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(54) **Apparatus for controlling a variable displacement compressor.**

(57) Disclosed is an apparatus for controlling a variable displacement compressor, in which a solenoid valve is controlled depending on internal and external thermal load conditions of the compressor for selectively blocking fluid communication between high and low pressure sides.

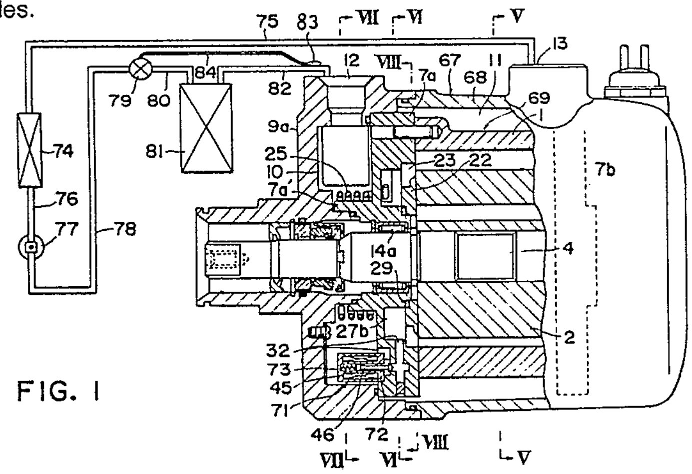


FIG. I

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# APPARATUS FOR CONTROLLING A VARIABLE DISPLACEMENT COMPRESSOR

The present invention relates to an apparatus for controlling a sliding-vane rotary compressor suitable for use in an automotive air conditioning system and including a mechanism for adjusting displacement thereof.

There are known various adjustment mechanisms incorporated in a sliding-vane rotary compressor for adjusting displacement thereof. On the one hand there are internal control systems using a pressure-operated control valve (US-A-4 060 343). On the other hand external control systems are well known using a solenoid valve acting on a communication line for effecting external control of the displacement of the compressor (JP-A-58 72 690).

The object of the present invention is to provide an apparatus for controlling a variable displacement compressor relyably without causing objectionable delay in controlling operation and being simple in construction and capable of effecting a fine control of the compressor.

According to the present invention there is provided an apparatus for controlling a variable displacement compressor, which comprises:
electric on-off means for selectively blocking the communication between a low pressure chamber and a high pressure chamber in the compressor;
sensor means for detecting internal and external thermal load conditions for controlling operation of the compressor; and
control means for controlling operation of the electric on-off means on the basis of the interal and external thermal load conditions detected by the sensor means.

With this construction, both internal and external displacement controls of the compressor are effected by a single controller. Thus, the apparatus as a whole is simple in construction.

Many other advantages and features of the present invention will become manifest to those versed in the art upon making reference to the detailed description and the accompanying sheets of drawings in which preferred structural embodiments incorporating the principles of the present invention are shown by way of illustrative example.

FIG. 1 is a schematic view showing the general construction of a refrigeration cycle incorporating a sliding-vane rotary compressor employed in a controller for variable displacement compressors according to the present invention;

FIG. 2 is a cross-sectional view taken along line V - V of FIG. 1;

FIG. 3 is a cross-sectional view taken along line VI - VI of FIG. 1;

FIG. 4 is a cross-sectional view taken along line VII - VII of FIG. 1;

FIG. 5 is a cross-sectional view taken along line VIII - VIII of FIG. 1;

FIG. 6 is a block diagram showing a controller according to one embodiment; and

FIG. 7 is a block diagram showing a controller according to another embodiment.

FIG. 1 shows the general construction of a refrigeration cycle in which a sliding-vane rotary compressor (variable displacement compressor) is incorporated. The compressor includes a housing 67 composed of a tubular casing 68 opening at one end and a shell 9a connected by bolts (not shown) to the casing 68 so as to close the open end of the casing 68. The casing 68 has a discharge port 13 disposed on the rear side thereof and extending through an upper wall of the casing 68 for discharging a refrigerant gas acting as a heat transferring medium. The shell 9a has a refrigerant gas intake port 12 formed in an upper wall thereof. The discharge port 13 and the intake port 12 are held in fluid communication with a high pressure chamer 11 and a low pressure chamber 10, respectively.

The housing 67 contains a compressor body 69 which essentially comprises a cylinder 1, a pair of side blocks 7a, 7b connected to the cylinder 1 to close the opposite open ends of the cylinder 1, a substantially cylindrical rotor 2 rotatably disposed in the cylinder 1, and a drive shaft 4 connected to the rotor 2 for rotating the latter. The drive shaft 4 is rotatably supported by a pair of radial bearings 14a (only one appearing with the side block 7a) mounted in the respective side blocks 7a, 7b.

As shown in FIG. 2, the cylinder 1 includes an elliptical inner wall which defines jointly with the outer peripheral wall of the rotor 2 a pair of operating spaces 3a, 3b disposed in diametrically opposite symmetrical relation.

The rotor 2 has a plurality (four in the illustrated embodiment) of radial slots 5 circumferentially spaced at equal angular intervals, and vanes 6 movably inserted in the respective slots 5.

The side block 7a has a pair of diametrically opposite symmetrical intake holes 16a, 16b, as shown in FIGS. 2 through 5. The intake holes 16a, 16b are located at respective positions in which compression chambers 8, which are defined by and between the cylinder 1, rotor 2, vanes 6 and side blocks 7a, 7b, becomes maximum in volumetric size. The intake holes 16a, 16b extend through the thickness of the side block 7a so that the compression chambers 8 are communicatable through the intake holes 16a, 16b with a low pressure chamber 10 defined between the shell 9a and the side block 7a.

The cylinder 1 has a pair of discharge holes 17a, 17b extending through its confronting peripheral wall portions and connecting therethrough the compression chambers 8 and a high pressure chamber 11 which is defined in the casing 68. The discharge holes 17a, 17b have disposed theein a pair of delivery valves 20a, 20b and associated stoppers 21a, 21b.

The side block 7a, as shown in FIG. 5, has formed in its one surface an annular groove 23 facing the rotor 2. The groove 23 has a pair of arcuate by-pass ports 70, 70 disposed in diametrically opposite symmetrical relation for connecting therethrough the compression chambers 8 and the low pressure chamber 10. The open area of the by-pass ports 70, 70 is adjusted by a ring-like adjustment member 22 which is rotatably fitted in the annular groove 23 and is angularly movable in either direction. The adjustment member 22 includes a pair of cut-out recesses 24a, 24b extending arcuately along the outer peripheral edge thereof and disposed in diametrically opposite symmetrical relation. The adjustment member 22 further includes a pair of integral tongue-like pressure-retaining portions 26a, 26a extending from one of its opposite surfaces and disposed in diametrically opposite symmetrical relation. The pressure-retaining portions 26a, 26a are slidably fitted in a pair of arcuate guide grooves 27a, 27b. With the pressure-retaining portions 26a, 26b, the guide grooves 27a, 27b are each divided into first and second pressure chambers 28a, 28a′; 28b, 28b′ disposed on opposite sides of the corresponding pressure-retaining portion 26a, 26b. The first pressure chambers 28a, 28b communicate with the low pressure chamber 10 via the intake holes 16a, 16b and the by-pass ports 70. One of the second pressure chambers (Pc chamber) 28a′ communicates with the high pressure chamber 11 via an orifice 34. The second pressure chambers 28a′, 28b′ are held in communication with each other via a connecting passage 30. The orifice 34 is disposed between the second pressure chamber 28a′ and the high pressure chamber 11.

A seal member 29 of a specific design is fitted over a central portion of one surface of the adjustment member 22 and also over opposite edges of each of the pressure-retaining portions 26a, 26b. With this seal member 29, there are provided hermetic seals between the first and second pressure chambers 28a, 28a′; 28b, 28b′ and between the central portion of the adjustment member 22 and a central portion of the annular groove 23 in the side block 7a.

The adjustmemt member 22 is urged by a biasing means composed of a spring 25 to turn in one direction (counterclockwise direction in FIG. 5) to enlarge the open area of the by-pass ports 70. The spring 25 is fitted around a central cylindrical boss 7a′ extending from she side block 7a toward the low pressure chamber 10. The spring 25 is connected at one end to the central boss 7a′ and at the other end to the adjustment member 22.

The second pressure chamber 28b′, as shown in FIG. 3, is held in communication with the low pressure chamber 10 via a first high pressure guide passage 32 in which a solenoid valve (on-off means) 71 is disposed. The valve 71 is opened upon energization and includes a housing 72, an exciting coil 45 disposed in the housing 72, a needle valve element 47 movable to open and close the first high pressure guide passage 32, and a valve spring 73 for urging the needle valve element 47 in a direction to close the valve. In response to energization and de-energization of the exciting coil 45, the needle valve element 47 of the solenoid valve 71 opens and closes the first high pressure guide passage 32 to thereby selectively make and block the communication between the low pressure chamber 10 and the high pressure chamber 11 through the first high pressure guide passage 32, the second pressure chamber 28b′, the connecting passage 30, the second pressure chamber 28a, and the orifice 34.

The sliding-vane rotary compressor constitutes part of the refrigeration system or cycle shown in FIG. 1. To this end, the discharge port 13 of the compressor is connected through a line 75 to the inlet of a condenser 74, the outlet of which is connected to the inlet of an expansion valve 79 successively through a line 76, a reservoir 77 and a line 78. The outlet of the expansion valve 79 is connected via a line 82 to the inlet of an evaporator 81, the outlet of which is connected via a line 82 to the intake port 12 of the compressor. The expansion valve 79 is connected through capillary tube 84 to a thermo-sensing tube 84 closely juxtaposed on the line 82 at the outlet side of the evaporator 81.

FIG. 6 is a block diagram showing a controller, wherein the reference numeral 55 denotes a sensor means for detecting both external and internal thermal load conditions of the air conditioning system including a power source of the compressor. The sensor means 55 is composed of an external sensor means 55a for detecting the external thermal load conditions, and an internal sensor means 55b for detecting the internal thermal load conditions. The external sensor means 55a comprises an engine cooling water temperature switch 56, an accelerator switch 57 and an evaporator outlet switch 58. The engine water temperature switch 56 is disposed in a device for cooling an engine (not shown) and is adapted to be turned on when the temperature of engine cooling water exceeds a preset value. The accelerator switch 57 is disposed adjacent to an accelerator pedal (not shown) and is adapted to be turned on when the step-in or depressing angle exceeds a predetermined value. The engine cooling water temperature switch 56 and the accelerator switch 57 have fixed contacts 56a, 57a, respectively, connected to ground level. Movable contacts 56b, 57b of these switches 56, 57 are connected, in negative logic, to the input side of an OR gate or circuit 60. A pair of DC power sources DC5V is connected via resistors to the junctions, respectively, between the engine cooling water temperature switch 56 and the OR circuit 60 and between the accelerator switch 57 and the OR circuit 60. The evaporator outlet switch 58 is disposed adjacent to the outlet of the evaporator 81 and is adapted to be turned on when the pressure Pe of the regrigerant gas at the evaporator outlet exceeds a preset value. The evaporator switch 58 has a grounded fixed contact 58a and a movable contact 58b connected to the input side of a first AND gate or circuit 61.

The internal sensor means 55b comprises a Pc pressure switch 59 disposed in a suitable position which is normally held in communication with the second pressure chambers (Pc chamber) 28a′, 28b′. The Pc pressure switch 59 is adapted to be turned on when the pressure Pc in the second pressure chambers 28a′, 28b′ exceeds a preset value. The Pc pressure switch 59 has a grounded fixed contact 59a and a movable contact 59b connected to the input side of a second AND gate or circuit 62 via a non-illustrated inverter. A pair of DC power sources DC5V is connected via resistors to the junctions, respectively, between the evaporator outlet switch 58 and the first AND circuit 61, and between the Pc pressure switch 59 and the second AND circuit 62.

The controller further includes a control means 63 composed of an oscillator 64, a logic circuit or unit 65, a driver circuit 66, a DC power source DC12V and the DC power sources DC5V. The oscillator 64 produces a pulse signal for enabling the solenoid valve 71 to alternately connecting and blocking flow communication between the low pressure chamber 10 and the high pressure chamber 11. The oscillator 64 is connected to the input side of each of the first and second AND circuits 61, 62.

The logic circuit or unit 65 is composed of the first and second AND circuits 61, 62 and the OR circuit 60. The output sides of the AND circuits 61, 62 are connected to the input side of the OR circuit 60. These circuits 60 -62 are provided for controlling the solenoid valve 71 on the basis of the internal and external thermal load conditions detected by the sensor means 55.

The driver circuit 66 includes a first transistor Tr1, a second transistor Tr2, a first resistor R1, a second resistor R2, a third resistor R3, a diode D and a capacitor C.

The DC power source DC12V is connected through the diode D to the collectors of the first and second transistors Tr1, Tr2. The emitter of the first transistor Tr1 is directly connected to the ground level while the emitter of the second transistor Tr2 is grounded via the base of the first transistor Tr1 and the first resistor R1.

The output side of the OR circuit 60 is connected to the base of the second transistor Tr2 via the capacitor C and the second resistor R2 that are connected in parallel relation. The third resistor R3 is connected to the junction between the second transistor Tr2, the capacitor C and the second resistor R2 and also to the junction between the first and second transistor Tr1, Tr2 and further to one terminal of the first resistor R1.

The exciting coil 45 of the solenoid valve 71 has one terminal connected to the junction between the DC power source DC12V and the diode D, the other terminal thereof being connected to the diode D and also to the junction between the first and second transistors Tr1, Tr2.

Operation of the sliding-vane rotary compressor of the foregoing construction is described below in greater detail.

The drive shaft 4 is driven by a vehicle engine to rotate the rotor 1 in the clockwise direction in FIG. 2 whereupon the vanes 8 project radially outwardly from the radial slots 5 due to the centrifugal force and the back pressrue acting thereon. With revolution of the rotor 1, the vanes 6 slide along inner wall of the cylinder 1 during which time the compression chambers 8 between the vanes 6 subsequently increase and decrease in size. In the intake stroke in which the compression chambers 8 increases in size, the refrigerant gas is drawn into the compression chambers 8 from the intake holes 16a, 16b. In the succeeding compression stroke in which the compression chambers 8 reduces in size, the refrigerant gas is compressed in the compression chambers 8. In the succeeding discharge stroke, the delivery valves 20a, 20b are forced to open by the pressure of the compressed refrigerant gas, whereupon the refrigerant gas is discharged from the the compressor successively through the discharge holes 17a, 17b, the high pressure chamber 11 and the discharge port 13. The compressed refrigerant gas thus discharged is then circulated through the refrigeration system.

While the compressor is in operation, the pressure in the low pressure chamber 10 is introduced as a low pressure Ps to the first pressure chambers 28a, 28b through the intake holes 16a, 16b. At the same time, the pressure in the high pressure chamber 11 is introduced as a high pressure Pd to the second pressure chambers 28a′, 28b′ through the orifice 34. With this arrangement, the pressure-retaining portions 26a, 26b are subjected concurrently to a first force tending to turn the adjustment member 22 in the direction of the arrow B in FIG. 5 to thereby enlarge the open area of the by-pass ports 70 (the first force is a combination of the pressure in the first pressure chambers 28a, 28b and the force of the spring 25), and a second force tending to turn the adjustment member 22 in the direction of the arrow A in FIG. 5 to thereby reduce the open area of the by-pass ports 70 (the second force is the pressure in the second pressure chambers 28a′, 28b′). Consequently, in response to a difference between the first and second forces, the adjustment member 22 is turned in either direction to adjust the open area of the by-pass ports 70, thereby controlling the compression starting timing and hence the displacement of the compressor. The pressure of the first pressure chambers 28a, 28b and the pressure in the second pressure chambers 28a′ 28b′ are changed by the solenoid valve 71 which is operative to alternately open and close the first high pressure guide passage 32 for making and blocking fluid communication between the low presser chmamber 10 and the second pressure chambers 28a′ 28b′. With this pressrue change, the adjustment member 22 is turned in either direction to thereby vary the open area of the by-pass ports 70. It is therefore apparent that a continuous adjustable control of displacement of the compressor is possible by properly controlling the operation of the solenoid valve 71.

The evaporator outlet switch 58 which is disposed adjacent to the outlet of the evaporator 81 is turned on when the evaporator outlet pressure Pe becomes higher than a preset value such as 2.0 $Kg/cm^2$, for example. In this instance, no output appears on the output side of the first AND circuit 61 of the logic unit 65. Consequently, the driver circuit 66 does not receive any driving signal from the logic unit 65 with the result that the solenoid valve 71 remains in the valve closing position, thereby blocking the first high pressure guide passage 32. The pressure Pd in the high pressure chamber 11 is introduced through the orifice 34 into the second pressure chambers 28a′, 28b′ to increase the presssure Pc in these second chambers. When the pressure Pc exceeds the combined force of the pressure in the first pressure chambers 28a, 28b and the force of the spring 25, the spring 25 yields up, permitting the adjustment member 22 to turn in the direction of the arrow A in FIG. 5 until the adjustment member 22 assumes its angular position indicated by the phantom lines in which the by-pass ports 70 are fully closed by the adjustment member 22. Under such condition, all amount of the refrigerant gas which has been fed to the compression chambers 8 through the intake holes 16a, 16b is compressed and then discharged. The compressor is now operating at full power with a maximum displacement.

When the pressure Pc is excessively high such as, for example, greater than 10 $kg/cm^2$, the Pc pressure switch 59 is turned on to produce an on-signal which in turn is inputted, in negative logic, to the second AND circuit 62. Since pulse signals (on-off signal to the solenoid 71) are supplied by the oscillator 64 to the second AND circuit 62, the second AND circuit 62 delivers periodical voltage signals through the OR circuit 60 to the driver circuit 66 as long as the Pc pressure switch 59 is kept in on-stage. The periodical voltage signals thus supplied cause the first and second transistors Tr1, Tr2 to be triggered or turned on correspondingly to thereby alternately energize and de-energize the exciting coil 45. In response thereto, the solenoid valve 71 alternately opens and closes the first high pressure guide passage 32. This enables that the pressure in the second pressure chambers 28a′, 28b′ (i.e., Pc pressure) is relieved toward the low pressure chamber 10 through the first high pressure guide passage 32. Then, the Pc pressure is decreased. When the Pc pressure becomes lower than the preset value such as 10 $Kg/cm^2$, for example, the Pc pressure switch 59 is turned off. Then the off-signal is supplied, in negative logic, to the second AND circuit 62 which in turn terminates supply of the pulse signals to the driver circuit 66 to the oscillator 64. In the absence of the signal supply, the solenoid valve 71 is kept in valve-closing position, thereby blocking the first high pressure guide passage 32.

When the outlet pressure Pe of the evaporator 81 becomes lower than the preset value such as, 2.0 $Kg/cm^2$, for example, the evaporator outlet switch 58 is turned off. So long as the off-stage of the evaporator outlet switch 58 continues, the first AND circuit 61 sends periodical voltage signals through the OR circuit 60 to the driver circuit 66, in synchronism with pulse signals received from the oscillator 64. Upon reciept of the voltage signals, the first and second transistors Tr1, Tr2 are periodically turned on, thereby alternately energizing and de-energizing the exciting coil 45. In response thereto, the solenoid vlave 71 alternately opens and closes the first high pressure guide passage 32. This valve operation enables that the Pc pressure in the second pressure chambers 28a′, 28b, is relieved toward the low pressure side or the low pressure chamber 10. With this pressure relief, the Pc pressure is dropped with the result that the adjustment member 22 is caused to turn in the direction of the arrow 9 of FIG. 5 until the cut-out recesses 24a, 24b are brought in registry with the corresponding by-pass ports 70. The by-pass ports

70 are thus opened as indicated by the solid lines in FIG. 5. Consequently, the refrigerant gas which has been introduced through the intake holes 16a, 16b to the compression chambers 6 is allowed to flow through the by-pass ports 70 into the low pressure chamber 10. With the by-pass ports 70 thus open, the compression starting timing is retarded and hence the amound of refrigerant gas to be trapped in the compression chambers 8 is reduced. The power or displacement of the compressor is therefore reduced.

It appears from the foregoing that a delay in controlling operation is avoidable because the displacement of the compressor is controlled in such a manner that the outlet pressure Pe of the evaporator in the refrigerant cycle is always maintained at the preset value.

The engine cooling water temperature switch 56 is turned on when the engine cooling water becomes hotter than a preset value. As the on-off signals of the engine cooling water temperature switch 56 are inputted, in negative logic, to the OR circuit 60 in the logic unit 65, the OR circuit 60 continuously delivers a voltage signal to the driver circuit 66 so long as the switch 56 is kept in on-stage. In response to the voltage signal thus supplied, the first and second transistors Tr1, Tr2 are turned on to thereby energize the exciting coil 45, whereupon the solenid valve 71 opens the first high pressure guide passage 32. The Pc pressure is now relieved through the first high pressure guide passage 32 toward the low pressure chamber 10. With this pressure relief, the Pc pressure is dropped and hence the compression starting timing is retarded in the same manner as demonstrated when the evaporator outlet switch 58 is turned off. As a result, the displacement of the compressor is reduced and engine load is also reduced correspondingly. With this load reduction, it is possible to avoid an engine overheating.

In case the temperature of engine cooling water is lower than the preset value, the engine cooling water temperature switch 56 is turned off. Since the off-signal of the switch 56 is delivered, in negative logic, to the OR circuit 60, the OR circuit 60 does not supply a voltage signal to the driver cricuit 66 so long as the switch 56 is kept in off-stage. Under such condition, the solenoid valve 71 keeps the first high pressure guide passage 32 in blocked condition.

The accelerator switch 57 is turned on when the depression or step-in angle exceeds a preset value. Since signals from the accelerator switch 57 is delivered, in negative logic, to the OR circuit 60 in the logic unit 65, the OR circuit 60 continuously sends voltage signals to the driver circuit 66 so long as the accelerator switch 57 is kept in on-stage. In this condition, the first and second transistors Tr1, Tr2 are turned on to thereby energize the excitig coil 45. Upon energization of the coil 45, the solenoid valve 71 opens the first high pressure guide pass age 32 whereupon the Pc pressure is relieved through the first high pressure guide passage 32 toward the low pressure chamber 10. This pressure relief lowers the Pc pressure. Further, with the first high pressure guide passage 32 thus opened, the compression starting timing is retarded correspondingly and hence the amount of refrigerant gas to be trapped in the compression chambers 8 is also reduced, in the same manner as experienced when the evaporator outlet switch 58 is turned off. Since the displacement of the compressor is reduced, the engine load is also reduced. This is advantageous in that part of the engine power which is corresponding to the reduced engine load can be used for cruising of the vehicle.

When the accelerator depression angle is smaller than the preset value, the accelerator switch 57 is turned off. So long as such off-stage of the accelerator switch 57 continues, the OR circuit 60 does not issue a voltage signal to the driver circuit 66. Thus, the solenid valve 71 keeps the first high pressure guide passage 32 in blocked condition.

FIG. 7 shows a modified apparatus for controlling variable displacement compressor according to another embodiment. The controller is substantially identical with the controller of the foregoing embodiment with the exception that the evaporator outlet switch 58 as required in the foregoing embodiment is ommitted for, reduced cost, and a controll valve 67 with a pressure responsive bellows is provided. With the controller thus constructed, the control of displacement of the compressor is effected basically internally by the bellows-actuated control valve 67 but partly externally by an electric circuit incorporating the switch 58.

Other structual details and function of the controller are the same as those of the controller shown in FIG. 6 and a description is not necessary. With this similarity in view, the same or corresponding parts are indicated by the same reference characters throughout FIGS. 6 and 7.

Although the foregoing embodiments are described with respect to sliding-vane rotary compressors, the present invention is not limited to such embodiments. Rather, the invention is also useful when embodied in a compressor of different type.

Further, in place of the oscillator 64, a duty ratio control system may be used. The duty ratio control system is operative in response to the pressure Ps of the lower pressure side which varies in the range of 1.7 - 2.0 $Kg/cm^2$. As the pressure Ps becomes close to 1.7 kg/cm$^2$, the opening period of the solenoid valve 71 is elongated to nearly 100%, thereby operating the compressor at a reduced power. On the contrary, when the intake pressure Ps becomes equal to 2.0 Kg/cm$^2$, the valve opening time is reduced to 0%, thereby operating the compressor at full power.

Although the sensor means 55 in the illustrated embodiements comprises the engine cooling water temperature switch 56, the accelerator switch 57, the evaporator outlet switch 58, and the Pc pressure switch 59, the present invention is not limited to these switches. Rather, it is possible to omit or modify any one of these switches. Addition of the other sensor is also possible.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

## Claims

1. An apparatus for controlling a variable displacement compressor, which comprises:

(a) electric on-off means (71) for selectively blocking the communication between a low pressure chamber (10) and a high pressure chamber (11) in said compressor;

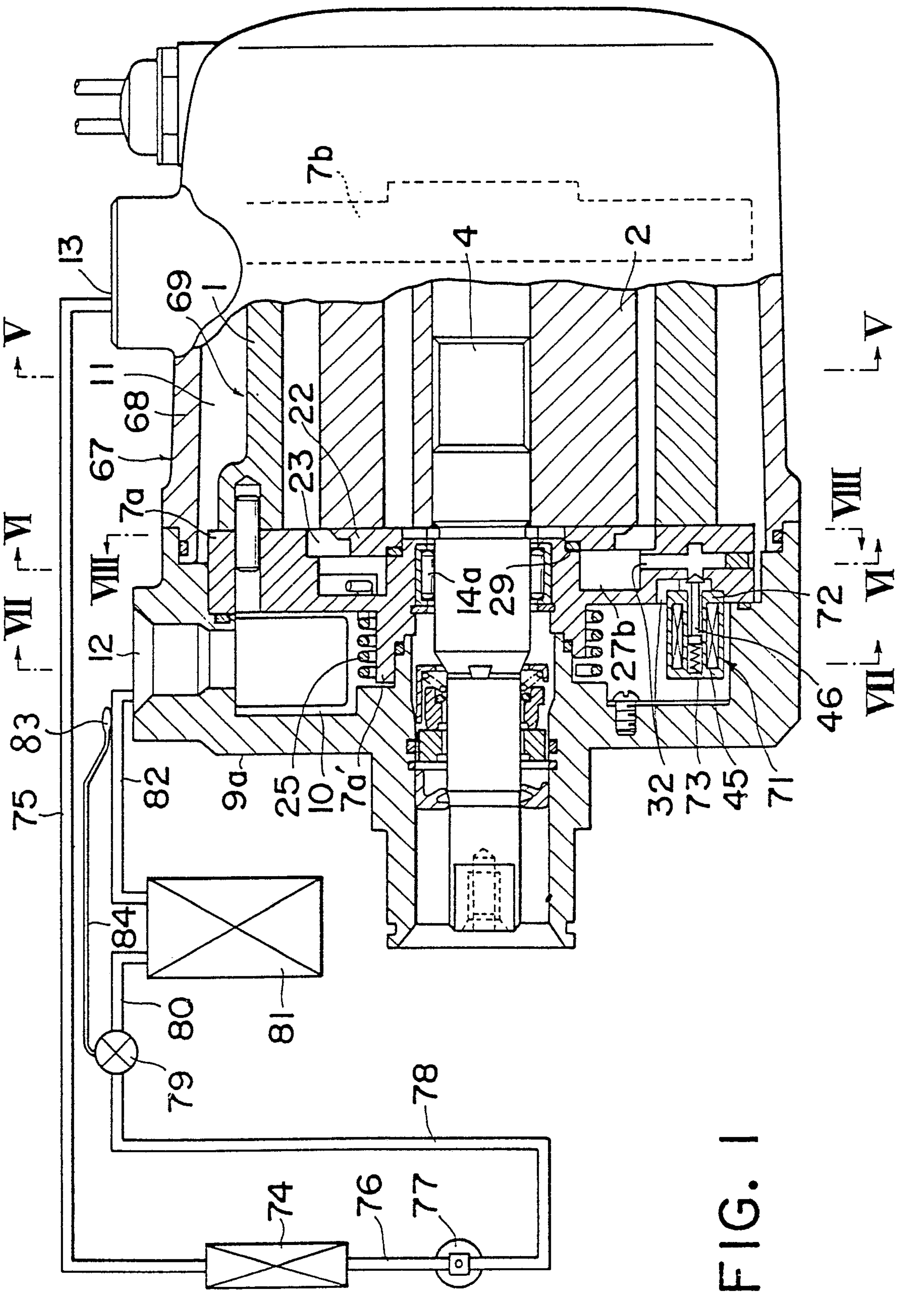
(b) sensor means (55) for detecting internal and external thermal load conditions for controlling operation of said compressor; and

(c) control means (63) for controlling operation of said electric on-off means (71) on the basis of the internal and external thermal load conditions detected by said sensor means (55).

2. An apparatus according to claim 1, said compressor comprising a sliding-vane rotary compressor.

3. An apparatus according to claim 1, said electric on-off means (71) comprising a solenoid valve (45, 46, 47).

4. An apparatus according to claim 1, said sensor means (55) including a pressure switch (59) operative in response to the pressure in said low pressure chamber (10) and/or including a temperature switch (56) operative in response to the temperature of engine cooling water and/or including an accelerator switch (57) operative in response to the depressing angle of an accelerator pedal and/or including a pressure switch (57) operative in response to the pressure in the outlet of an evaporator (81).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46
83
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FIG. 1

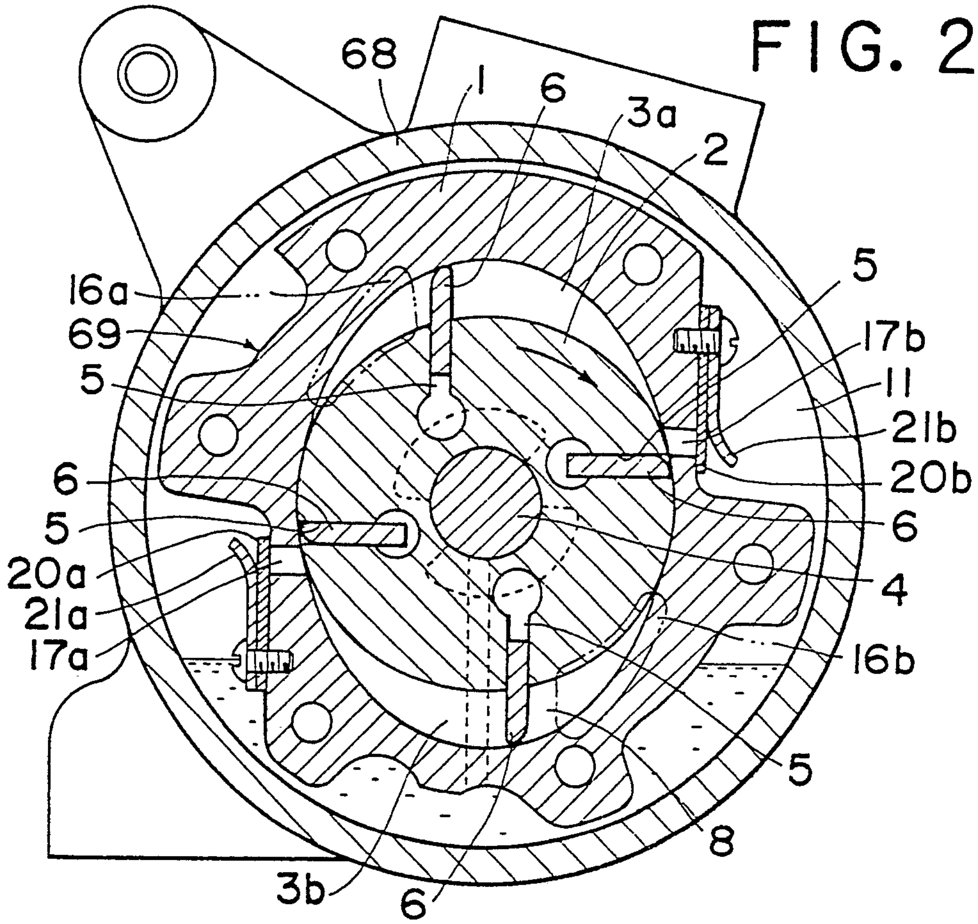
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FIG. 2

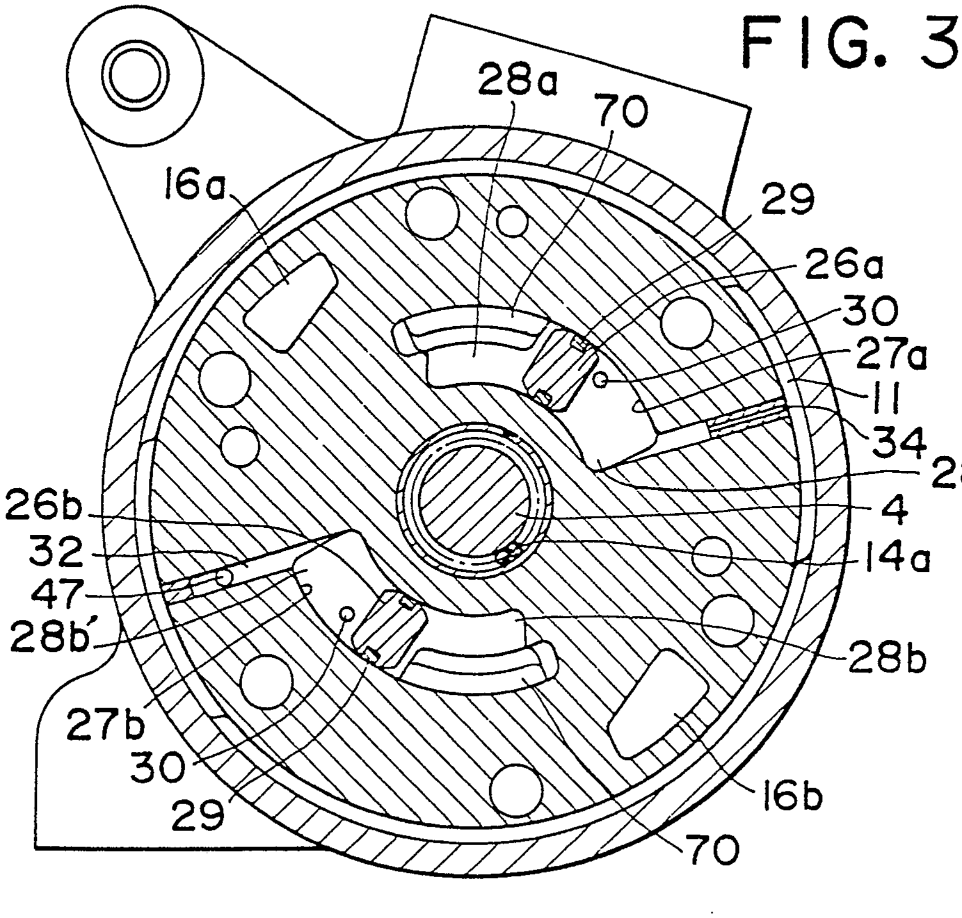
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FIG. 3

FIG. 4

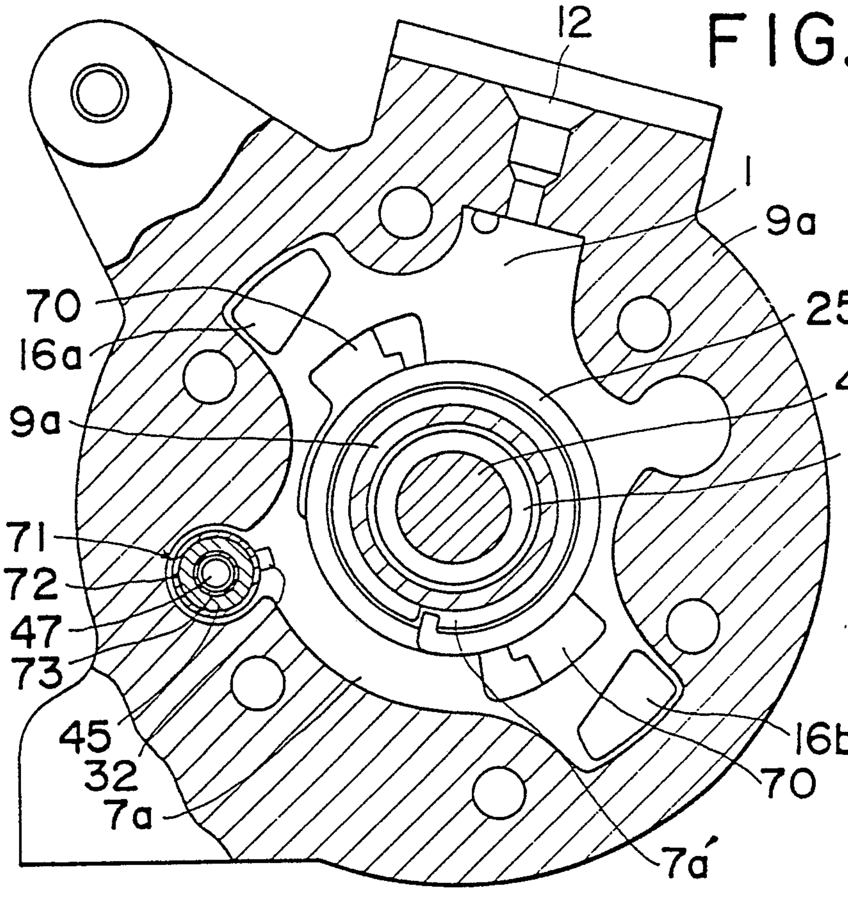
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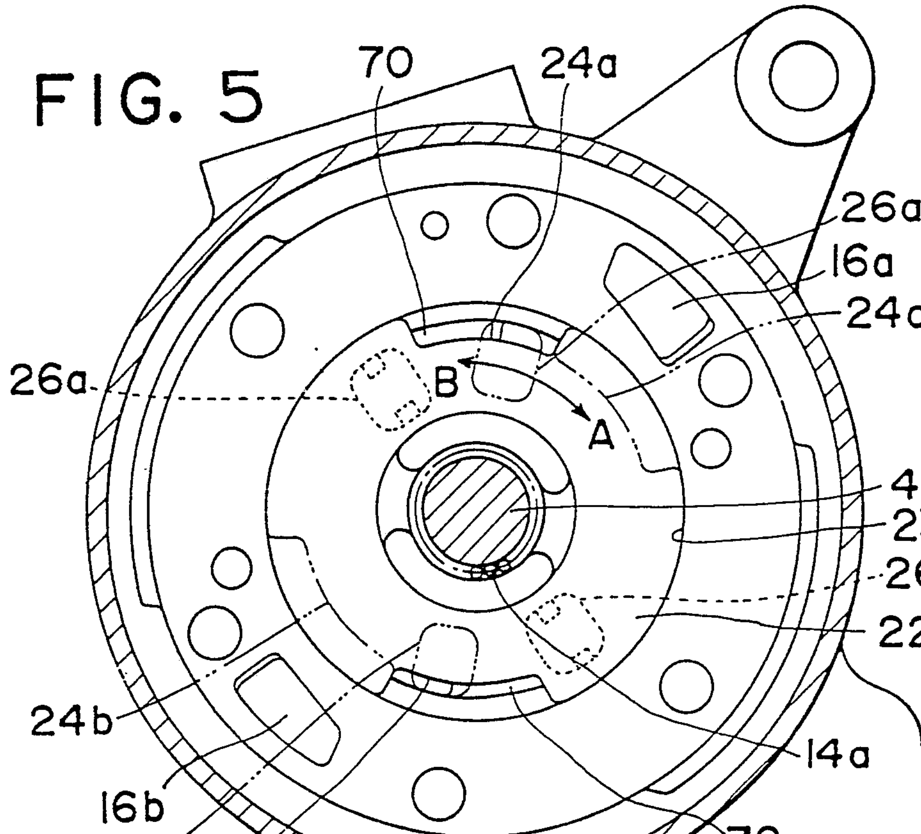
FIG. 5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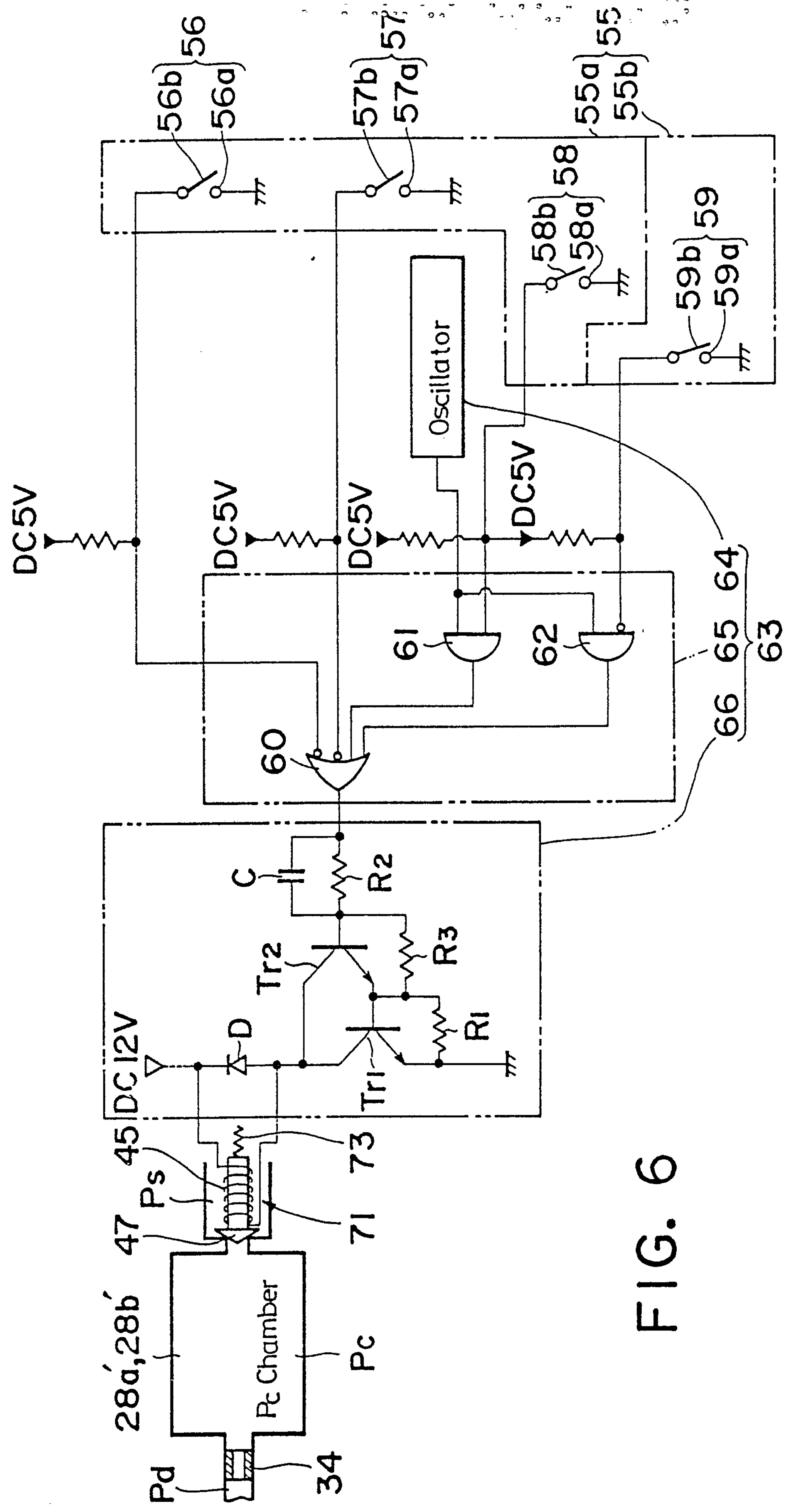
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DC5V
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65
63
66
61
62
60
C
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R3
Tr2
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Pc
Pd
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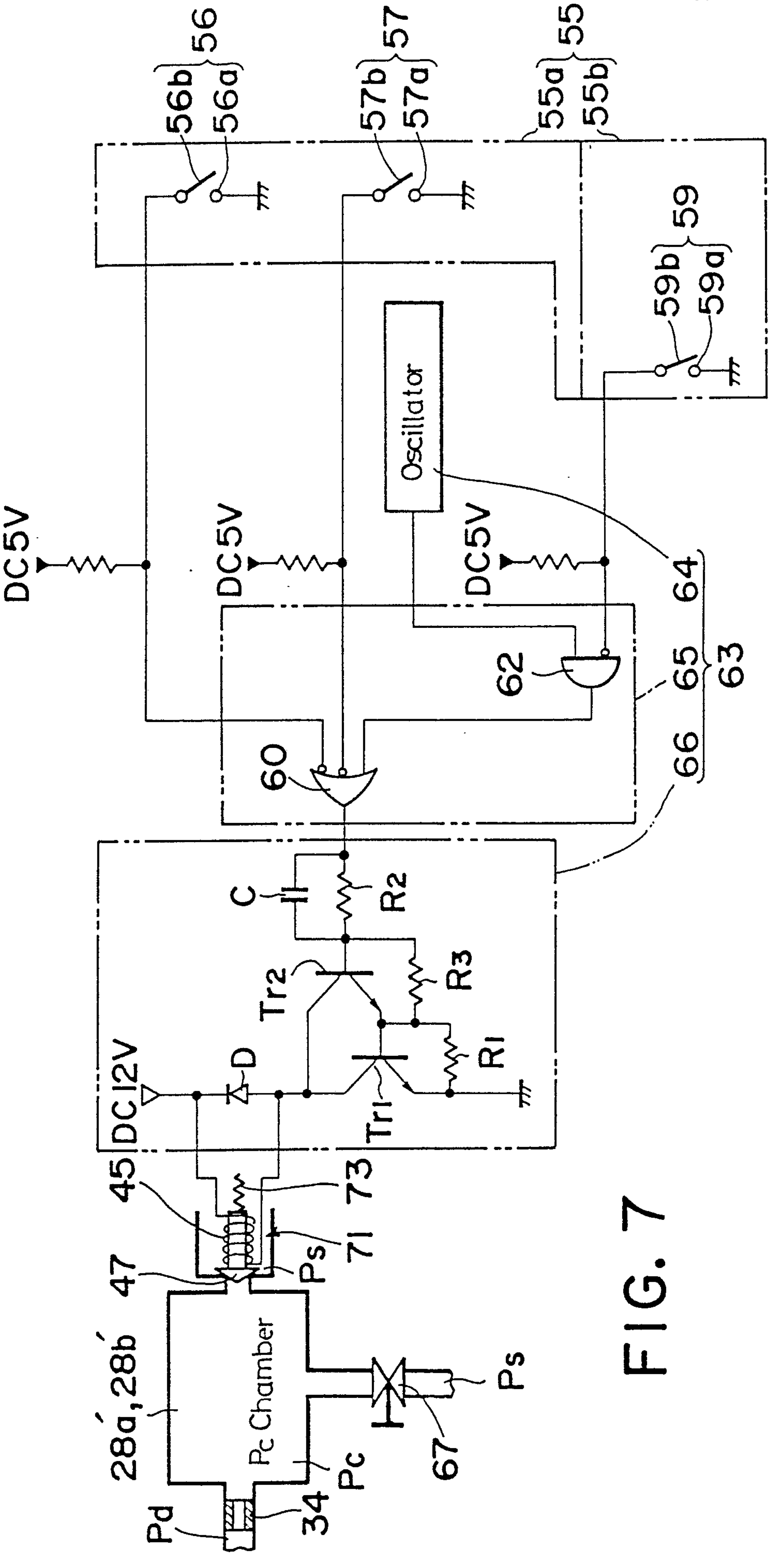
FIG. 6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57a
55
55a
55b
59
59b
59a
Oscillator
DC5V
DC5V
DC5V
64
65
63
62
60
66
C
R2
R3
Tr2
R1
D
Tr1
DC12V
45
73
71
47
Ps
28a′, 28b′
Pc Chamber
Pc
Ps
67
Pd
34

FIG. 7