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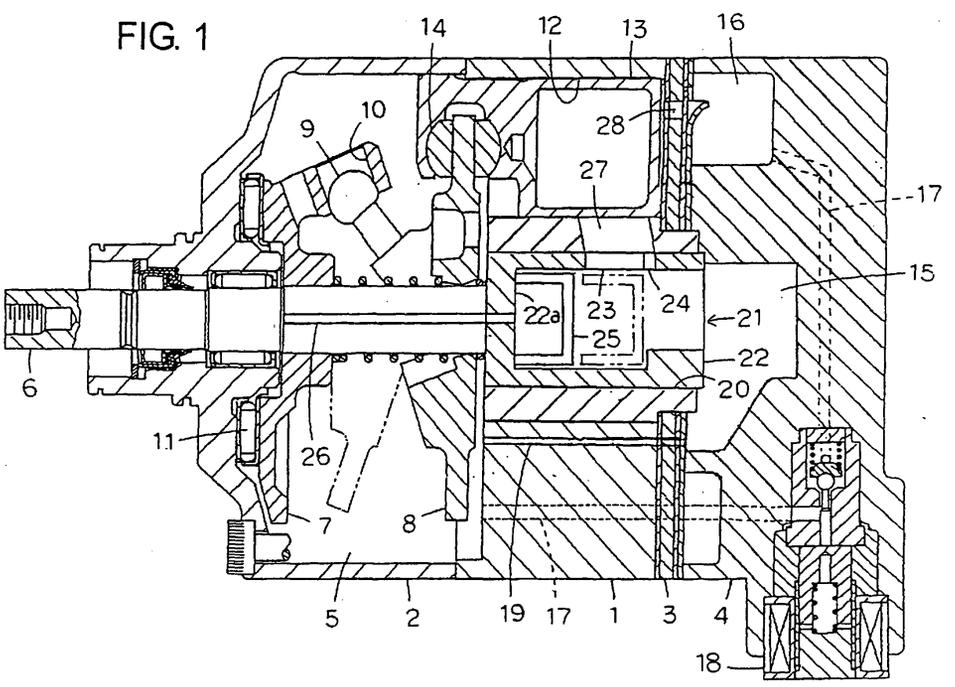
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(54) Piston-type variable displacement compressor

(57) In a piston-type variable displacement compressor according to the present invention, a rotary valve includes a guide passage having a main suction port for securing a flow rate corresponding tomaximum-displacement operation and a sub suction port for effecting throttling to a flow rate low enough to suppress pressure fluctuation during variable displacement operation, and during maximum displacement operation, the spool is moved by a suction gas flow to totally open both the main suction port and the sub suction port, and during variable displacement operation, the spool is moved by a pressure difference between the suction chamber pressure and the crank chamber pressure to close the main suction port while keeping the sub suction port open.

FIG. 1



EP 1 591 662 A2

Description

BACKGROUND OF THE INVENTION

Field of the Invention:

[0001] The present invention relates to a piston-type variable displacement compressor, and more particularly to a reduction in pressure fluctuation during variable displacement operation.

Description of the Related Art:

[0002] In a piston-type variable displacement compressor, in which pistons reciprocate within cylinder bores as a drive shaft rotates, it is possible to vary the displacement through variable control of the piston stroke. However, when the flow rate is low, the amount of gas passing through the suction valve is reduced, so that self-excited vibration of the suction valve is liable to be caused in a free vibration region where the suction valve does not abut a stopper. When such self-excited vibration is generated, a fluctuation in pressure is generated and propagated to an evaporator connected to the compressor, which may lead to generation of noise.

[0003] For example, JP 7-324678 A discloses a compressor in which an opening area of a suction flow passage is controlled by using a rotary valve with a multi-stepped cutout groove serving as a guide passage for introducing suction gas into an operation chamber of a cylinder bore defined by a piston from a suction pressure region, thereby mitigating the shock when starting the compressor.

[0004] Using such a rotary valve makes it possible to mitigate to some degree the pressure fluctuation when the flow rate is low. However, the rotary valve of JP 7-324678 A is axially urged by a spring so as to minimize the opening area. As the pressure of the crank chamber becomes higher than the pressure of the suction chamber, the rotary valve is moved against the urging force of the spring, and the opening area increases, thus resulting in an increase in flow rate. Therefore, during maximum displacement operation, in particular, it is necessary to greatly compress the spring to increase the opening area to a maximum degree, so that there is a fear of involving a deterioration in performance of the compressor.

SUMMARY OF THE INVENTION

[0005] The present invention has been made with a view toward solving the above problem in the prior art. It is an object of the present invention to provide a piston-type variable displacement compressor capable of mitigating the fluctuation in pressure during variable displacement operation without involving deterioration in performance during maximum displacement operation.

[0006] The present invention provides a piston-type variable displacement compressor in which pistons are respectively accommodated in a plurality of cylinder bores arranged around a drive shaft and in which a rotary valve with a guide passage for introducing a suction gas into operation chambers in the cylinder bores defined by the pistons is arranged rotatably in synchronism with the drive shaft, variable control being effected on the stroke of the pistons in the cylinder bores by adjusting a crank chamber pressure. In the piston-type variable displacement compressor, the rotary valve includes: a guide passage having a main suction port for securing a flow rate corresponding to maximum displacement operation and a sub suction port for effecting throttling to a flow rate low enough to suppress pressure fluctuation during variable displacement operation, and a spool axially movably arranged under a suction chamber pressure and the crank chamber pressure. In the piston-type variable displacement compressor, during maximum displacement operation, the spool is moved by a suction gas flow to totally open both the main suction port and the sub suction port, and during variable displacement operation, the spool is moved by a pressure difference between the suction chamber pressure and the crank chamber pressure to close the main suction port while keeping the sub suction port open.

[0007] During maximum displacement operation, the spool of the rotary valve is caused to retract by the suction gas flow to make both the main suction port and the sub suction port totally open, and during variable displacement operation, the spool of the rotary valve advances due to the pressure difference between the suction chamber pressure and the crank chamber pressure to close the main suction port, so that suction is effected solely through the sub suction port.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Fig. 1 is a sectional view of the construction of a piston-type variable displacement compressor according to Embodiment 1 of the present invention;
Fig. 2 is a schematic diagram illustrating how a rotary valve behaves during maximum displacement operation in Embodiment 1;
Fig. 3 is a schematic diagram illustrating how the rotary valve behaves during variable displacement operation in Embodiment 1;
Fig. 4 is a schematic diagram illustrating how the rotary valve behaves during maximum displacement operation in Embodiment 2;
Fig. 5 is a schematic diagram illustrating how the rotary valve behaves during variable displacement operation in Embodiment 2;
Fig. 6 is a schematic diagram illustrating how the rotary valve behaves during maximum displacement operation in Embodiment 3; and
Fig. 7 is a schematic diagram illustrating how the

rotary valve behaves during variable displacement operation in Embodiment 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] In the following, embodiments of the present invention will be described with reference to the drawings.

Embodiment 1

[0010] Fig. 1 shows a construction of a piston-type variable displacement compressor according to Embodiment 1. A front housing 2 is connected to the front end portion of a cylinder block 1, and a rear housing 4 is connected to the rear end portion of the cylinder block 1 through the intermediation of a valve forming member 3. A crank chamber 5 is defined by the cylinder block 1 and the front housing 2, and a drive shaft 6 is rotatably supported by the cylinder block 1 and the front housing 2 so as to extend through the crank chamber 5. The forward end portion of the drive shaft 6 protrudes outwardly from the front housing 2 and is connected to a rotary drive source (not shown) , such as a vehicle engine or a motor. Inside the front housing 2, a rotary support member 7 is fixed to the drive shaft 6, and a swash plate 8 is mounted so as to be engaged with the rotary support member 7. The swash plate 8 has at its center a through-hole, through which the drive shaft 6 extends, and, in this state, a guide pin 9 protruding from the swash plate 8 is slidably fitted into a guide hole 10 formed in the rotary support member 7. Due to the engagement of the guide pin 9 and the guide hole 10, the swash plate 8 rotates integrally with the drive shaft 6, and is supported so as to be capable of sliding in the axial direction of the drive shaft 6 and tilting. Further, the rotary support member 7 is rotatably supported by a thrust bearing 11 arranged in the front end inner wall portion of the front housing 2.

[0011] Inside the cylinder block 1, a plurality of cylinder bores 12 are formed and arranged around the drive shaft 6, and a piston 13 is slidably accommodated in each cylinder bore 12. Each piston 13 is engaged with the outer peripheral portion of the swash plate 8 through the intermediation of a shoe 14. When the swash plate 8 rotates with the drive shaft 6, each piston 13 reciprocates in the axial direction of the drive shaft 6 inside the cylinder bore 12 through the shoe 14.

[0012] At the center of the rear housing 4, there is defined a suction chamber 15 facing the valve forming member 3, and, in the outer periphery of the suction chamber 15, there is defined a discharge chamber 16 surrounding the suction chamber 15.

[0013] Further, formed in the cylinder block 1 and the rear housing 4 is a communication passage 17 allowing communication between the crank chamber 5 and the discharge chamber 16, and, at some midpoint of the communication passage 17, there is arranged a displacement control valve 18 consisting of an electromagnetic valve. Further, formed in the cylinder block 1 is a bleeding passage 19 establishing communication between the crank chamber 5 and the suction chamber 15.

[0014] At the center of the cylinder block 1, there is formed a valve accommodating chamber 20 so as to extend therethrough in the axial direction, and the valve accommodating chamber 20 accommodates a rotary valve 21 arranged at the rear end of the drive shaft 6. The rotary valve 21 rotates in synchronism with the drive shaft 6, and has a bottomed cylindrical member 22, the interior of which communicates with the suction chamber 15. A main suction port 23 and a sub suction port 24 are formed in the cylindrical member 22.

[0015] The cylindrical member 22 movably contains a cylindrical spool 25. Further, a bottom portion 22a of the cylindrical member 22 communicates with the crank chamber 5 through a communication passage 26 formed in the drive shaft 6.

[0016] Operation chambers in the cylinder bores 12 defined by the pistons 13, and the valve accommodating chamber 20 of the cylinder block 1 communicate with each other through communication passages 27. The main suction port 23 and the sub suction port 24 of the cylindrical member 22 of the rotary valve 21 are formed at axial positions corresponding to the communication passages 27.

[0017] As shown in Fig. 2, the main suction port 23 has a large opening area S1 in order to secure the flow rate during maximum displacement operation, whereas the sub suction port 24, which is formed adjacent to the main suction port 23 in the axial direction, has a small opening area S2 in order to effect throttling to a level low enough to restrain the pressure fluctuation during variable displacement. The main suction port 23 is selectively opened and closed according to the movement of the spool 25, whereas the sub suction port 24 is constantly open independently of the movement of the spool 25. A suction pressure Ps of the suction chamber 15 acts on the front surface of the spool 25 facing the suction port 20, and the pressure Pc of the crank chamber 5 acts on the rear surface of the spool 25 facing the bottom portion 22a of the cylindrical chamber 22.

[0018] When the spool 25 retracts inside the cylindrical chamber 22 toward the bottom portion 22a, both the main suction port 23 and the sub suction port 24 are opened as shown in Fig. 2. Conversely, as shown in Fig. 3, when the spool 25 advances inside the cylindrical chamber 22 toward the suction port 20, the spool 25 abuts a stopper at a position where the main suction port 23 is totally closed, leaving solely the sub suction port 24 open.

[0019] Next, the operation of the piston-type variable displacement compressor of Embodiment 1 will be described. Through backward movement of the piston 13 following rotation of the drive shaft 6, that is, through the retraction thereof within the cylinder bore 12, refrigerant

gas in the suction chamber 15 enters the cylindrical member 22 of the rotary valve 21. At this time, the main suction port 23 and the sub suction port 24 of the cylindrical member 22 of the rotary valve 21 rotating in synchronism with the drive shaft 6 are at positions corresponding to the communication passage 27 connected to the cylinder bore 12, and the refrigerant gas flows into the cylinder bore 12 by way of the main suction port 23, the sub suction port 24 and the communication passage 27.

[0020] During the subsequent forward movement of the piston 13, that is, when the piston 13 advances within the cylinder bore 12, the main suction port 23 and the sub suction port 24 of the cylindrical member 22 of the rotary valve 21 rotating in synchronism with the drive shaft 6 are at rotating positions deviated from the communication passage 27 connected to the cylinder bore 12, and the refrigerant gas in the cylinder bore 12 is discharged into the discharge chamber 16 by pushing away a discharge reed portion from a discharge port 28 of the valve forming member 3.

[0021] The opening of the displacement control valve 18 is set, whereby control is effected on the balance between the amount of gas introduced into the crank chamber 5 through the communication passage 17 and the amount of gas introduced from the crank chamber 5 through the bleeding passage 19, thereby controlling the pressure Pc of the crank chamber 5. When the opening of the displacement control valve 18 is changed to thereby change the pressure Pc of the crank chamber 5, the pressure difference between the crank chamber 5 and the cylinder bore 12 with the piston 13 therebetween is changed, thereby changing the tilting angle of the swash plate 8. As a result, the stroke of the pistons 13, that is, the discharge displacement of the compressor, is adjusted.

[0022] For example, when the pressure Pc of the crank chamber 5 is lowered, the tilting angle of the swash plate 8 increases, and the stroke of the pistons 13 increases, resulting in an increase in discharge displacement. Conversely, when the pressure Pc of the crank chamber 5 is raised, the tilting angle of the swash plate 8 decreases, and the stroke of the pistons 13 is reduced, resulting in a reduction in discharge displacement.

[0023] During maximum displacement operation, the pressure Pc of the crank chamber 5 is reduced through setting of the opening of the displacement control valve 18, and becomes substantially equal to the pressure Ps of the suction chamber 15. As a result, due to the gas flowing into the cylindrical member 22 from the suction chamber 15, the spool 25 of the opening control valve V retracts inside the cylindrical chamber 22 toward the bottomport ion 22a . This causes, as shown in Fig. 2, both the main suction port 23 and the sub suction port 24 to be totally opened, with the opening area becoming S1 + S2. This allows discharge of maximum displacement. At this time, no urging force due to the spring, etc. is acting on the spool 25, so that there is substantially no energy loss when the spool 25 retracts, whereby the performance at the time of maximum displacement is secured.

[0024] During variable displacement operation, the pressure Pc of the crank chamber 5 is raised through setting of the opening of the displacement control valve 18, and becomes higher than the pressure Ps of the suction chamber 15. Thus, the spool 25 advances inside the cylindrical chamber 22 toward the suction chamber 15, and, as shown in Fig. 3, a state is attained in which the main suction port 23 is totally closed, with solely the sub suction port 24 being open. That is, the opening area is S2. As a result, the passage for the suction gas is throttled, and the pressure fluctuation is restrained to a sufficient degree.

Embodiment 2

[0025] Fig. 4 shows the construction of the rotary valve of a piston-type variable displacement compressor according to Embodiment 2. In the cylindrical chamber 22, a first spool 29 is movably accommodated, and, on the rear side of the first spool 29, a second spool 30 is movably accommodated. Between the first spool 29 and the second spool 30, there is arranged a spring 31. The pressure Ps of the suction chamber 15 acts on the front surface of the first spool 29, and the pressure Pc of the crank chamber 5 acts on the rear surface of the second spool 30. Otherwise, this embodiment is of the same construction as Embodiment 1.

[0026] During maximum displacement operation, the pressure Pc of the crank chamber 5 is substantially equal to the pressure Ps of the suction chamber 15, so that the first spool 29 is pushed within the cylindrical member 22 toward the bottom portion 22a by the suction gas flow, and retracts together with the second spool 30. As a result, as shown in Fig. 4, both the main suction port 23 and the sub suction port 24 are totally opened to make the opening area S1 + S2. At this time, the spring 31 just retracts together with the first spool 29 and the second spool 30, and no urging force is exerted, so that there is substantially no energy loss, and the performance corresponding to maximum displacement operation is secured.

[0027] During variable displacement operation, the pressure Pc of the crank chamber 5 is raised to become higher than the pressure Ps of the suction chamber 15, so that the second spool 30 advances within the cylindrical member 22, causing the first spool 29 to advance through the spring 31. As a result, as shown in Fig. 5, the main suction port 23 is totally closed by the first spool 29, and only the sub suction port 24 is open, thereby restraining pressure fluctuation to a sufficient degree.

[0028] In this way, during maximum displacement operation, the urging force of the spring 31 does not act on the first spool 29, thereby securing the requisite performance,and during variable displacement operation,

the urging force of the spring 31 acts on the first spool 29, thus providing an auxiliary force for the operation of closing the main suction port 23.

Embodiment 3

[0029] Fig. 6 shows a construction of the rotary valve of a piston-type variable displacement compressor according to Embodiment 3. In Embodiment 3, Embodiment 1 shown in Figs. 1 through 3 is modified such that, instead of the main suction port 23, there are formed in the cylindrical member 22 of the rotary valve 21 a first suction port 32 for securing the flow rate corresponding to maximum displacement operation, and a second suction port 33 adjacent to the first suction port 32 so as to be on the leading side with respect to the rotating direction of the rotary valve. The first suction port 32 has an opening area S3, and the second suction port 33 has an opening area S4 that is smaller than the opening area S3 of the first suction port 32. Further, the sub suction port 24 is formed so as to be axially adjacent to the first suction port 32. Otherwise, this embodiment is of the same construction as Embodiment 1.

[0030] Since the second suction port 33 having the small opening area S4 is formed adjacent to the first suction port 32 so as to be on the leading side with respect to the rotating direction of the rotary valve, when communication between the operation chamber of the cylinder bore 12 and the suction chamber 15 begins, only a small amount of refrigerant gas flows into and out of the operation chamber, whereby, even when the actual suction timing is deviated from the optimum suction timing due to the operating condition of the compressor, it is possible to suppress generation of pressure fluctuation due to suction pulsation.

[0031] During maximum displacement operation, the spool 25 retracts within the cylindrical member 22 toward the bottom portion, and as shown in Fig. 6, the first suction port 32, the second suction port 33 and the sub suction port 24 are all totally opened, with the opening area being S3 + S4 + S2, whereby discharge of maximum displacement is possible.

[0032] During variable displacement operation, the spool 25 advances within the cylindrical member 22 toward the suction chamber 15, and as shown in Fig. 7, the first suction port 32 and the second suction port 33 are totally closed, with only the sub suction port 24 being open. That is, the opening area is S2, and pressure fluctuation is restrained to a sufficient degree.

[0033] While in Embodiments 1 through 3 described above the sub suction port 24 is constantly open regardless of the movement of the spool 25 or the first spool 29, this should not be construed restrictively. It is also possible to adopt a construction in which as the spool 25 or the first spool 29 moves, the sub suction port 24 is opened and closed like the main suction port 23, the first suction port 32 and the second suction port 33.

[0034] According to the present invention, during maximum displacement operation, the spool of the rotary valve is moved by the suction gas flow to totally open both the main suction port and the sub suction port, and during variable displacement operation, the spool of the rotary valve is moved by the difference in pressure between the suction chamber and the crank chamber to close the main suction port while keeping the sub suction port open, so that it is possible to achieve a reduction in pressure fluctuation during variable displacement operation without involving a deterioration in performance during maximum displacement operation.

[0035] In a piston-type variable displacement compressor according to the present invention, a rotary valve includes a guide passage having a main suction port for securing a flow rate corresponding to maximum-displacement operation and a sub suction port for effecting throttling to a flow rate low enough to suppress pressure fluctuation during variable displacement operation, and during maximum displacement operation, the spool is moved by a suction gas flow to totally open both the main suction port and the sub suction port, and during variable displacement operation, the spool is moved by a pressure difference between the suction chamber pressure and the crank chamber pressure to close the main suction port while keeping the sub suction port open.

Claims

1. A piston-type variable displacement compressor in which pistons are respectively accommodated in a plurality of cylinder bores arranged around a drive shaft and in which a rotary valve with a guide passage for introducing a suction gas into operation chambers in the cylinder bores defined by the pistons is arranged rotatably in synchronism with the drive shaft, variable control being effected on the stroke of the pistons in the cylinder bores by adjusting a crank chamber pressure,

   the rotary valve comprising:

   a guide passage having a main suction port for securing a flow rate corresponding to maximum displacement operation and a sub suction port for effecting throttling to a flow rate low enough to suppress pressure fluctuation during variable displacement operation, and

   a spool axially movably arranged under a suction chamber pressure and the crank chamber pressure,

   during maximum displacement operation, the spool being moved by a suction gas flow to totally open both the main suction port and the sub suction port, and

   during variable displacement operation, the spool being moved by a pressure difference between the suction chamber pressure and the

crank chamber pressure to close the main suction port while keeping the sub suction port open.

2. A piston-type variable displacement compressor according to Claim 1, wherein the rotary valve comprises a cylindrical member which rotates in synchronism with the drive shaft and which has the main suction port and the sub suction port,

the spool being axially movably arranged in the cylindrical member.

3. A piston-type variable displacement compressor according to Claim 1, wherein the spool comprises:

a first spool movably arranged in order to open and close the main suction port and adapted to receive the suction chamber pressure,
a second spool movably arranged on a back portion of the first spool and adapted to receive the crank chamber pressure, and
a spring arranged between the first spool and the second spool,
during maximum displacement operation, the second spool moving away from the first spool to totally open the main suction port without exerting any load due to the spring on the first spool, and
during variable displacement operation, the second spool moving toward the first spool to exert a load due to the spring on the first spool to thereby close the main suction port.

4. A piston-type variable displacement compressor according to Claim 1, wherein the main suction port comprises:

a first suction port for securing a flow rate corresponding to maximum displacement operation, and
a second suction port formed adjacent to the first suction port with respect to a rotating direction of the rotary valve.

5. A piston-type variable displacement compressor according to Claim 1, wherein the sub suction port is constantly open independently of the movement of the spool.

6. A piston-type variable displacement compressor according to Claim 1, further comprising:

a cylinder block defining the plurality of cylinder bores;
a front housing connected to a front end portion of the cylinder block and defining the crank chamber; and
a rear housing connected to a rear end portion of the cylinder block and defining the suction chamber,
the drive shaft being rotatably supported by the cylinder block and the front housing.

7. A piston-type variable displacement compressor according to Claim 6, wherein the rotary valve is arranged in the cylinder block.

8. A piston-type variable displacement compressor according to Claim 1, wherein a first communication passage providing communication between the crank chamber and the rotary valve is formed in the drive shaft.

9. A piston-type variable displacement compressor according to Claim 6, further comprising:

a discharge chamber formed in the rear housing;
a second communication passage establishing communication between the crank chamber and the discharge chamber;
a bleeding passage establishing communication between the crank chamber and the suction chamber; and
a displacement control valve arranged in the second communication passage and adapted to control the pressure in the crank chamber through adjustment of the opening of the second communication passage.

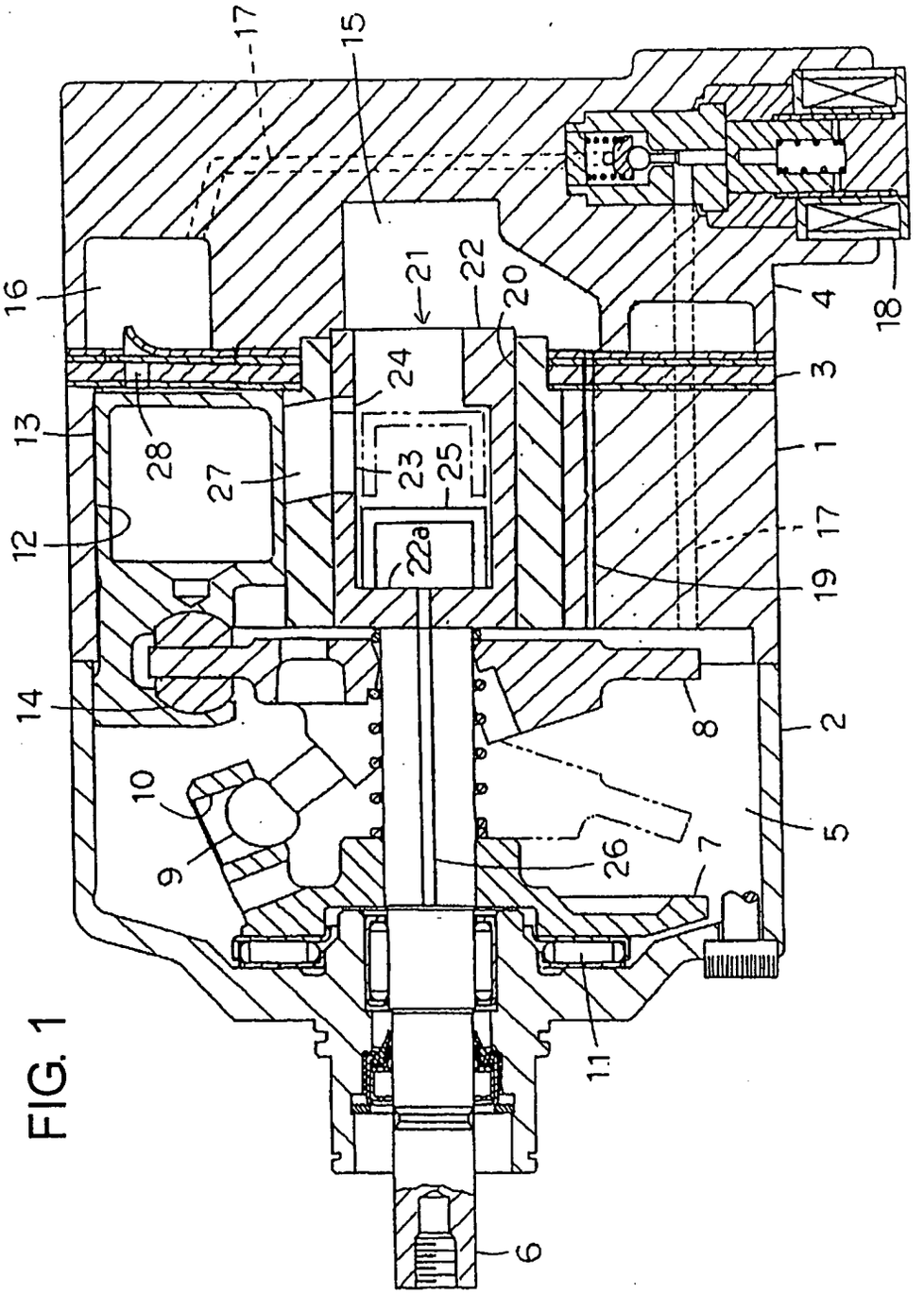

17
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28
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22a
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FIG. 1

FIG. 2

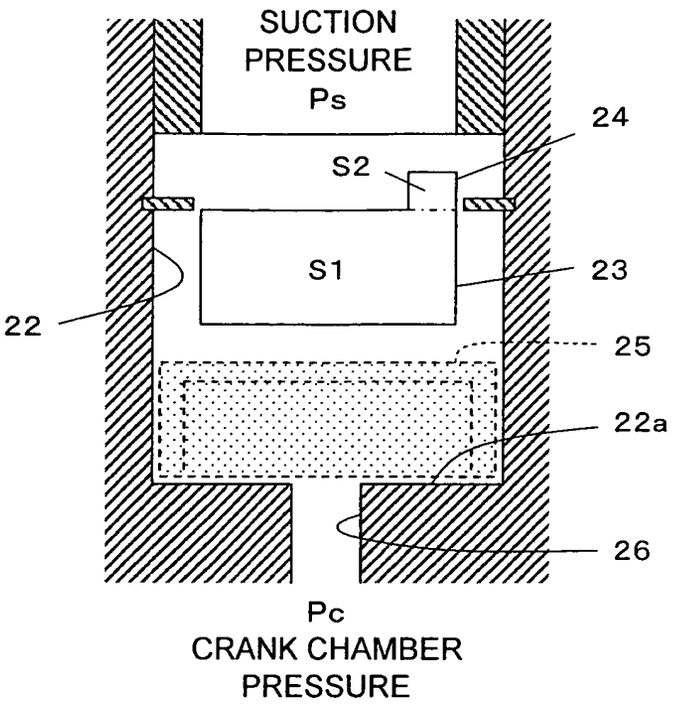

SUCTION
PRESSURE
Ps
24
S2
S1
23
22
25
22a
26
Pc
CRANK CHAMBER
PRESSURE

FIG. 3

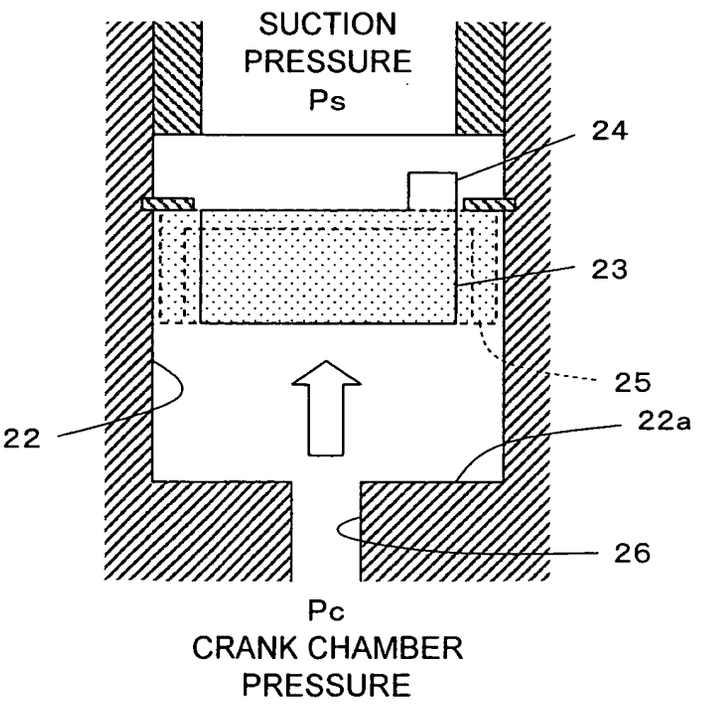

SUCTION
PRESSURE
Ps
24
23
25
22
22a
26
Pc
CRANK CHAMBER
PRESSURE

FIG. 4

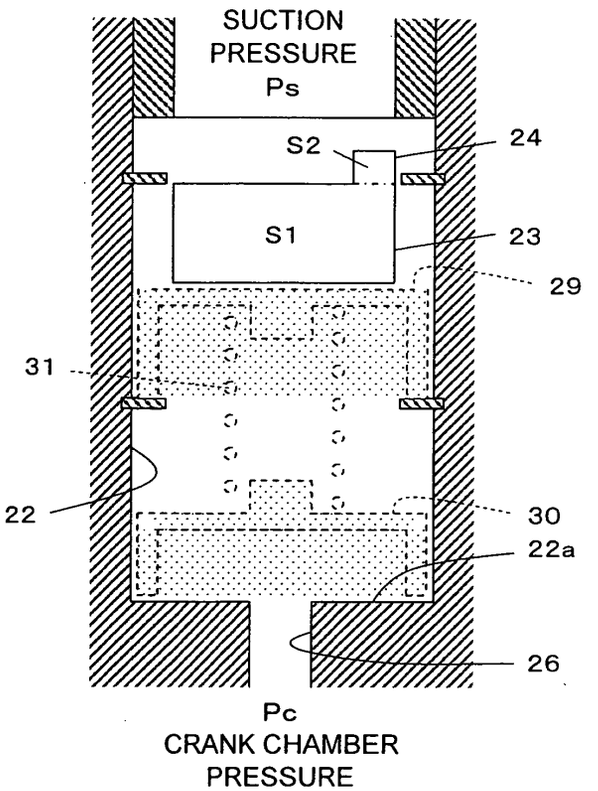

SUCTION
PRESSURE
Ps
S2
24
S1
23
29
31
22
30
22a
26
Pc
CRANK CHAMBER
PRESSURE

FIG. 5

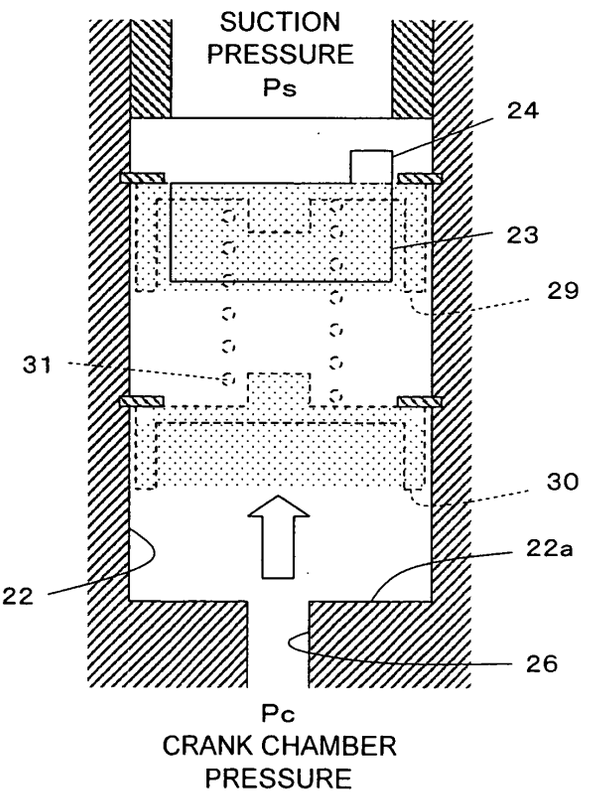

SUCTION
PRESSURE
Ps
24
23
29
31
30
22a
22
26
Pc
CRANK CHAMBER
PRESSURE

FIG. 6

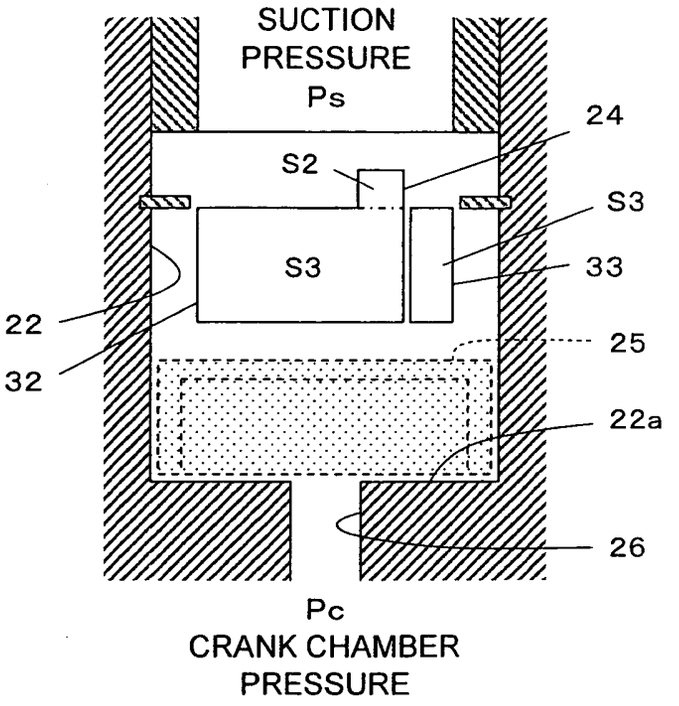
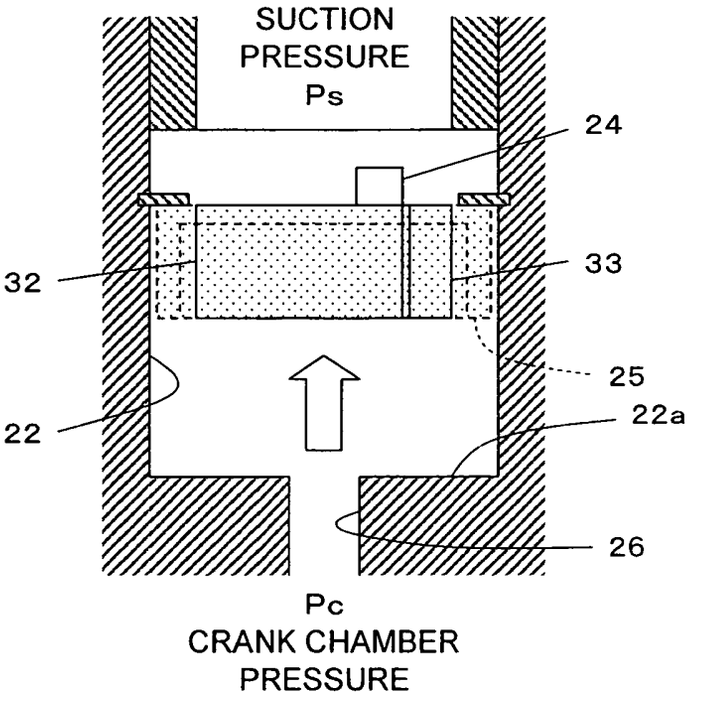

SUCTION
PRESSURE
Ps
24
S2
S3
S3
33
22
25
32
22a
26
Pc
CRANK CHAMBER
PRESSURE

FIG. 7


SUCTION
PRESSURE
Ps
24
32
33
25
22
22a
26
Pc
CRANK CHAMBER
PRESSURE