



- (51) **International Patent Classification:**
B04B 9/10 (2006.01) *B04B 15/02* (2006.01)
- (21) **International Application Number:**
PCT/JP2012/060648
- (22) **International Filing Date:**
13 April 2012 (13.04.2012)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
2011-091600 15 April 2011 (15.04.2011) JP
2012-047417 2 March 2012 (02.03.2012) JP
- (71) **Applicant** (*for all designated States except US*): **Hitachi Koki Co., LTD.** [JP/JP]; 15-1, Konan 2-chome, Minato-ku, Tokyo, 1086020 (JP).
- (72) **Inventors; and**
- (75) **Inventors/Applicants** (*for US only*): **INANIWA, Masahiro. TAKAHASHI, Hiroyuki. AKATSU, Kouichi. OUYAMA, Hisanobu. HODOTSUKA, Yuki. OSAWA, Hidetaka.**
- (74) **Agent:** **Shin-Ei Patent Firm, P.C.;** Toranomom East Bldg. 8F, 7-13, Nishi-Shimbashi 1-chome, Minato-ku, Tokyo, 1050003 (JP).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

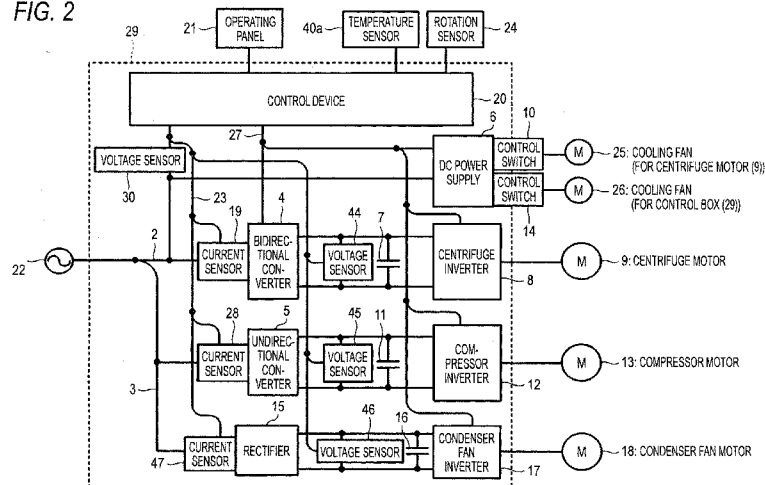
(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: CENTRIFUGE

FIG. 2



(57) Abstract: A centrifuge including: a rotor configured to hold a sample and configured to be detachably mounted, a rotation chamber accommodating the rotor, a plurality of motors configured to be rotationally driven by three-phase AC power, and a control device configured to control centrifuging operation, wherein one of the plurality of motors is a centrifuge motor configured to rotate the rotor, and the control device is configured to change distribution of power supplied to the centrifuge motor and power supplied to another motor of the plurality of motors during one operation.

DESCRIPTION

Title of Invention

CENTRIFUGE

Technical Field

Aspects of the present invention relate to a centrifuge capable of corresponding to various power supply situation without changing a configuration thereof, achieving reduction in size and low noise and realizing high-precision temperature control.

Background Art

A centrifuge, in particular, a so-called high-speed refrigerated centrifuge has been widely used in the experimental laboratory or the routine operation of manufacturing process in which ability for cooling and maintaining the rotor rotating at high speed at a lower temperature (for example, 4 °C) and ability for accelerating or decelerating the rotor in a short time are required. This centrifuge is a device capable of obtaining samples centrifuged by holding a sample placed in tube/bottle to be separated and precipitated on a rotor, accelerating and then stabilizing the rotor set on crown in a chamber to a predetermined rotation number and then decelerating and stopping the rotor.

In a related-art high-speed refrigerated centrifuge, it is usual that the centrifuging time of a sample is not so long and thus it is important to improve the collection efficiency of separated and precipitated material by

reducing acceleration/deceleration time of a rotor. Accordingly, it is especially demanded that the acceleration/deceleration time is short. Further, when a sample is separated and precipitated during centrifuging operation, in order to prevent the separated and precipitated sample from being deteriorated due to decrease in biochemical activity and temperature, there is need an ability for accurately retaining the sample held in the rotor at a lower temperature (for example, 4 °C) during centrifuging operation. In addition, small installation space and compact size are also important. Furthermore, since the centrifuge is often used in a quiet ambient environment such as research room or experimental laboratory, it is also important to reduce an operating noise.

Meanwhile, the destination (shipping address) of the centrifuge is worldwide, and thus, the power situation varies for each country. For this reason, in related-art, the centrifuge is configured to cover voltage/frequency/power supply capacity of power sources by one design specification. In a general configuration of a product commercially available from the present applicant, a motor for accelerating/decelerating a rotor is subjected to a variable speed control by an inverter and both a compressor motor and a condenser fan of a cooling unit for holding a sample at a lower temperature are subjected to ON-OFF control by a single-phase induction motor.

A technology for incorporating a variable speed motor of an inverter control type in the centrifuge has been proposed in

JP-A-H07-246351. The technology disclosed in JP-A-H07-246351 has a configuration that the current supplied from the power supply or returned to the power supply forms a current waveform in which the power factor is high and the harmonic current is reduced, when a motor for rotationally driving the rotor is subjected to the power running and the power regeneration operation. Further, the technology disclosed in JP-A-H06-170282 is so configured that the rotation number of a cooling fan in a region where the power frequency supplied is 60 Hz is reduced to be consistent with the rotation number thereof in a region where the power frequency is 50 Hz and the noise level of the cooling fan generated due to the change of the power frequency is not fluctuated.

Summary of Invention

Technical Problem

In related art, in order to use one design specification as much as possible for each power voltage for each destination, an autotransformer is provided to the power input unit of the centrifuge. This is for controlling a centrifuge motor, a compressor motor and a condenser fan, which are usually difficult to match the power supply voltage. A tap of the autotransformer is switched so that each power voltage matches an inner operating voltage of the centrifuge. At this time, the current capacity of the connection power is varies. Accordingly, when the power supply capacity is small, the current of the centrifuge motor during acceleration of the rotor is adapted to the voltage specification having smallest current capacity and does not exceed the power supply capacity. In this way, the

acceleration of the rotor becomes blunt. Alternatively, the operation of the compressor motor of the cooling machine is stopped until the end of the acceleration of the rotor in order to allocate the power supply voltage to acceleration of the rotor. In this case, the rotor is allowed to be warmed due to windage loss generated by the rotation thereof. However, when this control method is adopted, original function of the centrifuge is deteriorated.

In related-art, a compressor motor and a condenser fan has been utilized, in which the rotation number of the motor is changed as the power frequency changes and thus cooling capacity is also changed. At this time, a compressor motor having a large capacity is employed, in order to ensure sufficient cooling capacity even at 50 Hz power supply at which the circulation amount of the refrigerant is reduced due to decrease in the rotation number thereof. Similarly, a condenser fan having a large size is employed, in order to ensure sufficient heat discharge even at 50 Hz power supply at which the heat discharge amount of the condenser is reduced due to decrease in the rotation number thereof. However, when these compressor motor and condenser fan are used at 60 Hz power supply, the rotation number of the motor or the fan rises and thus operating noise becomes larger. A product incorporating sound insulating and noise barrier equipment has been commercialized in order to suppress the operating noise. This is the same as in a cooling fan of the motor for driving the rotor and a cooling fan for the control device.

In a related-art temperature control of the rotor, ON-OFF control of the compressor motor is carried out by setting the rotation number of the compressor motor to a single rotation number depending on the power frequency. According to this control, temperature control accuracy is degraded in a region where the temperature of the rotor is greatly pulsated during rotation thereof or the windage loss of the rotor is small. As a countermeasure, a method for utilizing a variable speed compressor in an inverter control type has been proposed. However, according to this method, in a case of a control in which intermittent ON-OFF operation as well as continuous variable speed operation is required, the temperature control performance of the rotor is poor at boundary region between the continuous variable speed operation and the intermittent ON-OFF operation, at which region the windage loss of the rotor is small. Accordingly, high-precision temperature control cannot be achieved.

The present invention has been made to solve the above-described problem and it is an object of the present invention to provide a centrifuge in which there is no need to mount an autotransformer in view of the voltage situation of the worldwide destination and which can easily deal with the difference in the power supply capacity.

Another object of the present invention is to provide a compact and low noise centrifuge which is capable of extremely suppressing decline of cooling capacity or noise rise even when the power frequency of power supply is different and does not incorporate extra sound insulating material

and noise barrier material.

Another object of the present invention is to provide a centrifuge capable of achieving high-precision temperature control accuracy even in a region where the windage loss of the rotor is small.

Solution to Problem

Representative aspects of the invention disclosed herein are as follows.

In a first aspect, there is provided a centrifuge including: a rotor configured to hold a sample and configured to be detachably mounted, a rotation chamber accommodating the rotor, a plurality of motors configured to be rotationally driven by three-phase AC power, and a control device configured to control centrifuging operation, wherein one of the plurality of motors is a centrifuge motor configured to rotate the rotor, and the control device is configured to change distribution of power supplied to the centrifuge motor and power supplied to another motor of the plurality of motors during one operation.

In a second aspect, the centrifuge further includes an inverter control type cooling machine, wherein the control device is configured to control a maximum distribution power supplied to the motor during a rotation acceleration of the rotor and a maximum distribution power supplied to the motor during a rotation stabilization of the rotor to be different from each other.

In a third aspect, the control device is configured to allocate a predetermined power to the cooling machine during the rotation acceleration of the rotor.

In a fourth aspect, the control device is configured to change a distribution ratio of the power supplied to the motors, depending on the type of the rotor mounted or a power supply capacity of the connection power.

In a fifth aspect, the centrifuge further includes: a converter configured to convert the AC power into DC power; a first inverter configured to convert DC output of the converter into AC power to supply the converted AC power to the centrifuge motor; and a second inverter configured to convert DC output of the converter into AC power to supply the converted AC power to the other motor, wherein the control device is configured to change the distribution ratio by adjusting an amount of power supplied from the first and second inverters.

In a sixth aspect, the distribution ratio of the power supplied to the centrifuge motor and the power supplied to the other motor of the plurality of motors is set in advance for each type of the rotor and stored in a storage device of the control device.

In a seventh aspect, the centrifuge further includes: a cooling device configured to cool the rotation chamber; a converter configured to convert the AC power into DC power, a first inverter configured to convert DC output of the converter into AC power to supply the converted AC power to the centrifuge motor, and a second inverter configured to convert

DC output of the converter into AC power to supply the converted AC power to the other motor, wherein the cooling device includes a compressor motor which is configured to be controlled in a variable speed by the converted AC power supplied from the second inverter, and a distribution ratio of the power supplied to the centrifuge motor and the power supplied to the compressor is changed depending on the type of the rotor.

In an eighth aspect, the boost converter has a function of converting the AC power supply into DC power and a function of converting the DC power supplied from the first inverter into AC power to return the converted AC power to the AC power supply.

In a ninth aspect, the other motor includes a condenser fan which is configured to send wind to a condenser for cooling a refrigerant in the cooling device, and the control device is configured to carry out the feedback controls of each of the centrifuge motor, the compressor motor and the condenser fan.

In a tenth aspect, the centrifuge further includes a third inverter configured to convert the DC power from the boost converter into AC power in order to control the condenser fan in a variable speed.

In an eleventh aspect, the rotation number of the condenser fan during the variable speed control is changed depending on the type of the rotor mounted.

In a twelfth aspect, there is provided a centrifuge including: first and second converters for converting AC power supplied from an AC power supply into DC power, a centrifuge inverter connected to the first converter,

a centrifuge motor configured to be controlled in a variable speed by an output of the centrifuge inverter, a rotor configured to be driven by the centrifuge motor and configured to centrifuge a sample, a chamber housing the rotor therein, an evaporator configured to cool the chamber, a compressor configured to compress a refrigerant to supply the compressed refrigerant in a circulation manner to the evaporator, a compressor inverter connected to the second converter, a compressor motor configured to be controlled in a variable speed by the output of the compressor inverter and configured to drive the compressor, and a control device configured to control these components, wherein the control device is configured to carry out the feedback controls of the centrifuge motor and the compressor motor and is configured to control the rotation number of the compressor motor depending on a distribution parameter of power allocated to the centrifuge motor and the compressor motor, which are set in advance during the acceleration of the rotor.

In a thirteenth aspect, the control device is configured to change the distribution parameter of power allocated to the centrifuge motor and the compressor motor between an acceleration rotation of the rotor and a steady rotation of the rotor.

In a fourteenth aspect, the distribution parameters are set in advance for each type of the rotor and stored in a storage device of the control device, and the control device is configured to identify the type of the rotor mounted and carry out the control in accordance with the distribution parameter stored in the storage device.

In a fifteenth aspect, the first boost converter is a bidirectional

converter which is configured to convert DC power supplied from the centrifuge inverter into converted AC power to regenerate the power to AC power supply, in addition to the function of converting the AC power into the DC power.

In a sixteenth aspect, during the acceleration of the rotor, the control device is configured to control a rotation number of the compressor motor to a rotation number that is substantially same as a rotation number by which the rotor can be maintained in a thermal equilibrium state at a preset temperature.

In a seventeenth aspect, after the acceleration of the rotor ends and the rotor transits to a constant speed rotation, the control device is configured to control the rotation number of the compressor motor to be higher than a rotation number which is required for cooling and holding the rotor to a target temperature.

In an eighteenth aspect, there is provided a centrifuge comprising: a rotation chamber accommodating a rotor which is configured to hold a sample, a centrifuge motor configured to rotationally drive the rotor, an inverter control type cooling machine configured to cool the rotation chamber and a control device configured to control the operation of the centrifuge motor and the cooling machine, wherein the control device is configured to control a maximum distribution power allocated to the cooling machine during rotational acceleration of the rotor to be different from a maximum distribution power allocated to the cooling machine during rotational stabilization of the rotor.

In a nineteenth aspect, the maximum distribution power allocated to the cooling machine during rotational acceleration of the rotor is smaller than the maximum distribution power allocated to the cooling machine during rotational stabilization of the rotor.

In a twentieth aspect, the cooling machine includes a compressor motor configured to be controlled in a variable speed, an upper limit of a rotational frequency of the compressor motor is set to a lower value during the rotational acceleration and set to a higher value during the rotational stabilization, and the control device is configured to allow the compressor motor to operate within a range of the set upper limit.

In a twenty-first aspect, the control device is configured to control the rotation of the compressor motor to be subjected to PID control or ON-OFF control during the rotational stabilization of the rotor.

In a twenty-second aspect, the maximum distribution power allocated to the cooling machine during the rotational acceleration and the rotational stabilization of the rotor is set in accordance with the type of the rotor mounted.

In a twenty-third aspect, there is provided a centrifuge including: a rotation chamber accommodating a rotor which is configured to hold a sample and is configured to be detachably mounted, a centrifuge motor configured to rotationally drive the rotor, a cooling machine configured to cool the rotation chamber, and a control device configured to control the operation of the centrifuge motor and the cooling machine, wherein the cooling machine includes an inverter control type compressor motor, and

the control device is configured to control the compressor motor to rotate at a first speed during rotational acceleration of the centrifuge motor and to switch the compressor motor to rotate at a second speed higher than the first speed when the centrifuge motor reaches a rotation number close to a preset rotation number.

In a twenty-fourth aspect, the rotation number close to a preset rotation number is a rotation number lower than the preset rotation number by several hundreds of rotations.

In a twenty-fifth aspect, there is provided a centrifuge including: a rotation chamber accommodating a rotor configured to hold a sample and is configured to be detachably mounted, a centrifuge motor configured to rotationally drive the rotor, an inverter control type cooling machine configured to cool the rotation chamber and a control device configured to control the operation of the centrifuge motor and the cooling machine, wherein an upper limit of the rotation number of the cooling machine is set in accordance with values of current flowing through the centrifuge motor.

In a twenty-sixth aspect, a maximum distribution power allocated to the cooling machine during the latter half of rotational acceleration of the rotor is smaller than a maximum distribution power allocated to the cooling machine during the rotational stabilization of the rotor.

In a twenty-seventh aspect, there is provided a centrifuge including: a rotor configured to hold a sample, a rotation chamber accommodating the rotor, a motor configured to drive the rotor and configured to be

rotationally driven by an inverter circuit, a cooling machine configured to cool the rotor, an operating panel configured to receive operating conditions such as a cooling temperature or an operating time, and a control device configured to control the centrifuging operation, wherein, when the lowest input temperature that the operating panel can receive is set as a preset temperature, the distribution power allocated to the cooling machine during acceleration of the rotor is set smaller than the distribution power allocated to the cooling machine during stabilization operation of the rotor.

Advantageous Effects of Invention

According to the first aspect, the control device is configured to change the distribution ratio of the power supplied to the centrifuge motor and the power supplied to another motor of the plurality of motors during one operation. By this configuration, it is possible to effectively rotate each motor within a limited range of power supply.

According to the second aspect, the control device is configured to control the maximum distribution power supplied to the motor during the rotation acceleration of the rotor and the maximum distribution power supplied to the motor during the rotation stabilization of the rotor to be different from each other. Accordingly, it is possible to quickly accelerate the rotor within a limited range of power supply.

According to the third aspect, the control device is configured to

allocate a predetermined power to the cooling machine during the rotation acceleration of the rotor. By this configuration, the cooling machine is not stopped even during acceleration of the rotor and thus it is possible to drive the cooling machine without causing adverse effects such as temperature rise.

According to the fourth aspect, the control device is configured to change the distribution ratio of the power supplied to the motors, depending on the type of the rotor mounted or the power supply capacity of the connection power. Accordingly, it is possible to quickly accelerate the rotor while ensuring a required cooling capacity to match the cooling property of the rotor.

According to the fifth aspect, the control device is configured to change the distribution ratio of the power by adjusting the amount of power consumed by the first and second inverters. By this configuration, it is possible to easily control the distribution ratio of the power using the inverters.

According to the sixth aspect, the distribution ratio of the power is set in advance depending on the type of the rotor or the power supply capacity of the connection power and stored in a storage device of the control device. Accordingly, if the type of the rotor or the power supply capacity of the connection power is known, the distribution ratio of the power is determined and thus it is possible to easily control the control

device.

According to the seventh aspect, the cooling device includes a compressor motor which is configured to be controlled in a variable speed by the AC power supplied from the second inverter and a distribution ratio of the power supplied to the centrifuge motor and the power supplied to the compressor is changed depending on the type of the rotor. Accordingly, the operation and cooling of the rotor can be independently controlled in an optimal manner.

According to the eighth aspect, the first converter has a function of converting the AC power supply into DC power and a function of converting the DC power supplied from the centrifuge inverter into AC power to return the converted AC power to the AC power supply. By this configuration, the receiving power factor becomes higher and thus it is possible to accelerate or decelerate the rotor in a short time. Further, it is possible to strongly cool the rotor rotating at high speed and therefore the power line harmonics can be reduced. Furthermore, electric energy generated during regenerative braking deceleration of the rotor is absorbed to the power supply by the reverse power flow function or the variable speed type compressor for cooling the rotor. Accordingly, there is no need to mount so-called regenerative deceleration discharge resistor thereon. Thereby, the centrifuge can be made in a compact manner and thus space-saving can be realized.

According to the ninth aspect, the other motor includes a condenser fan which is configured to send wind to a condenser for cooling a refrigerant in the cooling device and the control device is configured to carry out the feedback controls of each of the centrifuge motor, the compressor motor and the condenser fan. Accordingly, a low noise can be realized while ensuring the cooling capacity required for rapidly approaching the temperature of the rotor to the target temperature.

According to the tenth aspect, the centrifuge further includes a third inverter configured to convert the DC power from the converter into AC power in order to control the condenser fan in a variable speed. By this configuration, the condenser fan can be controlled independently of the compressor motor.

According to the eleventh aspect, the rotation number of the condenser fan during the variable speed control is changed depending on the type of the rotor mounted. Accordingly, optimal cooling capacity can be achieved to match the type of the rotor.

According to the twelfth aspect, the control device is configured to carry out the feedback controls of the centrifuge motor and the compressor motor and is configured to control the rotation number of the compressor motor depending on a distribution parameter of power allocated to the centrifuge motor and the compressor motor, which are set in advance during the acceleration of the rotor. Accordingly, the configuration of the

centrifuge does not depend on the supply voltage and the centrifuge can be operated within the power supply capacity of the connection power. For this reason, there is no need to provide an autotransformer and thus the centrifuge can be operated at a maximum ability thereof within the power supply capacity of the connection power. Further, there is no need to switch a tap matching the voltage of the destination. In this way, a compact product can be made and thus productivity is improved. Further, since the configuration of the centrifuge does not depend on the supply frequency and the compressor motor and the condenser fan as major noise sources are operated at a suitable rotation number using a variable speed control, there is no need to prepare a noise reducing member which has sound insulating properties and noise barrier performance so as to allow the centrifuge to be operated at 60 Hz. Further, since the current of the rotor during acceleration is set and stored to be adjusted in accordance with the power supply capacity of the destination and the centrifuge is controlled to operate at substantially maximum power supply current value based on the adjusted contents, the maximum performance can be always realized in accordance with the power conditions.

According to the thirteenth aspect, the control device is configured to change the distribution parameter of power allocated to the centrifuge motor and the compressor motor between the acceleration rotation and the steady rotation of the rotor. In this way, it is possible to increase the power allocation to the centrifuge motor during the acceleration and to reduce the power allocation to the centrifuge motor during the steady

rotation, as compared to the case of the acceleration.

According to the fourteenth aspect, the control device is configured to identify the type of the rotor mounted and carry out the control in accordance with the distribution parameter stored in the storage device. In this way, the present invention can be easily realized simply by executing the computer program by using the control device.

According to the fifteenth aspect, the first boost converter is a bidirectional converter which is configured to convert DC power supplied from the centrifuge inverter into converted AC power to regenerate the power to AC power supply. In this way, electric energy generated during regenerative braking deceleration of the rotor is absorbed to the power supply by the reverse power flow function or the variable speed type compressor for cooling the rotor. Accordingly, there is no need to mount a so-called regenerative deceleration discharge resistor thereon. Thereby, the centrifuge can be made in a compact manner and thus space-saving can be realized. Further, the operation and cooling of the rotor can be independently controlled in an optimal manner.

According to the sixteenth aspect, during the acceleration of the rotor, the control device is configured to control the rotation number of the compressor motor to a rotation number that is substantially same as the rotation number by which the rotor can be maintained in a thermal equilibrium state at a preset temperature of the rotor. Accordingly, it is

possible to prevent the rotor from being excessively overheated during acceleration thereof. Thereby, it is possible to prevent an original performance of the refrigerated centrifuge from being deteriorated.

According to the seventeenth aspect, after the acceleration of the rotor ends and thus the rotor transits to a constant speed rotation, the control device is configured to control the rotation number of the compressor motor to be higher than a rotation number which is required for cooling and maintaining the rotor to a target temperature. In this way, the cooling ability of the cooling device at the stabilization state can be sufficiently secured.

According to the eighteenth aspect, the control device is configured to control the maximum distribution power allocated to the cooling machine during rotational acceleration of the rotor to be different from the maximum distribution power allocated to the cooling machine during stabilization of the rotor. Accordingly, it is possible to efficiently rotate the cooling machine within a limited range of power supply.

According to the nineteenth aspect, the maximum distribution power allocated to the cooling machine during acceleration of the rotor is smaller than the maximum distribution power allocated to the cooling machine during stabilization of the rotor. Accordingly, it is possible to quickly accelerate the rotor within a limited range of power supply.

According to the twentieth aspect, an upper limit of the rotational frequency of the compressor motor during the acceleration is set lower than an upper limit thereof during the stabilization. Accordingly, it is possible to distribute more power to the centrifuge motor side and thus it is possible to quickly accelerate the rotor.

According to the twenty-first aspect, the control device is configured to control the rotation of the compressor motor to be subjected to PID control or ON/PFF control during the rotational stabilization of the rotor. In this way, it is possible to cool the rotation chamber to a target temperature with high precision.

According to the twenty-second aspect, the maximum distribution power allocated to the cooling machine during the acceleration of the rotor and the maximum distribution power allocated to the cooling machine during stabilization of the rotor are set in accordance with the type of the rotor mounted. Accordingly, it is possible to quickly accelerate the rotor while ensuring a required cooling capacity to match the cooling property of the rotor.

According to the twenty-third aspect, the inverter control type compressor motor is configured to rotate at the first lower speed during rotational acceleration of the centrifuge motor and the compressor motor is switched to rotate at the second higher speed when the centrifuge motor reaches a rotation number close to the stabilized rotation number.

Accordingly, it is possible to quickly cool the rotation chamber to a target temperature.

According to the twenty-fourth aspect, the rotation speed of the compressor motor is increased from the first speed toward the second speed at the rotation number of the centrifuge motor lower than the stabilized rotation number by several hundreds of rotations. Accordingly, the centrifuge motor is decelerated and power consumption is reduced. In this way, it is possible to immediately raise the rotation speed of the compressor motor.

According to the twenty-fifth aspect, the upper limit of the rotation number of the cooling machine is set in accordance with values of current flowing through the centrifuge motor. Accordingly, it is possible to maximally cool the rotation chamber within a limited range of power supplied.

According to the twenty-sixth aspect, the maximum distribution power allocated to the cooling machine during the latter half of rotational acceleration of the rotor is smaller than the maximum distribution power allocated to the cooling machine during the rotational stabilization of the rotor. Therefore, it is possible to control the rotation of the rotor to be preferentially stabilized.

According to the twenty-seventh aspect, the distribution power

allocated to the cooling machine during acceleration of the rotor is set smaller than the distribution power allocated to the cooling machine during stabilization operation of the rotor. In this way, a power required during acceleration of the rotor can be supplied to the motor for driving the rotor and therefore it is possible to efficiently accelerate the rotor.

The foregoing and other objects and features of the present invention will be apparent from the detailed description below and accompanying drawings.

Brief Description of Drawings

FIG. 1 is a sectional view schematically illustrating the entire configuration of a centrifuge according to an embodiment of the present invention.

FIG. 2 is a block diagram illustrating the centrifuge according to the embodiment of the present invention.

FIG. 3 is a view illustrating a display and operation screen of a setting means for setting the distribution parameters of AC source current of the centrifuge according to the embodiment of the present invention.

FIG. 4 is a table illustrating an example of the distribution parameters of AC source current stored in the control device of the centrifuge according to the embodiment of the present invention.

FIG. 5 is a view illustrating an actual measured example of a relationship among the rotation number of the rotor, the rotation number of compressor motor and the current during an

acceleration/stabilization/deceleration stop of R22A4 type rotor in the centrifuge according to the embodiment of the present invention.

FIG. 6 is a view illustrating an actual measured example of a relationship among the rotation number of the rotor, the rotation number of compressor motor and the current during an acceleration/stabilization/deceleration stop of R10A3 type rotor in the centrifuge according to the embodiment of the present invention.

FIG. 7 is a view for explaining a relationship between the type of the rotor and the power distribution in the centrifuge according to a second embodiment of the present invention.

FIG. 8 is a block diagram illustrating the centrifuge according to a third embodiment of the present invention, in a state of being connected to a three-phase AC power supply.

FIG. 9 is a view illustrating an actual measured example of a centrifuge according to a fourth embodiment of the present invention, in a case where R22A4 type rotor is rotated at rotation number of 22000 min^{-1} and a temperature sensor 40a is utilized in the control of cooling and maintaining the temperature of a sample at 4°C .

FIG. 10 is a view illustrating an actual measured example of a centrifuge according to the fourth embodiment of the present invention, in a case where R22A4 type rotor is rotated at rotation number of 22000 min^{-1} and a temperature sensor 40b is utilized in the control of cooling and maintaining the temperature of a sample at 4°C .

FIG. 11 is a view illustrating an actual measured example of a centrifuge according to the fourth embodiment of the present invention, in

the control of rotating R22A4 type rotor at rotation number of 10000 min^{-1} and cooling and maintaining the temperature of a sample at 4°C .

FIG. 12 is a view illustrating an actual measured example of a centrifuge according to the fourth embodiment of the present invention, in the control of rotating R10A3 type rotor at rotation number of 7800 min^{-1} and cooling and maintaining the temperature of a sample at 4°C .

FIG. 13 is a view illustrating an actual measured example of a centrifuge according to the fourth embodiment of the present invention, in the control of rotating R22A4 type rotor at rotation number of 10000 min^{-1} , cooling and maintaining the temperature of a sample at 4°C , and then changing the rotation number to 12000 min^{-1} at this state.

FIG. 14 is a view illustrating a relationship between a ratio of a preset rotation number to a maximum rotation number of a rotor 31 and an initial rotation number of a compressor motor 13 at the start of control thereof.

FIG. 15 is a view illustrating a relationship between a target control temperature of the temperature sensor 40a and a windage loss of a rotor at respective rotation number of the R22A4 type rotor in the centrifuge.

FIG. 16 is a view illustrating a relationship between a target control temperature of the temperature sensor 40a and a windage loss of a rotor at respective rotation number of the R10A3 type rotor in the centrifuge.

FIG. 17 is a view illustrating a relationship between an initial value of I (integration term) and a temperature-time change rate ($^\circ\text{C}/\text{sec}$) in which a measured temperature value of the temperature sensor 40a is reduced during two minutes immediately before migration to PID control.

FIG. 18 is a table illustrating an example of some combinations of the relationship between the type of a rotor 31 and the rotation number of a condenser fan 18 used in the centrifuge.

FIG. 19 is a view illustrating a relationship between the rotation numbers of a rotor and the rotation number of a compressor motor 13 when the rotation number of the rotor rises and is stabilized at a preset rotation number in a centrifuge according to a fifth embodiment of the present invention.

FIG. 20 is a view illustrating a relationship between the current of a centrifuge motor 9 and the rotation number of a compressor motor 13 when the rotation number of the rotor rises and is stabilized at a preset rotation number in a centrifuge according to a sixth embodiment of the present invention.

Description of Embodiment

Hereinafter, the embodiment of the present invention will be described by referring to the accompanying drawings. In the following drawings, same reference numerals will be given to the same components and a repetitive description thereof will be omitted.

FIG. 1 is a sectional view schematically illustrating the entire configuration of a centrifuge 1 according to an embodiment of the present invention. The centrifuge 1 includes a rotation chamber 48 inside a body thereof. A centrifuge motor 9 as a driving source is provided below the rotation chamber. As the centrifuge motor 9, a high-frequency induction

motor in which a variable speed control by an inverter is allowed or a magnet brushless synchronous motor is utilized. A rotation sensor 24 for detecting a rotation number of an output shaft (motor shaft) is provided on a lower portion of the centrifuge motor 9 and a DC fan 25 for cooling the centrifuge motor 9 is provided on a side portion thereof. A rotor 31 is detachably mounted on a leading end of the output shaft (motor shaft) which extends upward from the centrifuge motor 9 to an interior of a chamber 32. The chamber 32 is an approximately cylindrical vessel and provided at its upper portion with a circular opening. The circular opening on an upper side of the chamber 32A is covered with a door 43 in which an insulation material is embedded. The door is configured to open and close the rotation chamber of the rotor 31. The door 43 is locked in a closed state by a lock mechanism (not-illustrated) during the operation of the centrifuge 1.

A pipe evaporator 33 is wound around an outer periphery of the chamber 32. The surrounding of the chamber is thermally insulated by an appropriate insulation material 34 such as a blowing agent. A compressor 35 is provided for compressing a refrigerant to supply the refrigerant in a circulation manner and includes a compressor motor 13. The compressor supplies the compressed refrigerant from a discharge pipe 36 to a condenser 37. The refrigerant is radiated and cooled by wind from a condenser fan 18 of the condenser 37 so that the refrigerant is liquefied. Further, the refrigerant is sent to a lower portion of the evaporator 33 wound around the outer periphery of the chamber 32 through a capillary 38.

The heat is generated in the rotation chamber 48 due to a windage loss during the rotation of the rotor 31 and absorbed in vaporization heat generated during the evaporation of the refrigerant in the evaporator 33. Vaporized refrigerant is discharged from the top of the evaporator 33 and returns to the compressor 35 through a suction pipe 42. A temperature sensor 40a is provided at a portion contacting a metal part in a bottom of the chamber 32 in which the rotor 31 is accommodated and indirectly detects the temperature of the rotor 31. Further, a seal rubber 41 is made of a rubber and configured to plug a through-hole through which an output shaft of the centrifuge motor 9 penetrates. A temperature sensor 40b (illustrated in the dashed-line) is embedded in the seal rubber and used to indirectly detect the temperature of the rotor 31. Although two temperature sensors 40a and 40b are provided in the present embodiment, it is not essential to employ two temperature sensors. For example, only one of them may be used. Further, the temperature sensors may be provided in other locations. However, in this case, care must be taken because the detection accuracy can be changed when indirectly detecting the temperature of the rotor 31.

A control box 29 for accommodating a control device (will be described later) is provided inside of the centrifuge 1. The control device includes a micro computer, a timer and a storage device, etc., all of which are not illustrated. The control device is configured to control the whole of the centrifuge 1 including the rotation control of the centrifuge motor 9 and the operation control of a chiller for controlling the temperature of the

rotation chamber 48. Accordingly, various electric equipments or electronic circuits are included inside of the control box 29 and respectively heat up when being operated. For this reason, a DC fan 26 for cooling is provided and sends cooling air to the electric equipments or electronic circuits when the control device is activated. The detected temperature of the temperature sensor 40a is fed back to the control device 20. The rotation number of a compressor motor 13 provided in the compressor 35 is so controlled that the sample in the rotor 31 reaches a predetermined target temperature. As mentioned above, five electric drive motors of the DC fan 25, the DC fan 26, the centrifuge motor 9, the compressor motor 13 and the condenser fan 18 are included in the centrifuge 1. However, three electric drive motors of the centrifuge motor 9, the compressor motor 13 and the condenser fan 18 are particularly involved in the present invention.

An operating panel 21 is provided on the top of the centrifuge 1. Preferably, the operating panel 21 is a touch-type liquid crystal display panel. Centrifuge operation conditions such as the operating rotation number (rotation speed) setting, the operation time setting and the cooling temperature setting of the rotor 31 holding the sample are inputted through the operating panel 21 and various information are displayed on the operating panel 21.

FIG. 2 is a block diagram illustrating the centrifuge according to the embodiment of the present invention. As illustrated in the dashed line,

the centrifuge is accommodated in the control box 29. In the configuration of FIG. 2, a power supply line 2 is connected to a single-phase AC power supply 22. Mainly, a bidirectional converter 4, a unidirectional converter 5, a rectifier 15 and a DC power supply 6 are connected to the power supply line 2. A centrifuge motor current sensor 19 can measure the current waveform in a state of being insulated. The bidirectional converter 4 is operated as a boost converter through the centrifuge motor current sensor 19 to convert the power of the AC power supply 22 into a DC power, during the power rectification. Further, the bidirectional converter is operated as a step-down converter to convert the DC power into AC power and regenerates the power of the AC power supply 22, during the power inversion. In this way, the bidirectional converter has a high power factor. DC power supply end of the bidirectional converter 4 is connected to a centrifuge inverter 8 via a smoothing condenser 7. Inversion terminal of the centrifuge inverter 8 is connected to the centrifuge motor 9 which is constituted by the high-frequency induction motor or the magnet brushless synchronous motor and configured to rotationally drive the rotor 31. The configuration and operation of the bidirectional converter 4 has been described in detail in JP-A-H07-246351. Specifically, AC side of the bidirectional converter is connected to the AC power supply 22 and DC side thereof is connected to the smoothing condenser 7. Further, a switching device such as a bipolar transistor, IGBT, FET, etc., are connected in opposite direction parallel to a plurality of rectifying devices constituting the bidirectional converter 4. Herein, the bidirectional converter 4 is not limited to such a configuration.

For example, a related-art bidirectional converter may be used as the bidirectional converter.

When the centrifuge motor 9 is accelerated by supplying DC power to DC power supply end, the current waveform of the passing current has the same shape as and is phase-synchronous with the sinusoidal waveform of the supply voltage waveform while boosting the DC power to a constant DC voltage higher than a peak value of the supply voltage by the boost function of the bidirectional converter 4. Therefore, a receiving power factor is improved. During the regenerative deceleration of the centrifuge motor 9, the voltage of the DC power supply end is lowered by the step-down function of the bidirectional converter 4 while being substantially same as the supply voltage of AC power supply 22 and following the voltage waveform thereof. And, the current waveform of the passing current is same as the sine waveform of the supply voltage waveform and the flowing direction thereof is opposite to that of the sine waveform. Therefore, a power factor of a reverse power flow is improved and the power returns to the AC power supply 22. The output of the voltage sensor 44 is transmitted to the control device 20 via an input control line 23 and is monitored by the control device while being utilized in the control operations.

The power supply line 2 is also connected to the DC power supply 6. DC fan 25 and DC fan 26 are respectively connected to DC constant voltage output end of the DC power supply 6 via controls switches 10, 14

for controlling ON-OFF of the DC fan 25 and the DC fan 26. Further, the DC constant voltage output end of the DC power supply 6 is connected to the control device 20. A switching type stabilized power supply can be used as the DC power supply 6 and is capable of handling a wide range of supply voltage of the AC power supply 22. In this way, according to the present embodiment, it is possible to obtain a constant rotation number regardless of the power voltage/frequency by using each fan as DC fan, instead of AC fan. Further, it is also possible to securely obtain a constant cooling capacity.

The unidirectional converter 5 is connected to the AC power supply 22 via a compressor motor current sensor 28. The current sensor can measure the current waveform while insulating the current waveform. The current sensor converts the power of the AC power supply 22 into DC power in a high power factor. The DC power supply end of the unidirectional converter 5 is connected to a compressor inverter 12 while the smoothing condenser 11 is provided therebetween. The inversion terminal of the compressor inverter 12 is connected to the compressor motor 13 such as the high-frequency induction motor or the magnet brushless synchronous motor. The current waveform of the passing current has the same shape as and is phase-synchronous with the sine waveform of the supply voltage waveform while supplying DC power from the DC power supply end of the unidirectional converter 5 to the smoothing condenser 11 and boosting the DC power to DC power several tens of volts higher than the peak value of the AC power supply 22 by the boost function

of the unidirectional converter. Therefore, a receiving power factor is improved. The charging voltage of the smoothing condenser 11 is supplied to the compressor inverter 12 and converted into AC voltage value by the compressor inverter 12 to drive the compressor motor 13. The rotation number of the compressor motor 13 is dependent on the frequency of the AC voltage and the maximum allowable rotation number thereof is slightly smaller than 120 Hz, that is, 7200 min^{-1} . The compressor motor 13 is always subjected to a reaction force for compressing the refrigerant. As soon as the power supply is shut-off, the compressor motor is decelerated and stopped and thus it is not possible to generate a regenerative power. Accordingly, there is no necessary a bidirectional conversion function by the bidirectional converter as in the case of the circuit of the centrifuge motor 9. A voltage sensor 45 is provided between the unidirectional converter 5 and the compressor inverter 12 and measures the charging voltage of the smoothing condenser 11 in a state of being insulated. The output of the voltage sensor 45 is transmitted to the control device 20 via an output control line 27 and is monitored by the control device while being utilized in the control operations.

The power of the AC power supply 22 is also supplied to a rectifier 15 via a power supply line 3. A DC output end of the rectifier 15 is connected to a condenser fan inverter 17 via the smoothing condenser 16. A condenser fan 18 including the high-frequency induction motor or the magnet brushless synchronous motor is connected to an output end of the condenser fan inverter 17. Power requirements of the centrifuge motor 9

and the compressor motor 13 are usually up to about 2 to 4 kW and the power requirements of the DC power supply 6 and the condenser fan 18 are about 100 W in total. It is not necessary to improve the power factor by a boost operation. Further, when it is necessary to suppress the power line harmonics, a reactor may be provided in a power input. When it is necessary to further suppress the power line harmonics, it may be preferable to improve the power factor.

From the output control line 27 of the control device 20, a selecting signal for causing the bidirectional converter 4 to operate in any one of a boost converter operation or a step-down converter operation and a selecting signal for causing the DC fans 25, 26 to operate in any one of a rotation mode or a stop mode by ON-OFF control of the control switches 10, 14 are outputted. Signal for performing voltage feedback control using pulse width modulation (PWM), for example, is outputted to each of the centrifuge inverter 8, the compressor inverter 12 and the condenser fan inverter 17 and further to each of the centrifuge motor 9, the compressor motor 13 and the condenser fan 18 in order to absorb the changes in the supply voltage and apply an appropriate voltage depending on the rotation status of these motors. A signal for variable speed control of a rotation number of the centrifuge motor 9 including ON and OFF by the control of the output voltage/output frequency is outputted to the centrifuge inverter 8. Similarly, in order to control the compressor motor 13 and the condenser fan 18 in the same manner as described above, a variable speed control of a rotation number thereof including ON and OFF are performed for each of

the compressor inverter 12 and the condenser fan inverter 17. A method for controlling these motors is carried out by the control device 20 and is similar to a known VVVF control technology, or a sensor using vector control technology or sensorless vector control technology. These motors are driven by providing a suitable voltage and a slipping or a synchronous frequency depending on the rotation number of the motors.

Since the rectifier 15 of the condenser fan inverter 17 can respond to various voltages of the AC power supply 22 without using an expensive boost function, it is possible to achieve an inexpensive configuration of performing the voltage feedback control using pulse width modulation in order to use the operation voltage of the condenser fan 18 as a minimum voltage of the AC power supply 22 and respond to other high voltages of the AC power supply 22. A current sensor 47 and a voltage sensor 46 are provided on the condenser fan inverter 17 and can measure the current waveform in a state of being insulated. A signal thereof is inputted to the control device 20 via the input control line 23. The current of the condenser fan inverter 17 and the voltage of the smoothing condenser 16 can be monitored from the control device 20.

From the input control line 23 of the control device 20, inputted are a voltage monitoring signal of a voltage sensor 30 detecting the line voltage of the AC power supply 22, absorbing the changes in the voltage of the AC power supply 22 and causing the control device 20 to perform the voltage feedback control for each of the centrifuge inverter 8, the

compressor inverter 12 and the condenser fan 18, a current monitoring signal of the centrifuge motor current sensor 19 provided in an input unit of the bidirectional converter 4 and detecting the current flowing in the bidirectional converter 4, a current monitoring signal of the compressor motor current sensor 28 provided in an input unit of the unidirectional converter 5 and detecting the current flowing in the unidirectional converter 5 and a signal of the rotation sensor 24 detecting the rotation number of the centrifuge motor 9. The voltage sensor 30 measures the voltages of the AC power supply 22.

The control device 20 is provided with the operating panel 21 for inputting centrifuge operation conditions such as the type, the operating rotation number setting, the operation time setting and the cooling temperature setting of the rotor 31 centrifuging the sample and storing the setting values. The control device is configured to output the distribution parameters of the source current of the AC power supply 22 connected thereto to the operating panel 21, depending on the setting values. Further, the control device 20 can store a supply voltage setting value and the allowable rated current as the parameters. The display contents of the operating panel 21 will be described by referring to FIG. 3

In high-speed refrigerated centrifuge according to the present invention, 200V series are used as an input voltage and the rated supply voltage of the AC power supply 22 varies depending on the country of the destination. For example, in single-phase alternating current, 200V, 208V,

220V, 230V, or 240V is used as the rated supply voltage. Further, in three-phase alternating current, 400V is used as the rated supply voltage. However, in a case of the three-phase alternating current, a voltage between a power ground PE and each line is used as the rated supply voltage. Accordingly, in fact, 230V is used as a voltage between each phase. Typically, range of voltage fluctuation has a lower limit of -15% therefrom and an upper limit of +10% therefrom. Further, there is a need to respond to the supply voltage range of 170V to 264V. For example, rated power supply capacity of the AC power supply 22 on one side is 30A, 24A, 23A, 22A or 21A in single-phase alternating current and 30A or 15A in three-phase alternating current. The power frequency is selected from 50Hz or 60Hz and the characteristics of the AC power supply are not affected due to the difference of the power frequency. However, any one of the power frequency is selectively utilized in other control and thus the power frequency is selected for the present. Such a power parameter is inputted via an operating screen of the operating panel 21 and stored in the control device.

FIG. 3 illustrate a display example of the operating panel 21 in a state where a rated voltage of 200V, a power frequency of 50Hz, a rated current of 30A and a single-phase alternating current condition are set as the power parameters. The rated voltage is listed in Input Voltage section 130, the frequency is listed in Frequency section 131, the number of phase is listed in Phase section 132 and the rated current is listed in Current section 133. By respectively placing a check mark 134 on any one of the

numbers listed in each of the sections and pushing OK button 134, these checked setting values are stored in the control device 20. Herein, the rated voltage is selected depending on the power supply of the destinations. Such a setting operation is carried out by the manufacturer during the factory shipment of the centrifuge, for example. However, such a setting operation may be carried out again in a case where the destination is changed in a relay hub after the product shipment or in a case where a local worker uses a power supply different from the setting power supply during the factory shipment. In this case, the control device 20 determines the distribution ratio of the power to the centrifuge motor 9 and the compressor motor 13 based on the setting rated current.

In this example, a total input power is 6000W as a result of 200V times 30 A and a fixed power consumption of the compressor motor 13 is 2400W. And, the acceleration of the rotor 31 is controlled by a power of 3600W remained after subtracting the fixed power consumption of 2400W from the total input power of 6000W. Accordingly, the power consumption of the centrifuge motor 9 becomes 3600W. The control device 20 controls the centrifuge inverter 8 and the compressor inverter 12 via the output control line 27 so that the passing current of the centrifuge motor current sensor 19 becomes 18 A and the rotation number of the compressor motor 13 becomes 58Hz (which corresponds to 3480min^{-1} as a result of 58Hz times 60) during the acceleration of the centrifuge motor 9. After the stabilized acceleration of the rotor 31, the power consumption of the centrifuge motor 9 decreases. Accordingly, an operation control is

carried out in such a way that the rotation number of the compressor motor 13 is increased to 65Hz and the cooling capacity of the rotor 31 becomes strong.

Herein, the power of 2400W distributed to the compressor motor 13 is a maximum power consumption of the compressor motor 13 when being operated at 58Hz. The rotation number of 58Hz is the rotation number of the compressor motor 13 capable of preventing the rotor 31 being excessively overheated during the acceleration period thereof. The power consumption of the compressor motor 13 increases as the heat absorption of the evaporator 33 increases.

FIG. 4 illustrates an example of the distribution parameters of the AC source current of the centrifuge 1 according to the present embodiment. These distribution parameters are stored in a storage means of the control device 20 in the form of a table, for example, in advance. Herein, a combination of each rated supply voltage/rated power supply capacity and the allowable input power and a distribution parameter corresponding to the combination are included in the table. These indicate the factors of the distribution parameter and determined examples as a result of operating the screen of FIG. 3. The setting conditions in FIG. 3 indicate an example of using the rated current of 30A at the single-phase rated voltage of 200V. In addition to this example, each parameter in a condition for operating the centrifuge under the same noise and cooling condition is stored.

For example, the allowable input power becomes 5040W when the rated voltage of the AC power supply 22 is 240V and the rated current thereof is 21A. At this time, the input power of the centrifuge motor 9 is set as 2640W and the control device 20 outputs a slipping instructions to the centrifuge inverter 8 so that the output of the centrifuge motor current sensor 19 becomes 11.00A . The term numbers of 1 to 6 in FIG. 4 respectively use the rotor 31 of different family and it is difficult to cool the rotor. Accordingly, the rotation number of the condenser fan 18 is set as 54Hz.

In a case where the three-phase rated voltage is 400V (in fact, a voltage between each phase is 230V, as mentioned above) and the rated current is set as 15A/phase (per each one phase) as illustrated in the term number 5, the allowable input power of the centrifuge motor 9 is calculated as 6900W. However, the input power of the centrifuge motor 9 is determined as 3450W because the source rated current of the centrifuge motor current sensor 19 is restricted to 15A. In a case where the rated current is set as 30A/phase (per each one phase) as illustrated in the term number 6, the allowable input power of the centrifuge motor 9 is calculated as 13800W. However, the input power of the centrifuge motor 9 is determined as a maximum of 3900W due to the restriction of the driving torque during acceleration thereof and the source rated current of the centrifuge motor current sensor 19 is restricted to 16.95A. In this way, the rotation numbers of the centrifuge motor 9 and the compressor motor 13 are preset in accordance with the combination of each rated supply

voltage/rated power supply capacity and the allowable input power. Further, the rotation numbers are individually set in during the acceleration of the rotor 31 and after the stabilization thereof.

Of course, it is not necessary that the noise and cooling condition of the centrifuge according to the present invention is limited to the conditions mentioned above. Accordingly, the distribution parameters can be also variously set, regardless of the parameters mentioned above. The centrifuge can be driven in the maximum capacity thereof under various power situations of the AC power supply 22 depending on the setting values.

Meanwhile, when the rotor 31 can be identified, the windage loss, a moment of inertia and a maximum rotation speed (which will be described later) thereof are automatically determined. Accordingly, the identification of the rotor 31 is particularly advantageous for realizing the present embodiment. Such an identification of the rotor 31 may be automatically acquired by a rotor identification device disclosed in JP-A-H11-156245 or an operator may manually set the rotor 31 from the operating panel 21 to identify the rotor.

FIG. 5 is a view illustrating an actual measured example of an operation in which the control device 20 causes a R22A4 type rotor (which has low moment of inertia and is used in the high-speed refrigerated centrifuge commercially available from the present applicant) to be

accelerated at relatively high-speed rotation of a maximum rotation number of 22000min^{-1} and a moment of inertia of $0.0141\text{kg}\cdot\text{m}^2$, to be stabilized at 22000min^{-1} and then to be decelerated, depending on the distribution parameters determined as mentioned above.

The rotation numbers of the rotor 31 and the centrifuge motor 9 are represented by reference numeral 100 (left vertical axis: rotation number (min^{-1}) scale), the rotation number of the compressor motor 13 is represented by reference numeral 101 (right vertical axis: rotation number (Hz) scale), the output of the centrifuge motor current sensor 19 is represented by reference numeral 102 (right vertical axis: current (A) scale), the output of the compressor motor current sensor 28 is represented by reference numeral 103 (right vertical axis: current (A) scale). Reference numeral 104 represents a total current value (right vertical axis: current (A) scale) of the output of the centrifuge motor current sensor 19 and the output of the compressor motor current sensor 28. In this case, the power consumptions of the condenser fan 18, the DC fan 25 and the DC fan 26 is approximately 100 W in total and therefore the total current value 104 is substantially equal to the current consumption of the entire centrifuge.

Until the R22A4 type rotor 31 reaches a stabilized rotation number of 22000min^{-1} in about 41 seconds after the start of acceleration thereof as represented by line 100, the rotation number of the compressor motor 13 is controlled to the rotation number of 58Hz in which the thermal equilibrium

state of the cooled rotor 31 is achieved, as represented by line 101 of the rotation number. At this rotation number of 58Hz, there is no case that the rotor 31 is carelessly warmed during acceleration thereof and also the current consumption of the entire centrifuge which temporarily increases for the acceleration of the rotor 31 can be constantly maintained at a level slightly lower than approximately 30A, as represented by line 104 of the total current value. Until the R22A4 type rotor 31 reaches a stabilized rotation number of 20000min^{-1} after the start of acceleration thereof, the control device 20 outputs a slipping instruction to the centrifuge inverter 8 using the output of the centrifuge motor current sensor 19 as a feedback signal so that the passing current of the centrifuge motor current sensor 19 becomes about 18A and the input power of the centrifuge motor 9 becomes about 3600W, as represented by line 102. Meanwhile, the control device 20 is operated within the setting rated power capacity of about 6000W at the current of about 30A when the input power from the AC power supply 22 is 200V, in conjunction with the maximum input power of the compressor motor 13 of about 12A and the power consumption of about 2400W, as represented by line 103. Accordingly, the centrifuge has exhibited its maximum ability.

At this time, a constant current control method for finely controlling the rotation number of the compressor motor 13 may be carried out so that the passing current of the unidirectional converter 5 becomes a constant current. However, according to this method, it is difficult to stabilize the passing current due to a bad response of the rotation number.

Rather, it is desirable to maintain the rotation number of the compressor motor 13 in a predetermined rotation number, since a constant current characteristic is excellent and an abnormal noise is also not generated.

After R22A4 type rotor reaches a stabilized rotation number of 22000min^{-1} , the rotation number of the compressor motor 13 is increased to 65Hz, for example, to strongly cool the rotor 31. The rotation number of 65Hz is the rotation number of the compressor motor 13 capable of suppressing a noise generated from the compressor 35 below a prescribed noise limit values of the centrifuge, for example, below 58dB. Consequently, it is possible to suitably suppress a noise from the centrifuge 1.

When the R22A4 type rotor is decelerated and stopped at about 36 seconds from the stabilized state of 22000min^{-1} , the output of the centrifuge motor current sensor 19 during deceleration of the rotor 31 becomes minus values, as represented by line 102. Further, electric energy generated during regenerative braking deceleration of the rotor 31 is absorbed to the Ac power supply 22 by the reverse power flow function of the bidirectional converter 4 or absorbed from the unidirectional converter 5 to the compressor motor 13 via the compressor inverter 12 when the compressor motor 13 is operating, as represented by line 104. Accordingly, in the centrifuge 1 according to the present embodiment, there is no need to mount so-called regenerative deceleration discharge resistor thereon. Thereby, the centrifuge 1 can be made in a compact

manner and thus space-saving can be realized. Further, since the operation and cooling of the rotor can be completely independently controlled in an optimal manner and the receiving power factor is high, it is possible to accelerate or decelerate the rotor in a short time while strongly cooling the rotor 31 rotating at high speed. In this way, the power line harmonics can be reduced. The current is temporarily increased immediately before the stop of the rotor 31, as represented by line 102. This is intended to perform DC braking operation for preventing the centrifuged sample from being scattered using a smoothing deceleration.

Typically, the centrifuge is required to respond to a combination with a rotor having a variety of moment of inertia and maximum rotation number. FIG. 6 illustrates the same characteristics as in FIG. 5, in a case where a R10A3 type rotor (which has high moment of inertia and is used in the high-speed refrigerated centrifuge commercially available from the present applicant) is accelerated for about 100 seconds at relatively low-speed rotation of a maximum rotation number of 10000min^{-1} and a moment of inertia of $0.277\text{kg}\cdot\text{m}^2$, stabilized at 10000min^{-1} and then decelerated and stopped in about 90 seconds after the stabilization, using the same control method as in FIG. 5 by the centrifuge according to the present invention. Line 110 (left vertical axis: rotation number (min^{-1}) scale) represents the rotation number of the centrifuge motor 9, line 111 (right vertical axis: rotation number (Hz) scale) represents the rotation number of the compressor motor 13, line 112 (right vertical axis: current

(A) scale) represents the output of the centrifuge motor current sensor 19, and line 113 (right vertical axis: current (A) scale) represents the output of the compressor motor current sensor 28. Line 114 (right vertical axis: current (A) scale) represents a total current value of the output of the centrifuge motor current sensor 19 and the output of the compressor motor current sensor 28.

It is understood that the control device 20 is operated within the setting rated power capacity of about 6000W at the current of about 30A when the input power from the AC power supply 22 is 200V and the centrifuge of the present embodiment has exhibited its maximum ability, regardless of moment of inertia value of the rotor 31. Next, selection and setting in the control of the rotation number of the condenser fan 18 will be described.

Since the control selection range of the rotation number of the condenser fan 18 is ranged from 0Hz to 60Hz and the maximum power consumption thereof is 75W, the power consumption of entire centrifuge is hardly affected by the power consumption of the condenser fan. However, since the increase in the rotation number significantly affects on the noise, it is necessary to suppress the rotation number of the condenser fan as long as the cooling capacity of the rotor 31 can be secured.

FIG. 15 is a graph illustrating the magnitude of a target control temperature and a windage loss of R22A4 type rotor. FIG. 16 is a graph

illustrating the magnitude of a target control temperature and a windage loss of R10A3 type rotor. In FIG. 15, lines 170 to 172 represent target control temperatures of the R22A4 type rotor when being cooled to respective preset temperature and line 173 represents the relationship between the magnitudes of the rotation number and the windage loss of the rotor 31. Herein, the difference of the target control temperature in accordance with the difference of the rotor 31 will be explained when the target control temperature is at 4 °C. As is apparent from the comparison between lines 170 and 173 of FIG. 15 and lines 175 and 178 of FIG. 16, the R22A4 type small-capacity high-speed rotation rotor has a small surface area and heat sources of windage loss thereof are concentrated. Accordingly, a large cooling capacity is required even though the windage loss is small. In contrast, the R10A3 type large-capacity low-speed rotation rotor has a large surface area and heat sources of windage loss thereof are widely spread. Accordingly, only a small cooling capacity is sufficient even though the windage loss is large.

More generally, in large-capacity rotor, a cover member for covering the outer surface of the rotor is required in order to reduce the windage loss and a great wind noise tends to occur due to the deformation of the cover member during rotation of the rotor. From the relationship between the required cooling capacity of the rotor and the noise occurred while considering above factors, the upper limit of the rotation number of the condenser fan 18 is automatically selected and set in accordance with the type of the rotor 31 used in the centrifuge, as illustrated in FIG. 18.

Meanwhile, the R15A type rotor in FIG. 18 is a rotor (which is used in the high-speed refrigerated centrifuge commercially available from the present applicant and has medium moment of inertia) that rotates at relatively low-speed rotation of a maximum rotation number of 15000 min^{-1} and a moment of inertia of $0.1247 \text{ kg}\cdot\text{m}^2$.

Of course, the preset rotation number of the condenser fan 18 significantly affecting on the cooling capacity and the noise may be added to the factors for determining the distribution parameters mentioned above. Alternatively, the rotation number of the condenser fan 18 may be suitably changed by considering the relationship between the required cooling capacity and the rotation number of the compressor motor 13 or the rotation number of the centrifuge motor 9.

Hereinabove, since the configuration of the centrifuge 1 according to the present embodiment does not depend on the supply voltage, there is no need an autotransformer. Further, there is no need to switch a tap matching to the voltage of the destination. In this way, a compact product can be made and thus productivity is improved. Further, since the configuration of the centrifuge does not depend on the supply frequency and the compressor motor and the condenser fan as major noise sources are operated at a suitable rotation number using variable speed control, the centrifuge having excellent sound insulating properties and noise barrier performance can be realized. Further, since the current of the rotor during acceleration is set and stored to be adjusted in accordance with the power

supply capacity of the destination and the centrifuge is controlled to operate at substantially maximum power supply current value based on the adjusted contents, the maximum performance can be always realized in accordance with the power conditions.

<Embodiment 2>

Next, a control for changing the distribution ratio of the power to the centrifuge motor 9 and the compressor motor 13 in accordance with the type of the rotor 31 mounted will be described by referring to FIG. 7. As illustrated in FIG. 7, the type of the rotor 31 and the distribution parameters are stored in a storage device in advance in the form of a table. The control device 20 identifies the type of the rotor 31 mounted and controls the power supply to the centrifuge inverter 8 and the compressor inverter 12 in accordance with the distribution parameters read out from the storage device.

As an example, the control device 20 is operated within the setting rated power capacity of about 6000W at the current of about 30A when the input power from the AC power supply 22 is 200V. In R22A4 type small-capacity high-speed rotation rotor of term number 1, since the acceleration time is short but large cooling capacity is required, the power of the centrifuge motor 9 during acceleration is restricted to approximately 3350W. Meanwhile, the rotation number of the compressor motor 13 is made to a high-speed of 64Hz to secure sufficient cooling capacity.

In R10A3 type large-capacity low-speed rotation rotor of term number 3, since the acceleration time is long but large cooling capacity is not required, the power supply distributed to the centrifuge motor 9 is increased to approximately 3900W to shorten the acceleration time, during the acceleration thereof. Meanwhile, the rotation number of the compressor motor 13 is made to a low-speed of 50Hz to reduce the cooling capacity. Since the rotor of term number 2 is R15A type medium-capacity medium-speed rotation rotor, the rotation number of the compressor motor 13 and the power of the centrifuge motor 9 during acceleration are determined in the middle of term number 1 and 3. Meanwhile, in a case of other power condition where the rated voltage and rated current of the AC power supply 52 are changed, it is preferable that the distribution parameters are determined in advance based on the above ideas and stored in the storage device.

In this way, the distribution parameters are set and stored so that the rotation number of the compressor motor 13 and the power of the centrifuge motor 9 during acceleration can be suitably distributed to match the acceleration time and cooling property of the rotor 31 in accordance with the power supply capacity of the destinations and the type of the rotor 31 mounted. Further, since the centrifuge is controlled to determine the distribution ratio of the power to the centrifuge motor 9 and other motors based on the above contents, the optimal performance can be always realized in accordance with the power conditions.

<Embodiment 3>

Next, a third embodiment of the present invention will be described by referring to FIG. 8. By referring to the block diagram of the centrifuge of FIG. 8, the third embodiment is different from the first embodiment of FIG. 1 in that a three-phase AC power supply is used as a power supply and the power supply line 2 and the power supply line 3 are connected to a different phase of the AC power supply 52. Other parts with same reference numerals are the same as in the block diagram of the first embodiment illustrated in FIG. 1.

When the centrifuge controls the rotor 31 to be stabilized in a predetermined rotation number, the power consumption becomes larger in a case of cooling and keeping the rotor at a temperature of 4 °C, for example. In a case of the centrifuge in which the rotor 31 is rotated in the atmosphere, a normal power consumed at the centrifuge motor 9 is substantially same as the power consumed at the compressor motor 13 and becomes approximately 1kW to 2kW. In this case, a value obtained by multiplying a conversion efficiency of the powers into the driving force to these powers is equal to the windage loss of the rotor 31. Meanwhile, since both the power consumption of the DC power supply 6 and the power consumption of the condenser fan 18 are approximately 50W to 100W, the power consumptions of the supply line 2 and the supply line 3 are substantially same. When these supply lines are connected to different phase of three-phase alternating current of the AC power supply 52, the power consumptions are balanced without being biased. The method for

connecting the supply line 2 and the supply line 3 to the AC power supply 22 as illustrated in FIG. 1 is a versatile connection method since it is very easy to separate the connection therebetween and reconnect as illustrated in FIG. 8 or vice versa.

In the centrifuge according to the third embodiment, the bidirectional converter 4 as a converter of the large-capacity centrifuge motor 9 enhances the power factor of the AC power supply 22 and is boost controlled to be a DC voltage obtained by adding about 10V to the peak voltage of 264V power supply voltage. Since the DC output voltage charged into the smoothing condenser 7 is controlled to a constant voltage of about 385V, the inverter circuit of the centrifuge motor 9 can be stably controlled in response to the fluctuation of the supply voltage of the AC power supply 22. Similarly, the compressor motor 13 has a large capacity. The unidirectional converter 5 supplies power to the compressor motor 13 and can respond to 170V to 264V supply voltage fluctuation or the supply frequency change of between 50Hz and 60Hz. Accordingly, the compressor motor 13 is also controlled in a stable manner.

Of course, the ability to cool a chamber 32 depends on the rotation number of the compressor motor 13 of the compressor 35. In addition, the ability is greatly influenced by the air volume of the condenser fan 18 cooling the condenser 37. In particular, there is a problem that the noise and maximum cooling capacity of the centrifuge are changed in accordance with the supply frequency environment of 50Hz and 60Hz to be used. For

example, in AC fan type condenser fan 18, the air volume per hour is 1800m^3 and the noise level is approximately 50.6dB in the power frequency of 50 Hz, while the air volume per hour is 2040m^3 and the noise level is approximately 54.3dB in the power frequency of 60Hz. That is, the air volume increases by approximately dozen % but the noise level also rises by approximately 3 to 4dB in the power frequency of 60Hz.

Similarly, in the case of AC fan cooling the centrifuge motor 9 or the control box 29, the air volume and the noise level in the power frequency of 60Hz are larger than in the power frequency of 50Hz. In this way, the ability to cool the chamber 32 becomes larger in the condenser fan 18 having the power frequency of 60Hz, as compared to the power frequency of 50Hz. Accordingly, in the power frequency of 50Hz, the maximum cooling ability of the rotation chamber 48 of the centrifuge is small and the noise level thereof is also small. In contrast, in the power frequency of 60Hz, the maximum cooling ability of the rotation chamber 48 of the centrifuge is large but the noise level thereof is also large. The DC voltage of the DC power supply 6 is, for example, 24V and DC 24V is supplied even though the supply voltage varies in a range of 170 V to 264V. Accordingly, the DC fan 25 and the DC fan 26 are maintained in a constant rotation number and the air volume and the wind pressure does not change. In this way, it is possible to cool the centrifuge motor 9 or the control box 29 without depending on the supply voltage and the power frequency and without change in the noise level.

As mentioned above, in the third embodiment, the centrifuge is operated in such a way that the supply voltage and the power frequency are freely selected and the distribution parameters are determined by stored setting results of the connected supply voltage and the allowable rate current. Accordingly, it is not necessary to prepare the autotransformer even though the voltage of AC power supply connected is variously changed and it is possible to eliminate the difference in the cooling ability and the noise level due to the difference of the power frequency of 50Hz and 60Hz. As a result, the centrifuge having optimal maximum cooling ability and noise barrier performance can be realized. Further, not only connection to the single-phase AC power supply and but also connection to the multi-phase power supply can be easily changed. At this time, the multi-phase power supply causes the bidirectional converter 4 of the centrifuge motor 9 and the unidirectional converter 5 of the compressor 13 to be powered by different phases. Accordingly, the current amount used per respective phase can be reduced. As result, the operation of the centrifuge becomes possible, even though the source impedance of the AC power supply is high.

<Embodiment 4>

Next, an operation for controlling the temperature of the rotor 31 of the centrifuge 1 will be described. In this operation, the temperature of the rotor 31 is rapidly approached to a target preset temperature regardless of the magnitude of the windage loss of the rotor 31 and then the temperature of the rotor is controlled with a high precision.

In a related-art temperature control method, since the temperature of the chamber 32 is detected by the temperature sensor 40b and the compressor motor 13 is subjected to an intermittent control (ON-OFF control), the overshoot and undershoot are repeatedly generated when the temperature of the sample in the rotor 31 is controlled to a desired target temperature and thus the pulsation to the surface temperature of the rotor 31 side of the chamber 32 occurs. Meanwhile, a temperature correction value is calculated in advance by an experiment, etc., and corresponds to the difference between the target temperature (target control temperature) of the temperature sensor 40b during the rotation of the rotor 31 and the temperature of the sample in the rotor 31. In order to compensate for errors occurring in such a temperature control, the temperature correction value is utilized to realize high precision. However, in ON-OFF control of a related-art compressor 35, the noise generated during ON-OFF switching and the instantaneous voltage drop of the AC power supply 22 are accompanied and, in addition to this, the temperature of the rotor 31 is controlled while the temperature in the chamber 32 is being pulsated. Accordingly, further high-precision temperature control for overcoming the temperature fluctuation width was a challenge for many years. As a means for detecting the temperature of the rotor 31, a radiation thermometer is provided in the rotation chamber 48 of the rotor 31. The radiation thermometer is configured to directly measure the temperature of the bottom surface of the rotor 31. The temperature thus measured is used as the target control temperature to control and maintain the rotor 31 at a desired temperature. However, in the embodiment of the present

invention, a method indirectly measuring the temperature of the chamber 32 by the temperature sensors 40a, 40b such as a thermistor will be described below.

In the temperature correction value, the occurring amount due to the windage loss and the amount of heat exchange between the chamber 32 and the rotor 31 are changed depending on the type/shape of the rotor, in addition to the operating rotation number of the rotor 31 and the maintaining temperature of the sample. Accordingly, the temperature correction value is determined in advance in accordance with the type of the rotor/the operating rotation number of the rotor/the maintaining temperature of the sample and stored in the operating panel 21 or the control device 20. Further, the temperature correction value which was in the operation and temperature control condition other than the type of the rotor 31 is utilized in order to improve the accuracy of the temperature control.

Recently, in consumer equipments such as an air conditioner or a refrigerator, a technology in which the compressor motor 13 of a cooling machine is driven by the compressor inverter 12 in a variable-speed has been widely developed and considered to be applied in the field of the centrifuge. However, in the centrifuge, the maintaining temperature of the sample is in a wide range from -20 °C to 40 °C and the windage loss is largely varied in a range from several hundreds of W to 2kW depending on the rotation number or the type of the rotor. For this reason, a

temperature control technology completely different from the consumer equipments is required in a case of being applied to an inverter type cooling machine. Now, the type, a relationship among the rotation number and the windage loss of the rotor will be described by referring to FIG. 15 and FIG. 16. FIG. 15 is a view illustrating a relationship between the target control temperature of the temperature sensor 40a and the windage loss of the rotor at respective rotation number of the R20A4 type rotor in the centrifuge commercially available from Hitachi Koki Co., Ltd. Horizontal axis indicates the rotation number (min^{-1}) of the rotor 31. Herein, the windage loss (unit: W) 173 of the rotor 31 corresponds to the right vertical axis and the windage loss of the rotor 31 is substantially proportional to the rotation number thereof. The windage loss of the rotor is proportional to nearly 2.8 square of the rotation number of the rotor 31 in an approximation expression.

Even if the inverter type cooling machine is employed and a so-called temperature feedback PID control method is employed, the amount of heat generation of the rotor is greatly varied depending on the operating conditions, as mentioned above. Herein, the temperature feedback PID control method includes a proportional term, an integration term and a differential term and uses the difference between the detected temperature of the temperature sensor 10a and setting target temperature. The relationship between the rotation number and the target control temperature of the rotor 31 is indicated by 170 to 172. Herein, 170 indicates a curve of target control temperature in a case of cooling the rotor

31 to 20 °C, 171 indicates a curve of target control temperature in a case of cooling the rotor to 10 °C and 172 indicates a curve of target control temperature in a case of cooling the rotor to 4 °C. As is apparent from the curves 170 to 172, the windage loss of the rotor increases as the rotation number of the rotor 31 rises and thus it is desirable to set the target control temperature to a small value. As such, PID control parameters distributed to the proportional term, the integration term and the differential term have optimal values which are greatly varied depending on the temperature control conditions. Accordingly, it is difficult to uniformly determine a proper value of the PID control parameters. For this reason, hunting of the control temperature is likely to occur when only PID control for the rotation number of the compressor motor 13 is performed and thus further improvements in the accuracy of control temperature cannot be expected. Accordingly, it is required to improve the temperature control accuracy by suppressing an undesirable temperature difference between the upper and lower rotor temperature.

Accordingly, in the fourth embodiment, the control device 20 feeds back the detected temperature of the temperature sensor 40a provided on the bottom of the chamber 32 and controls the rotation number of the compressor motor 13 in the compressor 35 so as to allow the sample in the rotor 31 to be a setting target temperature. The rotation number of the condenser fan 18 configured to send wind for heat dissipation of the condenser 37 is controlled to 50Hz as mentioned above.

FIG. 16 is a view illustrating a relationship between the target control temperature of the temperature sensor 40a and the windage loss of the rotor at respective rotation number of the R10A3 type rotor commercially available from the present applicant. The R10A3 type rotor is large and a rotor diameter thereof is large, as compared to the R20A4 type rotor. Accordingly, the degree rise of the windage loss (unit: W) 178 of the rotor 31 due to the rise of the rotation number becomes larger than the windage loss 173 of FIG. 15. However, since the surface area of the R10A3 type rotor is larger than that of the R20A4 type rotor, cooling effect thereof is superior to the R20A4 type rotor owing to cooling of the chamber 32. Accordingly, the relationship between the rotation number and the target control temperature of the rotor 31 is indicated by 175 to 177. Herein, 175 indicates a curve of target control temperature in a case of cooling the rotor 31 to 20 °C, 176 indicates a curve of target control temperature in a case of cooling the rotor to 10 °C and 177 indicates a curve of target control temperature in a case of cooling the rotor to 4 °C. As is apparent from the curves 175 to 177 of target control temperature, the windage loss of the rotor increases as the rotation number of the rotor rises and thus the target control temperature is set to a small value.

FIG. 9 illustrates the rotation number (unit: Hz) 150 of the compressor motor 13, the measured temperature (unit: °C) 151 of the temperature sensor 40a and the bottom temperature (unit: °C) 152 of the rotor 31 when the R22A4 type rotor as the rotor 31 is rotated in a rotation number of 22000min^{-1} and the temperature of the sample is controlled to 4

°C in the centrifuge 1 according to the present embodiment. Horizontal axis thereof indicates lapse time after the rotation of the rotor 31.

In this rotor, the target control temperature for cooling the rotor 31 rotating in the rotation number of 22000min^{-1} to 4 °C is set as -12.7 °C, as illustrated by line 172 of FIG. 15. The control rotation number of the compressor motor 13 at this time is set as 58Hz in the acceleration stage of the rotor 31 and set as 65Hz after the rotor 31 is stabilized at the rotation number of 22000min^{-1} , as indicated in the vicinity of 0 to 500 seconds of FIG. 9. By controlling in this way, the detected temperature of the temperature sensor 40a is dropped over time and reaches -12.2 °C in the vicinity of 650 seconds, which is higher than the target control temperature by 0.5 °C. In this way, PID control for controlling the rotation number of the compressor motor 13 by PID calculation using the detected temperature of the temperature sensor 40a and the target control temperature is started. Initial value of I (integration term) at the start of the PID control of FIG. 17 can be determined by a temperature-time change rate (°C/sec) in which an measured temperature value of the temperature sensor 40a is reduced during two minutes immediate before migration to PID control, for example.

For example, since the temperature-time change rate (°C/sec) is approximately 1.2 °C for two minutes in FIG. 17, 50Hz is supplied as an initial value of I term at the PID control. Herein, the sum of P, I and D at the PID control is used as a compressor frequency. In this case, although

new values are determined as P and D at each operation, I is integrated along the time axis and therefore. Accordingly, an effect such as a control offset at a later is exhibited if I is supplied as an initial value in advance. By these control operations, the rotation number of the compressor motor 13 during migration to PID control is maintained at a high level and the temperature of the temperature sensor 40a approaches to the control target temperature in a rapid and smooth manner. The reason is that the cooling speed of the rotor 31 becomes faster and thus I during migration to PID control is set to a small value in a case where the temperature-time change rate becomes larger and I during migration to PID control is set to a large value in a case where the temperature-time change rate becomes smaller. In this way, it is possible to give an inflection point in the control of the rotation number of the compressor motor 13, thereby rapidly approaching the temperature of the temperature sensor 40a to the control target temperature, in both cases.

By these control operations, the calculated rotation number of the compressor motor 13 obtained by PID calculation is finally stabilized to the rotation number of approximately 48Hz although several overshoot/undershoot of the rotation number is essentially involved. Thereafter, the rotation number of the compressor motor is stably controlled. During this time, the bottom temperature 152 of the rotor 31 which is substantially equal to the temperature of the sample of the rotor 31 is smoothly dropped from 26 °C at the start of the control over time and maintained exactly at 4 °C.

FIG. 10 illustrates a relationship among the rotation number (unit: Hz) 153 of the compressor motor 13, the bottom temperature (unit: °C) 155 of the rotor 31 and the measured temperature (unit: °C) 154 of a temperature sensor 40b over time when the R22A4 type rotor is rotated in a rotation number of 22000min^{-1} and the temperature of the sample is cooled to 4 °C in a related-art centrifuge. Unlike the present embodiment of FIG. 9, the temperature sensor 40b provided in the seal rubber 41 is used to carry out the temperature control in the related-art centrifuge, instead of the temperature sensor 40a. This example is the same as the actual measured example illustrated in FIG. 9, except that the cooling target temperature of the temperature sensor 40b is changed from -12.7 °C of FIG. 9 from -7 °C owing to the difference of the temperature control target.

As is apparent from FIG. 10, since the control rotation number of the related-art compressor motor 13 is not stably converged over time due to the repetition of overshoot and undershoot, the noise occurred from the compressor motor 13 is fluctuated and the bottom temperature of the rotor 31 is continuously pulsated and thus the temperature control accuracy is degraded. The reason is that the response property such as the time lag in the temperature change of the evaporator 33 and the time constant relative to the change of the rotation number of the compressor motor 13 is poor because the temperature sensor 40b is covered with the seal rubber 41. Accordingly, it is desirable to use the temperature sensor 40a illustrated in FIG. 9 in order to carry out the temperature control according to the present

embodiment, instead of using the temperature sensor 40b illustrated in FIG. 10. The reason is that the response property relative to the temperature change of the evaporator 33 is good because the temperature sensor 40a is provided in contact with the metal part of the chamber 32.

FIG. 11 illustrates a relationship among the rotation number (unit: Hz) 156 of the compressor motor 13, the measured temperature (unit: °C) 157 of the temperature sensor 40a and the bottom temperature (unit: °C) 158 of the rotor 31 over time when the R22A4 type rotor as the rotor 31 is rotated in a rotation number of 10000min^{-1} and the temperature of the sample in the rotor 31 is controlled to 4 °C in the centrifuge 1. The bottom temperature of the rotor is substantially equal to the temperature of the sample of the rotor 31. Under this condition, the windage loss of the rotor 31 corresponds to 11% of a case explained in FIG. 9 and is less than 100W. When the rotation number 156 corresponding to the measured temperature 157 is less than the minimum rotation number (for example, 15Hz in the present embodiment) in accordance with the temperature control operations, the rotation number control of the compressor motor 13 is switched from PID continuous rotation number control to ON state of 20Hz and OFF state. Normally, in the compressor motor 13, a maximum rotation number (maximum continuous rotation number) and a minimum rotation number (minimum continuous rotation number) which can be continuously performed are set in consideration of the relationship between rated voltage and stability. Herein, the continuous rotation number during intermittent control is set as 20 Hz which is higher than the minimum

continuous rotation number of the compressor motor 13. In the present invention, respective rotation number of the compressor motor 13 during ON-OFF control, that is, a start-stop rotation number is 20Hz in ON state and 0 (zero) Hz in OFF state.

Since the minimum rotation number which can be continuously performed are set as 15Hz which is lower than the rotation number (20Hz) during ON time in the ON-OFF control, it is possible to achieve an excellent temperature control property, even when the range of heat absorption between the minimum continuous rotation number control and the ON-OFF intermittent control is overlapped and the control state is switched between the continuous rotation number control at a lower speed and the ON-OFF intermittent control. Although the measured temperature 157 of the temperature sensor 40a is slightly pulsated in accordance with the repetitive controls of ON and OFF states of the compressor motor 13, it is understood that the bottom temperature 158 of the rotor 31 is not changed and thus the temperature control can be carried out in a stable and accuracy manner.

The target control temperature of the temperature sensor 40a is approximately -1 °C and the rotation number of the compressor motor 13 is initially 65Hz in the vicinity of the 100 seconds to 300 seconds at the start of the temperature control. When the temperature of the temperature sensor 40a is changed to -0.5 °C by the PID control, the rotation number is controlled to be continuously lowered. However, since the measured

temperature 157 of the temperature sensor 40a is further dropped when the compressor motor 13 is continuously operated even at a minimum continuous rotation number of 15Hz, the compressor motor 13 is turned off when the target control temperature is dropped to -3 °C lower than approximately -1 °C by -2 °C and ON-OFF control of the compressor motor 13 is performed. Furthermore, when the measured temperature 157 of the temperature sensor 40a is switched to rise and becomes 0 °C higher than the target control temperature by 1 °C, the compressor motor 13 is turned on again. In this ON-OFF control, OFF state is switched to ON state when the measured temperature is higher than the target control temperature by +1 °C whereas ON state is switched to OFF state when the measured temperature is lower than the target control temperature -1 °C. OFF state is ensured for minimum of 60 seconds (minimum OFF time) when OFF state is switched to ON state and ON state whereas ON state is ensured for minimum of 30 seconds (minimum ON time) when ON state is switched to OFF state. The reason is that ON state is required when the pressure difference between the suction pipe 42 and the discharge pipe 36 is smaller than a predetermined value and OFF state is required when the pressure difference is larger than the predetermined value, in consideration of oil lubrication of the compressor 35.

FIG. 12 illustrates a relationship among the rotation number (unit: Hz) 159 of the compressor motor 13, the measured temperature (unit: °C) 160 of the temperature sensor 40a and the bottom temperature (unit: °C) 161 of the rotor 31 over time when the R10A3 type rotor as the rotor 31 is

rotated in a rotation number of 7800 min^{-1} and the temperature of the sample in the rotor 31 is controlled to 4°C in the centrifuge 1. The bottom temperature of the rotor is substantially equal to the temperature of the sample of the rotor 31. The target temperature of the control temperature sensor 40a is approximately -2°C . Under this condition, the windage loss of the rotor 31 is approximately 630 W and the rotation number of the compressor motor 13 is controlled to a continuous rotation number which is slightly larger than the lower limit value (that is, 15Hz) of the continuous control rotation number in accordance with the temperature control operations, as illustrated by the rotation number 159 of the compressor motor 13. Since this rotation number is lower than the rotation number (20Hz) during ON time in the ON-OFF control of FIG. 9, it is possible to improve the controllability in a region between the continuous rotation number control at a lower speed and the ON-OFF control, in which the range of heat absorption between the continuous rotation number control at a lower speed and the ON-OFF control at 20 Hz is overlapped.

FIG. 13 is a view illustrating an actual measured example of the temperature control of the centrifuge 1 in such a way of rotating R22A4 type rotor at the rotation number of 10000 min^{-1} , cooling and maintaining the temperature of a sample at 4°C , and then changing the rotation number to 12000 min^{-1} at this state. In contrary to FIG. 11, the control of the rotation number (unit: Hz) 163 of the compressor motor 13 is changed from the ON-OFF control of 20 Hz to the PID continuous rotation number

control in accordance with the temperature control operations, as illustrated by the rotation number (unit: Hz) 162 of the compressor motor 13. The target control temperature of the temperature sensor 40a is initially approximately -1 °C and becomes approximately -2 °C after the setting change of the rotation number. Similar to FIG. 11, the rotation number 162 of the compressor motor 13 is set as 65Hz at 0 to 200 seconds at the start of the temperature control and continuously lowered to 15Hz by a continuous rotation number control using the PID control. After that, the ON-OFF control is performed.

Thereafter, if the rotation number of the rotor 31 increases from 10000min^{-1} to 12000min^{-1} at the change timing of preset rotation number 174 in the vicinity of approximately 2000 seconds, the windage loss of the rotor 31 slightly increases. Accordingly, a state where the detected temperature of the temperature sensor 40a is larger than new target control temperature of -2 °C by 0.5 °C is continued over 180 seconds when the rotation number of the compressor motor 13 is in a state of ON state at 25Hz. In this way, the control device 20 causes the compressor motor 13 to be subjected to the continuous rotation number control using the PID control. The control situation after that is same as in FIG. 12.

The initial rotation number 162 of the compressor motor 13 after migration to the PID control of continuous rotation becomes 30 Hz in the vicinity of approximately 1900 seconds to 2300 seconds. As the PID control starts, the temperature of the rotor 31 is prevented from being

excessively dropped due to excessive rotation number. This relationship is summarized in FIG. 14. Specifically, when the target control temperature and the detected temperature of the temperature sensor 40a are close to each other within a predetermined range in several times, the initial rotation number of the compressor motor 13 at the start of the PID control is set to be changed again as a rotation number which is calculated by multiplying a coefficient obtained from the ratio of a preset rotation number to a settable maximum rotation number of the rotor 31, to a predetermined maximum continuous rotation number of the compressor motor 13. When the ratio (%) of the preset rotation number to the maximum rotation number of the rotor 31 is equal or less than 65%, the rotation number (Hz) of the compressor motor 13 is set as 30 Hz as a whole. For example, when the rotor 31 has a maximum rotation number of 22000 rpm and a preset rotation number of 12000 rpm, the ratio of the preset rotation number to the maximum rotation number of the rotor 31 is 54.5%. That is, this ratio is less than 65% and therefore the initial rotation number of the compressor motor 13 at the start of the PID control is set as 30 Hz, as illustrated in FIG. 14.

Herein, the initial rotation number of the compressor motor 13 is dependent from the windage loss of the rotor 31 at the start of the PID control. Accordingly, first, the amount of heat generation of the rotor is calculated from the windage loss coefficient of the rotor group registered in advance and the rotating speed of the rotor 31 during operation and used as a coefficient. And then, the rotation number of the compressor motor

may be reset by multiplying the coefficient to the maximum continuous rotation number of the compressor motor 13.

<Embodiment 5>

Next, a relationship between the rotation number of the rotor and the rotation number of the compressor motor 13 when the operation of the centrifuge 1 is started, the rotation number of the rotor rises and is stabilized at a preset rotation number will be described by referring to FIG. 19. The horizontal axes in (1) and (2) of FIG. 19 are same time axis and described side by side. In operation, the rotor 31 is placed into the rotation chamber 48 and a door 43 is closed. Thereafter, the preset rotation number of the centrifuge is set to 22000 rpm by the operating panel 21 and then the centrifuging time and preset temperature are set. In this way, the operation of the centrifuge is started at time t11. Then, with the rise of the rotation number of the centrifuge motor 9, a motor current 211 rises, as illustrated the rotation number 201 in FIG. 19 (1). The acceleration ends at time t3 and the stabilization state (a state where the rotor 31 is driven in a constant speed operation at the preset rotation number) is achieved. In FIG. 19 (1), the operation state of the centrifuge motor 9 is illustrated by three states of "stop," "acceleration" and "stabilization."

Herein, since the centrifuge motor 9 is an electric motor, there is a characteristic that the current during start-up and acceleration thereof becomes larger than the current during stabilization. Even under such circumstances, in order to short the acceleration time and thus achieve the

stabilization state as soon as possible, it is desirable to allocate a lot of power to the centrifuge motor 9 by reducing the maximum power allocated to the compressor motor 13 and increasing the power allocated to the centrifuge motor 9 by just that. Meanwhile, the reduction of the power allocation to the centrifuge motor 9 means that the rotation number of the compressor motor 13 may not reach a desired rotation number. For example, even in a case where it is intended to rapidly cool the interior of the rotation chamber 48 by increasing the compressor motor 13 to a maximum continuous rotation number (for example, 85Hz), there is a case where the increase in the rotation number may be restricted due to the power supply capacity of the connection power. In the present embodiment, the ratio of the power allocation to the compressor motor 13 during acceleration and stabilization of the centrifuge motor 9 is changed. For example, a lot of power is allocated to the centrifuge motor 9 by restricting the upper limit of the rotation number of the compressor motor 13 to 58Hz when the centrifuge motor is accelerated. Further, the upper limit of the rotation number of the compressor motor 13 is set to 67Hz by degrading the power allocation to the centrifuge motor 9 when the centrifuge motor is stabilized. Here, since 58Hz and 67Hz are values set by the power supply capacity of the connection power, the upper limit of the rotation number of the compressor motor 13 is changed depending on the power supply capacity.

In this way, in the present embodiment, a ratio between the power allocation to an inverter control type cooling machine and the power

allocation to the centrifuge motor 9 is changed during acceleration and stabilization of the rotor 31. By configuring in this way, the power allocation (maximum distribution power) to the centrifuge motor 9 during acceleration of the rotor increases and thus the acceleration is early terminated and further, the power allocation (maximum distribution power) to the centrifuge motor 9 during stabilization of the rotor is reduced and the power allocation (maximum distribution power) to the compressor motor 13 increases by just that. Accordingly, it is possible to desirably cool the interior of the rotation chamber 48.

In FIG. 19 (2), when the rotor 31 becomes the stabilized state at time t_3 , the control device 20 raises the rotation number of the compressor motor 13 from 58Hz to 67Hz and thus is in a normal operation state of 67Hz at time t_4 . Thereafter, when the compressor motor 13 is continuously operated at 67Hz and thus the interior of the rotation chamber 48 is sufficiently cooled, the rotation number of the compressor motor 13 is gradually dropped at time t_5 by PID control and thus the rotation chamber 48 is controlled to maintain the target temperature thereof. In the example of FIG. 19, the rotation number of the compressor motor is maintained slightly above 58Hz after time t_5 . However, the rotation number of the compressor motor 13 after a sufficient time has lapsed from stabilization varies depending on the type, the preset temperature and the rotation number of the rotor. Further, when the target temperature of the rotation chamber 48 is high, the rotation number of the compressor motor 13 after a sufficient time has lapsed from stabilization may be dropped near

a minimum continuous rotation number or less. When the preset rotation number of the compressor motor 13 is less than the minimum continuous rotation number, the intermittent ON-OFF operation of the compressor motor 13 is carried out by PID control.

According to the fifth embodiment as described above, the power allocation (maximum distribution power) to the centrifuge motor 9 and to the compressor motor 13 is controlled to be changed during acceleration and stabilization of the rotor. Accordingly, the rotor 31 can be securely cooled in such a way that the power allocation to the centrifuge motor 9 increases to rapidly accelerate the rotor during the acceleration and the power allocation to the centrifuge motor 9 is reduced during the stabilization (steady rotation), as compared to the case of the acceleration. Meanwhile, in the fifth embodiment, the maximum power allocated to the compressor motor during the acceleration from time t_1 to t_3 is limited by the rotation number of 58Hz of the compressor motor 13. However, instead of fixing the maximum power to the limited amount, the period is subdivided into two periods, that is, the front half period and rear half period of the acceleration or more finely subdivided so that the ratio of the power allocation to the centrifuge motor 9 and the compressor motor 13 can be finely controlled to be changed in each period. Even in this case, it is desirable that the power allocation to the centrifuge motor 9 immediately after the stabilization is smaller than the power allocation to the centrifuge motor 9 at last period during the acceleration.

<Embodiment 6>

Next, the sixth embodiment of the present invention will be described by referring to FIG. 20. The fifth embodiment has a configuration in which the allocation of power to the centrifuge motor 9 during the acceleration and stabilization is changed, that is, the power allocation can be changed in two stages. In contrast, the sixth embodiment has a characteristic configuration in which the ratio of the power allocation can be continuously changed depending on the value of the current used in the centrifuge motor 9. FIG. 20 (1) illustrates the value (unit: A) of current flowing through the centrifuge motor when leading from acceleration time to stabilization time of the rotor 31. In operation, the rotor 31 is placed into the rotation chamber 48 and a door 43 is closed. Thereafter, the preset rotation number of the centrifuge is set to 22000 rpm by the operating panel 21 and then the centrifuging time and preset temperature are set. In this way, the operation of the centrifuge is started at time t11. Then, with the rise of the rotation number of the centrifuge motor 9, a motor current 211 rises as illustrated. The rise of the motor current 211 is made non-uniform depending on the type of the rotor or the control method used. However, since the centrifuge motor 9 of the present embodiment is driven by the centrifuge inverter 8, the motor current rises to near 4A immediately after time t11, and then rises almost linearly as in arrow 211a, and then rises to about 13A in the vicinity of arrow 211b. Herein, since the maximum distribution power (upper limit) of the motor current 211 during acceleration depending on the power supply capacity is 13A, the acceleration is continued in a state of being kept in the upper limit current. In this way, since the rotation number of

the centrifuge motor 9 reaches the preset rotation number 22000 rpm at time t13, the operation is transited to a constant speed operation. Then, the current of the centrifuge motor 9 is dropped to about 7.5A.

FIG. 20 (2) is a graph illustrating the change in the rotation number 212 of the compressor motor 13. The horizontal axes in (1) and (2) of FIG. 20 are same time axis and described side by side. In the sixth embodiment, (the power consumption of the centrifuge motor 9 + the power consumption of the compressor motor 13) at each time is controlled so that it falls within the range of the power consumption allocated to the centrifuge motor 9 and the compressor motor 13 in the total power supply capacity. Thereby, the microcomputer included in the control device 20 is configured to set the rotation number 212 of the compressor motor 13 depending on the current value (output of the current sensor 19 in FIG. 2) of the centrifuge motor 9. The rotation number 212 in FIG. 20 (2) greatly rises after the start at time t11 and then rises greater than the upper limit of the centrifuge motor 9 of 67Hz during the constant speed rotation (after time t13). However, since the total of the power consumptions of the centrifuge motor 9 and the compressor motor 13 reaches the upper limit of the allocated power value at arrow 212a and the power consumption of the centrifuge motor 9 tends to rise further, the rotation number 212 is reduced as in arrow 212b in order to drop the power consumption of the compressor motor 13 by just that.

Since the power consumption of the centrifuge motor 9 is

significantly degraded immediately before the end of the acceleration time, that is, just before time t13 (in the vicinity of several hundreds of rotation) as illustrated by arrow 211c, the rotation number of the compressor motor 13 is raised by the degraded amount as illustrated in arrow 212d and finally stabilized in the vicinity of 67Hz as illustrated by arrow 212e. Meanwhile, the rotation number 67Hz of the compressor motor 13 corresponds to a preset rotation number when the temperature of the rotation chamber 48 is intended to be maximally cooled in a range of allocated maximum distribution power in an initial stage of the centrifuging operation. If the temperature of the rotation chamber 48 is dropped to a target temperature once, it is sufficient to maintain the target temperature. Accordingly, it is possible to significantly drop the rotation number of the compressor motor 13. In this way, PID control is carried out in the control after time t15 and thus the rotation number of the compressor motor 13 is controlled to a lower rotation.

Hereinabove, although the present invention has been specifically described based on respective embodiment, the present invention is not limited to the above embodiment. For example, the present invention can be variously modified without departing from the gist of the present invention.

This application claims priority from Japanese Patent Application No. 2011-091600 filed on April 15, 2011, and from Japanese Patent Application No. 2012-047417 filed on March 2, 2012, the entire contents

of which are incorporated herein by reference.

Industrial Applicability

According to an aspect of the invention, there is provided a centrifuge in which there is no need to mount an autotransformer in view of the voltage situation of the worldwide destination and which can easily deal with the difference in the power supply capacity.

According to another aspect of the invention, there is provided a compact and low noise centrifuge which is capable of extremely suppressing decline of cooling capacity or noise rise even when the power frequency of power supply is different and does not incorporate extra sound insulating material and noise barrier material.

According to another aspect of the invention, there is provided a centrifuge capable of achieving high-precision temperature control accuracy even in a region where the windage loss of the rotor is small.

Claims

What is claimed is:

1. A centrifuge comprising:

a rotor configured to hold a sample and configured to be detachably mounted,

a rotation chamber accommodating the rotor,

a plurality of motors configured to be rotationally driven by three-phase AC power, and

a control device configured to control centrifuging operation,

wherein one of the plurality of motors is a centrifuge motor configured to rotate the rotor, and

the control device is configured to change distribution of power supplied to the centrifuge motor and power supplied to another motor of the plurality of motors during one operation.

2. The centrifuge according to claim 1, further comprising an inverter control type cooling machine,

wherein the control device is configured to control a maximum distribution power supplied to the motor during a rotation acceleration of the rotor and a maximum distribution power supplied to the motor during a rotation stabilization of the rotor to be different from each other.

3. The centrifuge according to claim 2,

wherein the control device is configured to allocate a predetermined power to the cooling machine during the rotation acceleration of the rotor.

4. The centrifuge according to any one of claims 1 to 3,
wherein the control device is configured to change a distribution ratio of the power supplied to the motors, depending on the type of the rotor mounted or a power supply capacity of the connection power.
5. The centrifuge according to any one of claims 1 to 4, further comprising:
a converter configured to convert the AC power into DC power;
a first inverter configured to convert DC output of the converter into AC power to supply the converted AC power to the centrifuge motor;
and
a second inverter configured to convert DC output of the converter into AC power to supply the converted AC power to the other motor,
wherein the control device is configured to change the distribution ratio by adjusting an amount of power supplied from the first and second inverters.
6. The centrifuge according to claim 5,
wherein the distribution ratio of the power supplied to the centrifuge motor and the power supplied to the other motor of the plurality of motors is set in advance for each type of the rotor and stored in a storage device of the control device.
7. The centrifuge according to claim 1, further comprising:

a cooling device configured to cool the rotation chamber;
a converter configured to convert the AC power into DC power,
a first inverter configured to convert DC output of the converter into AC power to supply the converted AC power to the centrifuge motor,
and

a second inverter configured to convert DC output of the converter into AC power to supply the converted AC power to the other motor,

wherein the cooling device includes a compressor motor which is configured to be controlled in a variable speed by the converted AC power supplied from the second inverter, and

a distribution ratio of the power supplied to the centrifuge motor and the power supplied to the compressor is changed depending on the type of the rotor.

8. The centrifuge according to claim 7,

wherein the boost converter has a function of converting the AC power supply into DC power and a function of converting the DC power supplied from the first inverter into AC power to return the converted AC power to the AC power supply.

9. The centrifuge according to claim 8,

wherein the other motor includes a condenser fan which is configured to send wind to a condenser for cooling a refrigerant in the cooling device, and

the control device is configured to carry out the feedback controls

of each of the centrifuge motor, the compressor motor and the condenser fan.

10. The centrifuge according to claim 9, further comprising a third inverter configured to convert the DC power from the boost converter into AC power in order to control the condenser fan in a variable speed.

11. The centrifuge according to claim 9,
wherein the rotation number of the condenser fan during the variable speed control is changed depending on the type of the rotor mounted.

12. A centrifuge comprising:
first and second converters for converting AC power supplied from an AC power supply into DC power,

a centrifuge inverter connected to the first converter,

a centrifuge motor configured to be controlled in a variable speed by an output of the centrifuge inverter,

a rotor configured to be driven by the centrifuge motor and configured to centrifuge a sample,

a chamber housing the rotor therein,

an evaporator configured to cool the chamber,

a compressor configured to compress a refrigerant to supply the compressed refrigerant in a circulation manner to the evaporator,

a compressor inverter connected to the second converter,

a compressor motor configured to be controlled in a variable speed by the output of the compressor inverter and configured to drive the compressor, and

a control device configured to control these components,

wherein the control device is configured to carry out the feedback controls of the centrifuge motor and the compressor motor and is configured to control the rotation number of the compressor motor depending on a distribution parameter of power allocated to the centrifuge motor and the compressor motor, which are set in advance during the acceleration of the rotor.

13. The centrifuge according to claim 12,

wherein the control device is configured to change the distribution parameter of power allocated to the centrifuge motor and the compressor motor between an acceleration rotation of the rotor and a steady rotation of the rotor.

14. The centrifuge according to claim 13,

wherein the distribution parameters are set in advance for each type of the rotor and stored in a storage device of the control device, and

the control device is configured to identify the type of the rotor mounted and carry out the control in accordance with the distribution parameter stored in the storage device.

15. The centrifuge according to claim 14,

wherein the first boost converter is a bidirectional converter which is configured to convert DC power supplied from the centrifuge inverter into converted AC power to regenerate the power to AC power supply, in addition to the function of converting the AC power into the DC power.

16. The centrifuge according to any one of claims 12 to 15,

wherein, during the acceleration of the rotor, the control device is configured to control a rotation number of the compressor motor to a rotation number that is substantially same as a rotation number by which the rotor can be maintained in a thermal equilibrium state at a preset temperature.

17. The centrifuge according to claim 16,

wherein after the acceleration of the rotor ends and the rotor transits to a constant speed rotation, the control device is configured to control the rotation number of the compressor motor to be higher than a rotation number which is required for cooling and holding the rotor to a target temperature.

18. A centrifuge comprising:

a rotation chamber accommodating a rotor which is configured to hold a sample,

a centrifuge motor configured to rotationally drive the rotor,

an inverter control type cooling machine configured to cool the rotation chamber and

a control device configured to control the operation of the centrifuge motor and the cooling machine,

wherein the control device is configured to control a maximum distribution power allocated to the cooling machine during rotational acceleration of the rotor to be different from a maximum distribution power allocated to the cooling machine during rotational stabilization of the rotor.

19. The centrifuge according to claim 17,

wherein the maximum distribution power allocated to the cooling machine during rotational acceleration of the rotor is smaller than the maximum distribution power allocated to the cooling machine during rotational stabilization of the rotor.

20. The centrifuge according to claim 17 or 18,

wherein the cooling machine includes a compressor motor configured to be controlled in a variable speed,

an upper limit of a rotational frequency of the compressor motor is set to a lower value during the rotational acceleration and set to a higher value during the rotational stabilization, and

the control device is configured to allow the compressor motor to operate within a range of the set upper limit.

21. The centrifuge according to claim 17 or 18,

wherein the control device is configured to control the rotation of the compressor motor to be subjected to PID control or ON-OFF control

during the rotational stabilization of the rotor.

22. The centrifuge according to claim 18,

wherein the maximum distribution power allocated to the cooling machine during the rotational acceleration and the rotational stabilization of the rotor is set in accordance with the type of the rotor mounted.

23. A centrifuge comprising:

a rotation chamber accommodating a rotor which is configured to hold a sample and is configured to be detachably mounted,

a centrifuge motor configured to rotationally drive the rotor,

a cooling machine configured to cool the rotation chamber, and

a control device configured to control the operation of the centrifuge motor and the cooling machine,

wherein the cooling machine includes an inverter control type compressor motor, and

the control device is configured to control the compressor motor to rotate at a first speed during rotational acceleration of the centrifuge motor and to switch the compressor motor to rotate at a second speed higher than the first speed when the centrifuge motor reaches a rotation number close to a preset rotation number.

24. The centrifuge according to claim 23,

wherein the rotation number close to a preset rotation number is a rotation number lower than the preset rotation number by several hundreds

of rotations.

25. A centrifuge comprising:

a rotation chamber accommodating a rotor configured to hold a sample and is configured to be detachably mounted,

a centrifuge motor configured to rotationally drive the rotor,

an inverter control type cooling machine configured to cool the rotation chamber and

a control device configured to control the operation of the centrifuge motor and the cooling machine,

wherein an upper limit of the rotation number of the cooling machine is set in accordance with values of current flowing through the centrifuge motor.

26. The centrifuge according to claim 25,

wherein a maximum distribution power allocated to the cooling machine during the latter half of rotational acceleration of the rotor is smaller than a maximum distribution power allocated to the cooling machine during the rotational stabilization of the rotor.

27. A centrifuge comprising:

a rotor configured to hold a sample,

a rotation chamber accommodating the rotor,

a motor configured to drive the rotor and configured to be rotationally driven by an inverter circuit,

a cooling machine configured to cool the rotor,
an operating panel configured to receive operating conditions such as a cooling temperature or an operating time, and
a control device configured to control the centrifuging operation,
wherein, when the lowest input temperature that the operating panel can receive is set as a preset temperature, the distribution power allocated to the cooling machine during acceleration of the rotor is set smaller than the distribution power allocated to the cooling machine during stabilization operation of the rotor.

FIG. 1

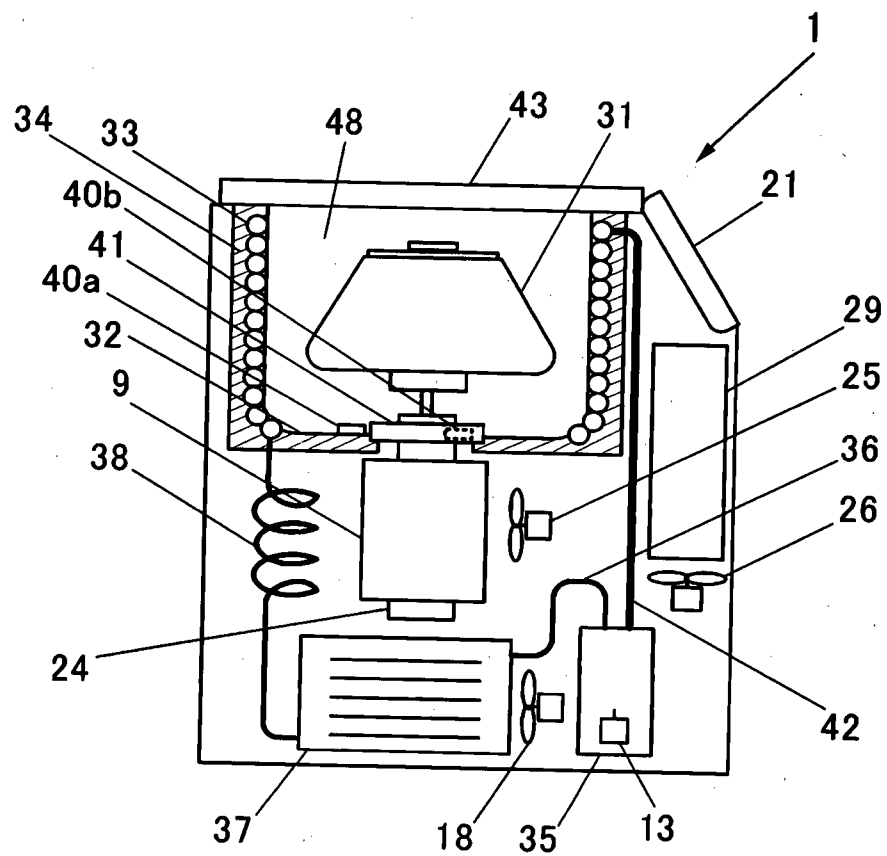


FIG. 2

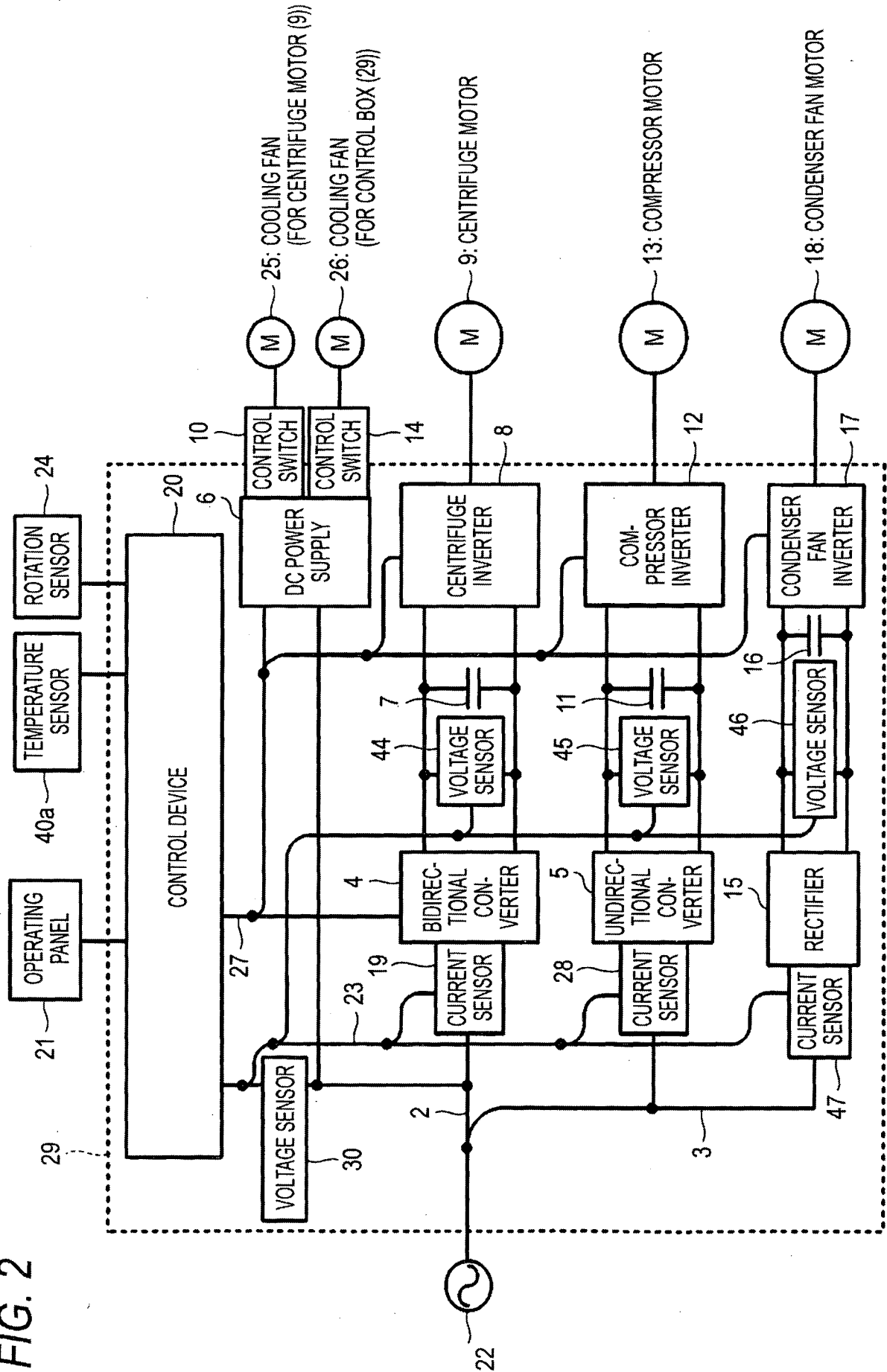


FIG. 3

130 131 132 133 **X**

Power Source Management Table

Input Voltage	Frequency	Phase	Max. Current
<input type="checkbox"/> 400V	<input type="checkbox"/> 60Hz	<input type="checkbox"/> 3Phase	<input checked="" type="checkbox"/> 30A
<input type="checkbox"/> 240V	<input checked="" type="checkbox"/> 50Hz	<input checked="" type="checkbox"/> 1Phase	<input type="checkbox"/> 24A
<input type="checkbox"/> 230V			<input type="checkbox"/> 23A
<input type="checkbox"/> 220V			<input type="checkbox"/> 22A
<input type="checkbox"/> 208V			<input type="checkbox"/> 21A
<input checked="" type="checkbox"/> 200V			<input type="checkbox"/> 15A

134 134 134 135 134

Cancel **OK**

FIG. 4

TERM NUMBER	ALLOWABLE RATED INPUT POWER OF AC POWER SUPPLY (1)			DISTRIBUTION PARAMETER			
	RATED VOLTAGE (V)	RATED CURRENT (A)	ALLOWABLE INPUT POWER (W)	ROTATION NUMBER (Hz) OF COMPRESSOR MOTOR (13)/ POWER (W) DURING ACCELERATION	POWER (W) OF CENTRIFUGE MOTOR (9) DURING ACCELERATION	CURRENT (A) OF CURRENT SENSOR (19) OF CENTRIFUGE MOTOR DURING ACCELERATION	ROTATION NUMBER (Hz) OF COMPRESSOR MOTOR (13) AFTER STABILIZATION
1	SINGLE PHASE 240	21	5040	58/2400	2640	11.00	67
2	SINGLE PHASE 230	22	5060	58/2400	2660	11.56	67
3	SINGLE PHASE 220	23	5060	58/2400	2660	12.09	67
4	SINGLE PHASE 208	24	4992	58/2400	2792	12.46	67
5	THREE PHASE 400	15/PHASE	6900	58/2400	3450	15.00	67
6	THREE PHASE 400	30/PHASE	13800	58/2400	3900	16.95	67
7	SINGLE PHASE 200	30	6000	58/2400	3600	18.00	65
8	SINGLE PHASE 220	30	6600	58/2400	3600	18.00	65

FIG. 5

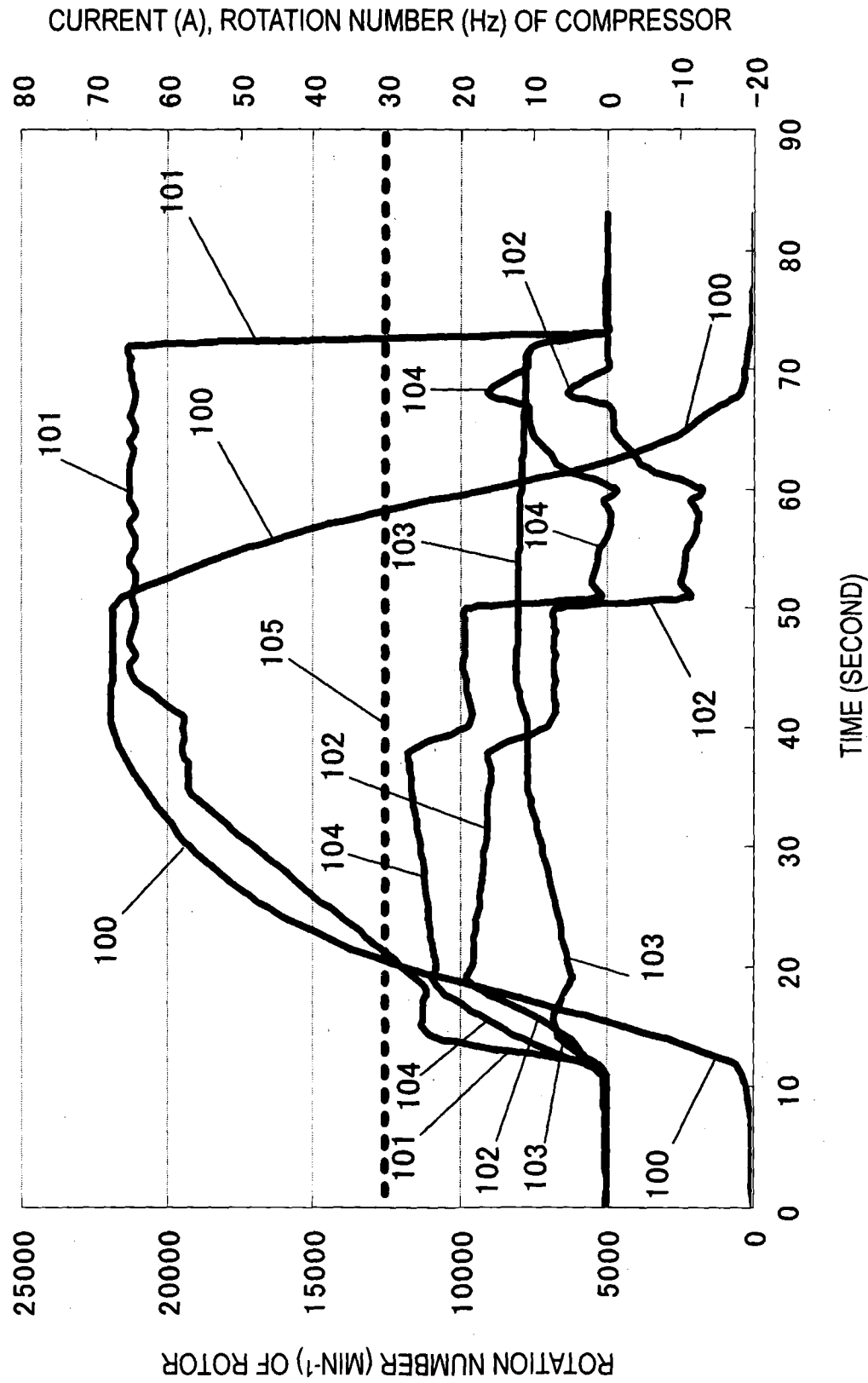


FIG. 6

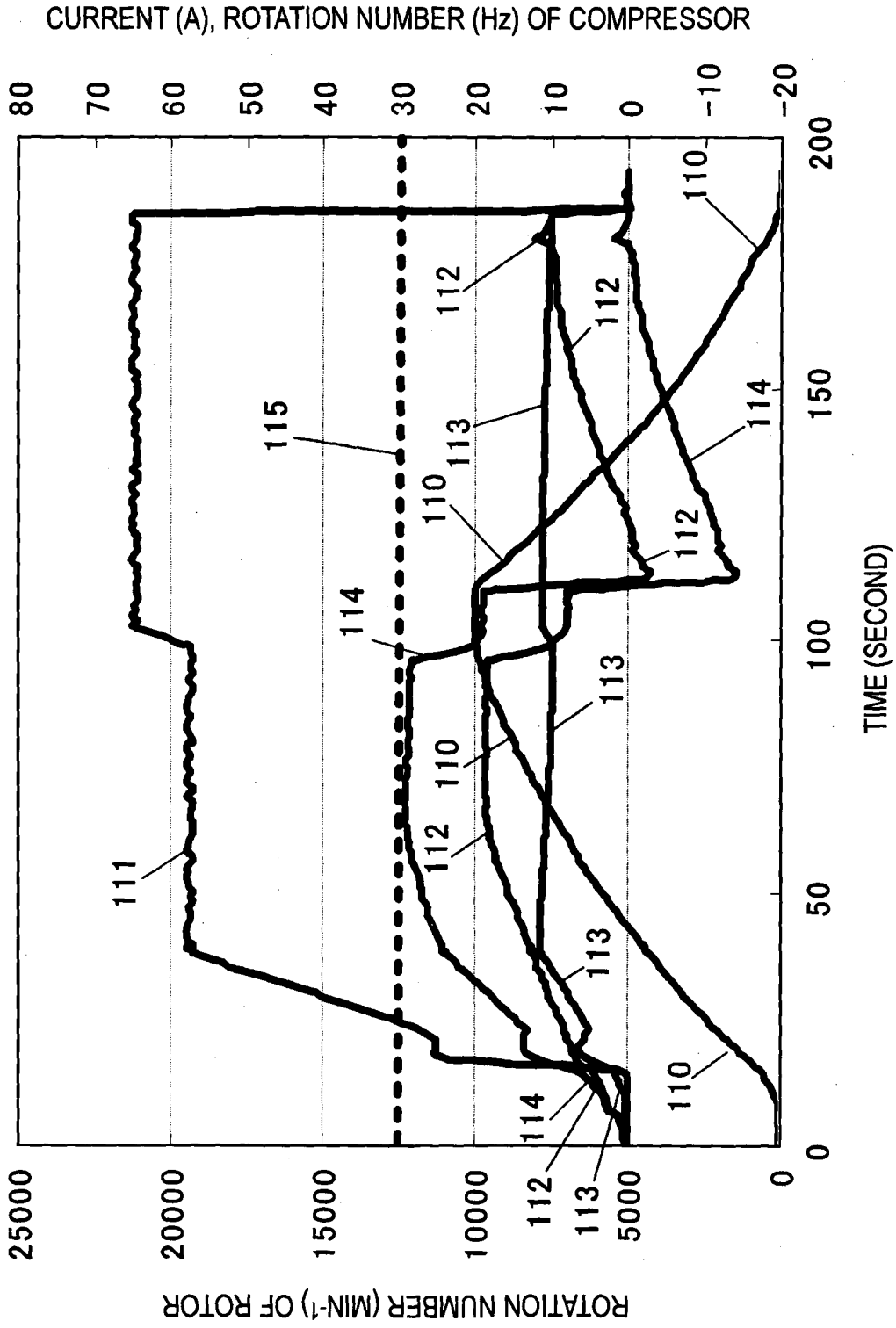


FIG. 7

TERM NUMBER	TYPE OF ROTOR	DISTRIBUTION PARAMETER (AC POWER SUPPLY 1: RATED VOLTAGE: SINGLE PHASE 200V, RATED CURRENT: 30A)			
		ROTATION NUMBER (Hz) OF COMPRESSOR MOTOR (13)/ POWER (W) DURING ACCELERATION	POWER (W) OF CENTRIFUGE MOTOR (9) DURING ACCELERATION	CURRENT (A) OF CURRENT SENSOR (19) OF CENTRIFUGE MOTOR DURING ACCELERATION	ROTATION NUMBER (Hz) OF COMPRESSOR MOTOR (13) AFTER STABILIZATION
1	R22A4 TYPE (SMALL CAPACITY HIGH SPEED ROTATING ROTOR)	64/2648	3352	16.76	65
2	R15A TYPE (MEDIUM CAPACITY MEDIUM SPEED ROTATING ROTOR)	58/2400	3600	18.00	65
3	R10A3 TYPE (LARGE CAPACITY LOW SPEED ROTATING ROTOR)	50/2070	3930	19.65	65

FIG. 8

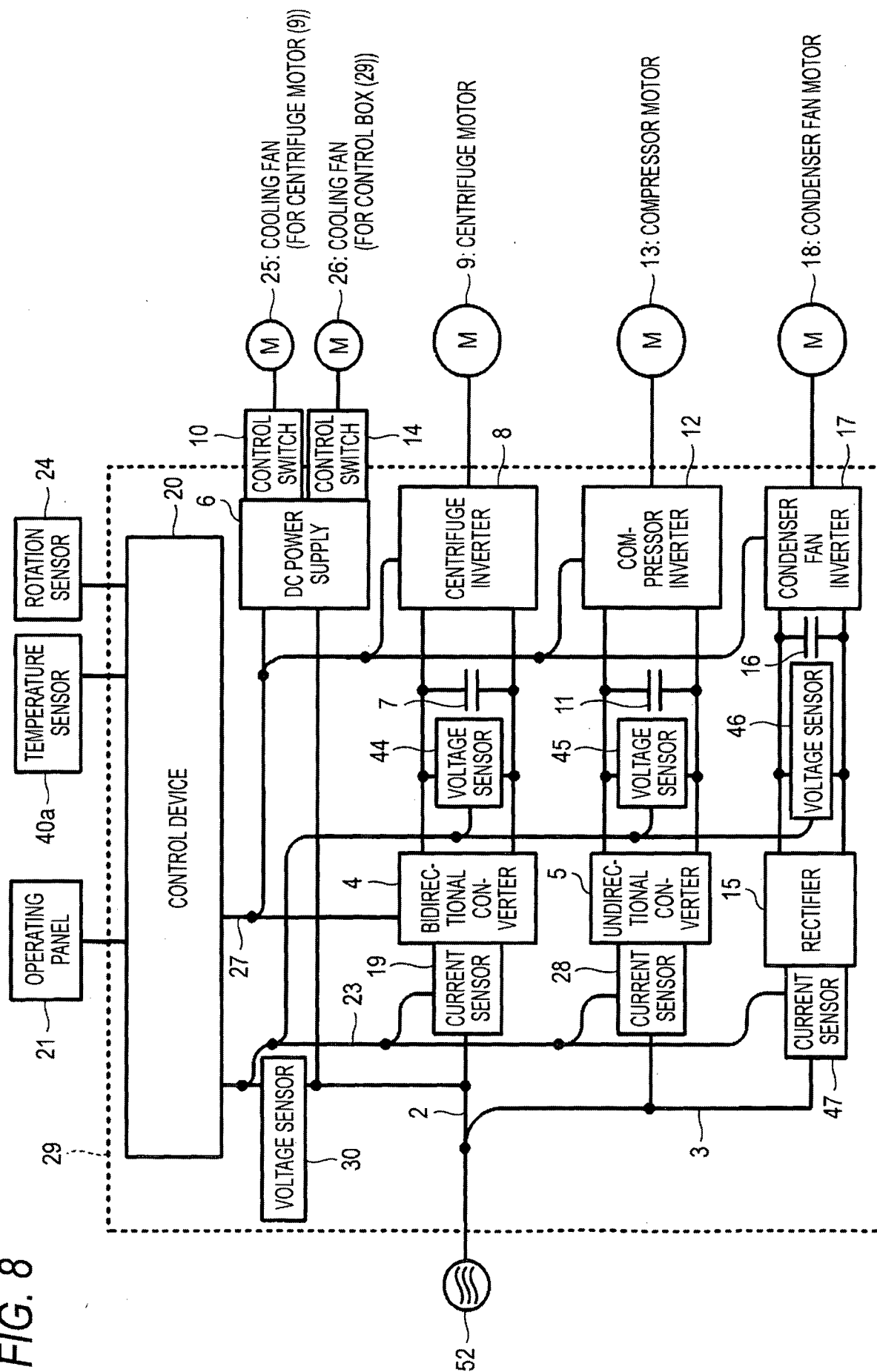


FIG. 9

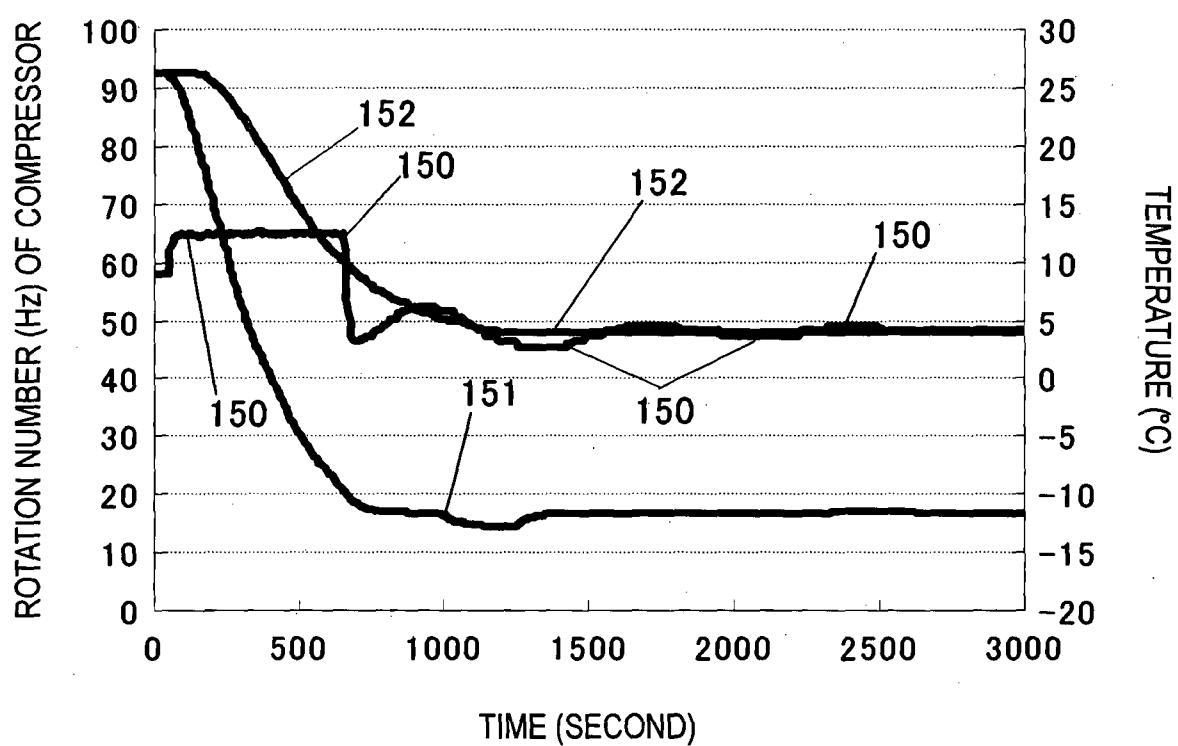


FIG. 10

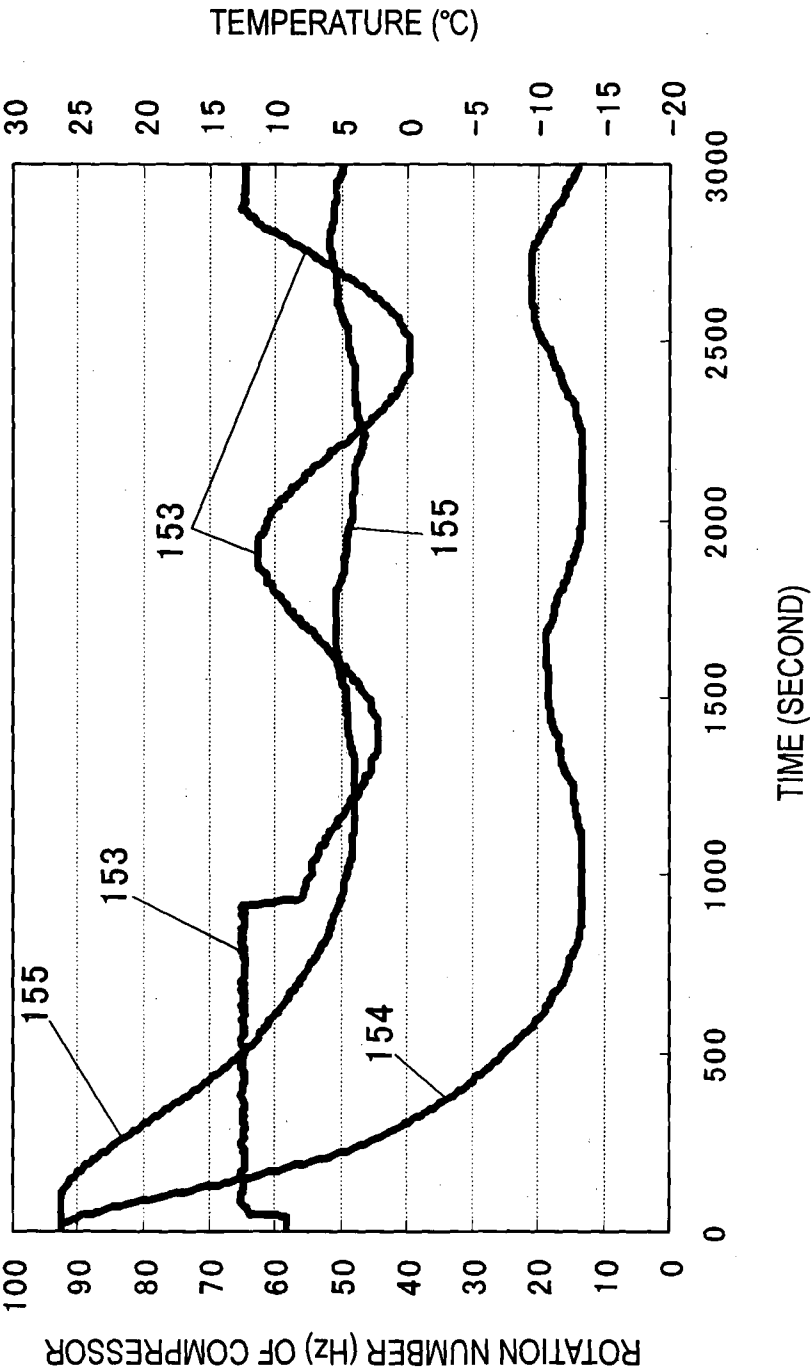


FIG. 11

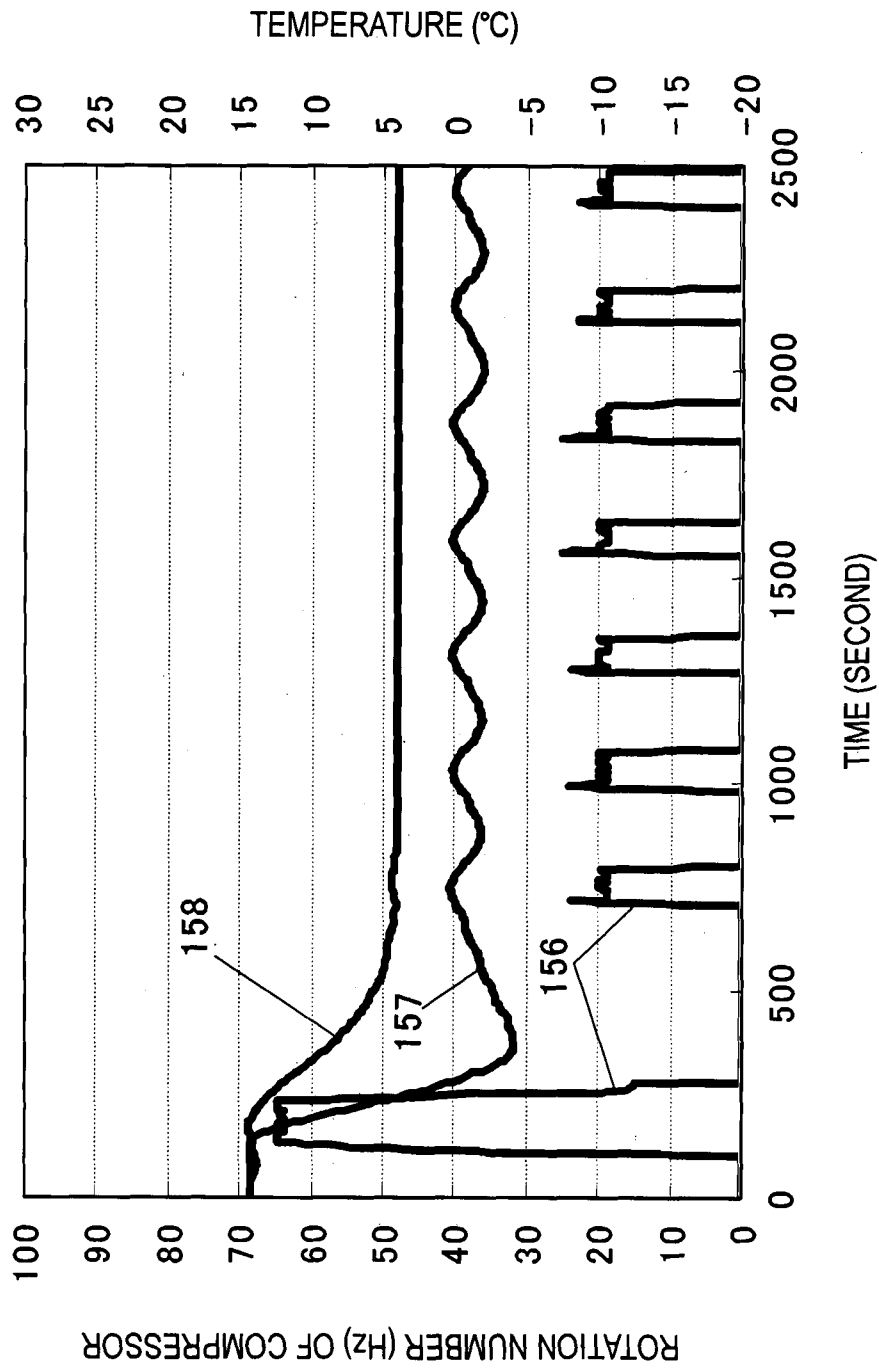


FIG. 12

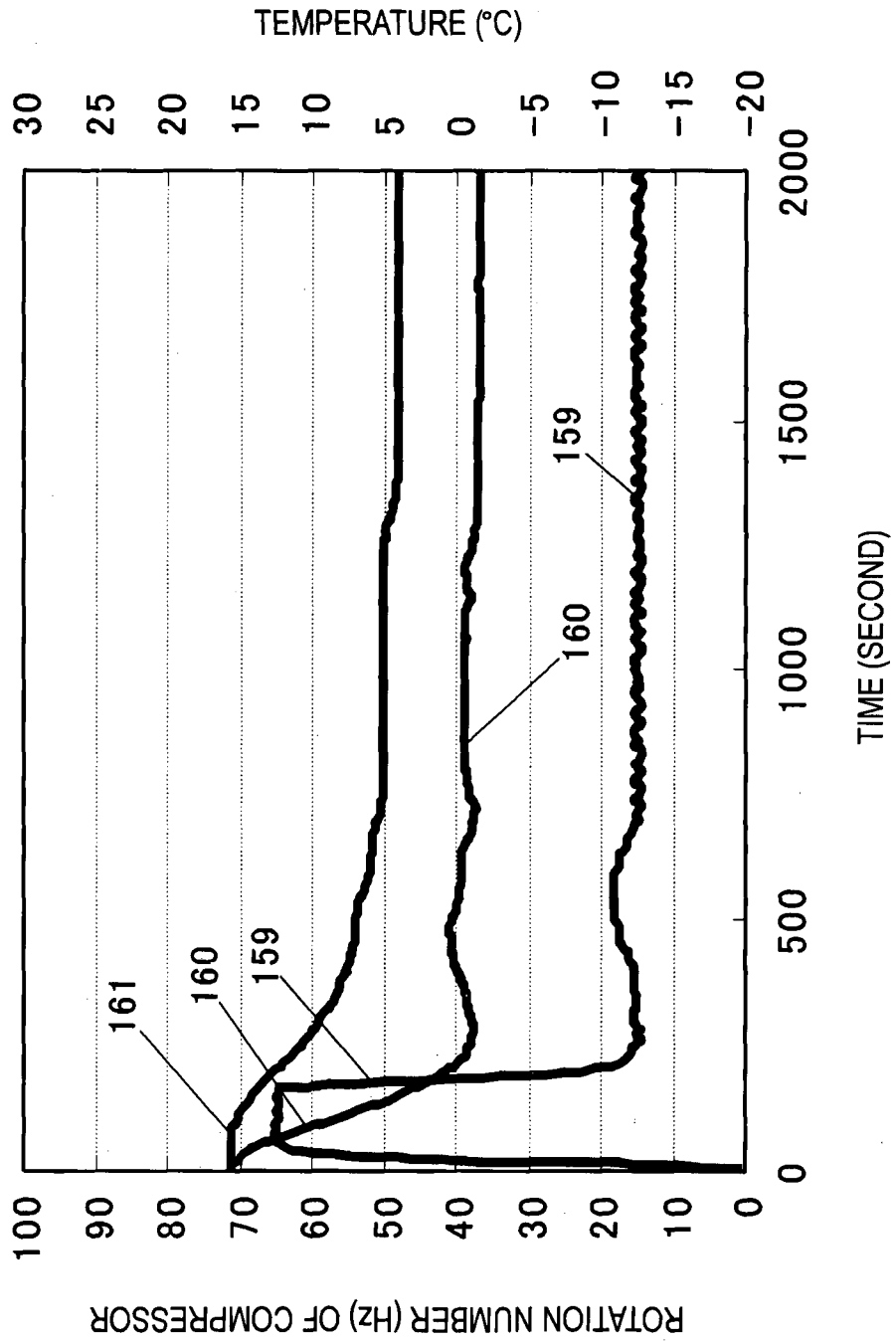


FIG. 13

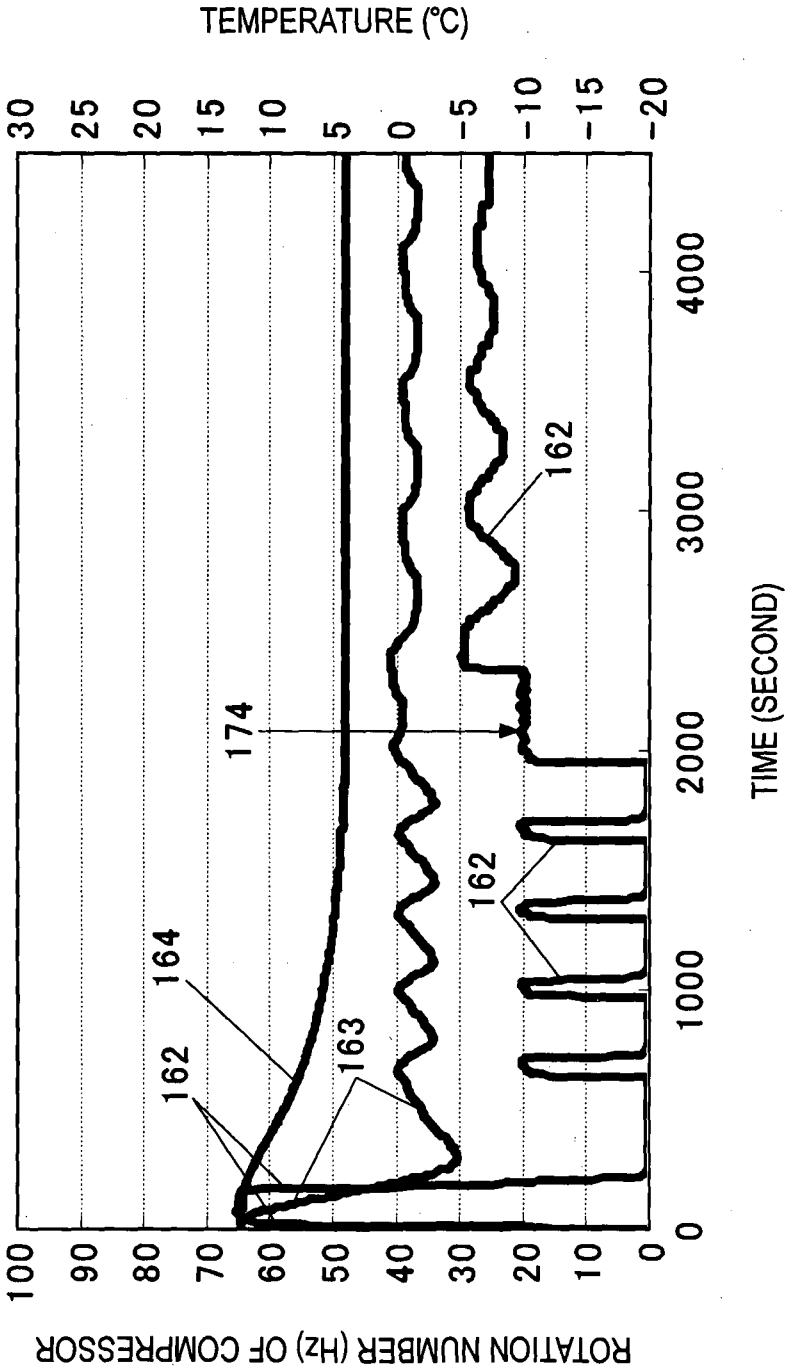


FIG. 14

RATIO (%) OF PRESET ROTATION NUMBER TO MAXIMUM ROTATION NUMBER	ROTATION NUMBER (Hz) OF COMPRESSOR MOTOR (13)
100	65
95	64
90	61
85	53
80	45
75	38
70	31
BELOW 65	30

FIG. 15

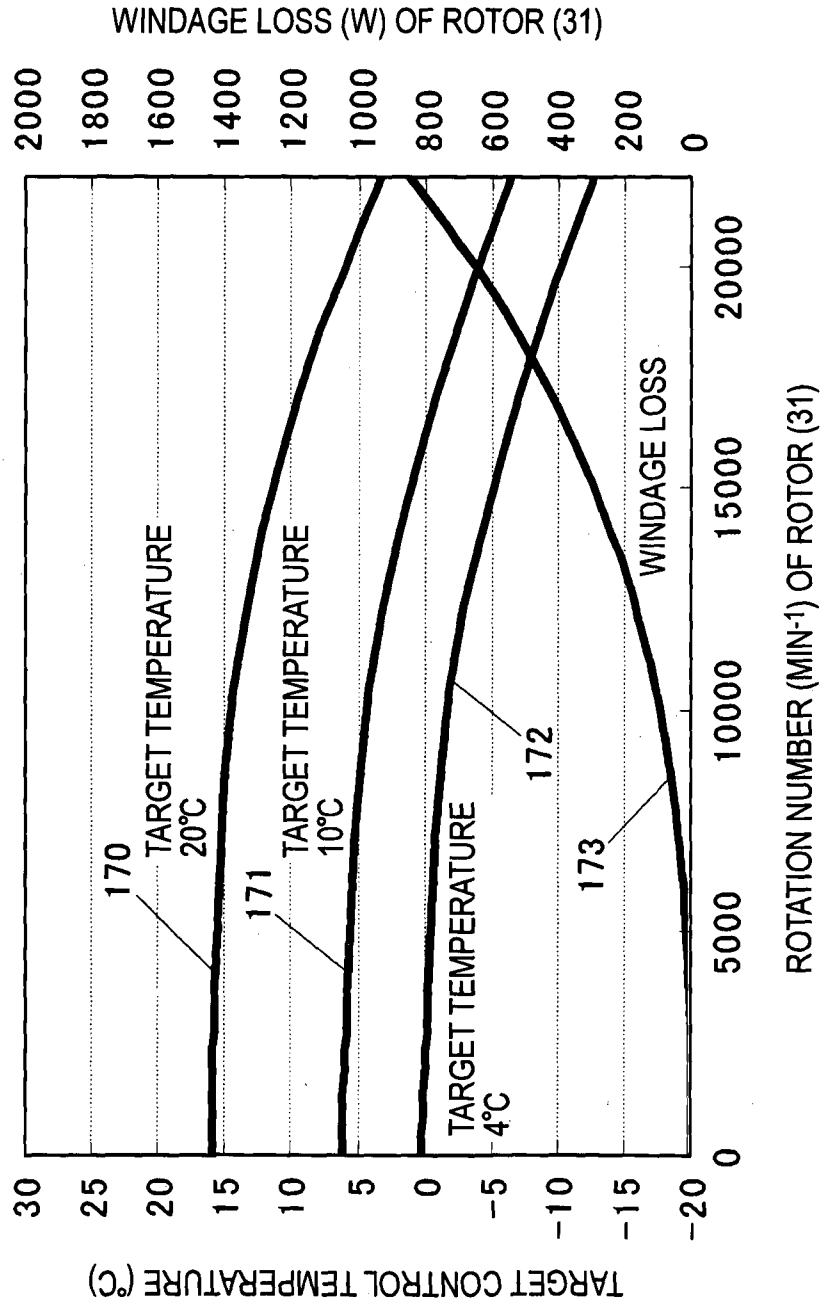


FIG. 16

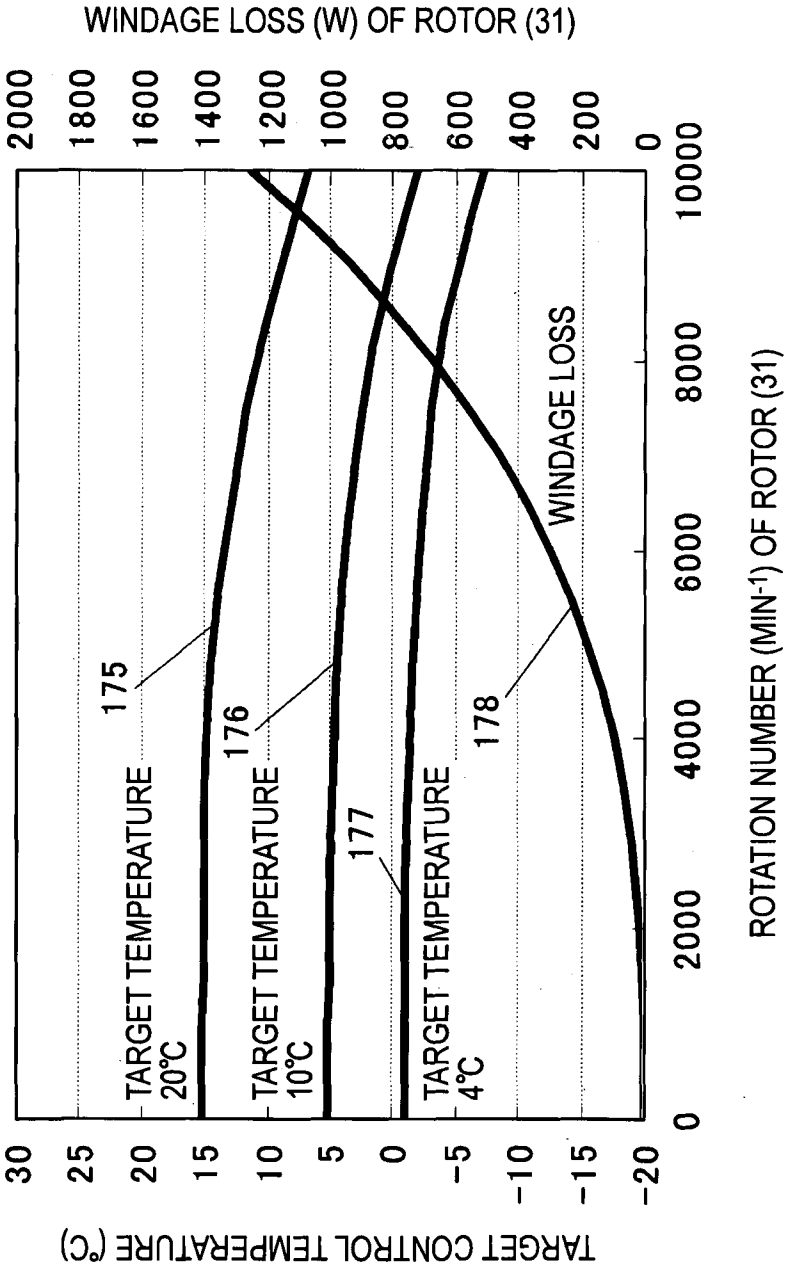
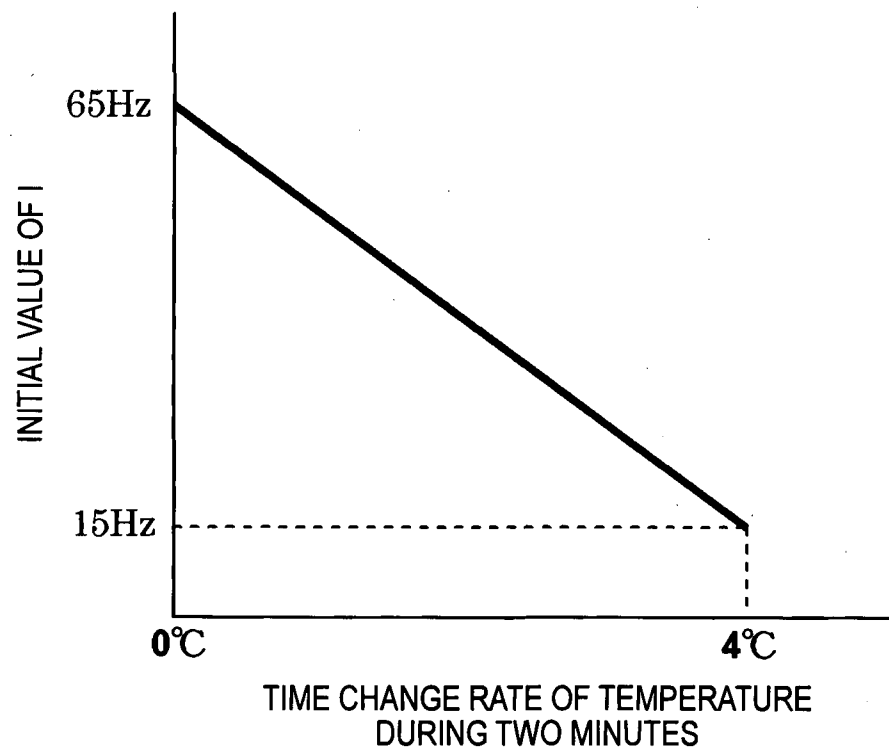


FIG. 17**FIG. 18**

TERM NUMBER	TYPE OF ROTOR (31)	ROTATION NUMBER (Hz) OF CONDENSER FAN (18)
1	R22A4 TYPE (SMALL CAPACITY HIGH SPEED ROTATING ROTOR)	60
2	R15A TYPE (MEDIUM CAPACITY MEDIUM SPEED ROTATING ROTOR)	54
3	R10A3 TYPE (LARGE CAPACITY LOW SPEED ROTATING ROTOR)	50

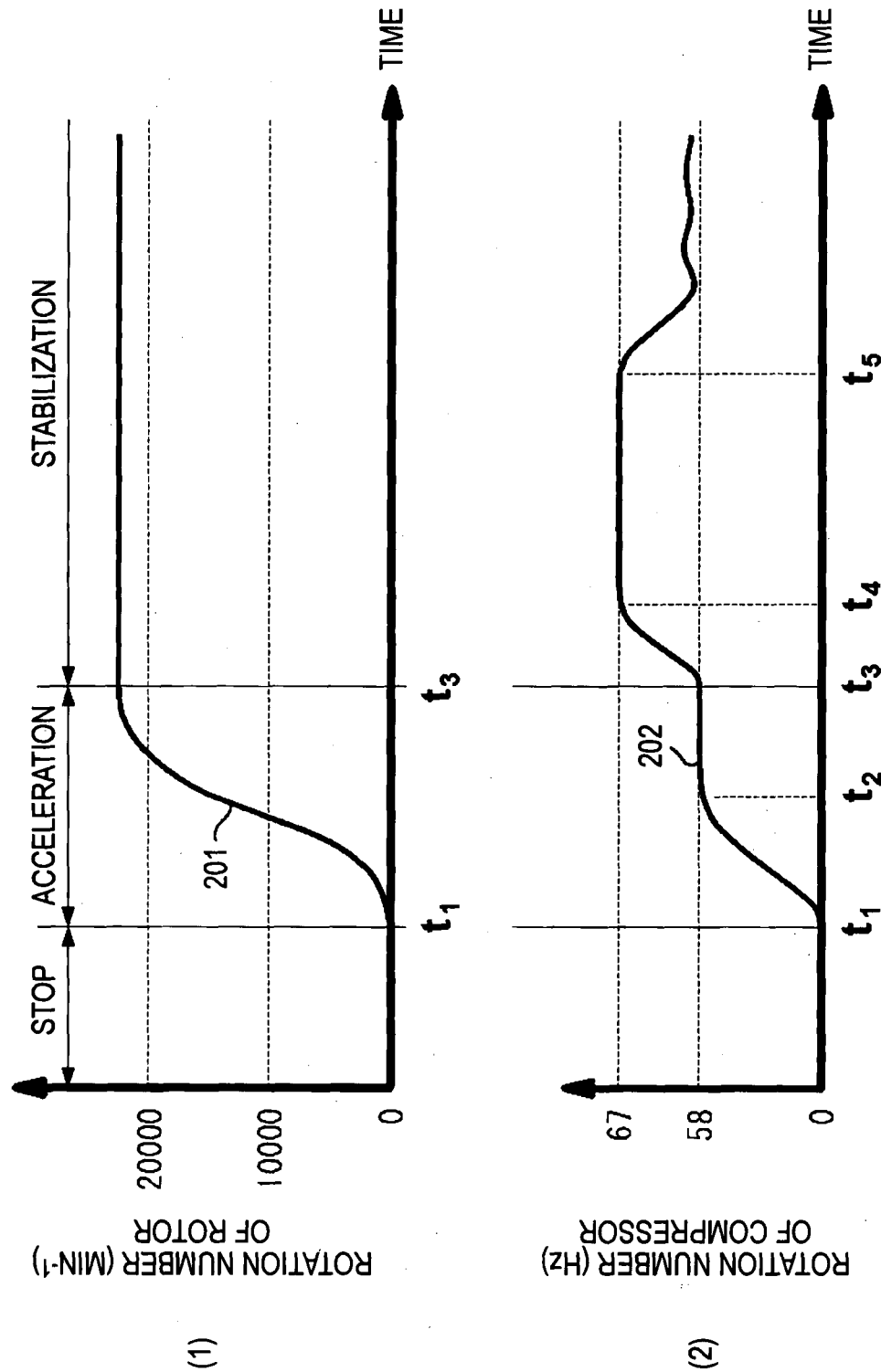


FIG. 19

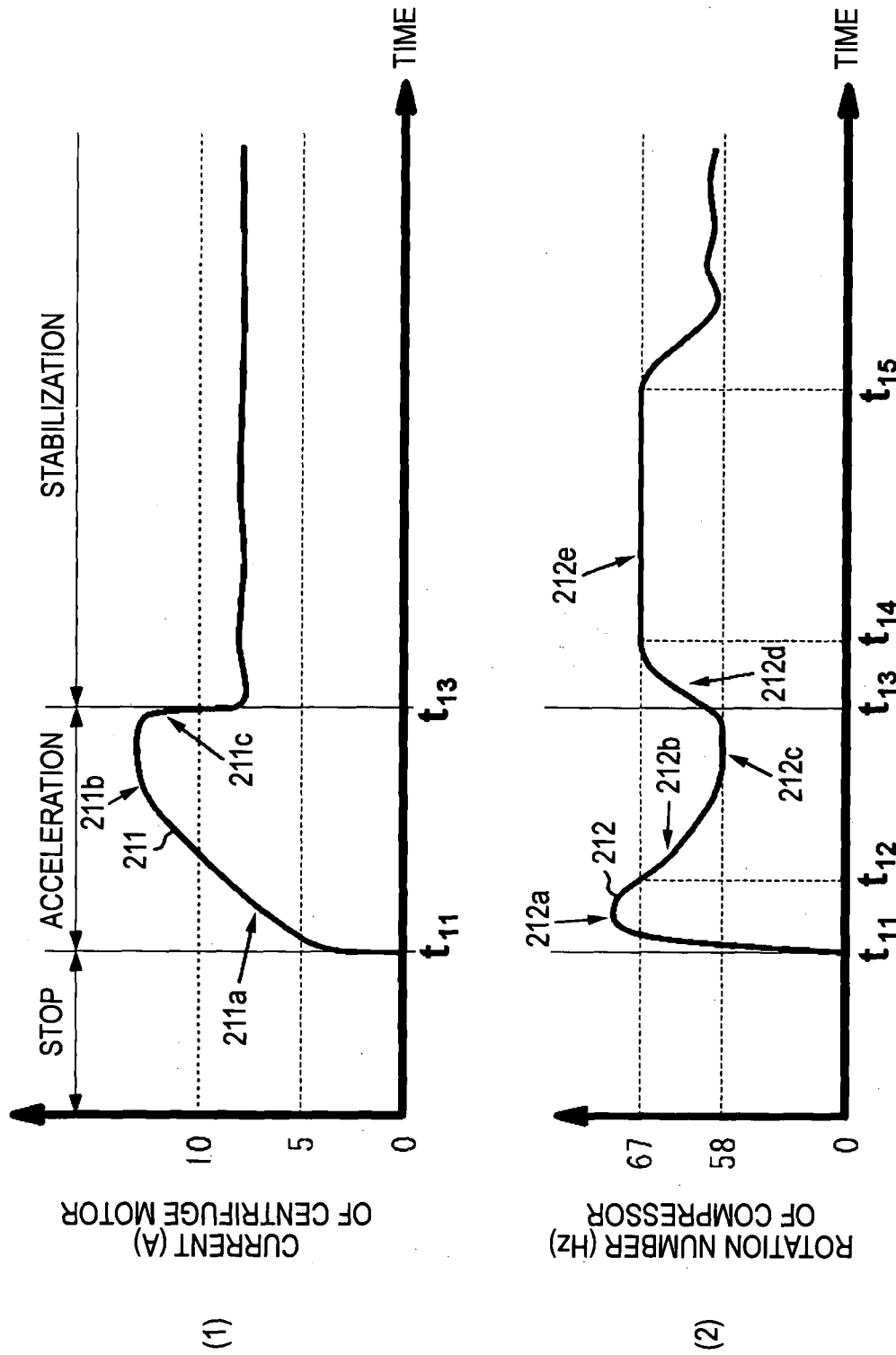


FIG. 20

INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2012/060648

A. CLASSIFICATION OF SUBJECT MATTER

INV. B04B9/10 B04B15/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B04B H02P H02M

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 866 621 B1 (MUELLER HEIKO [DE] ET AL) 15 March 2005 (2005-03-15)	1-4
Y	the whole document	5-11
X	US 5 261 252 A (PERUCH ANGELO [US]) 16 November 1993 (1993-11-16)	1-4
Y	the whole document	5-11
X	US 2002/092802 A1 (EVANA ROBERT R [US] ET AL) 18 July 2002 (2002-07-18)	1-4
Y	paragraph [0031] - paragraph [0046]; figure 1	5-11
Y	US 6 204 627 B1 (WATANABE SHINJI [JP] ET AL) 20 March 2001 (2001-03-20)	5-11
	the whole document	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

6 July 2012

Date of mailing of the international search report

19/07/2012

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Leitner, Josef

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/060648

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 12-27
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 12-27

The present application contains 27 claims, of which 6 are independent. There is no clear distinction between the independent claims because of overlapping scope. There are so many claims, and they are drafted in such a way that the claims as a whole are not in compliance with the provisions of clarity and conciseness of Article 6 PCT, as it is particularly burdensome for a skilled person to establish the subject-matter for which protection is sought. The non-compliance with the substantive provisions is to such an extent, that the search was performed taking into consideration the non-compliance in determining the extent of the search (PCT Guidelines 9.19 and 9.25). The search was based on the subject-matter that, as far as can be understood, could reasonably be expected to be claimed later in the procedure, and the corresponding claims, namely 1 - 11.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2012/060648

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6866621	B1	15-03-2005	DE 19932721 C1 18-01-2001
			EP 1196247 A1 17-04-2002
			JP 4365062 B2 18-11-2009
			JP 2003504197 A 04-02-2003
			US 6866621 B1 15-03-2005
			WO 0105516 A1 25-01-2001
US 5261252	A	16-11-1993	NONE
US 2002092802	A1	18-07-2002	NONE
US 6204627	B1	20-03-2001	JP 3496532 B2 16-02-2004
			JP 2000061360 A 29-02-2000
			US 6204627 B1 20-03-2001