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(54) Expansion device

(57) An expansion device 3 containing a differential pressure control valve has a temperature-sensing actuator like a shape-memory alloy spring 21 disposed at an outlet 14. When an air conditioner is started under a high-load condition in which the outlet temperature is high, the shape-memory alloy spring 21 senses the high temperature, to urge a spring 18 determining a valve-opening point of the differential pressure control valve, whereby the differential pressure control valve is opened in advance or placed in a state capable of opening in response to a very low differential pressure, thereby making it possible to cause refrigerant to flow at a large flow rate until the outlet temperature is lowered to a certain temperature.

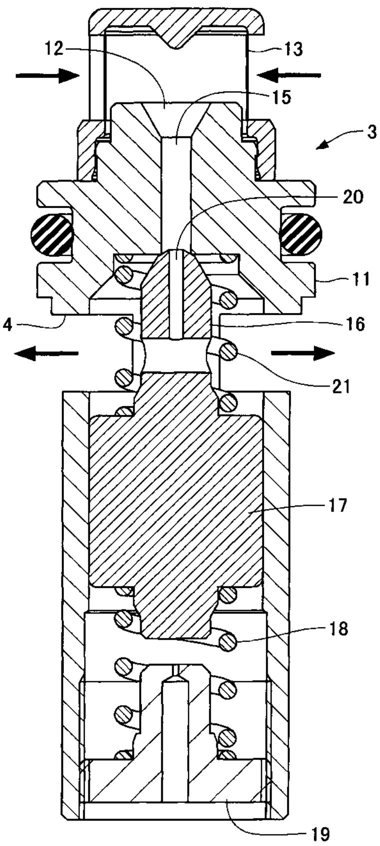

FIG. 2

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Description

[0001] The invention relates to an expansion device according to the preamble of claim 1 and of claim 8.

[0002] A known refrigeration cycle for an automotive air-conditioner comprises a compressor, a condenser or a gas cooler, a receiver to separate condensed or cooled refrigerant into a gas and a liquid, an expansion device, and an evaporator. The expansion device is generally a thermostatic expansion device and senses the temperature and pressure at an outlet of the evaporator, and controls the flow rate to the evaporator.

[0003] In another known refrigeration cycle (JP-2005-249380 A) the expansion device is a differential pressure control valve that senses a differential pressure between an inlet pressure and an outlet pressure, and progressively opens as the value of the differential pressure increases. The expansion device includes a valve element in a refrigerant passage, and a spring urging the valve element in valve-closing direction. After the start of the automotive air conditioner, when the pressure at the inlet is increased by the discharge pressure of the compressor and the pressure at the outlet is decreased by the suction pressure of the compressor, causing that the differential pressure exceeds a valve-opening differential value pressure set by the spring, the expansion device opens and the valve lift increases as the differential pressure value increases. When the automotive air conditioner is at rest no differential pressure is generated. The differential pressure control valve is closed by the spring. When the compressor starts to operate at maximum displacement, the pressure at the inlet of the expansion device immediately increases. On the other hand, refrigerant on the outlet side of the expansion device is drawn-in by the compressor, whereby the outlet pressure thereat is about to be lowered. However, the accumulator between the expansion device and the compressor inhibits an immediate pressure reduction, so that the inlet pressure of the expansion device further increases, and when the differential pressure value reaches the valve-opening differential pressure, the expansion device opens. However, if the outlet pressure cannot be lowered rapidly enough a sufficiently large differential pressure cannot be generated, causing a continued throttling operation of refrigerant, even though the inlet pressure of the expansion device increases further. In such a case, the compressor performs displacement control to reduce the displacement, thereby preventing that the discharge pressure becomes too high. Reduction of displacement of the compressor at the start of the automotive air conditioner means, however, that the automotive air conditioner does not cool or that it takes a long time before the air conditioner starts to cool efficiently.

[0004] This tendency is conspicuous particularly in case of carbon dioxide refrigerant having a very high operating pressure and the automotive air conditioner starting when the temperature in an engine room is very high. Then, already before the start of the automotive air conditioner, the inlet and outlet pressures at the expansion device are markedly increased by radiant heat from the hot atmosphere, the sun, and so forth, and hence the load on the automotive air conditioner becomes very high. When the automotive air conditioner is started in this high-load state, the inlet pressure of the expansion device immediately increases from the already high pressure value to an extremely high-pressure region that might be dangerous for the refrigeration cycle. In order to avoid such an abnormally high pressure, the compressor starts displacement control toward reduced displacement, so that the automotive air conditioner hardly cools and so that it takes a very long time to achieve a satisfying cooling-down operation.

[0005] It is an object of the invention to provide an expansion device which allows to shorten cool down time when an automotive air conditioner is started under a high-load condition.

[0006] This object is achieved by the features of claim 1 and of claim 8.

[0007] When the refrigeration cycle is exposed to a high-temperature state before the start of the automotive air conditioner, the differential pressure control valve is in an open state or in the state capable of opening in response to a very low differential pressure. Therefore, it is possible to allow refrigerant to flow at a large flow rate immediately after the start of the automotive air conditioner. This eliminates the inconvenience that when the automotive air conditioner is started under a high-load condition, the flow rate of refrigerant circulating through the refrigeration cycle becomes small to make it difficult to cool.

Brief description of the drawings:

[0008]

Fig. 1 is a system diagram of a refrigeration cycle,

Fig. 2 is a cross-section of a first embodiment of an expansion device of the refrigeration cycle,

Fig. 3 shows a temperature-spring load characteristic of a temperature-sensing actuator,

Fig. 4 is a diagram showing changes in the restriction passage cross-sectional area of the expansion device, with respect to changes in the differential pressure,

Fig. 5 is a cross-section of a second embodiment of the arrangement of an expansion device,

Fig. 6 is a cross-section of a third embodiment of an expansion device,

Fig. 7 is a cross-section of a fourth embodiment of an expansion device,

Fig. 8 is a cross-section of a fifth embodiment of an expansion device,

Fig. 9 is a cross-section of a sixth embodiment of an expansion device,

Fig. 10 is a cross-section of a seventh embodiment of an expansion device,

Fig. 11 is a cross-section of an eight embodiment of an expansion device.

[0009] In Fig. 1 a refrigeration cycle, using carbon dioxide as refrigerant, by way of example, comprises a compressor 1 for compressing refrigerant, a gas cooler 2 for cooling the compressed refrigerant, an expansion device 3 for throttling and expanding the cooled refrigerant, an evaporator 4 for evaporating the expanded refrigerant, an accumulator 5 for storing surplus refrigerant in the refrigeration cycle and separating refrigerant in a gaseous phase from the evaporated refrigerant to send the gaseous refrigerant to the compressor 1, and an internal heat exchanger 6 for performing heat exchange between refrigerant flowing from the gas cooler 2 to the expansion device 3 and refrigerant flowing from the accumulator 5 to the compressor 1. In FIG. 1, arrows indicate respective flow directions of refrigerant.

[0010] The refrigerant is changed by the expansion device 3 into a two-phase gas-liquid state, and when evaporated by heat exchange in the evaporator 4 between the refrigerant and air in the vehicle compartment, the refrigerant cools the air in the vehicle compartment by depriving the air of latent heat of vaporization.

[0011] In a refrigeration cycle using carbon dioxide as refrigerant, it is a common practice to dispose the internal heat exchanger 6 that performs heat exchange between refrigerant at the outlet of the gas cooler 2 and refrigerant at the inlet of the compressor 1, so as to lower the enthalpy of refrigerant at the inlet of the evaporator 4 and to thereby enhance the cooling power of the refrigeration cycle.

[0012] The internal heat exchanger 6 has a high-pressure passage for high-pressure refrigerant introduced from the gas cooler 2, and a low-pressure passage for low-pressure refrigerant introduced from the accumulator. The expansion device 3 is disposed at the outlet of the high-pressure passage.

[0013] The expansion device 3 of Fig. 2 is disposed in the internal heat exchanger 6 and has a body 11 with an upper end refrigerant inlet 12 and a strainer 13 for withholding foreign matter. A refrigerant outlet 14 is in a side portion of the body 11. An axial hole 15 is formed between the inlet 12 and the outlet 14. An axially movable valve element 16 is disposed in a space communicating with the refrigerant outlet 14, for co-operation with the valve hole 15. The valve element 16 is integral with a piston 17 slidably disposed in a hollow cylindrical portion formed in a lower portion of the body 11. On a side of the piston 17 remote from the valve element 16 a spring 18 urges the valve element 16 in valve-closing direction. The valve element 16 and the spring 18 constitute a differential pressure control valve which opens in response to a differential pressure between the pressure at the inlet 12 and the pressure at the outlet 14.

[0014] The spring 18 is received by an adjustment screw 19 screwed into the hollow cylindrical portion of the body 11. By adjusting the axial screwing depth of the adjustment screw 19 in the body 11, it is possible to set a certain valve-opening differential pressure at which the differential pressure control valve opens. The valve element 16 is provided with an orifice 20 bypassing the differential pressure control valve. The orifice 20 allows a minimum flow rate required let pass compressor-lubricating oil circulating with the refrigerant. A shape-memory alloy spring 21 is disposed in the space communicating with the refrigerant outlet 14 for urging the valve element 16 in valve-opening direction. The shape-memory alloy spring 21 forms a temperature-sensing actuator which senses the temperature of refrigerant at the refrigerant outlet 14 of the expansion device 3, and actuates the differential pressure control valve in valve-opening direction when the sensed refrigerant temperature exceeds a predetermined value. The shape-memory alloy spring 21 has a bidirectional shape memory effect, i.e. the spring load reversibly changes with respect to temperature cycling, and as shown in Fig. 3, has characteristics such as the spring load is small and the rate of change in spring load with respect to a change in temperature is also very small at temperatures lower than the transformation temperature (15° in the illustrated example), whereas at temperatures higher than the transformation temperature, the rate of increase in spring load with respect to a rise in temperature suddenly increases. Further, at temperatures not lower than a predetermined temperature (25° in the illustrated example), i.e. a temperature even higher than the transformation temperature, the spring load is saturated and does not increase further.

[0015] When the automotive air conditioner is started, and operates in a steady state, the outlet temperature of the expansion device 3 is normally not higher than 15°. Then the differential pressure control valve has a characteristic indicated by a thick solid line in Fig. 4. More specifically, when the outlet temperature is not higher than 15°, the shape-memory alloy spring 21 generates the minimum spring load, so that when the differential pressure ΔP remains sufficiently small, the spring 18 will overcome the spring load of the shape-memory alloy spring 21, to urge the valve element 16 in valve-closing direction until the differential pressure control valve is closed. At this time, the differential pressure control valve forms a restriction passage which has a restriction passage cross-sectional area determined by the orifice 20.

[0016] When the differential pressure ΔP rises to exceed $\Delta P1$, the differential pressure control valve opens, whereafter the valve element 16 lifts in proportion to a rise in the differential pressure to increase the restriction passage cross-sectional area. The flow rate increases.

[0017] When the automotive air conditioner is at rest, and the outside air temperature is as high as 40°C, for example, refrigerant has very high temperatures in every location in the refrigeration cycle. Of course, the outlet temperature of the expansion device 3 also is high, and the shape-memory alloy spring 21 senses the outlet temperature to generate the maximum spring load. At this time, if the spring load of the shape-memory alloy spring 21 is set to be approximately equal to the spring load of the spring 18, the valve-opening differential pressure at which the differential pressure control valve opens is set to be approximately equal to zero, and hence when the automotive air conditioner is started in this state, and once refrigerant flows even at a slight flow rate, the differential pressure control valve instantly fully opens, whereby the restriction passage cross-sectional area becomes maximum, as shown in Fig. 4 in the case of the outlet temperature being not lower than 25°.

[0018] When the outlet temperature is very high, if the spring load of the shape-memory alloy spring 21 is set to be larger than the spring load of the spring 18, the shape-memory alloy spring 21 overcomes the spring load of the spring 18, to urge the valve element 16 in valve-opening direction. This places the differential pressure control valve in an open state before the start of the automotive air conditioner.

[0019] As described above, in a state in which the ambient temperature is so high that load on the automotive air conditioner is very high, the shape-memory alloy spring 21 sensing the outlet temperature sets the valve-opening differential pressure to a lower value, or holds the differential pressure control valve in the open state. Therefore, it is possible to cause refrigerant to flow at a large flow rate when the automotive air conditioner is started. For the expansion device 3 to be open at the start of the automotive air conditioner, or immediately after the start thereof means that the inlet pressure of the expansion device 3 cannot become abnormally high immediately after the start of the compressor 1. Further, for refrigerant to flow at a large flow rate immediately after the start of the compressor 1 means that the compressor 1 can continue with the operation at maximum displacement such that it is possible to lower the outlet temperature of the expansion device 3 soon, whereby cool down time can be shortened.

[0020] As the compressor 1 continues operation at maximum displacement, the outlet temperature becomes lower before long. When the outlet temperature of the expansion device 3 becomes lower than the predetermined temperature (25° in the illustrated example), the spring load of the shape-memory alloy spring 21 progressively decreases. As a result, the valve element 16 is pushed by the spring 18 to move in valve-closing direction, and accordingly the restriction passage cross-sectional area is also progressively reduced. At this time, the valve-opening differential pressure at which the differential pressure control valve opens also increases from the state approximately equal to zero, and when the outlet temperature of the expansion device 3 lowers to 20°, the valve-opening differential pressure at which the differential pressure control valve opens shifts to $\Delta P0$, and when the outlet temperature of the expansion device 3 further lowers to 15°, the valve-opening differential pressure shifts to $\Delta P1$.

[0021] The expansion device 31 in Fig. 5 (second embodiment) is configured such that a first differential pressure control valve and a second differential pressure control valve having a larger port or valve hole diameter than the first differential pressure control valve function in parallel with each other. When the outlet temperature of the expansion device 3 is high, the shape-memory alloy spring 21 opens the second differential pressure control valve, thereby allowing refrigerant to flow at an even larger flow rate.

[0022] In the expansion device 31, the second differential pressure control valve is formed in the body 11 between the inlet 12 and the outlet 14. A valve hole 32 has a larger inner diameter than the valve hole of the first differential pressure control valve. An axially movable valve element 33 is disposed in the space communicating with the outlet 14, for co-operation with the valve hole 32. The valve element 33 is integral with an axially movable piston 34 disposed in a hollow cylindrical portion in a lower portion of the body 11. On a valve element side of the piston 34 the shape-memory alloy spring 21 is disposed for urging the valve element 33 in valve-opening direction, and on a side of the piston 34 remote from the valve element 33 a spring 35 urges the valve element 33 in valve-closing direction. An adjustment screw 36 screwed into an open end of the hollow cylindrical portion of the body 11 allows to adjust both spring loads of the shape-memory alloy spring 21 and the spring 35.

[0023] The first differential pressure control valve uses a hole axially formed through the valve element 33 of the second differential pressure control valve as the valve hole 15. The valve element 16 and the piston 17 are axially movably accommodated in the piston 34 of the second differential pressure control valve. The load of the spring 18 for setting the valve-opening differential pressure is adjusted by the adjustment screw 19 which is screwed into an open end of the piston 34 of the second differential pressure control valve.

[0024] When the automotive air conditioner is operating in the steady state, and the outlet temperature becomes approximately 15° or less which is assumed when the automotive air conditioner serves as an air conditioner, the shape-memory alloy spring 21 senses the outlet temperature and generates the minimum spring load. The second differential pressure control valve is closed. Now, insofar as the differential pressure ΔP is small, the first differential pressure control valve is closed, so that the expansion device 31 has a fixed restriction passage cross-sectional area determined by the cross-sectional area of the orifice 20 of the first differential pressure control valve. When the differential pressure ΔP rises to first exceed the valve-opening differential pressure set by the spring 18 of the first differential pressure control valve, the first differential pressure control valve opens, whereafter the restriction passage cross-sectional area proportionally increases as the differential pressure ΔP increases.

[0025] When the automotive air conditioner is started under a high-load condition, the shape-memory alloy spring 21 senses a very high outlet temperature and responds by lifting the valve element 33 of the second differential pressure control valve, thereby opening the valve hole 32 which has a larger inner diameter than the valve hole 15 of the first differential pressure control valve, to allow refrigerant to flow at a large flow rate. It should be noted that when the automotive air conditioner is operating in the steady state, the second differential pressure control valve opens when the differential pressure ΔP increases until it overcomes the spring load of the spring 35, and hence the second differential pressure control valve also functions as a pressure-relief valve for avoiding abnormally high pressure in a high-pressure circuit.

[0026] In the first and second embodiments, the outlet temperature is sensed by the temperature-sensing actuator formed by the shape-memory alloy spring 21, whereby it is judged that the automotive air conditioner is being started under a high-load condition.

[0027] For the following embodiments a case will be described in which the outlet pressure is sensed instead to judge whether the automotive air conditioner is being started under a high-load condition. More specifically, when the automotive air conditioner is at rest, the inlet and the outlet of the expansion device communicate via an orifice, and hence refrigerant is equal in temperature, pressure, and density between the inlet and the outlet. Now, if refrigerants have the same density, since temperature and pressure have a linear relation therebetween, it is possible to consider that sensing of the outlet pressure is equivalent to sensing of the outlet temperature. This makes it possible to provide an expansion device having the same functions as the first and second embodiments by configuring the expansion device such that it is actuated to be fully opened when the pressure at the refrigerant outlet exceeds pressure corresponding to the refrigerant temperature of 25° in the case of the above-described example shown in Fig. 3.

[0028] The expansion device 41 in Fig. 6 (third embodiment) is distinguished from the Fig. 2 expansion device 3 in that the temperature-sensing actuator is changed into a pressure-sensing actuator. More specifically, in the expansion device 41 in Fig. 6, a power element 42 operates, when high pressure is sensed, in a direction of reducing the spring load of the spring 18 which sets the valve-opening differential pressure at which the differential pressure control valve opens. The power element 42 is screwed onto the hollow cylindrical portion of the body 11..

[0029] In the power element 42 a diaphragm 45 made of a thin metal plate is held between an outer housing 43 having a centre projected outward and an inner housing 44 having an opening in the centre thereof and having a hub connected to the body 11. The outer peripheries of the housings 43 and 44 and the diaphragm 45 are welded together under atmosphere or vacuum atmosphere. A hermetically sealed space between the outer housing 43 and the diaphragm 45 accommodates a snap plate or a disc spring 46, a spring 47, and a spring-receiving member 48. On a side of the diaphragm 45 remote from the disc spring, a displacement-transmitting member 49 transmits the displacement of the diaphragm 45 to the spring 18. A stopper 50 in the form of a step is formed on an inner wall of the inner housing 44, for restricting the motion of the displacement-transmitting member 49 in the direction of increasing the spring load of the spring 18. This inhibits the power element 42 from changing the setting of the valve-opening differential pressure at which the differential pressure control valve opens, when the automotive air conditioner is operating in the steady state.

[0030] The power element 42 has the same characteristic as shown in Fig. 3. However, the horizontal axis represents pressure corresponding to temperature, and the vertical axis represents the stroke of the displacement-transmitting member 49 which axially moves following the displacement of the diaphragm 45.

[0031] When the automotive air conditioner is operating in the steady state and the outlet temperature is approximately 15° or less which is assumed when the automotive air conditioner serves as an air conditioner, the outlet pressure is low, and therefore the diaphragm 45 of the power element 42 is displaced upward, as viewed in FIG. 6. At this time, the stopper 50 restricts the motion of the displacement-transmitting member 49 to prevent the stroke thereof from being changed.

[0032] Inversely, when the automotive air conditioner is started under a high-load condition, the outlet temperature and accordingly the pressure are very high. In this case, the diaphragm 45 is displaced by the high pressure toward the side of the disc spring 46, and the displacement is transmitted to the spring 18 via the displacement-transmitting member 49, whereby the spring load of the spring 18 is reduced. The valve-opening differential pressure at which the differential pressure control valve opens is set to zero or a very low differential pressure. With this configuration, the differential pressure control valve fully opens upon generation of even a slight differential pressure.

[0033] After the automotive air conditioner is started, the outlet temperature progressively lowers until the power element 42 senses the pressure corresponding to temperature e.g. of 25°, whereupon the shape of the disc spring 46 is changed from a shape in which the centre thereof is recessed inward into a shape in which the centre thereof is inflated outward. After that, the spring load of the spring 18 is approximately linearly increased according to the reduction of the pressure. Alternately, when the power element 42 senses the pressure corresponding to the temperature of 25°, the shape of the disc spring 46 may be changed in a snap action manner such that the displacement-transmitting member 49 is brought into abutment with the stopper 50. In this case, when the power element 42 senses the pressure corresponding to the temperature of 25°, the disc spring 46 operates such that the valve-opening differential pressure at which the differential pressure control valve opens is returned to the valve-opening differential pressure at which the differential pressure control valve opens when the automotive air conditioner is operating in the steady state, and the setting of the valve-opening differential pressure is effected by adjusting the spring loads of the disc spring 46 and the spring 47. The load of the disc spring 46 is adjusted by combining a plurality of disc springs (three in the illustrated example) having respective appropriate spring loads while compensating for the deficit of the spring load with the spring 47.. Further, the final fine adjustment of the spring load is performed by plastically inwardly deforming an end face of the outer housing 43 to change the position of the spring-receiving member 48 in the direction of compressing the spring 47.

[0034] It should be noted that in the present embodiment, part of a screw thread of the body 11, which is screwed into the power element 42, is cut such that the outlet pressure easily reaches the diaphragm 45. The cut part is not necessarily required since portions of the power element 42 and the body 11 screwed together may not be completely hermetically sealed.

[0035] The expansion device 51 in Fig. 7 (fourth embodiment) is distinguished from the third embodiment in that the configuration of the power element 42 and the method of connecting the power element 42 and the body 11 are changed. First, in the expansion device 51 in Fig. 7, the power element 42 and the body 11 are connected by press-fitting the hollow cylindrical portion of the body 11 into the opening of the inner housing 44.

[0036] In the power element 42, the inner housing 44 includes a diaphragm-receiving portion 52 which has an annular shape and has a portion opposed to the diaphragm 45 inwardly extended. The diaphragm-receiving portion 52 is useful for filling a space formed by the outer housing 43 and the diaphragm 45 with gas. The gas-filled power element 42 is formed by welding all the outer peripheries of the outer and inner housings 43 and 44 and the diaphragm 45 to each other under high-pressure gas atmosphere. After that, the power element 42 is left standing in the atmosphere until it is assembled with the body 11. In doing this, the diaphragm-receiving portion 52 receives the diaphragm 45 inflated toward an open end of the inner housing 44 by the pressure of the gas filling the inside to thereby prevent the diaphragm 45 from being deformed beyond a displaceable stroke. In the gas-filled power element 42, the spring loads of the disc spring 46 and the spring 47 can be reduced, and hence in the illustrated example, the number of the disc springs combined to form the disc spring 46 is reduced to two. Further, the power element 42 is configured such that a spring-receiving member 53 is interposed between the spring 47 and the disc spring 46 which are for use in adjusting the spring loads, such that the disc spring 46 is urged by the centre thereof. With this arrangement, compared with the third embodiment, in which the spring 47 urges the disc spring 46 via a portion distant from the centre thereof, it is possible to obtain a larger adjustment margin when fine adjustment of the load of the spring 47 is performed by inwardly deforming the end face of the outer housing.

[0037] The expansion device 61 in Fig. 8 (fifth embodiment) is distinguished from the third embodiment in that the open state of the expansion device is maintained while the automotive air conditioner is at rest in an environment with a high ambient temperature. More specifically, in the first embodiment, by setting the spring load of the shape-memory alloy spring 21 generated when the ambient temperature is high, to a value even larger than the spring load which sets the valve-opening differential pressure to zero, the valve element 16 is lifted to thereby maintain the open state when the automotive air conditioner is at rest. In contrast, in the third embodiment, the pressure-sensing actuator acts only in the direction of reducing the spring load set for the expansion device 31. Therefore, even if the spring load of the spring 18 is reduced, the spring load can only be reduced to 0. This makes it impossible to maintain the open state of the expansion device 31 during stoppage of the automotive air conditioner.

[0038] To cope with the above problem, the expansion device 61 in Fig. 8 is provided with pressure-sensing follow-up means disposed between the displacement-transmitting member 49 and the space communicating with the refrigerant outlet 14, for axially moving back and forth according to pressure sensed by the pressure-sensing actuator. The pressure-sensing follow-up means includes a hollow cylindrical spring-receiving portion 62 axially slidably disposed in the hollow cylindrical portion of the body 11, and a spring 63 urging the hollow cylindrical spring-receiving portion 62 toward the power element 42. The hollow cylindrical spring-receiving portion 62 has an engaging portion 64. When the hollow cylindrical spring-receiving portion 62 moves toward the power element 42, the engaging portion 64 engages with the piston 17 in the hollow cylindrical spring-receiving portion 62, for lifting the valve element 16. The other end of the hollow cylindrical spring-receiving portion 62 is formed with an adjustment screw 65 that adjusts the spring load of the spring 18 for setting the valve-opening differential pressure at which the differential pressure control valve opens.

[0039] When the automotive air conditioner is at rest and ambient temperature is high, no differential pressure is generated across the expansion device 61 and the power element 42 senses pressure corresponding to the ambient temperature. At this time, since the power element 42 senses high pressure, the diaphragm 45 is displaced toward the side of the disc spring 46. At this time, the hollow cylindrical spring-receiving portion 62 and the displacement-transmitting member 49 are moved toward the power element 42 by the urging force of the spring 63, in a manner following the displacement. During the process, the engaging portion 64 moves toward the power element 42 together with the piston 17, to lift the valve element 16 integral with the piston 17, whereby the expansion device 61 is maintained in the open state.

[0040] The expansion device 71 of Fig. 9 (sixth embodiment) is constructed by providing the fourth embodiment with a pressure-sensing follow-up means e.g. of Fig. 8. The expansion device 71 has a spring 72 in the space communicating with the refrigerant outlet 14. With this arrangement, when the ambient temperature is high and the automotive air conditioner is at rest, no differential pressure is generated across the expansion device 71, and the power element 42 senses pressure corresponding to the ambient temperature, while the diaphragm 45 is displaced toward the side of the disc spring 46. Since the spring 72 urges the piston 17, the spring 18, and the displacement-transmitting member 49 toward the power element 42, in a manner following the displacement, the valve element 16 integrally formed with the piston 17 is lifted, whereby the expansion device 71 is maintained in the open state.

[0041] The expansion device 81 in Fig. 10 (seventh embodiment) is distinguished from the second embodiment in that the temperature-sensing actuator is changed to the pressure-sensing actuator appearing in Fig. 6. More specifically, in the expansion device 81 In Fig. 10, the power element 42 that operates, when high pressure is sensed, in the direction of reducing the spring load of the spring 35 urging the second differential pressure control valve in the valve-closing direction is screwed onto the hollow cylindrical portion of the body 11.

[0042] When the automotive air conditioner is at rest and the ambient temperature is very high, the outlet temperature and accordingly the pressure are very high. In this case, the diaphragm 45 of the power element 42 receives the high pressure and becomes displaced toward the side of the disc spring 46. The displacement is transmitted to the spring 35 via the displacement-transmitting member 49 to reduce the spring load of the spring 35, whereby the valve-opening differential pressure at which the second differential pressure control valve opens is set to zero or a very small differential pressure. With this arrangement, the second differential pressure control valve fully opens in response to even a slight differential pressure, and the restriction passage cross-sectional area of the expansion device 81 is set to a passage cross-sectional area determined by the valve hole 32 having an inner diameter larger than the valve hole 15 of the first differential pressure control valve, enabling refrigerant to flow at a large flow rate.

[0043] The expansion device 91 in Fig. 11 (eighth embodiment) is constructed by providing the expansion device 81 of the seventh embodiment with the pressure-sensing follow-up means e.g. of Fig. 8. More specifically, in the expansion device 91 in Fig. 11, a spring 92 is disposed in the space communicating with the refrigerant outlet 14, for urging the piston 34 in the valve-opening direction.

[0044] With this arrangement, when the ambient temperature is high and the automotive air conditioner is at rest, no differential pressure is generated across the expansion device 91, and the power element 42 senses pressure corresponding to the ambient temperature to displace the diaphragm 45 toward the side of the disc spring 46, thereby setting the valve-opening differential pressure at which the second differential pressure control valve opens, to a lower value. When pressure corresponding to the outlet temperature becomes higher than pressure setting the valve-opening differential pressure to 0, the spring 92 urges the piston 34, the spring 35, and the displacement-transmitting member 49 toward the power element 42, in a manner following the displacement of the diaphragm 45. This causes the valve element 33 to be lifted, whereby the expansion device 91 is maintained in the open state.

[0045] Although in some of the above-described embodiments, the actuator for setting the valve-opening differential pressure at which the second differential pressure control valve opens to a lower value is configured such that it directly senses the outlet temperature or outlet pressure, this is not limitative. Instead, the actuator may be configured such that it senses the temperature or pressure in a low-pressure circuit connected to the refrigerant outlet. This is because in the low-pressure circuit extending from the refrigerant outlet of the expansion device to the refrigerant inlet of the compressor, the temperature and pressure of refrigerant are substantially the same at the start of the automotive air conditioner. For example, as shown in FIG. 1, when the expansion device 3 is mounted in the heat exchanger 6, the actuator may be configured such that it senses the temperature or pressure of refrigerant at a low-pressure inlet of the heat exchanger 6, or when the expansion device 3 is mounted in the evaporator 4, the actuator may be configured such that it senses the temperature or pressure of refrigerant at a refrigerant outlet of the evaporator 4.

Claims

1. An expansion device (3) for expanding refrigerant circulating through a refrigeration cycle, the expansion device (3) having an inlet (12) and an outlet (14) **characterised by**
a differential pressure control valve which opens in response to a differential pressure between an inlet pressure and an outlet pressure, and
an actuator (21, 42) that sets a valve-opening differential pressure at which said differential pressure control valve opens, to a lower value, when the outlet temperature or outlet pressure corresponding to the

outlet temperature is higher than a certain temperature which is present when the refrigeration cycle is operating in a steady state.

2. The expansion device according to claim 1, **characterised in that** the actuator (21) is a shape-memory alloy spring for sensing the outlet temperature, and is operable when the temperature becomes higher than the temperature at which the refrigeration cycle is operating in the steady state, to increase a rate of a load increase to thereby set the valve-opening differential pressure at which the differential pressure control valve opens, to a lower value, or to directly open the differential pressure control valve.

3. The expansion device according to claim 1, **characterised in that** the actuator (42) senses the outlet pressure and converts the sensed outlet pressure into a stroke in a direction of opening or closing the differential pressure control valve, and that the actuator is operable when the sensed pressure becomes equal to a pressure corresponding to a temperature higher than the temperature at which the refrigeration cycle is operating in the steady state, to increase the stroke and to set the valve-opening differential pressure at which said differential pressure control valve opens to zero or to a very low differential pressure.

4. The expansion device according to claim 3, **characterised in that** the actuator (42) is co-operating with a stopper (50) for inhibiting the valve-opening differential pressure from being changed for the differential pressure control valve, when the actuator (42) senses the outlet pressure corresponding to the temperature at which the refrigeration cycle is operating in the steady state.

5. The expansion device according to claim 3, **characterised in that** said actuator (42) is a power element that hermetically holds a diaphragm (45) between a first housing (43) having a centre projected outward and a second housing (44) having a central opening, that a snap plate or a disc spring (46) is provided within the first housing (43), for supporting the diaphragm as the diaphragm is displaced inward by receiving the outlet pressure, and for being largely displaced inward when the outlet pressure becomes equal to the outlet pressure corresponding to the temperature higher than the temperature at which the refrigeration cycle is operating in the steady state.

6. The expansion device according to claim 5, **characterised in that** the second housing (44) of the power element (42) includes a diaphragm-receiving portion which has an annular shape and has a portion opposed to the diaphragm (45) radially inwardly extended, and that a space formed by the first housing (43) and said diaphragm (45) is filled with gas.

7. The expansion device according to claim 5, **characterised by** pressure-sensing follow-up means (62, 63, 64, 65) for axially moving the differential pressure control valve back and forth corresponding to displacements of the diaphragm (45), the differential pressure control valve being maintained in an open state when the diaphragm (45) senses pressure even higher than pressure which sets the valve-opening differential pressure to 0.

8. An expansion device for expanding refrigerant circulating through a refrigeration cycle, the expansion device having an inlet (12) and an outlet (14)
characterised by a first differential pressure control valve which opens in response to a differential pressure between an inlet pressure and outlet pressure,
by a second differential pressure control valve that has a valve hole (32) formed between the inlet (12) and the outlet (12), the valve hole having a diameter larger than a valve hole (15) of the first differential pressure control valve; and
by an actuator (21, 42) that sets a valve-opening differential pressure at which the second differential pressure control valve opens, to a lower value, when the outlet temperature or outlet pressure corresponding to the outlet temperature is higher than a certain outlet temperature at which the refrigeration cycle is operating in a steady state.

9. The expansion device according to claim 8, **characterised in that** the actuator (21) is a shape-memory alloy spring for sensing the outlet temperature, and being operable when the outlet temperature becomes higher than the certain outlet temperature at which the refrigeration cycle is operating in the steady state, to increase a rate of increase in a generated load to thereby set the valve-opening differential pressure at which the second differential pressure control valve opens, to a lower value, or to directly open said second differential pressure control valve.

10. The expansion device according to claim 8, **characterised in that** the actuator (42) senses the outlet pressure and converts the second outlet pressure into a stroke in a direction of opening or closing the second differential pressure control valve, and that the actuator (42) is operable when the sensed outlet pressure becomes equal to a pressure corresponding to a temperature higher than the temperature at which the refrigeration cycle is operating in the steady state, to increase the stroke to thereby set the valve-opening differential pressure at which said second differential pressure control valve opens to zero or a very low differential pressure.

11. The expansion device according to claim 10, **characterised by** pressure-sensing follow-up means (62-65) for axially moving the second differential pressure control valve back and forth corresponding to a change of the stroke, and that the second differential pressure control valve is maintained in an open state when the sensed outlet pressure becomes even higher than pressure which sets the valve-opening differential pressure at which the second differential pressure control valve opens to 0.

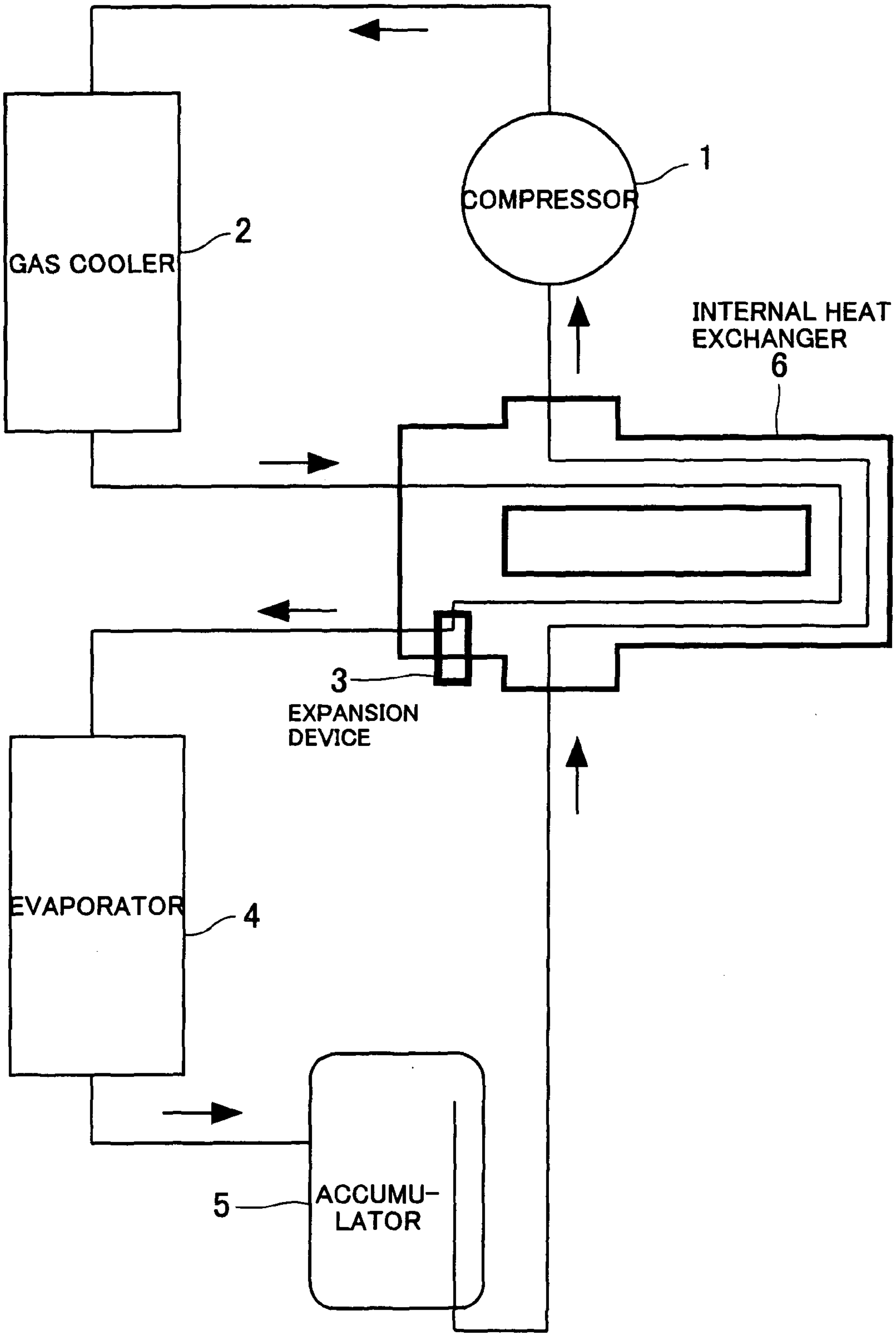
COMPRESSOR
1
GAS COOLER
2
INTERNAL HEAT EXCHANGER
6
3
EXPANSION DEVICE
EVAPORATOR
4
5
ACCUMU-LATOR

FIG. 1

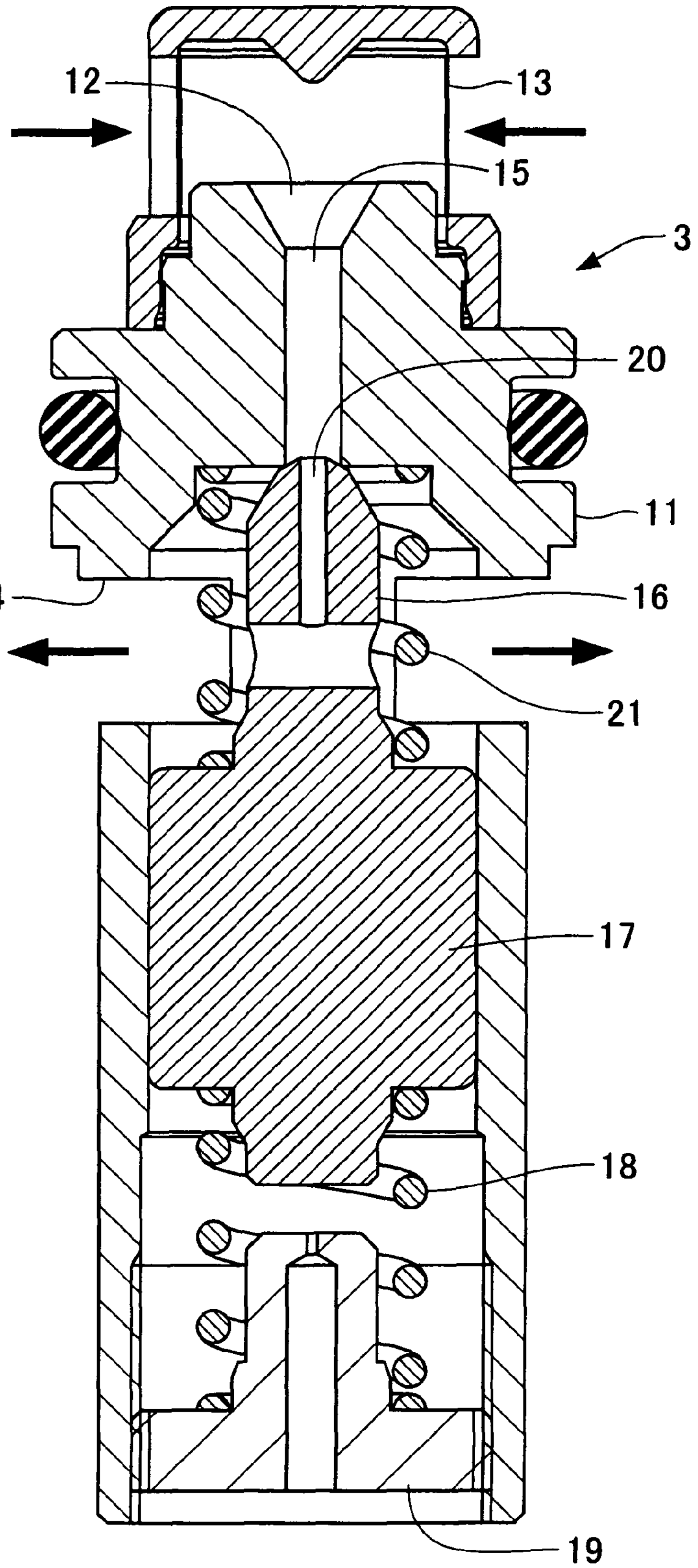

FIG. 2

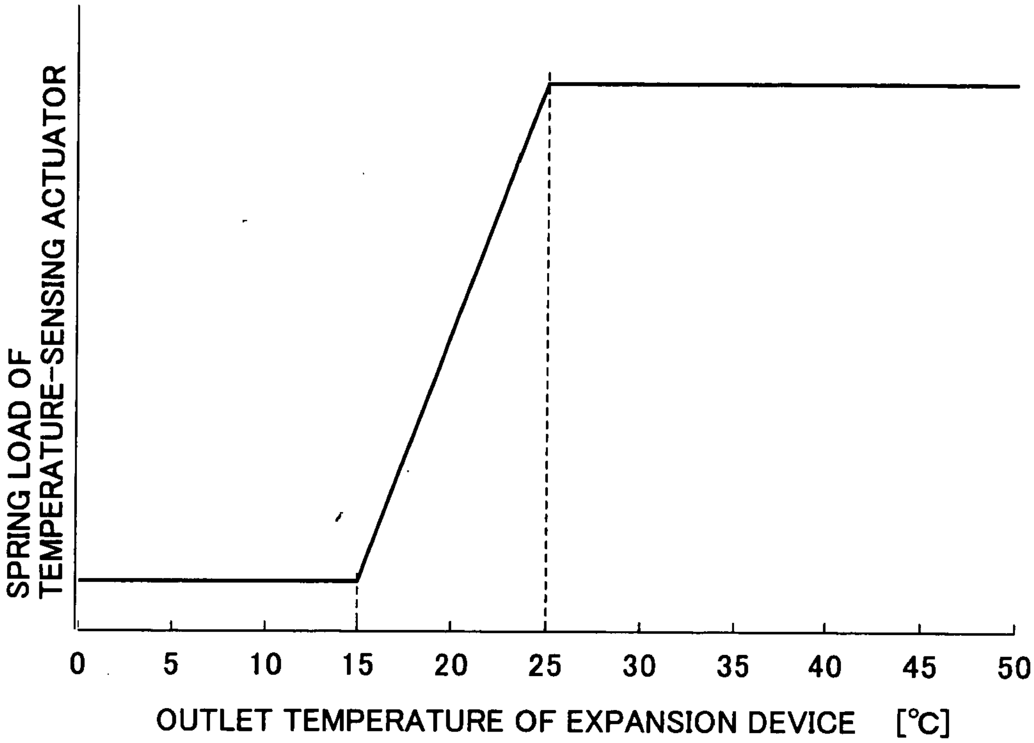
SPRING LOAD OF
TEMPERATURE-SENSING ACTUATOR
0
5
10
15
20
25
30
35
40
45
50
OUTLET TEMPERATURE OF EXPANSION DEVICE [°C]

FIG. 3

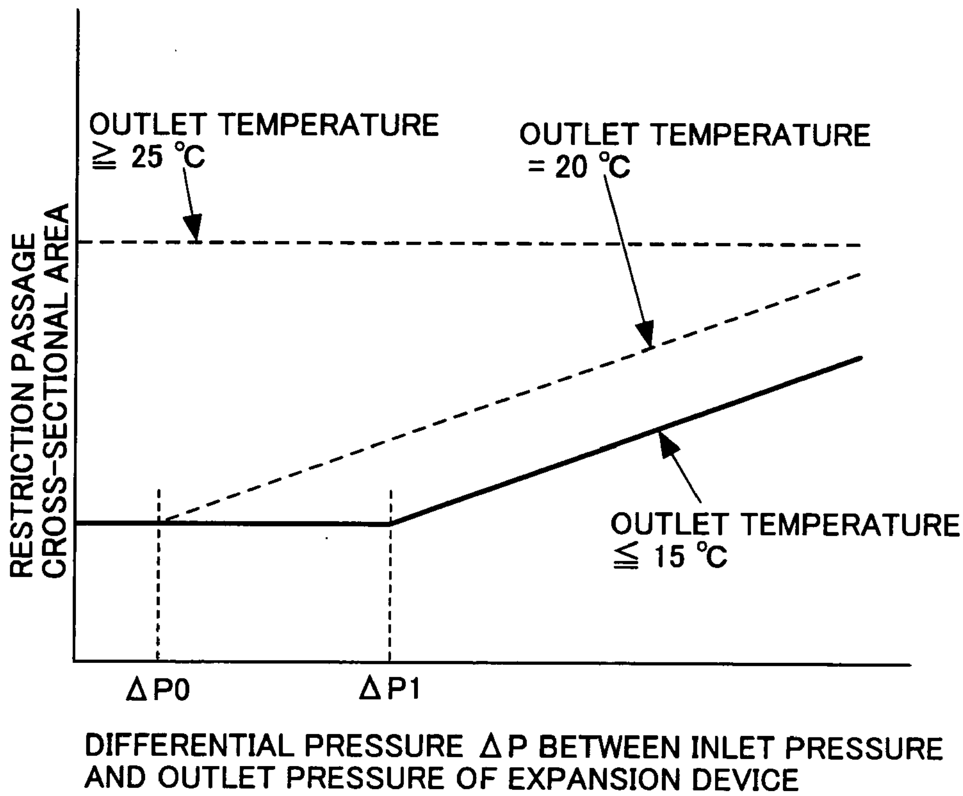
OUTLET TEMPERATURE
≧ 25 ℃
OUTLET TEMPERATURE
= 20 ℃
RESTRICTION PASSAGE
CROSS-SECTIONAL AREA
OUTLET TEMPERATURE
≦ 15 ℃
ΔP0
ΔP1
DIFFERENTIAL PRESSURE ΔP BETWEEN INLET PRESSURE
AND OUTLET PRESSURE OF EXPANSION DEVICE

FIG. 4

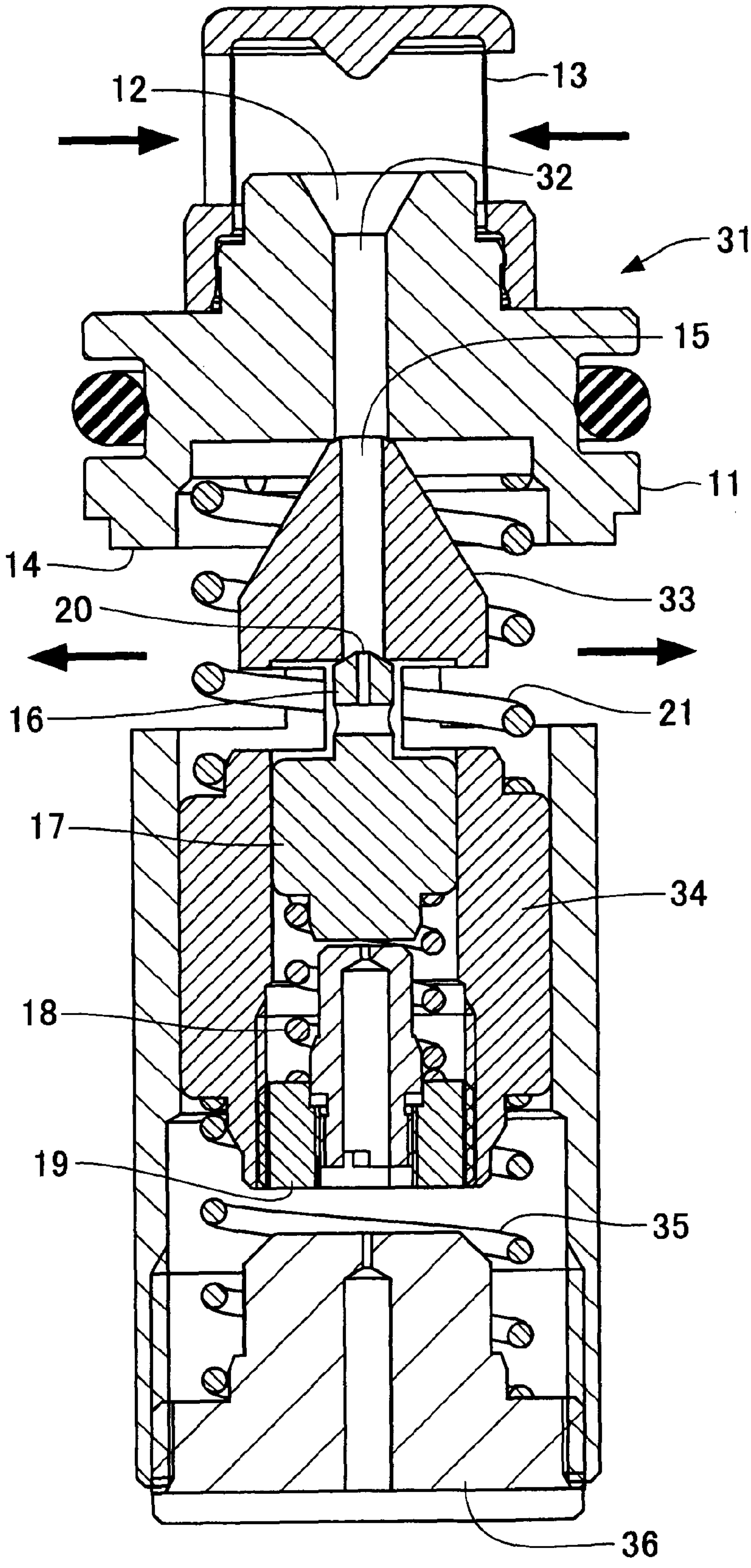

FIG. 5

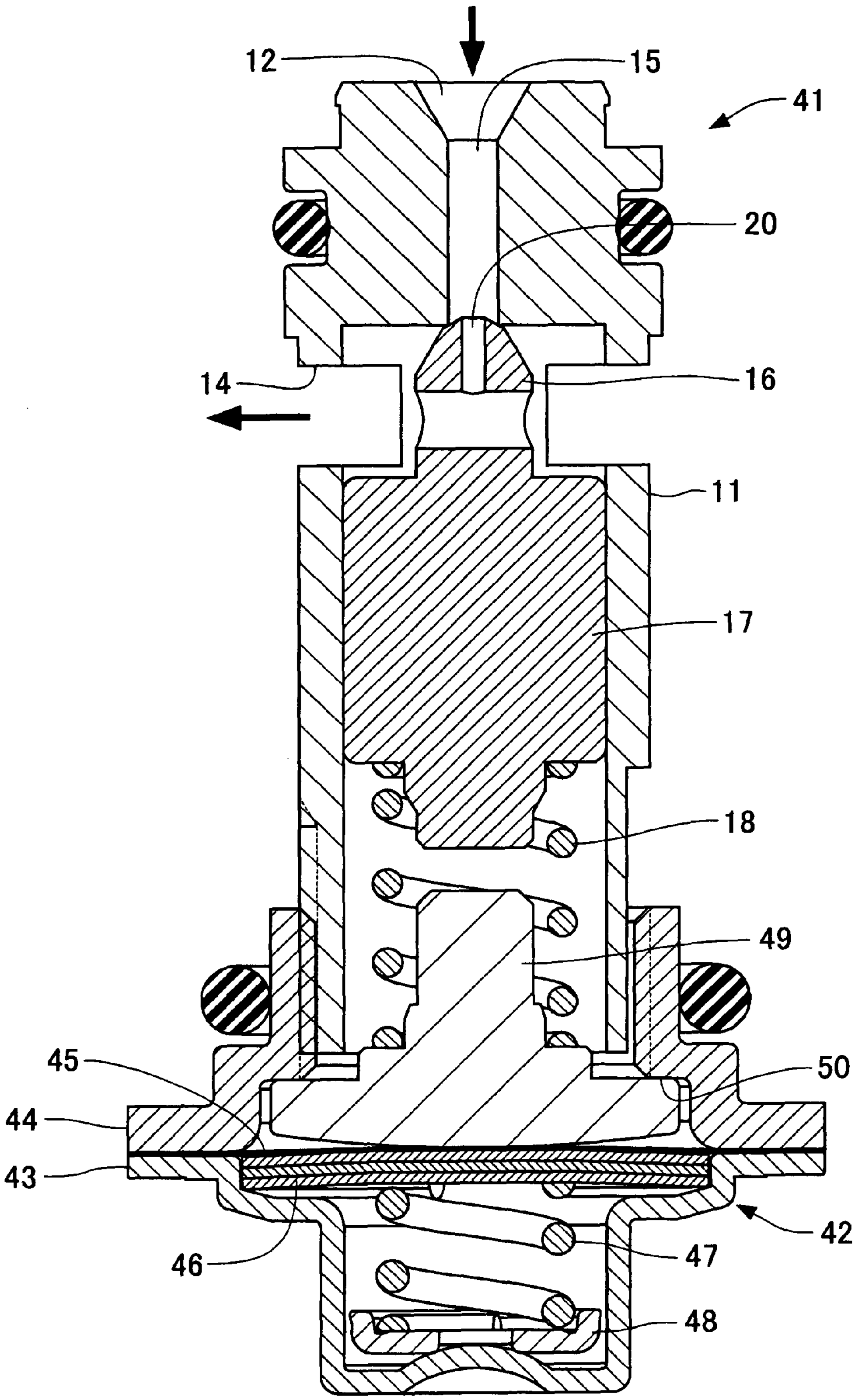

FIG. 6

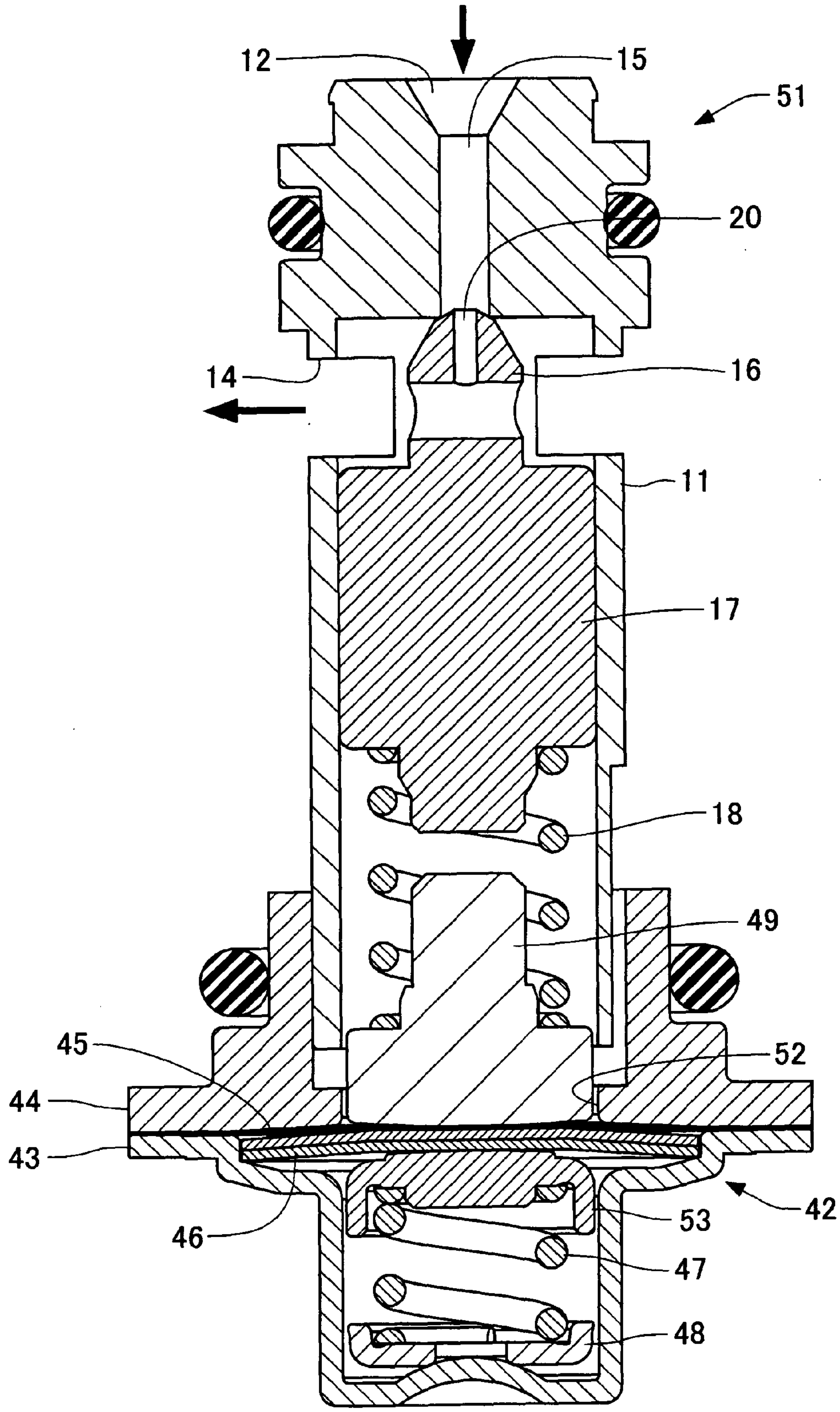

FIG. 7

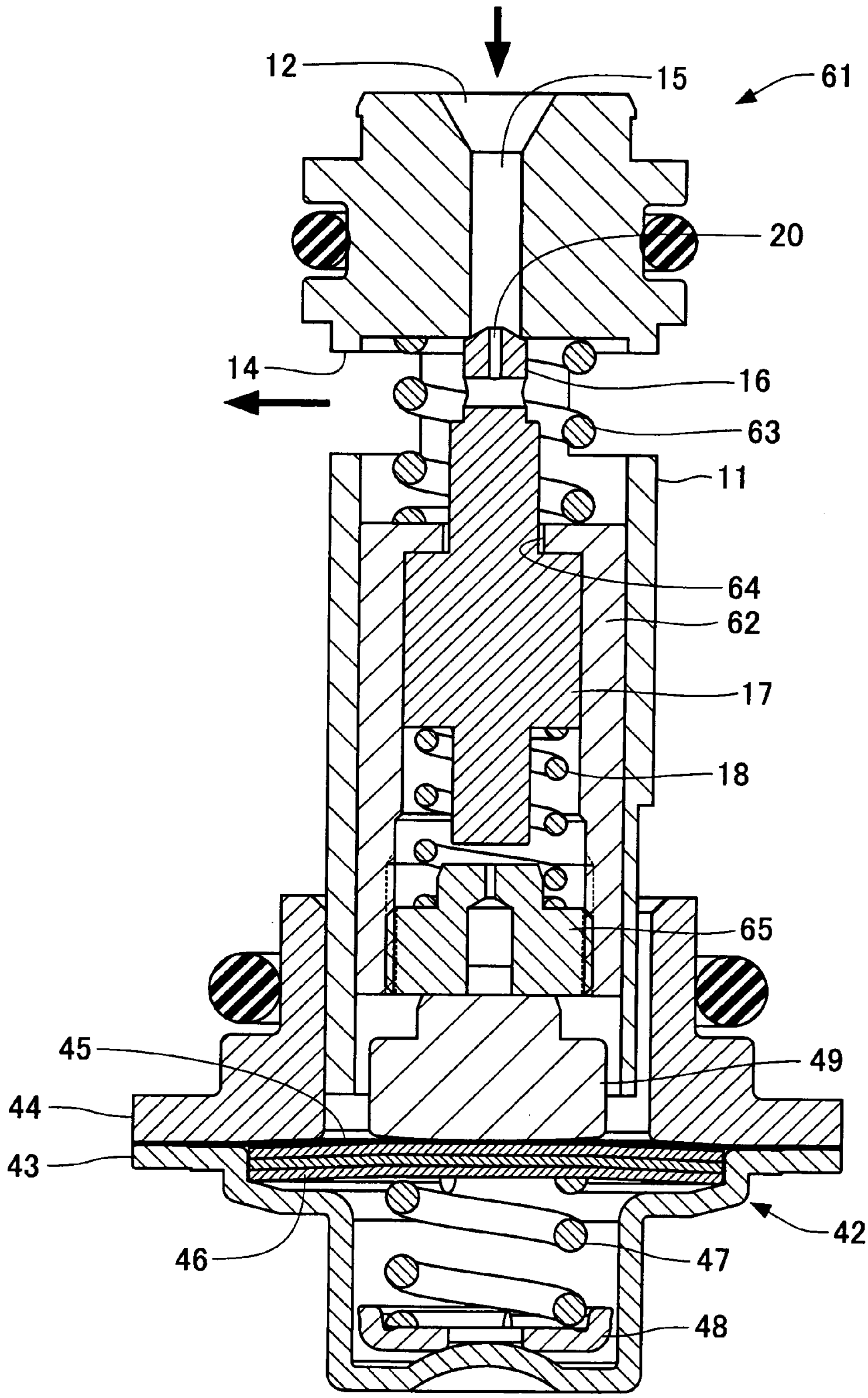

FIG. 8

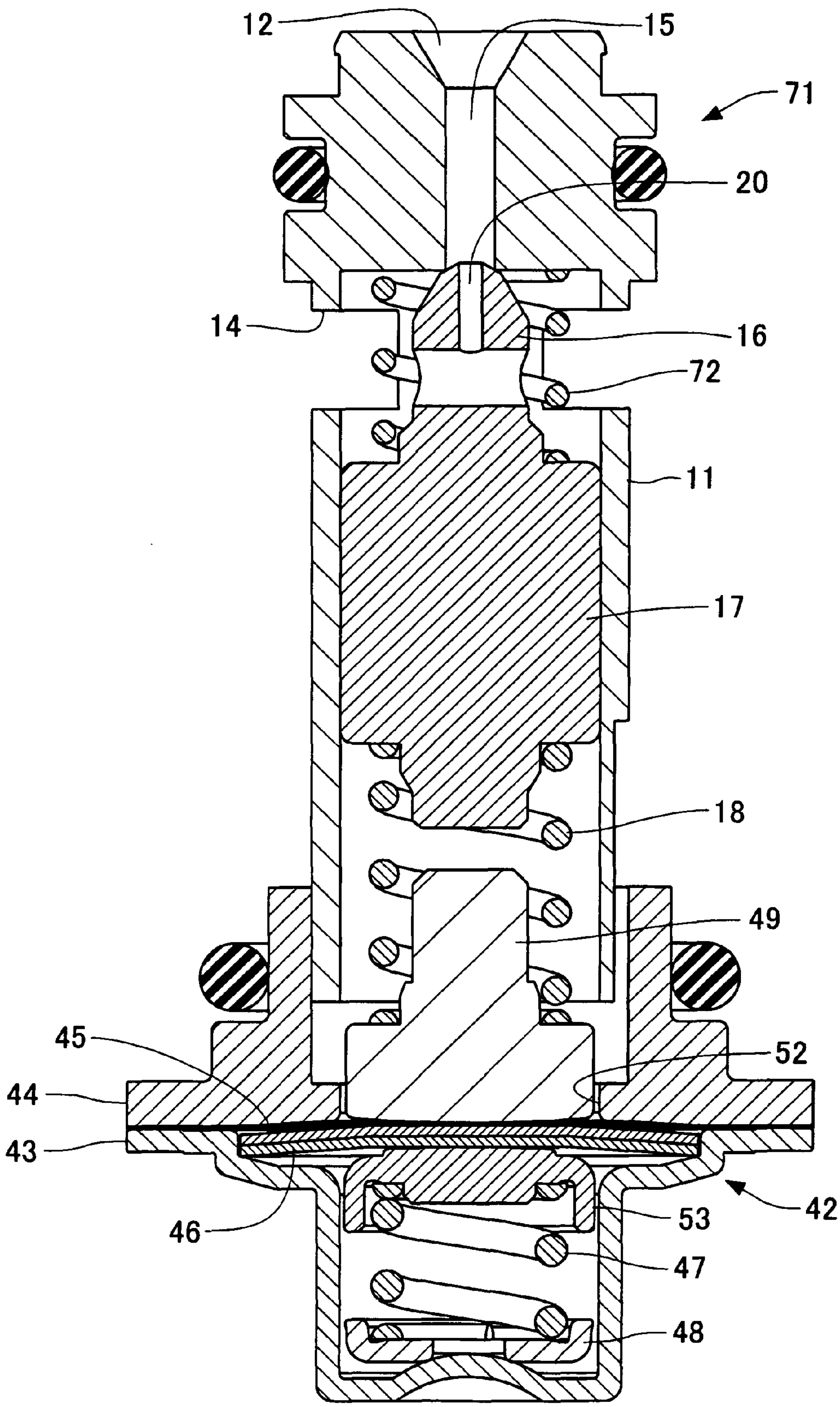

FIG. 9

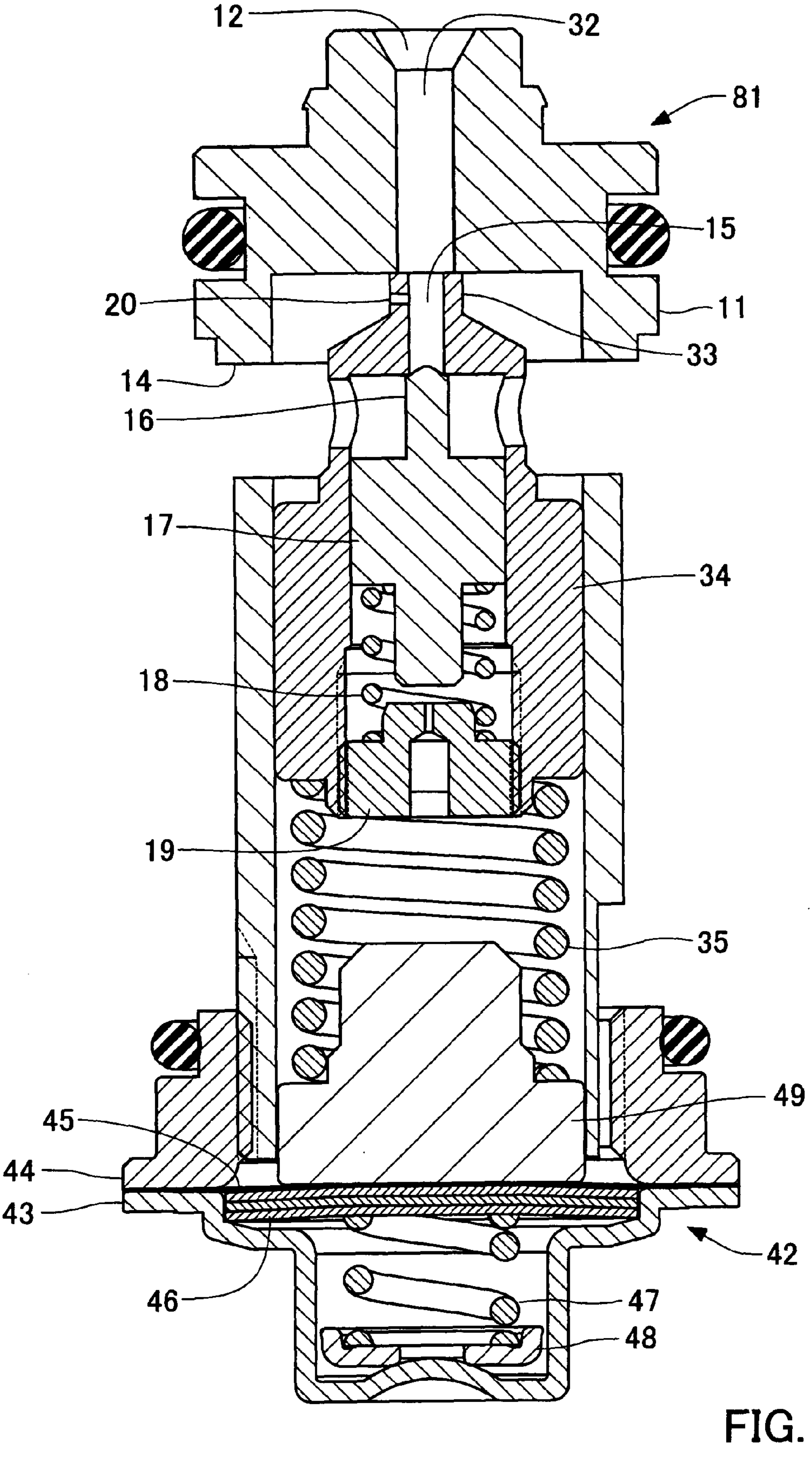

FIG. 10

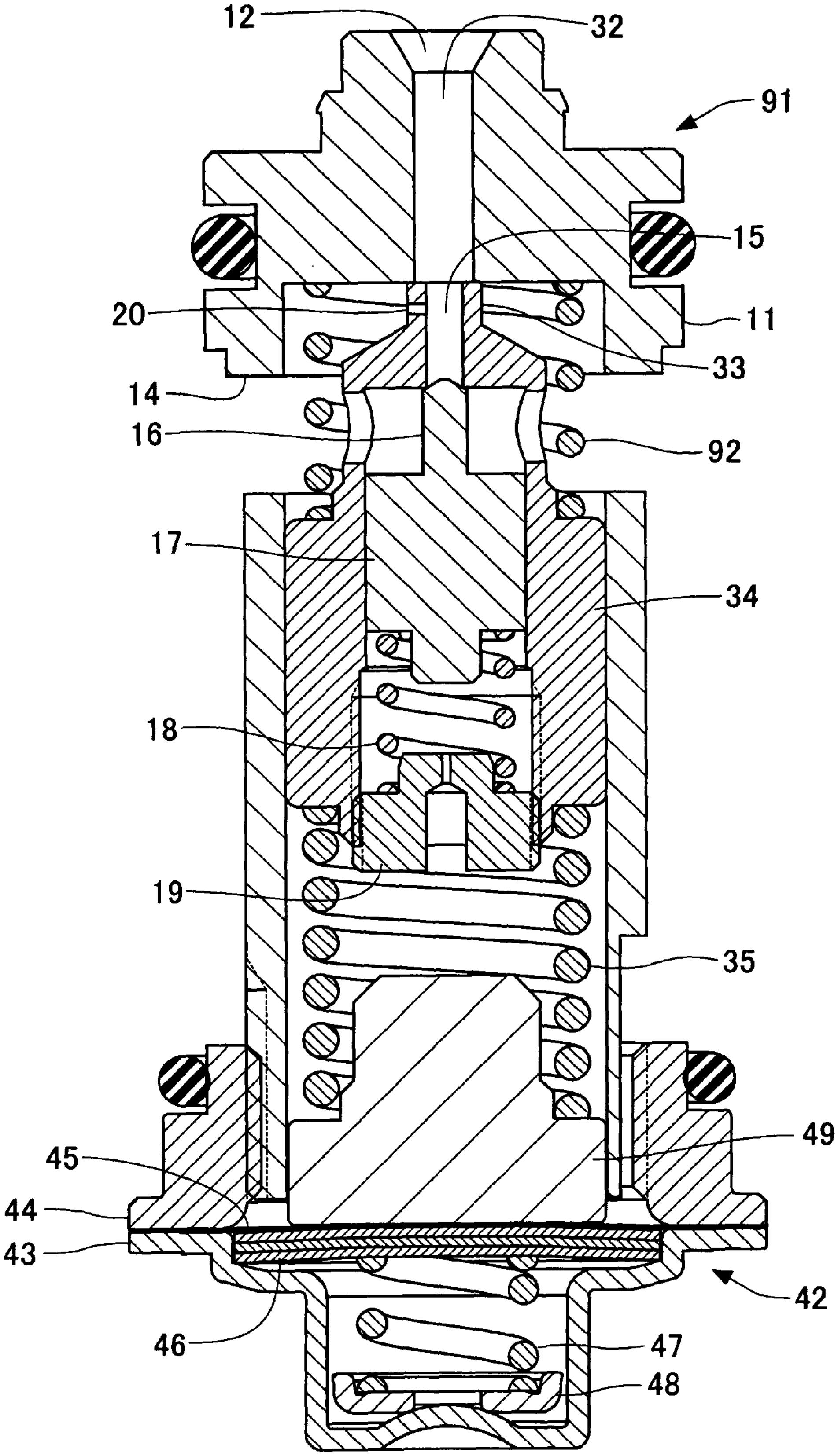

FIG. 11

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2005249380 A **[0003]**