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(54) HIGH AND LOW PRESSURE GAS SELECTOR VALVE OF REFRIGERATOR

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(52) **U.S. Cl.** ..... **62/6**

(57) **ABSTRACT**

There are provided a housing that has a generally cylindrical-shaped internal circumferential surface, a housing passage that includes a high-pressure gas passage and a low-pressure gas passage which are formed on the housing surface, a generally cylindrical-shaped rotor that is supported by bearings, and which rotates with a micro-clearance away from the internal circumferential surface of the housing without touching the housing, and a rotor passage that is formed inside the rotor, and through which gas flows at the time its openings align with the valve housing passage. Load to the rotating axis of the rotor due to the pressure of the supplied gas to the valve is cancelled, and the clearance between the rotor and the housing are maintained at a proper level, by installing pluralities of high-pressure gas supply ports and low-pressure gas supply ports of the housing in symmetrical positions relative to the rotating axis of the rotor.

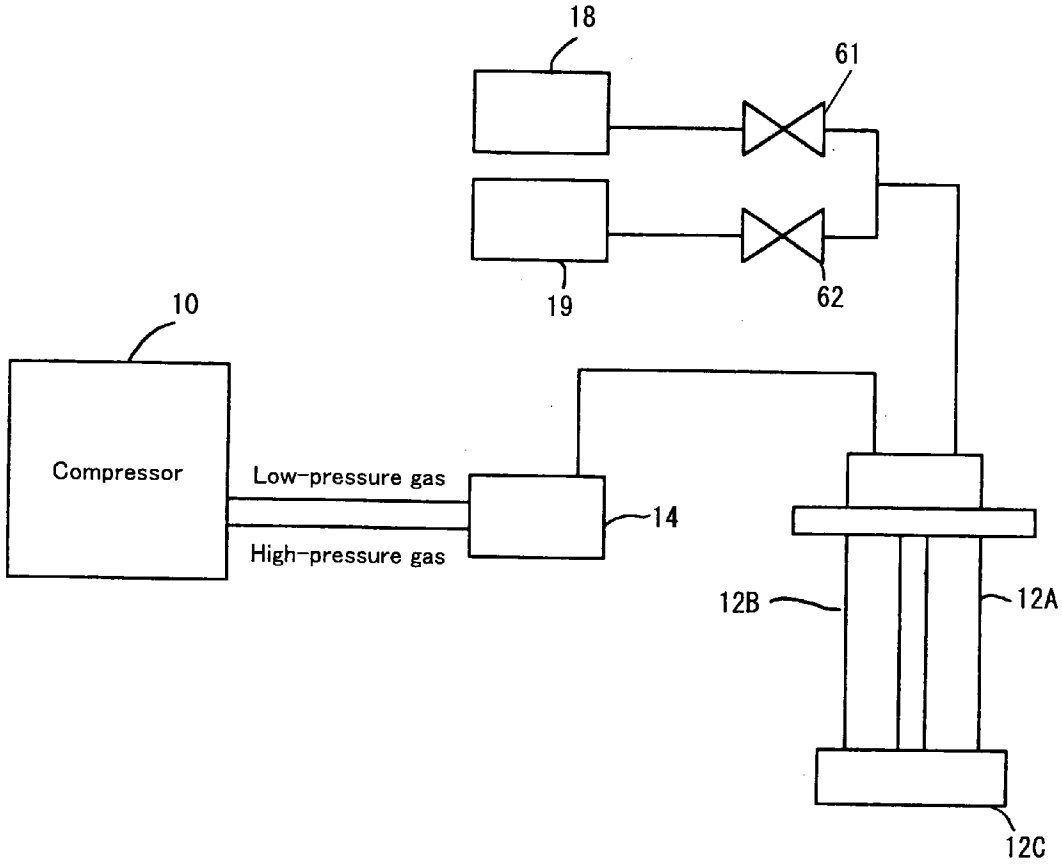


Fig.1

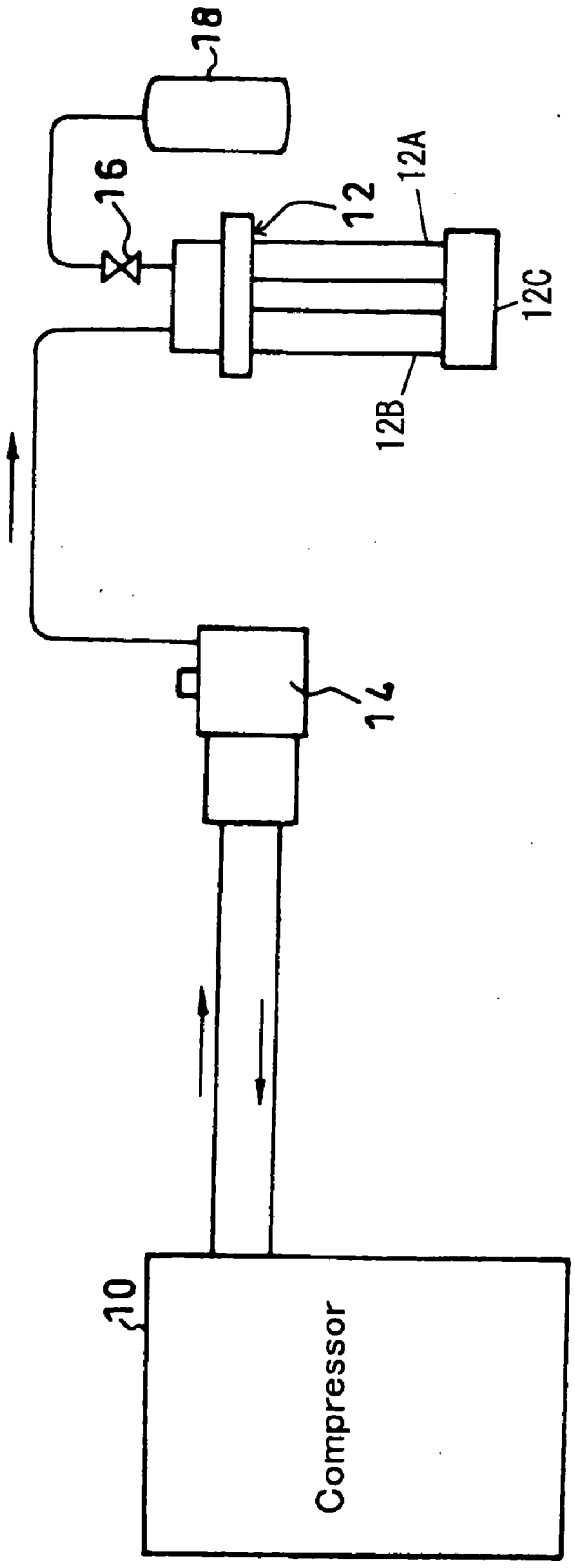


Fig.2

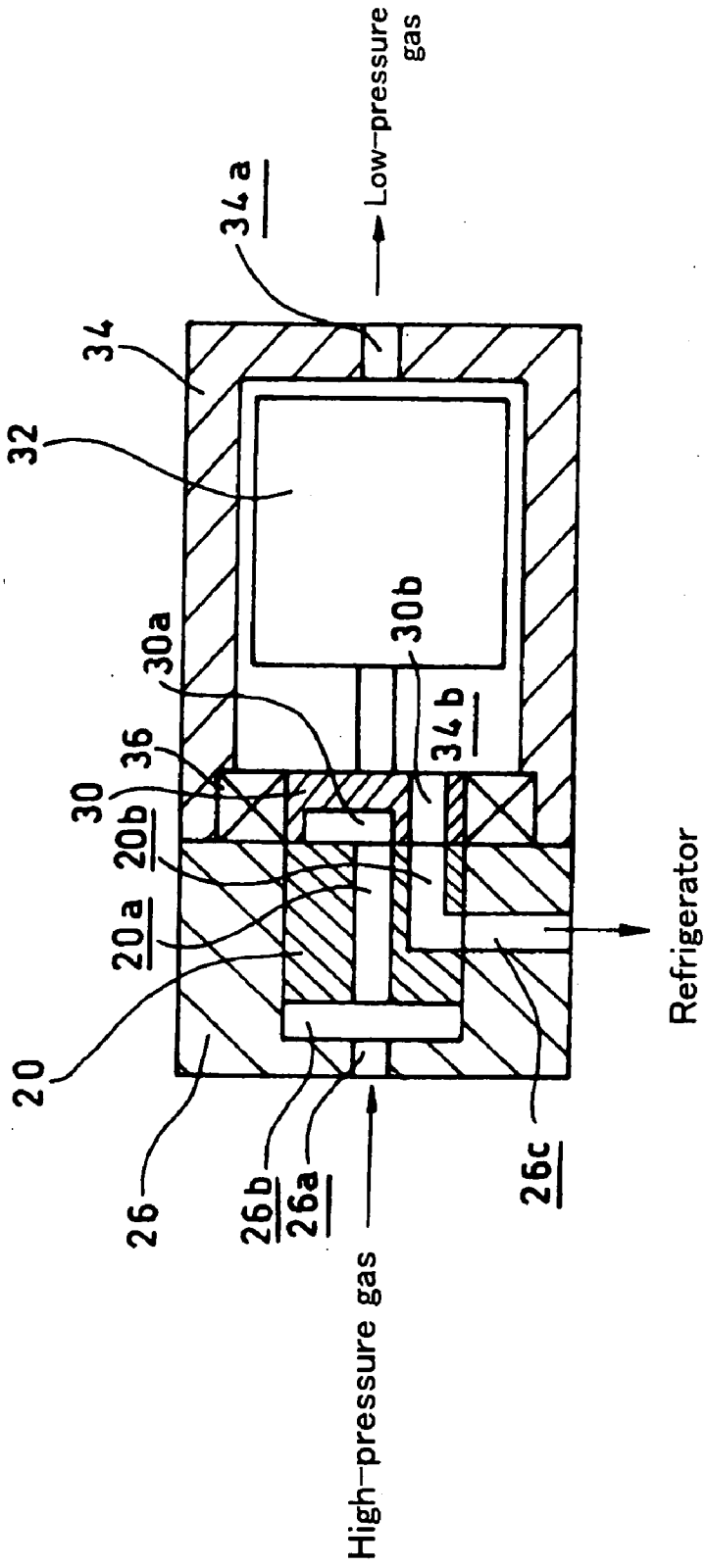

Low-pressure gas
34a
34
32
30a
30b
34b
36
30
20b
20a
20
26
26b
26a
26c
Refrigerator
High-pressure gas

Fig.3

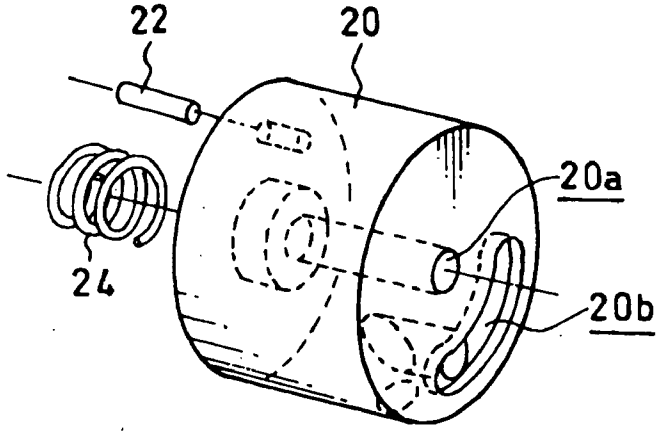



Fig.4

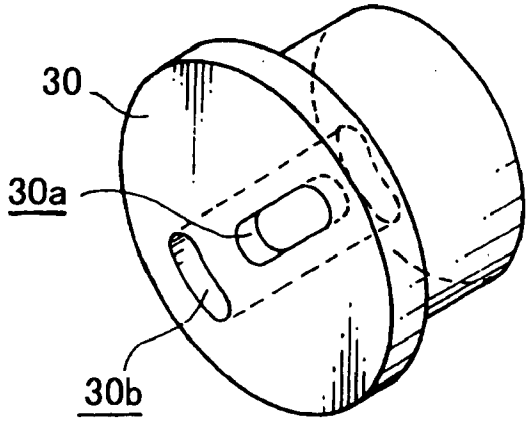



Fig.5

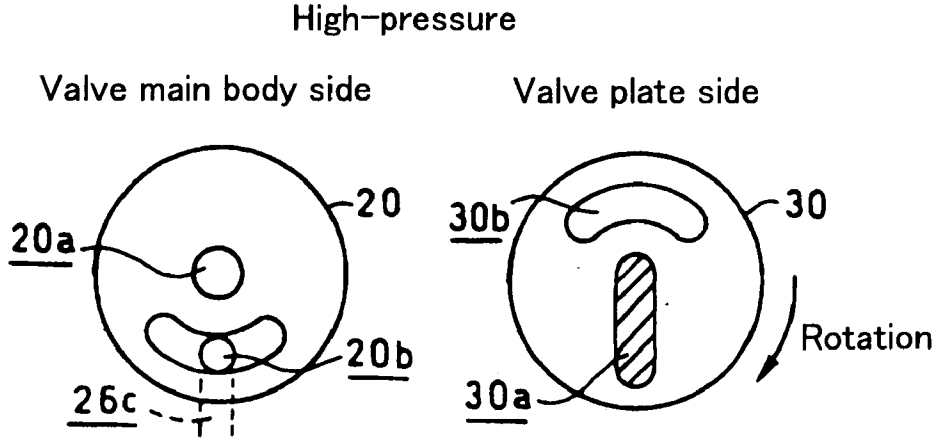


Fig.6

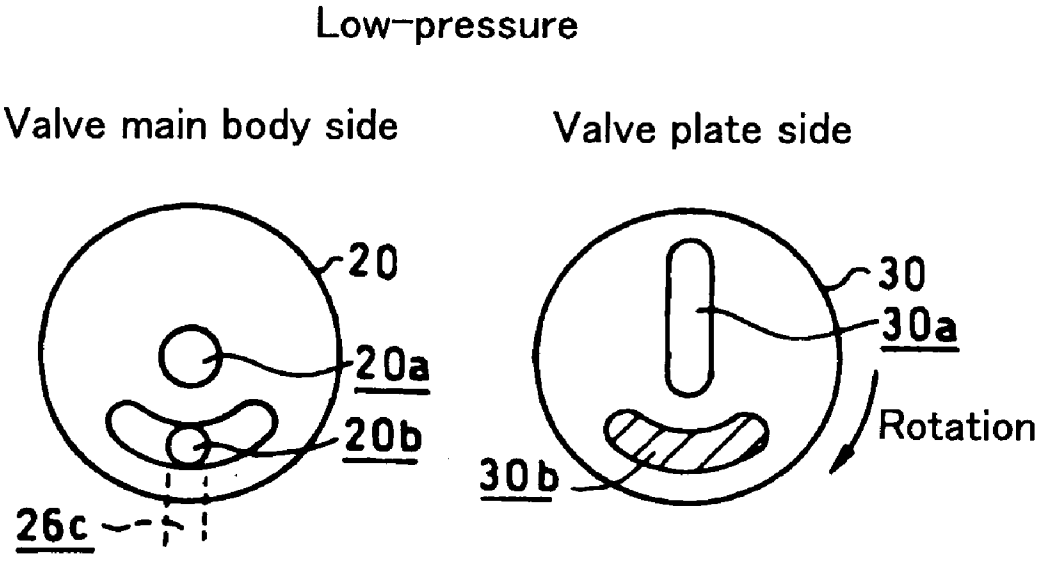

Low-pressure
Valve main body side
Valve plate side
20
20a
20b
26c
30
30a
Rotation
30b

Fig. 7

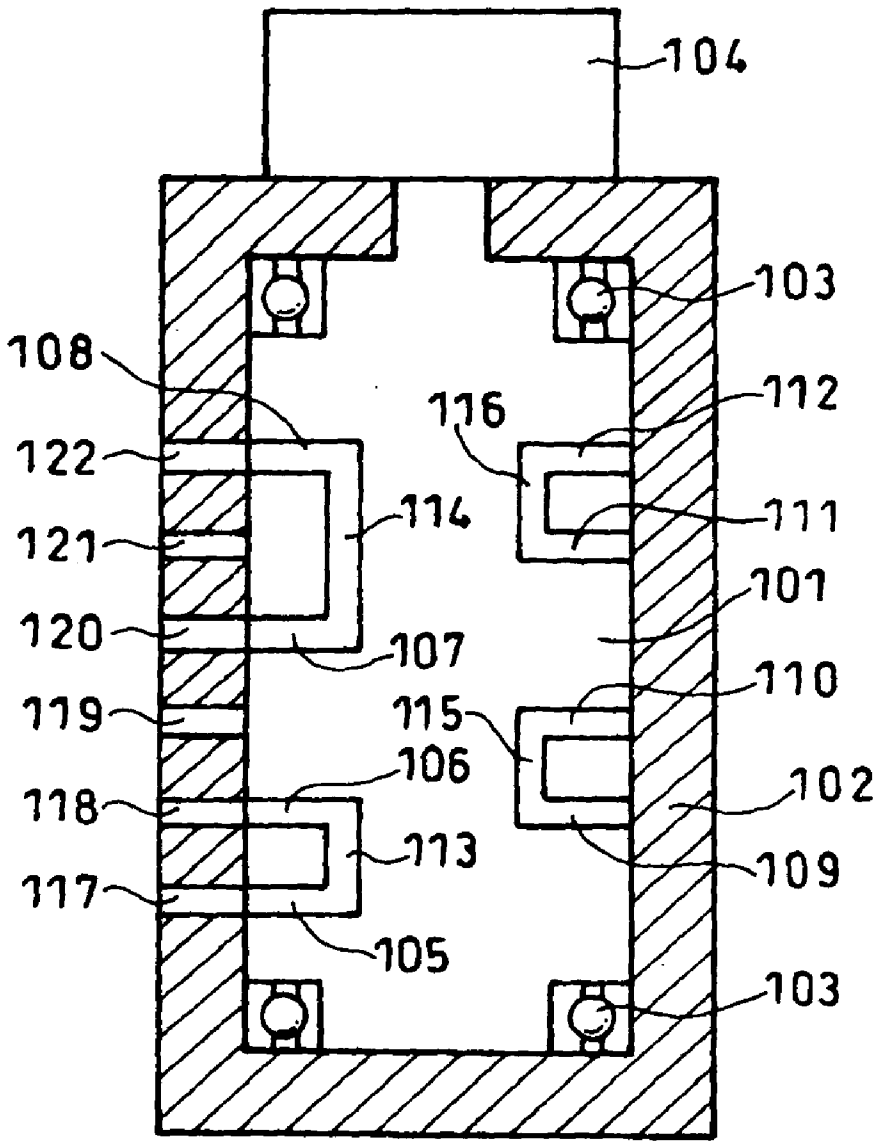

104
103
108
112
116
122
114
111
121
101
120
107
110
119
115
106
102
118
113
109
117
105
103

Fig.8

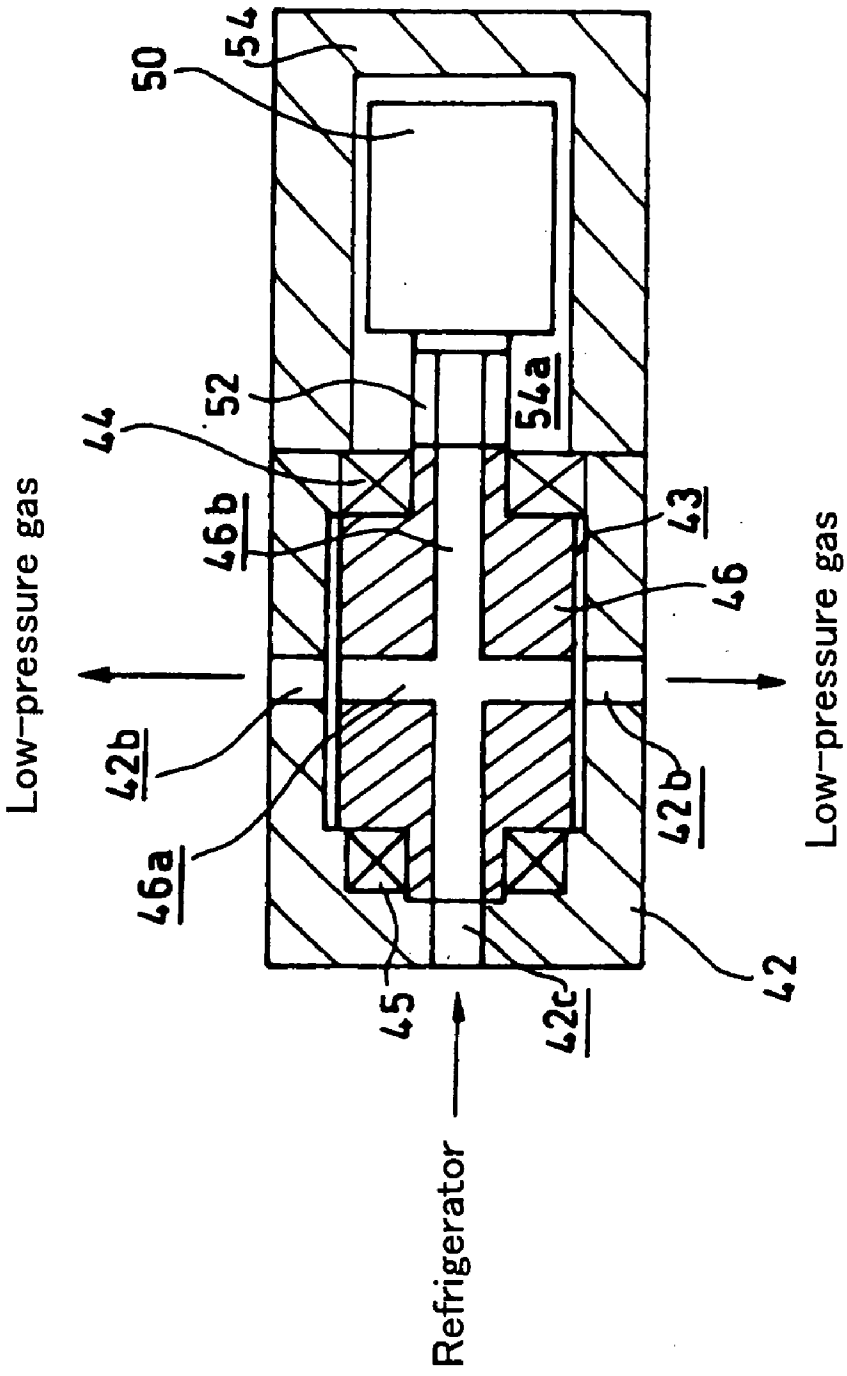

50
54
54a
52
44
46b
43
46
42b
42b
46a
42
45
42c
Low-pressure gas
Low-pressure gas
Refrigerator

Fig.9

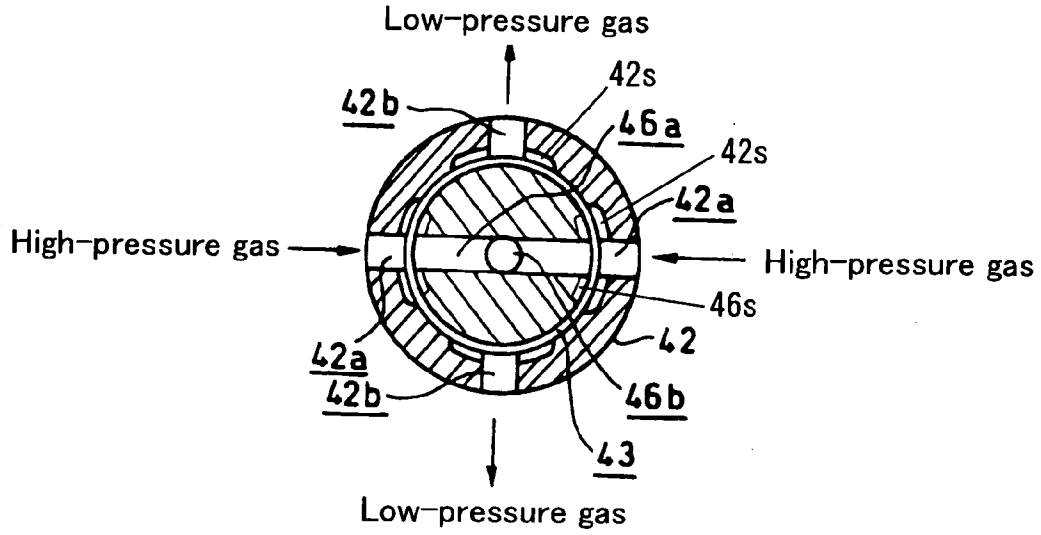

Low-pressure gas
42s
42b
46a
42s
42a
High-pressure gas
High-pressure gas
46s
42
42a
42b
46b
43
Low-pressure gas

Fig.10

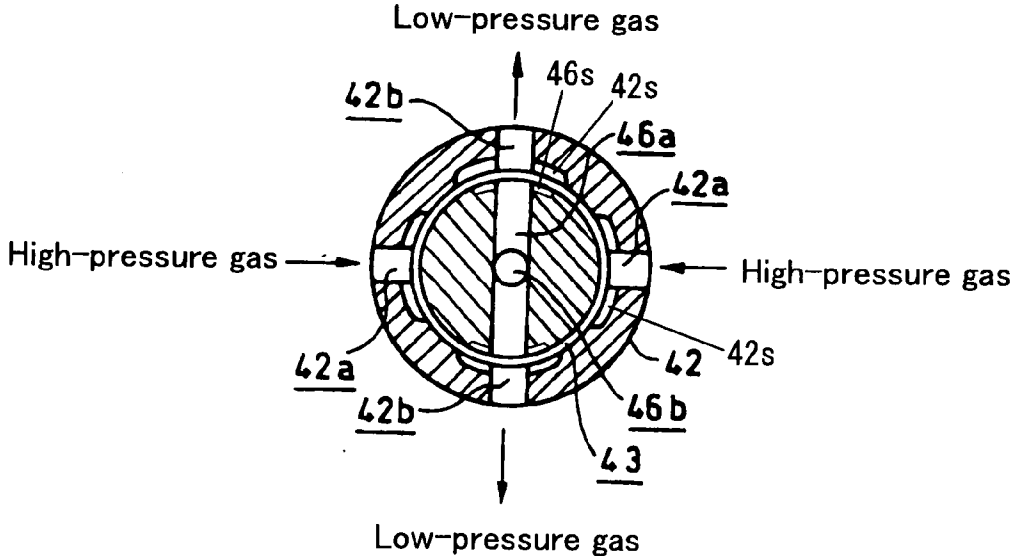

Low-pressure gas
46s
42s
42b
46a
42a
High-pressure gas
High-pressure gas
42s
42
42a
42b
46b
43
Low-pressure gas

Fig.11

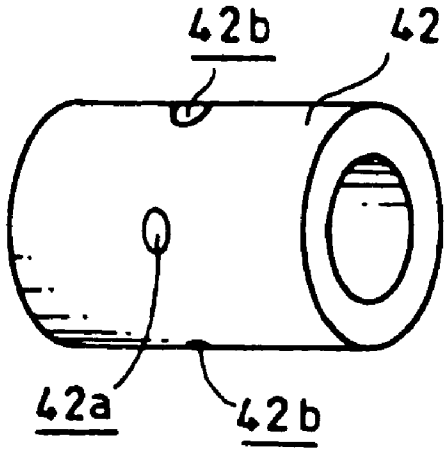



Fig.12

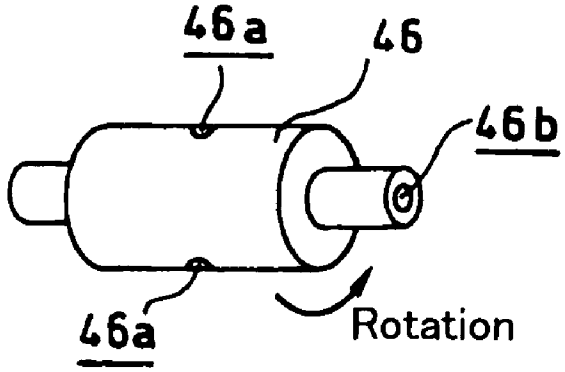


Fig.13

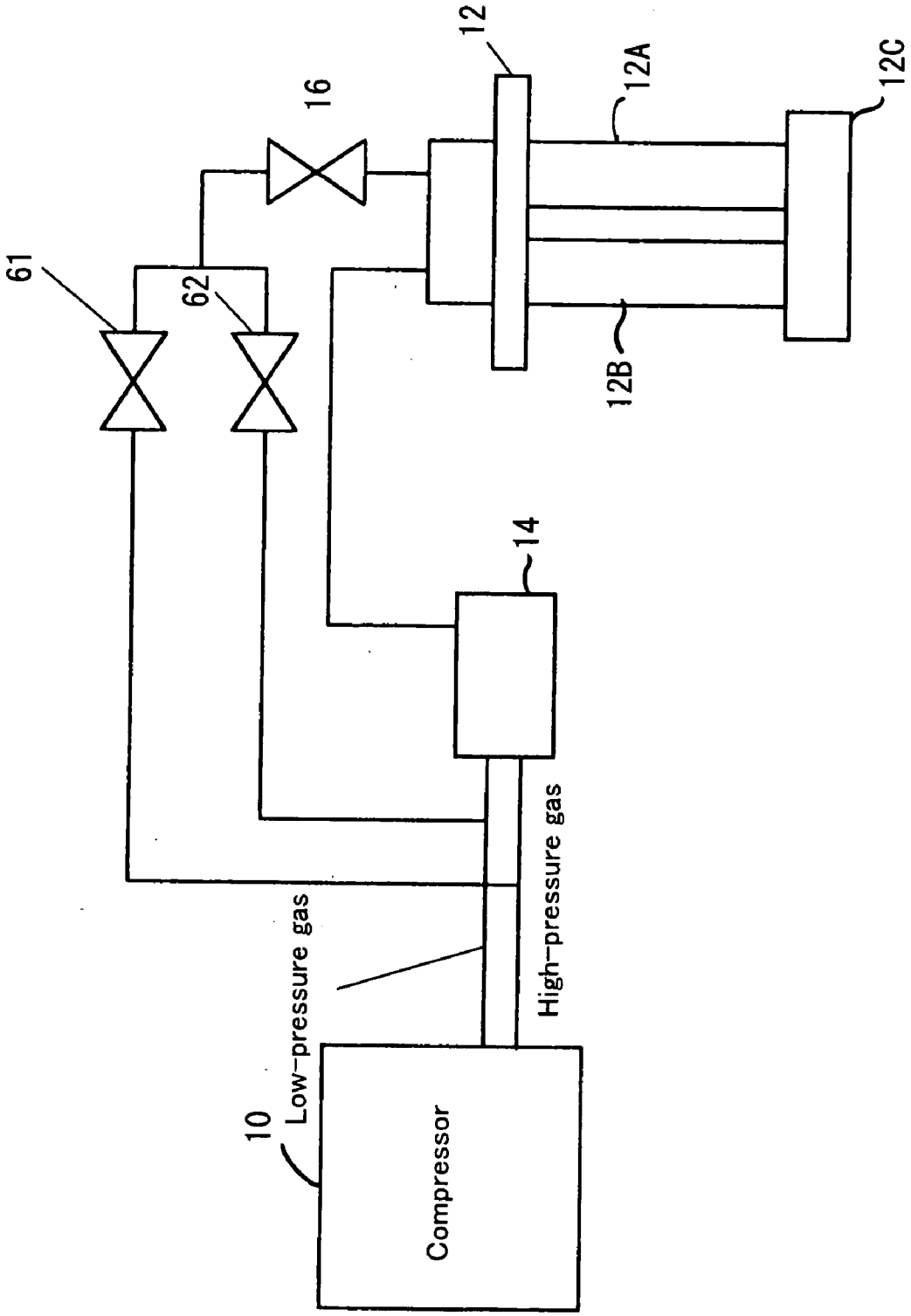
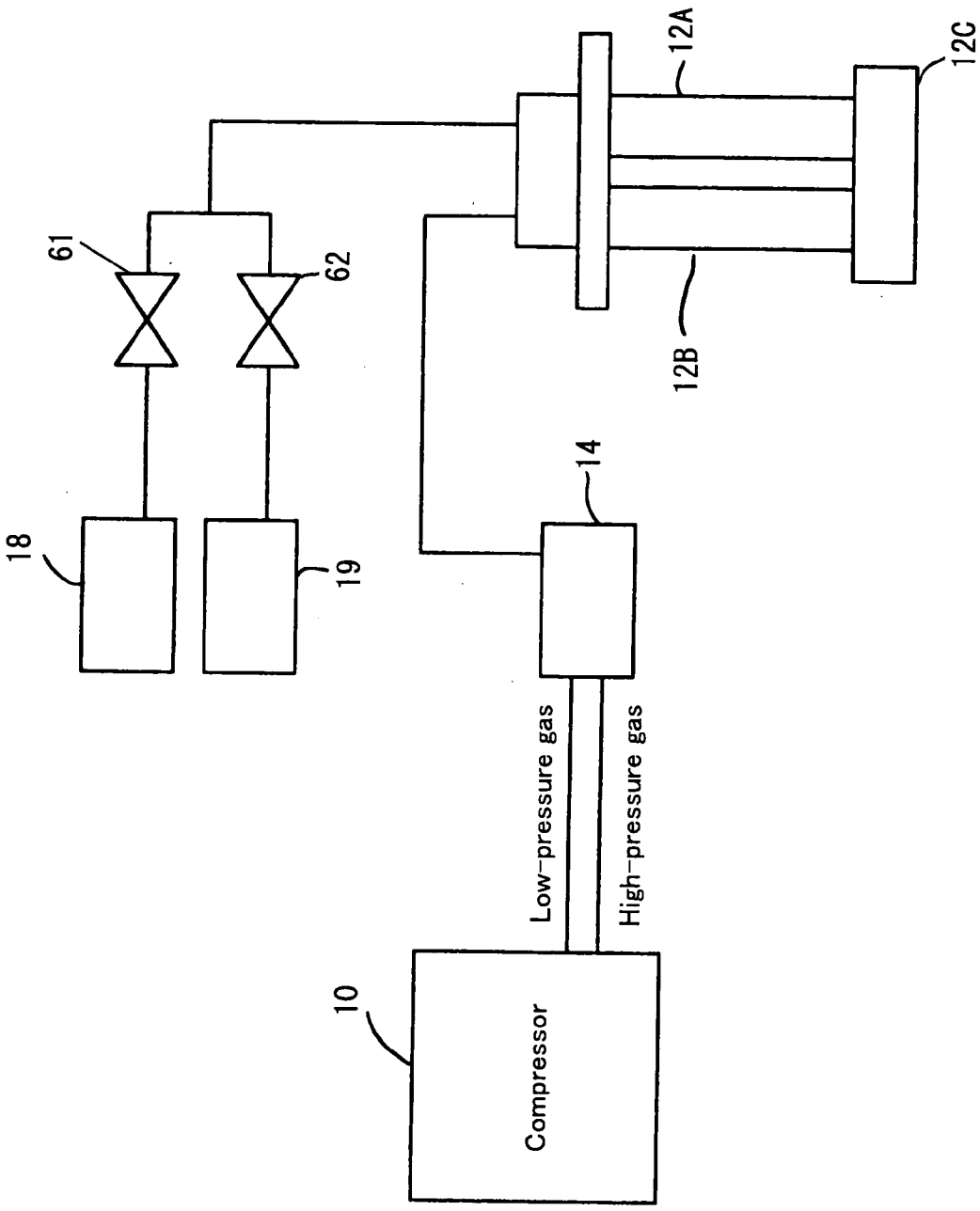

12
16
12A
12C
61
62
12B
14
High-pressure gas
Low-pressure gas
10
Compressor

Fig. 14


12A
12C
61
62
12B
14
18
19
Low-pressure gas
High-pressure gas
10
Compressor

# HIGH AND LOW PRESSURE GAS SELECTOR VALVE OF REFRIGERATOR

## TECHNICAL FIELD

[0001] The present invention relates to a high-low pressure gas directional control valve of a refrigerator, and particularly relates to a high-low pressure gas directional control valve of a refrigerator that can be made longer in life, higher in efficiency, more compact, and lighter, no wear, no dust formation and which is suitable for using in pulse tube coolers and Gifford McMahon (GM) cryocoolers.

## BACKGROUND ART

[0002] In pulse tube coolers and GM cryocoolers, a high-low pressure gas directional control valve **14** is used to change-over periodically between high-pressure gas and low-pressure gas generated by a compressor **10**, and to send them to a refrigerator **12**, as shown in **FIG. 1**. In the figure, reference numeral **12**A denotes a pulse tube, **12**B denotes a heat regenerator tube, **12**C denotes a cooling stage, **16** denotes an orifice, and **18** denotes a buffer tank.

[0003] As described in Japanese Patent No.2617681 and shown in **FIG. 2**, for example, a conventional high-low pressure gas directional control valve is composed of: a valve main body **20** that is whirl-stopped to a valve housing **26** by a pin **22** whose form is shown in **FIG. 3** and to which spring force is applied toward a valve plate **30** by a coil spring **24**; the valve housing **26** for accommodating the valve main body **20**; a valve plate **30** in the form shown in **FIG. 4**; a drive motor **32** for rotating the valve plate **30**, and a motor casing **34** for accommodating the drive motor **32**.

[0004] A space **26***b* on the left side of aforementioned valve main body **20** is connected to the high-pressure gas side of the compressor (not shown) through a high-pressure gas passage **26***a* of the valve housing **26**. On the other hand, a space **34***b* on the right side of the valve plate **30** is connected to the low-pressure gas side of the compressor through a low-pressure gas passage **34***a* of the motor casing **34**. Through actions of the pressure difference and the spring **24**, the valve main body **20** is pressed against the valve plate **30**. This seals the gas flowing through a valve main body high-pressure gas passage **20***a*, a valve plate high-pressure gas passage **30***a*, a valve plate low-pressure gas passage **30***b*, and a valve main body refrigerator side gas passage **20***b*, those of which are located along the valve main body **20** and the valve plate **30**.

[0005] In **FIG. 2**, reference numeral **36** denotes a bearing that supports the valve-plate **30** so as that the plate can freely rotate.

[0006] Either of the aforementioned valve main body **20** or valve plate **30** (the valve plate **30** in this case) is rotated by the drive motor **32**, and the other (the valve main body **20** in this case) is whirl-stopped. The gas is changed-over at the timing and opening following the pattern formed on the contact face as shown in **FIG. 5** (high-pressure supplying state) and **FIG. 6** (low-pressure recovering state). As a result, gas flows through passages or space **26***a*→**26***b*→**20***a*→**30***a* →**20***b* →**26***c* (high-pressure supplying state), or passages or space **26***c*→**20***b*→**30***b*→**34***b*→**34***a* (low-pressure recovering state as shown in **FIG. 2**) formed in the interior, and the gas is supplied to or recovered from the refrigerator through valve housing refrigerator side gas passage **26***c*.

[0007] However, in this kind of high-low pressure gas directional control valve, the valve main body **20** is pressed against the valve plate **30** and is sealed by the sliding surface, hence the valve main body **20** and the valve plate **30** wear out, and periodic replacement is required. Moreover, the sliding surface resistance is high, necessitating use of a large sized high torque motor as the drive motor **32**, which leads to a bigger size of the unit itself. Furthermore, there have been problems such as the passage formed in the valve main body **20** and the valve plate **30** becoming sophisticated in form, which led to increase in pressure loss, and the decrease in performance of the refrigerator.

[0008] Moreover, in Japanese Patent Laid-Open Publication No.2001-91078 as shown in **FIG. 7, a** rotary valve has been proposed, which consists of a circular horizontally-section rotor **101** that rotates around the central axis, and a housing **102** that accommodates this rotor **101** so as to freely rotate. In this rotary valve, a plurality of ports **105** to **112** are installed on the external circumferential surface of the aforementioned rotor **101**, and a plurality of ports **117** to **122** corresponding to the aforementioned ports **105** to **112** are also installed on the internal circumferential surface of the aforementioned housing **102**. This rotary valve changes-over, by the rotation of the aforementioned rotor **101**, between the state in which the ports in both groups **105** to **108**, **117**, **118**, **120**, **122** connect communicatively by matching the prescribed ports **105** to **108** of the rotor **101** to the corresponding ports **117**, **118**, **120**, **122** of the aforementioned housing **102**, and the state in which the ports in both groups **105** to **108**, **117**, **118**, **120**, **122** do not connect communicatively due to disengagement of the aforementioned matching. In the figure, reference numeral **103** denotes an axle-bearing, and reference numeral **104** denotes a motor.

[0009] However, there was a problem that it did not operate so well, with increasing leaks from the high-pressure side to the low-pressure side, since all the ports are formed asymmetrical regarding the central axis of the rotor **101**, and the valve is not balanced when pressurized.

## DISCLOSURE OF THE INVENTION

[0010] The present invention was made to solve the aforementioned conventional problems, and it is an object of this invention to provide a high-low pressure gas directional control valve that can be made longer in life, higher in efficiency, more compact, lighter, no wear, and no dust information.

[0011] The present invention solved the aforementioned problems by the following means, in the high-low pressure gas directional control valve of a refrigerator that is used to change-over periodically between high-pressure gas and low-pressure gas from a compressor. That is, by providing a housing that has a generally cylindrical-shaped internal circumferential surface, several housing passages that include high-pressure gas passages and low-pressure gas passages formed on a wall surface of the housing, a generally cylindrical-shaped rotor supported by bearings and which rotates with a micro-clearance away from the internal circumferential surface of the aforementioned housing without touching the housing, and a rotor passage formed inside the rotor, through which gas flows at the time its openings align with the aforementioned housing passage, wherein

pluralities of high-pressure gas supply ports and low-pressure gas supply ports of the aforementioned housing are provided in symmetrical position regarding the rotating axis of the aforementioned rotor.

[0012] Furthermore, a low-pressure gas supply port of the housing is provided in a same plane as the high-pressure gas supply port, so that harmful moment does not affect to a rotor axis due to pressure of the supplied high-pressure gas and low-pressure gas.

[0013] Furthermore, the high-pressure gas or low-pressure gas flowing into the aforementioned rotor passage is made to be supplied to the refrigerator, through passages formed along a central axis of the rotor and on an edge face of the housing.

[0014] Furthermore, the aforementioned passage formed along the central axis of the rotor is made to have openings on both end faces of the rotor, making the pressure at both ends equal, which cancels the load along the central axis of the rotor, and maintains the position of the rotor at a proper position, and which also reduces the load on the motor.

[0015] Furthermore, at least one of the housing and the rotor may be provided with a slit to adjust timing.

[0016] The present invention also provides a refrigerator that uses the aforementioned high-low pressure gas directional control valve.

[0017] The present invention also provides a cryogenic device that uses the aforementioned refrigerator.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0018] **FIG. 1** is a block diagram showing the overall construction of an example of a pulse tube cooler, which is a target application of the present invention.

[0019] **FIG. 2** is a longitudinal sectional view showing the overall construction of an example of conventional high-low pressure gas directional control valve.

[0020] **FIG. 3** is a perspective view showing the form of a valve main body in the same valve.

[0021] **FIG. 4** is a perspective view showing the form of a valve plate in the same valve.

[0022] **FIG. 5** is a front view showing the relative relation of the valve main body and the valve plate in a high-pressure gas supplying state, in the same valve.

[0023] **FIG. 6** is a front view showing the relative relation of the valve main body and the valve plate in a low-pressure gas supplying state, in the same valve.

[0024] **FIG. 7** is a longitudinal sectional view showing a construction of a conventional rotary valve disclosed in Japanese Patent Laid-Open Publication No.2001-91078.

[0025] **FIG. 8** is a longitudinal sectional view showing the overall construction of an embodiment of a high-low pressure gas directional control valve according to the present invention.

[0026] **FIG. 9** is a cross sectional view showing a high-pressure gas supplying state in the same embodiment.

[0027] **FIG. 10** is a cross sectional view showing a low-pressure gas supplying state in the same embodiment.

[0028] **FIG. 11** is a perspective view showing a valve housing that is used in the aforementioned embodiment.

[0029] **FIG. 12** is a perspective view showing a rotor that is used in the same embodiment.

[0030] **FIG. 13** is a piping diagram showing an example where the present invention is applied to a four-valve type pulse tube cooler.

[0031] **FIG. 14** is a piping diagram showing an example where the present invention is applied to an active-buffer type pulse tube cooler.

## BEST MODE FOR CARRYING OUT THE INVENTION

[0032] A detailed description of embodiments of the present invention will be described in detail hereafter, with references to the drawings.

[0033] A high-low pressure gas directional control valve of this embodiment is provided with the following, as shown in **FIG. 8** (longitudinal sectional view), **FIG. 9** (cross sectional view in a state of high-pressure gas being supplied to a refrigerator), and **FIG. 10** (cross sectional view in a state of low-pressure gas being supplied to a refrigerator): a valve housing **42** having a generally cylindrical-shaped internal circumferential surface, of a form shown in **FIG. 11**; a pair of high-pressure gas passages **42***a* and a pair of low-pressure gas passages **42***b* (generically called housing passages) formed axially symmetrical on the wall surface of the valve housing **42**; a generally cylindrical-shaped rotor **46** as shown in **FIG. 12**, which is supported by bearings **44** and **45**, and which rotates with a micro-clearance **43** away from the internal circumferential surface of the housing **42** without touching the valve housing **42**; a direction control gas passage **46***a* and a refrigerator side gas passage **46***b* (generically called rotor passages) that are formed inside the rotor **46**, and through which gas flows at the time its openings align with the passages **42***a* or **42***b* of the valve housing **42**.

[0034] Sealing of the gas is done by the micro-clearance **43** between the rotor **46** and the housing **42**. Consequently, the micro-clearance **43** can be made to be, for example, from 5 to 100 $\mu$m. That is, it is preferable to have a clearance of 5 $\mu$m or greater to prevent contact, and 100 $\mu$m or less to prevent unfavorable effects on the performance of the refrigerator.

[0035] In **FIG. 8**, reference numeral **50** denotes a drive motor for rotating the rotor **46** through a coupling **52**, and reference numeral **54** denotes a casing of the drive motor **50**, and reference numeral **54***a* denotes a space inside the casing **54**.

[0036] In this embodiment, the rotor **46** supported by the two bearings **44** and **45** rotates without touching the housing **42**. passages are formed in the rotor **46** and housing **42**, and gas flows through the rotor passage at the time each of their openings aligns. That is, as shown in **FIG. 9**, high-pressure gas is supplied to the refrigerator through passages or space **42***a*→**46***a*→**46***b*→**42***c*, when the high-pressure gas passages **42***a* of the valve housing **42** and the direction control passage **46***a* of the rotor **46** face to each other. On the other hand, as shown in **FIG. 10**, low-pressure gas is recovered from the refrigerator through passages or space **42***c*→**46***b*→**46***a*→**42***b*, when the low-pressure gas passages **42***b* of the

valve housing **42** and the direction control passage **46***a* of the rotor **46** face to each other.

[**0037**] Two channels of high-pressure gas supply ports **42***a* from the compressor are installed on symmetrical positions regarding the rotor **46** axis, and both of them are connected in a vertical direction regarding the rotor axis. Since there are two channels in axially symmetrical positions, vertical load on the rotating axis of the rotor **46** due to the pressure of the supplied high-pressure gas is cancelled, and the clearance **43** between the rotor **46** and the housing **42** is maintained at a proper level, preventing unbalanced clearance and partial wear of the rotor, and reducing the load on the motor **50**.

[**0038**] Low-pressure gas supply ports **42***b* from the compressor are of the same construction as the high-pressure gas side, and form passages at the same plane but with 90 degrees angle relative to high-pressure gas passages **42***a*.

[**0039**] A space **54***a* inside the casing, where the drive motor **50** is installed, is connected communicatively to the space **42***c* that is used for supplying to the refrigerator, through the rotor passage **46***b*. This cancels the axial load on the rotor **46** by maintaining the same pressure all the time, and keeps the rotor **46** at a proper position, preventing unbalanced clearance and partial wear of the rotor, and also reducing the load on the motor **50**.

[**0040**] In this kind of structure, sealing is done by the rotor **46** and the housing **42** in a non-contact state, hence there are no sliding surfaces, and regular replacement of parts are not required. It should be noted that, there are some leaks because it is a non-contact sealing, but this problem is small compared to the flow rate supplied to the refrigerator.

[**0041**] Furthermore, by balancing the pressure, the load on the drive motor **50** is decreased by making the rotating resistance of the rotor **46** as small as possible. Hence smaller motors can be adopted, enabling smaller and lighter units, and enabling lower power consumption.

[**0042**] Furthermore, by balancing the pressure, the micro-clearance **43** for sealing can be secured with stability. Furthermore, a high efficiency operation with little pressure loss is possible, since the passage shape is simple.

[**0043**] In this embodiment, slits **42***s* and **46***s* are provided to both the housing **42** and the rotor **46**. So, change-over timing of the valve can be changed easily. However, one of the slits **42***s* and **46***s* or both may be omitted.

[**0044**] The loss due to leak from the micro-clearance **43** for sealing of the high-low pressure gas directional control valve in the following conditions was approximately 40W, which was 0.5% of compressor input, and was within the range of being negligible. Here, the outer diameter of the valve rotor **46** was 20 mm, the overall length of the valve rotor was 24 mm, the inner diameter of the gas passages **42***a* to **42***c*, **46***a*, and **46***b* each were 3 mm, and the micro-clearance **43** for sealing was 15 $\mu$m. A geared compact DC motor, with a variable selectable frequency of 1 to 10 Hz by the change of the drive voltage, was used for the drive motor **50**, using drive voltage 1-24V and DC drive current 5 mA (at DC 3V drive). And bearings **44**, **45** with general-use specifications were used.

[**0045**] The valve unit according to the present invention can also be applied to a phase control mechanism for a pulse tube cooler, aside from various pulse tubes.

[**0046**] In case of a four-valve type pulse tube cooler, as shown in **FIG. 13, a** phase control at a high temperature end of the pulse tube **12**A is achieved by means of two switching valves **61** and **62** instead of a buffer. One end of each of the two valves **61** and **62** is connected to the high temperature end of the pulse tube **12**A via a common orifice **16**. The other ends thereof are connected to the high-pressure gas supply line and the low-pressure gas supply line of the compressor **10**, respectively. The two valves are controlled so as to periodically open and close according to a predetermined timing chart to provide an optimal phase between the pressure variation and the gas displacement inside the pulse tube, thereby obtaining a desired refrigerating performance.

[**0047**] This phase control valve is operated in the same manner as that of the high-low pressure switching valve unit **14** arranged between the regenerator **12**B and the compressor **10**. Thus, the valve unit according to the present invention can be applied to the four-valve type phase control valve.

[**0048**] In case of an active-buffer type pulse tube cooler, as shown in **FIG. 14**, the phase control at the high temperature end of the pulse tube **12**A is not achieved by the combination of one buffer and an orifice, but by the combination of two or more buffers **18** and **19** and the same number of switching valves **61** and **62**. These buffers **18** and **19** are kept in a medium pressure state which is a state between the high pressure and low pressure states of the compressor. However, the respective pressures in the buffers are different from each other. The buffers are connected to the high temperature end of the pulse tube via the respective switching valves. The respective switching valves are controlled so as to periodically open and close, according to a predetermined timing chart to provide an optimal phase between the pressure variation and the gas displacement inside the pulse tube, thereby obtaining a desired refrigerating performance.

[**0049**] This phase control valve is operated in the same manner as that of the high-low pressure switching valve unit **14** arranged between the regenerator **12**B and the compressor **10**. Thus, the valve unit according to the present invention can be applied to the active-buffer type phase control valve.

[**0050**] Further, since there is no wear, it can also be applied to a low temperature application.

[**0051**] Industrial Applicability

[**0052**] The present invention can be used in a high-low pressure gas directional control valve of a refrigerator for extremely low temperature, such as GM cryocoolers and pulse tube coolers etc.

[**0053**] According to the present invention, it is possible to maintain the clearance between the rotor and the housing at a proper level, and also to reduce the load on the motor, by having a balanced axial and vertical load on the rotating axis of the rotor. Therefore, it is possible to make the high-low pressure gas directional control valve longer in life, higher in efficiency, more compact, lighter, no wear and no dust formation enabling a long term, stable operation, and a drive motor that is more compact and lower in power consumption.

1. A high-low pressure gas directional control valve of a refrigerator for changing-over periodically between a high-pressure gas and a low-pressure gas from a compressor comprising:

a housing having a generally cylindrical-shaped internal circumferential surface;

housing passages including high-pressure gas passages and low-pressure gas passages formed on a wall surface of said housing;

a generally cylindrical-shaped rotor being supported by bearings, and rotating with a micro-clearance away from said internal circumferential surface of said housing without touching said housing; and

a rotor passage formed inside said rotor, having gas flow through it at the time its openings align with said housing passage;

wherein said high-low pressure gas directional control valve of a refrigerator is characterized by having a plurality of high-pressure gas supply ports and a plurality of low-pressure gas supply ports of said housing installed each in a symmetrical position regarding a rotating axis of said rotor.

2. The high-low pressure gas directional control valve of a refrigerator according to claim 1, characterized by having a low-pressure gas supply port of said housing in a same plane as said high-pressure gas supply port.

3. The high-low pressure gas directional control valve of a refrigerator according to claim 1 or claim 2, characterized in that the high-pressure gas or low-pressure gas flowing into said rotor passage is made to be supplied to said refrigerator through passages formed along a central axis of said rotor, and also formed on an edge face of said housing.

4. The high-low pressure gas directional control valve of a refrigerator according to claim 3, characterized in that said passage formed along the central axis of said rotor is made to have openings on both end faces of said rotor.

5. The high-low pressure gas directional control valve of a refrigerator according to any one of the claims 1 to 4, at least one of the housing and the rotor is provided with a slit to adjust timing.

6. A refrigerator using the high-low pressure gas directional control valve of a refrigerator according to any one of the claims 1 to 5.

7. A cryogenic device using the refrigerator according to claim 6.

* * * * *