(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 832 822 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.09.2007 Bulletin 2007/37

(51) Int Cl.:
F25B 41/06 *(2006.01)*

(21) Application number: **07003767.6**

(22) Date of filing: **23.02.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **07.03.2006 JP 2006060813**

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(54) **Expansion valve**

(57) A thermostatic expansion valve 3 is applied to a refrigeration cycle having an internal heat exchanger 5 for heat exchange between high-temperature refrigerant flowing from a condenser 2 to the expansion valve 3 and low-temperature refrigerant flowing from an evaporator 4 2 via the expansion valve 3 to a compressor. The expansion valve 3 comprises a bypass passage 3a or 3b for guiding refrigerant either from a high-pressure refrigerant inlet or a low-pressure refrigerant outlet to the downstream side of a temperature-sensing section, such that moist refrigerant is mixed with refrigerant whose degree of superheat is controlled by the expansion valve 3. This lowers the temperature of refrigerant that is drawn into the compressor 1.

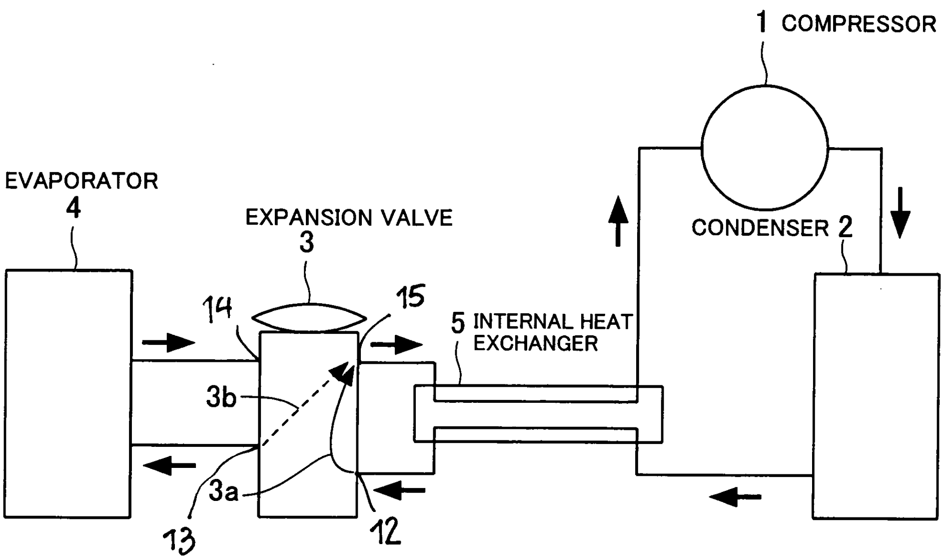

FIG. 1

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Description

[0001] The invention relates to an expansion valve according to the preamble of claim 1, for a refrigeration cycle of an automotive air conditioner.

[0002] From the viewpoint of environmental problems concerning global warming carbon dioxide may be used as the refrigerant in place of a CFC substitute (HFC-134a in refrigeration cycles for automotive air conditioners. To enhance the efficiency with carbon dioxide an internal heat exchanger is generally used in such refrigeration cycles (JP-A-2001-108308). The internal heat exchanger exchanges heat between refrigerant flowing from a gas cooler for cooling high-temperature, high-pressure refrigerant to an expansion valve, and refrigerant from an accumulator to the compressor. Gaseous-phase refrigerant drawn out of the accumulator is superheated by the refrigerant flowing on the high-pressure side of the internal heat exchanger, before it returns to the compressor. This enables the compressor to operate more efficiently with dry refrigerant.

[0003] In contrast, also in refrigeration cycles using HFC-134a, it is contemplated to employ an internal heat exchanger to achieve improved efficiency. However, in a refrigeration cycle using HFC-134a a thermostatic expansion valve is generally used which controls refrigerant at the evaporator outlet such that it has a predetermined degree of superheat. As a result, refrigerant already superheated at the evaporator outlet is further superheated by the internal heat exchanger and then is delivered to the compressor. Particularly when the refrigeration cycle operates under high refrigeration load, there arises the problem that the refrigerant temperature in the compressor rises too high and causes a severe deterioration of the lubricating oil in the compressor.

[0004] It is an object of the invention to provide an expansion valve which is capable of preventing the temperature of refrigerant compressed by a compressor from becoming too high, when a refrigeration load on a refrigeration cycle using an internal heat exchanger is high.

[0005] This object is achieved by the features of claim 1.

[0006] The expansion valve is configured such that moist refrigerant is caused to flow through the bypass passage to a downstream side of the temperature-sensing section. In case of an implemented internal heat exchanger, it is possible to lower the temperature of the refrigerant which is delivered to the compressor via the heat exchanger, and prevent that the temperature of refrigerant compressed by the compressor under a high refrigerant load condition becomes too high. This prevents thermal deterioration of the lubricating oil in the compressor. In both alternatives the respective bypass passage guides sufficient "wet" refrigerant to the downstream side of the temperature sensing section to lower the temperature there.

Fig. 1 is a system diagram of a refrigeration cycle, and schematically indicates two alternative expansion valves,

Fig. 2 is a section of a first embodiment of the expansion valve,

Fig. 3 is section view of a second embodiment of the expansion valve,

Fig. 4 is a section of a third embodiment of the expansion valve,

Fig. 5 is a section of a fourth embodiment of the expansion valve,

Fig. 6 is a section of a fifth embodiment of the expansion valve,

Fig. 7 is a section of a sixth embodiment of the expansion valve,

Fig. 8 is a section of a seventh embodiment of the expansion valve.

[0007] The description is based on refrigeration cycles using HFC-134a and an internal heat exchanger.

[0008] The refrigeration cycle in Fig. 1 comprises a compressor 1, a condenser 2, an expansion valve 3, and an evaporator 4. An included internal heat exchanger 5 exchanges heat between refrigerant flowing from the condenser 2 to the expansion valve 3 and refrigerant flowing from the evaporator 4 to the compressor 1 via the expansion valve 3.

[0009] The expansion valve 3 is a so-called thermostatic expansion valve having a temperature-sensing section for sensing the temperature and pressure of refrigerant exiting the evaporator 4, and for controlling the flow rate delivered to the evaporator 4 according to the sensed temperature and pressure. The expansion valve 3 internally includes either a bypass passage 3a (indicated by a solid arrow) for delivering high-pressure liquid refrigerant from the internal heat exchanger 5 to a downstream side of the temperature-sensing section, or a bypass passage 3b (indicated by a broken line arrow) for delivering low-pressure gas-liquid mixed refrigerant intended for flowing to the evaporator 4 to the downstream side of the temperature-sensing section.

[0010] The expansion valve 10 in Fig. 2 has the bypass passage 3a (first embodiment). A body 11 is formed with a high-pressure refrigerant inlet 12 connected (high-temperature, high-pressure liquid refrigerant) to the outlet of the internal heat exchanger 5, a low-pressure refrigerant outlet 13 (low-temperature, low-pressure liquid throttled and expanded by the expansion valve 10) connected to the evaporator 4, a refrigerant passage inlet 14 connected to (evaporated refrigerant) the outlet of the evaporator 4, and a refrigerant passage outlet 15 connected to the inlet of the internal heat exchanger 5.

[0011] In a passage between the high-pressure refrigerant inlet 12 and the low-pressure refrigerant outlet 13 a valve seat 16 is integrally formed in the body 11. A ball-shaped valve element 17 is movably disposed on one side of the valve seat 16. A valve element receiver 18, and a compression coil spring 19 urging the valve element 17 in valve closing direction to the valve seat 16 are arranged in a space accommodating the valve element 17. A lower end of the compression coil spring 19 is supported by a spring receiver 20 which is fitted into an adjustment screw 21 screwed into a lower end of the body 11. The adjustment screw 21 allows adjustments of the compression coil spring load.

[0012] In an upper end of the body 11 a temperature-sensing section is provided, comprising an upper housing 22, a lower housing 23, a diaphragm 24 dividing a space enclosed by the housings, and a disk 25 disposed below the diaphragm 24.

[0013] A shaft 26 is disposed below the disk 25 for transmitting the displacements of the diaphragm 24 to the valve element 17. An upper portion of the shaft 26 is heid by a holder 28 which extends across a refrigerant passage 27 between the refrigerant passage inlet 14 and the refrigerant passage outlet 15. A compression coil spring 29 laterally loads an upper end section of the shaft 26 in the holder 28 to suppress axial vibrations of the shaft 26.

[0014] The body 11 contains the bypass passage 3a according to Fig. 1, in front of a separate through hole 30 through which high-pressure refrigerant may bypass the expansion valve 10. The through hole 30 extends between the high-pressure refrigerant inlet 12 and the refrigerant passage 27, and contains a differential pressure control valve. The differential pressure control valve comprises a valve seat 31 in the body 11, a movable valve element 32 downstream of the valve seat 31, a compression coil spring 33 urging the valve element 32 in valve-closing direction, and a spring receiver 34 for the compression coil spring 33 press-fitted into the through hole. The valve element 32 is bar-shaped and has a plurality of axial peripheral communication grooves 32a. When the differential pressure control valve is opened, the high-pressure liquid refrigerant flows through the communication grooves 32a.

[0015] The expansion valve 10 senses pressure and temperature of refrigerant returning from the evaporator 4 via the refrigerant passage inlet 14 into the refrigerant passage 27. When the temperature is high or the pressure is low, the diaphragm 24 is displaced downward and the shaft 26 moves the valve element 17 in valve-opening direction. When the temperature is low or the pressure is high, the valve element 17 is caused to move in valve-closing direction. The respective opening degree of the expansion valve 10 is controlled to control the flow rate of refrigerant to the evaporator 4, such refrigerant flowing from the evaporator 4 into the refrigerant passage 27 has a predetermined degree of superheat.

[0016] On the other hand, liquid refrigerant delivered from the evaporator 4 into the refrigerant passage inlet 14 is mixed via the through hole 30 with superheated refrigerant passing through the refrigerant passage 27. The bypassing amount of liquid refrigerant is controlled according to the differential pressure between pressure in the high-pressure refrigerant inlet 12 and pressure in the refrigerant passage 27. When the refrigeration load is low, the differential pressure between discharge pressure and suction pressure in the compressor 1 is low, and hence the differential pressure between the pressure in the high-pressure refrigerant inlet 12 and the pressure in the refrigerant passage 27 is also low, such that the differential pressure control valve in the through hole 30 is closed. In this case, liquid refrigerant is inhibited from directly flowing to the refrigerant passage 27 at the downstream side of the temperature-sensing section. As long as the refrigeration load is low, the temperature of refrigerant compressed by the compressor 1 is already not very high.

[0017] When the refrigeration load is high, the differential pressures between the discharge pressure and the suction pressure in the compressor 1 and between the high-pressure refrigerant inlet 12 and the refrigerant passage 27 also increase. When the differential pressure across the differential pressure control valve becomes equal to a predetermined value (e.g. 1.3 MPa) or higher, the differential pressure control valve opens against the urging force of the compression coil spring 33. Liquid refrigerant flows to the downstream side of the temperature-sensing section and mixes with the liquid refrigerant in the superheated state. This lowers the temperature of the refrigerant in the superheated state to thereby change the mixture into moist refrigerant. The internal heat exchanger 5 causes this moist refrigerant to exchange heat with lowered-temperature refrigerant from the condenser 2, whereby the refrigerant undergoes evaporation and is superheated, and then superheated refrigerant is drawn into the compressor 1. The temperature of refrigerant drawn into the compressor 1 is prevented from becoming too high, which prevents the temperature of refrigerant compressed by the compressor 1 from becoming too high. This prevents thermal deterioration of lubricating oil in the compressor 1, which oil circulates together with the refrigerant through the refrigeration cycle.

[0018] In the expansion valve 40 (second embodiment) the through hole 30 (bypass passage 3a) is provided with an orifice 35 having a very small cross-sectional area, such that liquid refrigerant always flows through. Therefore, although the temperature of the refrigerant flowing into to the internal heat exchanger 5 can be too low when the refrigeration load is low, it is possible to reduce costs compared with the first embodiment.

[0019] The expansion valve 50 in Fig. 4 (third embodiment) has the through hole 30 (here the bypass passage 3b) in the body 11 between the low-pressure refrigerant outlet 13 and the refrigerant passage 27. The already mentioned differential pressure control valve is also inserted into the through hole 30 in Fig. 4. In this case, the spring load of the compression coil spring 33 is set such that the differential pressure control valve is opened when the differential pressure thereacross is not lower than a predetermined value of e.g. 0.03 MPa. When the refrigeration load is low, the flow rate through the evaporator 4 is low, and hence the differential pressure between the inlet an the outlet of the evaporator 4 is also low, and moreover the differential pressure is approximately equal to the differential pressure across the differential pressure control valve in the through hole 30, so that the differential pressure control valve remains closed. As a result, when high-pressure liquid refrigerant passes through a clearance between the valve element 17 and the valve seat 16, all the gas-liquid mixed refrigerant expanded at the low-pressure refrigerant outlet 13 is delivered to the evaporator 4, and is inhibited from directly bypassing to the downstream side of the temperature-sensing section.

[0020] When the refrigeration load is high, the flow rate through the evaporator 4 is high, and hence the differential pressure between the inlet and the outlet of the evaporator 4 becomes high, that is, the value of the differential pressure across the differential pressure control valve is increased. When the differential pressure becomes equal to the predetermined value or higher, the differential pressure control valve opens against the urging force of the compression coil spring 33. Then the liquid refrigerant flows to the downstream side of the temperature-sensing section and mixes with refrigerant in the superheated state. The temperature of refrigerant drawn into the compressor 1 is prevented from becoming too high, which also prevents the temperature of refrigerant compressed by the compressor 1 from becoming too high. This prevents thermal deterioration of lubricating oil in the compressor 1.

[0021] The expansion valve 60 in Fig. 5 (fourth embodiment) again has the orifice 35 formed in the through hole (the bypass passage 3b). The orifice 35 may be larger than in Fig. 3. Gas-liquid mixed refrigerant always flows though the through hole 30 and mixes with refrigerant flowing through the refrigerant passage 27, thereby lowering the temperature of refrigerant delivered to the internal heat exchanger 5, which prevents the temperature of refrigerant compressed by the compressor 1 from becoming too high.

[0022] In the expansion valve 70 in Fig. 6 (fifth embodiment), the through hole 30 (bypass passage 3b) is formed centrally and axially in the body 11 such that the shaft 26 loosely extends through the through hole 30. In the through hole 30, the valve element 32 of the differential pressure control valve is axially movably disposed as a guide for the shaft 26. The compression coil spring 33 is disposed between the valve element 32 and the holder 28, and urges the valve element 32 in valve closing direction to the valve seat 31 formed by a stepped transition portion to a narrower portion 30a in the through hole 30. The shaft 26 passes through the narrower portion with radial clearance.

[0023] The expansion valve 70 operates in quite the same manner as the third embodiment.

[0024] Further, although the mouth of the bypass passage 3b, through which refrigerant is supplied from the through hole 30 to the refrigerant passage 27, is disposed at a location of the refrigerant passage 27, opposed to the temperature-sensing section, low-temperature gas-liquid mixed refrigerant that has been supplied from the through hole 30 to the refrigerant passage 27 through the differential pressure control valve is immediately carried away toward the refrigerant passage outlet 15 by flowing refrigerant exiting the evaporator 4, so that the gas-liquid mixed refrigerant mixes with refrigerant returning from the evaporator 4 first on the downstream side of the temperature-sensing section, without interfering with the temperature sensing function of the temperature-sensing section.

[0025] In the expansion valve 80 in Fig. 7 (sixth embodiment) the through hole 30 (bypass passage 3b) is formed centrally and axially in the body 11 such that the shaft 26 loosely passes through the through hole 30. The orifice 35 is also defined by the shaft 26 in the intermediate narrower portion 30a of the through hole 30. The expansion valve 80 operates in the same manner as the expansion valve 60 (the fourth embodiment).

[0026] The expansion valve 90 in Fig. 8 (seventh embodiment) is for a refrigeration cycle employing a double tube 36 as a pipe toward the compressor 1 and the condenser 2. The double tube 36 is formed by coaxially arranging an outer tube 36a and an inner tube 36b. Since refrigerant flowing through the outer tube 36a and refrigerant flowing through the inner tube 36b are separated by the inner tube 36b, the double tube 36 also fulfils the function of the internal heat exchanger 5.

[0027] The expansion valve 90 has the high-pressure refrigerant inlet 12 connected to the condenser 2 upstream of the valve seat 16 and the valve element 17. The compression coil spring 19 and the spring receiver 20 are disposed on the downstream side of the valve element 17. The through hole 30 (bypass passage 3b) is formed between a low-temperature, low-pressure chamber 17a where the valve element 17 is disposed, and the refrigerant passage 27 through which refrigerant returning from the evaporator 4 passes. The valve element 32 of the differential pressure control valve is movably guided on the shaft 26 to open and close the through hole 30. The valve element 32 is disposed at an open end of the through hole 30 where this opens into the refrigerant passage 27. The valve element 32 is disc-shaped and has a spring collar 32a and is urged by the compression coil spring 33 to the valve seat 31.

[0028] High-temperature, high-pressure liquid refrigerant from the outer tube 36a to the high-pressure refrigerant inlet 12 is throttled and expanded into low-temperature, low-pressure refrigerant by passing between the valve element 17 and the valve seat 16, and is delivered from the iow-pressure refrigerant outlet 13 to the evaporator 4. Refrigerant returning from the evaporator 4 is received by the refrigerant passage inlet 14, and passes through the refrigerant passage 27 to the refrigerant passage outlet 15 and into the inner tube 36b. The temperature-sensing section senses the temperature and pressure of the refrigerant passing through the refrigerant passage 27, to control the flow rate of refrigerant to be delivered to the evaporator 4.

[0029] Further, the differential pressure control valve 31, 32 senses the differential pressure between the pressure of refrigerant in the low-pressure refrigerant outlet 13 and the pressure of refrigerant in the refrigerant passage 27, to control the flow rate through the through hole 30 between the low-pressure refrigerant outlet 13 and the refrigerant passage 27. Although refrigerant is supplied from the through hole 30 to the refrigerant passage 27, at a location of the refrigerant passage 27, opposed to the temperature-sensing section, low-temperature gas-liquid mixed refrigerant that has been supplied from the bypass passage 30 to the refrigerant passage 27 through the differential pressure control valve is carried away toward the refrigerant passage outlet 15 by flowing refrigerant evaporated by the evaporator 4, so that the temperature of the gas-liquid mixed refrigerant is not sensed by the temperature-sensing section.

[0030] Although the above-described embodiments are applied to refrigeration cycles having the internal heat exchanger 5 and using HFC-134a, the present invention can also be applied to refrigeration cycles that use another refrigerant with a small global warming coefficient and similar physical properties.

Claims

1. A thermostatic expansion valve (3, 10, 40, 50, 60, 70, 80, 90) for controlling a refrigerant flow rate to be delivered to an evaporator (4) by a temperature-sensing section sensing a temperature and a pressure of the refrigerant exiting the evaporator (4), the expansion valve having in a body (11) a high-pressure refrigerant inlet (12), a low-pressure refrigerant outlet (13) connected to an evaporator inlet, a refrigerant passage (27) for refrigerant exiting the evaporator (4), the refrigerant passage (27) containing at least a part of the temperature sensing section, **characterised in that** the expansion valve (3, 10, 40, 50, 60, 70, 80, 90) contains a bypass passage (3a, 3b) extending between the refrigerant passage (27) and either the high-pressure refrigerant inlet (12) or the low-pressure refrigerant outlet (13), for passing through either high-pressure liquid refrigerant from the high-pressure refrigerant inlet (12) or low-pressure gas-liquid mixed refrigerant from the low-pressure refrigerant outlet (13) to a downstream side of the temperature sensing section in the refrigerant passage (27).

2. Expansion valve according to claim 1, **characterised in that** the bypass passage (3a, 3b) contains an orifice (35) formed in the body (11), and that the bypass passage (3a, 3b) at least partly is formed by a through hole (30) extending in the body (11) either between the high-pressure refrigerant inlet (12) and the refrigerant passage (27) or the low-pressure refrigerant outlet (13) and the refrigerant passage (27).

3. Expansion valve according to claim 1, **characterised in that** the bypass passage (3a, 3b) contains a differential pressure control valve (31, 32) in a through hole (30) of the body (11), that opens when the differential pressure thereacross becomes not lower than a predetermined value.

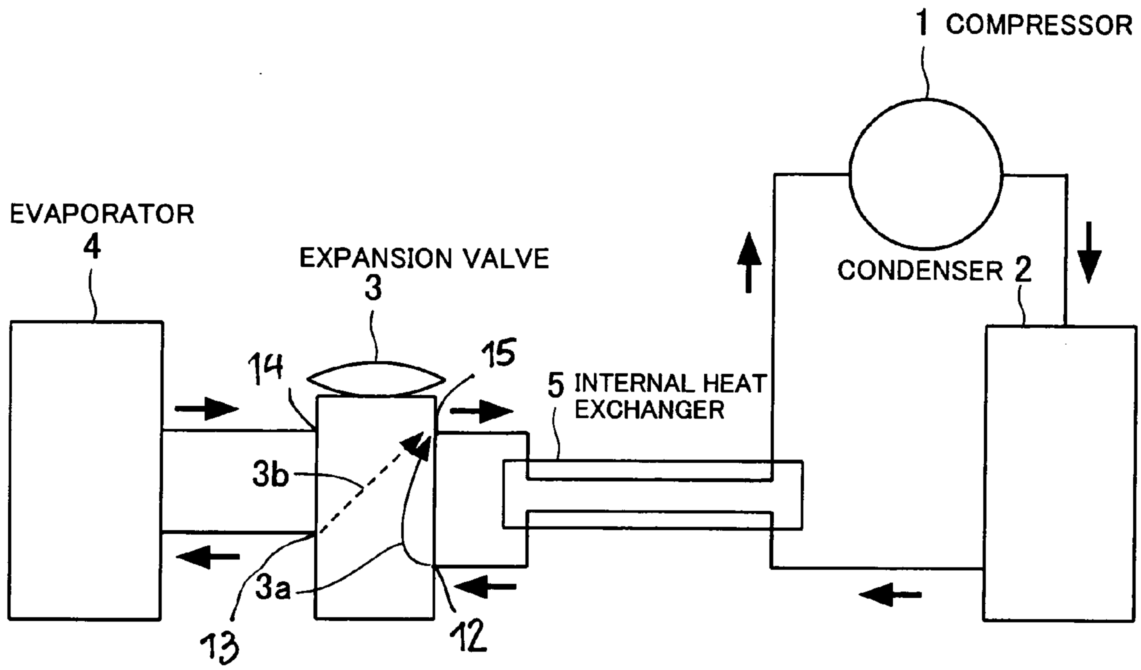
4. Expansion valve according to claim 1, **characterised in that** the bypass passage (3a, 3b) is formed by a through hole (30) in the body (11), that a shaft (26) loosely penetrates the through hole (30) and that the shaft (26) is disposed between the temperature sensing section and a valve element (17) that controls the refrigerant flow rate to the evaporator (4).

5. Expansion valve according to claims 3 and 4, **characterised in that** the differential pressure control valve (31, 32) has a valve element (32) slidably guided on or slidably guiding the shaft (26) in the through hole (30), and a valve seat (31) at a stepped transition from the through hole (30) to a narrowed portion (30a) of the through hole (30), the shaft (26) loosely extending also through the narrowed portion (30a).

6. Expansion valve according to claims 2 and 4, **characterised in that** the orifice (35) is defined between the shaft (26) and a narrowed portion (30a) of the through hole (30).

7. Expansion valve according to claim 2, **characterised in that** the through hole (30) is formed in the body (11) separated from another through hole of the body (11) which other through hole contains a shaft (26).

8. Expansion valve according to at least one of the preceding claims, **characterised in that** the expansion valve (3, 10, 40, 50, 60, 70, 80, 90) is applied to a refrigeration cycle provided with an internal heat exchanger (5) that performs heat exchange between refrigerant exiting a condenser (2) and refrigerant entering a compressor (1), the internal heat exchanger (5) being connected respectively to the high-pressure refrigerant inlet (12) and to an outlet (15) of the refrigerant passage (27).


1 COMPRESSOR
EVAPORATOR
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EXPANSION VALVE
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CONDENSER 2
14
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5 INTERNAL HEAT
EXCHANGER
3b
3a
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FIG. 1

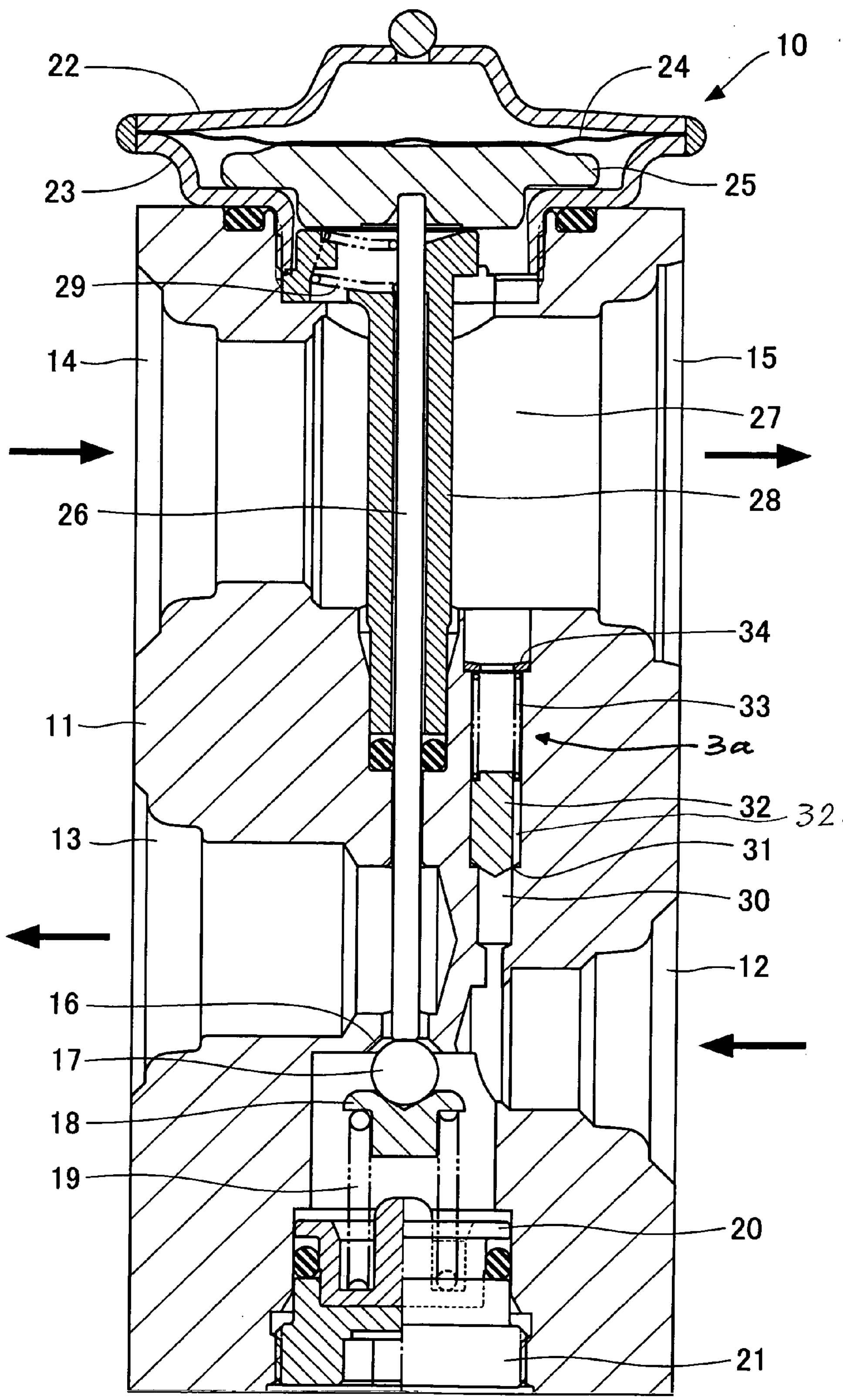
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FIG. 2

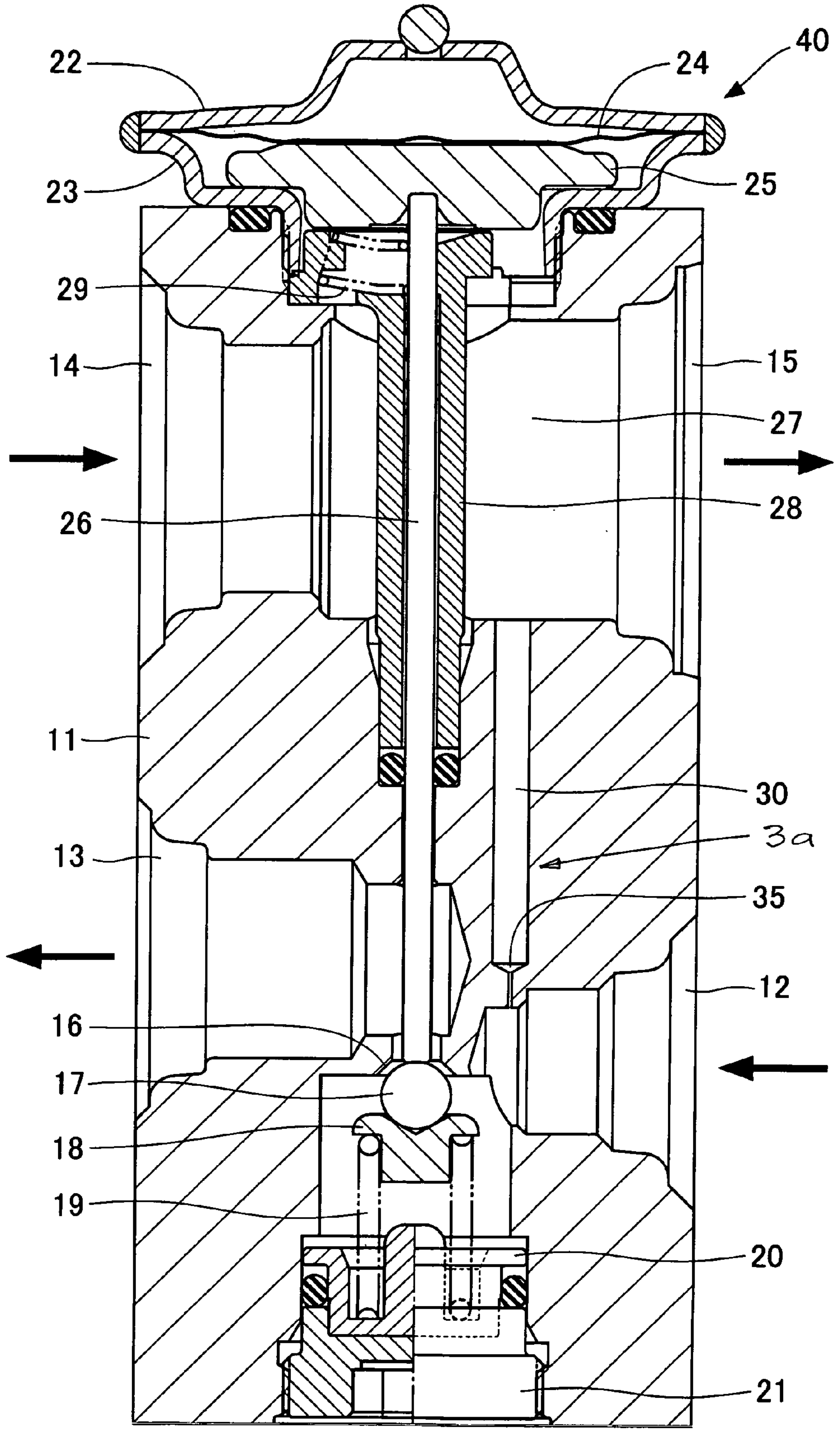

FIG. 3

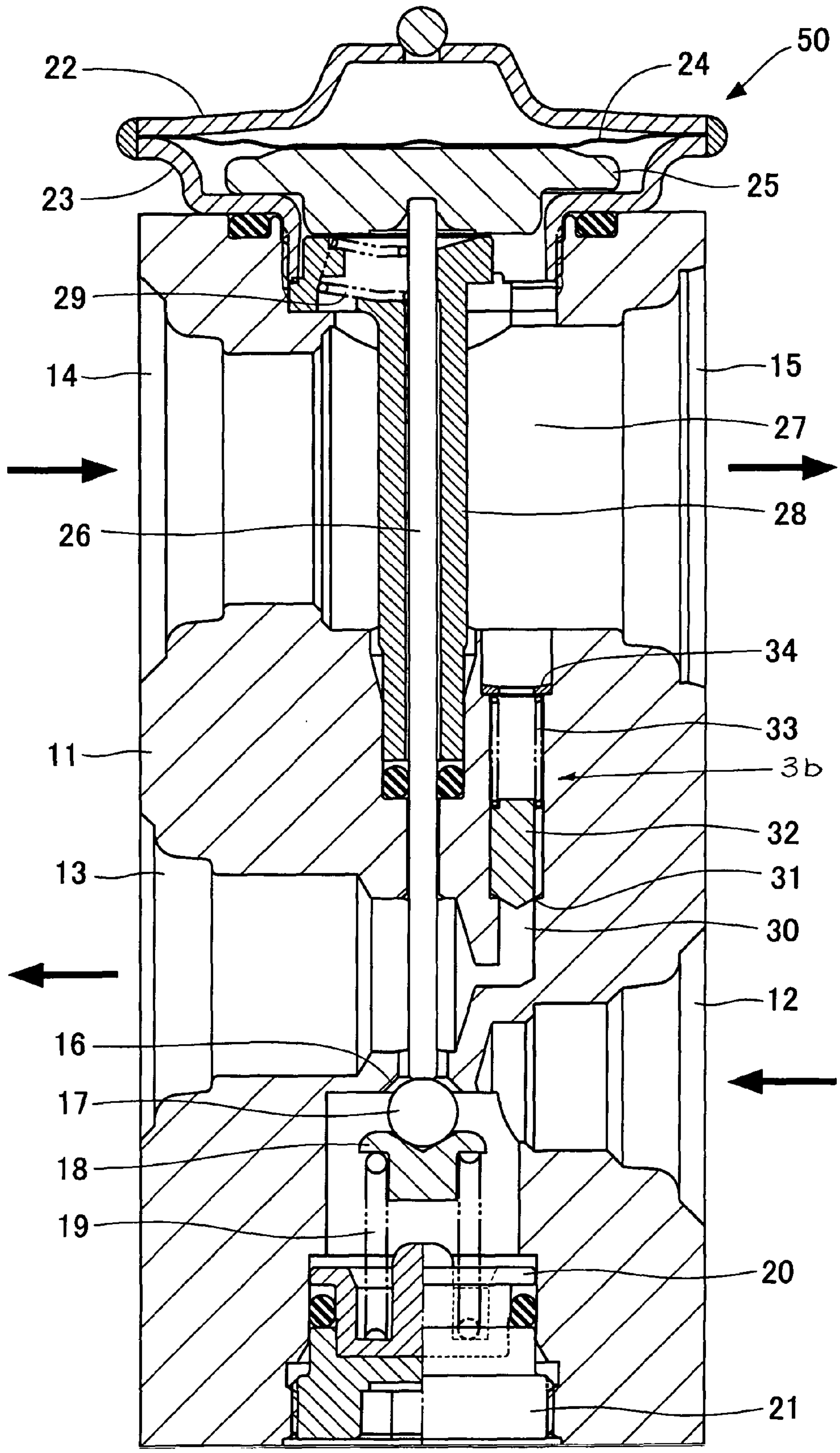
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FIG. 4

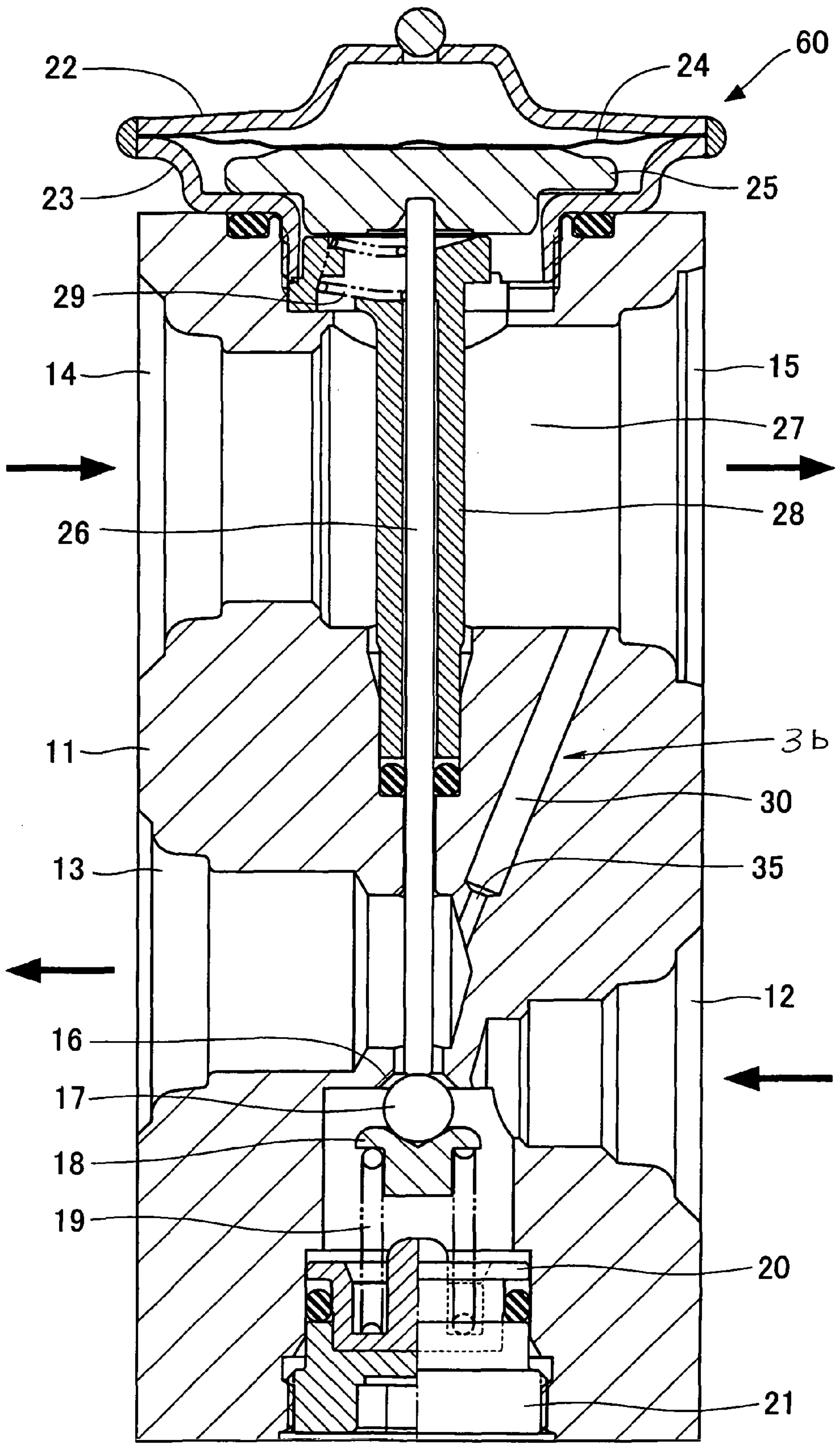

FIG. 5

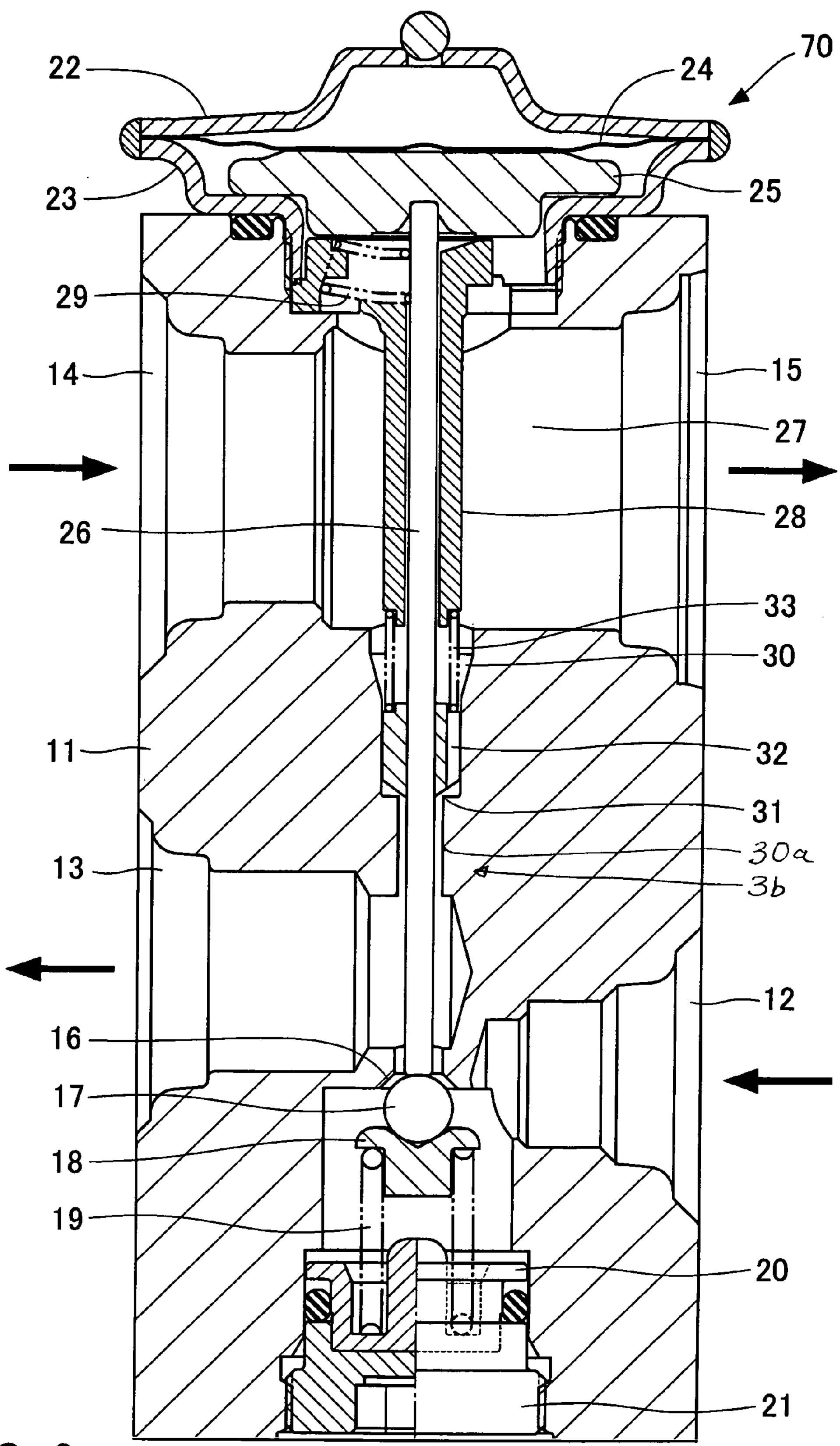

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FIG. 6

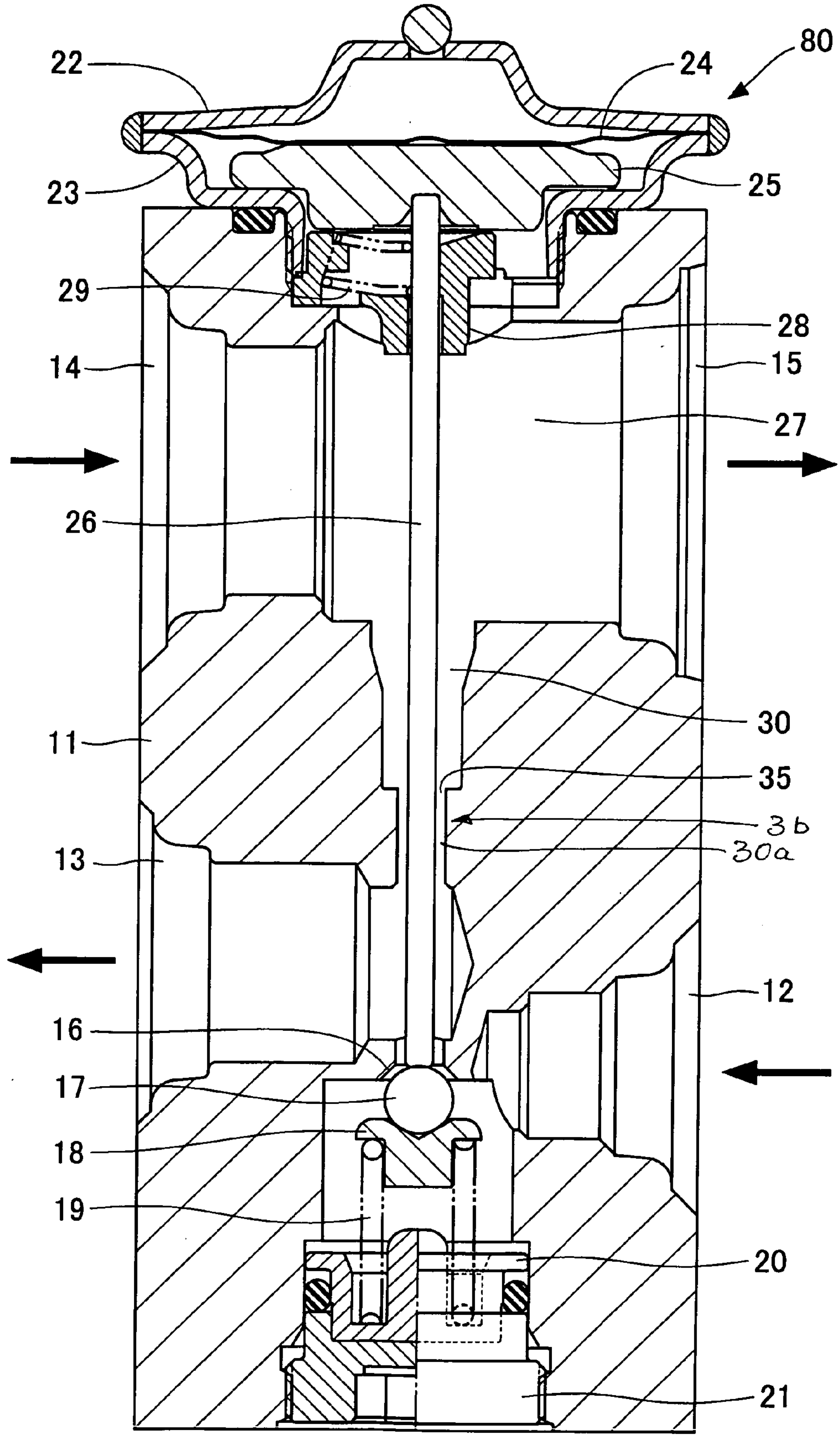
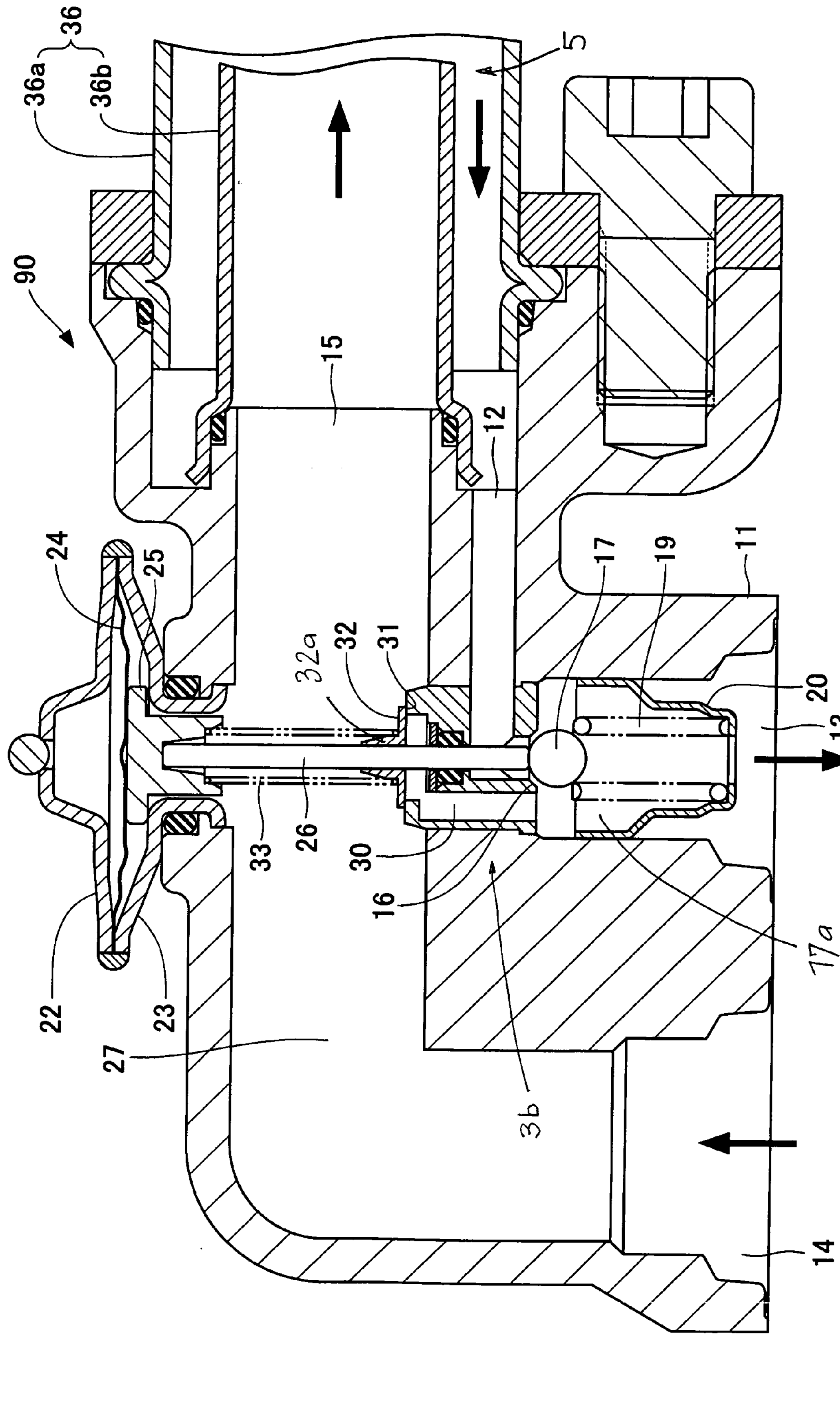


FIG. 7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17a
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3b
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FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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