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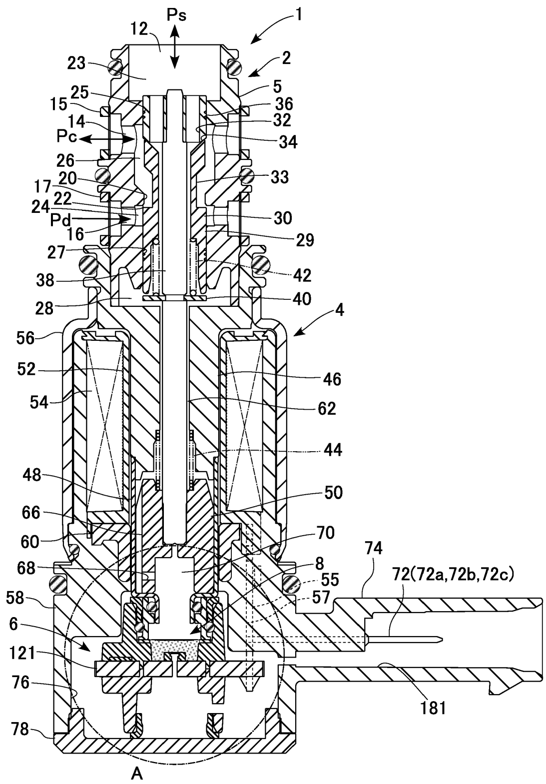
(54) CONTROL VALVE FOR VARIABLE DISPLACEMENT COMPRESSOR

(57) A control valve (1) includes a solenoid (4) mounted on a body (5), and a pressure sensor (8) to detect a predetermined refrigerant pressure to be referred to for power supply control of the solenoid (4). The solenoid (4) includes a solenoid body integrally mounted on the body (5) in an axial direction, an electromagnetic coil (54) held by the solenoid body and having a working space on an inner side thereof, a core (46) fixed to the solenoid body coaxially with the electromagnetic coil (54), a plunger (50) supported in the working space such that the plunger (50) is displaceable in the axial direction, and a power supply line connected to the electromagnetic coil (54) and drawn out from a side of the solenoid body opposite to the body (5). The pressure sensor (8) includes a pressure sensing part that senses the refrigerant pressure and is displaced by the sensed refrigerant pressure, and an output line to output a detection signal depending on a displacement of the pressure sensing part. The pressure sensor (8) is positioned on a side of the electromagnetic coil (54) opposite to the body (5).

FIG.4



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Description

[0001] The present invention relates to a control valve for controlling the discharging capacity of a variable displacement compressor.

[0002] An automotive air conditioner generally includes a compressor, a condenser, an expander, an evaporator, and so forth arranged in a refrigeration cycle. The compressor is, for example, a variable displacement compressor (hereinafter also referred to simply as a "compressor") capable of varying the refrigerant discharging capacity in order to maintain a constant level of cooling capacity irrespective of the engine speed. In this compressor, a piston for compression is linked to a wobble plate, which is mounted to a rotational shaft driven by an engine. The angle of the wobble plate is changed to change the stroke of the piston, by which the refrigerant discharging rate is regulated. The angle of the wobble plate is changed continuously by supplying part of the discharged refrigerant into a hermetically-closed control chamber and thus changing the balance of pressures working on both faces of the piston. The pressure (referred to as a "control pressure" below) Pc in this control chamber is controlled by a control valve provided between a discharge chamber and the control chamber or between the control comber and a suction chamber of the compressor.

[0003] Various control techniques are used for such control valves, such as control for regulating a pressure difference between predetermined two points in a compressor to a preset pressure difference, and control for regulating a predetermined pressure to a preset pressure, for example. Such a control valve often includes a solenoid as a drive section. Control valves employing any of the control techniques include a mechanism for transmitting the drive force of a solenoid to a valve element, a spring generating a counterforce against the drive force, or the like. The preset pressure difference or the preset pressure are mechanically set by a spring load, but can be electrically changed by a change in the amount of current supplied to the solenoid.

[0004] Such a control valve operates according to control commands from an external controller. The controller determines the preset pressure difference or the preset pressure on the basis of predetermined external information detected by sensors, such as the vehicle engine speed, the temperatures inside and outside the vehicle interior, and the temperature of air out from an evaporator, for example. In addition, power supply to the control valve is controlled such that the drive force for maintaining the preset pressure difference or the preset pressure is obtained (refer, for example, to JP 2001-107854 A). In this process, the valve mechanism operates autonomously to maintain the preset pressure difference or the preset pressure according to the amount of supplied current even when the refrigerant pressure fluctuates.

Related Art List

[0005] (1) Japanese Patent Application Publication No. 2001-107854

[0006] In order to improve the control accuracy, some controllers perform feedback control using the preset pressure difference or the preset pressure as a target value, for example. In this case, a compressor is provided with a pressure sensor for detecting a pressure that is a target of the feedback control. Such an additional pressure sensor, however, causes the compressor to include an additional mounting hole for mounting the pressure sensor, additional refrigerant leakage due to the mounting hole, an additional sealing structure for sealing to prevent the refrigerant leakage, and the like. This leads to an increase in the size of the compressor, an increase in production cost, and the like.

[0007] One purpose of an embodiment of the present invention is to improve the accuracy of control of a variable displacement compressor by a simple structure.

[0008] One embodiment of the present invention relates to a control valve for a variable displacement compressor. The control valve is insertable in a mounting hole formed in the variable displacement compressor and configured to control a discharging capacity of a refrigerant discharged by the compressor. The control valve includes: a valve body having a flow passage for the refrigerant, and a valve hole formed in the flow passage; a valve element that moves toward and away from the valve hole to close and open a valve section; a solenoid mounted on the valve body and configured to apply a drive force in an axial direction to the valve element, the drive force being dependent on a current supplied to the solenoid; and a pressure sensor to detect a predetermined refrigerant pressure to be referred to for power supply control of the solenoid.

[0009] The solenoid includes: a solenoid body integrally mounted on the valve body in the axial direction; an electromagnetic coil held by the solenoid body and having a working space on an inner side thereof; a core fixed to the solenoid body coaxially with the electromagnetic coil; a plunger supported in the working space such that the plunger is displaceable in the axial direction; and a power supply line connected to the electromagnetic coil and drawn out from a side of the solenoid body opposite to the valve body. The pressure sensor includes: a pressure sensing part that senses the refrigerant pressure and is displaced by the sensed refrigerant pressure; and an output line to output a detection signal depending on a displacement of the pressure sensing part. The pressure sensor is positioned on a side of the electromagnetic coil opposite to the valve body.

[0010] The control valve according to this embodiment is to be inserted into the mounting hole of the compressor from a first end side of the control valve (that is, a leading end side of the valve body), the pressure sensor is integrally provided with a second end side of the control valve (that is, an end side of the solenoid body opposite to the valve body). In addition, the power supply line of the solenoid and the output line of the pressure sensor are mounted together on the solenoid body side. Thus, it is sufficient to provide a mounting hole used in common for mounting the control valve and for mounting the pressure sensor in the compressor. This achieves improvement in the accuracy of control on the compressor with a simple structure.

FIG. 1 is a diagram illustrating a system to which a control valve according to a first embodiment is applicable;
FIG. 2 is a schematic diagram illustrating an electrical configuration of the control valve and other surrounding components;
FIG. 3 is a schematic view of a refrigeration cycle mainly illustrating a compressor;
FIG. 4 is a cross-sectional view illustrating a structure of the control valve according to the first embodiment;
FIG. 5 is an enlarged view of part A in FIG. 4;
FIG. 6 is a cross-sectional view illustrating a structure of a control valve according to a second embodiment;
FIG. 7 is a cross-sectional view illustrating a structure of a control valve according to a third embodiment;
FIG. 8 is a cross-sectional view illustrating a structure of a control valve according to a fourth embodiment;
FIG. 9 is a cross-sectional view illustrating a structure of a control valve according to a fifth embodiment; and
FIG. 10 is a schematic diagram illustrating an electrical configuration of a control valve and other surrounding components according to a modification.

[0011] Certain embodiments of the invention will now be described. The description does not intend to limit the scope of the present invention, but to exemplify the invention.

[0012] Embodiments of the present invention will now be described in detail with reference to the drawings. In the description below, for convenience of description, the positional relationship in each structure may be expressed with reference to how the structure is depicted in the drawings.

[First Embodiment]

[0013] FIG. 1 is a diagram illustrating a system to which a control valve according to a first embodiment is applicable.

[0014] The control valve 1 is applicable to an air conditioning system, which is part of a vehicle control system. The vehicle control system is connected with multiple electronic control units (hereinafter referred to as "ECUs") for controlling various systems via an in-vehicle network. As illustrated, an engine ECU 101 for controlling an engine, a brake ECU 103 for controlling a brake system, an air conditioner ECU 105 for controlling an air conditioner, and the like are connected via a communication line L1. The air conditioner ECU 105 is connected to controllers for devices included in the air conditioning system via a communication line L2.

[0015] In the present embodiment, the communication line L1 in a main network is constituted by a CAN bus, while the communication line L2 in a sub-network is constituted by a LIN bus. In other words, CAN (Controller Area Network) is employed as the communication protocol for the main network, while LIN (Local Interconnect Network) is employed as a communication protocol for the sub-network. The air conditioner ECU 105 operates as a master node connected to the LIN bus. The control valve 1 operates as a slave node connected to the LIN bus. In a modification, CAN may be employed for both of the main network and the sub-network. Alternatively, a communication protocol other than CAN and LIN may be employed for at least one of the main network and the sub-network.

[0016] A refrigeration cycle of the air conditioning system includes a compressor 100 for compressing a circulating refrigerant, a condenser 111 for condensing the compressed refrigerant, an expansion valve 113 for throttling and expanding the condensed refrigerant and delivering the resulting spray of refrigerant, and an evaporator 115 for evaporating the misty refrigerant to cool the air in a vehicle interior by evaporative latent heat. The compressor 100 is a variable displacement compressor. The control valve 1 is an electromagnetic valve driven by a solenoid and configured to control the discharging capacity of the compressor 100 according to a command from the air conditioner ECU 105.

[0017] The air conditioner ECU 105 determines a target value (preset pressure P_{set}) of a suction pressure Ps of the compressor 100 on the basis of predetermined external information detected by sensors, such as the engine speed, the temperatures inside and outside the vehicle interior, and the temperature of air out from the evaporator 115. The air conditioner ECU 105 then outputs information indicating the preset pressure P_{set} as a command signal to the control valve 1. Upon receiving the command signal, the control valve 1 controls power supply to the solenoid so that the suction pressure Ps is maintained at the preset pressure P_{set}. The power supply control is performed through feedback control, which will be described below. When a request to reduce load torque of the compressor 100 is received from the engine ECU 101 while the engine is under high load, such as during acceleration of the vehicle, during uphill movement of the vehicle, or the like, the air conditioner ECU 105 also outputs a command signal indicating the request to the control valve 1. Upon receiving the command signal, the control valve 1 interrupts power supply to the solenoid or reduces the power supply to a predetermined minimum level to switch the compressor 100 to a minimum capacity operation mode where the compressor 100 operates with the minimum capacity.

[0018] FIG. 2 is a schematic diagram illustrating an electrical configuration of the control valve 1 and other surrounding components.

[0019] A controller of the control valve 1 includes various circuits that function as a control unit and a communication unit on a circuit board 121. The controller is constituted mainly by a microcomputer 123, and includes a power supply circuit 125, a communication circuit 127 (a transceiver), and a drive circuit 129. The microcomputer 123 functions as a "control unit," and the communication circuit 127 functions as a "communication unit." A pressure sensor 8 for detecting the suction pressure Ps is also mounted on the circuit board 121.

[0020] The power supply circuit 125 supplies a power supply voltage supplied via the air conditioner ECU 105 to the microcomputer 123, the communication circuit 127, the drive circuit 129, and the pressure sensor 8. The power supply to a solenoid 4 is also conducted via the power supply circuit 125. Specifically, a power supply line 55 and a ground line 57 of the solenoid 4 are connected to the microcomputer 123 via the drive circuit 129. Power from the power supply circuit 125 is supplied to the drive circuit 129 and then to the solenoid 4 via the microcomputer 123. A detection signal from the pressure sensor 8 is input to the microcomputer 123 via an output line 59.

[0021] The microcomputer 123 includes a CPU configured to execute various types of arithmetic processing, a ROM configured to store control programs and the like, a RAM to be used as a work area for data storage and program execution, a nonvolatile memory (such as an EEPROM) configured to retain stored data even after power-off, an input/output interface, and the like.

[0022] The communication circuit 127 functions as a LIN transceiver, configured to receive a command signal from the air conditioner ECU 105 and send the received command signal to the microcomputer 123. The communication circuit 127 is also configured to send an output signal from the microcomputer 123 to the air conditioner ECU 105. The drive circuit 129 outputs a drive signal obtained through duty control to an electromagnetic coil of the solenoid 4 in accordance with a command from the microcomputer 123.

[0023] The microcomputer 123 computes a control quantity (a duty ratio of current supplied to the solenoid 4) to bring the suction pressure Ps closer to the preset pressure P_{set} on the basis of a control signal received via the communication circuit 127, and outputs a drive command (a drive pulse) for achieving the control quantity to the drive circuit 129. The drive circuit 129 supplies a drive current (a current pulse) obtained through duty control to the solenoid 4 in accordance with the drive command.

[0024] In the present embodiment, feedback control is performed to bring the suction pressure Ps closer to the preset pressure P_{set}. Specifically, information indicating an optimum preset pressure P_{set} depending on a vehicle control state is sent as a control command from the air conditioner ECU 105. The microcomputer 123 receives the control command, while also receiving information on the actual suction pressure Ps detected by the pressure sensor 8. The microcomputer 123 then computes the duty ratio on the basis of a deviation of the detected suction pressure Ps from the preset pressure P_{set}, and outputs a drive signal obtained through duty control.

[0025] In the present embodiment, as illustrated, a power supply line (VCC), a ground line (GND) and the communication line L2 extend from the air conditioner ECU 105, and connected to a power supply terminal 72a, a ground terminal 72b, and a communication terminal 72c, respectively, of the circuit board 121. Ground lines (GND) of the respective circuits on the circuit board 121 are connected to the ground terminal 72b.

[0026] FIG. 3 is a schematic view of the refrigeration cycle mainly illustrating the compressor 100.

[0027] The compressor 100 includes, in addition to a mechanism for compressing a refrigerant, the control valve 1 configured to control the refrigerant discharging capacity and a discharge valve 160 to prevent backflow of the discharged refrigerant in a housing.

[0028] The housing of the compressor 100 is constituted by an assembly of a cylinder block 102, a front housing 104 connected to a front end side of the cylinder block 102, and a rear housing 106 connected to a rear end side of the cylinder block 102. A valve plate 108 is disposed between the cylinder block 102 and the rear housing 106. The cylinder block 102 includes a plurality of cylinders 110 around an axis of the cylinder block 102. A crankcase 112 is formed in a space surrounded by the cylinder block 102 and the front housing 104. While the crankcase 112 corresponds to a "control chamber" in the present embodiment, a pressure chamber additionally formed in the crankcase or outside of the crankcase may function as a "control chamber" in a modification.

[0029] A suction chamber 114, a discharge chamber 116, and a mounting hole 118 are defined in the rear housing 106. In addition, the rear housing 106 has a refrigerant inlet 120 through which the refrigerant is introduced from the evaporator 115 side into the suction chamber 114, a refrigerant outlet 122 through which the discharged refrigerant is delivered from the discharge chamber 116 toward the condenser 111 side, a communication passage 124 through which the suction chamber 114 and the mounting hole 118 communicate, a communication passage 126 through which the crankcase 112 and the mounting hole 118 communicate, and a communication passage 128 through which the discharge chamber 116 and the mounting hole 118 communicate.

[0030] A rotational shaft 130 is disposed through the center of the crankcase 112. The rotational shaft 130 is rotatably supported by a bearing 132 in the cylinder block 102 and a bearing 134 in the front housing 104. A lug plate 136 is fixed to the rotational shaft 130, and a swash plate 140 (corresponding to a "wobble plate") is supported via a support arm 138, or the like, protruding from the lug plate 136.

[0031] The swash plate 140 is tiltable with respect to the axis of the rotational shaft 130, and is connected to pistons 142, which are slidably disposed in the cylinders 110, via shoes 144. A front end part of the rotational shaft 130 extends through the front housing 104 to outside of the front housing 104, and a bracket 146 is screwed on a front end portion of the front end part. In addition, a lip seal 148 is provided to externally seal a gap between the rotational shaft 130 and the front housing 104 at the front part. The lip seal 148 is in sliding contact with the circumferential surface of the rotational shaft 130 and prevents leakage of gas refrigerant along the circumferential surface.

[0032] A bearing 150 is provided at a front end part of the front housing 104, and rotatably supports a pulley 152. The pulley 152 transmits the drive force of the engine to the rotational shaft 130 via the bracket 146.

[0033] The suction chamber 114 communicates with the cylinders 110 via suction relief valves 154 formed in the valve plate 108, and also communicates with an outlet of the evaporator 115 via the refrigerant inlet 120. The discharge chamber 116 communicates with the cylinders 110 via discharge relief valves 156 formed in the valve plate 108, and also communicates with an inlet of the condenser 111 via the refrigerant outlet 122. Note that an orifice having a fixed cross-sectional area is formed in a refrigerant passage (not illustrated) through which the crankcase 112 and the suction chamber 114 communicate, to permit flow of refrigerant at a preset minimum flow rate from the crankcase 112 to the suction chamber 114, so that internal circulation of the refrigerant in the compressor 100 is secured.

[0034] The swash plate 140 is held at a position at an angle determined by a balance of loads of springs 157 and 158 that bias the swash plate 140 in the crankcase 112, loads caused by pressures acting on the respective faces of pistons 140 connected with the wash plate 140, and the like. The angle of the swash plate 140 can be changed continuously by introducing part of the discharged refrigerant into the crankcase 112 to change a control pressure P_c and change the balance of pressures acting on the respective faces of the pistons 142. The change in the angle of the swash plate 140 changes the stroke of the pistons 142, which regulates the refrigerant discharging capacity. The pressure in the crankcase 112 is controlled by the control valve 1.

[0035] The discharge valve 160 is positioned between the discharge chamber 116 and the refrigerant outlet 122 of the rear housing 106. The discharge valve 160 functions as a "check valve" configured to permit forward flow of the refrigerant being discharged from the compressor 100 and block backward flow of the refrigerant. A fixed orifice 117 is formed upstream of the discharge valve 160. A pressure difference (Pd1 - Pd2) occurs between a first discharge pressure Pd1, which is an upstream pressure of the fixed orifice 117, and a second discharge pressure Pd2, which is a downstream pressure of the fixed orifice 117. The first discharge pressure Pd1 is equal to the pressure in the discharge chamber 116. For flow control to maintain the discharge flow rate of the compressor 100 at a constant flow rate, the control valve 1 may be configured to sense the pressure difference (Pd1 - Pd2). A pressure loss due to the fixed orifice 117 is, however, practically negligible in the refrigeration cycle as a whole, and there is little difference between the first discharge pressure Pd1 and the second discharge pressure Pd2. Thus, in the description below, the first discharge pressure Pd1 and the second discharge pressure Pd2 will be collectively referred to as "discharge pressures Pd" unless the discharge pressures are distinguished from each other.

[0036] The compressor 100 having the structure as described above introduces the gas refrigerant, which has been introduced from the evaporator 115 side into the suction chamber 114, into the cylinders 110, compresses the introduced refrigerant, and discharges high-temperature and high-pressure refrigerant from the discharge chamber 116 toward the condenser 111. Part of the discharged refrigerant is introduced into the crankcase 120 via the control valve 1 to be used for capacity control of the compressor 100.

[0037] FIG. 4 is a cross-sectional view illustrating a structure of the control valve according to the first embodiment.

[0038] The control valve 1 is a Ps control valve configured to control the flow rate of the refrigerant introduced from the discharge chamber 116 into the crankcase 112 such that the suction pressure Ps of the compressor 100 is maintained at a preset pressure. The control valve 1 is constituted by an assembly of a valve unit 2, the solenoid 4, and a control unit 6. The control unit 6 includes the pressure sensor 8, and is provided integrally with the solenoid 4.

[0039] The valve unit 2 includes a main valve for introducing part of the discharged refrigerant into the crankcase during operation of the compressor 100, and a subvalve (a so-called bleed valve) for letting the refrigerant in the crankcase 112 out to the suction chamber 114 at the startup of the compressor 100. The solenoid 4 drives the main valve in an opening or closing direction to adjust the opening degree of the main valve and thus control the flow rate of the refrigerant introduced into the crankcase 112. The valve unit 2 includes a stepped cylindrical body 5 (which functions as a "valve body"), and the main valve and the sub-valve formed inside the body 5.

[0040] The body 5 has ports 12, 14, and 16 formed in this order from a top end thereof. The port 12 functions as a "suction chamber communication port" communicating with the suction chamber 114. The port 14 functions as a "control chamber communication port" communicating with the crankcase 112. The port 16 functions as a "discharge chamber communication port" communicating with the discharge chamber 116.

[0041] A main passage through which the port 16 and the port 14 communicate, and a sub-passage through which the port 14 and the port 12 communicate are formed in the body 5. The main valve is provided in the main passage while the sub-valve is provided in the sub-passage. Thus, the control valve 1 has a structure in which the sub-valve, the main valve, the solenoid 4, and the control unit 6 are arranged in this order from one end of the control valve 1. In the main passage, a main valve hole 20 and a main valve seat 22 are provided. In the sub-passage, a sub-valve hole 32 and a sub-valve seat 34 are provided.

[0042] The port 12 allows a working chamber 23 defined (formed) in an upper part of body 5 and the suction chamber 114 to communicate with each other. The port 16 allows the refrigerant at a discharge pressure Pd to be introduced from the discharge chamber 116. A main valve chamber 24 is formed between the port 16 and the main valve hole 20, and the main valve is located in the main valve chamber 24. The refrigerant whose pressure is changed to a control pressure Pc through the main valve is delivered toward the crankcase 112 through the port 14 during steady operation of the compressor 100, while refrigerant at the control pressure Pc discharged from the crankcase 112 is introduced through the port 14 at the startup of the compressor 100. A sub-valve chamber 26 is formed between the port 14 and the main valve hole 20, and the sub-valve is located in the sub-valve chamber 26. The refrigerant at the suction pressure Ps is introduced through the port 12 during steady operation of the compressor 100, while the refrigerant whose pressure is changed to the suction pressure Ps through the sub-valve is delivered toward the suction chamber 114 through the port 12 at the startup of the compressor 100.

[0043] Cylindrical filter members 15 and 17 are mounted on the ports 14 and 16, respectively. The filter members 15 and 17 each have a mesh for preventing or reducing entry of foreign materials into the body. The filter member 17 restricts entry of foreign materials into to the port 16 while the main valve is open, and the filter member 15 restricts entry of foreign materials into the port 14 while the sub-valve is open.

[0044] The main valve hole 20 is formed between the main valve chamber 24 and the sub-valve chamber 26, and the main valve seat 22 formed at an end portion of a lower end opening of the main valve hole 20. A guiding passage 25 is formed between the port 14 and the working chamber 23 in the body 5. A guiding passage 27 is formed in a lower part (the part opposite to the main valve hole 20 with respect to the main valve chamber 24) of the body 5. A stepped cylindrical valve drive member 29 is slidably inserted in the guiding passage 27.

[0045] The valve drive member 29 has an upper half part being reduced in diameter, extending through the main valve hole 20, and constituting a partition part 33 that separates the inside from the outside of the valve drive member 29. A stepped portion formed at a middle part of the valve drive member 29 constitutes a main valve element 30, which closes and opens the main valve by touching and leaving the main valve seat 22. The main valve element 30 touches and leaves the main valve seat 22 from the side of the main valve chamber 24 to close and open the main valve and thus control the flow rate of the refrigerant flowing from the discharge chamber 116 to the crankcase 112. The partition part 33 has an upper portion increasing upward in diameter into a tapered shape, and the sub-valve seat 34 is formed at an upper end opening of the partition part 33. The sub-valve seat 34 functions as a movable valve seat that displaces together with the valve drive member 29. Although the valve drive member 29 and the main valve element 30 are distinguished from each other in the present embodiment, the valve drive member 29 may alternatively be regarded as the "main valve element".

[0046] A cylindrical sub-valve element 36 is inserted in the guiding passage 25. An internal passage of the sub-valve element 36 forms the sub-valve hole 32. The internal passage connects the sub-valve chamber 26 and the working chamber 23 with each other when the sub-valve is opened. The sub-valve element 36 and the sub-valve seat 34 are at positions facing each other along the axial direction. The sub-valve element 36 touches and leaves the sub-valve seat 34 in the sub-valve chamber 26 to close and open the sub-valve.

[0047] An elongated actuating rod 38 is also provided along the axis of the body 5. An upper end part of the actuating rod 38 is connected to the sub-valve element 36. A lower end part of the actuating rod 38 is connected to a plunger 50, which will be described below, of the solenoid 4. An upper half part of the actuating rod 38 extends through the valve drive member 29, and has an upper portion being reduced in diameter. The sub-valve element 36 is fixed to the reduced-diameter portion.

[0048] A ring-shaped spring support 40 is fitted into and supported by a middle portion in the axial direction of the actuating rod 38. A spring 42 for biasing the valve drive member 29 in the closing direction of the main valve and the sub-valve is mounted between the valve drive member 29 and the spring support 40. During control of the main valve, the valve drive member 29 and the spring support 40 are tensioned by the elastic force of the spring 42, and the main valve element 30 and the actuating rod 38 move integrally.

[0049] When the sub-valve element 36 touches the sub-valve seat 34 to close the sub-valve, the release of refrigerant from the crankcase 112 to the suction chamber 114 is blocked. When the sub-valve element 36 leaves the sub-valve seat 34 to open the sub-valve, the release of refrigerant from the crankcase 112 to the suction chamber 114 is permitted.

[0050] The solenoid 4 includes a stepped cylindrical core 46, a bottomed cylindrical sleeve 48 mounted on a lower end of the core 46, a stepped cylindrical plunger 50 contained in the sleeve 48 and disposed opposite to the core 46 along the axial direction, a cylindrical bobbin 52 mounted (outserted) around the core 46 and the sleeve 48, an electromagnetic coil 54 wound around the bobbin 52 and configured to generate a magnetic circuit when power is supplied thereto, a cylindrical casing 56 provided in such a manner as to cover the electromagnetic coil 54 from outside, an end member 58 provided in such a manner as to seal off a lower end opening of the casing 56, and a collar 60 embedded in the end member 58 at a position below the bobbin 52. The collar 60 is made of a magnetic material. The collar 60, the core 46, and the casing 56 constitute a yoke. The casing 56 and the end member 58 constitute a "solenoid body."

[0051] The valve unit 2 and the solenoid 4 are secured in such a manner that the lower end part of the body 5 is press-fitted into an upper end opening of the core 46. A pressure chamber 28 is formed between the core 46 and the valve drive member 29. The actuating rod 38 is inserted in and through the center of the core 46 in the axial direction. The pressure chamber 28 communicates with the working chamber 23 through the internal passages in the valve drive member 29 and the sub-valve element 36. Thus, the suction pressure Ps in the working chamber 23 is also introduced into the pressure chamber 28. The suction pressure Ps is also introduced into the sleeve 48 via a communication passage 62 formed by a spacing between the actuating rod 38 and the core 46.

[0052] A spring 44 (functioning as a "biasing member") for biasing the core 46 and the plunger 50 in directions away from each other is mounted between the core 46 and the plunger 50. The spring 44 functions as a so-called off-spring for opening the main valve while the solenoid 4 is powered off. The actuating rod 38 is coaxially connected with each of the sub-valve element 36 and the plunger 50. The actuating rod 38 has an upper portion press-fitted into the sub-valve element 36 and a lower end portion press-fitted into the upper portion of the plunger 50. The actuating rod 38, the sub-valve element 36, and the plunger 50 constitute a "movable member", which is displaced integrally with the valve drive member 29 during control of the main valve.

[0053] The actuating rod 38 transmits the solenoid force, which is a suction force generated between the core 46 and the plunger 50, to the main valve element 30 and the sub-valve element 36 as necessary. At the same time, a load generated by the spring 44 is exerted on the actuating rod 38 against the solenoid force. Thus, while the main valve is controlled, a force adjusted by the solenoid force acts on the main valve element 30 to appropriately control the opening degree of the main valve. At the startup of the compressor 100, the actuating rod 38 is displaced relative to the body 5 against the biasing force of the spring 44 and according to the magnitude of the solenoid force to close the main valve, and lifts up the sub-valve element 36 to open the sub-valve after the main valve is closed. In this manner, the bleeding function is achieved.

[0054] The sleeve 48 is made of a nonmagnetic material and has a stepped cylindrical shape. An upper end part of the sleeve 48 is press-fitted around a lower end part of the core 46. A lower part of the sleeve 48 is reduced in diameter and is open on the side of the pressure sensor 8.

[0055] A communicating groove 66 is formed in parallel with the axis on a lateral surface of the plunger 50, and a communicating hole 68 connecting the inside and the outside of the plunger 50 is provided in a lower portion of the plunger 50. Such a structure enables the suction pressure Ps to be introduced into a back pressure chamber 70 through a spacing between the plunger 50 and the sleeve 48, and also to the pressure sensor 8, even when the plunger 50 is located at a bottom dead point as shown in FIG. 4.

[0056] The power supply line 55 and the ground line 57 connected to the electromagnetic coil 54 extend from the bobbin 52, and are connected to the circuit board 121 (more particularly, the drive circuit 129) of the control unit 6. The power supply terminal 72a, the ground terminal 72b, and the communication terminal 72c (which will also be collectively referred to as "connection terminals 72") mentioned above extend from the circuit board 121, and are led out through the end member 58.

[0057] The end member 58 has a stepped cylindrical shape, and is installed in such a manner as to cover the entire structure inside the solenoid 4 contained in the casing 56 from below. The end member 58 is made of a corrosion-resistant plastic material, which is disposed such that part of the end member 58 is also present in a spacing between the casing 56 and the electromagnetic coil 54. A connector part 74 is integrally formed as a lateral part of the end member 58. The connection terminals 72 are placed inside the connector part 74. A chamber 76 is formed inside the end member 58, where the control unit 6 is accommodated. A cap member 78 is mounted to close a lower end opening of the end member 58.

[0058] FIG. 5 is an enlarged view of part A in FIG. 4.

[0059] The control unit 6 includes the pressure sensor 8 and other circuits described above mounted on the circuit board 121. The pressure sensor 8 includes a sensor body 131 having a cylindrical shape, and a sensor module 133 supported at the center of the sensor body 131. The sensor body 131 is constituted by an upper body 135 and a lower body 137, which are assembled with the circuit board 121 (printed circuit board) between the upper body 135 and the lower body 137. The sensor module 133 is installed inside the upper body 135. A through-passage 139 along the axis of the sensor body 131 is formed through the sensor body 131 and the circuit board 121. The sensor module 133 is positioned across the through-passage 139.

[0060] The through-passage 139 has a pressure space, which is separated into a first pressure chamber 143 and a second pressure chamber 145 by the sensor module 133. The sensor module 133 has a pressure sensing member 161 (which functions as a "pressure sensing part") including a sensing element 151, a diaphragm 153, and a protective material 155 between the sensing element 151 and the diaphragm 153. The diaphragm 153 is supported by a housing 163 inside the upper body 135. The housing 163 is constituted by an upper housing 165 having a stepped cylindrical shape and a lower housing 167 having a ring shape. The diaphragm 153 is supported at an outer edge thereof between the upper housing 165 and the lower housing 167.

[0061] The sensing element 151 has a thin part and a thick part, the thin part being a pressure receiving part 171 configured to sense pressure and shifts in position in response to the sensed pressure, the thick part being a supporting part 173 that supports the pressure receiving part 171 from outside in the radial direction. The supporting part 173 is mounted on the circuit board 121. The sensing element 151 is a piezoresistive sensor having a plurality of resistive elements such as a strain gauge on the pressure receiving part 171. The resistive elements constitutes a bridge circuit.

[0062] The protective material 155 is made of a fluorine-based or silicon-based rubber or gel material that is electrical insulating. The protective material 155 is provided to cover the pressure receiving part 171 of the sensing element 151 from above, and protects a sensor circuit exposed on the top surface of the pressure receiving part 171. The pressure received by the diaphragm 153 is also transmitted to the sensing element 151 via the protective material 155. That is, the protective material 155 also functions as a transmitting material for transmitting pressure. The sensing element 151 outputs a detection signal depending on a difference in pressure between the first pressure chamber 143 and the second pressure chamber 145. The detection signal from the sensor module 133 is output to the microcomputer 123 via the output line 59. In a modification, incompressible fluid such as oil may be used for the protective material 155 (transmitting material).

[0063] The pressure sensor 8 is supported between the sleeve 48 and the cap member 78 in the axial direction, and fixed relative to the end member 58 (solenoid body). An O ring 175 is disposed between a small-diameter part of the sleeve 48 and the upper housing 165, and an O ring 177 is disposed between the upper housing 165 and the upper body 135. This prevents leakage of the refrigerant introduced into the back pressure chamber 70.

[0064] A space surrounded by the sensor module 133 and the sleeve 48 constitutes the first pressure chamber 143. The suction pressure Ps in the back pressure chamber 70 is applied to an upper surface of the pressure sensing member 161. The second pressure chamber 145 communicates with the inside of the lower body 137. The lower body 137 has a communication hole 179 communicating the inside and the outside of the lower body 137 with each other. Thus, the second pressure chamber 145 communicates with the outside air through the communication hole 179, the chamber 76, and an inner passage 181 of the connector part 74. Thus, the atmospheric pressure is introduced into the second pressure chamber 145. The pressure sensor 8 senses the pressure difference between the suction pressure Ps and the atmospheric pressure, that is, the gauge pressure of the suction pressure Ps. In a modification, the second pressure chamber 145 may be hermetically closed and kept at vacuum. This allows the pressure sensor 8 to sense the absolute pressure of the suction pressure Ps.

[0065] Next, operation of the control valve will be described with reference to FIG. 4.

[0066] In the present embodiment, the pulse width modulation (PWM) technique is employed for controlling power supply to the solenoid 4. The PWM control is control of supplying a pulsed current with a frequency of about 400 Hz set at a predetermined duty ratio, which is performed by the microcomputer 123 by driving the drive circuit 129. The drive circuit 129 includes a PWM output unit configured to output a pulse signal (pulsed current) with a specified duty ratio.

[0067] In the control valve 1, while the solenoid 4 is powered off, that is, while the air conditioning system is not in operation, the suction force does not act between the core 46 and the plunger 50. In the meantime, the biasing force of the spring 44 is transmitted to the valve drive member 29 via the plunger 50, the actuating rod 38, and the sub-valve element 36. As a result, the main valve element 30 is separated from the main valve seat 22 and the main valve becomes in a fully open state. In this process, the sub-valve remains in the closed state.

[0068] When a starting current is supplied to the electromagnetic coil 54 of the solenoid 4 at the startup of the air conditioning system, the sub-valve is opened. The starting current is higher than a current (also referred to as a "holding current") during steady control of the solenoid 4. Specifically, the main valve element 30 is first lifted up by the biasing force of the spring 42, and touches the main valve seat 22. As a result, the main valve is closed, which restricts introduction of the discharged refrigerant into the crankcase 112. In this process, since the force from the solenoid 4 is greater than the biasing force of the spring 42, the sub-valve element 36 is lifted up together with the actuating rod 38 even after the main valve is closed. As a result, the sub-valve element 36 leaves the sub-valve seat 34 to open the sub-valve, by which the bleeding function is effectively achieved. Specifically, after the main valve is closed and introduction of the discharged refrigerant into the crankcase 112 is restricted, the sub-valve is opened and the refrigerant in the crankcase 112 is quickly released to the suction chamber 114. This allows the compressor to be quickly started.

[0069] During steady control of the solenoid 4, the feedback control described above is performed. Specifically, the microcomputer 123 acquires control command information (information indicating the preset pressure P_{set}) received from the air conditioner ECU 105, and also acquire information on the actual suction pressure Ps detected by the pressure sensor 8. The microcomputer 123 then computes the duty ratio on the basis of a deviation of the detected suction pressure Ps from the preset pressure P_{set}, and outputs a drive command to the drive circuit 129. In response to the drive command, the drive circuit 129 supplies a drive current obtained through duty control to the solenoid 4. The main valve element 30 stops at a valve lifted position where the force in the valve opening direction generated by the spring 44 is balanced with the force in the valve closing direction from the solenoid 4. This allows control to bring the suction pressure Ps closer to the preset pressure P_{set} or maintain the suction pressure Ps at the preset pressure P_{set} with high accuracy. Note that the microcomputer 123 may successively receive information representing the preset pressure P_{set} from the air conditioner ECU 105, or may use a previously received preset pressure P_{set} until a new preset pressure P_{set} is sent from the air conditioner ECU 105. The microcomputer 123 may send information detected by the pressure sensor 8 to the air conditioner ECU 105.

[0070] When the engine load increases during such steady control and a command instructing to decrease the load on the compressor 100 is received from the air conditioner ECU 105, the microcomputer 123 interrupts power supply to the solenoid 4 or limit the power supply to a preset minimum level. When the power supply to the solenoid 4 is interrupted, the suction force does not act between the core 46 and the plunger 50, and thus the main valve element 30 is separated from the main valve seat 22 by the biasing force of the spring 44, bringing the main valve into the fully-open state. During this process, since the sub-valve element 36 is basically seated on the sub-valve seat 34, the sub-valve is in the closed state. As a result, the refrigerant at the discharge pressure Pd introduced from the discharge chamber 116 into the port 16 passes through the main valve in the fully-open state and flows through the port 14 into the crankcase 112. This increases the control pressure Pc, and makes the compressor 100 operate with the minimum capacity.

[0071] In the present embodiment, as described above, while the control valve 1 is to be inserted into the mounting hole 118 of the compressor 100 from the first end side of the control valve 1, the control unit 6 is integrally provided with the second end side of the control valve 1. In addition, the circuits of the control unit 6 and the circuits of the solenoid 4 are mounted together on the circuit board 121, and common connection terminals 72 are provided in the connector part 74 at the second end side. This eliminates the need for providing an additional mounting hole for mounting the control unit 6 in the compressor 100. This reduces parts where leakage of the refrigerant may occur in the compressor 100. Since the control unit 6 and the solenoid 4 have the connector part in common, the control valve 1 can be made more compact, and the number of processes for mounting connectors on the compressor 100 is reduced. Since the control unit 6 is provided with the communication circuit 127, the number of terminals led to the outside of the control valve 1 is reduced. As a result, the manufacturing cost for the compressor 100 can be reduced.

[0072] Furthermore, the feedback control performed by the control unit 6 using an output from the pressure sensor 8 increases the accuracy of the Ps control. Since the control unit 6 is provided on the control valve 1 independently of the air conditioner ECU 105, electrical disturbances caused between the air conditioner ECU 105 and the control valve 1 have little influence to the control performed by the control unit 6. Thus, according to the present embodiment, the configuration to control the compressor 100 with high accuracy is achieved simply and at a low cost.

[Second Embodiment]

[0073] FIG. 6 is a cross-sectional view illustrating a structure of a control valve according to a second embodiment. The following description will focus on the differences from the first embodiment. In FIG. 6, components or parts substantially the same as those in the first embodiment will be designated by the same reference numerals.

[0074] A control valve 201 of the present embodiment includes, in addition to the structure of the control valve 1 of the first embodiment, a power element 210 for autonomously (mechanically) adjusting the suction pressure Ps (corresponding to a "pressure to be sensed"). The control valve 201 is a so-called Ps sensing valve configured to control the flow rate of the refrigerant introduced from the discharge chamber 116 into the crankcase 112 so that the suction pressure Ps of the compressor 100 is maintained at a preset pressure. The control valve 201 is formed of an integral assembly of a body 205 having a stepped cylindrical shape and the solenoid 4 in the axial direction. An end member 213 is fixed to close an upper end opening of the body 205. In the control valve 201, the power element 210, the sub-valve, the main valve, the solenoid 4, and the control unit 6 are arranged in this order from one end side of the control valve 201.

[0075] The power element 210 is positioned in the working chamber 23. The power element 210 includes a bellows 245 that senses the suction pressure Ps and is shifted in position by the suction pressure Ps. A spring 246 to bias the bellows 245 in an extending direction (the opening direction of the main valve) is set inside the power element 210. The power element 210 generates a counterforce against the solenoid force by displacement of the bellows 245. The counterforce is also transmitted to the main valve element 30 via the actuating rod 38 and the sub-valve element 36.

[0076] The actuating rod 38 extends through the sub-valve element 36, and has an end operably connected to the power element 210. A drive force (also referred to as a "pressure-sensing drive force") generated by expansion/contraction movement of the power element 210 is exerted on the actuating rod 38 against the solenoid force. Thus, while the main valve is controlled, a force adjusted by the solenoid force and the pressure-sensing drive force acts on the main valve element 30 to appropriately control the opening degree of the main valve. Even during the control of the main valve, when the suction pressure Ps has become substantially high, the actuating rod 38 is displaced relative to the body 205 against the biasing force of the bellows 245, and lifts up the sub-valve element 36 to open the sub-valve after closing the main valve. This achieves the bleeding function.

[0077] In the structure as described above, when a starting current is supplied to the solenoid 4, this opens the sub-valve when the suction pressure Ps is higher than a valve-opening pressure (which will be also referred to as a "sub-valve opening pressure") determined by the amount of the supplied current. Thus, the solenoid force is greater than the biasing force of the spring 42, which integrally lifts up the sub-valve element 36. As a result, the sub-valve element 36 leaves the sub-valve seat 34 to open the sub-valve. Note that the "sub-valve opening pressure" changes with the preset pressure P_{set} varying depending on the environment in which the vehicle is present.

[0078] When the current value supplied to the solenoid 4 is within a control current range for the main valve, the opening degree of the main valve is autonomously regulated so that the suction pressure Ps becomes the preset pressure P_{set}. The preset pressure P_{set} changes depending on the amount of current supplied to the solenoid 4. In this control state of the main valve, the sub-valve element 36 is seated on the sub-valve seat 34 and the sub-valve remains in the closed state. Since the suction pressure Ps is relatively low, the bellows 245 expands and the main valve element 30 moves to regulate the opening degree of the main valve. In this process, the main valve element 30 stops at a valve lifted position where the force in the valve opening direction generated by the spring 44, the force in the valve closing direction from the solenoid, and the force in the valve opening direction generated by the power element 6 depending on the suction pressure Ps are balanced.

[0079] When the refrigeration load is increased and the suction pressure Ps becomes higher than the preset pressure P_{set}, for example, the bellows 245 contracts, and the main valve element 30 is thus displaced relatively upward (in the valve closing direction). As a result, the valve opening degree of the main valve becomes smaller, and the compressor operates to increase the discharging capacity. Consequently, the suction pressure Ps changes in the lowering direction. Conversely, when the refrigeration load becomes smaller and the suction pressure Ps becomes lower than the preset pressure P_{set}, the bellows 245 expands. As a result, the power element 210 biases the main valve element 30 in the valve opening direction, increasing the valve opening degree of the main valve, and the compressor operates to reduce the discharging capacity. Consequently, the suction pressure Ps is kept at the preset pressure P_{set}.

[0080] During the steady control as described above, the microcomputer 123 performs the feedback control to correct the autonomous control of the main valve. Specifically, the microcomputer 123 computes the duty ratio on the basis of the deviation of the detected suction pressure Ps from the preset pressure P_{set} (to reduce the deviation close to zero), and corrects a drive command to the drive circuit 129.

[0081] According to the present embodiment, the Ps sensing valve also produces the effects similar to those in the first embodiment. Furthermore, the autonomous control performed by the operation of the power element 210 improves the responsiveness of the control of bringing the suction pressure Ps closer to the preset pressure P_{set}. When the time constant of the pressure sensor 8 increases, the autonomous operation reduces delay of the control. Conversely, when control response is delayed due to pressure sensing in the autonomous control, the feedback control reduces the delay in the response. Control hunting due to a delay in response can also be prevented or reduced. In other words, since the control valve 201 is provided with the pressure sensing part and the control unit, the improvement in the responsiveness of the Ps sensing valve and the improvement in the accuracy of the Ps control are achieved at the same time.

[Third Embodiment]

[0082] FIG. 7 is a cross-sectional view illustrating a structure of a control valve according to a third embodiment. The following description will focus on the differences from the first embodiment. In FIG. 7, components or parts substantially the same as those in the first embodiment will be designated by the same reference numerals.

[0083] A control valve 301 of the present embodiment is different from that of the first embodiment in including no bleed valve and in the arrangement of the valve elements and the solenoid. The control valve 301 includes a body 305 (which functions as a "valve body") having a stepped cylindrical shape, and a solenoid 304 mounted on the body 305 in the axial direction.

[0084] A port 16 (discharge chamber communication port) is formed at an upper end opening of the body 305, and a port 14 (control chamber communication port) and a port 12 (suction chamber communication port) are formed in this order from the top at a lateral side of the body 305. The body 305 has a flow passage 318 through which the port 14 and the port 16 communicate with each other, and a pressure chamber 28 communicating with the port 12. A valve hole 20 is formed at an intermediate position of the flow passage 318, and a valve seat 22 is formed at an upstream end of the valve hole 20. A filter member 315 having a bottomed cylindrical shape is attached to the port 16.

[0085] In the body 305, a guiding passage 327 is formed through a partition part between the flow passage 318 and the pressure chamber 28. The valve hole 20 and the guiding passage 327 are coaxial along the axis of the body 305. The pressure chamber 28 is open widely to below the body 305. A communication passage 332 is formed on the outer side of the guiding passage 327. The communication passage 332 extends in parallel with the guiding passage 327. The port 12 and the pressure chamber 28 communicate with each other through the communication passage 332.

[0086] A valve chamber 24 is formed between the port 16 and the valve hole 20. A valve element 330 having a ball shape is disposed in the valve chamber 24. The valve seat 22 has a concave spherical surface having a radius of curvature slightly larger than that of the valve element 330 such that the valve element 330 easily touches and leaves the valve seat 22. The valve element 330 touches and leaves the valve seat 22 from the upstream side to close and open the valve section. A spring support 340 is fixed to an upper end part of the body 305, and a spring 342 is disposed between the valve element 330 and the spring support 340. The spring 342 biases the valve element 330 in the valve closing direction. The load of the spring 342 is adjusted by the position on the body 305 to which the spring support 340 is fixed.

[0087] A shaft 338 extends through the valve hole 20 and the guiding passage 327 in the axial direction. The shaft 338 is slidably supported in the guiding passage 327. An upper end part of the shaft 338 having a smaller diameter extends through the valve hole 20 and supports the valve element 330 from the downstream side. A lower end part of the shaft 338 extends across the pressure chamber 28 and is connected to a plunger 350 of the solenoid 304.

[0088] The solenoid 304 includes a cylindrical casing 356, a bobbin 52 contained in the casing 356, an electromagnetic coil 54 wound around the bobbin 52, a cylindrical sleeve 348 supporting the bobbin 52 from the inside, an end member 358 positioned to cover a lower end opening of the casing 356, and a collar 362 embedded in the end member 358 below the bobbin 52. The casing 356 and the end member 358 constitute a "solenoid body." Needless to say, components of the "solenoid body" may also include a member (such as the sleeve 48) fixed relative to the casing 356 or the end member 358. In any case, the sensor body 131 is fixed relative to the solenoid body.

[0089] In addition, the plunger 350 and a core 346 are positioned in a working space 360 formed on an inner side of the electromagnetic coil 54. The sleeve 348 is made of a nonmagnetic material, and holds the electromagnetic coil 54 between the sleeve 348 and the casing 356. The sleeve 348 has a flange part 357 extending radially outward from an upper end opening of the sleeve 348, and being held between the body 305 and the casing 356. The core 346 has a stepped cylindrical shape, and is fixed in such a state that an upper half part of the core 346 is inserted in a lower end part of the sleeve 348. The core 346 has a through-hole 366 along the axial direction. The through-hole 366 is a stepped hole. An upper half part of the through-hole 366 is a large-diameter part with a diameter slightly larger than the remaining part of the through-hole 366. The spring 44 is contained in the large-diameter part.

[0090] The plunger 350 has a stepped columnar shape, and is slidably supported in the sleeve 348. A lower end part of the shaft 338 is coaxially press-fitted into an upper half part of the plunger 350. The plunger 350 is positioned on a side opposite to the control unit 6 with respect to the core 346, and faces the core 346 in the axial direction. A disk-shaped spacer 370 made of a nonmagnetic material is placed between the core 346 and the plunger 350. The spring 44 is a coiled spring with a load larger than the load of the spring 342, and is disposed between a stepped position in the through-hole 366 and the spacer 370. The spring 44 supports the plunger 350 via the spacer 370 in the axial direction, and biases the plunger 350 away from the core 346. An O ring 372 for sealing is attached on a lower end surface of the body 305.

[0091] The inside of the core 346 is open on the side of the pressure sensor 8. A communication groove 66 parallel to the axis is formed on a side surface of the plunger 350 to communicate with through-hole 366 of the core 346. This structure allows the suction pressure Ps in the pressure chamber 28 to be also introduced into the pressure sensor 8. The pressure sensor 8 is supported in the axial direction between the core 346 and the cap member 78, and fixed relative to the end member 358 (solenoid body). A space surrounded by the sensor module 133 and the core 346 constitutes the first pressure chamber 143, and the suction pressure Ps is applied to an upper surface of the pressure sensing member 161.

[0092] In the structure described above, while the solenoid 304 is powered off, the suction force does not act between the core 346 and the plunger 350. In the meantime, since the load of the spring 44 is set at a load significantly greater than the load of the spring 342, the plunger 350 is shifted upward, and moves together with the shaft 338 to move the valve element 330 in the valve opening direction. As a result, the valve section becomes in the fully-open state, the control pressure Pc increases, and the compressor operates in the minimum capacity operation mode.

[0093] When a starting current is supplied to the solenoid 304, the core 346 sucks (pulls) the plunger 350 against the biasing force of the spring 44. Accordingly, the valve element 330 is pressed downward by spring 342 and touches the valve seat 22, which brings the control valve 301 into the closed state.

[0094] When the operation switches to the steady control and a holding current is supplied to the solenoid 304, a force caused by the pressure difference between the discharge pressure Pd and the control pressure Pc (that is, a force corresponding to the pressure difference acting on the valve element 330), a force caused by the pressure difference between the control pressure Pc and the suction pressure Ps (that is, a force corresponding to the pressure difference acting on the shaft 338), a net force of the springs 342 and 44, and the suction force of the solenoid 304 are balanced. Thus, the valve element 330 is lifted up, leaving the valve seat 22, and set at a certain valve opening degree. As a result, the refrigerant at the discharge pressure Pd is controlled at a flow rate according to the valve opening degree before being introduced into the crankcase 112, and the compressor 100 switches to operation with a capacity according to the control current. The microcomputer 123 performs the feedback control described above on the basis of the deviation of the detected suction pressure Ps, which is detected by the pressure sensor 8, from the preset pressure P_{set}, which is received from the air conditioner ECU.

[0095] According to the present embodiment, the effects similar to those in the first embodiment are achieved even with the structure in which the sub-valve (bleed valve) is not used.

[Fourth Embodiment]

[0096] FIG. 8 is a cross-sectional view illustrating a structure of a control valve according to a fourth embodiment. The following description will focus on the differences from the first embodiment. In FIG. 8, components or parts substantially the same as those in the first embodiment will be designated by the same reference numerals.

[0097] A control valve 401 of the present embodiment is a so-called Pd - Ps differential pressure regulating valve that controls the flow rate of refrigerant introduced from the discharge chamber 116 to the crankcase 112 so that the pressure difference (Pd - Ps) between the discharge pressure Pd and the suction pressure Ps of the compressor 100 becomes closer to a preset pressure difference ΔP_{set}, which is a control target value.

[0098] The control valve 401 is formed of an integral assembly of a body 405 and a solenoid 404. A port 16 (discharge chamber communication port) is formed at an upper end of the body 405, and a port 14 (control chamber communication port) and a port 12 (suction chamber communication port) are formed at a lateral side of the body 405.

[0099] In the body 405, a valve seat forming member 416 having a stepped cylindrical shape is provided in a passage through which the port 16 and the port 14 communicate with each other. The valve seat forming member 416 has a higher hardness than the body 405. The valve seat forming member 416 is coaxially inserted in an upper part of the body 405 and fixed thereto. The valve seat forming member 416 has a through-hole 495 along the axis, and a lower half part of the through-hole 495 functions as a valve hole 20. A valve chamber 24 communicating with the port 14 is formed below the valve seat forming member 416 in the body 405. A lower half part of the valve seat forming member 416 has a tapered shape with an outer diameter decreasing downward, and extends into the valve chamber 24. A valve seat 22 is formed at a lower end surface of the valve seat forming member 416. A valve element 430 is positioned in the valve chamber 24 to face the valve seat 22 from below. The valve element 430 moves toward and away from the valve seat 22 to regulate the opening degree of the valve section.

[0100] A bleed hole 496 parallel to the through-hole 495 is formed at a position radially outside of the through-hole 495 in the valve seat forming member 416. The bleed hole 496 is to ensure oil circulation in the compressor in such a manner that a minimum required amount of refrigerant is delivered into the control chamber even while the valve section is closed.

[0101] A partition 426 is provided to divide an internal space of the body 405 into an upper space and a lower space. The upper space above the partition 426 constitutes a valve chamber 24, and the lower space below the partition 426 constitutes a pressure chamber 28. The valve chamber 24 communicates with the control chamber via the port 14. The pressure chamber 28 communicates with the suction chamber 114 via the port 12. A guiding part 432 extending in the axial direction is formed at the center of the partition 426. A guiding passage 427 is formed through the guiding part 432 along the axis, and an elongated actuating rod 434 is inserted into the guiding passage 427 such that the actuating rod 434 is slidable in the axial direction. The valve element 430 is coaxially formed at an upper end of the actuating rod 434. The valve element 430 and the actuating rod 434 are integrally formed with each other through cutting of a stainless steel material.

[0102] The guiding part 432 protrudes by a small amount on an upper surface side of the partition 426, and protrudes by a large amount on a lower surface side of the partition 426. The guiding part 432 has a tapered shape with an outer diameter decreasing downward, and extends into the pressure chamber 28. This allows the guiding passage 427 to have a sufficient length, and the actuating rod 434 to be stably supported. The valve element 430 moves integrally with the actuating rod 434, and touches the valve seat 22 with a top surface thereof and leaves from the valve seat 22 to close and open the valve section. Since the valve seat forming member 416 has a sufficiently high hardness, the valve seat 22 is hardly deformed by repeated seating of the valve element 430 on the valve seat 22, which provides the durability of the valve section.

[0103] A retaining ring 436 (E ring) is fitted to a lower part of the actuating rod 434. A disk-shaped spring support 437 is provided such that the downward movement of the spring support 437 is restricted by the retaining ring 436. A spring 444, which biases the actuating rod 434 downward (in the valve opening direction) is set between the spring support 437 and the body 405 (the partition 426). The spring 444 is a tapered spring with a diameter decreasing from the lower surface of the partition 426 toward the spring support 437 located below the partition 426. The tapered shape of the guiding part 432 as described above allows the tapered spring 444 to be set. A lower part of the body 405 constitutes a connecting part connected with the solenoid 404.

[0104] A filter member 445 to prevent or reduce entry of foreign materials into the port 16 is provided at an upper end opening of the body 405.

[0105] The solenoid 404 includes a cylindrical core 446, a stepped cylindrical sleeve 448 mounted (outserted) around the core 446, a plunger 450 contained in the sleeve 448 and positioned to face the core 446 in the axial direction, a bobbin 52 mounted (outserted) around the sleeve 448, an electromagnetic coil 54 wound around the bobbin 52, a cylindrical casing 456 covering the electromagnetic coil 54 from outside, a stepped cylindrical connecting member 462 mounted above the bobbin 52 and between the core 446 and the casing 456, and an end member 458 attached to a lower end opening of the casing 456. The sleeve 448 is made of a nonmagnetic material, and has an upper half part housing the core 446 and a lower half part housing the plunger 450. A lower part of the sleeve 448 is reduced in diameter and open to the pressure sensor 8.

[0106] An insertion hole 467 is formed through the center of the core 446, and a shaft 438 extends through the insertion hole 467. The shaft 438 is formed coaxially with the actuating rod 434 and supports the actuating rod 434 from below. The shaft 438 has a diameter larger than the diameter of the actuating rod 434. The plunger 450 is mounted on a lower half part of the shaft 438. In the present embodiment, the shaft 438 and the actuating rod 434 constitute a "transmitting rod" that transmits the solenoid force to the valve element 430.

[0107] The plunger 450 is coaxially supported by the shaft 438 at an upper part of the plunger 450. A retaining ring 470 (E ring) is fitted to a predetermined position in an intermediate part in the axial direction of the shaft 438. The retaining ring 470 restricts upward movement of the plunger 450. A communicating groove 466 is formed in parallel with the axis on a lateral surface of the plunger 450, and a communication passage 62 through which the refrigerant passes is formed between the plunger 450 and the sleeve 448.

[0108] A ring-shaped shaft support member 472 is press-fitted into an upper end part of the core 446, and supports an upper end part of the shaft 438 in such a manner that the shaft 438 is slidable in the axial direction. The outer surface of the shaft support member 472 is partially cut out to form a communication passage between the core 446 and the shaft support member 472. The suction pressure Ps is also introduced into the solenoid 404 via the communication passage.

[0109] The lower end part of the sleeve 448 is slightly reduced in diameter, where a ring-shaped shaft support member 476 is press-fitted. The shaft support member 476 slidably supports a lower end part of the shaft 438. Thus, the shaft 438 is supported at two points by the upper shaft support member 472 and the lower shaft support member 476, which allows the plunger 450 to stably operate in the axial direction. A communicating groove 478 is formed on the outer surface of the shaft support member 476, which provides a communication passage between the sleeve 448 and the shaft support member 476. The suction pressure Ps introduced into the solenoid 404 is transferred to the back pressure chamber 70 via the communication passage between the core 446 and the shaft 438, the communication passage between the plunger 450 and the sleeve 448, and the communication passage between the shaft support member 476 and the sleeve 448. The back pressure chamber 70 communicates with the first pressure chamber 143.

[0110] A spring 442 that biases the plunger 450 upward, that is, in the valve closing direction, is set between the shaft support member 476 and the plunger 450. Thus, the valve element 430 receives, as a spring load, the net force of a force in the valve opening direction exerted by the spring 444 and a force in the valve closing direction exerted by the spring 442. Since, however, the load of the spring 444 is larger than the load of the spring 442, the combined spring load of the springs 444 and 442 acts in the valve opening direction.

[0111] The structure as described above allows the suction pressure Ps in the pressure chamber 28 to be also introduced into the pressure sensor 8. The pressure sensor 8 is supported in the axial direction between the sleeve 448 and the cap member 78, and fixed relative to the end member 458 (solenoid body). A space surrounded by the sensor module 133 and the sleeve 448 constitutes the first pressure chamber 143, and the suction pressure Ps is applied to the upper surface of the pressure sensing member 161.

[0112] In the structure described above, the actuating rod 434 has a diameter slightly smaller than, but approximately equal to, the inner diameter of the valve hole 20. Thus, the influence of the control pressure Pc acting on the valve element 430 in the valve chamber 24 is almost canceled out. As a result, the pressure difference (Pd - Ps) between the discharge pressure Pd and the suction pressure Ps practically acts on the valve element 430 over a pressure-receiving area of approximately the same size as the valve hole 20. The valve element 430 operates such that the pressure difference (Pd - Ps) is maintained at the preset pressure difference ΔP_{set} set by a control current supplied to the solenoid 404.

[0113] While the solenoid 404 is powered off, the load in the valve opening direction caused by the net force of the springs 444 and 442 separates the valve element 430 away from the valve seat 22 and holds the valve section in the fully-open state. As a result, the compressor 100 operates in the minimum capacity operation mode.

[0114] When a starting current is supplied to the solenoid 404, the plunger 450 is sucked (pulled) by the core 446 with a maximum suction force. Thus, the valve element 430, the actuating rod 434, the shaft 438, and the plunger 450 move together in the valve closing direction, and the valve element 430 touches the valve seat 22. As a result, the compressor 100 operates in a maximum capacity operation mode.

[0115] When the operation switches to the steady control and a holding current is supplied to the solenoid 404, the valve element 430, the actuating rod 434, the shaft 438, and the plunger 450 move together. In this process, the valve element 430 stops at a valve lifted position where the spring load of the spring 444 biasing the actuating rod 434 in the valve opening direction, the spring load of the spring 442 basing the plunger 450 in the valve closing direction, the load of the solenoid 404 biasing the plunger 450 in the valve closing direction, a force caused by the discharge pressure Pd received by the valve element 430 in the valve opening direction, and a force caused by the suction pressure Ps received by the valve element 430 in the valve closing direction are balanced.

[0116] When, in this balanced state, the rotating speed of the compressor rises with the engine speed, which increases the discharging capacity, the pressure difference (Pd - Ps) increases, applying a force in the valve opening direction to the valve element 430. This further lifts up the valve element 430 and increases the flow rate of the refrigerant flowing from the discharge chamber 116 to the crankcase 112. As a result, the control pressure Pc increases, the compressor 100 operates in a direction to decrease the discharging capacity, and control is performed such that the pressure difference (Pd - Ps) becomes the preset pressure difference ΔP_{se}t. Conversely, when the engine speed decreases, operation reverse to the above is performed, and control is performed such that the pressure difference (Pd - Ps) becomes the preset pressure difference ΔP_{se}t.

[0117] During the steady control as described above, the control valve 401 performs control such that the pressure difference (Pd - Ps) is maintained at the preset pressure difference ΔP_{set} in a normal state where the suction pressure Ps is not lower than the preset pressure P_{set}, and such that the suction pressure Ps becomes closer to the preset pressure P_{set} when the suction pressure Ps is lower than the preset pressure P_{set}. Thus, the control valve 401 basically functions as a Pd - Ps differential pressure regulating valve that controls the pressure difference (Pd - Ps), but also functions as a Ps control valve when the suction pressure Ps has excessively lowered, so as to prevent excessive cooling.

[0118] When the detected suction pressure Ps is lower than the preset pressure P_{set}, the microcomputer 123 performs the feedback control to bring the suction pressure Ps closer to the preset pressure P_{set}. Specifically, the microcomputer 123 computes a duty ratio on the basis of a deviation of the suction pressure Ps from the preset pressure P_{set}, and outputs a drive command to the drive circuit 129.

[0119] According to the present embodiment, the control valve that performs control such that the pressure difference between two predetermined points in the compressor 100 is constant also produces the effects similar to those in the first embodiment. Furthermore, the pressure difference (Pd - Ps) can be estimated from a control setting value, and the suction pressure Ps can be obtained on the basis of a detection value from the pressure sensor 8. The value of the discharge pressure Pd can be estimated from the estimated pressure difference (Pd - Ps) and the obtained suction pressure Ps. This eliminates the need for providing an additional sensor for detecting the discharge pressure Pd. In the present embodiment, the control of the pressure difference (Pd - Ps) is regarded as main control while the control of the suction pressure Ps is regarded as auxiliary control. In a modification, the control of the suction pressure Ps may be regarded as main control. Specifically, the microcomputer 123 may perform feedback control such that the suction pressure Ps is brought closer to the preset pressure P_{set} during steady control. In this case, the control valve 401 autonomously operates to keep the suction pressure Ps constant while bringing the pressure difference (Pd - Ps) to a preset pressure difference ΔP_{set} that is optimum for the suction pressure Ps.

[Fifth Embodiment]

[0120] FIG. 9 is a cross-sectional view illustrating a structure of a control valve according to a fifth embodiment. The following description will focus on the differences from the first embodiment. In FIG. 9, components or parts substantially the same as those in the first embodiment will be designated by the same reference numerals.

[0121] A control valve 501 of the present embodiment is a flow control valve for control such that the discharge flow rate of the compressor 100 becomes a set flow rate. The control valve 501 is formed of an integral assembly of a body 505 and a solenoid 504 in the axial direction. An end member 513 is fixed at an upper end opening of the body 505. A power element 510 is integrated with the end member 513.

[0122] The body 505 has a stepped cylindrical shape, and has a port 517 (discharge chamber downstream side communication port), a port 16 (discharge chamber communication port), a port 14 (control chamber communication port), and a port 12 (suction chamber communication port) formed in this order from the top at a lateral side of the body 505. In addition, a communication hole 520 is formed through the end member 513 in the axial direction, and a port 516 (discharge chamber communication port) is formed at an upper end opening of the communication hole 520. Thus, a first discharge pressure Pd1 in the discharge chamber 116 is introduced into the power element 510 through the port 516.

[0123] The port 517 allows a pressure chamber 523, which is defined in an upper part of the body 505, to communicate with the downstream side of the fixed orifice 117 (the upstream side of the discharge valve 160), and allows the second discharge pressure Pd2 to be introduced into the pressure chamber 523. The power element 510 is positioned in the pressure chamber 523. A guiding passage 525 (first guiding passage) is formed between the port 16 and the pressure chamber 523. A guiding passage 527 (second guiding passage) is formed between the port 12 and the port 14. An actuating rod 538 is inserted through the guiding passages 525 and 527. A valve chamber 24 and a valve hole 20 are formed between the port 14 and the port 16. The actuating rod

538 is slidably supported in the guiding passages 525 and 527, with an upper end side connected to the power element 510 and a lower end side connected to a plunger 550 of the solenoid 504. A valve element 530 is integrally formed at an intermediate position of the actuating rod 538.

[0124] The power element 510 includes a bellows 545 that senses the pressure difference (Pd1 - Pd2) between the first discharge pressure Pd1 and the second discharge pressure Pd2, and is shifted in position by the pressure difference (Pd1 - Pd2). A spring 542 to bias the bellows 545 in an extending direction (the valve opening direction) is set inside the power element 510. The power element 510 generates a counterforce against the solenoid force by displacement of the bellows 545. The counterforce is also transmitted to the valve element 530 via the actuating rod 538. In view of the stability of the pressure difference (Pd1 - Pd2) to be sensed, the second discharge pressure Pd2 is preferably introduced from a position away from the discharge valve 160 (check valve).

[0125] The solenoid 504 includes a core 546, a sleeve 548, the plunger 550, a bobbin 52, an electromagnetic coil 54, a casing 556, and an end member 558. A lower end part of the actuating rod 538 is inserted in and supported by the plunger 550.

[0126] In the structure described above, the outer diameter of the valve element 530 (the inner diameter of the guiding passage 527) is slightly larger than, but approximately equal to, the inner diameter of the valve hole 20. Thus, the influence of the control pressure Pc acting on the valve element 530 is substantially cancelled out.

[0127] While the solenoid 504 is powered off, the biasing force of the spring 44 separates the valve element 530 away from the valve seat 22 and holds the valve section in the fully-open state. As a result, the compressor 100 operates in the minimum capacity operation mode.

[0128] When a starting current is supplied to the solenoid 504, the plunger 550 is sucked (pulled) by the core 546 with a maximum suction force. Thus, the valve element 530, the actuating rod 538, and the plunger 550 move together in the valve closing direction, and the valve element 530 touches the valve seat 22. As a result, the compressor 100 operates in the maximum capacity operation mode.

[0129] When the operation switches to the steady control and a holding current is supplied to the solenoid 504, the valve element 530, the actuating rod 538, and the plunger 550 move together. In this process, the valve element 530 stops at a valve lifted position where the spring load of the spring 44 biasing the actuating rod 538 in the valve opening direction, the load of the solenoid 504 biasing the plunger 550 in the valve closing direction, a force caused by the discharge pressure Pd received by the valve element 530 in the valve opening direction, and a force caused by the suction pressure Ps received by the valve element 530 in the valve closing direction are balanced.

[0130] When, in this balanced state, the rotating speed of the compressor rises with the engine speed, which increases the discharge flow rate, the pressure difference (Pd1 - Pd2) increases and the bellows 545 expands. This further lifts up the valve element 530 and increases the flow rate of the refrigerant flowing from the discharge chamber 116 to the crankcase 112. As a result, the control pressure Pc increases, the discharge flow rate of the compressor 100 decreases, and control is performed such that the pressure difference (Pd1 - Pd2) becomes a preset pressure difference ΔPd_{set}. Conversely, when the engine speed decreases, operation reverse to the above is performed, and control is performed such that the pressure difference (Pd1 - Pd2) becomes the preset pressure difference ΔPd_{set}. When the pressure difference (Pd1 - Pd2) is kept constant, the discharge flow rate is also constant. As a result, the discharge flow rate is maintained at a preset flow rate.

[0131] During the steady control as described above, the control valve 501 performs control such that the pressure difference (Pd1 - Pd2) is maintained at the preset pressure difference ΔPd_{set} in a normal state where the suction pressure Ps is not lower than the preset pressure P_{set}, and such that the suction pressure Ps becomes closer to the preset pressure P_{set} when the suction pressure Ps is lower than the preset pressure P_{set}. Thus, the control valve 501 basically functions as a flow control valve that maintains the discharge flow rate at a preset flow rate, but also functions as a Ps control valve when the suction pressure Ps has excessively lowered, so as to prevent excessive cooling.

[0132] When the detected suction pressure Ps is lower than the preset pressure P_{set}, the microcomputer 123 performs the feedback control to bring the suction pressure Ps closer to the preset pressure P_{set}. Specifically, the microcomputer 123 computes a duty ratio on the basis of a deviation of the suction pressure Ps from the preset pressure P_{set}, and outputs a drive command to the drive circuit 129.

[0133] According to the present embodiment, the control valve that performs control such that the discharge flow rate of the compressor 100 becomes constant also produces the effects similar to those in the first embodiment. In the present embodiment, the flow control is regarded as main control while the control of the suction pressure Ps is regarded as auxiliary control. In a modification, the control of the suction pressure Ps may be regarded as main control. Specifically, the microcomputer 123 may perform feedback control such that the suction pressure Ps is brought closer to the preset pressure P_{set} during steady control. In this case, the control valve 501 autonomously operates to keep the suction pressure Ps constant while bringing the pressure difference (Pd1 - Pd2) to a preset pressure difference ΔPd_{set} that is optimum for the suction pressure Ps.

[0134] With the pressure sensor 8 capable of detecting the value of the suction pressure Ps, the torque of the compressor 100 can also be calculated on the basis of the suction pressure Ps and a preset flow rate. Such calculation of torque may be carried out by the microcomputer 123 or the air conditioner ECU 105. In the former case, torque information can be sent from the microcomputer 123 to the air conditioner ECU 105. In the latter case, flow rate information and information on the suction pressure Ps can be sent from the microcomputer 123 to the air conditioner ECU 105, and the torque can be calculated by the air conditioner ECU 105. According to the present embodiment, torque control through control on the refrigerant flow rate, control on the blowout air temperature through control on the suction pressure, estimation of torque based on an output from the pressure sensor 8, and the like can be performed. This achieves both power saving through torque control and improved comfort through air temperature control.

[0135] The description of the present invention given above is based upon certain embodiments. The embodiments are intended to be illustrative only and it will be obvious to those skilled in the art that various modifications could be further developed within the technical idea underlying the present invention.

[0136] In the embodiments described above, an example configuration in which the circuit board 121 has the communication circuit 127 (transceiver) as a communication unit as illustrated in FIG. 2 has been presented. In a modification, a configuration in which such communication circuit 127 is not included but the microcomputer 123 and the air conditioner ECU 105 communicate with each other may be used.

[0137] FIG. 10 is a schematic diagram illustrating an electrical configuration of a control valve 701 and other surrounding components according to a modification. In this modification, the microcomputer 123 and the air conditioner ECU 105 communicate with each other through serial communication. A MOSI line 172c, a MISO line 172d, and a SCK line 172e are provided between the microcomputer 123 and the air conditioner ECU 105. The MOSI line 172c is a communication line connecting in input port of the microcomputer 123 with an output port of the air conditioner ECU 105. The MISO line 172d is a communication line connecting an output port of the microcomputer 123 with an input port of the air conditioner ECU 105. The SCK line 172e is a communication line for sending a synchronizing clock from the air conditioner ECU 105 to the microcomputer 123.

[0138] With this structure, in this modification, the power supply terminal 72a, the ground terminal 72b and three communication terminals 172c, 172d, and 172e (also collectively be referred to as "connection terminals 172") extend from a circuit board 721, and are arranged inside the connector part 74.

[0139] In the embodiments described above, an example of the structure of the pressure sensor 8 has been presented. Needless to say, a pressure sensor 8 having a different structure may be used. While a pressure sensor having a strain gauge has been presented in the embodiments described above, a pressure sensor having a magnetic sensor may be used. For example, a magnetic sensor including a magnet in provided integrally with a pressure sensing member and being configured to output a detection signal depending on displacement of the magnet caused by displacement of the pressure sensing member may be used. The microcomputer 123 may calculate the suction pressure Ps and the like on the basis of the detection value from the magnetic sensor.

[0140] In the embodiments described above, as illustrated in FIG. 4, a configuration in which the control unit 6 is integrally provided with the pressure sensor 8 has been presented. In a modification, the control unit 6 and the pressure sensor 8 may be provided separately and individually mounted in the chamber 76 in the solenoid body.

[0141] In the embodiments described above, as illustrated in FIG. 2, a configuration in which the drive circuit 129 and the power supply circuit 125 are arranged outside of the microcomputer 123. However, one or both of the drive circuit 129 and the power supply circuit 125 may be provided inside the microcomputer 123. The same applies to the modification in FIG. 10.

[0142] In the embodiments described above, a structure in which the control unit is provided in the solenoid body has been presented. In a modification, the pressure sensor may be provided in the solenoid body, and other circuits and the like may be provided outside of the control valve. Other circuits and the like may be included in the air conditioner ECU. The solenoid body may integrally include a common connector part having connection terminals connected to the power supply line and the ground line of the solenoid and connection terminals connected to the power supply line, the ground line, and the output line of the pressure sensor. In addition, a detection signal from the pressure sensor may be output to the air conditioner ECU via the output line. The control valve may perform only input/output of power supply and output from the pressure sensor. The air conditioner ECU may compute pressure on the basis of the output from the pressure sensor and supply necessary control current to the control valve.

[0143] In the embodiments described above, an example in which the pressure sensor senses the suction pressure Ps has been presented. In a modification, a configuration in which the pressure sensor senses the control pressure Pc may be used. In this case, the control pressure Pc may be a gauge pressure or an absolute pressure. A passage for introducing the control pressure Pc into the pressure sensor may be formed in at least one of the valve body and the solenoid body. Alternatively, the pressure sensor may sense a pressure difference (Pd - Ps) between the discharge pressure Pd and the suction pressure Ps. Alternatively, the pressure sensor may sense a pressure difference (Pd1 - Pd2) between the first discharge pressure Pd1 and the second discharge pressure Pd2. In this case, a passage for introducing the discharge pressure Pd (the first discharge pressure Pd1, the second discharge pressure Pd2) to the pressure sensor may be formed in at least one of the valve body and the solenoid body. Note that, in the embodiments described above, as illustrated in FIG. 3, an example in which the fixed orifice 117 is formed on the upstream side of the discharge valve 160 has been presented. In a modification, a fixed orifice 117 may be formed on the downstream side of the discharge valve 160. In addition, a pressure difference between upstream pressure and downstream pressure of the fixed orifice 117 may be sensed and used for flow control.

[0144] In the embodiments described above, the control valve that performs control in such a manner that the valve opening degree is regulated through PWM control has been presented. In a modification, a control valve that performs control in such a manner that the valve section is opened and closed even during steady control and that the opening and closing timings (open and closed periods) are changed may be used. For example, a control valve in which the valve section can be opened and closed at about 10 Hz and the valve open period is regulated may be used.

[0145] In the embodiments described above, as illustrated in FIG. 5, an example in which the pressure sensing member (the pressure sensing part) of the pressure sensor includes the sensing element, the diaphragm, and the protective material (the transmitting material) between the sensing element and the diaphragm has been presented. In a modification, a sensing element and a protective material may constitute a pressure sensing member without a diaphragm. Alternatively, a sensing element alone may constitute a pressure sensing member without a diaphragm and a protective material. In such a structure, the working space on the inner side of the electromagnetic coil may be open to the pressure sensing member. Specifically, a part of the pressure sensor that receives a difference pressure and is deformed by the difference pressure, whose deformation is electrically detected and converted into a pressure value, may be a "pressure sensing part."

[0146] In the embodiments described above, the control valve for so-called "inflow control" for regulating the flow rate of refrigerant introduced from the discharge chamber into the control chamber to change the discharging capacity of the compressor has been presented. In a modification, a control valve for so-called "outflow control" for regulating the flow rate of refrigerant delivered from the control chamber to the suction chamber to change the discharging capacity of the compressor may be used. The control valve for outflow control may be integrally provided with the pressure sensor 8 and perform feedback control such that the suction pressure Ps is brought closer to the preset pressure P_{set}.

[0147] In the embodiments described above, a structure in which the working space on the inner side the electromagnetic coil is open to the pressure sensing member of the pressure sensor has been presented. In a modification, the working space and the pressure sensing member may be separated from each other. A pressure to be sensed may be introduced through a port additionally formed on the solenoid body and transferred to the pressure sensing member.

[0148] In the embodiments described above, a structure in which the control unit is positioned on a side opposite to the valve body with respect to the electromagnetic coil has been presented. In a modification, the control unit may be provided between the valve body and the solenoid body or inside of the valve body. With such a structure as well, an object of improving control accuracy with a single control valve can be achieved.

[0149] Although not mentioned in the embodiments described above, a logic IC having the functions of a drive circuit may be mounted on the circuit board of the control valve. The logic IC may operate on the basis of a command signal from the air conditioner ECU to control the solenoid.

[0150] In the embodiments described above, an example in which information representing the preset pressure P_{set} is sent as a control command from the air conditioner ECU to the microcomputer 123 has been presented. The "information representing the preset pressure P_{set}" may be a value representing the preset pressure P_{set} itself or may be temperature information associated with the preset pressure P_{set}.

[0151] The present invention is not limited to the above-described embodiments and modifications only, and the components may be further modified to arrive at various other embodiments without departing from the scope of the invention. Various other embodiments may be further formed by combining, as appropriate, a plurality of structural components disclosed in the above-described embodiments and modifications. Furthermore, one or some of all of the components exemplified in the above-described embodiments and modifications may be left unused or removed.

Claims

1. A control valve (1, 201, 301, 401, 501) for a variable displacement compressor (100), the control valve (1, 201, 301, 401, 501) being insertable in a mounting hole (118) formed in the variable displacement compressor (100) and configured to control a discharging capacity of a refrigerant discharged by the compressor (100), the control valve (1, 201, 301, 401, 501) comprising:

   a valve body (5, 205, 305, 405, 505) having a flow passage for the refrigerant, and a valve hole (20) formed in the flow passage;
   a valve element (30, 330, 430, 530) that moves toward and away from the valve hole (20) to close and open a valve section;
   a solenoid (4, 304, 404, 504) mounted on the valve body (5, 205, 305, 405, 505), and configured to apply a drive force in an axial direction

to the valve element (30, 330, 430, 530), the drive force being dependent on a current supplied to the solenoid (4, 304, 404, 504); and
a pressure sensor (8) to detect a predetermined refrigerant pressure (Ps) to be referred to for power supply control of the solenoid (4, 304, 404, 504),
wherein the solenoid (4, 304, 404, 504) includes:

a solenoid body (56, 58, 356, 358, 456, 458, 556, 558) integrally mounted on the valve body (5, 205, 305, 405, 505) in the axial direction;
an electromagnetic coil (54) held by the solenoid body (56, 58, 356, 358, 456, 458, 556, 558) and having a working space on an inner side thereof;
a core (46, 346, 446, 546) fixed to the solenoid body (56, 58, 356, 358, 456, 458, 556, 558) coaxially with the electromagnetic coil (54);
a plunger (50, 350, 450, 550) supported in the working space such that the plunger (50, 350, 450, 550) is displaceable in the axial direction; and
a power supply line (55) connected to the electromagnetic coil (54) and drawn out from a side of the solenoid body (56, 58, 356, 358, 456, 458, 556, 558) opposite to the valve body (5, 205, 305, 405, 505),

wherein the pressure sensor (8) includes:

a pressure sensing part (161) that senses the refrigerant pressure (Ps) and is displaced by the sensed refrigerant pressure (Ps); and
an output line (59) to output a detection signal depending on a displacement of the pressure sensing part (161), and

wherein the pressure sensor (8) is positioned on a side of the electromagnetic coil (54) opposite to the valve body (5, 205, 305, 405, 505).

2. The control valve (1, 201, 301, 401, 501) according to claim 1,

wherein the pressure sensor (8) is accommodated in a space in the solenoid body (56, 58, 356, 358, 456, 458, 556, 558) on a side opposite to the valve body (5, 205, 305, 405, 505).

3. The control valve (1, 201, 301, 401, 501) according to claim 1 or claim 2,

wherein the pressure sensor (8) has a sensor body (131) surrounding the pressure sensing part (161),
wherein the sensor body (131) is fixed relative to the solenoid body (56, 58, 356, 358, 456, 458, 556, 558),
wherein the refrigerant pressure (Ps) is introduced into the working space, and
wherein the working space is open to the pressure sensing part (161).

4. The control valve (1, 201, 301, 401, 501) according to any one of claims 1 to 3, further comprising:

a control unit (123) to receive a detection signal from the pressure sensor (8) through the output line (59), and perform power supply control on the solenoid (4, 304, 404, 504) based on a command from an external controller (105),
wherein the control unit (123) is position on a side of the electromagnetic coil (54) opposite to the valve body (5, 205, 305, 405, 505), and
wherein the control unit (123) performs feedback control to bring a control quantity defined in association with the refrigerant pressure (Ps) closer to a target value based on command information from the external controller (105) and detection information from the pressure sensor (8).

5. The control valve (1, 201, 301, 401, 501) according to claim 4,

wherein the solenoid body (56, 58, 356, 358, 456, 458, 556, 558) integrally includes a common connector part (74) having a connection terminal (72) connected to a communication line (L2) between the control valve (1, 201, 301, 401, 501) and the external controller (105) and a connection terminal (72) connected to the power supply line (55).

6. The control valve (1, 201, 301, 401, 501) according to claim 5, further comprising:

a circuit board (121) having mounted thereon a control circuit (123) functioning as the control unit (123), a communication circuit (127) to communicate with the external controller (105), and the pressure sensor (8),
wherein the circuit board (121) is positioned on a side of the electromagnetic coil (54) opposite to the valve body (5, 205, 305, 405, 505).

7. The control valve (1, 201, 301, 401, 501) according to any one of claims 1 to 3,

wherein the solenoid body (56, 58, 356, 358, 456, 458, 556, 558) integrally includes a common connector part (74) having a connection terminal (72a) connected to the power supply line (55) and a connection terminal (72c) connected to the output line (59).

FIG.1

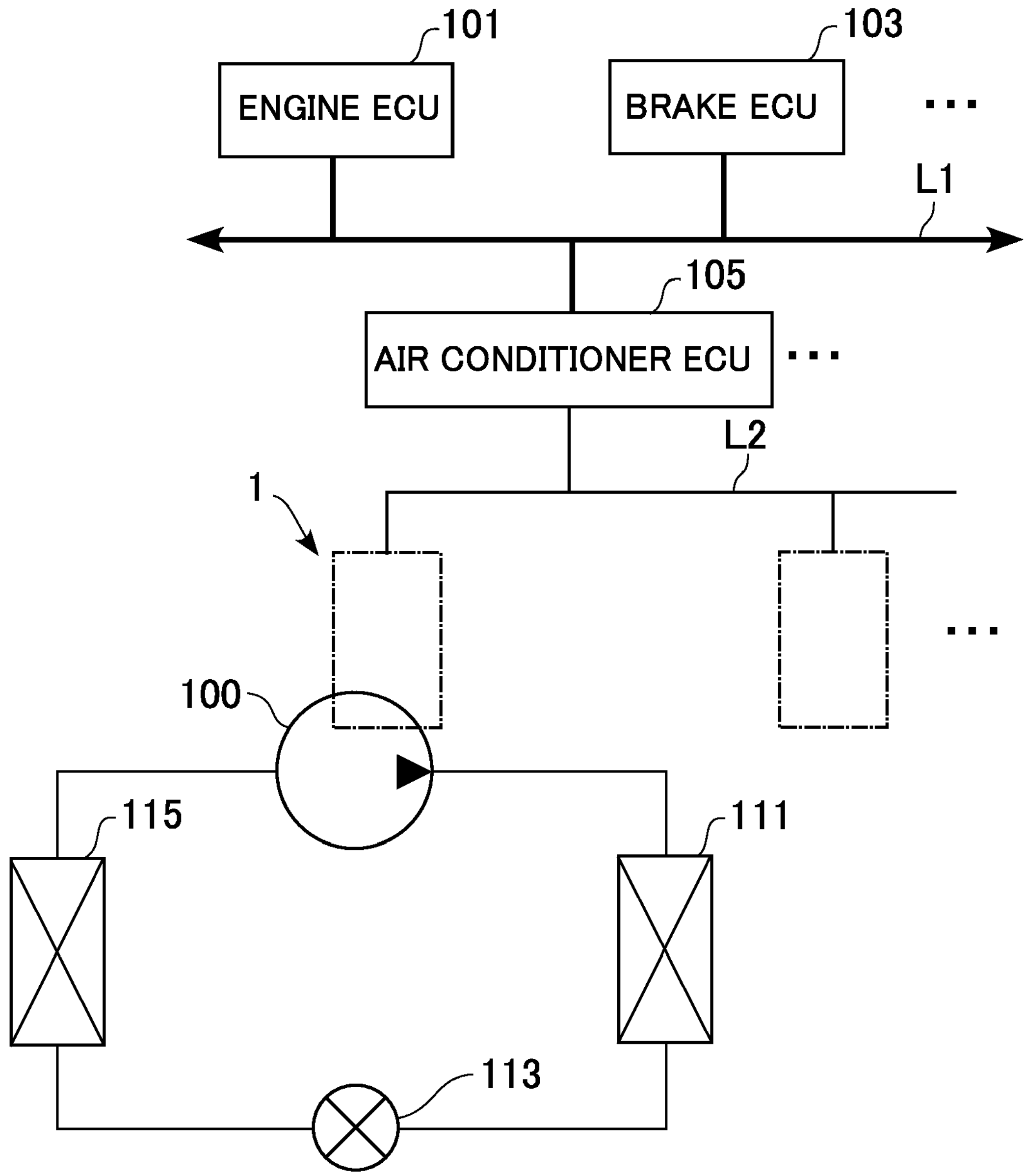
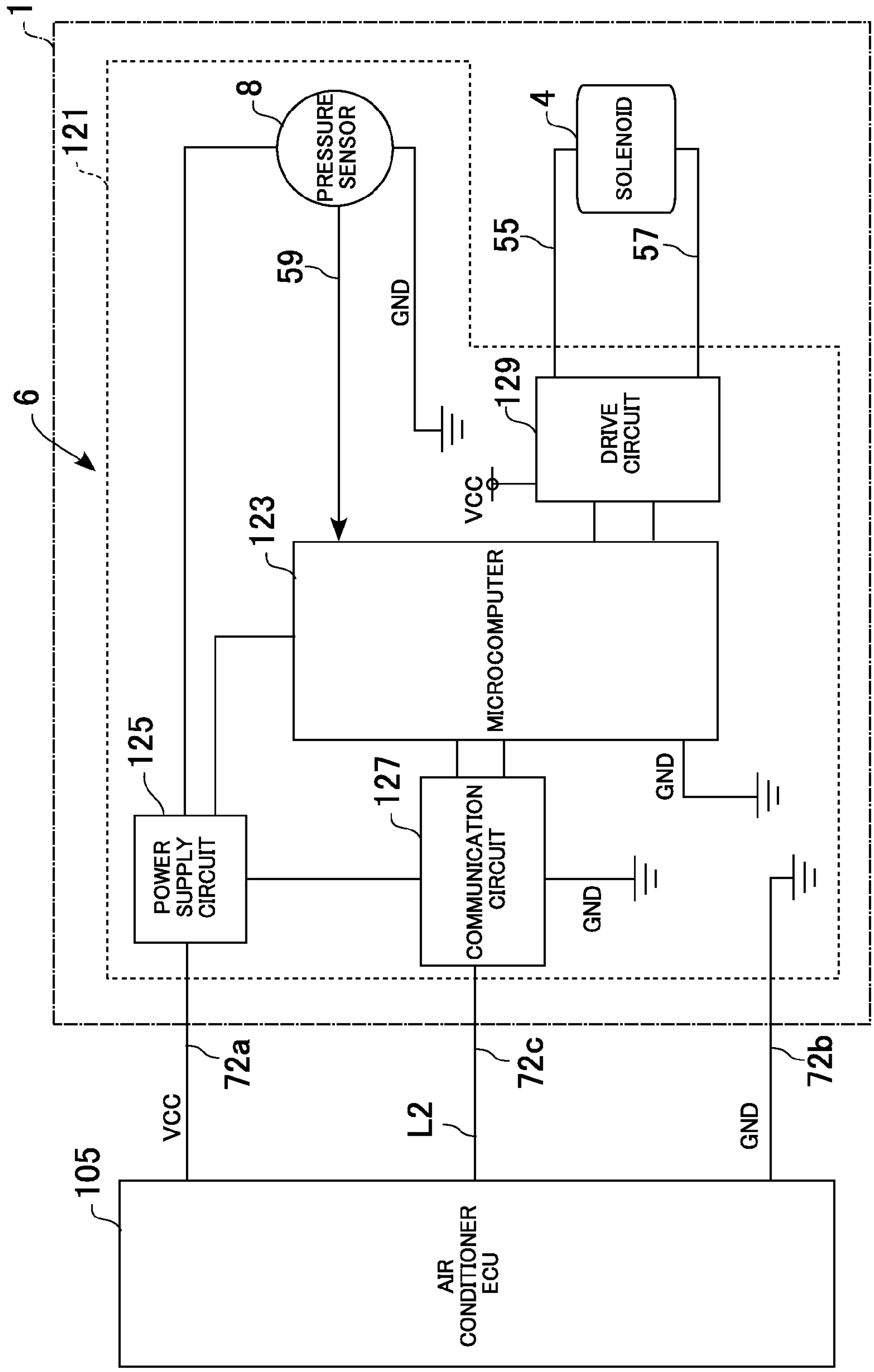

101
ENGINE ECU
103
BRAKE ECU
...
L1
105
AIR CONDITIONER ECU
...
L2
1
...
100
115
111
113

FIG.2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121
8
PRESSURE SENSOR
4
SOLENOID
55
57
59
GND
6
129
DRIVE CIRCUIT
VCC
123
MICROCOMPUTER
GND
125
POWER SUPPLY CIRCUIT
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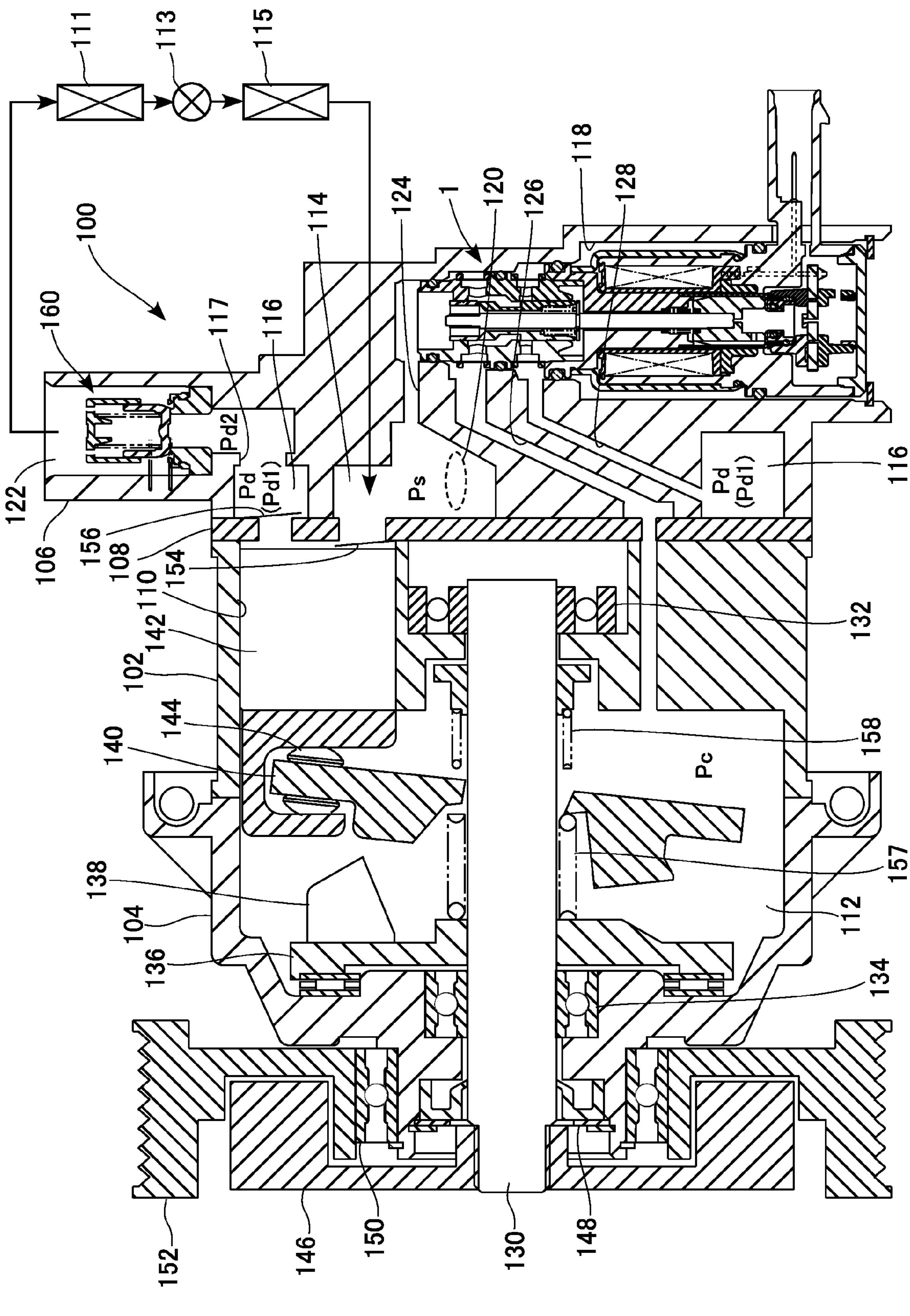
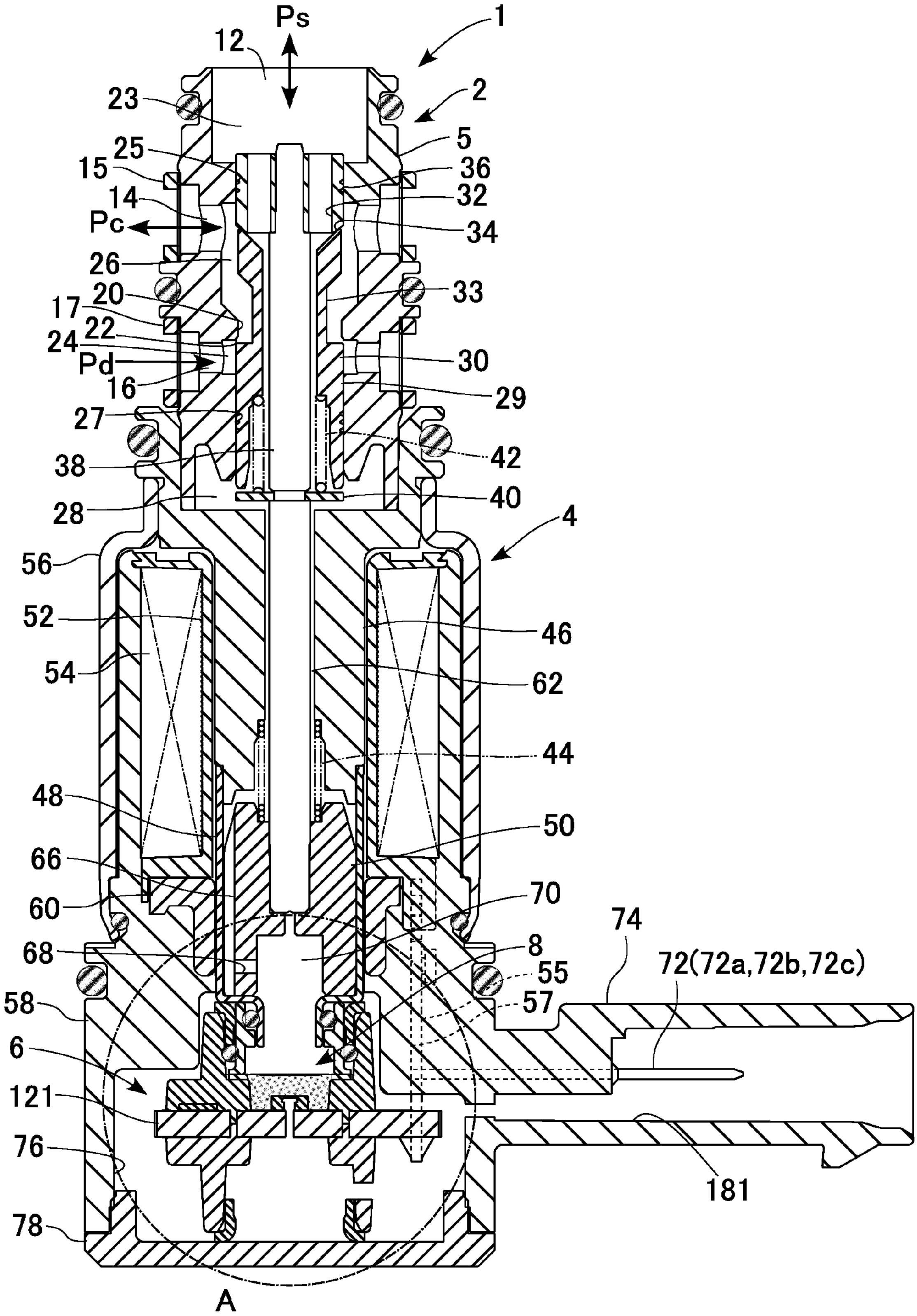
GND
72a
72c
72b
VCC
L2
GND
105
AIR CONDITIONER ECU

FIG.3



111
113
115
100
160
117
116
114
124
1
120
126
118
128
Pd2
Pd
(Pd1)
Ps
116
122
106
156
108
154
110
142
102
132
144
140
158
Pc
138
104
157
136
112
134
152
146
150
130
148

FIG.4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14
Pc
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16
29
27
42
38
40
28
4
56
52
46
54
62
44
48
50
66
70
60
74
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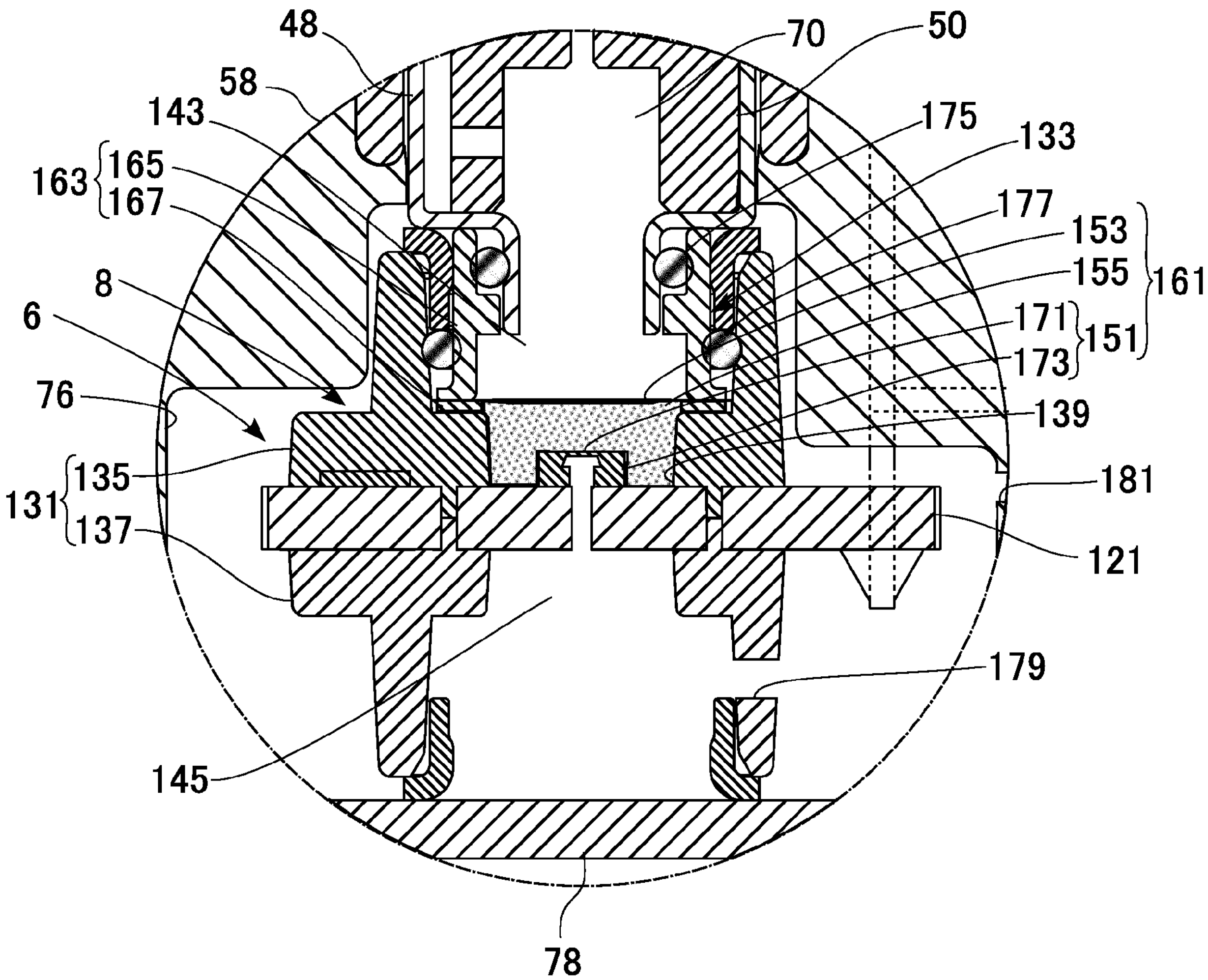
68
72(72a,72b,72c)
55
58
57
6
121
76
181
78
A

FIG.5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165
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177
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151
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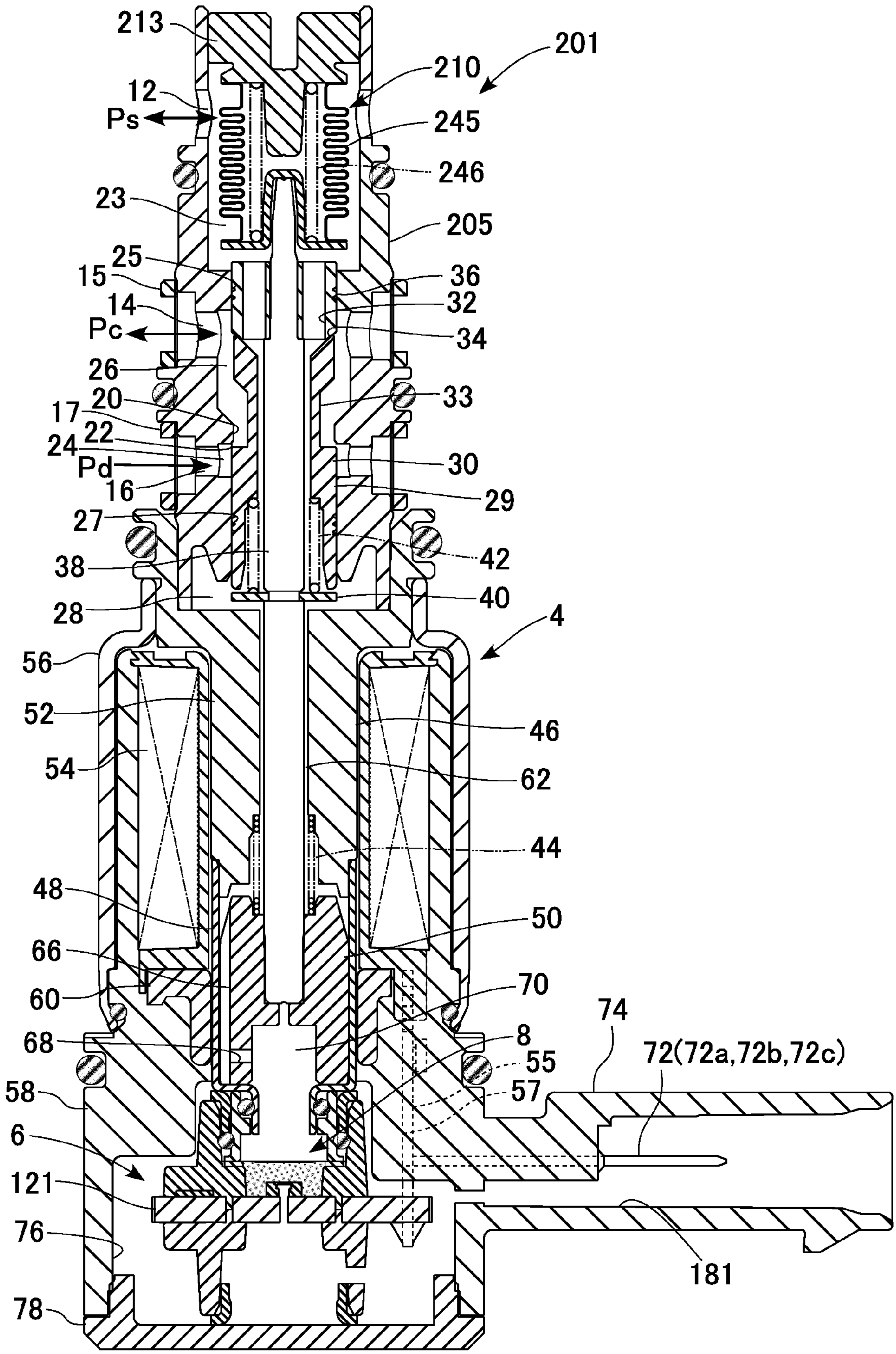
139
131
135
137
181
121
179
145
78

FIG.6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201
210
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Ps
245
246
23
205
25
15
36
32
14
Pc
34
26
20
33
17
22
24
30
Pd
16
29
27
42
38
28
40
4
56
52
46
54
62
44
48
50
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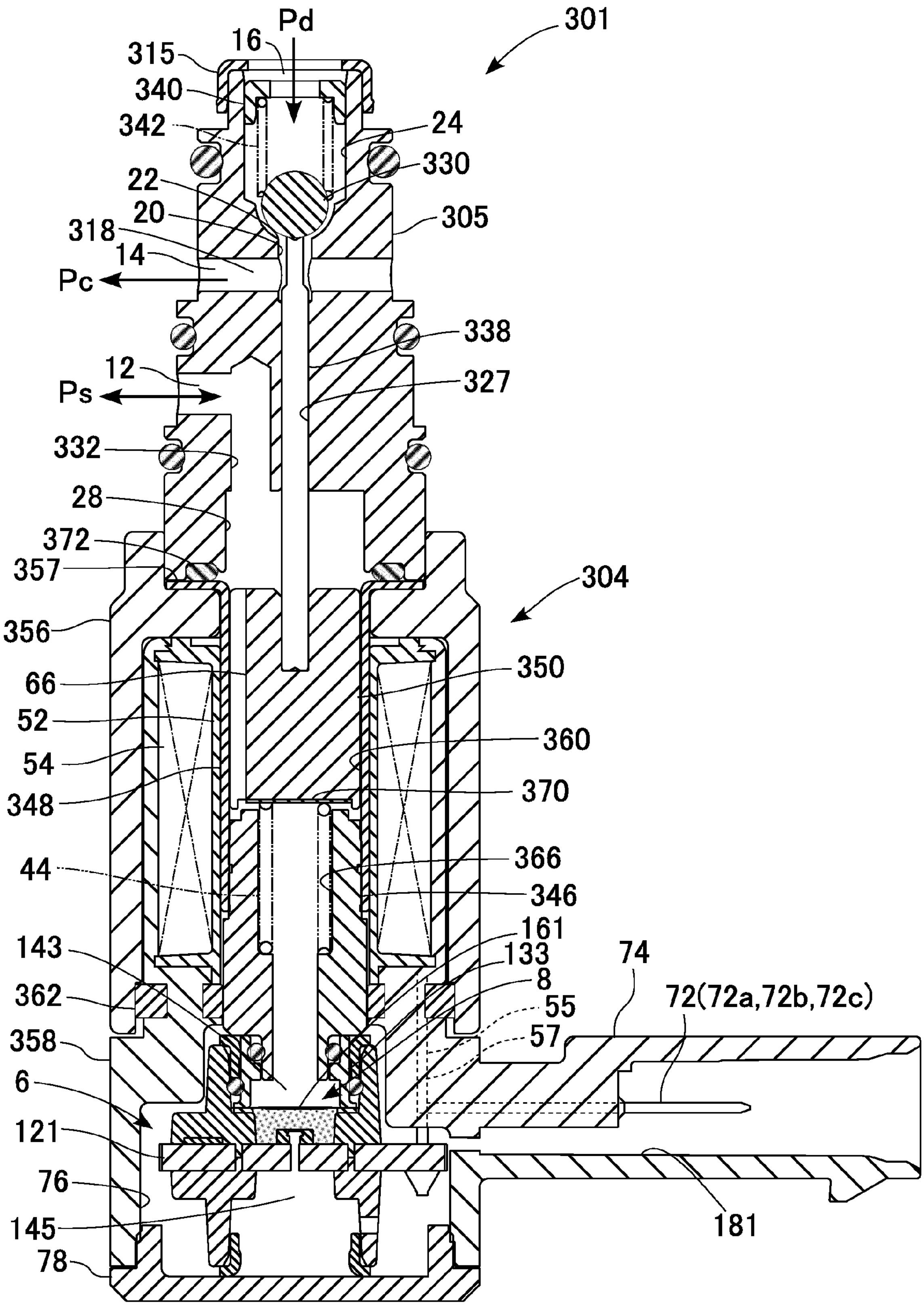
121
76
181
78

FIG.7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Pd
16
315
340
342
24
330
22
20
305
318
14
Pc
338
12
Ps
327
332
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372
357
304
356
350
66
52
360
54
348
370
44
366
346
143
161
133
74
362
8
72(72a,72b,72c)
55
358
57
6
121
76
181
145
78

FIG.8

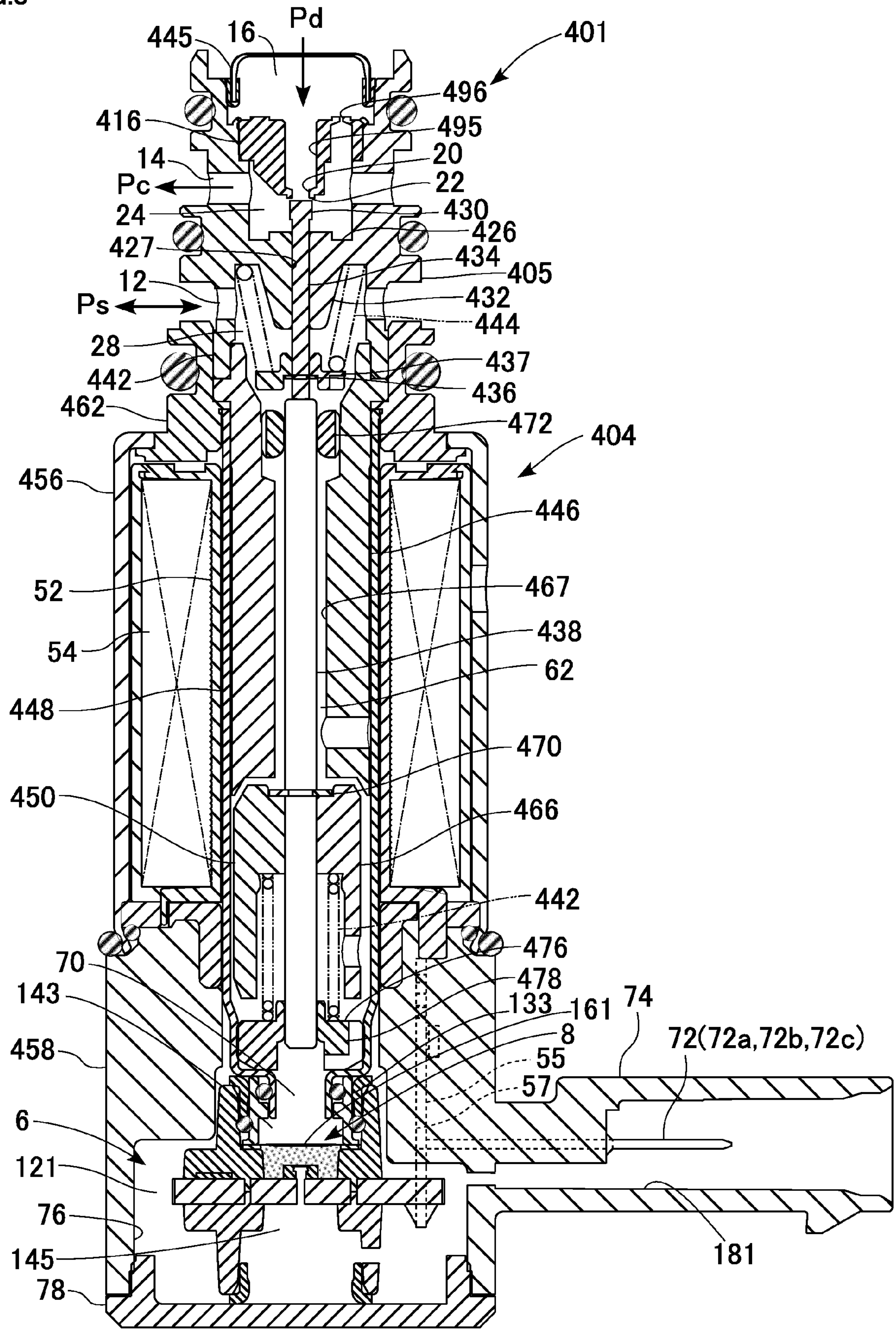
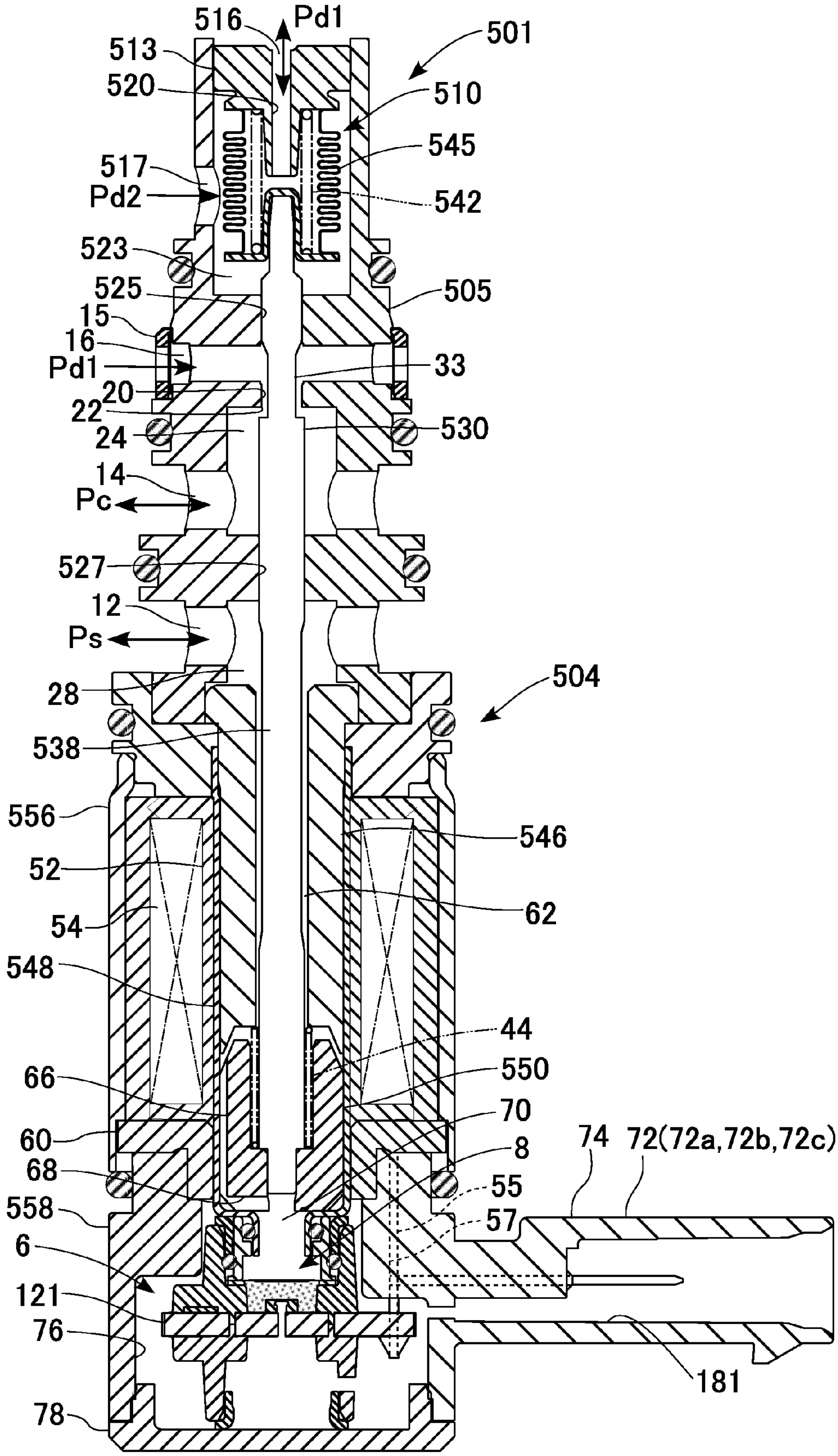

Pd
445
16
401
496
416
495
14
20
Pc
22
24
430
426
427
434
405
12
432
Ps
444
28
437
442
436
462
472
404
456
446
52
467
54
438
62
448
470
450
466
442
476
70
478
143
133
161
74
8
458
72(72a,72b,72c)
55
57
6
121
76
181
145
78

FIG.9


516
Pd1
501
513
520
510
545
517
Pd2
542
523
505
525
15
16
Pd1
33
20
22
24
530
14
Pc
527
12
Ps
504
28
538
556
546
52
62
54
548
44
66
550
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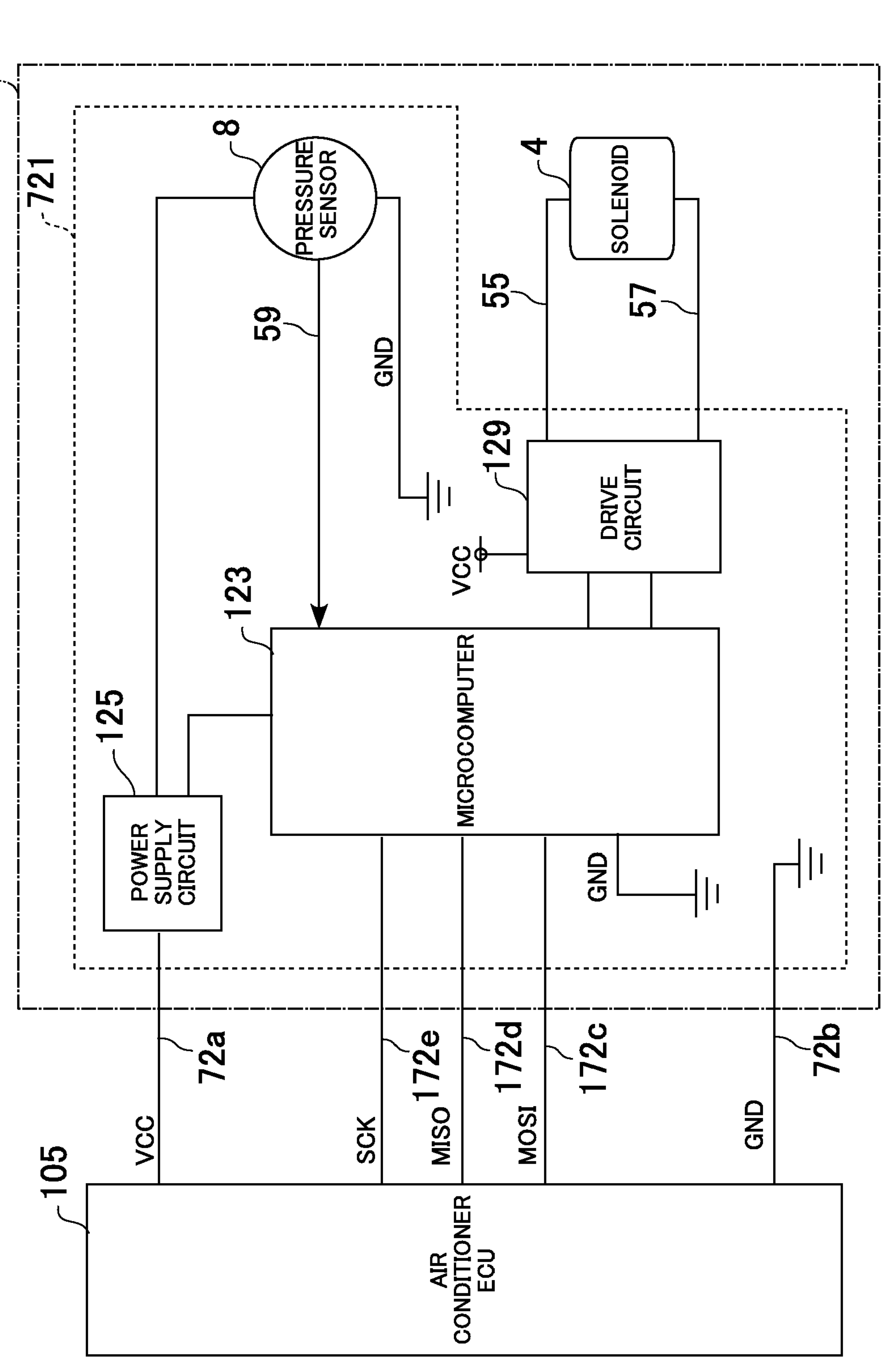
60
74
72(72a,72b,72c)
8
68
55
558
57
6
121
76
181
78

FIG.10


701
721
8
PRESSURE SENSOR
4
SOLENOID
55
57
59
GND
129
DRIVE CIRCUIT
VCC
123
MICROCOMPUTER
125
POWER SUPPLY CIRCUIT
GND
72a
172e
172d
172c
72b
VCC
SCK
MISO
MOSI
GND
105
AIR CONDITIONER ECU

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Application Number
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1

Place of search	Date of completion of the search	Examiner
Munich	21 September 2017	Homan, Peter

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