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(71) Applicant: **Mitsubishi Electric Corporation**
Tokyo 100-8310 (JP)

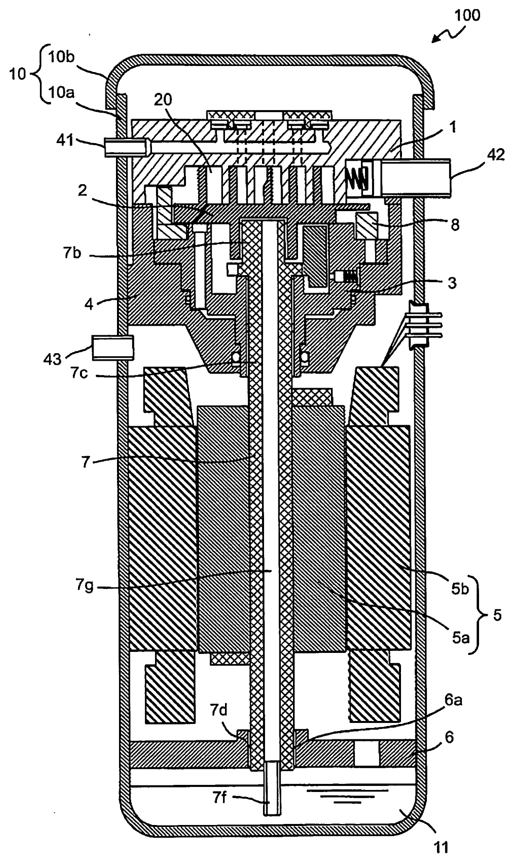
(72) Inventors:
- **MYOGAHARA, Masashi**
  Tokyo 100-8310 (JP)
- **NISHIKI, Teruhiko**
  Tokyo 100-8310 (JP)
- **TAKAHASHI, Hiroyasu**
  Tokyo 100-8310 (JP)
- **MISAKA, Rei**
  Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner GbR**
Theresienhöhe 13
80339 München (DE)

(54) HEAT PUMP DEVICE, COMPRESSOR WITH INJECTION MECHANISM, AND METHOD OF MANUFACTURING SCROLL COMPRESSOR WITH INJECTION MECHANISM

(57) To prevent not fully compressed refrigerant from flowing in an injection circuit. A compressor comprises compressing portions 1 and 2 that form a compression chamber 20 and compress a sucked refrigerant sucked in by the compression chamber 20, the sucked refrigerant being compressed from a suction pressure to a discharge pressure; and a refrigerant injecting portion that injects an injection refrigerant into an intermediate pressure portion where the sucked refrigerant has an intermediate pressure, which is higher than the suction pressure and lower than the discharge pressure, in the compression chamber 20. The refrigerant injecting portion comprises a refrigerant inlet chamber 1e, which the injection refrigerant enters from an injection circuit via an injection pipe 41; and an on-off valve chamber 1f that is connected to the refrigerant inlet chamber 1e and the intermediate pressure portion of the compression chamber 20. The on-off valve chamber 1f is formed with a connection port to the refrigerant inlet chamber 1e and a connection pipe to the intermediate pressure portion on the same surface in the chamber. The on-off valve chamber 1f is provided with an on-off valve 30 that opens and closes the connection port to the refrigerant inlet chamber 1e according to a pressure difference between a refrigerant on the refrigerant inlet chamber 1e side and a refrigerant on the intermediate pressure portion side.

Fig. 1



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Description

Technical Field

[0001] The present invention relates to a heat pump apparatus equipped with an injection circuit and an injectable compressor equipped with an injection mechanism, for example. The present invention also relates to a method of producing a scroll compressor equipped with an injection mechanism.

Background Art

[0002] There is a compressor equipped with an injection mechanism for supplying a high-pressure refrigerant from a condenser to a compression chamber through an injection circuit (see Patent Document 1).

Related Art Document

Patent Document

[0003]

Patent Document 1: JP 2006-112708 A

Disclosure of the Invention

Problems to be Solved by the Invention

[0004] With a scroll compressor equipped with an injection mechanism, not fully compressed refrigerant in a compression chamber flows out to an injection circuit side, when the valve of the injection circuit (a third expansion valve 14 shown in Fig. 1 of Patent Document 1) is closed and an injection operation is not performed. More specifically, the injection circuit has a dead volume in the process of compression while the injection operation is not performed. This results in a reduction in compression efficiency.
The not fully compressed refrigerant in the compression chamber also flows out to a condenser side in the injection circuit when the pressure of the compression chamber becomes transiently higher than the pressure of an immediate refrigerant having just flown out from the condenser.
It is an object of the present invention to prevent such not fully compressed refrigerant in a compression chamber from flowing out to an injection circuit side, for example.

Means to Solve the Problems

[0005] A heat pump apparatus according to this invention includes, for example:

a main refrigeration circuit including a compressor, a radiator, a first expansion valve and an evaporator connected in series;
an injection circuit connecting a portion between the radiator and the first expansion valve in the main refrigeration circuit and an injection pipe mounted on the compressor, the injection circuit including a second expansion valve; and
a mechanism that closes a flow channel between the injection pipe on the compressor and a compression chamber when an opening of the second expansion valve is reduced, and opens the flow channel between the injection pipe on the compressor and the compression chamber when the opening of the second expansion valve is increased.

[0006] The mechanism operates based on a pressure difference between a refrigerant flowing in the main refrigerant circuit and a refrigerant flowing in the injection circuit.
[0007] The mechanism includes:

a refrigerant inlet chamber provided in the flow channel, the refrigerant inlet chamber letting the refrigerant flow in from the injection circuit through the injection pipe; and
an on-off valve chamber provided in the flow channel between the refrigerant inlet chamber and the compression chamber, the on-off valve chamber being connected to the refrigerant inlet chamber and the compression chamber, formed with a connection port to the refrigerant inlet chamber and a connection port to the compression chamber, which are formed on a same surface of the on-off valve chamber, and including an on-off valve that opens and closes the connection port to the refrigerant inlet chamber based on a pressure difference between a refrigerant on a refrigerant inlet chamber side and a refrigerant on a compression chamber side.

[0008] An injectable compressor according to this invention includes:

a compressing portion forming a compression chamber, and compressing a sucked refrigerant sucked in by the compression chamber from a suction pressure to a discharge pressure, and
a refrigerant injecting portion injecting an injection refrigerant into an intermediate pressure portion where the sucked refrigerant has an intermediate pressure, which is higher than the suction pressure and lower than the discharge pressure, in the compression chamber formed by the compressing portion.

The refrigerant injecting portion includes:

a refrigerant inlet chamber in which the injection refrigerant flows from outside; and
an on-off valve chamber connected to the refrigerant

inlet chamber and the intermediate pressure portion of the compression chamber, and formed with a connection port to the refrigerant inlet chamber and a connection port to the compression chamber, which are formed on a same surface in the on-off valve chamber.

The on-off valve chamber includes an on-off valve opening and closing the connection port to the refrigerant inlet chamber based on a pressure difference between a refrigerant on a refrigerant inlet chamber side and a refrigerant on a compression chamber side.

[0009] The on-off valve is a plate member placed movably along a predetermined moving direction in the on-off valve chamber, the plate member being formed with a hole at a position overlapping with the connection port to the intermediate pressure portion when the connection port to the refrigerant inlet chamber is closed.

[0010] The on-off valve is formed with a guide hole through which a guide rod extends in the moving direction in the on-off valve chamber.

[0011] The on-off valve chamber is formed into a cylindrical shape with a bottom surface where the connection port to the refrigerant inlet chamber and the connection port to the intermediate pressure portion are formed. The on-off valve is a circular plate member formed with the guide hole, the guide hole being engaged with the guide rod to prevent the on-off valve from rotating around the guide rod.

[0012] The on-off valve chamber is formed into a cylindrical shape with a bottom surface where the connection port to the refrigerant inlet chamber and the connection port to the intermediate pressure portion are formed. The on-off valve is formed into a shape of a circle whose diameter is smaller than a diameter of the bottom surface of the on-off valve chamber. The on-off valve is formed with the guide hole having a size substantially the same as the circumference of the guide rod and a shape substantially the same as a peripheral shape of the guide rod.

[0013] The on-off valve is a plate spring.

[0014] The compressing portion includes:

an orbiting scroll including orbiting spiral teeth formed on an upper surface side of an orbiting base plate; and

a fixed scroll including fixed spiral teeth formed on a lower surface side of a fixed base plate, the fixed spiral teeth being engaged with the orbiting spiral teeth of the orbiting scroll to form the compression chamber. The refrigerant inlet chamber is a chamber formed inside the fixed base plate, extending from a side portion of the fixed base plate. The on-off valve chamber is a chamber formed on an upper surface side of the fixed base plate.

[0015] The on-off valve chamber is a chamber formed by covering a recess formed on the upper surface side of the fixed base plate with a backplate.

[0016] The compressing portion includes a pair of the orbiting spiral teeth of the orbiting scroll and the fixed spiral teeth of the fixed scroll engaged with each other to form a paired compression chamber. The on-off valve chamber is provided for each compression chamber of the paired compression chamber.

[0017] The injectable compressor further includes:

a hermetically sealed container storing the compressing portion and the refrigerant injecting portion, and

an injection pipe mounted through a side surface of the hermetically sealed container for allowing the injection refrigerant to flow into the refrigerant inlet chamber from outside.

[0018] The hermetically sealed container includes:

a lower container; and

an upper container combined with the lower container to create a hermetically sealed space inside the hermetically sealed container.

The injection pipe is mounted through a side surface of the lower container.

[0019] A method of producing an injectable scroll compressor according to this invention includes:

forming orbiting spiral teeth on a surface of one side of an orbiting base plate;

forming fixed spiral teeth on a surface of one side of a fixed base plate;

forming a side hole on a side portion of the fixed base plate;

forming a recess on a surface of another side of the fixed base plate;

forming on the fixed base plate a first communication hole that connects a bottom surface of the recess and the side hole, and a second communication hole that connects the bottom surface of the recess and the surface of the one side of the fixed base plate;

placing an on-off valve in the recess formed on the fixed base plate, the on-off valve opening and closing the first communication hole;

mounting a backplate on the fixed base plate so that the backplate covers an opening of the recess where the on-off valve is placed;

placing in a hermetically sealed container the orbiting base plate formed with the orbiting spiral teeth;

placing in the hermetically sealed container the fixed base plate formed with the fixed spiral teeth so that the fixed spiral teeth are engaged with the orbiting spiral teeth to form a compression chamber;

connecting a suction pipe to a suction opening of the compression chamber, the suction pipe allowing a sucked refrigerant to flow into the compression chamber from outside the hermetically sealed container; and connecting an injection pipe to the side hole, the injection pipe allowing an injection refrigerant to flow in the side hole from outside the hermetically sealed container.

Effect of the Invention

[0020] A heat pump apparatus according to this invention opens and closes a flow channel between an injection pipe and a compression chamber according to the opening of a second expansion valve. This can prevent not fully compressed refrigerant in a compression chamber from flowing out to an injection circuit side when an injection operation is not performed or the like.

Brief Description of the Drawings

[0021]

[Fig. 1] Fig. 1 shows a vertical cross section of a scroll compressor 100 according to a first embodiment.
[Fig. 2] Fig. 2 is an enlarged view (1) of an upper portion of the scroll compressor 100 of Fig. 1.
[Fig. 3] Fig. 3 is an enlarged view (2) of the upper portion of the scroll compressor 100 of Fig. 1.
[Fig. 4] Fig. 4 is an enlarged view (3) of the upper portion of the scroll compressor 100 of Fig. 1.
[Fig. 5] Fig. 5 shows a heat pump apparatus equipped with an injection circuit.
[Fig. 6] Fig. 6 shows a Mollier Diagram illustrating a state of a refrigerant in the heat pump apparatus of Fig. 5.
[Fig. 7] Fig. 7 shows relative positions of an orbiting scroll 2 with respect to a fixed scroll 1 at every 90 degrees when suction is completed at 0 degree.
[Fig. 8] Fig. 8 is an exploded perspective view illustrating a configuration of an injection chamber 1f.
[Fig. 9] Fig. 9 shows a vicinity of one of injection chambers 1f when an injecting operation is performed.
[Fig. 10] Fig. 10 shows a vicinity of one of the injection chambers 1f when the injecting operation is not performed.
[Fig. 11] Fig. 11 is a vertical cross section of the scroll compressor 100 according to a second embodiment.

Best Mode for Carrying out the Invention

[0022] Embodiments of the present invention will be described with reference to the drawings.
In the following description, a term "injection" is defined as to return a liquid refrigerant, a two-phase refrigerant, or a gas refrigerant (of high pressure) discharged from a condenser back to a compression chamber of a compressor to be compressed again. In addition, a liquid refrigerant, a two-phase refrigerant, or a gas refrigerant (of high pressure) passed through a condenser is called an injection refrigerant. It is to be noted that the refrigerant passed through a condenser may not necessarily be an immediate refrigerant having just passed through a condenser. The refrigerant may be one having just passed a predetermined expansion valve, a predetermined heat exchanger or the like. The condenser may be read as a radiator, a heat exchanger to heat the load side, or a gas cooler.

Embodiment 1.

[0023] Fig. 1 shows a vertical cross section of a scroll compressor 100 according to a first embodiment. The scroll compressor 100 is an injectable compressor equipped with an injection mechanism, as described later.
Fig. 2 to Fig. 4 show enlarged views of the same upper portion of the scroll compressor 100 shown in Fig. 1. Specifically, Fig. 2 mainly illustrates a fixed scroll 1, Fig. 3 mainly illustrates an orbiting scroll 2, and Fig. 4 mainly illustrates a compliant frame 3 and a guide frame 4. Broken lines in Fig. 1 to Fig. 4 indicate components that usually cannot be seen.
[0024] First of all, the configuration of the scroll compressor 100 is described.
As shown in Fig. 1, the scroll compressor 100 is formed to include the fixed scroll 1, the orbiting scroll 2, the compliant frame 3, the guide frame 4, an electric motor 5, a sub frame 6, a main shaft 7, and an Oldham mechanism 8, all of which are stored in a hermetically sealed container 10.
It is to be noted that the fixed scroll 1 and the orbiting scroll 2 are generically called a compressing portion.
[0025] The fixed scroll 1 is now described with reference to Fig. 1 and Fig. 2.
The outer surface of the fixed scroll 1 is fixed to the guide frame 4 by bolts to be secured.
On a surface on one side (the lower side in Fig. 2) of a base plate 1a of the fixed scroll 1, plate spiral teeth 1b (fixed spiral teeth) are formed. The spiral teeth 1b of the fixed scroll 1 and spiral teeth 2b (orbiting spiral teeth), described later, of the orbiting scroll 2 are engaged with each other to form a compression chamber 20.
On an outer surface of the one side (the lower side in Fig. 2) of the base plate 1a, two substantially linear Oldham guide grooves 1c are formed. The Oldham guide grooves 1c are engaged with nails 8b of the Oldham mechanism 8 in such a manner as to enable the nails to slide backwards and forwards.
[0026] A discharge port 1d is formed through the base plate 1a substantially at a central portion thereof. A refrigerant inlet chamber 1e is formed inside the base plate 1a from a side portion thereof to allow an injection refrigerant to flow in from an injection circuit outside the hermetically concealed container 10 via an injection pipe 41 (a refrigerant inlet port). The injection pipe 41 is mounted at the side portion of the base plate la through the hermetically sealed container 10.

On a surface of the other side (the upper side in Fig. 2) of the base plate 1a, there are two on-off valve chambers 1f (check valve chambers), which are sealed by a back plate 31 covering the openings of two recesses. Each of the on-off valve chambers 1f has connection ports on the bottom surface: one is connected to an inlet chamber communication channel 1g (an inlet chamber communication hole, or a first communication hole) communicating with the refrigerant inlet chamber 1e, and the other is connected to a compression chamber communication channel 1h (a compression chamber communication hole, or a second communication hole) communicating with the compression chamber 20. Inside each on-off valve chamber 1f, an on-off valve 30 (a check valve) is stored.

The on-off valve 30 and the backplate 31 will be described later in detail.

It is to be noted that a mechanism for injecting the injection refrigerant into the compression chamber, including such as the refrigerant inlet chamber 1e, the inlet chamber communication channel 1g, the on-off valve chamber 1f, the compression chamber communication channel 1h, the on-off valve 30, and the backplate 31, is called a refrigerant injecting portion.

[0027] The orbiting scroll 2 is now described with reference to Fig. 1 and Fig. 3.

On a surface of one side (the upper side in Fig. 3) of a base plate 2a of the orbiting scroll 2, and plate spiral teeth 2b, which are substantially the same in shape as the spiral teeth 1b of the fixed scroll 1, are formed. As described earlier, the spiral teeth 1b of the fixed scroll 1 and the spiral teeth 2b of the orbiting scroll 2 are engaged with each other to form the compression chamber 20.

On an outer surface of the base plate 2a on the opposite side (the lower side in Fig. 3) to the side where the spiral teeth 2b are formed, two substantially linear Oldham guide grooves 2e are formed. The Oldham guide grooves 2e each have a substantially 90 degree phase difference from one of the Oldham guide grooves 1c of the fixed scroll 1. Each Oldham guide groove 2e is engaged with a nail 8a of the Oldham mechanism 8 in such a manner as to enable the nail to slide backwards and forwards.

[0028] At a central portion of the base plate 2a on the opposite surface (the lower side in Fig. 3) to the surface where the spiral teeth 2b are formed, a cylindrical hollow is formed as a boss portion 2f having an orbiting shaft bearing 2c inside. The orbiting shaft bearing 2c is engaged with an orbiting shaft portion 7b provided at an upper end of the main shaft 7. It is to be noted that a gap between the orbiting shaft bearing 2c and the orbiting shaft portion 7b is called a boss gap 15a.

On the outer diameter side of the boss portion 2f, a thrust surface 2d is formed slidably under pressure against a thrust bearing 3a of the compliant frame 3. It is to be noted that a gap between the thrust surface 2d of the orbiting scroll 2 and the compliance frame 3 on the outer diameter side of the boss portion 2f is called a boss peripheral gap 15b. A gap between the base plate 2a of the orbiting scroll 2 and the compliant fame 3 on the outer diameter side of the thrust bearing 3a is called a base plate peripheral gap 15c. The base plate peripheral gap 15c is a low pressure space under suction gas environmental pressure (suction pressure).

The base plate 2a also has a bleed hole 2j, which is formed through the base plate from the surface of the fixed scroll 1 side (the upper side in Fig. 3) to the surface of the compliant frame 3 side (the lower side in Fig. 3). In other words, the bleed hole 2j is provided on the base plate 2a to allow a space on the side of the compression chamber 20 to be communicated with a space on the side of the thrust surface 2d. More specifically, the bleed hole 2j is arranged so that the circle trajectory of an opening of the bleed hole 2j on the compliant frame 3 side (a lower opening 2k) during normal operation always stays within the thrust bearing 3a of the compliant frame 3. This arrangement prevents leakage of refrigerant from the bleeding hole 2j to the boss peripheral gap 15b or the base plate peripheral gap 15c.

[0029] The compliant frame 3 and the guide frame 4 are now described with reference to Fig. 1 and Fig. 4.

The compliant frame 3 is supported by cylindrical surfaces 4a and 4b formed on the inner peripheral surface of the guide frame 4, in the radial direction at two surfaces formed on the outer peripheral surface, upper and lower cylindrical surfaces 3d and 3e. At a central portion of the compliant frame 3, a main shaft bearing 3c and an auxiliary main shaft bearing 3h are formed to support in the radial direction, the main shaft 7 driven by the electric motor 5 for rotation.

It is to be noted that a gap between the guide frame 4 and the compliant frame 3, which is separated by ring-shaped seal materials 16a and 16b at upper and lower portions, is called a frame gap 15d. There are two ring-shaped seal grooves formed on the inner peripheral surface of the guide frame 4 to store the seal materials 16a and 16b. These seal grooves, however, may alternatively be formed on the outer peripheral surface of the compliant frame 3.

The compliant frame 3 is also formed with a communication hole 3s at a position facing the lower opening 2k of the bleeding hole 2j. The communication hole 3s is formed through the compliant frame 3, extending from the thrust bearing 3a side to the frame gap 15d side to allow the bleeding hole 2j to communicate with the frame gap 15d constantly or intermittently.

The compliant frame 3 also has an adjustment valve space 3p in which a valve 3t, a valve holder 3y, and an intermediate pressure adjustment spring 3m are stored for adjusting the pressure of the boss peripheral gap 15b. The intermediate pressure adjustment spring 3m is made shorter than its original length when stored in the adjustment valve space 3p. It is to be noted that a gap between the compliant frame 3 and the guide frame 4 on the outer diameter side of the valve 3t is called a valve peripheral gap 15e.

The compliant frame 3 also has a reciprocating sliding portion 3x formed on the outer diameter side of the thrust bearing 3a. The reciprocating sliding portion 3x allows an Oldham mechanism annular portion 8c to move slidably backwards and forwards. The reciprocating sliding portion 3x has a communication hole 3n that allows the valve peripheral gap 15e to communicate with the base plate peripheral gap 15c.

[0030] The guide frame 4 is fixed to the hermetically sealed container 10 by shrink fitting or welding on the outer peripheral surface. However, the guide frame 4 has cuts formed on its outer peripheral surface, so there is a flow channel secured for allowing the refrigerant discharged from the discharge port 1d to flow to the discharge pipe 43.

On the inner peripheral surface of the guide frame 4 on the fixed scroll 1 side (the upper side in Fig. 4), the upper fitting cylindrical surface 4a is formed. The upper fitting cylindrical surface 4a is engaged with the upper fitting cylindrical surface 3d formed on the outer peripheral surface of the compliant frame 3.

On the inner peripheral surface of the guide frame 4 on the electric motor 5 side (the lower side in Fig. 4), the lower fitting cylindrical surface 4b is formed. The lower fitting cylindrical surface 4b is engaged with the lower fitting cylindrical surface 3e formed on the outer peripheral surface of the compliant frame 3.

[0031] The main shaft 7 is now described with reference to Fig. 1.

On the orbiting scroll 2 side of the main shaft 7 (the upper side in Fig. 1), the orbiting shaft portion 7b is formed so that it is rotatably attached to the orbiting shaft bearing 2c of the orbiting scroll 2. On a lower side of the orbiting shaft portion 7b, a main shaft portion 7c is formed so that it is rotatably attached to the main shaft bearing 3c and the auxiliary main shaft bearing 3h of the compliant frame 3.

On the opposite side of the main shaft 7 (the lower side in Fig. 1), a sub shaft portion 7d is formed so that it is rotatably attached to a sub shaft bearing 6a of the sub frame 6. Between the sub shaft portion 7d and the main shaft portion 7c, a rotor 5a of the electric motor 5 is shrink fitted. The rotor 5a is surrounded by a stator 5b.

Inside the main shaft 7, a high-pressure oil feed hole 7g is formed in the axial direction through the main shaft 7. Into the lower end surface of the main shaft 7, an oil pipe 7f communicating with the high-pressure oil feed hole 7g is press fitted.

[0032] An operation of the scroll compressor 100 is now described.

A low pressure sucked refrigerant enters, via a suction pipe 42, the compression chamber 20 formed by the spiral teeth 1b of the fixed scroll 1 and the spiral teeth 2b of the orbiting scroll 2. The injection refrigerant flowing in via the injection pipe 41 from outside is also injected into the compression chamber 20 through the refrigerant inlet chamber 1e, the inlet chamber communication channel 1g, the on-off valve chamber 1f, and the compression chamber communication channel 1h. If an injection operation is not performed, the injection refrigerant is not injected into the compression chamber 20.

The main shaft 7 is driven by the electric motor 5 to operate the orbiting scroll 2. The orbiting scroll 2 does not rotate itself but orbits (eccentric circling movement) by the Oldham mechanism 8, and performs a compression operation to increasingly reduce the volume of the compression chamber 20. This compression operation allows the sucked refrigerant to have high pressure. The high pressure sucked refrigerant is then discharged into the hermetically sealed container 10 through the discharge port 1d of the fixed scroll 1. The discharged refrigerant is discharged outside the hermetically sealed container 10 through the discharge pipe 43. Therefore, the internal pressure of the hermetically sealed container 10 is increased.

[0033] As described above, the internal pressure of the hermetically sealed container 10 is increased during steady operation. This high pressure causes refrigerant oil 11 accumulated at the bottom of the hermetically sealed container 10 to flow towards the orbiting scroll 2 side (the upper side in Fig. 1) through the oil pipe 7f and the high pressure oil feed hole 7g. The high pressure refrigerant oil then flows through the boss gap 15a where the pressure of the refrigerant oil is reduced to an intermediate pressure Pm 1, which is higher than suction pressure and the same or lower than discharge pressure, into the boss peripheral gap 15b.

The high pressure oil flowing through the high-pressure oil feed hole 7g is led to the gap between the main shaft bearing 3c and the main shaft portion 7c from a horizontal hole provided on the main shaft 7. The pressure of the refrigerant oil between the main shaft bearing 3c and the main shaft portion 7c is reduced to the intermediate pressure Pm 1, which is higher than the suction pressure and the same or lower than the discharge pressure. Then, the refrigerant oil flows in the boss peripheral gap 15b.

It is to be noted that the refrigerant oil having the intermediate pressure Pm 1 in the boss peripheral gap 15b generally becomes two-phase of gas refrigerant and refrigerant oil by the foaming of refrigerant dissolved in the refrigerant oil.

[0034] The refrigerant oil having the intermediate pressure Pm 1 in the boss peripheral gap 15b flows to the valve peripheral gap 15e through the adjustment valve space 3p. The refrigerant oil in the valve peripheral gap 15e is discharged to the inner side of the Oldham mechanism annular portion 8c through the communication hole 3n. More specifically, the refrigerant oil, when passing through the adjustment valve space 3p, pushes up the intermediate pressure adjustment valve 3t against additional pressure applied by the intermediate pressure adjustment spring 3m, and then flows into the valve peripheral gap 15e.

The refrigerant oil having the intermediate pressure Pm 1 in the boss peripheral gap 15b is fed to the thrust surface 2d of the orbiting scroll 2 and the sliding portion of the thrust bearing 3a of the compliant frame 3, and then discharged to the inner side of the Oldham mechanism annular portion 8c.

The refrigerant oil discharged to the inner side of the Oldham mechanism annular portion 8c is fed to the sliding surface of the Oldham mechanism annular portion 8c and also to the surfaces where the nail 8a and a nail 8b of the Oldham mechanism 8 slide, and then released to the base plate peripheral gap 15c.

[0035] It is also to be noted that the intermediate pressure Pm 1 in the boss peripheral gap 15b is expressed as "Pm 1 = Ps + α", where α is a predetermined pressure almost determined by the spring power of the intermediate pressure adjustment spring 3m and the exposed area of the intermediate pressure adjustment valve 3t, and Ps is a suction environmental pressure, i.e., a low pressure.

[0036] The lower opening 2k of the bleeding hole 2j communicates constantly or intermittently with an opening provided on the thrust bearing 3a side (an upper opening 3u shown in Fig. 4) of the communication hole 3s on the compliant frame 3. This causes not fully compressed refrigerant gas in the compression chamber 20 to be led to the frame gap 15d via the bleeding hole 2j of the orbiting scroll 2 and the communication hole 3s of the compliant frame 3. This refrigerant gas, since it has not been fully compressed, has an intermediate pressure Pm 2, which is higher than the suction pressure and the same or lower than the discharge pressure.

Referring to the refrigerant gas led to the frame gap 15d, a very small amount of the refrigerant gas flows in both directions between the compression chamber 20 and the frame gap 15d during normal operation in response to a change in pressure of the compression chamber 20 because the frame gap 15d is a closed space hermetically sealed by the upper seal material 16a and the lower seal material 16b. In other words, the compression chamber 20 and the frame gap 15d seem like breathing.

[0037] It is to be noted that the intermediate pressure Pm 2 in the frame gap 15d is expressed as "Pm 2 = Ps $\times \beta$", where β is a predetermined multiplying factor almost determined by the position of the compression chamber 20, which communicates with the frame gap 15d, and Ps is the suction environmental pressure, i.e., a low pressure.

[0038] It is also to be noted that a total force (A+B) of force (A) caused by the intermediate pressure Pm 1 of the boss peripheral gap 15b and force (B) caused by pressure from the orbiting scroll 2 via the thrust bearing 3a acts on the compliant frame 3 as a downward force.

In addition, the total force (C+D) of force (C) caused by the intermediate pressure Pm 2 of the frame gap 15d and force (D) caused by a high pressure acting on a portion exposed to the high-pressure environment on a lower end surface also acts on the compliant frame 3 as an upward force.

The upward force (C+D) is set to be larger than the downward force (A+B) during normal operation.

[0039] During normal operation, the compliant frame 3 is lifted upwards towards the fixed scroll 1 side (the upper side in Fig. 1) since the upward force (C+D) is thus set to be larger than the downward force (A+B). More specifically, the compliant frame 3 is thus lifted towards the fixed scroll 1 (the upper side in Fig. 1) when the upper fitting cylindrical surface 3d is guided by the upper fitting cylindrical surface 4a of the guide frame 4, and the lower fitting cylindrical surface 3e is guided by the lower fitting cylindrical surface 4b of the guide frame 4. More specifically, the compliant frame 3 is thus lifted towards the fixed scroll 1 (the upper side in Fig. 1), and thereby pressed against the orbiting scroll 2 via the thrust bearing 3a.

The orbiting scroll 2 is also lifted towards the fixed scroll 1 side (the upper side in Fig. 1) like the compliant frame 3, since the compliant frame 3 is pressed against the orbiting scroll 2. As a result, the tips of the spiral teeth 2b of the orbiting scroll 2 come in contact with the base of teeth (the base plate 1a) of the fixed scroll 1, and also the tips of the spiral teeth 1b of the fixed scroll 1 come in contact with the base of teeth (the base plate 2a) of the orbiting scroll 2.

[0040] On the other hand, in a transitional period such as when the compressor starts to operate, or in such a case where the internal pressure of the compression chamber 20 is abnormally increased, the force (B) caused by pressure from the orbiting scroll 2 via the thrust bearing 3a becomes large. Therefore, the downward force (A+B) becomes larger than the upward force (C+D). As a result, the compliant frame 3 is pressed towards the guide frame 4 side (the lower side in Fig. 1). Then, the tips of the spiral teeth 2b of the orbiting scroll 2 are detached from the base of teeth of the fixed scroll 1 (the base plate 1a), and also the tips of the spiral teeth 1b of the fixed scroll 1 are detached from the base of teeth of the orbiting scroll 2 (the base plate 2a). Consequently, the internal pressure of the compression chamber 20 is reduced, thereby preventing the internal pressure of the compression chamber 20 from rising too much.

[0041] An operation of a heat pump apparatus (a refrigeration cycle apparatus) equipped with the scroll compressor 100 is now described. Fig. 5 shows an example of a circuit configuration of a heat pump apparatus equipped with an injection circuit. Fig. 6 is a Mollier diagram illustrating a state of a refrigerant in the heat pump apparatus shown in Fig. 5. Referring to Fig. 6, the horizontal axis indicates specific enthalpy and the vertical axis indicates refrigerant pressure.

[0042] First, an operation performed during heating is described. During heating operation, a four-way valve 58 is set so that a refrigerant flows in a course indicated by solid lines. It is to be noted that the heating operation here includes air heating for air conditioning and water heating for heating water to produce hot water.

The high-temperature high-pressure gas refrigerant (point 1 in Fig. 6) at a compressor 51 (the scroll compressor 100) is discharged through a discharge pipe 43 of the compressor 51. The high-temperature high-pressure gas refrigerant then enters a heat exchanger 52, as a condenser or a radiator, where heat is exchanged, and liquefies (point 2 in Fig. 6). During this process, heat absorbed from the refrigerant heats air or water to be used for air conditioning or water heating.

The liquid refrigerant from the heat exchanger 52 passes through a first expansion valve 53 (a pressure reducing mechanism) where pressure is reduced to an intermediate pressure, and thereby turns into two-phase gas-liquid (point 3 in Fig. 6). The two-phase gas-liquid refrigerant from the first expansion valve 53 enters a receiver 59 where heat is exchanged with a refrigerant to be sucked in by the compressor 51, and is thereby cooled and liquefied (point 4 in Fig. 6). Then, the flow of the liquid refrigerant from the receiver 59 is divided into a flow (mainstream) to the side including an inner heat exchanger 54 and a third expansion valve 55 and another flow (branch stream or injection circuit) to the side including a second expansion valve 56.

The liquid refrigerant in the mainstream passes through the inner heat exchanger 54 where heat is exchanged with the two-phase gas-liquid refrigerant in the branch stream as a result of pressure reduction through the second expansion valve 56, and is thereby further cooled (point 5 in Fig. 6). The liquid refrigerant as a result of cooling by the inner heat exchanger 54 passes through the third expansion valve 55 (a pressure reducing mechanism) where pressure is reduced, and thereby turns into two-phase gas-liquid (point 6 in Fig. 6). The two-phase gas-liquid refrigerant from the third expansion valve 55 enters a heat exchanger 57 as an evaporator, where heat is exchanged, and is thereby heated (point 7 in Fig. 6). The heated refrigerant from the heat exchanger 57 then passes through the receiver 59 to further absorb heat (point 8 in Fig. 6), and is then sucked in by the compressor 51 through the suction pipe 42.

The refrigerant flowing in the branch stream passes through the second expansion valve 56 (a pressure reducing mechanism) where pressure is reduced (point 9 in Fig. 6), and then enters the inner heat exchanger 54 where heat is exchanged (point 10 in Fig. 6), as described earlier. The two-phase gas-liquid refrigerant (an injection refrigerant) as a result of heat exchange at the inner heat exchanger 54 flows as two-phase gas-liquid in the refrigeration inlet chamber 1e of the fixed scroll 1 via the injection pipe 41 of the compressor 51.

In the compressor 51, the mainstream refrigerant sucked in through the suction pipe 42 (point 8 in Fig. 6) is compressed up to the intermediate pressure and thereby heated (point 11 in Fig. 6). The compressed and heated refrigerant having the intermediate pressure (point 11 in Fig. 6) joins the injection refrigerant (point 8 in Fig. 6) to reduce the temperature (point 12 in Fig. 6). The cooled refrigerant (point 12 in Fig. 6) is then further compressed and heated to increase its temperature and pressure (point 1 in Fig. 6), and then discharged (point 1 in Fig. 6). A compressing operation performed in the compressor 51 will be described further in detail later.

[0043] It is to be noted that the opening of the second expansion valve 56 is closed when the injection operation is not performed. More specifically, during injection operation, the opening of the second expansion valve 56 is increased from a predetermined opening. When the injection operation is not performed, the opening of the second expansion valve 56 is reduced from the predetermined opening. This prevents the injection refrigerant from flowing into the refrigerant inlet chamber 1e of the compressor 51. In other words, all the amount of refrigerant passing through the heat exchanger 52, the first expansion valve 53, and the receiver 59 is sucked in by the compressor 51 via the suction pipe 42.

It is to be noted that the opening of the second expansion valve 56 may be electronically controlled, for example.

[0044] An operation performed during cooling is now described. The four-way valve 58 is set so that a refrigerant flows in a course indicated by broken lines during cooling operation. The high-temperature high-pressure gas refrigerant (point 1 in Fig. 6) from the compressor 51 (the scroll compressor 100) is discharged through the discharge pipe 43 of the compressor 51. The high-temperature high-pressure gas refrigerant then enters the heat exchanger 57 as a condenser, where heat is exchanged, and liquefies (point 2 in Fig. 6). The liquid refrigerant from the heat exchanger 57 then passes through the third expansion valve 55 where pressure is reduced to the intermediate pressure, and thereby turns into two-phase gas-liquid (point 3 in Fig. 6). The two-phase gas-liquid refrigerant from the third expansion valve 55 then enters the inner heat exchanger 54 where heat is exchanged, and is thereby cooled and liquefied (point 4 in Fig. 6). In the inner heat exchanger 54, heat is exchanged between the two-phase gas-liquid refrigerant from the third expansion valve 55 and the two-phase gas-liquid refrigerant from the second expansion valve 56 (point 9 in Fig. 6) where the pressure of the liquid refrigerant from the inner heat exchanger 54 is reduced. The flow of the liquid refrigerant through the inner heat exchanger 54 (point 4 in Fig. 6) is divided into the receiver 59 side (the mainstream) and the inner heat exchanger 54 side (the branch stream, or the injection circuit).

The mainstream liquid refrigerant enters the receiver 59 where heat is exchanged with the refrigerant to be sucked in by the compressor 51, and is thereby further cooled (point 5 in Fig. 6). The cooled liquid refrigerant from the receiver 59 passes through the first expansion valve 53 where pressure is reduced, and thereby turns into two-phase gas-liquid (point 6 in Fig. 6). The two-phase gas-liquid refrigerant from the first expansion valve 53 enters the heat exchanger 52 as an evaporator where heat is exchanged, and is thereby heated (point 7 in Fig. 6). This heat absorption by refrigerant causes air, water, etc. to cool for such as air conditioning, water chilling and icing, and freezing.

The heated refrigerant from the heat exchanger 57 enters the receiver 59 to be further heated (point 8 in Fig. 6), and then sucked in by the compressor 51 via the suction pipe 42.

The refrigerant flowing in the branch stream passes through the second expansion valve 56 where pressure is reduced (point 9 in Fig. 6), and enters the inner heat exchanger 54 where heat is exchanged (point 10 in Fig. 6), as described earlier. The two-phase gas-liquid refrigerant (the injection refrigerant) from the inner heat exchanger 54 flows as two-phase gas-liquid into the refrigerant inlet chamber 1e of the fixed scroll 1 via the injection pipe 41 of the compressor 51.

It is to be noted that the compression operation in the compressor 51 is performed in the same manner as that performed during heating operation.

[0045] It is also to be noted that when the injection operation is not performed, the opening of the second expansion valve 56 is closed to stop the injection refrigerant from flowing into the refrigerant inlet chamber 1e of the compressor 51, in the same manner as that performed during heating operation.

[0046] It is also to be noted that the injection operation is usually performed during heating operation. Therefore, the injection operation is not usually performed during cooling operation. More specifically, the injection operation is not always performed during heating operation. Heating capacity may be enhanced if the injection operation is performed exclusively when the outside temperature is the same or below a predetermined temperature (e.g., 2 °C) or when the rotation frequency of the compressor is the same or higher than a predetermined frequency (e.g., 60 Hz), for example. This can result in achieving a heat pump apparatus having an efficient performance in heating air and water. When the injection operation is not necessary, the injection operation is not performed, even during heating operation, by closing the second expansion valve 56.

The above standard may not necessarily be used to decide whether to carry out the injection operation. Alternatively, the injection operation may be performed during cooling operation, for example.

[0047] As mentioned above, the heat exchanger 52 may be of a type that exchanges heat between a high-temperature high-pressure gas refrigerant or a low-temperature low-pressure liquid refrigerant and liquid such as water. Alternatively, another type of a heat exchanger that exchanges heat between a high-temperature high-pressure gas refrigerant or a low-temperature low-pressure liquid refrigerant and a gas such as air may be employed instead. In other words, the heat pump apparatus illustrated in Fig. 5 and Fig. 6 may alternatively be an air conditioner, a water heater, a freezer, or a refrigerator.

[0048] A compression operation performed by the scroll compressor 100 is now described.

Fig. 7 shows relative positions of an orbiting scroll 2 with respect to a fixed scroll 1 at every 90 degrees when suction is completed at 0 degree.

The spiral teeth 1b of the fixed scroll 1 and the spiral teeth 2b of the orbiting scroll 2 are engaged with each other to form a pair of compression chambers 20a and 20b. It is to be noted that the compression chambers 20a and 20b are generically called the compression chamber 20. The compression chamber 20 moves towards the center while gradually reducing its volume as the orbiting scroll 2 orbits according to the rotation of the main shaft 7. More specifically, a refrigerant sucked in by the compression chamber 20 is gradually compressed to increase its pressure, and moves towards the center as the orbiting scroll 2 orbiting according to the rotation of the main shaft 7. Then, when the compression chamber 20 communicates with the discharge port 1d at a central portion, the compressed refrigerant is discharged into the hermetically sealed container 10 through the discharge port 1d.

[0049] At 0 degree, the suction of the refrigerant is completed, as earlier mentioned. More specifically, at 0 degree, the refrigerant has been sucked in by the compression chamber 20 through the suction pipe 42, and the compression chamber 20 is hermetically sealed.

When the main shaft 7 rotates 90 degrees from 0 degree (a refrigerant suction completion point), the volume of the compression chamber 20 is slightly reduced, and the compression chamber 20 has moved slightly towards the central portion. At this point, the compression chamber 20 communicates with the compression chamber communication channel 1h. This allows the injection refrigerant to flow in the compression chamber communication channel 1h while the injection operation is performed. More specifically, the injection refrigerant is injected to an intermediate pressure portion where the sucked refrigerant sucked in by the compression chamber 20 through the suction pipe 42 has an intermediate pressure, which is higher than the suction pressure (low pressure) at the point when the refrigerant is sucked, and lower than the discharge pressure (high pressure) at the point when the refrigerant is discharged through the discharge port 1d.

The main shaft 7 rotates 180 degrees, 270 degrees and 360 degrees from the refrigerant suction completion point. During the rotation, the compression chamber 20 communicates with the compression chamber communication channel 1h. Therefore, during the rotation while the injection refrigerant continues to flow in the compression chamber 20 through the compression chamber communication channel 1h, the refrigerant in the compressing chamber 20 is increasingly compressed and moves gradually towards the central portion.

When the main shaft 7 rotates more than 360 degrees from the refrigerant suction completion period, the compression chamber 20 terminates the communication with the compression communication channel 1h. Thereafter, the refrigerant in the compression chamber 20 is continued to be compressed with no additional refrigerant flowing in from outside, until the compression chamber 20 communicates with the discharge port 1d.

When the main shaft 7 rotates more than 450 degrees from the refrigerant suction completion period, the compression chamber 20 communicates with the discharge port 1d, and then compressed refrigerant is discharged into the hermetically sealed container 10 through the discharge port 1d.

[0050] When the main shaft 7 rotates 360 degrees from the refrigeration suction completion point, the refrigerant has been sucked in by the outermost compression chamber 20. When the main shaft 7 rotates 450 degrees from the refrigeration suction completion point, the outermost compression chamber 20 begins to communicate with the compression chamber communication channel 1h. In such a manner, the refrigerant is compressed repeatedly in the scroll compressor 100.

[0051] The compression chambers 20a and 20b are arranged so that each of the compression chambers communicates with one of the compression chamber communication channels 1h communicating with the respective on-off valve chambers 1f. More specifically, the base plate 1a of the fixed scroll 1 is formed with the two on-off valve chambers 1f, as mentioned above. The compression chamber 20a is arranged to communicate with one of the two on-off valve chambers 1f, and the compression chamber 20b is arranged to communicate with the other on-off valve chamber 1f.

[0052] A configuration of the on-off valve chamber 1f is now described.

Fig. 8 is an exploded perspective view illustrating a configuration of the on-off valve chamber 1f. Referring to Fig. 8, broken lines indicate components that are usually invisible.

The two on-off valve chambers 1f are formed by covering two cylindrical recesses, which are formed on the opposite side to the side where spiral teeth 1b of the base plate 1a are formed in the fixed scroll 1, with the backplate 31, and fastening the backplate 31 with bolts 34 to seal the recesses. With this example, one piece of the backplate 31 is used to cover both the openings of the two recesses. Alternatively, however, a separate piece of the backplate 31 may be used to cover each recess.

On the bottom surface of each recess, a connection port to the inlet chamber communication channel 1g and a connection port to the compression chamber communication channel 1h are formed. The inlet chamber communication channel 1g communicates with the refrigerant inlet chamber 1e formed by extending inwards from a side portion of the base plate 1a. The compression chamber communication channel 1h communicates with a surface on the spiral teeth 1b side. More specifically, the compression chamber communication channel 1h communicates with the compression chamber 20. In other words, a connection port to the refrigerant inlet chamber 1e and a connection port to the compression chamber 20 are formed on the bottom surface of each recess.

[0053] Each of the on-off valve chambers 1f is provided with the on-off valve 30 that is formed like a circular plate whose diameter is almost the same or slightly smaller than the bore diameter of the recess. The on-off valve 30 is formed with a passage hole 30a and a guide hole 30b. The on-off valve 30 is placed so that the passage hole 30a overlaps with the connection port of the compression chamber communication channel 1h. The on-off valve 30 is placed in the on-off valve chamber 1f with a guide projection 31a (a guide rod), which is formed on the backplate 31, inserted through the guide hole 30b.

The guide projection 31a is a projection extending like a stick perpendicularly (an up-down direction in Fig. 1, a vertical direction) to the surface where the inlet chamber communication channel 1g and the compression chamber communication channel 1h are formed. The guide hole 30b is formed like a keyhole, and the guide projection 31a is formed like a key in a corresponding manner. Therefore, the on-off valve 30 is allowed to move in the vertical direction to the direction of the surface of the fixed base plate (the up-down direction in Fig. 1) in the on-off valve chamber 1f. However, the on-off valve 30 is not allowed to rotate around the guide projection 31a since the guide hole 30b and the guide projection 31a are engaged with each other. This prevents the passage hole 30a, which is arranged to communicate with the compression chamber communication channel 1h, from moving.

The on-off valve 30 may be shaped in a circle whose diameter is almost the same as the bore diameter of the recess, or the guide hole 30b may be formed substantially the same in size and shape as the circumference and outer periphery of the guide projection 31a. In this case, the on-off valve 30 is prevented from moving in a horizontal direction. If the on-off valve 30 is shaped in a circle whose diameter is almost the same as the bore diameter of the recess, however, burr may be caused if the outer surface of the on-off valve 30 and the inner wall of the recess rub against each other. Given this fact, it is desirable that the on-off valve 30 is shaped in a circle whose diameter is slightly smaller than the bore diameter of the recess, and also the guide hole 30b is formed substantially the same in size and shape as the circumference and outer periphery of the guide projection 31a.

With this example, since the recesses are formed into a cylindrical shape and the on-off valves 30 are formed like a circular plate for convenience of processing and manufacturing, the guide holes 30b and the guide projections 31a are intentionally designed in shape not to allow the on-off valve 30 to rotate. Alternatively, however, the recesses may be formed into a shape of a prism and the on-off valves 30 may be formed into a polygonal shape to prevent the on-off valves 30 from rotating.

[0054] An operation of the on-off valves 30 is now described.

Fig. 9 shows a vicinity of one of the on-off valve chambers 1f when the injecting operation is performed.

When the injection operation is performed, the two-phase gas-liquid injection refrigerant flows in the refrigerant inlet chamber 1e, which is formed inside the base plate 1a of the fixed scroll 1, through the injection pipe 41. The injection refrigerant in the refrigerant inlet chamber 1e flows in the two inlet chamber communication channels 1g.

Usually, the pressure of the injection refrigerant in the refrigerant inlet chamber 1e is higher than the pressure of the refrigerant in the compression chamber 20 (especially at the position where the compression chamber 20 communicates with the compression chamber communication channel 1h, i.e., the intermediate pressure portion). This causes the injection refrigerant in the inlet chamber communication channel 1g to push up the on-off valve 30 in the on-off valve chamber 1f towards the backplate 31 (the upper side in Fig. 9). As a result, the injection refrigerant in the inlet chamber communication channel 1g flows in the on-off valve chamber 1f. Then, when the compression chamber 20 communicates with the compression chamber communication channel 1h, the injection refrigerant of the on-off chamber 1f flows into the compression chamber 20 through the compression chamber communication channel 1h.

[0055] Fig. 10 shows a vicinity of one of the on-off valve chambers 1f when the injecting operation is not performed.

As described with reference to Figs. 4 and 5, the second expansion valve 56 in the heat pump apparatus is closed when the injection operation is not performed. Therefore, the injection refrigerant does not enter the refrigerant inlet chamber 1e.

However, the internal pressure of the compression chamber 20 (especially in the position where the compression chamber 20 communicates with the compression chamber communication channel, i.e., the intermediate pressure portion) is higher than the pressure of the refrigerant between the refrigerant inlet chamber 1e and the on-off valve chamber 1f. This causes the refrigerant in the compression chamber 20 to flow back to the on-off valve chamber 1f via the compression chamber communication channel 1h when the compression chamber 20 communicates with the compression chamber communication channel 1h.

More specifically, the refrigerant flows in the on-off valve chamber 1f through the passage hole 30a on the on-off valve 30. However, the internal pressure of the compression chamber 20 is higher than the internal pressure of the refrigerant inlet chamber 1e. Therefore, the refrigerant entering the on-off valve chamber 1f from the compression chamber 20 presses the on-off valve 30 against the inlet chamber communication channel 1g (the lower side in Fig. 10). This causes the on-off valve 30 to block the inlet chamber communication channel 1g. Accordingly, the refrigerant in the on-off valve chamber 1f is not allowed to flow out to the refrigerant inlet chamber 1e through the inlet chamber communication channel 1g.

[0056] More specifically, if the pressure of the refrigerant on the refrigerant inlet chamber 1e side is higher than the pressure of the refrigerant in the compression chamber 20 such as during injection operation, the on-off valve 30 is pushed towards the backplate 31 side, and therefore the on-off valve 30 opens. Consequently, the injection refrigerant flows in the on-off valve chamber 1f through the inlet chamber communication channel 1g, and then flows in the compression chamber 20 through the compression chamber communication channel 1h.

If the pressure of the refrigerant on the refrigeration inlet chamber 1e side is lower than the pressure of the refrigerant in the compression chamber 20 such as when the injection operation is not performed, the on-off valve 30 is pressed against the inlet chamber communication channel side 1g, and therefore the on-off valve 30 closes. As a result, the refrigerant flowing back from the compression chamber 20 into the on-off valve chamber 1f is not allowed to flow in the refrigerant inlet chamber 1e through the inlet chamber communication channel 1g.

In other words, the on-off valve 30 opens and closes according to a difference in pressure between the refrigerant on the refrigerant inlet chamber 1e side (the inlet chamber communication channel 1g) and the refrigerant in the compression chamber 20 (the compression chamber communication channel 1h).

[0057] This prevents the refrigerant in the compression chamber 20 from flowing back to the injection circuit even when the injection operation is not performed.

If the on-off valve 30 is not provided, the refrigerant in the compression chamber 20 flows back to the injection circuit. As a result, a volume between the compression chamber communication channel 1h and the second expansion valve 56 becomes dead volume in compression, which causes a considerable reduction in efficiency. That is to say that the use of the on-off valve 30 contributes largely to a reduction in the dead volume, improving compression efficiency.

[0058] However, the pressure of the refrigerant in the compression chamber 20 may transiently become higher than the pressure of the refrigerant in the refrigerant inlet chamber 1e even during injection operation. Even in such a case, the refrigerant is not allowed to flow out to the injection circuit by the on-off valve 30, like the case when the injection operation is not performed.

[0059] In a transition from where the injection operation is performed to where the injection operation is not performed, the internal pressure of the refrigerant inlet chamber 1e is increasingly reduced. When the internal pressure of the compression chamber 20 becomes almost the same as the internal pressure of the refrigerant inlet chamber 1e, then the on-off valve 30 pushed up towards the backplate 31 side (the upper side in Figs. 9 and 10) is pulled down by gravity towards the inlet chamber communication channel 1g (the lower side in Figs. 9 and 10). When the internal pressure of the compression chamber 20 becomes higher than the internal pressure of the refrigerant inlet chamber 1e, the on-off valve 30 is pressed towards the inlet chamber communication channel 1g (the lower side in Figs. 9 and 10) by the refrigerant flowing into the on-off valve chamber 1f from the compression chamber 20 through the passage hole 30.

In other words, the on-off valve 30 operates according only to the pressure difference and gravity. The on-off valve 30 operates without spring force of such as coil spring. This contributes to an increase in reliability and a reduction in production cost.

[0060] With this example, the connection port to the inlet chamber communication channel 1g and the connection port to the compression chamber communication channel 1h are formed on the bottom surface of the on-off valve chamber 1f. This allows the on-off valve 30 to descend easily towards the inlet chamber communication channel 1g (the lower side in Figs. 9 and 10) according to not only pressure differences but also gravity in the transition from the state where the injection operation is being carried out to the state where the injection operation is not performed, as mentioned earlier. Alternatively, however, the connection port to the inlet chamber communication channel 1g and the connection port to the compression chamber communication channel 1h may also be provided on a side surface or an upper surface of the on-off valve chamber 1f. In this particular case, the on-off valve 30 moves according to a pressure difference alone in a transition to the state where the injection operation is not performed. The movement of the on-off valve 30, however, may further be assisted by the use of coil spring or the like. More specifically, coil spring, or the like is used so that the on-off valve 30 is pressed towards the inlet chamber communication channel 1g when the internal pressure of the compression chamber 20 and the internal pressure of the refrigerant inlet chamber 1e are almost the same. This allow the on-off valve 30 to move towards the inlet chamber communication channel 1g easily in the transition from where the injection operation is being carried out to where the injection operation is not performed.

[0061] Coil spring or the like is also applicable between the on-off valve 30 and the backplate 31 to assist the descending movement of the on-off valve 30 towards the inlet chamber communication channel 1g (the lower side in Figs. 9 and 10) even when the connection port to the inlet chamber communication channel 1g and the connection port to the compression chamber communication channel 1h are formed on the bottom surface of the on-off valve chamber 1f.

[0062] As described above, the inlet chamber communication channel 1g, which communicates with the refrigerant inlet chamber 1e, and the compression chamber communication channel 1h, which communicates with the compression chamber 20, are formed on the same surface in the on-off valve chamber 1f. That surface is therefore allowed to be made flat, and thus the on-off valve 30 is allowed to have a simple structure.

[0063] A method of producing the scroll compressor 100 is now described.

First, the fixed scroll 1, the orbiting scroll 2, and so forth are formed into the shapes described above.

Especially with the fixed scroll 1, machining is used to form the spiral teeth 1b, a hole as the refrigeration inlet chamber 1e, the two recesses, holes as the inlet chamber connection chambers 1g, and holes as compression chamber communication channels 1h on the base plate 1a. Then, the on-off valves 30 are placed in the machined recesses, and the backplate 31 is mounted. The hole as the refrigeration inlet chamber 1e, the two recesses, the holes as the inlet chamber connection chambers 1g, and the holes as compression chamber communication channels 1h may be formed on the base plate 1a of the fixed scroll 1 by machine cutting in a linear fashion. The order of machining of the spiral teeth 1b, the holes as the refrigerant inlet chamber 1e, the two recesses, the holes as the inlet chamber communication channels 1g, and the holes as the compression chamber communication holes 1h does not matter.

Now, as shown in Fig. 1, the sub frame 6, the electric motor 5, the main shaft 7, the guide frame 4, the compliant frame 3, and the Oldham mechanism 8 are arranged in the lower container 10a of the hermetically sealed container 10. The orbiting scroll 2 is also arranged so that it engages with the main shaft 7. The fixed scroll 1 is also arranged so that the compression chamber 20 is formed between the orbiting scroll 2 and the fixed scroll 1. Then, the injection pipe 41 is mounted on the lower container 10a so that the injection pipe 41 is connected to the refrigerant inlet chamber 1e. The suction pipe 42 is mounted on the lower container 10a so that the suction pipe 42 is connected to the suction opening of the compression chamber 20. The discharge pipe 43 is mounted on the lower container 10a. The upper container 10b is also mounted on the lower container 10a to seal the container. The scroll compressor 100 is thus produced.

[0064] As described above, the scroll compressor 100 can thus prevent not fully compressed refrigerant from flowing back to the injection circuit, and also prevent the dead volume from increasing in the compression process.

Especially with the scroll compressor 100, the connection ports that connect the inlet chamber communication channel 1g and the compression chamber communication channel 1h to the on-off valve chamber 1f are thus formed on the same surface of the on-off valve chamber 1f. The on-off valve 30 thus opens and closes according to the difference in pressure between the inlet chamber communication channel 1g side and the compressor chamber communication channel 1h side. This can thus allow the on-off valve 30 to move and open/close smoothly, thereby improving reliability. This can also make the on-off valve chamber 1f compact. Furthermore, the scroll compressor 100 can thus control the opening and closing according to the pressure difference between the internal pressure of the compression chamber 20 and the pressure of the refrigerant inlet chamber 1e without using coil spring. This can contribute to a reduction in the number of components required, compared to an on-off valve using coil spring.

Also, with the scroll compressor 100, the refrigerant inlet chamber 1e, the two recesses, the inlet chamber communication channels 1g, and the compression chamber communication channels 1h are formed simply in a linear arrangement with respect to the base plate 1g of the fixed scroll 1. Then, the on-off valve chambers 1f are formed to include the on-off valves 30 placed therein, and covered with the backplate 31 as a lid. In other words, all that is needed to form the scroll compressor 100 is to form linear holes and arrange the on-off valves 30 and the backplate 31. Therefore, complicated work such as to cut a groove as a refrigerant channel on the valve seat of an on-off valve is not required. This can result in a reduction in the number of machining processes required.

[0065] Furthermore, the refrigerant inlet chamber 1e is formed from the side portion towards the inside of the base plate 1a of the fixed scroll 1. Therefore, the injection pipe 41 is only to be mounted on the side portion of the base plate 1a of the fixed scroll 1. This allows the injection pipe 41 to be mounted on the lower container 10a. In other words, there is no need to mount the injection pipe 41 on the upper container 10b. Therefor, it is very easy to fix the upper container 10b to the lower container 10a. Furthermore, the injection pipe 41 can be mounted on the side portion of the hermetically sealed container 10 since the injection pipe 41 only needs to be mounted on the side portion of the base plate 1a of the fixed scroll 1. This allows pipes to be connected to the injection pipe 41 to be installed on a side portion of the hermetically sealed container 10. The pipes do not need to be installed above the hermetically sealed container 10. If a heat pump apparatus equipped with a compressor is reduced in size, an outdoor unit would not generally allow extra space above and below the hermetically sealed container 10. The scroll compressor 100 is, however, space saving with respect to space above the hermetically sealed container 10, compared to a compressor requiring pipes connected to the injection pie 41 above the hermetically sealed container 10. The scroll compressor 100 can thus allow a heat pump apparatus to be reduced effectively in size.

Embodiment 2.

[0066] The scroll compressor 100 described in a second embodiment employs on-off valves 32 made from plate springs.

[0067] Fig. 11 is a vertical cross section of the scroll compressor 100 according to the second embodiment. The scroll compressor 100 shown in Fig. 11 of the second embodiment modifies the scroll compressor 100 shown in Fig. 1 of the first embodiment by replacing the on-off valve by one having a different configuration.

The scroll compressor 100 of the second embodiment employs the on-off valves 32 made from plate springs as mentioned above. The on-off valves 32 are placed to cover the openings of the inlet chamber communication channels 1g.

When the pressure of the refrigerant on the refrigerant inlet chamber 1e side is higher than the pressure of the refrigerant on the compression chamber 20 side such as during injection operation, the on-off valves 32 are pushed up towards a backplate 33 and bent. Then, the injection refrigerant flows in the on-off valve chamber 1f through the inlet chamber communication channel lg, and then flows into the compression chamber 20 through the compression chamber communication channel 1h.

When the pressure on the refrigerant inlet chamber 1e side is lower than the internal pressure of the compression chamber 20 such as when the injection operation is not performed, the on-off valve 32 is pressed against the inlet chamber communication channel 1g side. This prevents the refrigerant returning from the compression chamber 20 into the on-off valve chamber 1f from flowing out to the refrigerant inlet chamber 1e through the inlet chamber communication channels 1g.

[0068] The backplate 33 does not need to have a guide projection such as the guide projection 31a of the back plate 31 described in the first embodiment if the on-off valves 32 of plate springs are used. This can allow the back plate 33 to have a simple structure, as shown in Fig. 11.

[0069] As described above, the scroll compressor 100 equipped with the on-off valves 32 made from plate springs of the second embodiment can also achieve the same effect as that according to the scroll compressor 100 of the first embodiment.

[0070] The above description is summarized as follows.

The scroll compressor described in the above embodiments is characterized as follows: The fixed scroll and the orbiting scroll are engaged with each other in the hermetically sealed container. The orbiting scroll orbits around the fixed scroll without rotating itself. The refrigerant compressed in the compression chamber is thereby discharged to the discharge space at the back surface of the fixed scroll through the discharge port provided at the central portion of the fixed scroll. The compression chamber is formed with the plate spiral teeth of both the fixed scroll and the orbiting scroll. The scroll compressor allows the refrigerant having the intermediate pressure to be injected into the intermediate portion of the compression process. The intermediate pressure is the pressure between the pressure of the refrigerant flowing into the compression chamber and the pressure of the discharged refrigerant from the compression chamber.

The scroll compressor comprises the two on-off valves and the on-off valve chambers storing the two on-off valves in the refrigerant inlet chamber. The refrigerant inlet chamber is formed from the side portion towards the inside of the fixed scroll to allow the refrigerant to flow into the compression chamber through the compression chamber communication channels. The scroll compressor also comprises the back plate to seal the on-off valve chambers.

[0071] Therefore, even when the valve of the injection circuit is closed and the injection operation is not performed, only an extremely small amount of volume in a passage between the compression chamber communication channel and the on-off valve of the on-off valve chamber becomes dead volume. This can enhance compression efficiency.

[0072] With reference to the above description, the scroll compressor 100 is used as an example of the in-

jectable compressor. Alternatively, however, a different type of compressor equipped with an injection mechanism, such as a rotary compressor, be used instead as the injectable compressor.
With further reference to the above description, such as the refrigerant inlet chamber 1e and the on-off valve chambers 1f are provided on the base plate 1a of the fixed scroll 1 of the scroll compressor 100, as an example. Alternatively, however, such as the refrigerant inlet chamber 1e and the on-off valve chambers 1f may be provided separately from the base plate 1a of the fixed scroll 1.

Explanation of Reference Numerals

[0073]

1	fixed scroll
1a	base plate
1b	spiral tooth
1c	Oldham guide groove
1d	discharge port
1e	refrigerant inlet chamber
1f	on-off valve chamber
1g	inlet chamber communication channel
1h	compression chamber communication channel
2	orbiting scroll
2a	base plate
2b	spiral tooth
2c	orbiting shaft bearing
2d	thrust surface
2e	Oldham guide groove
2f	boss portion
2j	bleed hole
2k	lower opening
3	compliant frame
3a	thrust bearing
3c	main bearing
3d	upper fitting cylindrical surface
3e	lower fitting cylindrical surface
3h	auxiliary main bearing
3m	intermediate pressure adjustment spring
3n	communication hole
3p	adjustment valve space
3s	communication hole
3t	valve
3u	upper opening
3x	reciprocating sliding portion
3y	valve holder
4	guide frame
4a	upper fitting cylindrical surface
4b	lower fitting cylindrical surface
5	electric motor
5a	rotor
5b	stator
6	sub frame
6a	sub bearing
7	main bearing
7b	orbiting shaft portion
7c	main shaft portion
7d	sub shaft portion
7f	oil pipe
7g	high-pressure oil feed hole
8	Oldham mechanism
10	hermetically sealed container
10a	lower container
10b	upper container
15a	boss gap
15b	boss peripheral gap
15e	valve peripheral gap
15c	base plate peripheral gap
15d	frame gap
20	compression chamber
30,32	on-off valve
30a	communication hole
30b	guide hole
31,33	backplate
31a	guide projection
34	bolt
41	injection pipe
42	suction pipe
43	discharge pipe
51	compressor
52,57	heat exchanger
53	first expansion valve
54	inner heat exchanger
55	third expansion valve
56	second expansion valve
58	four-way valve
59	receiver
100	scroll compressor

Claims

1. A heat pump apparatus comprising:

a main refrigeration circuit including a compressor, a radiator, a first expansion valve and an evaporator connected in series;
an injection circuit connecting a portion between the radiator and the first expansion valve in the main refrigeration circuit and an injection pipe mounted on the compressor, the injection circuit including a second expansion valve; and
a mechanism that closes a flow channel between the injection pipe on the compressor and a compression chamber when an opening of the second expansion valve is reduced, and opens the flow channel between the injection pipe on the compressor and the compression chamber when the opening of the second expansion valve is increased.

2. The heat pump apparatus according to claim 1, wherein the mechanism operates based on a pressure difference between a refrigerant flowing in the main refrigerant circuit and a refrigerant flowing in the injection circuit.

3. The heat pump apparatus according to claim 1, wherein the mechanism comprises:

a refrigerant inlet chamber provided in the flow channel, the refrigerant inlet chamber allowing the refrigerant to flow in from the injection circuit through the injection pipe; and
an on-off valve chamber provided in the flow channel between the refrigerant inlet chamber and the compression chamber, the on-off valve chamber being connected to the refrigerant inlet chamber and the compression chamber, formed with a connection port to the refrigerant inlet chamber and a connection port to the compression chamber, which are formed on a same surface of the on-off valve chamber, and including an on-off valve that opens and closes the connection port to the refrigerant inlet chamber based on a pressure difference between a refrigerant on a refrigerant inlet chamber side and a refrigerant on a compression chamber side.

4. An injectable compressor comprising:

a compressing portion forming a compression chamber, and compressing a sucked refrigerant sucked in by the compression chamber from a suction pressure to a discharge pressure, and
a refrigerant injecting portion injecting an injection refrigerant into an intermediate pressure portion where the sucked refrigerant has an intermediate pressure, which is higher than the suction pressure and lower than the discharge pressure, in the compression chamber formed by the compressing portion,
the refrigerant injecting portion comprising:

a refrigerant inlet chamber in which the injection refrigerant flows from outside; and
an on-off valve chamber connected to the refrigerant inlet chamber and the intermediate pressure portion of the compression chamber, formed with a connection port to the refrigerant inlet chamber and a connection port to the compression chamber, which are formed on a same surface in the on-off valve chamber, and including an on-off valve opening and closing the connection port to the refrigerant inlet chamber based on a pressure difference between a refrigerant on a refrigerant inlet chamber side and a refrigerant on a compression chamber side.

5. The injectable compressor according to claim 4, wherein the on-off valve is a plate member placed movably along a predetermined moving direction in the on-off valve chamber, the plate member being formed with a hole at a position overlapping with the connection port to the intermediate pressure portion when the connection port to the refrigerant inlet chamber is closed.

6. The injectable compressor according to claim 5, wherein the on-off valve is formed with a guide hole through which a guide rod extends in the moving direction in the on-off valve chamber.

7. The injectable compressor according to claim 6, wherein the on-off valve chamber is formed into a cylindrical shape with a bottom surface where the connection port to the refrigerant inlet chamber and the connection port to the intermediate pressure portion are formed, and
wherein the on-off valve is a circular plate member formed with the guide hole, the guide hole being engaged with the guide rod to prevent the on-off valve from rotating around the guide rod.

8. The injectable compressor according to claim 6, wherein the on-off valve chamber is formed into a cylindrical shape with a bottom surface where the connection port to the refrigerant inlet chamber and the connection port to the intermediate pressure portion are formed, and
wherein the on-off valve is formed into a shape of a circle whose diameter is smaller than a diameter of the bottom surface of the on-off valve chamber, the on-off valve being formed with the guide hole having a size substantially the same as the circumference of the guide rod and a shape substantially the same as a peripheral shape of the guide rod.

9. The injectable compressor according to claim 4, wherein the on-off valve is a plate spring.

10. The injectable compressor according to claim 4, wherein the compressing portion comprises:

an orbiting scroll including orbiting spiral teeth formed on an upper surface side of an orbiting base plate; and
a fixed scroll including fixed spiral teeth formed on a lower surface side of a fixed base plate, the fixed spiral teeth being engaged with the orbiting spiral teeth of the orbiting scroll to form the compression chamber,
wherein the refrigerant inlet chamber is a chamber formed inside the fixed base plate, extending from a side portion of the fixed base plate, and
wherein the on-off valve chamber is a chamber formed on an upper surface side of the fixed

base plate.

11. The injectable compressor according to claim 10, wherein the on-off valve chamber is a chamber formed by covering a recess formed on the upper surface side of the fixed base plate with a backplate.

12. The injectable compressor according to claim 10, wherein the compressing portion includes a pair of the orbiting spiral teeth of the orbiting scroll and the fixed spiral teeth of the fixed scroll engaged with each other to form a paired compression chamber, and wherein the on-off valve chamber is provided for each compression chamber of the paired compression chamber.

13. The injectable compressor according to claim 4, further comprising:

a hermetically sealed container storing the compressing portion and the refrigerant injecting portion, and
an injection pipe mounted through a side surface of the hermetically sealed container for allowing the injection refrigerant to flow into the refrigerant inlet chamber from outside.

14. The injectable compressor according to claim 13, wherein the hermetically sealed container comprises:

a lower container; and
an upper container combined with the lower container to create a hermetically sealed space inside the hermetically sealed container,
wherein the injection pipe is mounted through a side surface of the lower container.

15. A method of producing an injectable scroll compressor, comprising:

forming orbiting spiral teeth on a surface of one side of an orbiting base plate;
forming fixed spiral teeth on a surface of one side of a fixed base plate;
forming a side hole on a side portion of the fixed base plate;
forming a recess on a surface of another side of the fixed base plate;
forming on the fixed base plate a first communication hole that connects a bottom surface of the recess and the side hole, and a second communication hole that connects the bottom surface of the recess and the surface of the one side of the fixed base plate;
placing an on-off valve in the recess formed on the fixed base plate, the on-off valve opening and closing the first communication hole;
mounting a backplate on the fixed base plate so that the backplate covers an opening of the recess where the on-off valve is placed;
placing in a hermetically sealed container the orbiting base plate formed with the orbiting spiral teeth;
placing in the hermetically sealed container the fixed base plate formed with the fixed spiral teeth so that the fixed spiral teeth are engaged with the orbiting spiral teeth to form a compression chamber;
connecting a suction pipe to a suction opening of the compression chamber, the suction pipe allowing a sucked refrigerant to flow into the compression chamber from outside the hermetically sealed container; and
connecting an injection pipe to the side hole, the injection pipe allowing an injection refrigerant to flow in the side hole from outside the hermetically sealed container.

Fig. 1

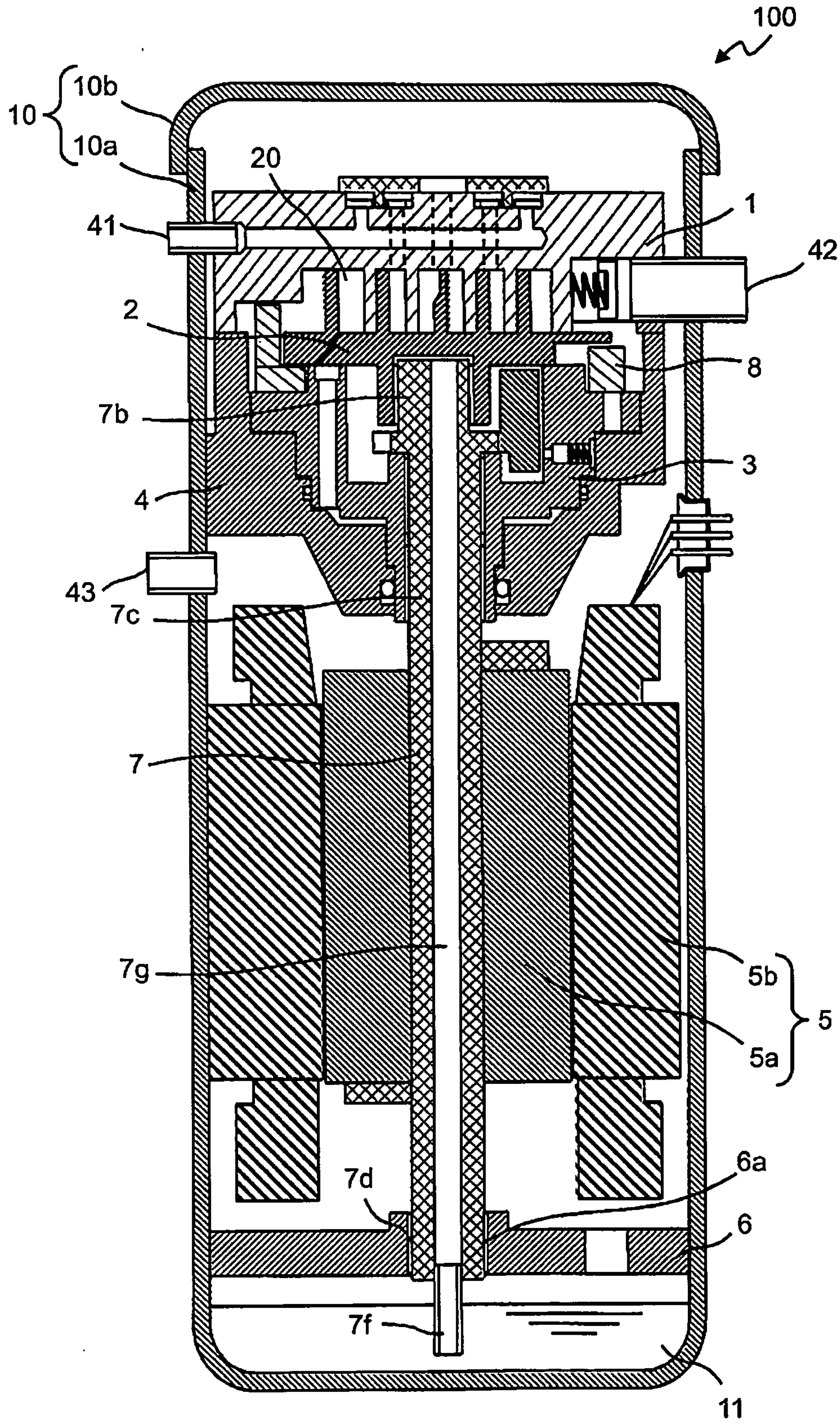

Fig. 2

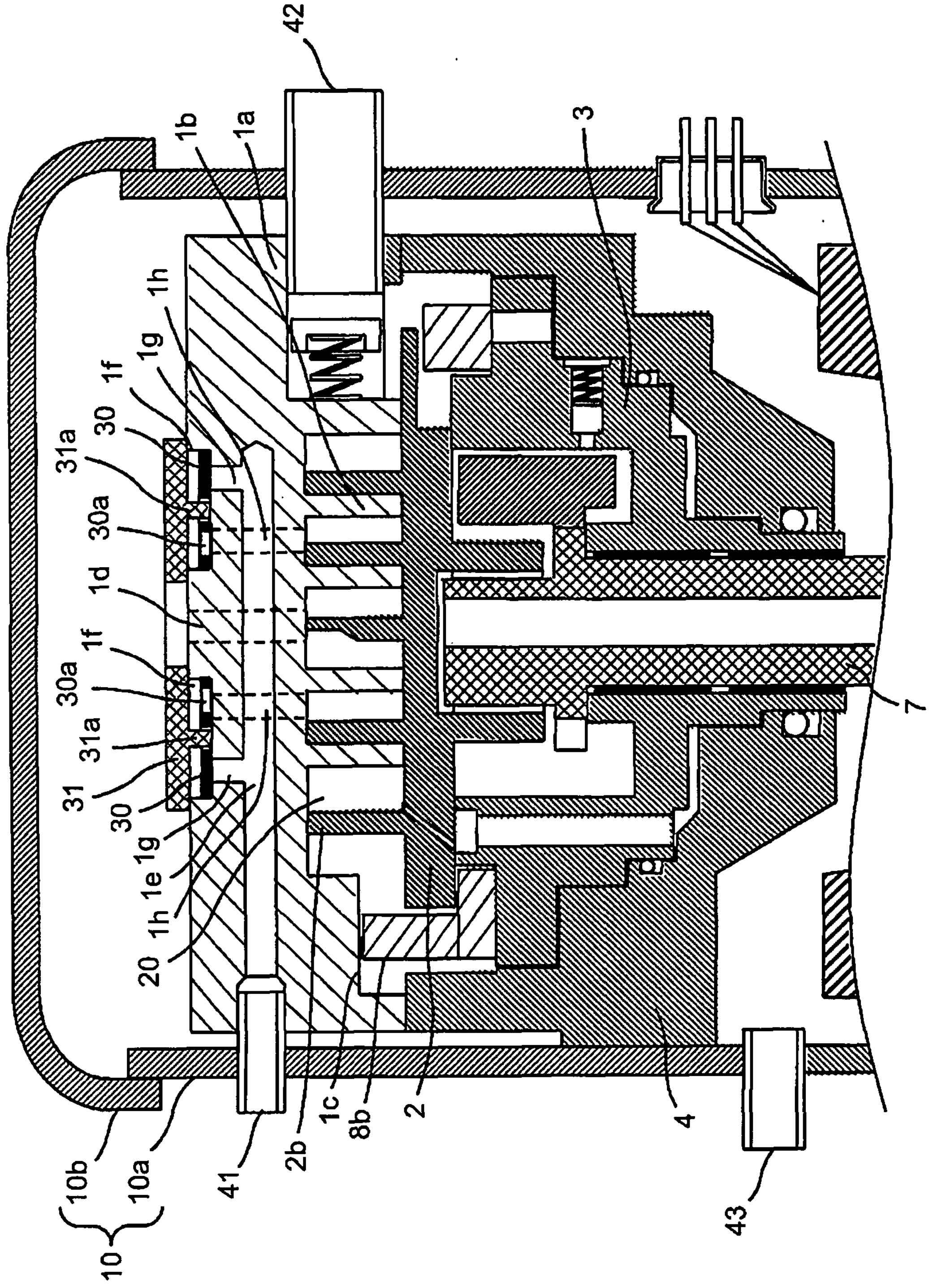
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Fig. 3

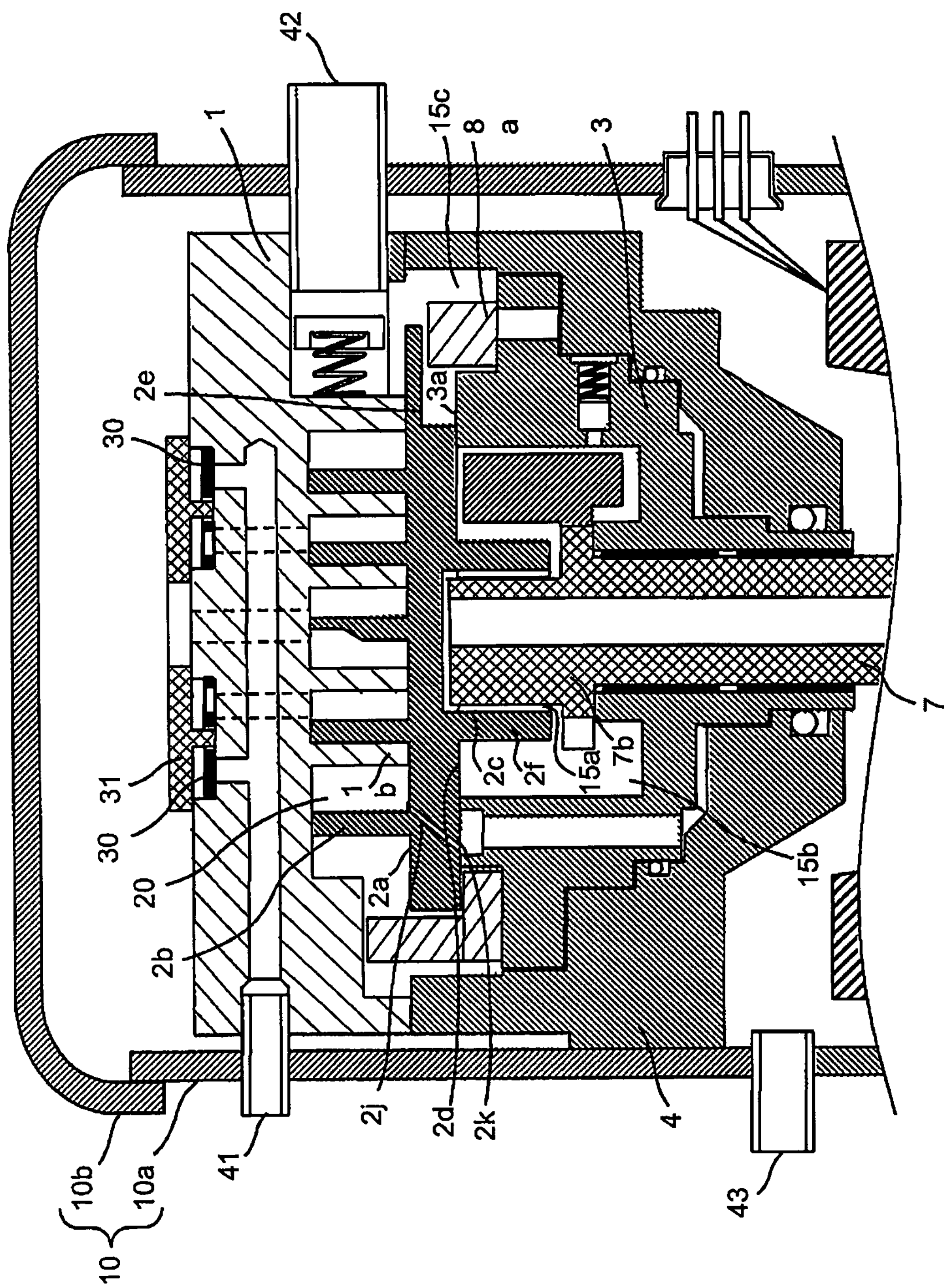

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Fig. 4

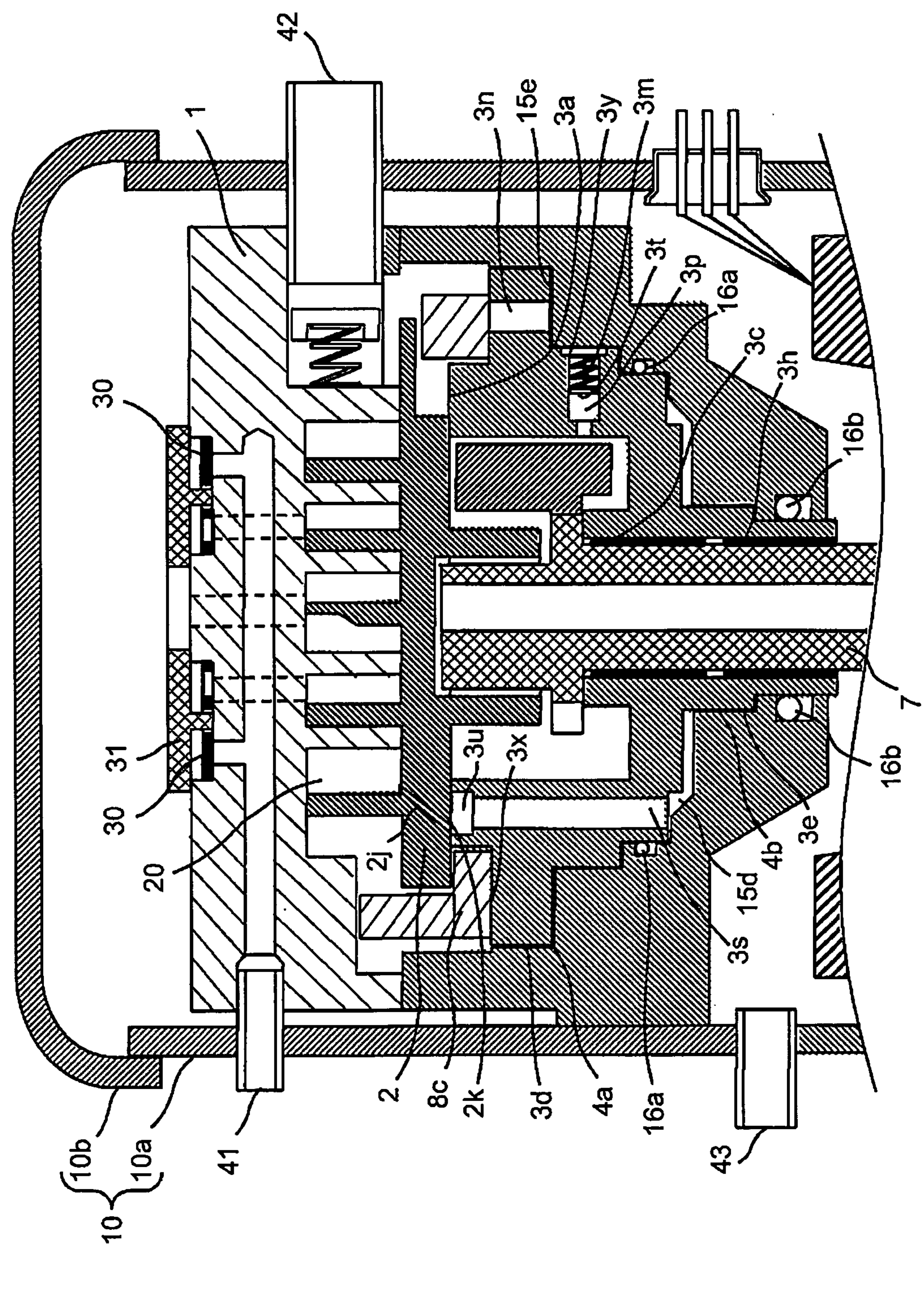
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Fig. 5

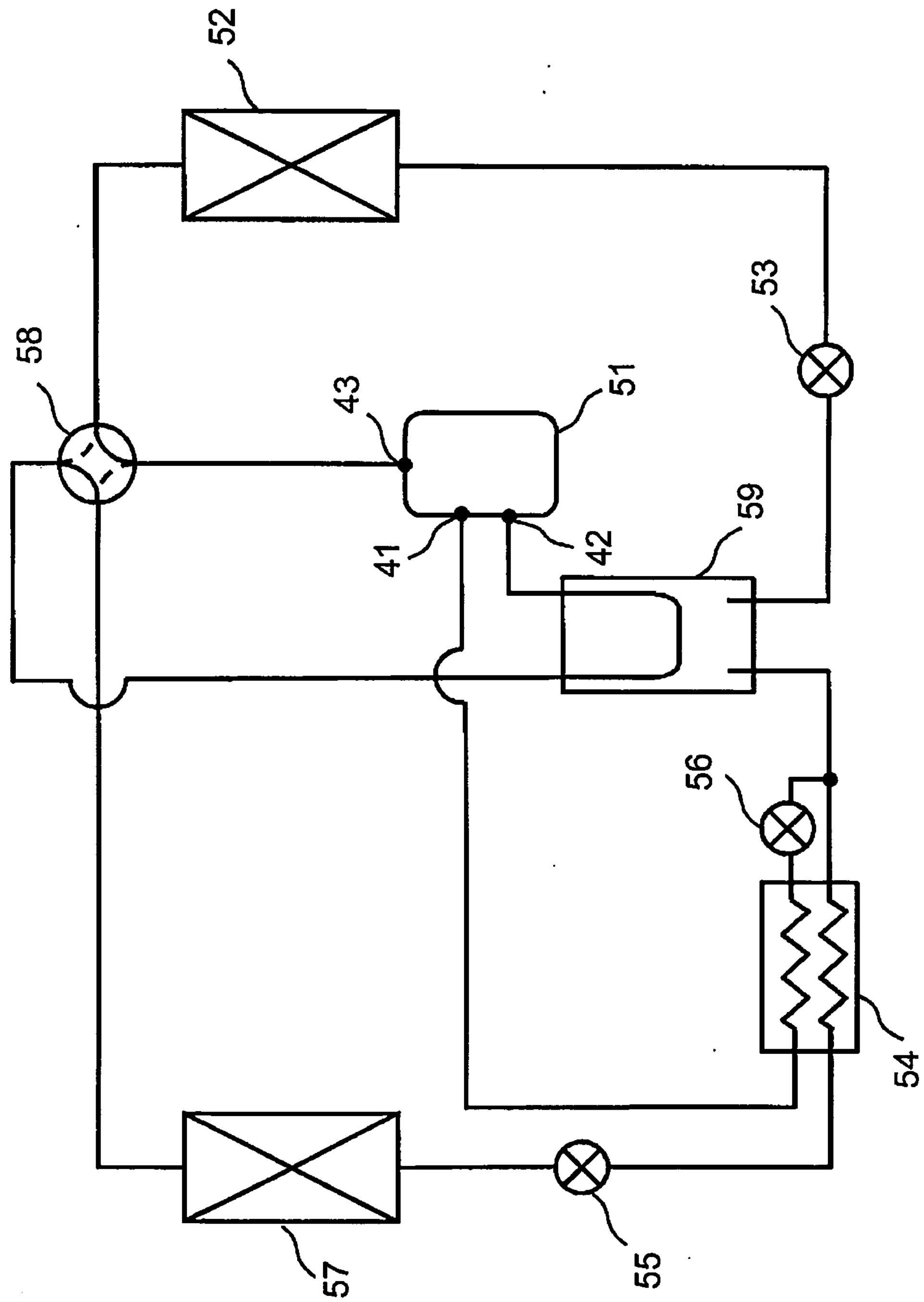

Fig. 6

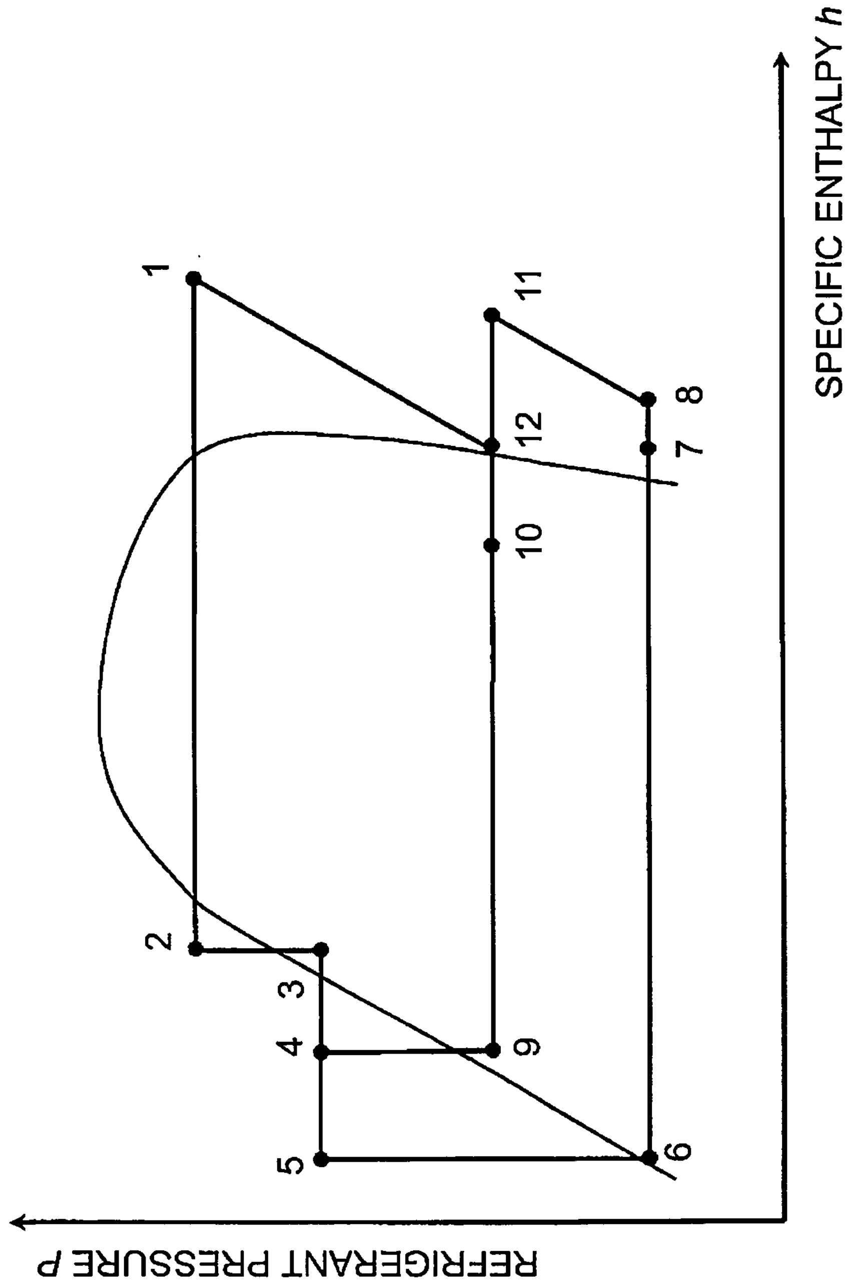
REFRIGERANT PRESSURE P
SPECIFIC ENTHALPY h
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Fig. 7

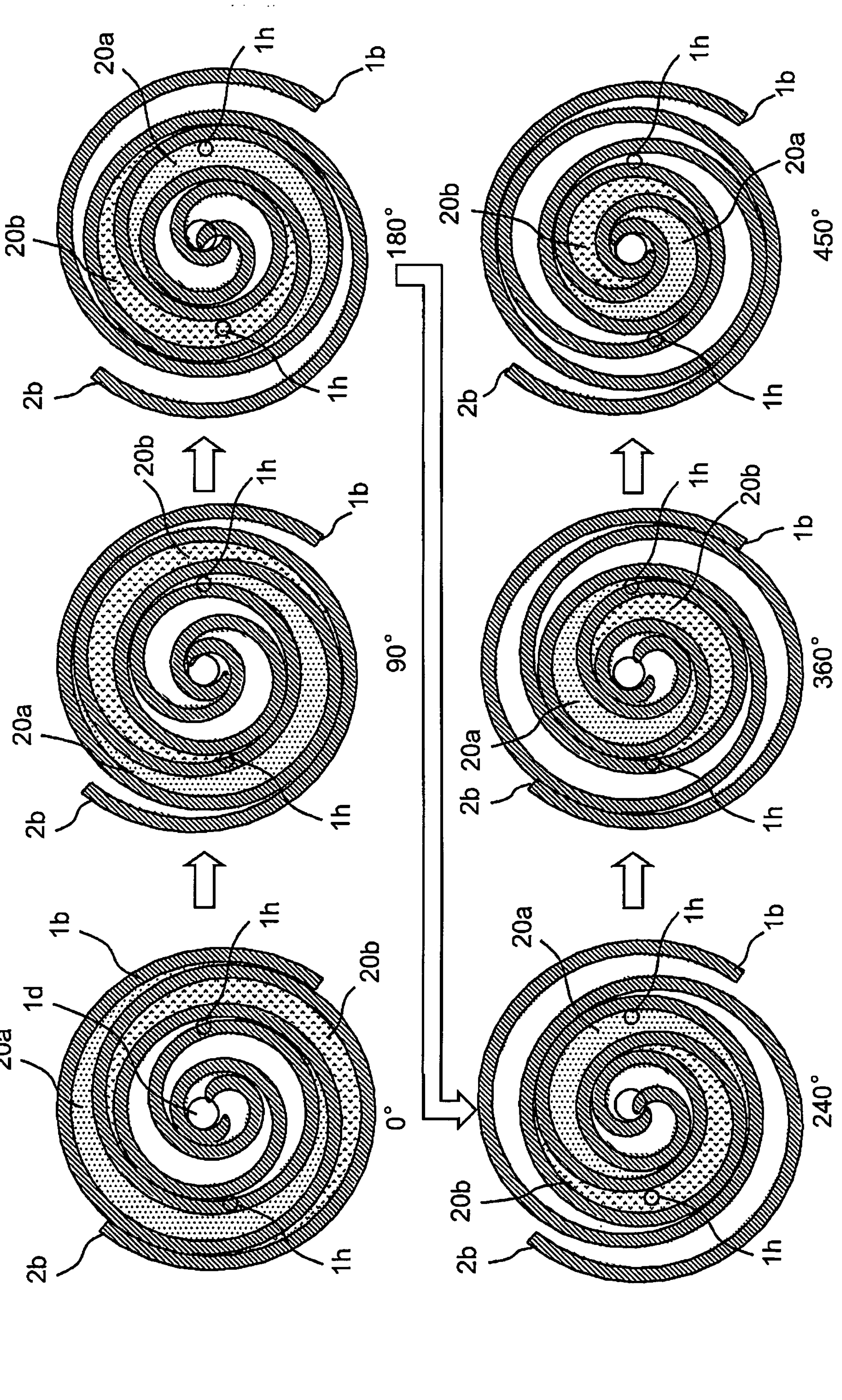


Fig. 8

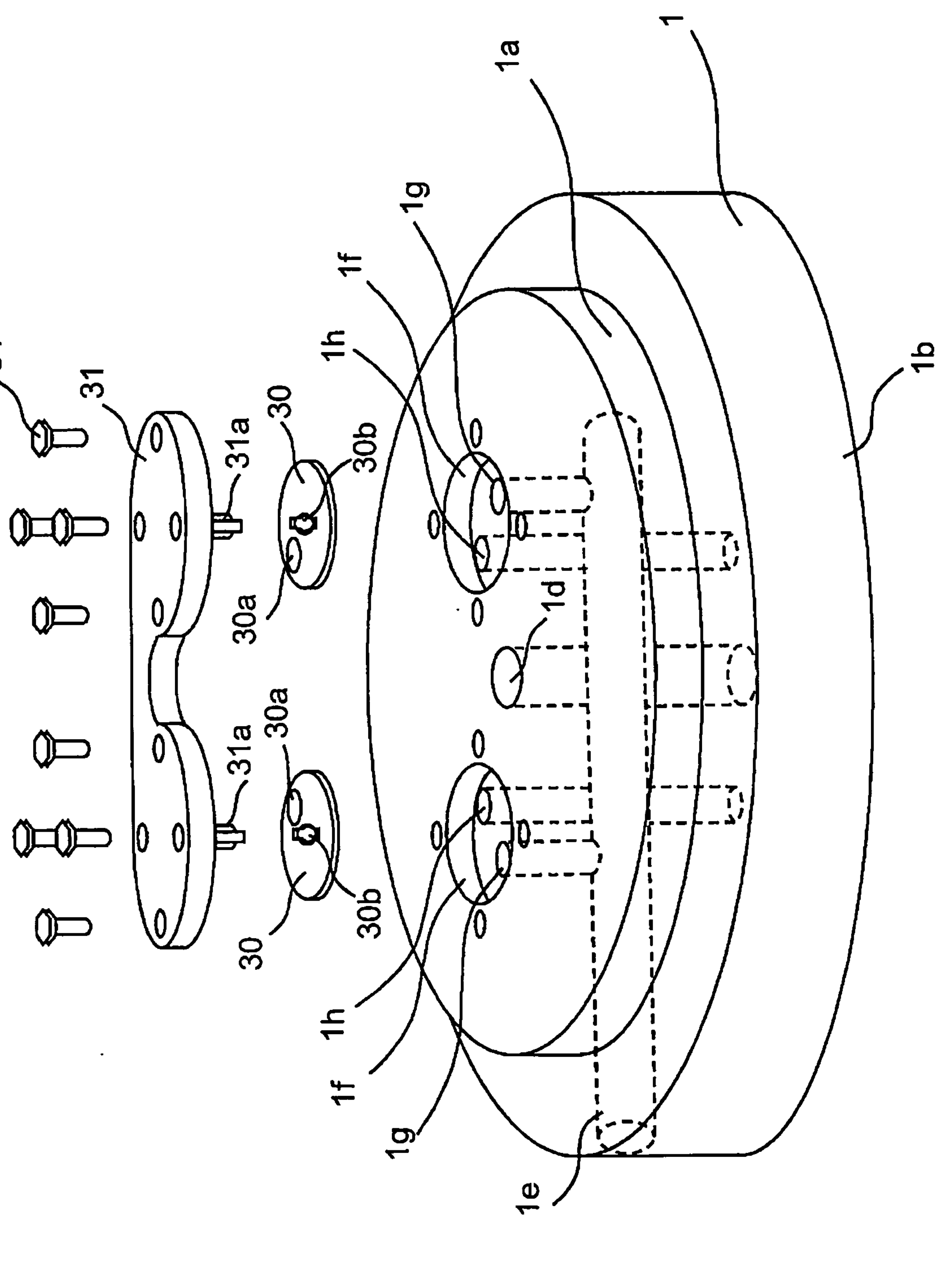


Fig. 9

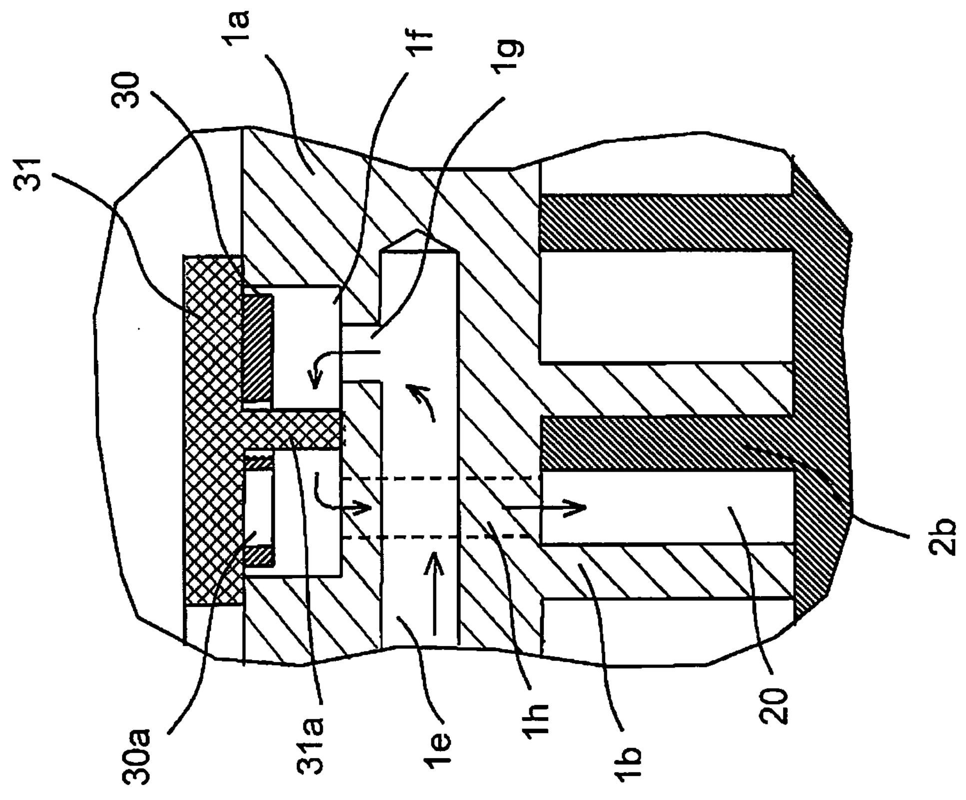


Fig. 10

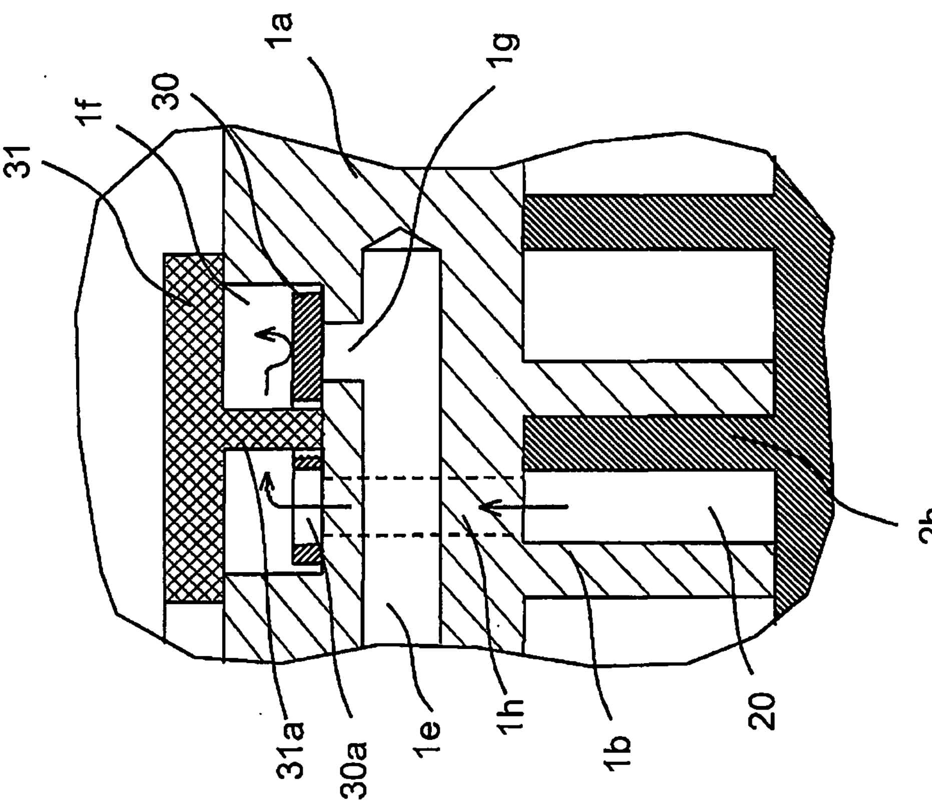
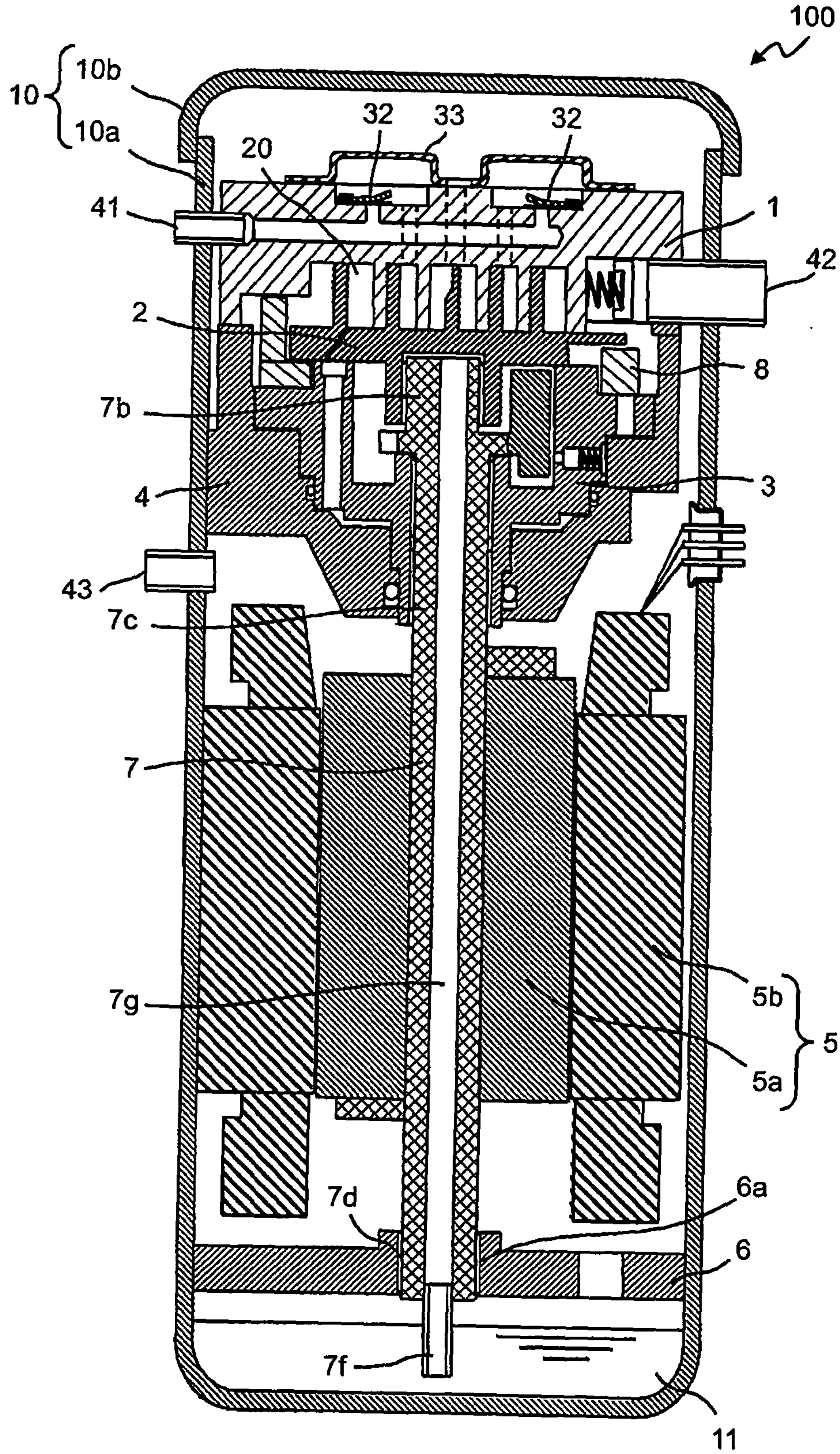


Fig. 11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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/063412

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i, F25B1/04(2006.01)i

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)
F25B1/00, F25B1/04

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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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 Y	JP 3-43691 A (Mitsubishi Electric Corp.), 25 February, 1991 (25.02.91), Page 3, upper left column, line 9 to lower right column, line 4; Figs. 1 to 3 (Family: none)	1-4 9,10-14
Y	JP 11-107945 A (Matsushita Electric Industrial Co., Ltd.), 20 April, 1999 (20.04.99), Par. Nos. [0030] to [0031]; Figs. 1, 2 (Family: none)	9
Y	JP 7-269475 A (Sanyo Electric Co., Ltd.), 17 October, 1995 (17.10.95), Figs. 1, 2; Par. No. [0028] (Family: none)	10-14

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
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"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	Date of mailing of the international search report
29 September, 2009 (29.09.09)	06 October, 2009 (06.10.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/063412

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 2008-101559 A (Hitachi Appliances, Inc.), 01 May, 2008 (01.05.08), Figs. 1, 2; Par. No. [0054] & CN 101165350 A & KR 10-2008-0035982 A	14

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Patent documents cited in the description

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