

FORM 1

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

611712

APPLICATION FOR A STANDARD PATENT

I\We,

SANDEN CORPORATION

of

20 KOTOBUKI-CHO
ISESAKI-SHI
GUNMA-KEN
JAPAN

hereby apply for the grant of a standard patent for an
invention entitled:

REFRIGERATING SYSTEM HAVING A
COMPRESSOR WITH INTERNALLY AND
EXTERNALLY CONTROLLED VARIABLE
DISPLACEMENT MECHANISM

which is described in the accompanying complete specification

Details of basic application(s):

Number of basic application	Name of Convention country in which basic application was filed	Date of basic application
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P 236,315/62

JP

22 SEP 87

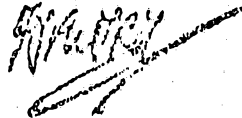
My/our address for service is care of GRIFFITH HACK & CO., Patent
Attorneys, 601 St. Kilda Road, Melbourne 3004, Victoria,
Australia.

DATED this 20th day of September

1988

SANDEN CORPORATION

GRIFFITH HACK & CO.



MOO2973 TO: The Commissioner of Patents.

Australian Patent Declaration Form

Forms 7 and 8

COMMONWEALTH OF AUSTRALIA

Patents Act 1952

DECLARATION IN SUPPORT OF A CONVENTION OR NON-CONVENTION
APPLICATION FOR A PATENT OR A PATENT OF ADDITION

In support of the application No. 22447/88 made by SANDEN
CORPORATION

for a patent for an invention entitled REFRIGERATING SYSTEM HAVING A
COMPRESSOR WITH INTERNALLY AND EXTERNALLY CONTROLLED VARIABLE DISPLACEMENT
MECHANISM Executive Vice-President

I/We, Masayoshi Ushikubo of of Sanden Corporation with its address

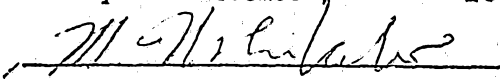
at c/o Sanden Corporation, 20 Kotobuki-cho, Isesaki-shi, Gunma, 372 Japan

do solemnly and sincerely declare as follows:-

1. I am/we are the applicant(s) for the patent, or am/are
authorised by the abovementioned applicant(s) to make this
declaration on its behalf.
2. The basic application(s) as defined by Section 141 of the Act
was/were made in the following country or countries on the
following date(s) by the following applicant(s) namely:-

in Japan on 22nd September, 1987
by Sanden Corporation
3. The said basic application(s) was/were the first
application(s) made in a Convention country in respect of the
invention the subject of the application.
4. The actual inventor(s) of the said invention is/are
Kiyoshi Terauchi, of 8-14 Heiwa-cho, Isesaki-shi, Gunma, 372 Japan
5. The facts upon which the applicant(s) is/are entitled to make
this application are as follows:-
The said applicant is the assignee of the said inventor.

DECLARED at Isesaki, Gunma this 12th day of December, 1988.


Masayoshi Ushikubo,
Executive Vice-President

(12) PATENT ABRIDGMENT (11) Document No. AU-B-22447/88
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 611712

(54) Title
REFRIGERATING SYSTEM HAVING A COMPRESSOR WITH INTERNALLY AND
EXTERNALLY CONTROLLED VARIABLE DISPLACEMENT MECHANISM

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(56) Prior Art Documents
AU 76058/87 F04B 25/04, 49/00, 49/06
AU 75913/87 F04B 25/04, 49/00, 49/06
AU 33235/85 F04B 49/06, F24F 11/00

(57) Claim

1. A refrigerating system including a refrigerant circuit, comprising a condenser, evaporator and compressor, the compressor including a compressor housing having a central portion, a front end plate at one end and a rear end plate at its other end, said housing having a cylinder block with a plurality of cylinders and a crank chamber, a piston slidably fitted within each of said cylinders, a drive mechanism coupled to said pistons to reciprocate said pistons within said cylinders, said drive mechanism including a drive shaft rotatably supported in said housing, a rotor coupled to said drive shaft and rotatable therewith, and coupling means for drivingly coupling said rotor to said pistons such that the rotary motion of said rotor is converted into reciprocating motion of said pistons, said coupling means including a member having a surface disposed

at an incline angle relative to said drive shaft, said incline angle of said member being adjustable to vary the stroke length of said pistons and the capacity of said compressor, said rear end plate having a suction chamber and a discharge chamber, variable displacement control means for controlling angular displacement of said adjustable member comprising first valve control means for controlling fluid communication between said crank chamber and said suction chamber in response to changes in refrigerant pressure in said compressor, said first valve control means comprising a first passageway providing fluid communication between said crank chamber and said suction chamber and first valve means for controlling the opening and closing of said first passageway to vary the capacity of the compressor by adjusting the incline angle, said first valve means comprising a first valve to directly open and close said first passageway, said variable displacement control means further comprising second valve control means for controlling fluid communication between said crank chamber and said suction chamber in response to a signal generated outside of the compressor, said second valve control means comprising a second passageway providing fluid communication between said crank chamber and said suction chamber and second valve means for controlling the opening and closing of said second passageway to vary the capacity of said compressor by adjusting the incline angle, said second valve means comprising a second valve to directly open and close said second passageway and override the operation of said first valve, and means for controlling the generation of said signal in response to at least one thermodynamic characteristic related to the evaporator as compared to two distinct boundary values.

AUSTRALIA

PATENTS ACT 1952

COMPLETE SPECIFICATION

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amendment of the
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TO BE COMPLETED BY APPLICANT

Name of Applicant:

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Complete Specification for the invention entitled:

REFRIGERATING SYSTEM HAVING A
COMPRESSOR WITH INTERNALLY AND
EXTERNALLY CONTROLLED VARIABLE
DISPLACEMENT MECHANISM

The following statement is a full description of this invention
including the best method of performing it known to me:-

REFRIGERATING SYSTEM HAVING A
COMPRESSOR WITH AN INTERNALLY AND EXTERNALLY
CONTROLLED VARIABLE DISPLACEMENT MECHANISM

TECHNICAL FIELD

The present invention relates to an improved automotive air conditioning system. More particularly, the present invention relates to a refrigerating system having a slant plate type compressor with an internally and externally controlled variable displacement mechanism suitable for use in an automotive air conditioning system. The present invention also relates to a method for varying the displacement of a slant plate type compressor.

BACKGROUND OF THE INVENTION

One construction of a slant plate type compressor, particularly a wobble plate compressor, with a variable capacity mechanism which is suitable for use in an automotive air conditioner is disclosed in U.S. Patent No. 3,861,829 issued to Roberts et al. Roberts et al. '829 discloses a wobble plate type compressor which has a cam rotor driving device to drive a plurality of pistons. The slant or incline angle of the slant surface of the wobble plate is varied to change the stroke length of the pistons which changes the displacement of the compressor. Changing the incline angle of the wobble plate is effected by changing the pressure difference between the suction chamber and the crank chamber in which the driving device is located.

In such a prior art compressor, the slant angle of the slant surface is controlled by the pressure in the crank chamber. Typically this control occurs in the following manner. The crank chamber communicates with the suction chamber through an aperture and the opening and closing of the aperture is controlled by a valve mechanism. The valve mechanism generally includes a bellows element and a needle valve, and is located in the suction chamber so that the



bellows element operates in accordance with changes in the suction chamber pressure.

In the above compressor, the pressure of the suction chamber is compared with a predetermined value by the valve mechanism. However, when the predetermined value is below a certain critical value, there is a possibility of frost forming on the evaporator in the refrigerant circuit. Thus, the predetermined value is usually set higher than the critical value to prevent frost from forming on the evaporator.

However, since suction pressures above this critical value are higher than the pressure in the suction chamber when the compressor operates at maximum capacity, the cooling characteristics of the compressor are inferior to those of the same compressor without a variable displacement mechanism.

Roberts et al. '829 discloses a capacity adjusting mechanism used in a wobble plate type compressor. As is typical in this type of compressor, the wobble plate is disposed at a slant or incline angle relative to the drive axis, nutates but does not rotate, and drivingly couples the pistons to the drive source. This type of capacity adjusting mechanism, using selective fluid communication between the crank chamber and the suction chamber can be used in any type of compressor which uses a slanted plate or surface in the drive mechanism. For example, U.S. Patent No. 4,664,604 issued to Terauchi discloses this type of capacity adjusting mechanism in a swash plate type compressor. The swash plate, like the wobble plate, is disposed at a slant angle and drivingly couples the pistons to the drive source. However, while the wobble plate only nutates, the swash plate both nutates and rotates. The term slant plate type compressor will therefore be used to refer to any type of compressor, including wobble and swash plate types, which use a slanted plate or surface in the drive mechanism.

A signal controlled compressor solenoid valve in combination with a pressure actuated bellows valve is disclosed in U.S. Patent ^{4,778,348}
~~Application Serial No. 076,282 which corresponds to Japanese Utility~~



~~Model Application No. 61-111994~~ to improve cooling characteristics and temperature control in the passenger compartment.

In a starting so-called "cool down" stage of an air conditioning system including such a compressor for initially cooling the passenger compartment, the second valve control device works to connect the crank chamber to the suction chamber due to a heat load on the evaporator of the air conditioning system being exceedingly above a single predetermined value. Once the heat load drops to the same predetermined value, the second valve control device closes the valve and only may reopen the valve if the heat load exceeds that single predetermined value which will normally only occur after the air conditioning system has been turned off and then restarted after a certain time period. Once the second valve control device closes the second valve, the first valve control device solely controls the capacity of the compressor.

The air conditioning system including the above mentioned variable displacement mechanism has no problem in a "cool down" stage when cooling recirculated room air.

However, in a "cool down" stage with fresh air intake, i.e., cooling fresh air which is brought into the room, the above mentioned air conditioning system has certain drawbacks.

Referring to Figure 9, the cool down characteristic of the prior art air conditioning system in a fresh air intake situation is shown. In Figure 9, a solid line, a dotted line and a dashed line show pressure of an evaporator outlet portion, pressure of a compressor suction chamber and a room (passenger compartment) temperature, respectively. In the cool down stage, the second valve control device works to connect the crank chamber to the suction chamber causing maximum displacement of the slant plate of a slant plate type compressor, so that the room temperature, the pressure in evaporator outlet portion and the pressure in the suction chamber fall quickly. When the pressure in the evaporator outlet portion falls to the single predetermined value P_1 that is the lower most point before frost forms on the evaporator surface, the second valve control device closes the second valve (time t_1 elapsed). After time t_1 , the first valve control device solely



controls the displacement of the compressor slant plate and maintains the suction chamber pressure slightly above P_1 . Immediately after time t_1 , the heat load is still large so that a large amount of refrigerant gas flows from the evaporator to the suction chamber. As a result, some pressure loss occurs between the evaporator outlet portion and the suction chamber which makes the pressure of the evaporator outlet portion quickly rise. The quick pressure rise in the evaporator outlet portion causes inefficient heat exchange which in turn causes the room temperature to quickly rise.

Furthermore, when the above mentioned air conditioning system incorporates a mechanical thermal expansion valve which maintains super heat values associated with the evaporator outlet portion generally constant, hunting of suction refrigerant gas flow tends to occur due to a mutual interference between the control of the variable displacement mechanism and the control of the expansion valve immediately after t_1 shown in Figure 9.

SUMMARY OF THE INVENTION

It is a primary object of this invention to eliminate a quick rising of the room temperature as a result of a quick rise in pressure in the evaporator outlet portion due to the pressure loss between the evaporator outlet portion and the suction chamber which occurs once the first valve control device achieves sole control of the variable displacement mechanism in a fresh air intake situation.

It is another object of this invention to eliminate hunting of suction refrigerant gas flow tending to happen due to the mutual interference between the control of the variable displacement mechanism and the control of the expansion valve once the first valve control device achieves sole control of the variable displacement mechanism.

The present invention is directed to a refrigerating system including a refrigerant circuit, comprising a condenser, evaporator and compressor. The compressor includes a compressor housing having a central portion, a



- 4A -

front end plate at one end and a rear end plate at its other end. The housing has a cylinder block with a plurality of a cylinders and a crank chamber, a piston slidably fitted within each of the cylinders and a drive mechanism coupled to



the pistons to reciprocate the pistons within the cylinders. The drive mechanism includes a drive shaft rotatably supported in the housing, a rotor coupled to the drive shaft and rotatable therewith, and a coupling mechanism for drivingly coupling the rotor to the pistons such that the rotary motion of the rotor is converted into reciprocating motion of the pistons. The coupling mechanism includes a member having a surface disposed at an incline angle relative to the drive shaft. The incline angle of the member is adjustable to vary the stroke length of the pistons and the capacity of the compressor. The rear end plate has a suction chamber and a discharge chamber. A variable displacement control mechanism controls angular displacement of the adjustable member and comprises a first valve control device for controlling fluid communication between the crank chamber and the suction chamber in response to changes in refrigerant pressure in the compressor. The first valve control device comprises a first passageway providing fluid communication between the crank chamber and the suction chamber and a first valve member for controlling the opening and closing of the first passageway to vary the capacity of the compressor by adjusting the incline angle. The first valve member comprises a first valve to directly open and close the first passageway. The variable displacement control mechanism further comprises a second valve control device for controlling fluid communication between the crank chamber and the suction chamber in response to a signal generated outside of the compressor. The second valve control device comprises a second passageway providing fluid communication between the crank chamber and the suction chamber and a second valve member for controlling the opening and closing of the second passageway to vary the capacity of the compressor by adjusting the incline angle. The second valve member comprises a second valve to directly open and close the second passageway and override the operation of the first valve. A circuit for controlling the generation of the signal in response to thermodynamic characteristics related to the evaporator provides the compressor with external control of the variable displacement mechanism as



compared to two boundary values of the thermodynamic characteristic.

The present invention is also directed to a method for varying the displacement of a slant plate compressor by sensing a thermodynamic characteristic related to the evaporator and selectively operating the second valve control device in comparison to the two boundary values.

Further objects, features and other aspects of the present invention will be understood from the detailed description of the preferred embodiment of the present invention with reference to the annexed drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a vertical longitudinal sectional view of a wobble plate type compressor with a variable displacement mechanism in accordance with one embodiment of the present invention.

Figure 2 is a schematic block diagram of one refrigerating circuit including the compressor shown in Figure 1.

Figure 3 is a schematic block diagram of another refrigerating circuit including the compressor shown in Figure 1.

Figure 4 is a graph showing cool down characteristics of the refrigerant circuits shown in Figure 2 or Figure 3.

Figure 5 is a schematic block diagram of still another refrigerating circuit including the compressor shown in Figure 1.

Figure 6 is a diagram showing various control stages of the solenoid valve corresponding to the control circuit shown in Figure 5 in response to a surface temperature of an evaporator fin.

Figure 7 is a schematic block diagram of yet another refrigerating circuit including the compressor shown in Figure 1.

Figure 8 is a diagram showing various control stages of the solenoid valve corresponding to the control circuit shown in Figure 7 in response to the surface temperature of the evaporator fin.

Figure 9 is a graph showing cool down characteristics of a refrigerant circuit including a known variable displacement wobble plate type compressor.



DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1, a wobble plate type compressor 10 in accordance with one embodiment of the present invention is shown. Compressor 10 includes a closed cylindrical housing assembly 11 formed by a cylinder block 12, a crank chamber 13 within cylinder block 12, a front end plate 14f and a rear end plate 14r.

Front end plate 14f is mounted on the left end portion of crank chamber 13, as shown in Figure 1, by a plurality of bolts (not shown). Rear end plate 14r and valve plate 15 are mounted on cylinder block 12 by a plurality of bolts (not shown). An opening 131 is formed in front end plate 14f for receiving a drive shaft 16 which is rotatably supported by front end plate 14f through bearing 132 which is disposed within opening 131. An inner end portion of drive shaft 16 is also rotatably supported by cylinder block 12 through bearing 122 which is disposed within a central bore 121. Central bore 121 provides a cavity in a center portion of cylinder block 12. Shaft seal 17 is disposed between an inner surface of opening 131 and an outer surface of drive shaft 16 at an outside of bearing 132. Thrust needle bearing 133 is disposed between an inner end surface of front end plate 14f and an adjacent axial end surface of cam rotor 20.

Cam rotor 20 is fixed on drive shaft 16 by pin member 18 which penetrates cam rotor 20 and drive shaft 16. Cam rotor 20 is provided with arm 21 having a pin 22. Slant plate 30 has an opening 33 formed at a center portion thereof. Spherical bushing 19, slidably mounted on drive shaft 16, slidably mates with an inner surface of opening 33 which is spherically concave in shape. Slant plate 30 includes arm 31 having slot 32 in which pin 22 is inserted. Cam rotor 20 and slant plate 30 are joined by hinged joint 40 including pin 22 and slot 32. Pin 22 is able to slide within slot 32 so that the angular position of slant plate 30 can be changed with respect to a longitudinal axis of drive shaft 16.

Wobble plate 50 is rotatably mounted on slant plate 30 through bearings 31 and 32. Rotation of wobble plate 50 is prevented by fork-shaped slider 60 which is attached to an outer peripheral end of wobble plate 50 and is slidably mounted on sliding rail 61 held between

front end plate 14f and cylinder block 12. In order to slide slider 60 on sliding rail 61, wobble plate 50 wobbles without rotation even though cam rotor 20 rotates.

Cylinder block 12 has a plurality of annularly arranged cylinders 70 in which respective pistons 71 slide. All pistons 71 are connected to wobble plate 50 by a corresponding plurality of connecting rods 72. Ball 73 at one end of rod 72 is received in socket 75 of pistons 71, and ball 74 at the other end of rod 72 is received in socket 51 of wobble plate 50. It should be understood that, although only one such ball socket connection is shown in the drawings, there are a plurality of sockets arranged peripherally around wobble plate 50 to receive the balls of various rods 72, and that each piston 71 is formed with a socket for receiving the other ball of rods 72.

Rear end plate 14r is shaped to define suction chamber 141 and discharge chamber 142. Valve plate 15, which is fastened to the end of cylinder block 12 by a plurality of screws (not shown) together with rear end plate 14r, is provided with a plurality of valved suction ports 151 connected between suction chamber 141 and respective cylinders 70, and a plurality of valved discharge ports 152 connected between discharge chamber 142 and respective cylinders 70. Suitable reed valves for suction ports 151 and discharge ports 152 are described in U.S. Patent No. 4,011,029 issued to Shimizu. Gaskets 15a and 15b are placed between cylinder block 12 and an inner surface of valve plate 15, and an outer surface of valve plate 15 and rear end plate 14r, to seal the mating surfaces of cylinder block 12, valve plate 15 and rear end plate 14r. Suction inlet port 141a and discharge outlet port 142a are formed at rear end plate 14r and connect to an external fluid circuit.

A variable displacement actuation mechanism comprises a first valve control device 81 and a second valve control device 82. The devices actuate the displacement of slant plate 30 with respect to drive shaft 16.

First valve control device 81 includes a bellows valve 811 which is disposed within chamber 812 formed in cylinder block 12. Chamber 812 is connected to crank chamber 13 through a hole or

passage 813 formed in cylinder block 12, and is also connected to suction chamber 141 through a hole or passage 814 formed in valve plate 15. Hole 813, chamber 812 and hole 814 provide fluid communication between crank chamber 13 and suction chamber 141. Bellows valve 811 comprises bellows element 811a of which one end is attached to an inner end surface of chamber 812, and a needle valve element 811b which is attached to the other end of bellows element 811a in order to face hole 814. Bellows element 811a is axially expanded and contracted in response to crank chamber pressure thereby causing needle valve element 811b to close and open hole 814 to keep the crank chamber pressure generally constant. Accordingly, first valve control device 81 controls fluid communication between crank chamber 13 and suction chamber 141 to keep the crank chamber pressure generally constant in response to changes in the crank chamber pressure. When the crank chamber pressure is kept constant, the suction chamber is also kept generally constant.

Second valve control device 82 includes solenoid valve 821 which is disposed within control chamber 822 formed in rear end plate 14r. Solenoid valve 821 comprises a casing 821a which encases control chamber 822, electromagnetic coil 821b and needle valve element 821c. Electromagnetic coil 821b surrounding needle valve element 821c is disposed within casing 821a. Holes 821d and 821e are formed in casing 821a. Hole 821d is formed at a top portion of casing 821a and faces later mentioned hole 823. Hole 821e is formed at a lower side wall portion and faces a hole 824 formed at partition wall 143. Needle valve element 821c is urged toward hole 821d by restoring force of bias spring 821f. A wire 821g conducts a later mentioned signal generated at a location outside the compressor to electromagnetic coil 821b. Hole 823 is formed in valve plate 15 and connects hole 821d and a conduit 825 formed in cylinder block 12. Therefore, crank chamber 13 is in fluid communication with control chamber 822 through conduit 825, hole 823 and hole 821d. Control chamber 822 communicates with suction chamber 141 through hole 821e and hole 824. When the external signal does not energize electromagnetic coil 821b, needle valve element 821c closes hole 821d by virtue of the

restoring force of bias spring 821f so that the communication between crank chamber 13 and suction chamber 141 is blocked. When the external signal energizes electromagnetic coil 821b, needle valve element 821c moves right in viewing Figure 1 and against the restoring force of bias spring 821f so that crank chamber 13 communicates with suction chamber 141 via conduit 825, hole 823, hole 821d, control chamber 822, hole 821e and hole 824. When communication between crank chamber 13 and suction chamber 141 is established through conduit 825 by the operation of second valve control device 82, the operation of first valve control device 81 is overridden.

Furthermore, the construction of solenoid valve 821 may be modified in a manner such that the closing of needle valve element 821c is retarded by spring 821f. Accordingly, the external signal would have to be reversed to appropriately actuate the valve.

Referring to Figure 2, a schematic block diagram of one refrigerating circuit including the compressor depicted in Figure 1 is shown. A refrigerant gas compressed by compressor 10 flows into a condenser 201 where it is condensed. The condensed refrigerant flows into evaporator 203 after passing through expansion valve 202. After passing through evaporator 203, the evaporated gas returns to compressor 10. A pressure actuation device 204 includes switch 204s and works in response to the sensed pressure in the outlet portion of evaporator 203 (a thermodynamic characteristic related to the evaporator).

The operation of pressure actuation device 204 will be described hereafter. When R14 is selected as a refrigerant, pressure device 204 is set to close pressure device switch 204s when the pressure in the evaporator outlet portion is sensed to be or reaches (i.e., is greater than or equal to) $2.3 \text{ kg/cm}^2 \cdot G$, wherein G is gauge pressure, so that an "on" signal is sent to solenoid valve 821 of second valve control device 82. The signal energizes electromagnetic coil 821b thereby opening the solenoid valve and causing maximum displacement of slant plate 30 so that maximum compression is achieved. On the other hand, pressure device 204 is also set to open switch 204s when the pressure in the evaporator outlet portion is sensed to fall to



(or below) $2.1 \text{ kg/cm}^2 \cdot \text{G}$, which is the lower most point before frost forms on the evaporator surface. As a result, an "off" signal is sent to solenoid valve 821 of second valve control device 82. The signal deenergizes electromagnetic coil 821b thereby closing the solenoid valve, allowing slant plate 30 to retract from maximum displacement and preventing frost formation on the evaporator surface.

Referring to Figure 4, the cool down characteristics of the above mentioned refrigerating circuit during the air conditioning process using fresh air intake, will be described hereafter. In Figure 4, the solid line, dotted line and dashed line show the pressure in the evaporator outlet portion, the pressure of the compressor suction chamber and room (e.g., automotive passenger compartment) temperature, respectively. When the passenger compartment provides a high heat load, which, for example, commonly occurs after the automobile has been left unattended for a while during summer, and the air conditioning system is then turned on, pressure device 204 subsequently actuates pressure device 204s to send an "on" signal to solenoid valve 821 due to the pressure in evaporator outlet portion reaching or being above $2.3 \text{ kg/cm}^2 \cdot \text{G}$, which is indicated as P2. Accordingly, electromagnetic coil 821b is energized so that needle valve element 821c opens hole 821d to communicate crank chamber 13 and suction chamber 141. As a result, compressor 10 operates with slant plate 30 at a maximum slant angle, i.e., with maximum displacement, so that the pressure in the evaporator outlet portion and the pressure in the suction chamber fall quickly as shown in Figure 4 up to time t_1 . When the pressure in the evaporator outlet portion falls to $2.1 \text{ kg/cm}^2 \cdot \text{G}$, which is indicated as P1, (time t_1 has elapsed) pressure device 204 deactivates pressure device switch 204s so that an "off" signal is sent to solenoid valve 821. Accordingly, electromagnetic coil 821b deenergizes so that needle valve element 821c closes hole 821d to block the communication between crank chamber 13 and suction chamber 141. After closing hole 821d, first valve control device 81 solely controls communication between crank chamber 13 and suction chamber 141 in response to changes in crank chamber pressure while keeping suction chamber pressure generally at $2.0 \text{ kg/cm}^2 \cdot \text{G}$. Even

If the suction chamber pressure is kept at $2.0 \text{ kg/cm}^2 \cdot G$, the pressure at the evaporator outlet may exceed $2.3 \text{ kg/cm}^2 \cdot G$, regardless of pressure loss between the evaporator and compressor which occurs during large heat loads, i.e., when the air to be cooled is at a relatively high temperature. When the pressure of evaporator outlet portion is sensed to exceed $2.3 \text{ kg/cm}^2 \cdot G$ again, pressure device switch 204s is actuated so as to excite electromagnetic coil 821b. As a result, the pressure in the evaporator outlet portion and the pressure in the suction chamber fall quickly as shown in Figure 4 between t_1 and t_2 . When the pressure in the evaporator outlet portion falls to $2.1 \text{ kg/cm}^2 \cdot G$, pressure device switch 204 cuts off the "on" signal so as to release the excitation of electromagnetic coil 821b. Once more, first valve control device 81 controls the compressor crank chamber and suction pressures. The above mentioned process is continuously repeated until the pressure in the evaporator outlet portion does not rise to $2.3 \text{ kg/cm}^2 \cdot G$ when first valve control device 81 is solely controlling the compressor pressures. In Figure 4, elapsed time t_2 shows the end of the repeated process, i.e., the on-off signal cycles. After t_2 , first valve control device 81 solely and continuously controls the compressor crank chamber and suction pressures. First valve control device 81 is set to keep or stabilize the suction chamber at a level above the refrigerant pressure level where frost would form on the evaporator, but below P_1 . This assures that the refrigerant pressure at the evaporator outlet does not rise to an unacceptable cooling level when the override function of the second control device ceases (after t_2).

Referring to Figure 3, another refrigerating circuit including the compressor depicted in Figure 1 is shown. In this refrigerating circuit, a thermal device 214 is used instead of pressure device 204 of Figure 2. Thermal device 214 includes switch 214s to send "on" or "off" signals to solenoid valve 821 of second valve control device 82 in response to the temperature of the air leaving evaporator 203 (another thermodynamic characteristic related to the evaporator). For example, when the temperature reaches $4^\circ C$, thermal device 214 actuates switch 214s so as to send an "on" signal to solenoid valve 821.

On the other hand, when the temperature falls to 1°C , thermal device switch 214s causes an "off" signal to be sent to solenoid valve 821.

In the above mentioned embodiments shown in Figures 2 and 3, second valve control device 82 works in response to the pressure in the outlet portion of evaporator 203 and the temperature of the air leaving evaporator 203, respectively, as the thermodynamic characteristic related to evaporator 203. However, other thermodynamic characteristics related to evaporator 203 can be used for operating second valve control device 82, for example, heat load on evaporator 203, the temperature of air approaching evaporator 203, the temperature of refrigerant within the outlet portion of evaporator 203 and the surface temperature of a fin of evaporator 203.

Furthermore, all these thermodynamic characteristics related to evaporator 203 have certain relations to one another through formulas or equations.

Referring to Figure 5, still another refrigerating circuit including compressor 10 of Figure 1 is shown. This refrigerating circuit comprises a control circuit 221-226 responsive to sensing circuits 220 and 222 to control the "on" time of solenoid valve 821. The duty cycle (time period when valve 821 is on) for solenoid valve 821 is controlled in accordance with the stepwise duty ratio determination of Figure 6 in addition to the on-off control depicted in the functions of refrigerating circuits shown in Figures 2 and 3.

A control of the duty ratio in the refrigerating circuit of Figure 5 will be described hereafter. One output signal which indicates a measured surface temperature of a fin of evaporator 203 sensed by thermal sensor 220 is sent to comparator 221 as a first input signal thereof. A predetermined temperature range setting circuit produces a second input signal which represents a range from 4°C as the upper limit value to 1°C as the lower limit value, for example, in 0.6°C steps. Comparator 221 compares the first input signal to one of the steps of the range of second input signals, and sends a signal which indicates that the first input signal is within the stepwise range of the second input signal and an output is provided of the determination to



duty ratio decision circuit 223. Circuit 223 decides an appropriate duty cycle for solenoid valve 821 as follows. Referring to Figure 6, when the first input signal is within the predetermined range of 1° to 4°C, the duty ratio is determined by the depicted stepwise curve which provides a duty ratio which decreases in accordance to the decreasing temperature value of the first input signal as shown. An output signal relating to the appropriate duty ratio is produced in circuit 223 and is provided to a pulse width modulation circuit 224. Pulse width modulation circuit 224 produces a control signal for controlling wave oscillator 225 to provide a pulse stream having a predetermined width in accordance with the signal from circuit 223. The pulse stream provided by square wave oscillator 225 is amplified by a power amplifier, and provides for controlling the duty cycle of solenoid valve 821. Solenoid valve 821 receives an "on" signal during pulse peaks.

Referring to Figure 7, yet another refrigerating circuit including the compressor shown in Figure 1 is shown. In this refrigerating circuit, "on" time (duty cycle) of solenoid valve 821 is controlled by a duty ratio in response to a signal similar to the control signal for the refrigerating circuit shown in Figure 5. However, in this embodiment, the duty ratio in this refrigerating circuit is determined from a continuous curve according to Figure 8.

Thus, a control of the duty ratio of this refrigerating control circuit may be described as follows. The first signal which represents the surface temperature of the fin of evaporator 203 sensed by thermal sensor 220 is transmitted to amplifier 231 for amplification. The amplified sensor signal is sent to a comparator 232 through a variable resistor 233. A sawtooth wave provided by a sawtooth wave oscillator 234 is sent to the comparator and is sliced by the amplified sensor signal. A slicing level is proportionate to an intensity of the first signal so that various pulses are produced at the output of comparator 232 in accordance to the intensity of the first signal. In addition, the slicing level is adjusted by variable resistor 233. The pulse produced by comparator 232 is amplified by a power amplifier, and sent to solenoid valve 821. Solenoid valve 821 receives an "on" signal during



pulse peaks of the provided output pulse stream of comparator 232. Further, it is well known to produce various width pulses indicating different duty ratios by slicing a sawtooth wave. One example of a duty ratio control of solenoid valve 821 in this refrigerating circuit is shown in Figure 8. In this example, the duty ratio of the output of comparator 232 is set at 0% when the surface temperature of the evaporator fin is under the lower limit value ($+1^{\circ}\text{C}$), and is set at 100% when the surface temperature is over the upper limit value ($+4^{\circ}\text{C}$) and then is set in the range of 5% to 95% continuously when the surface temperature is between the lower limit value and the upper limit value.

A refrigerating circuit in which solenoid valve 821 is controlled by only continuously "on" or "off" signals, as shown in Figures 2 and 3, is suitable for the variable displacement compressor in which the variable displacement mechanism works slowly in response to changes in the heat load. On the other hand, a refrigerating circuit in which solenoid valve 821 is controlled by a duty ratio control circuit as shown in Figures 5 or 7 is suitable for the variable displacement compressor in which the variable displacement mechanism works quickly in response to changes in the heat load.

Furthermore, in the above mentioned embodiments, a device which controls the fluid communication path between the crank chamber and the suction chamber in response to the crank chamber pressure is used for the first valve control device. However, the present invention allows use of other types of devices as the first valve control device. For instance, a device which controls the fluid communication path between the crank chamber and the suction chamber in response to the suction chamber pressure may be used.

The present invention has been described in detail in connection with preferred embodiments. These embodiments, however, are merely for example only and the invention is not restricted thereto. It will be easily understood by those skilled in the art that variations and modifications can easily be made within the scope of this invention as defined by the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A refrigerating system including a refrigerant circuit, comprising a condenser, evaporator and compressor, the compressor including a compressor housing having a central portion, a front end plate at one end and a rear end plate at its other end, said housing having a cylinder block with a plurality of cylinders and a crank chamber, a piston slidably fitted within each of said cylinders, a drive mechanism coupled to said pistons to reciprocate said pistons within said cylinders, said drive mechanism including a drive shaft rotatably supported in said housing, a rotor coupled to said drive shaft and rotatable therewith, and coupling means for drivingly coupling said rotor to said pistons such that the rotary motion of said rotor is converted into reciprocating motion of said pistons, said coupling means including a member having a surface disposed at an incline angle relative to said drive shaft, said incline angle of said member being adjustable to vary the stroke length of said pistons and the capacity of said compressor, said rear end plate having a suction chamber and a discharge chamber, variable displacement control means for controlling angular displacement of said adjustable member comprising first valve control means for controlling fluid communication between said crank chamber and said suction chamber in response to changes in refrigerant pressure in said compressor, said first valve control means comprising a first passageway providing fluid communication between said crank chamber and said suction chamber and first valve means for controlling the opening and closing of said first passageway to vary the capacity of the compressor by adjusting the incline angle, said first valve means comprising a first valve to directly open and close said first passageway, said variable displacement control means



further comprising second valve control means for controlling fluid communication between said crank chamber and said suction chamber in response to a signal generated outside of the compressor, said second valve control means comprising a second passageway providing fluid communication between said crank chamber and said suction chamber and second valve means for controlling the opening and closing of said second passageway to vary the capacity of said compressor by adjusting the incline angle, said second valve means comprising a second valve to directly open and close said second passageway and override the operation of said first valve, and means for controlling the generation of said signal in response to at least one thermodynamic characteristic related to the evaporator as compared to two distinct boundary values.

2. The refrigerating system of claim 1 wherein at least one said thermodynamic characteristic is the pressure at the outlet portion of the evaporator.

3. The refrigerating system of claim 1 wherein said at least one thermodynamic characteristic is the heat load at the evaporator.

4. The refrigerating system of claim 1 wherein said at least one thermodynamic characteristic is the temperature of air approaching the evaporator.

5. The refrigerating system of claim 1 wherein said at least one thermodynamic characteristic is the temperature of air leaving the evaporator.

6. The refrigerating system of claim 1 wherein said at least one thermodynamic characteristic is the temperature of refrigerant within the outlet portion of the evaporator.

7. The refrigerating system of claim 1 wherein said at least one thermodynamic characteristic is the surface temperature of a fin of the evaporator.



8. The refrigerating system of claim 1 wherein the signal generating control means comprises a signal generating means for generating the signal, the signal generating means responsive to predetermined range setting means for establishing a predetermined range of values of said at least one thermodynamic characteristic in accordance with said two distinct boundary values.

9. The refrigerating system of claim 8 wherein the signal generating control means provides stepwise signal control within the predetermined range of the predetermined range setting means.



10. The refrigerating system of claim 8 wherein the signal generating control means provides continuous signal control within the predetermined range setting means.

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11. The refrigerating system of claim 8 wherein the output signal of said signal generating means comprises a pulsed signal having a determined duty ratio, the duty cycle of said second valve control means of said variable displacement control means being responsive to the duty ratio of said pulsed signal output.

12. The refrigerating system of claim 11 wherein the duty ratio of said pulsed signal output is determined in stepwise range relationship to the range between the two distinct boundary values.

13. The refrigerating system of claim 11 wherein the duty ratio of said pulsed signal output is determined in continuous range relationship to the range between the two distinct boundary values.

14. The refrigerating system of claim 1 wherein said signal generating control means includes sending means for sending an on signal to said second valve control means in response to said at least one thermodynamic characteristic being at or above the upper distinct boundary value.

15. The refrigerating system of claim 14 wherein said sending means further sends an on signal when said thermodynamic characteristic descends from at or above the upper boundary value toward the lower boundary value.

16. The refrigerating system of claim 1 wherein said signal generating control means includes sending means for sending an off signal to said second valve control means in response to said at least one thermodynamic characteristic being at or below the lower distinct boundary value thereby causing the first valve control means to solely control the capacity of the compressor.

17. The refrigerating system of claim 16 wherein said sending means further sends an off signal when said thermodynamic characteristic ascends from at or below the lower boundary value toward the upper boundary value thereby causing the first valve control means to solely control the capacity of the compressor.

18. The refrigerating system of claim 1 wherein the lower distinct boundary value corresponds to a value slightly above the frost point of said evaporator.

19. The refrigerating system of claim 1 wherein said first valve control means controls said suction chamber pressure to be generally constant at a level above a refrigerant pressure level where frost forms on the evaporator and below the pressure converted from the lower distinct boundary value.

20. A method for varying the displacement of a slant plate compressor by varying the incline angle of an inclined drive member of the compressor by controlling fluid communication between a suction chamber and a crank chamber of the compressor comprising the steps of:

sensing a thermodynamic characteristic related to the evaporator;

operating a valve control means to provide communication between the suction chamber and the crank chamber whenever the thermodynamic characteristic is sensed to be above a first boundary value;

continuing the operation of the first mentioned valve control means to provide communication between the suction chamber and the crank chamber as the thermodynamic characteristic is sensed to be proceeding from the first boundary value downward to a second lower boundary value;

ceasing the operation of the first mentioned valve control means when the thermodynamic characteristic is sensed to move below the second boundary value;

controlling communication between the suction chamber and crank chamber by operating another valve control means responsive to refrigerant pressure in the compressor when the thermodynamic characteristic is sensed to be moving upward from below and toward the first boundary value; and

overriding the operation of the other valve control means and operating the first mentioned valve control means if the



thermodynamic characteristic is sensed to move above the first boundary value.

21. The method of claim 20 wherein the pressure at the outlet portion of an evaporator in a refrigerating system including the compressor is the sensed thermodynamic characteristic.

22. The method of claim 21 wherein the lower boundary value is a pressure above the pressure level at which frost would form on the evaporator.

23. The method of claim 21 wherein the other control valve means operates to provide communication between the suction chamber and the crank chamber so as to keep the suction pressure at a level above the pressure level at which frost would form on the evaporator but below the lower boundary value.

24. The method of claim 20 wherein the heat load at the evaporator is the sensed thermodynamic characteristic.

25. The method of claim 20 wherein the sensed thermodynamic characteristic is the temperature of air approaching the evaporator.

26. The method of claim 20 wherein the sensed thermodynamic characteristic is the temperature of air leaving the evaporator.

27. The method of claim 20 wherein the sensed thermodynamic characteristic is the temperature of refrigerant within the outlet portion of the evaporator.

28. The method of claim 20 wherein the sensed thermodynamic characteristic is the surface temperature of a fin of the evaporator.

29. A refrigerating system including a refrigerant circuit substantially as hereinbefore described with reference to the accompanying drawings.



30. A method of varying the displacement of a slant plate compressor substantially as hereinbefore described with reference to the accompanying drawings.

DATED THIS 7TH DAY OF MARCH 1991

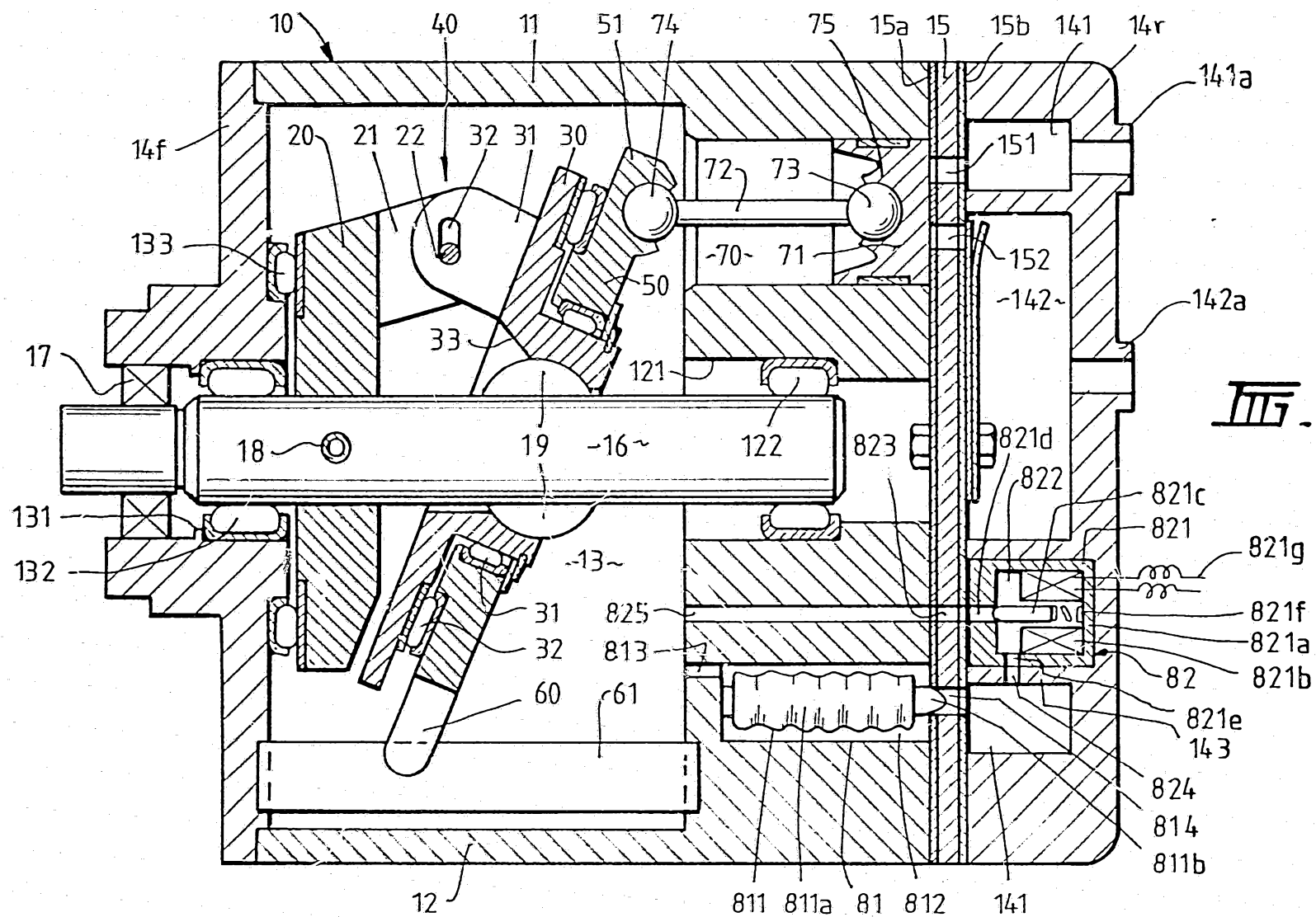
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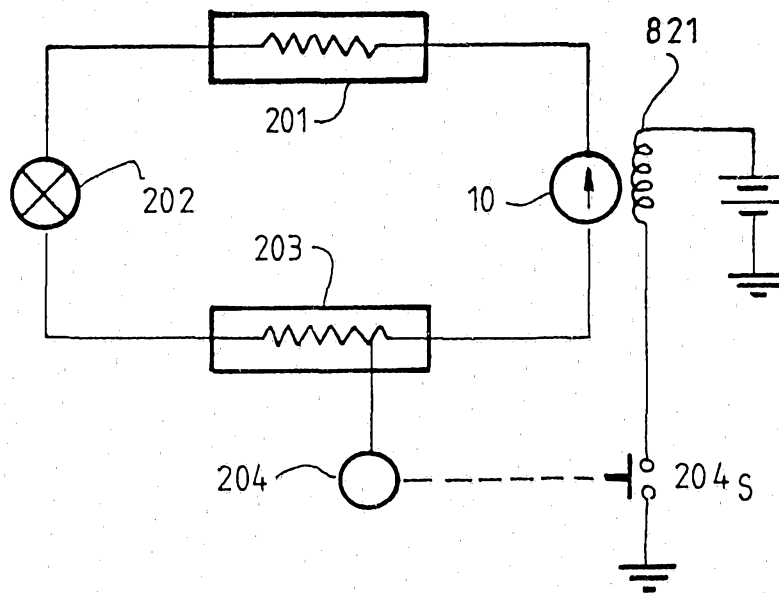


FIG. 2.

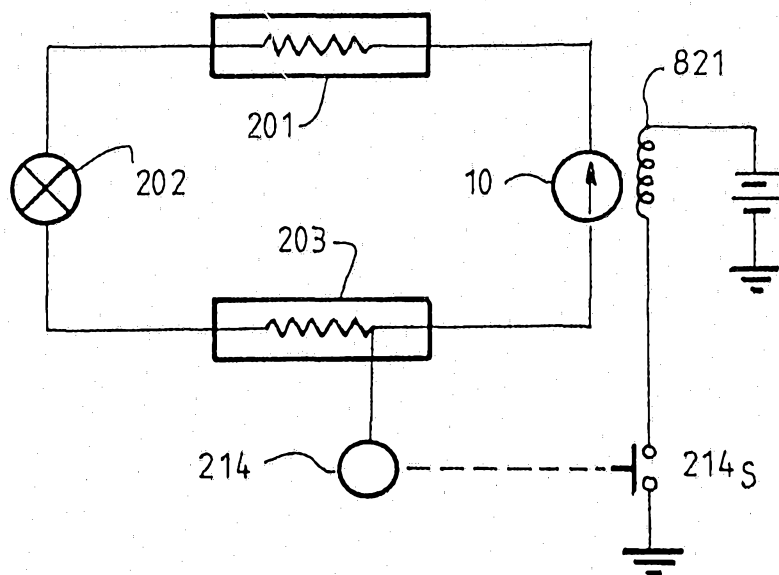
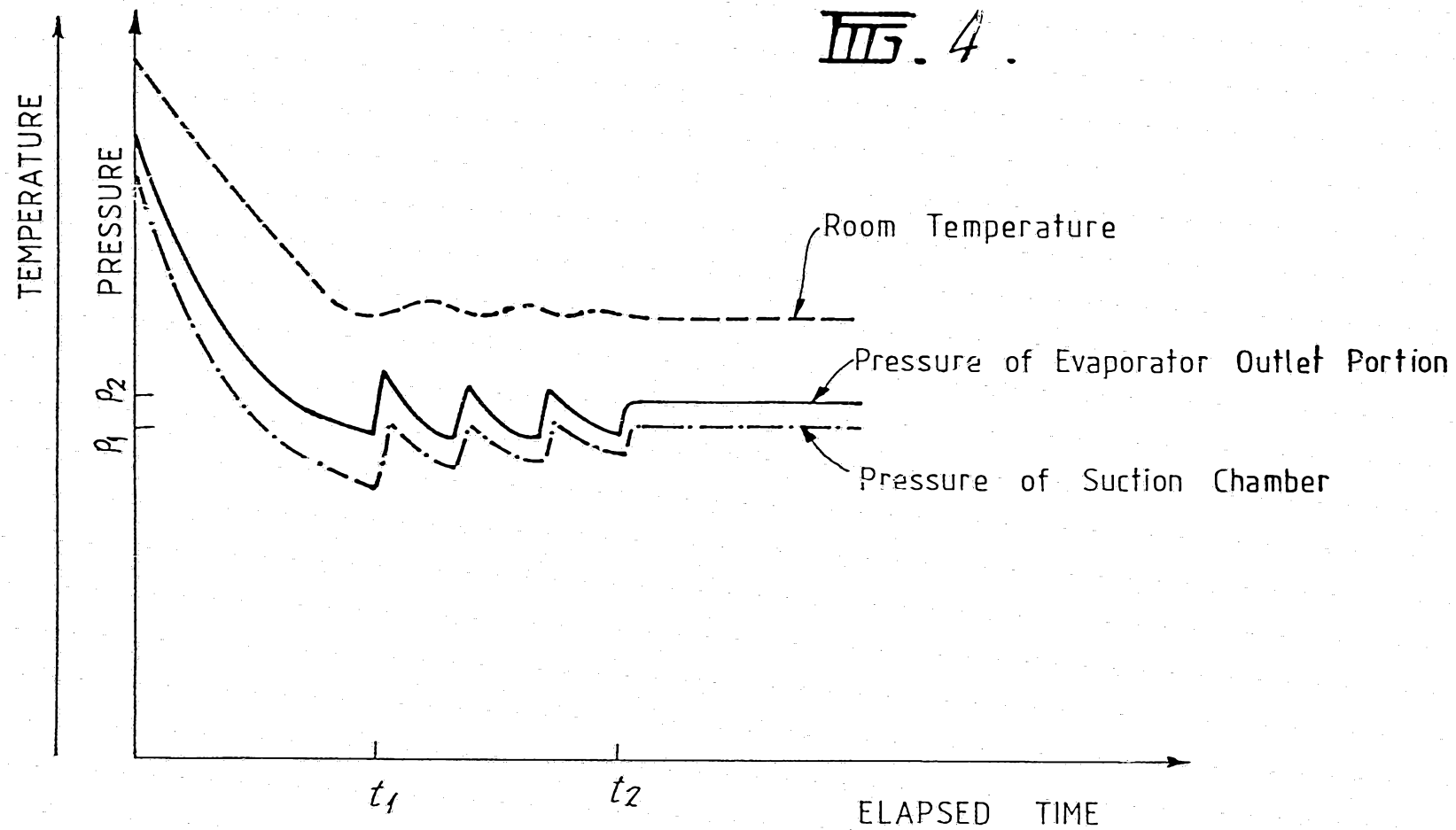


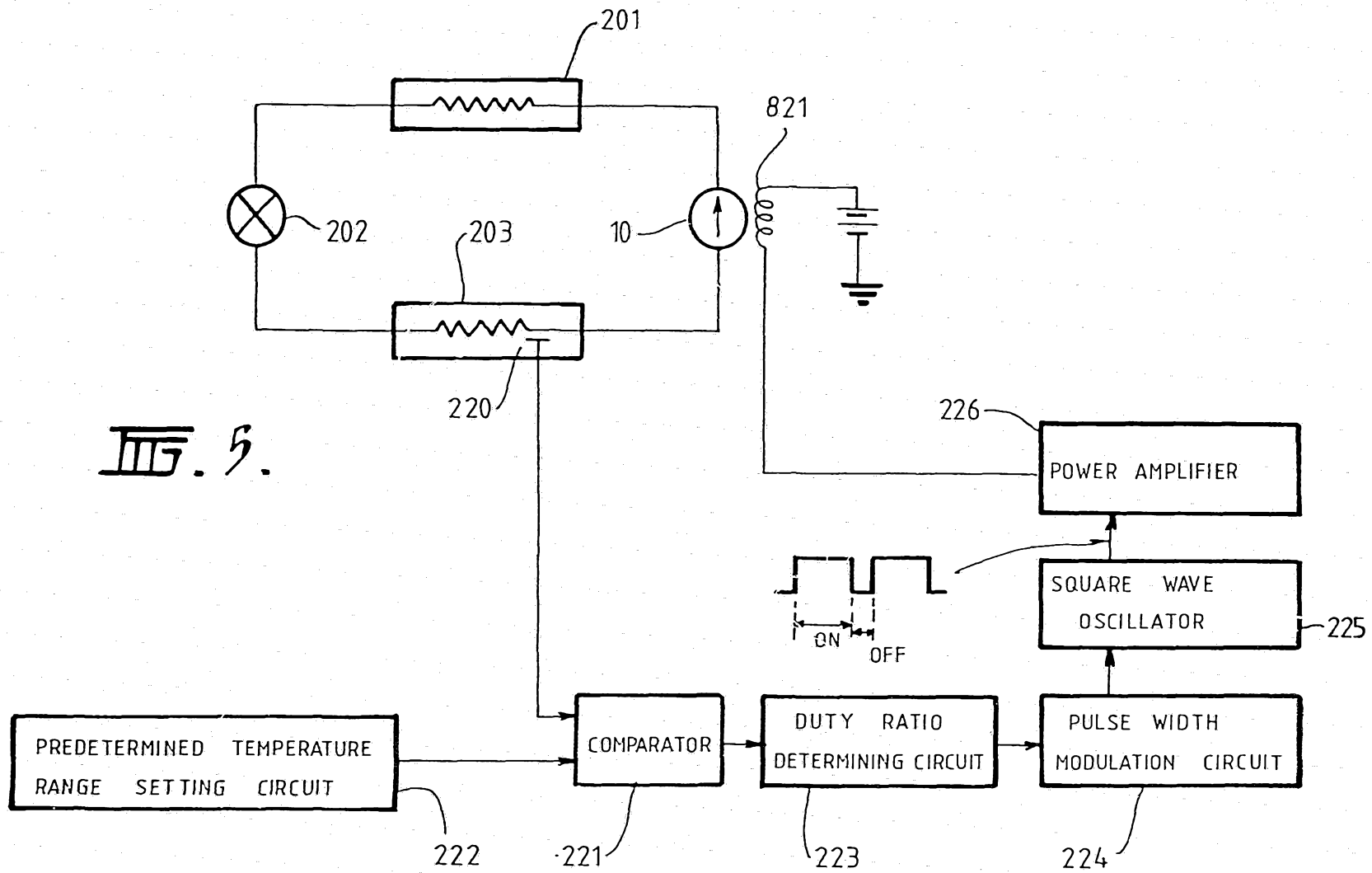
FIG. 3.

Fig. 4.



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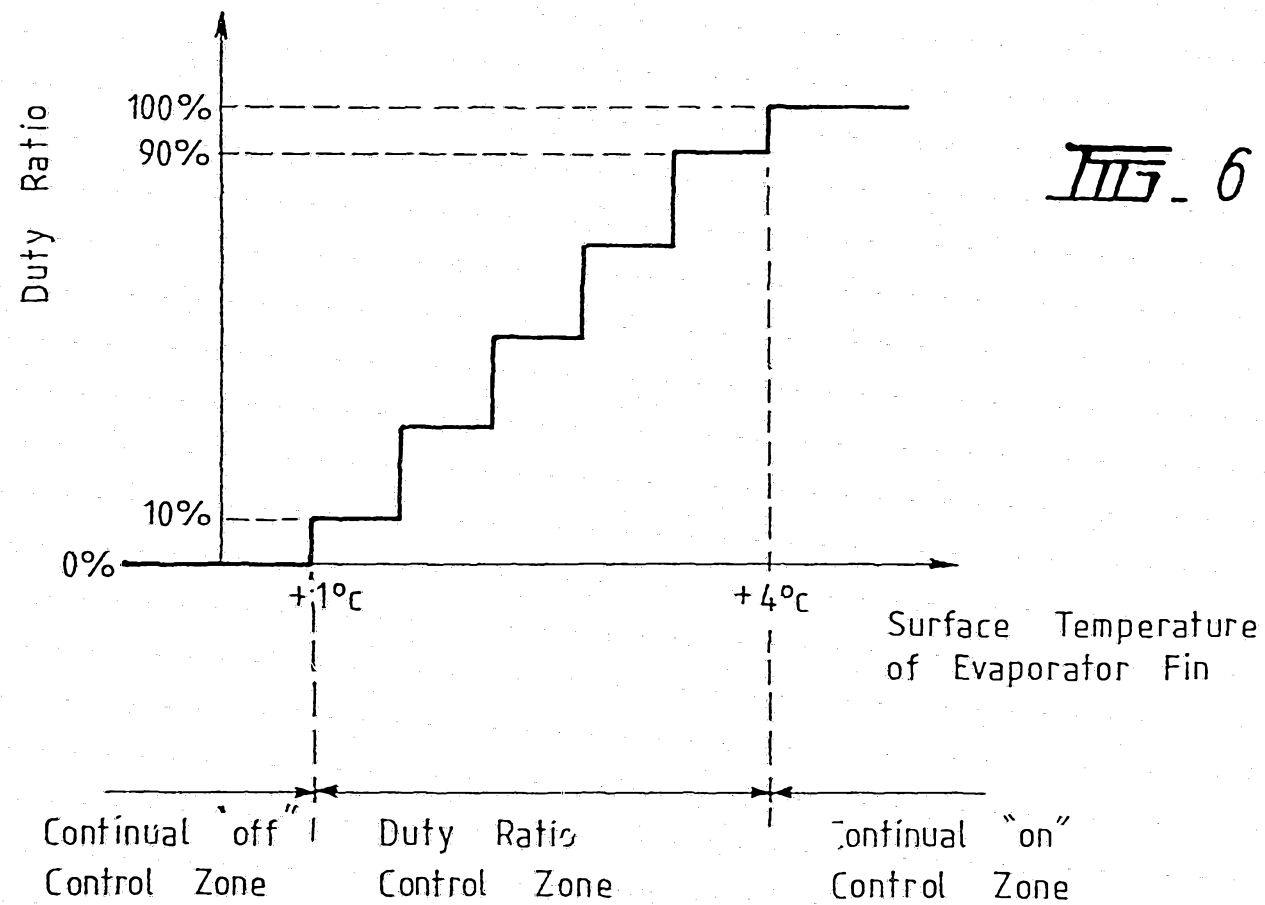


FIG. 6.

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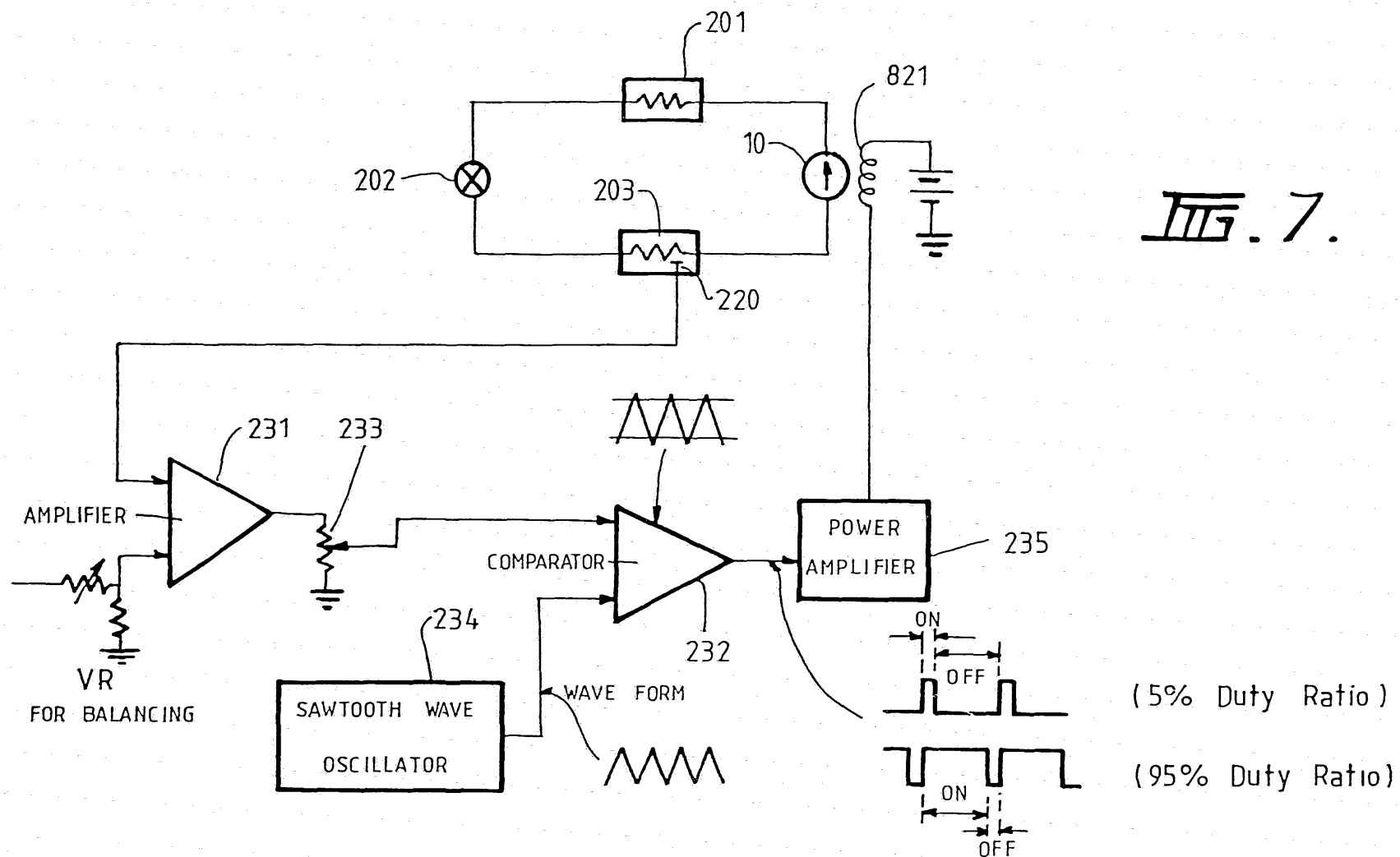
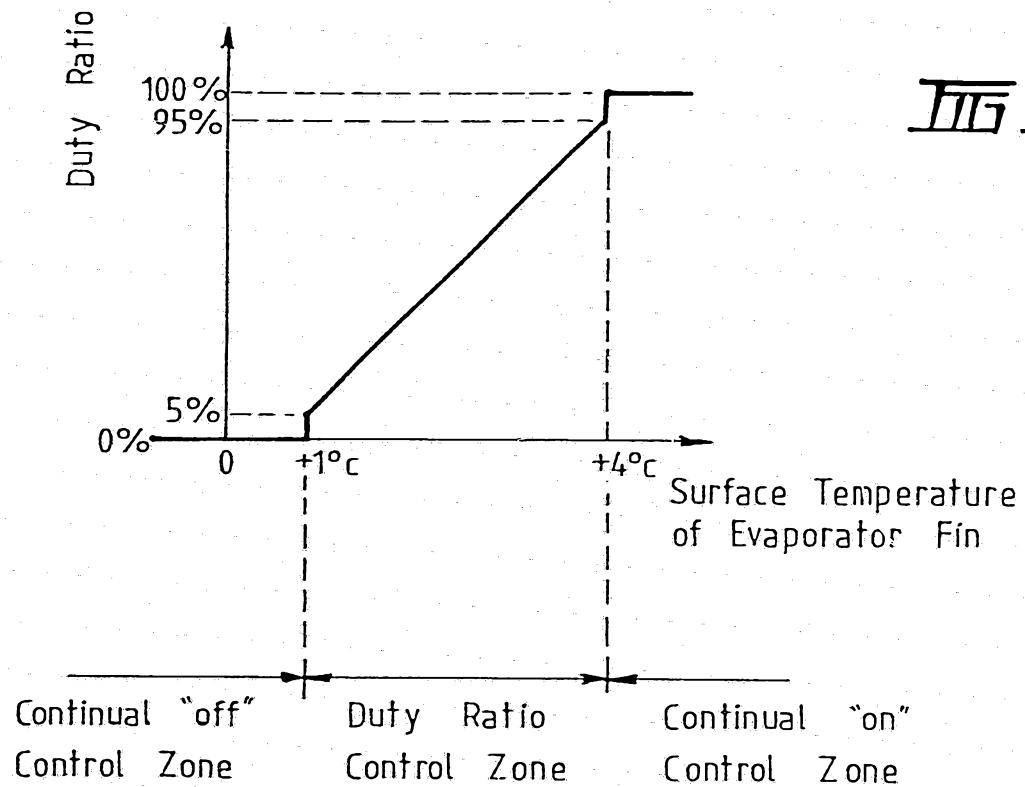


FIG. 7.



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FIG. 9.

