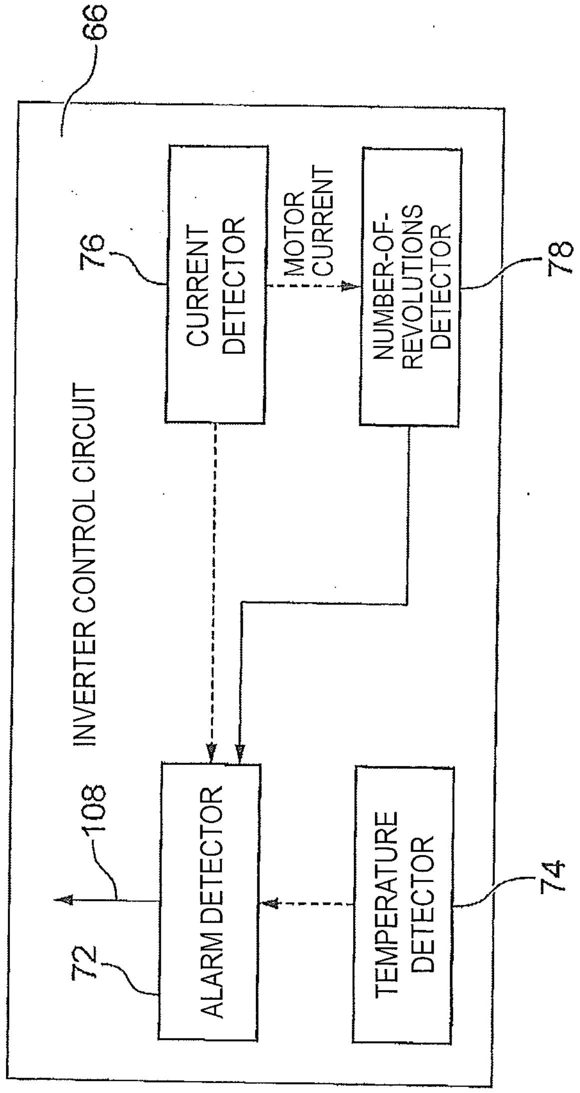
TH
102
PUMP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76
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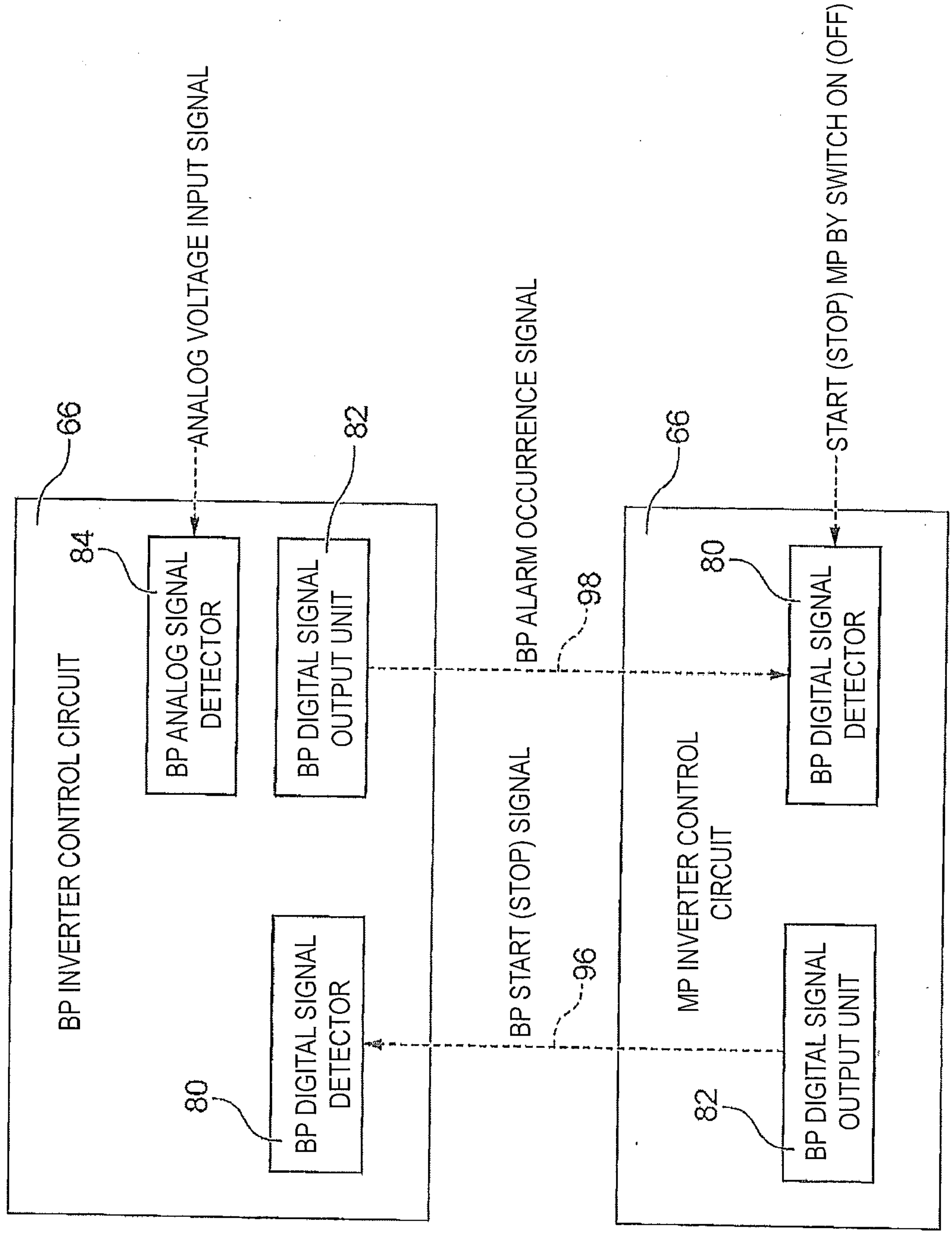
108
72
ALARM DETECTOR
TEMPERATURE DETECTOR
74

Fig. 4

Fig. 5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BP DIGITAL SIGNAL DETECTOR
BP ALARM OCCURRENCE SIGNAL
98
BP START (STOP) SIGNAL
96
MP INVERTER CONTROL CIRCUIT
66
80
BP DIGITAL SIGNAL DETECTOR
START (STOP) MP BY SWITCH ON (OFF)
82
BP DIGITAL SIGNAL OUTPUT UNIT

Fig. 6

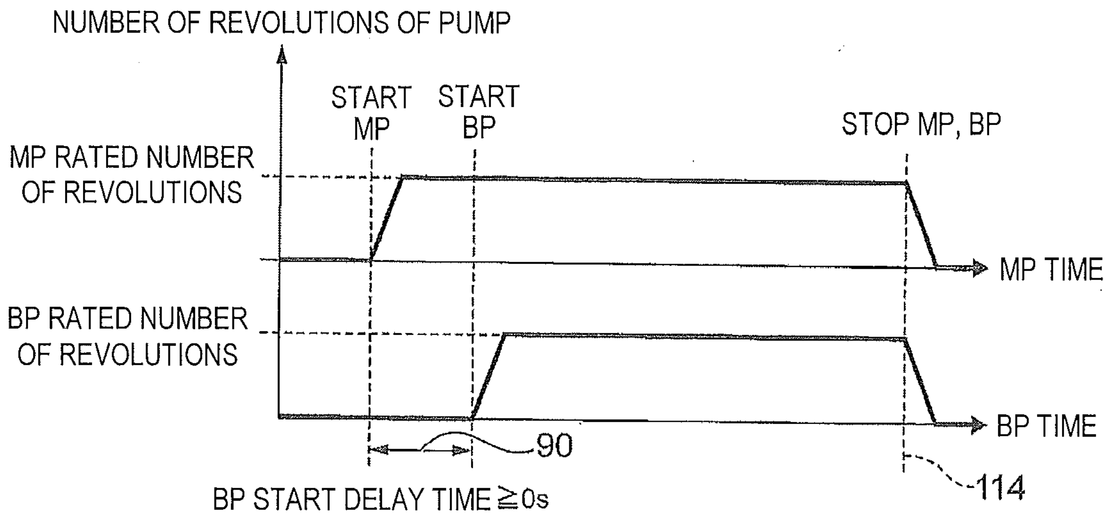
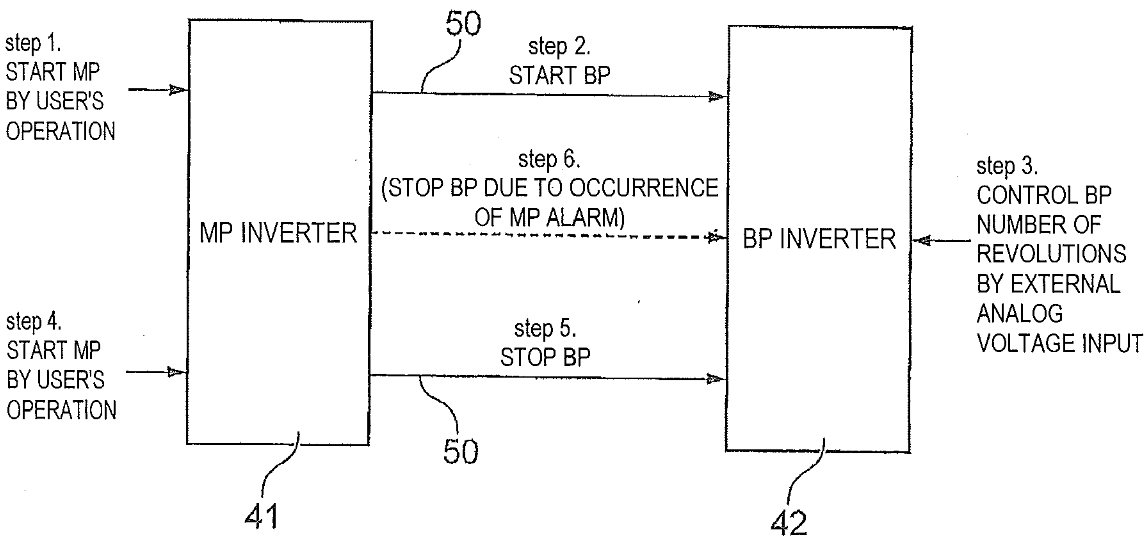

NUMBER OF REVOLUTIONS OF PUMP
START MP
START BP
STOP MP, BP
MP RATED NUMBER OF REVOLUTIONS
MP TIME
BP RATED NUMBER OF REVOLUTIONS
BP TIME
90
114
BP START DELAY TIME ≧0s

Fig. 7


step 1. START MP BY USER'S OPERATION
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step 2. START BP
step 6. (STOP BP DUE TO OCCURRENCE OF MP ALARM)
MP INVERTER
BP INVERTER
step 3. CONTROL BP NUMBER OF REVOLUTIONS BY EXTERNAL ANALOG VOLTAGE INPUT
step 4. START MP BY USER'S OPERATION
step 5. STOP BP
50
41
42

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	1 August 2018	Bocage, Stéphane

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