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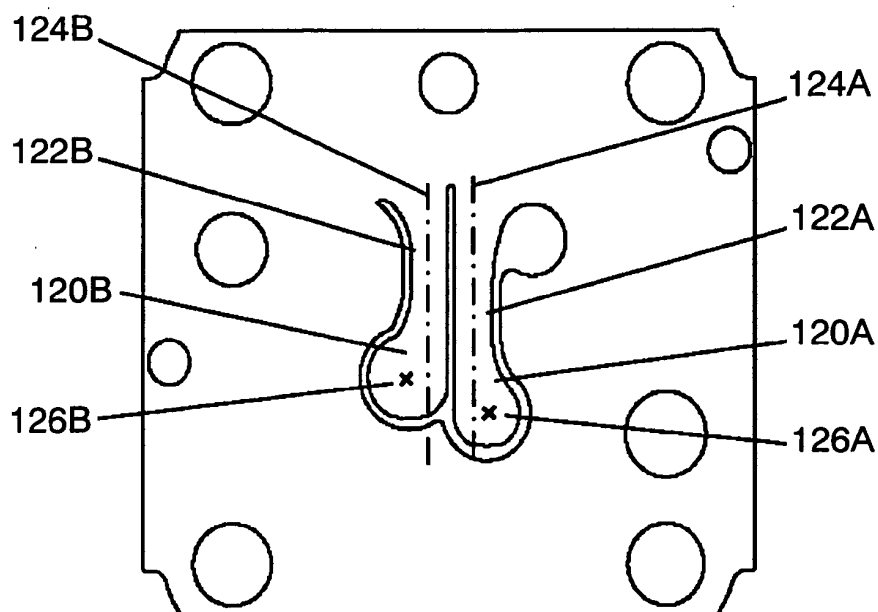
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(54) **REFRIGERANT COMPRESSOR**

(57) A valve plate includes a plurality of suction holes and a plurality of suction reed valves for opening and closing them. At least two of these suction reed valves have different natural frequencies. In this configuration, a natural frequency of one reed valve is larger.

Therefore, even when an operation frequency is changed to a higher frequency, the compressor can suck a refrigerant gas into a cylinder efficiently without occurring delayed closing and reduction of a lift amount. Thus, refrigerating capacity and compression efficiency can be increased.

FIG. 2



Description

TECHNICAL FIELD

[0001] The present invention relates to an improvement in efficiency of a hermetic compressor used in freezer-refrigerators, and the like.

BACKGROUND ART

[0002] Recently, an improvement in efficiency of a hermetic compressor used in freezer-refrigerators, and the like, has been strongly demanded. In a conventional hermetic compressor, the suction efficiency is increased by, for example, providing a valve device of a compression part with two holes, and the compression efficiency is improved. Such a compressor is disclosed in, for example, Japanese Patent Unexamined Publication No. H3-175174. Hereinafter, an example of a conventional hermetic compressor is described with reference to drawings.

[0003] FIG. 6 is a sectional view showing a conventional refrigerant compressor; and FIG. 7 is an exploded perspective view showing a valve of a conventional refrigerant compressor. To a hermetic container 51, an outlet port 52A that is one end of a suction tube 52 is connected. Another end of the suction tube 52 is connected to a piping at the low-pressure side of a refrigerating cycle (not shown). A motor 53 includes a stator 54 and a rotor 55, so as to drive a compression part 56. Furthermore, refrigerating machine oil 57 is preserved in a bottom portion of the hermetic container 51. A coil spring 58 elastically supports the motor 53 and the compression part 56.

[0004] The compression part 56 includes a cylinder head 61, a cylinder block 62, a valve plate 64, a suction reed valve 67, a piston 68, a connecting rod 70 and a suction muffler 30. The cylinder head 61 forms a suction space 61A and a discharge space 61B. The cylinder block 62 contains a cylinder 63. The valve plate 64 has two suction holes 65 and two discharge holes 66. The suction reed valve (hereinafter, referred to as "valve") 67 has a deformation part 67A. The connecting rod 70 is linked to an eccentric part 69A of a crank shaft 69. The suction muffler 30 communicates to a suction space 61A via a communicating tube 30A and to the suction hole 65 of the valve plate 64, and sucks a refrigerant gas from an inlet port 30B.

[0005] Hereinafter, an operation of the refrigerant compressor configured as mentioned above is described. Firstly, the motor 53 drives the compression part 56, so that the piston 68 reciprocates in the cylinder 63. A low temperature and low pressure refrigerant gas returning from an external refrigerating cycle (not shown) is firstly sucked into the hermetic container 51 from the suction tube 52. The refrigerant gas is further sucked from the inlet port 30B of the suction muffler 30 and passes through the suction hole 65 via the commu-

nicating tube 30A. During the suction stroke, by flexing the deformation part 67A of the valve 67, the refrigerant gas opens the valve 67 and is led to the cylinder 63. During the compression stroke, the valve 67 is closed.

Thus, the refrigerant gas is compressed to high temperature and high pressure, passes from the discharge hole 66 through a discharge tube (not shown) and is led to the external refrigerating cycle (not shown) so as to be used for a refrigerating operation.

[0006] At this time, the valve 67 is so designed as to have a natural frequency for carrying out an opening and closing operation with good timing in accordance with a low-speed operation frequency. Therefore, the compressor is capable of operation with a reduced suction loss and a high volumetric efficiency.

[0007] However, when a low-speed operation frequency is changed to a high-speed operation frequency due to the change in cooling load conditions, the timing of opening and closing operation determined by the natural frequency of the valve 67 is off. At this time, even when the pressure in the cylinder 63 exceeds the pressure in the suction space 61A of the cylinder head 61, the valve 67 does not complete a closing operation. Consequently, delayed closing occurs, causing a backflow of a refrigerant gas, so that the volumetric efficiency is lowered and the refrigerating capacity and the refrigerating efficiency are lowered.

[0008] As a solution to reduce the backflow of a refrigerant gas due to delayed closing of the valve 67, designing the valve 67 to have a high natural frequency in accordance with the high-speed operation is considered. In this case, since the spring constant of the deformation part 67A is increased, an amount of flexure is reduced, so that the suction loss is increased and accordingly the refrigerating capacity and the refrigerating efficiency are lowered.

SUMMARY OF THE INVENTION

[0009] The refrigerant compressor of the present invention includes a piston, a cylinder and a valve plate. The valve plate is provided at an opening end of the cylinder and includes a plurality of suction holes. The refrigerant compressor of the present invention further includes a plurality of suction reed valves, which is provided between the opening end of the cylinder and the valve plate, for opening and closing the plurality of suction holes, respectively. At least one of the suction reed valves has a natural frequency different from that of the other reed valves. With this configuration, even when an operation frequency is changed, delayed closing of the suction reed valve and reduction in an amount of flexure are prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a sectional view showing a refrigerant compressor in an embodiment of the preset invention. FIG. 2 is a front view showing a suction reed valve of the refrigerant compressor shown in FIG. 1.

FIG. 3 is a sectional view showing a cylinder head part of the refrigerant compressor shown in FIG. 1. FIG. 4 is a graph showing a pressure in a cylinder and an amount of flexure of a reed valve in one stroke in a low-speed operation of a refrigerant compressor in an embodiment of the present invention.

FIG. 5 is a graph showing a pressure in a cylinder and an amount of flexure of a reed valve in one stroke in a high-speed operation of a refrigerant compressor in an embodiment of the present invention.

FIG. 6 is a sectional view showing a conventional refrigerant compressor.

FIG. 7 is an exploded perspective view showing a valve of the refrigerant compressor of FIG. 6.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0011] FIG. 1 is a sectional view showing a refrigerant compressor in an embodiment of the preset invention. FIG. 2 is a front view showing a suction reed valve. FIG. 3 is a sectional view showing a cylinder head part.

[0012] To a hermetic container 1, an outlet port 2A that is one end of a suction tube 2 is connected. Another end of the suction tube 2 is connected to a piping at the low-pressure side of a refrigerating cycle (not shown). A motor 3 includes a stator 4 and a rotor 5, and drives a compression part 6. Furthermore, refrigerating machine oil 7 is preserved in a bottom portion of the hermetic container 1. A coil spring 8 elastically supports the motor 3 and the compression part 6.

[0013] The compression part 6 includes a cylinder head 101, a cylinder block 12, a valve plate 110, suction reed valves (hereinafter, referred to as "valve") 120A and 120B, a piston 18, a connecting rod 20 and a suction muffler 130. The cylinder head 101 forms a suction space 101A and a discharge space 101B. The cylinder block 12 contains a cylinder 13. The connecting rod 20 is linked to an eccentric part 19A of a crank shaft 19. The suction muffler 130 communicates to a suction space 101A via a communicating tube 130A and to suction holes 112A and 112B of the valve plate 110, and sucks a refrigerant gas from an inlet port 130B.

[0014] The valve plate 110 has the suction holes 112A and 112B and discharge holes (not shown). The suction holes 112A and 112B are respectively inclined from opening portions 114A and 114B of the valve plate 110 at the side of the cylinder 13 to opening portions 114C

and 114D of the valve plate 110 at the side of cylinder head 101 in the direction in which a distance between the suction holes is reduced. The valves 120A and 120B have deformation parts 122A and 122B having different lengths each other, respectively. Since the deformation part 122A is longer than the deformation part 122B, the spring constant of the valve 120A is smaller, and the valve 120A has a lower natural frequency than that of the valve 120B. Furthermore, the shapes of the valves 120A and 120B are asymmetric with respect to center-lines 124A and 124B of the deformation parts 122A and 122B. Positions of center points of the suction holes 112A and 112B correspond to points 126A and 126B of the valves 120A and 120B, respectively.

[0015] Seal parts 128A and 128B seal the suction holes 112A and 112B provided on the valve plate 110.

[0016] Hereinafter, an operation of the refrigerant compressor configured as mentioned above is described. FIG. 4 is a graph showing a pressure in a cylinder and an amount of flexure of a reed valve in one stroke in a low-speed operation of a refrigerant compressor in an embodiment of the present invention. FIG. 5 is a graph showing a pressure in a cylinder and an amount of flexure of a reed valve in one stroke in a high-speed operation of a refrigerant compressor in an embodiment of the present invention.

[0017] The motor 3 drives the compression part 6, so that the piston 18 reciprocates in the cylinder 13. A low temperature and low pressure refrigerant gas returning from an external refrigerating cycle (not shown) is firstly sucked into the hermetic container 1 from the suction tube 2. The refrigerant gas is further sucked from the inlet port 130B of the suction muffler 130 and passes through the suction holes 112A and 112B via the communicating tube 130A. During the suction stroke, by flexing the deformation parts 122A and 122B of the valves 120A and 120B, the refrigerant gas opens the valve 120A and 120B and is led to the cylinder 13. During the compression stroke, the valves 120A and 120B are closed, and the refrigerant gas is compressed to high temperature and high pressure, passes from the discharge hole through a discharge tube (not shown) and is led to the external refrigerating cycle to be used for a refrigerating operation.

[0018] When the piston 18 reciprocates in the cylinder 13, in the suction stroke, the piston 18 shifts to the side of a bottom dead center. In a low-speed operation, in this suction stroke, gas pressure load, which is generated by differential pressure when the pressure 140 in the cylinder 13 becomes lower than the pressure in the suction space 101A of the cylinder head 101, acts on the valves 120A and 120B. At this time, at a point 140A, the suction reed valves 120A and 120B start to open, and the refrigerant gas is sucked into the cylinder 13. The point 140A means a point at which the gas pressure load generated by differential pressure becomes larger than a resultant force of flexure load of the valves 120A-120B and an adhesion force with the viscosity of refrig-

erating machine oil at the seal parts of the valves 120A-120B.

[0019] Furthermore, in the compression stroke, the valves 120A and 120B are closed at a point 140B at which the pressure in the cylinder 13 exceeds the pressure in the suction space 101A of the cylinder head 101, and suction of the refrigerant gas from the suction muffler 130 is completed.

[0020] Between the point 140A and the point 140B, the valve 120A repeats opening and closing operations 150A twice at a natural frequency in primary deformation mode while flexing the deformation part 122A. Since the valve 120A is selected to have a natural frequency corresponding to a low-speed operation frequency, the valve 120A completes closing substantially with the same timing as the point 140B. Furthermore, since the spring constant of the valve 120A is small, even under conditions that the flow rate of sucked gas is slow during a low-speed operation, a suction loss due to the shortage of an amount of flexure is not increased.

[0021] Furthermore, the valve 120B has a natural frequency and a spring constant higher than those of the valve 120A, and repeats opening and closing operations 150B four times between the point 140A and the point 140B. At this time, the valve 120B opens widely with a certain amount of flexure according to the circulation amount of refrigerant at the first to third opening and closing operations 150B. At the fourth opening and closing operation, since in the compression stroke, the differential pressure between the pressure in the cylinder 13 and the pressure in the suction space 101A of the cylinder head 101 is extremely small. At this time, the refrigerant gas flows in the suction hole 112A of the valve 120A that flexes more largely. Consequently, the amount of a refrigerant gas flowing in the suction hole 112B of the valve 120B becomes very small and the dynamic pressure by the flow of the refrigerant gas is reduced. That is to say, the valve 120B hardly flexes and it completes opening and closing operation near the point 141B.

[0022] Therefore, backflow of the refrigerant gas due to delayed closing of the valves 120A and 120B is prevented, and the increase in suction loss due to the shortage of the amount of flexure in the suction stroke is also prevented. As a result, the volumetric efficiency is increased.

[0023] Furthermore, in a high-speed operation, between the point 141A and the point 141B, the valve 120B repeats opening and closing operations 151B three times and flexes with a certain amount of flexure according to the circulation amount of refrigerant, and then completes closing with good timing. The point 141A means a point at which the pressure in the cylinder 13 becomes lower than the pressure in the suction space 101A of the cylinder head 101. Furthermore, the point 141B means a point at which the pressure in the cylinder 13 exceeds the pressure in the suction space 101A of the cylinder head 101.

[0024] The valve 120A opens widely in a certain amount of flexure according to the circulation amount of refrigerant at the first opening and closing operation 151A. On the other hand, in the second opening and closing operation, since in a compression stroke, the differential pressure between the pressure in the cylinder 13 and the pressure in the suction space 101A of the cylinder head 101 is extremely small. Therefore, the refrigerant gas passes through the suction hole 112B of the valve 120B that flexes more largely. Consequently, the valve 120A hardly flexes and it completes the opening and closing operation near the point 141B.

[0025] Therefore, also in a high-speed operation, delayed closing or shortage of the amount of flexure of the valves 120A and 120B do not occur, so that the refrigerant gas is sucked into the cylinder 13 efficiently. Consequently, in a case where the operation frequency is changed, the refrigerating capacity and the compression efficiency of the compressor are increased.

[0026] Furthermore, the shapes of the valves 120A and 120B are asymmetric with respect to the centerlines 124A and 124B of the deformation parts 122A and 122B. Therefore, working points 126A and 126B of the gas pressure load that act on the valves 120A and 120B deviate from centerlines 124A and 124B of the flexing deformation of the valves 120A and 120B. Thus, the valves 120A and 120B start to open with torsion deformation. That is to say, torsional moment due to gas pressure load acts on the valves 120A and 120B. Consequently, on one side of circular seal parts 128A and 128B of the valves 120A and 120B, force for peeling off the adhesion portion with a viscosity of the refrigerating machine oil 7 is concentrated, thus making it easy to open the valves 120A and 120B. Accordingly, in the suction stroke, the valves 120A and 120B start to open earlier. Therefore, the refrigerant gas is sucked into the cylinder 13 efficiently, and the refrigerating capacity and the compression efficiency of the compressor are increased. Note here that in FIG. 2, both of the shapes of the valves 120A and 120B are asymmetric with respect to the centerlines 124A and 124B of the deformation parts 122A and 122B. However, they may be configured so that only one of the shapes is asymmetric.

[0027] A refrigerant gas inside the hermetic container 1 passes through the suction space 101A in a high-temperature cylinder head 101 via the suction muffler 130 and is sucked into the cylinder 13 from the suction holes 112A and 112B provided on the valve plate 110. Herein, the refrigerant gas inside the cylinder 13 is in a high temperature state of about 100°C by a compression action and is discharged to a discharge space 101B of the cylinder head 101. Thus, the cylinder head 101 is heated to high temperature state of about 80°C.

[0028] In this case, as an interval between the two suction holes 112A and 112B of the suction space 101A in the cylinder head 101, at least a distance corresponding to a sum of the widths of the seal part 128A and the seal part 128B is necessary. Herein, as shown in FIG.

3, in a case where the suction holes 112A and 112B are inclined, it is not necessary to consider the widths of the seal part 128A and the seal part 128B, and it is possible to greatly reduce the interval between the suction holes 112A and 112B. Thus, the suction space 101A in the cylinder head 101 can be configured to have a reduced volume and heat receiving area, so that the thermal transmission to the flowing refrigerant gas is reduced. Accordingly, the temperature of the refrigerant can be kept low, the density of the gas refrigerant increases and the circulation amount of the refrigerant increases. Consequently, the refrigerating capacity and the compression efficiency of the compressor increase. Note here that in FIG. 3, both of the suction holes 112A and 112B are inclined, but only one of them may be inclined.

[0029] Note here that in the embodiment, the number of the valves 120A and 120B is two. However, when the number is three or more, the same effect can be obtained.

[0030] Furthermore, in the embodiment, the natural frequency is changed by varying the lengths of the valves 120A and 120B. However, the same effect can be obtained even when the natural frequency is changed by varying the widths or shapes of the valves 120A and 120B.

[0031] Furthermore, in the embodiment, the case where the number of opening and closing operations in one stroke of the valve 120A and 120B is two to four is described, however the same effect can be obtained when the number is one or more.

INDUSTRIAL APPLICABILITY

[0032] A refrigerant compressor of the present invention includes a piston, a cylinder and a valve plate. The valve plate is provided at an opening end of the cylinder and has a plurality of suction holes. The refrigerant compressor of the present invention further includes a plurality of suction reed valves provided between the opening end of the cylinder and the valve plate, and opens and closes the plurality of suction holes, respectively. At least one of the suction reed valves has a natural frequency different from that of the other reed valves. With this configuration, since refrigerating capacity and compression efficiency of the refrigerant compressor can be increased, the refrigerant compressor can be used for air conditioners, freezer-refrigerators, and the like.

Claims

1. A refrigerant compressor, comprising:

- a piston;
- a cylinder housing the piston;
- a valve plate, which has a first suction hole and a second suction hole, provided at an opening end of the cylinder;

a first suction reed valve, which opens and closes the first suction hole, provided between the opening end of the cylinder and the valve plate; and

a second suction reed valve, which opens and closes the second suction hole and has a natural frequency different from that of the first reed valve, provided between the opening end of the cylinder and the valve plate.

2. The refrigerant compressor according to claim 1, wherein the first suction reed valve has a first deformation part and the second suction reed valve has a second deformation part, at least one of a shape of the first suction reed valve being asymmetric with respect to a centerline of the first deformation part and a shape of the second suction reed valve being asymmetric with respect to a centerline of the second deformation part.

3. The refrigerant compressor according to claim 1, wherein at least one of the first suction hole and the second suction hole is inclined from an opening end face of the valve plate at the cylinder to another end face in the direction in which an interval between the first suction hole and the second suction hole is reduced.

FIG. 1

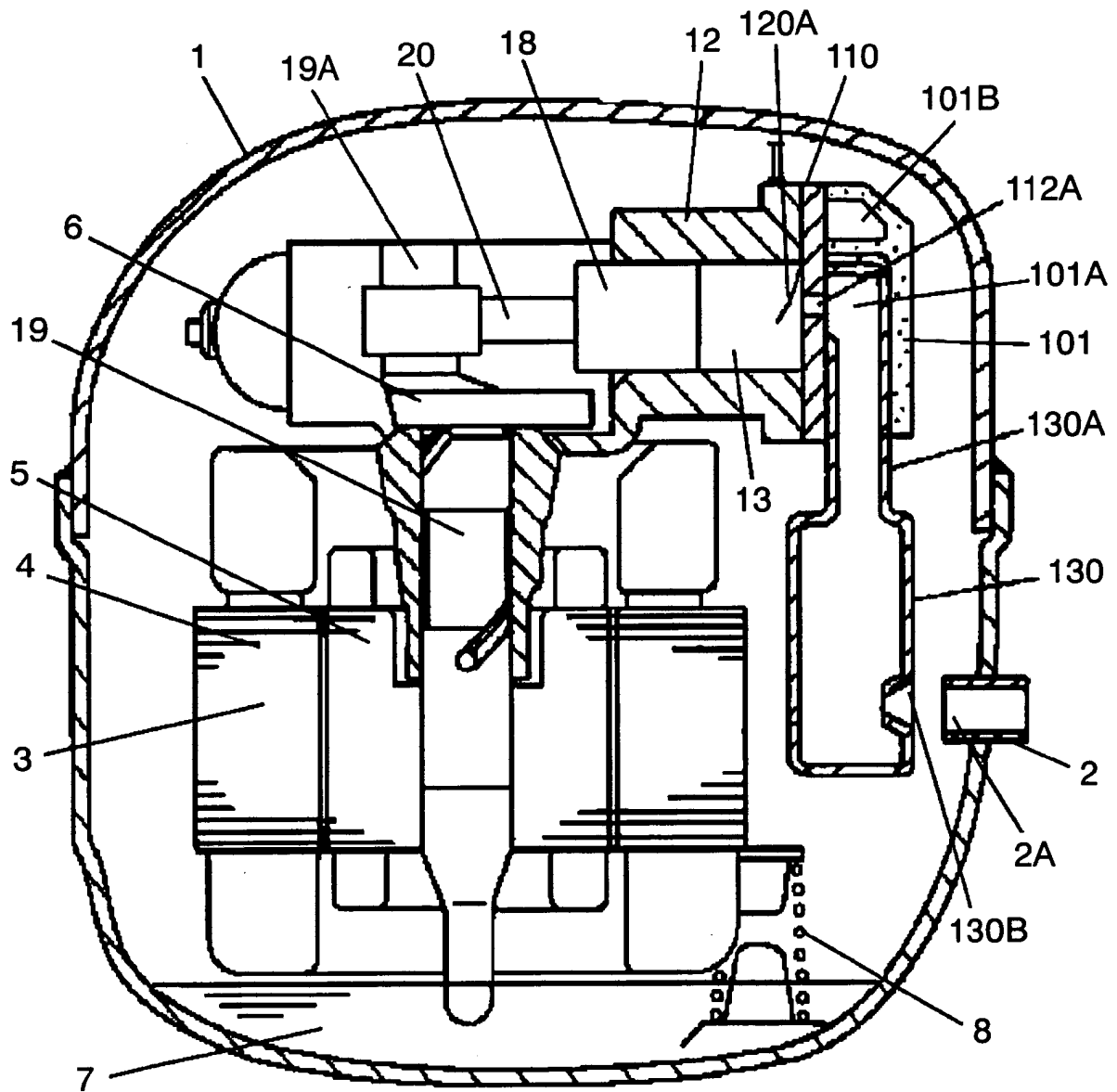


FIG. 2

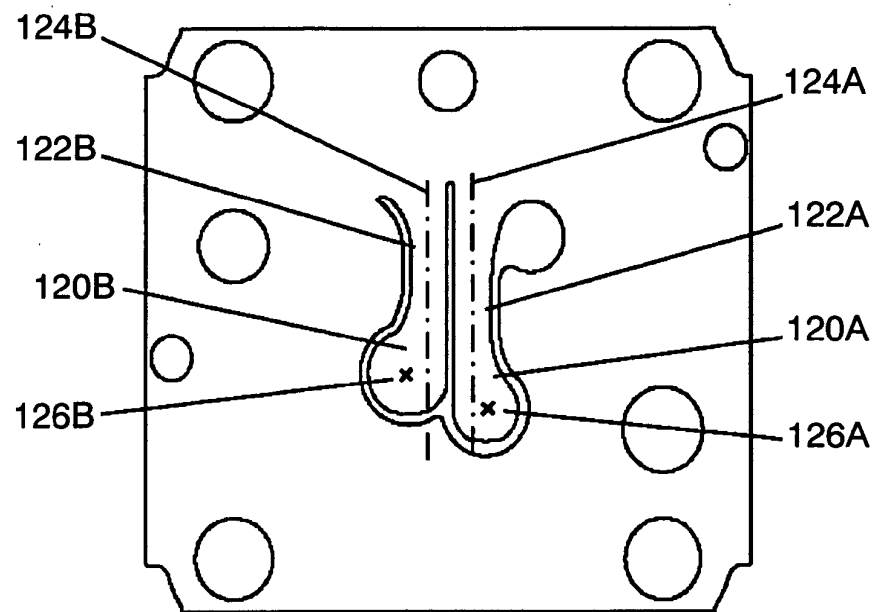


FIG. 3

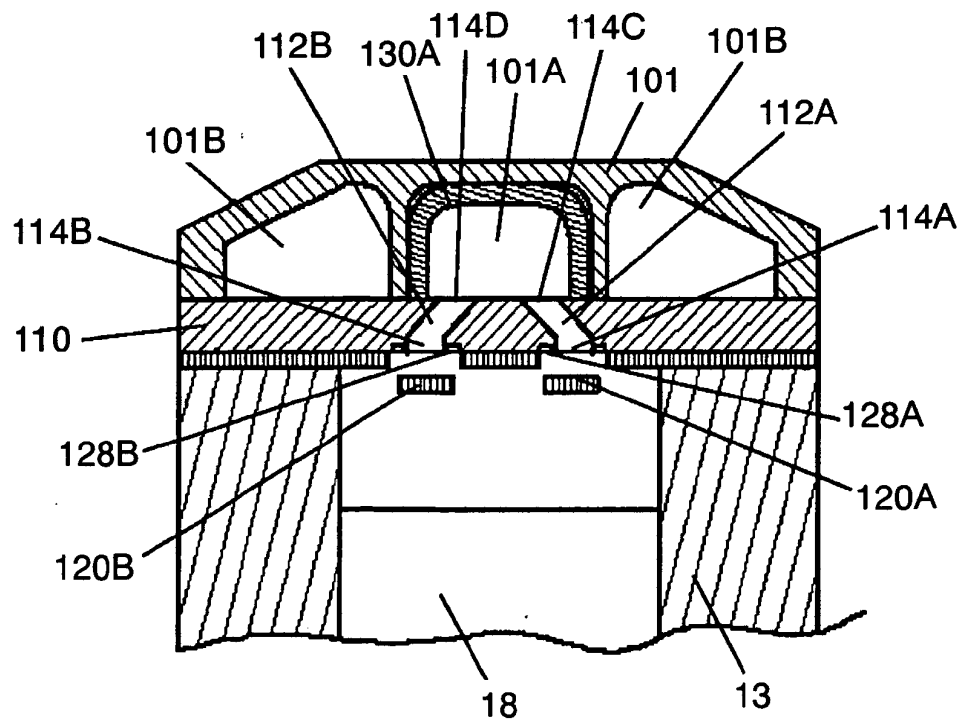


FIG. 4

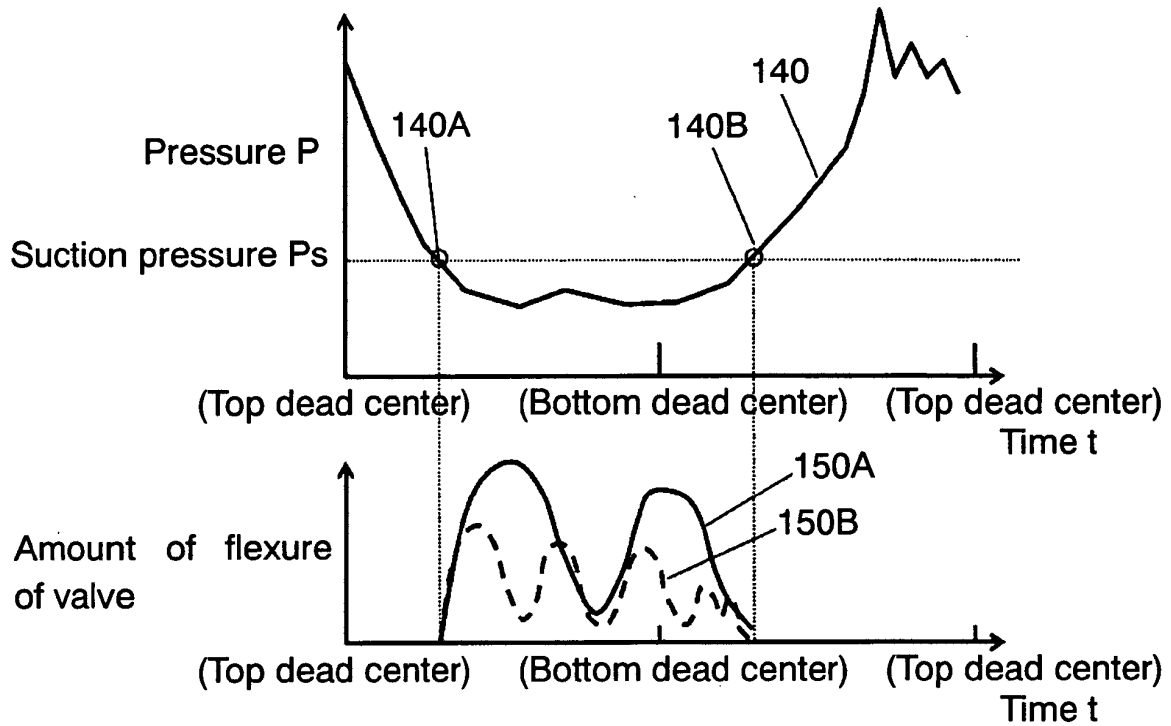


FIG. 5

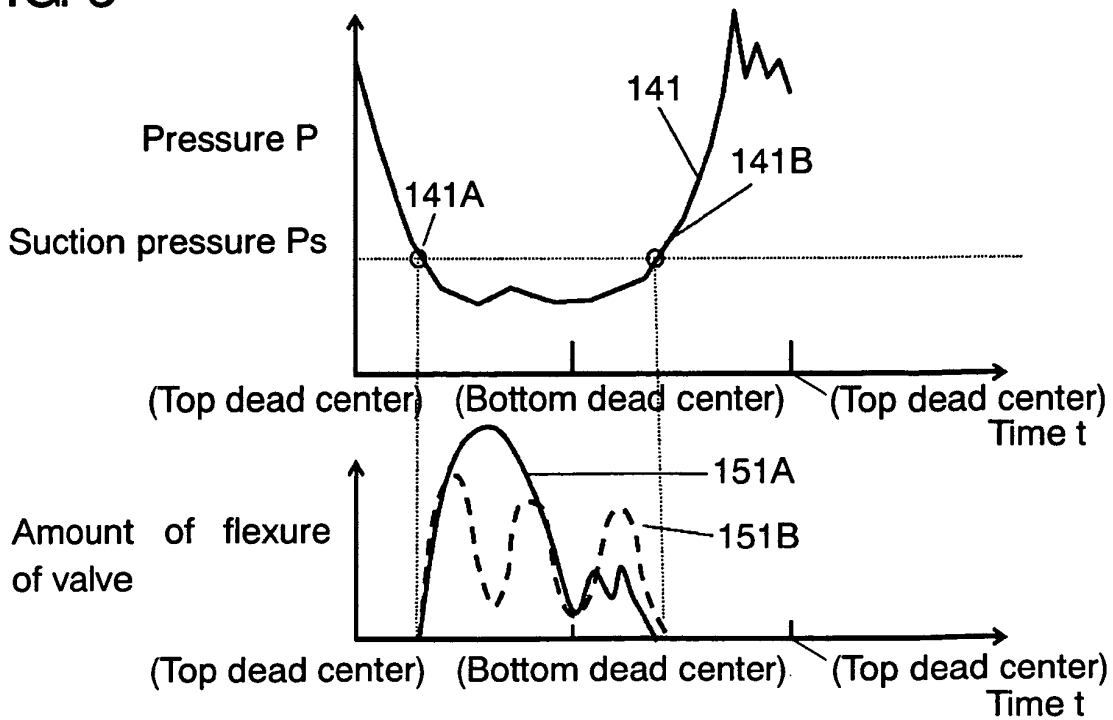


FIG. 6

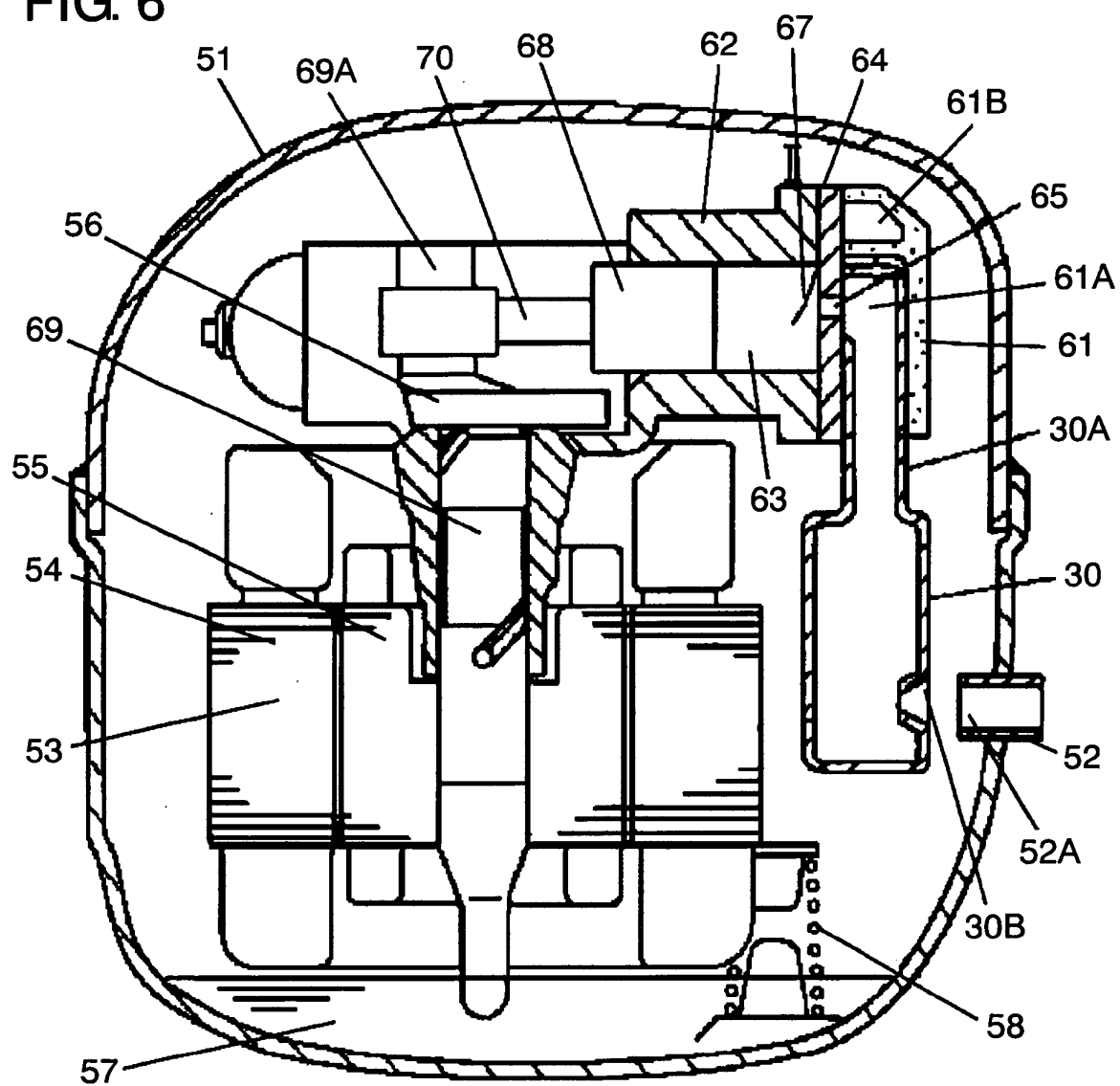
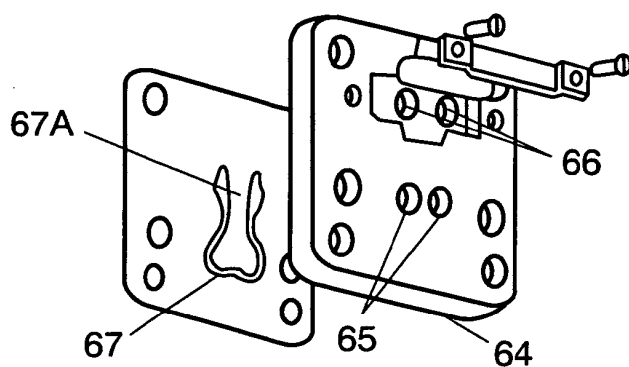


FIG. 7



Reference marks in the drawings

- 1 hermetic container
- 2 suction tube
- 2A outlet port
- 3 motor
- 4 stator
- 5 rotor
- 6 compression part
- 7 refrigerating machine oil
- 8 coil spring
- 12 cylinder block
- 13 cylinder
- 18 piston
- 19 crank shaft
- 19A eccentric part
- 20 connecting rod
- 30 suction muffler
- 30A communicating tube
- 30B inlet port
- 51 hermetic container
- 52 suction tube
- 52A outlet port
- 53 motor
- 54 stator
- 55 rotor
- 56 compression part
- 57 refrigerating machine oil
- 58 coil spring
- 61 cylinder head
- 61A suction space
- 61B discharge space
- 62 cylinder block
- 63 cylinder
- 64 valve plate
- 65 suction hole

66 discharge hole
67 suction reed valve
67A deformation part
68 piston
69 crank shaft
69A eccentric part
70 connecting rod
101 cylinder head
101A suction space
101B discharge space
110 valve plate
112A, 112B suction hole
114A, 114B, 114C, 114D opening portion
120A, 120B suction reed valve
122A, 122B deformation part
124A, 124B centerline
126A, 126B working point of gas pressure load
128A, 128B seal part
130 suction muffler
130A communicating tube
130B inlet port
140, 141 pressure
140A, 140B, 141A, 141B point
151A, 151B opening and closing operation

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/006578

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ F04B39/10		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) Int.Cl ⁷ F04B39/10		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2004 Kokai Jitsuyo Shinan Koho 1971-2004 Toroku Jitsuyo Shinan Koho 1994-2004		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2000-329066 A (Toyoda Automatic Loom Works, Ltd.),	1
Y	28 November, 2000 (28.11.00), & US 6419467 B1 & EP 1054157 A2	2
X	JP 9-228951 A (Matsushita Refrigeration Co.), 02 September, 1997 (02.09.97), Par. No. [0047]; Fig. 3 & US 6012908 A1 & EP 821763 A	1
Y	JP 9-280168 A (Toyoda Automatic Loom Works, Ltd.), 28 October, 1997 (28.10.97), Fig. 5 (Family: none)	2
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 06 August, 2004 (06.08.04)		Date of mailing of the international search report 24 August, 2004 (24.08.04)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/006578

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-332968 A (Calsonic Kansei Corp.), 22 November, 2002 (22.11.02), & US 2002/176786 A1 & EP 1255042 A2	2
Y	JP 2002-106466 A (Toyota Industries Corp.), 10 April, 2002 (10.04.02), (Family: none)	2
A	WO 1997/047882 A1 (Matsushita Refrigeration Co.), 18 December, 1997 (18.12.97), Fig. 62 & EP 845595 A1 & US 6152703 A	3

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/006578

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The feature common to the inventions of Claims 1-3 is the feature described in Claim 1.

However, the search has revealed that the common feature is disclosed in document JP 2000-329066 A (Toyoda Automatic Loom Works, Ltd.) 28 November 2000 (28.11.2000), and therefore it is not novel.
(Continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/006578

Continuation of Box No.III of continuation of first sheet(2)

As a consequence, the common feature above is not the special technical feature and there is no other same or corresponding technical relationship among the inventions of Claims 1-3.

Therefore, the inventions of Claims 1-3 do not satisfy the requirement of unity of invention.