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(54) **FLOW RATE CONTROL VALVE**

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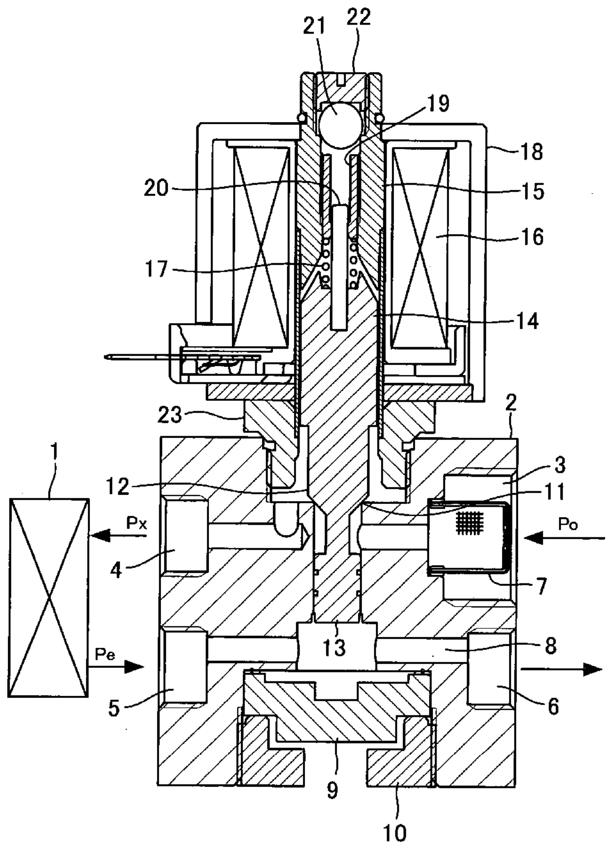
(57) **ABSTRACT**

There is provided a flow rate control valve of a constant flow-rate control type, which is simple in construction. The flow rate control valve is configured, by regarding a evaporator as a restriction passage, to include a constant differential pressure control valve for controlling the differential pressure before and after pressure loss caused by passage of refrigerant through the evaporator to be substantially constant. In the constant differential pressure control valve, a valve element receives pressure from the outlet of the flow rate control valve in a valve-closing direction, and a piston receives pressure from the outlet of the evaporator in a valve-opening direction. By controlling the differential pressure between pressure at the inlet of the evaporator and the pressure at the outlet of the evaporator such that it is substantially constant, the constant differential pressure control valve causes the refrigerant to flow into the evaporator at a constant flow rate dependent on electric current that energizes a solenoid. This makes it unnecessary to form a restriction passage in the flow rate control valve, and hence the construction of the flow rate control valve can be simplified, which makes it possible to provide a flow rate control valve manufactured at low cost.



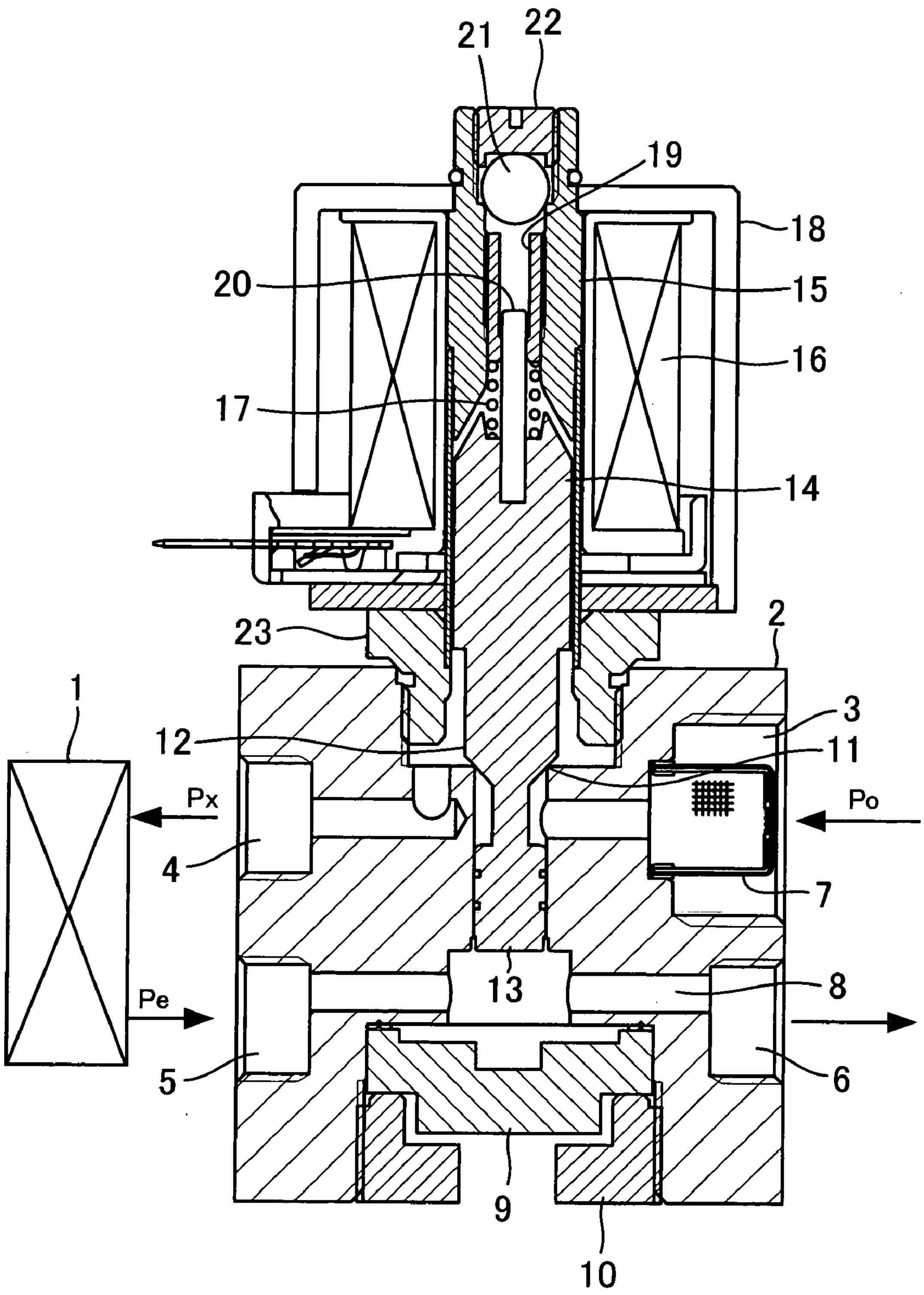


FIG. 1

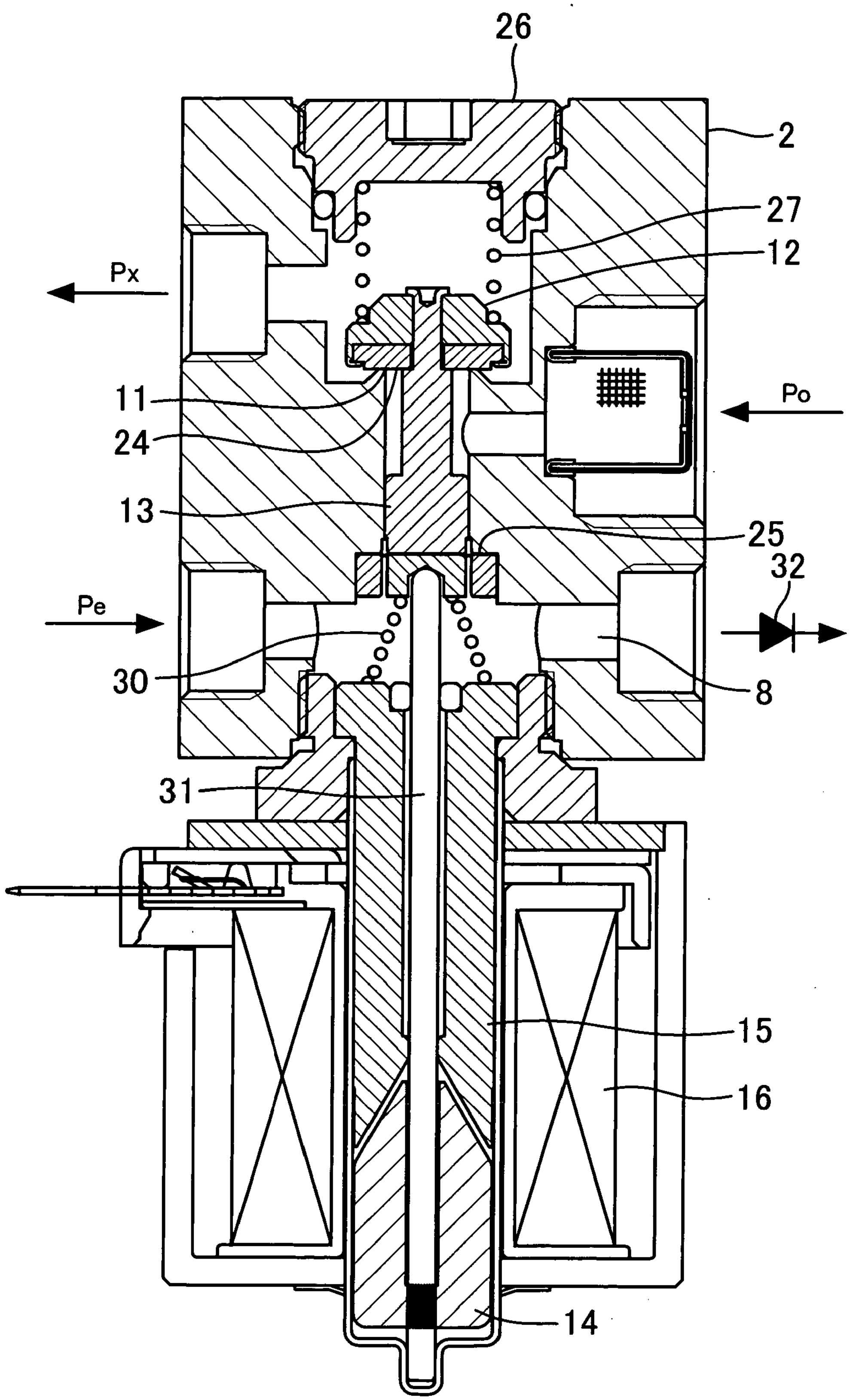


FIG. 2

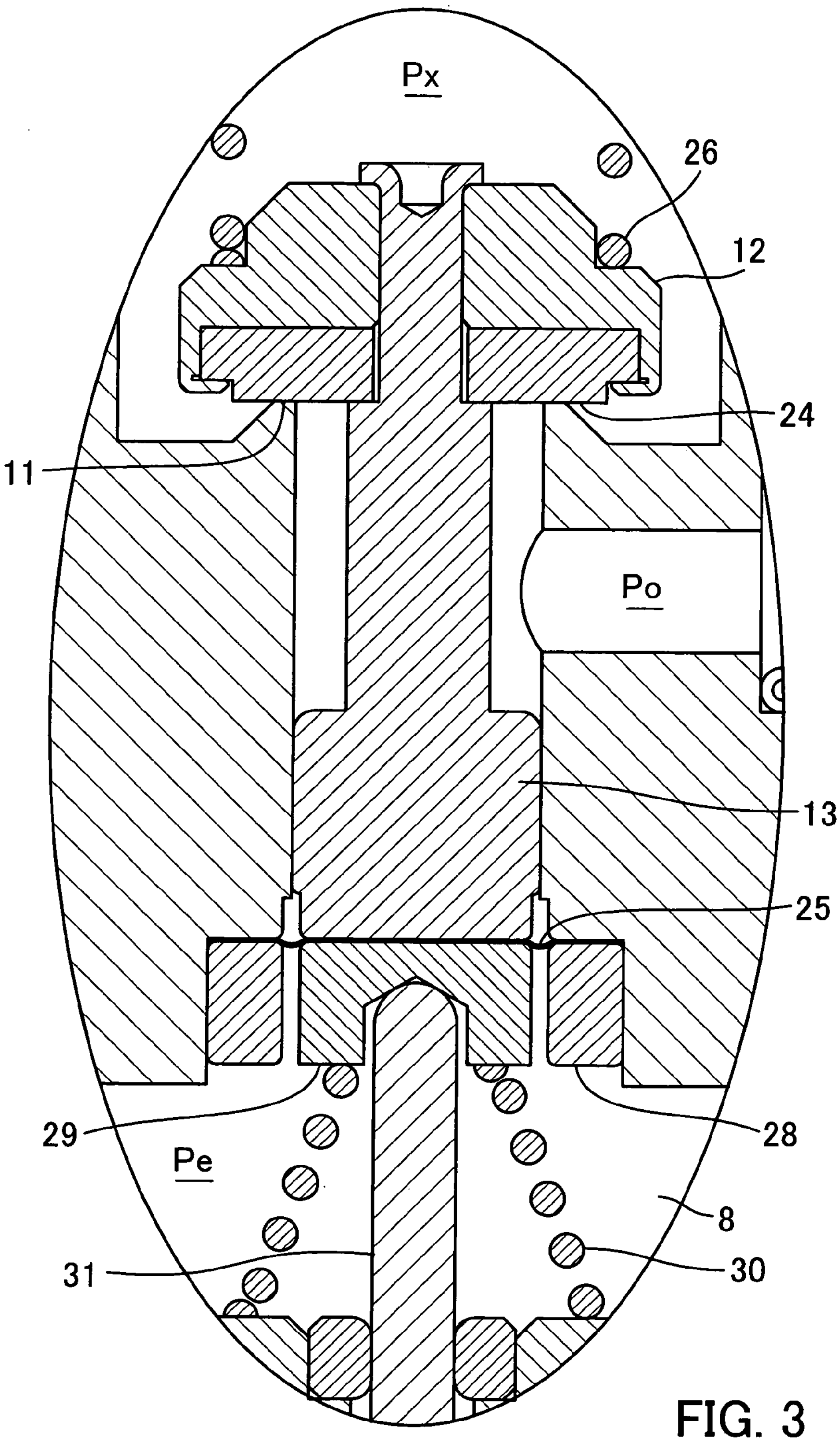


FIG. 3

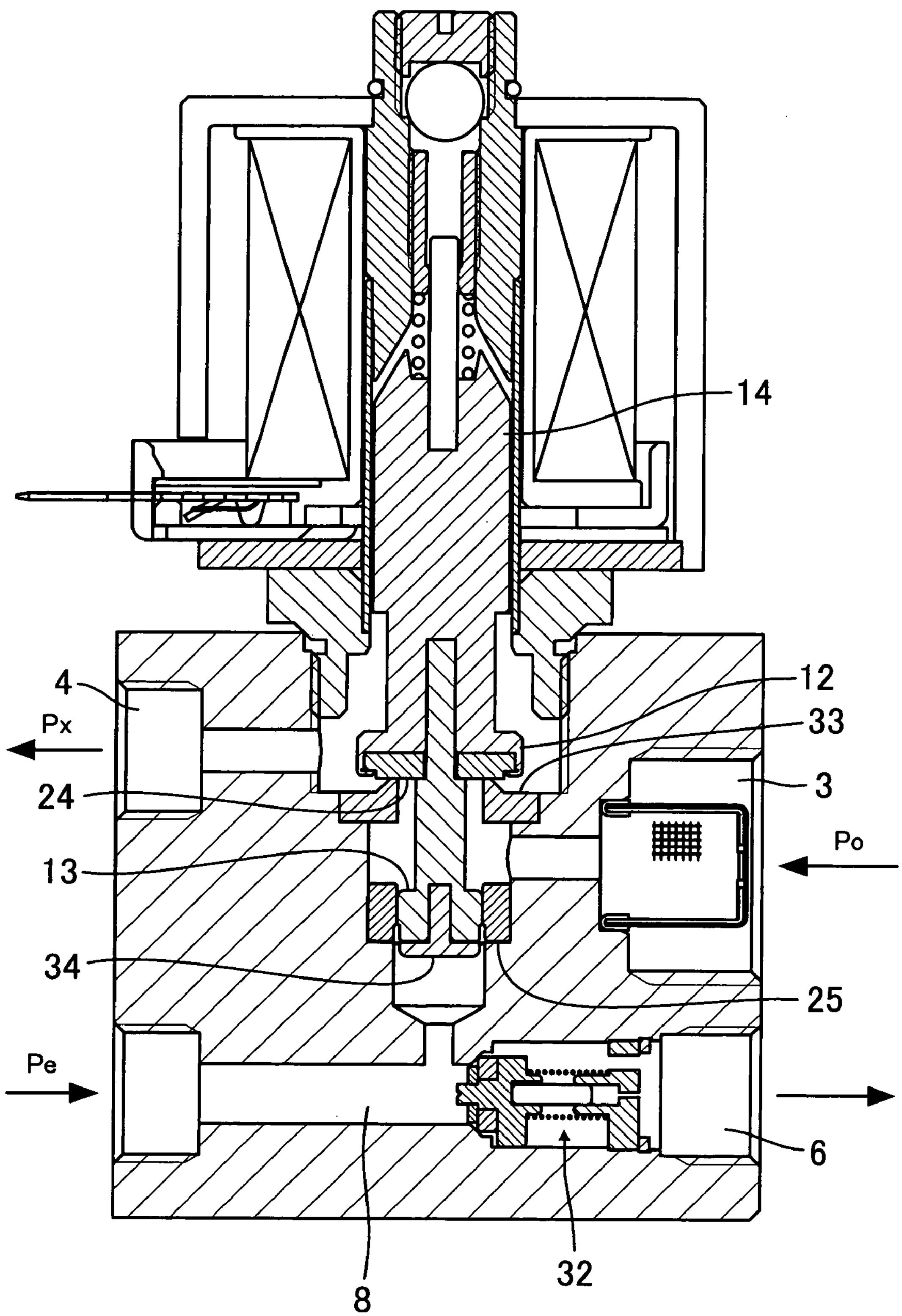


FIG. 4

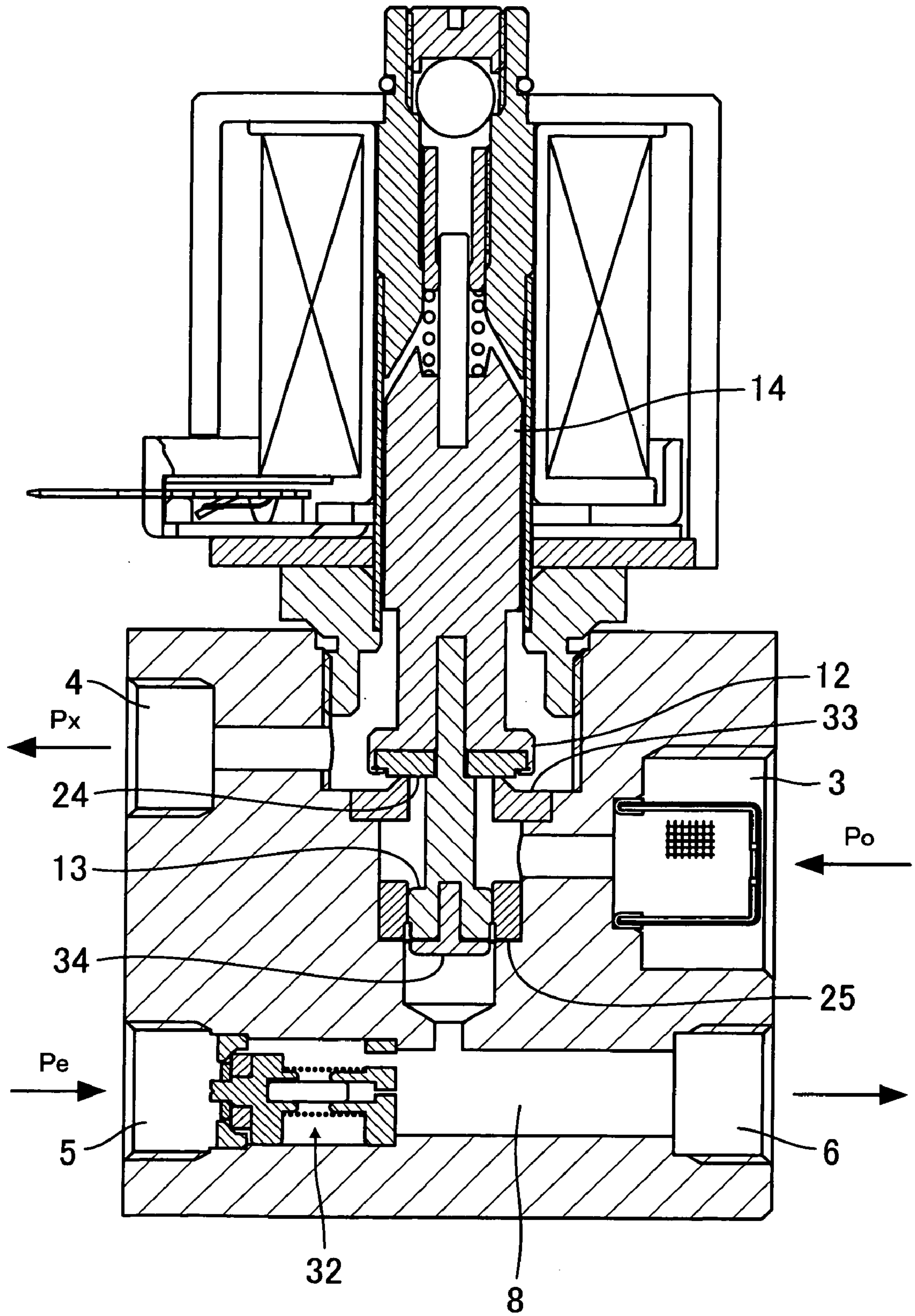


FIG. 5

FLOW RATE CONTROL VALVE

[0001] This application is a continuing application, filed under 35 U.S.C. §111(a), of International Application PCT/JP2004/002673, filed Mar. 3, 2004, it being further noted that priority is based upon Japanese Patent Application No. 2003-059353, filed Mar. 6, 2003.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to a flow rate control valve, and more particularly to a flow rate control valve used as an expansion device in a refrigeration cycle for an automotive air conditioner, which changes high-temperature, high-pressure refrigerant into low-temperature, low-pressure refrigerant to thereby deliver the refrigerant to an evaporator.

[0004] 2. Description of the Related Art

[0005] When a refrigeration cycle for an automotive air conditioner uses, as a control valve for controlling a compressor, a differential pressure control type that controls the differential pressure across the compressor or suction pressure of the same such that it is substantially constant, it is considered preferable to use, as an expansion device, an expansion valve of a flow rate control type different in control method, so as to stabilize the controllability of the system. A flow rate control valve of this kind has been described e.g. in Japanese Unexamined Patent Publication (Kokai) NO. 2001-153495.

[0006] The flow rate control valve includes a constant flow-rate mechanism. The constant flow-rate mechanism is configured based on a principle that if the cross-sectional area of a passage through which refrigerant flows between a refrigerant inlet and a refrigerant outlet and the differential pressure across the passage are determined, the flow rate of refrigerant flowing through the control valve can be controlled to be constant, and hence by varying one of the cross-sectional area and the differential pressure by a solenoid, it is possible to cause refrigerant to flow at a constant flow rate corresponding to a value set by the solenoid. More specifically, the constant flow-rate mechanism includes a flow passage cross-sectional area control valve for controlling the cross-sectional area of the passage, and a constant differential pressure control valve for controlling the differential pressure between the inlet and the outlet of the flow passage cross-sectional area control valve to be substantially constant, and is configured such that the flow passage cross-sectional area of the flow passage cross-sectional area control valve is controlled by the solenoid, to thereby hold the flow rate of refrigerant flowing through the flow rate control valve at a predetermined constant flow rate corresponding to a flow passage cross-sectional area set by the solenoid (see FIG. 1 in Japanese Unexamined Paten Publication (Kokai) No. 2001-153495). Alternatively, the constant flow-rate mechanism includes a restriction passage the cross-sectional area of which is not changed, and a differential pressure control valve for controlling the differential pressure between the inlet and the outlet of the restriction passage such that it is substantially constant, and is configured such that a differential pressure value set to the differential pressure control valve is controlled by the solenoid to thereby hold the flow rate of refrigerant flowing through the flow rate control valve at a predetermined constant flow rate corresponding to the differential pressure set by the solenoid (see FIG. 2 in Japanese Unexamined Paten Publication (Kokai) No. 2001-153495).

[0007] However, to control the flow rate to be constant, the conventional flow rate control valve includes the restriction passage for creating the differential pressure, and the differential pressure control valve for controlling the differential pressure across the restriction passage such that it is constant, and hence suffers from the problem of being complicated in construction.

SUMMARY OF THE INVENTION

[0008] The present invention has been made in view of these problems, and an object thereof is to provide a flow rate control valve of a constant flow-rate control type, which is simple in construction.

[0009] To solve the above problem, the present invention provides a flow rate control valve that controls a flow rate of refrigerant which is throttled and expanded to be delivered to an evaporator, such that the flow rate is substantially constant, comprising a constant differential pressure control valve that controls a differential pressure before and after pressure loss caused by passage of refrigerant through the evaporator, such that the differential pressure is substantially constant.

[0010] The above and other objects, features and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a first embodiment.

[0012] **FIG. 2** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a second embodiment.

[0013] **FIG. 3** is an expanded cross-sectional view showing essential components of the flow rate control valve according to the second embodiment.

[0014] **FIG. 4** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a third embodiment of the present invention.

[0015] **FIG. 5** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a fourth embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

[0017] **FIG. 1** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a first embodiment of the present invention.

[0018] The flow rate control valve is capable of performing constant flow rate control only after it is connected to an evaporator **1**, and has a body block **2** provided with a high-pressure refrigerant inlet **3** to which refrigerant at pressure Po is supplied, a low-pressure refrigerant outlet **4** from which refrigerant is delivered to the evaporator **1** while being expanded, a return refrigerant inlet **5** to which refrigerant is returned from the evaporator **1**, and a return refrigerant outlet **6** from which the returned refrigerant is delivered to a compressor. The high-pressure refrigerant inlet **3** has a strainer **7** disposed therein in a manner closing a passage formed therein.

[**0019**] The body block **2** has an upper portion thereof formed with a large-diameter hole, a central portion thereof formed with a cylinder concentric with the large-diameter hole and extending vertically, as viewed in **FIG. 1**, and a lower portion thereof formed with a hole that communicates with the cylinder formed in the central portion thereof. The hole in the lower portion of the body block **2** is communicated with the return refrigerant inlet **5** and the return refrigerant outlet **6**, by a return passage **8**, and an opening of the hole formed downward of the return passage **8** is closed by a packing pressed against the body block **2** by a screw **10** via a packing retainer **9**.

[**0020**] The rim of an upper end of the cylinder formed in the central portion of the body block **2** forms a valve seat **11**, and a valve element **12** is disposed in a manner opposed to the valve seat **11** from above, as viewed in **FIG. 1**, such that the valve element **12** can move to and away from the valve seat **11**. The valve element **12** is integrally formed with a piston **13**, which serves as a pressure-sensing member axially movably disposed within the cylinder, with a small-diameter shaft connecting between the valve element **12** and the piston **13**. In the cylinder, a refrigerant passage communicating with the high-pressure refrigerant inlet **3** opens in a portion where the small-diameter shaft is located. A chamber above the cylinder, formed by the large-diameter hole formed in the upper portion of the body block **2**, is communicated with the low-pressure refrigerant outlet **4** via a refrigerant passage.

[**0021**] Disposed on the top of the body block **2** is a solenoid which comprises a plunger **14** integrally formed with the valve element **12**, a core **15** disposed concentrically with the plunger **14**, an electromagnetic coil **16** disposed around the plunger **14** and the core **15**, a spring **17** disposed between the plunger **14** and the core **15**, and a yoke **18** surrounding the electromagnetic coil **16**. The core **15** is in the form of a hollow cylinder, and has an adjustment screw **19** screwed therein which adjusts the load of the spring **17**. The adjustment screw **19** as well has a hollow cylindrical shape, and forms a bearing that axially movably holds a shaft **20** having a lower end rigidly fixed to the plunger **14**. The upper open end of the core **15** is hermetically closed by a ball **21** and a locking screw **22**. The solenoid is screwed into the large-diameter hole formed in the top of the body block **2**, via a connecting portion **23** thereof.

[**0022**] Now, when the solenoid is deenergized, the plunger **14** is urged by the spring **17** in a direction away from the core **15**, and hence the valve element **12** is seated on the valve seat **11**, whereby the flow rate control valve is fully closed.

[**0023**] When a predetermined electric current is supplied to the electromagnetic coil **16** of the solenoid, the plunger **14** is attracted to the core **15** against the urging force of the spring **17**, which causes the valve element **12** to be lifted from the valve seat **11**, and the flow rate control valve is set to a predetermined valve lift dependent on the balance between a solenoid force dependent on the solenoid current and the load of the spring **17**. At this time, refrigerant introduced into the high-pressure refrigerant inlet **3** is throttled by a gap between the valve element **12** and the valve seat **11** and then expanded, thereafter being delivered from the low-pressure refrigerant outlet **4** to the evaporator **1**.

[**0024**] The effective diameter of the valve seat **11** and that of the piston **13** are approximately equal to each other, and hence the pressure Po of refrigerant supplied to a space between the valve element **12** and the piston **13** has no influence on the motions of the valve element **12** and the piston **13** since a force in a direction of pushing the valve element **12** upward and a force in a direction of pushing the piston **13** downward are approximately equal to each other and canceled out.

[**0025**] Further, pressure Px from the low-pressure refrigerant outlet **4** of the flow rate control valve, which is pressure on the downstream side of the valve element **12**, acts on the valve element **12**, and pressure from the return passage **8** of refrigerant acts on the lower surface of the piston **13**, so that the valve element **12** and the piston **13** is axially moved from respective positions set by the solenoid, in response to the differential pressure between pressure at the inlet of the evaporator **1** and pressure Pe at the outlet of the evaporator **1**. For example, when the differential pressure between the pressure at the inlet of the evaporator **1** and the pressure Pe at the outlet of the evaporator **1** increases, the pressure Pe at the outlet of the evaporator **1** acts to move the piston **13** downward, whereby the valve element **12** is moved in a valve-closing direction. This decreases the flow rate of refrigerant, and hence the flow rate control valve acts to reduce the differential pressure. Inversely, when the differential pressure decreases, the flow rate control valve acts to increase the differential pressure. Therefore, the flow rate control valve functions as a constant differential pressure control valve for providing control such that the differential pressure between the pressure at the inlet of the evaporator **1** and the pressure Pe at the outlet of the evaporator **1** is substantially constant. In other words, the flow rate control valve causes refrigerant to flow into the evaporator **1** at a substantially constant flow rate dependent on electric current that energizes the solenoid.

[**0026**] **FIG. 2** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a second embodiment of the present invention, and **FIG. 3** is an expanded cross-sectional view showing essential components of the flow rate control valve according to the second embodiment. It should be noted that component elements in **FIGS. 2 and 3** identical or similar to those shown in **FIG. 1** are designated by identical reference numerals, and detailed description thereof is omitted.

[**0027**] As distinct from the flow rate control valve according to the first embodiment, the flow rate control valve according to the second embodiment is configured to prevent internal leakage of refrigerant when the flow rate control valve is closed, and reverse the direction of actuation of the valve element **12** by the solenoid.

[**0028**] More specifically, a flexible valve sheet **24** is disposed on a seating surface of the valve element **12** via which the valve element **12** is seated on the valve seat **11** to thereby prevent leakage of refrigerant from a valve section, and a diaphragm **25** is disposed on a surface of the piston **13** at which the pressure Pe from the outlet of the evaporator **1** is received, to thereby substantially completely prevent leakage of refrigerant from the high-pressure refrigerant inlet **3** to the return passage **8** via the sliding portion of the piston **13**. A space where the valve element **12** is disposed is closed by an adjustment screw **26** screwed into the body block **2**, and a spring **27** for urging the valve element **12** in the valve-closing direction is disposed between the valve element **12** and the adjustment screw **26**. The load of the spring **27** can be adjusted by the screwing amount of the adjustment screw **26**.

[**0029**] The diaphragm **25** has its periphery brought into intimate contact with the body block **2** by press-fitting a ring member **28** in the body block **2**. The diaphragm **25** has an effective diameter approximately equal to the effective diameter of the valve seat **11**, and a disk **29** having an end face approximately equal to the lower end face of the piston **13** is contact with the central portion of the diaphragm **25**. A spring **30** causes the disk **29** to urge the diaphragm **25** in the valve-opening direction of the valve section.

[**0030**] The solenoid has the core **15** disposed toward the diaphragm **25**, and the plunger **14** disposed on a side opposite from the core **15**. The plunger **14** is rigidly fitted on the shaft **31**. The shaft **31** is disposed in a manner extending through the core **15**, and has a foremost end thereof in contact with the disk **29**. Therefore, by feeding electric current to the electromagnetic coil **16**, the solenoid acts to push the diaphragm **25**, the piston **13**, and the valve element **12** in the valve-opening direction.

[**0031**] Similarly to the flow rate control valve shown in **FIG. 1**, the present flow rate control valve is responsive to the differential pressure between the pressure at the inlet of the evaporator **1** and the pressure Pe at the outlet of the evaporator **1** received by the valve element **12** and the diaphragm **25**, to control the differential pressure to be substantially constant, to thereby cause refrigerant to flow into the evaporator **1** at a constant flow rate dependent on electric current that energizes the solenoid.

[**0032**] Further, the flow rate control valve is capable of substantially completely preventing internal leakage of refrigerant in a closed state during deenergization of the solenoid, so that e.g. when an inflammable gas, such as HFC-152a, propane, or butane, or carbon dioxide is used as refrigerant, the evaporator **1** can be isolated from a circuit on the condenser side in case the evaporator **1** is damaged, to thereby prevent a fire or oxygen deficiency from being caused by refrigerant having flowed from the evaporator **1** into the vehicle compartment. In this case, it is necessary to isolate the evaporator **1** also from a circuit on the suction side of the compressor by providing a check valve **32** in a manner inserted into a circuit on the outlet side of the evaporator **1**.

[**0033**] By providing the check valve **32** in piping between the return refrigerant outlet **6** of the flow rate control valve, which communicates with the return passage **8**, and the suction side of the compressor, and using the above-described flow rate control valve capable of preventing internal leakage of refrigerant as an expansion valve, it is possible to isolate the evaporator **1** as a component part of a refrigeration cycle for an automotive air conditioner, which is disposed in the vehicle compartment, from the refrigeration cycle when the automotive air conditioner is not operated. In this case, in stopping the automotive air conditioner, for example, the compressor is allowed to rotate for some time after stoppage of energization of the solenoid, and then stop. With this configuration, refrigerant within the evaporator **1** is collected via the check valve **32**, and the collected refrigerant is inhibited from flowing upstream to the evaporator **1** by the check valve **32**, and hence the dangerous gas is not released into the vehicle compartment even if the evaporator **1** is damaged e.g. by rupture.

[**0034**] **FIG. 4** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a third embodiment of the present invention. It should be noted that component elements in **FIG. 4** identical or similar to those shown in **FIGS. 1 and 2** are designated by identical reference numerals, and detailed description thereof is omitted.

[**0035**] The flow rate control valve according to the third embodiment is formed by providing the flow rate control valve shown in **FIG. 1** with the internal leakage-preventing mechanism of the flow rate control valve shown in **FIG. 2** and a backflow preventing mechanism for isolating the evaporator **1** from the refrigeration cycle during stoppage of the automotive air conditioner.

[**0036**] More specifically, the flow rate control valve according to the present embodiment is configured such that the valve element **12** is intimately seated on a valve seat-forming member **33** press-fitted in a passage between the high-pressure refrigerant inlet **3** and the low-pressure refrigerant outlet **4** via the valve sheet **24**, and a cylinder below the piston **13** is sealed by the diaphragm **25**. The diaphragm **25** has a central portion thereof attached to the piston **13** by a holding member **34**, and the piston **13** is rigidly fixed to the valve element **12** integrally formed with the plunger **14** of the solenoid. Further, the check valve **32** is interposed in the return passage **8** communicating with the return refrigerant outlet **6**, at a location between a branch position at which the return passage **8** branches into a space where the diaphragm **25** receives the pressure Pe from the outlet of the evaporator **1**, and the refrigerant outlet **6**. The check valve **32** is configured such that a spring provided toward the return refrigerant outlet **6** urges the valve element, and when the differential pressure between the suction pressure of the compressor and the pressure Pe at the outlet of the evaporator **1** becomes equal to or higher than a predetermined value, the check valve **32** opens to allow refrigerant to flow from the evaporator **1** to the compressor.

[**0037**] During operation of the automotive air conditioner, the flow rate control valve controls the differential pressure across the evaporator **1** such that it is substantially constant, to thereby cause refrigerant to flow into the evaporator **1** at a constant flow rate dependent on electric current that energizes the solenoid.

[**0038**] In stopping the automotive air conditioner, energization of the solenoid is stopped to cause the valve element **12** to be seated on the valve seat-forming member **33**, whereby the evaporator **1** is isolated from the condenser. Then, the compressor is caused to be continuously be rotated to thereby collect refrigerant from the evaporator **1** via the check valve **32**, whereafter the compressor is stopped. Thus, the check valve **32** isolates the evaporator **1** from the suction side of the compressor. At this time, since there is no refrigerant in the evaporator **1**, it is possible to prevent a dangerous gas from leaking into the vehicle compartment even if the evaporator **1** is damaged during stoppage of the automotive air conditioner.

[**0039**] **FIG. 5** is a central longitudinal cross-sectional view of the construction of a flow rate control valve according to a fourth embodiment of the present invention. It should be noted that component elements in **FIG. 5** identical or similar to those shown in **FIG. 4** are designated by identical reference numerals, and detailed description thereof is omitted.

[**0040**] In the flow rate control valve according to the fourth embodiment, the check valve **32** disposed in the return passage **8** is moved from the location toward the return refrigerant outlet **6** shown in **FIG. 4** to a location toward the return refrigerant inlet **5**.

[**0041**] Therefore, the flow rate control valve is responsive to the differential pressure obtained by adding the differential pressure across the evaporator **1** and the differential pressure across the check valve **32**, received by the valve element **12** and the diaphragm **25**, to control the differential pressure to be substantially constant, to thereby cause refrigerant to flow into the evaporator **1** at a constant flow rate dependent on electric current that energizes the solenoid.

[**0042**] It should be noted although in the above-described embodiments, the flow rate control valve is configured such that the constant differential pressure control valve automatically closes when the solenoid is deenergized, the flow rate control valve may be configured such that the constant differential pressure control valve automatically closes when the solenoid is energized.

[**0043**] As described hereinabove, in the present invention, the evaporator is regarded as a restriction passage and the flow rate control valve is configured to include the constant differential pressure control valve for controlling the differential pressure across the evaporator to be substantially constant. This makes it unnecessary to form a restriction passage in the flow rate control valve, and hence the construction of the flow rate control valve can be simplified, which makes it possible to provide a flow rate control valve that is manufactured at low cost.

[**0044**] The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.

1. A flow rate control valve that controls a flow rate of refrigerant which is throttled and expanded to be delivered to an evaporator, such that the flow rate is substantially constant, comprising:

a constant differential pressure control valve that controls a differential pressure before and after pressure loss caused by passage of refrigerant through the evaporator, such that the differential pressure is substantially constant.

2. The flow rate control valve according to claim 1, wherein the constant differential pressure control valve is configured such that a valve element for receiving pressure from a low-pressure refrigerant outlet of the valve toward the evaporator in a valve-closing direction, and a pressure-sensing member for receiving pressure from an outlet of the evaporator in a direction in which the valve element is opened move in unison with each other.

3. The flow rate control valve according to claim 1, comprising a solenoid for urging the valve element and the pressure-sensing member in a direction in which the valve element is opened.

4. The flow rate control valve according to claim 2, wherein an effective diameter of the valve element and an effective diameter of the pressure-sensing member are made approximately equal to each other.

5. The flow rate control valve according to claim 2, comprising a valve sheet provided on the valve element for sealing when the constant differential pressure control valve is closed, and a diaphragm for sealing a sliding portion of the pressure-sensing member.

6. The flow rate control valve according to claim 1, comprising a return passage for communicating between an outlet of the evaporator and a suction side of a compressor, and

wherein the pressure at the outlet of the evaporator is introduced from the return passage.

7. The flow rate control valve according to claim 6, wherein a check valve for preventing refrigerant from flowing upstream from the suction side of the compressor to the outlet of the evaporator is provided within the return passage.

8. The flow rate control valve according to claim 7, wherein the check valve is disposed toward a refrigerant outlet which is connected by piping to the suction side of the compressor.

9. The flow rate control valve according to claim 7, wherein the check valve is disposed toward a refrigerant inlet which is connected by piping to the outlet of the evaporator.

* * * * *