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(54) **VARIABLE-CAPACITY COMPRESSOR CONTROL VALVE**

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(57) **ABSTRACT**

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Provided is a variable-capacity compressor control valve where a decrease in the sealability or the operability due to shaft misalignment can be effectively suppressed without requiring high dimensional accuracy. The dimensions and the shape of each part are designed such that when the sub valve element closes the in-valve release passage, the tapered portion (sub valve element portion) provided at the lower end portion of the sub valve element enters the release through-hole of the in-valve release passage, and the sub valve element is thus aligned with the main valve element by the tapered portion.

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[ Normal operation time  
(Main valve element: Open,  
Sub valve element: Closed) ]

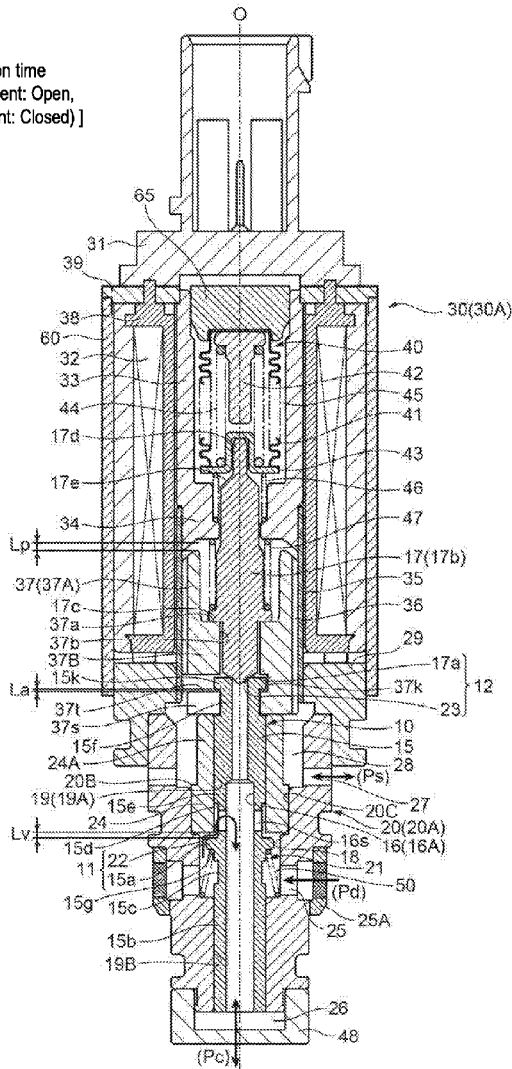


FIG. 1

[ Normal operation time  
 (Main valve element: Open,  
 Sub valve element: Closed) ]

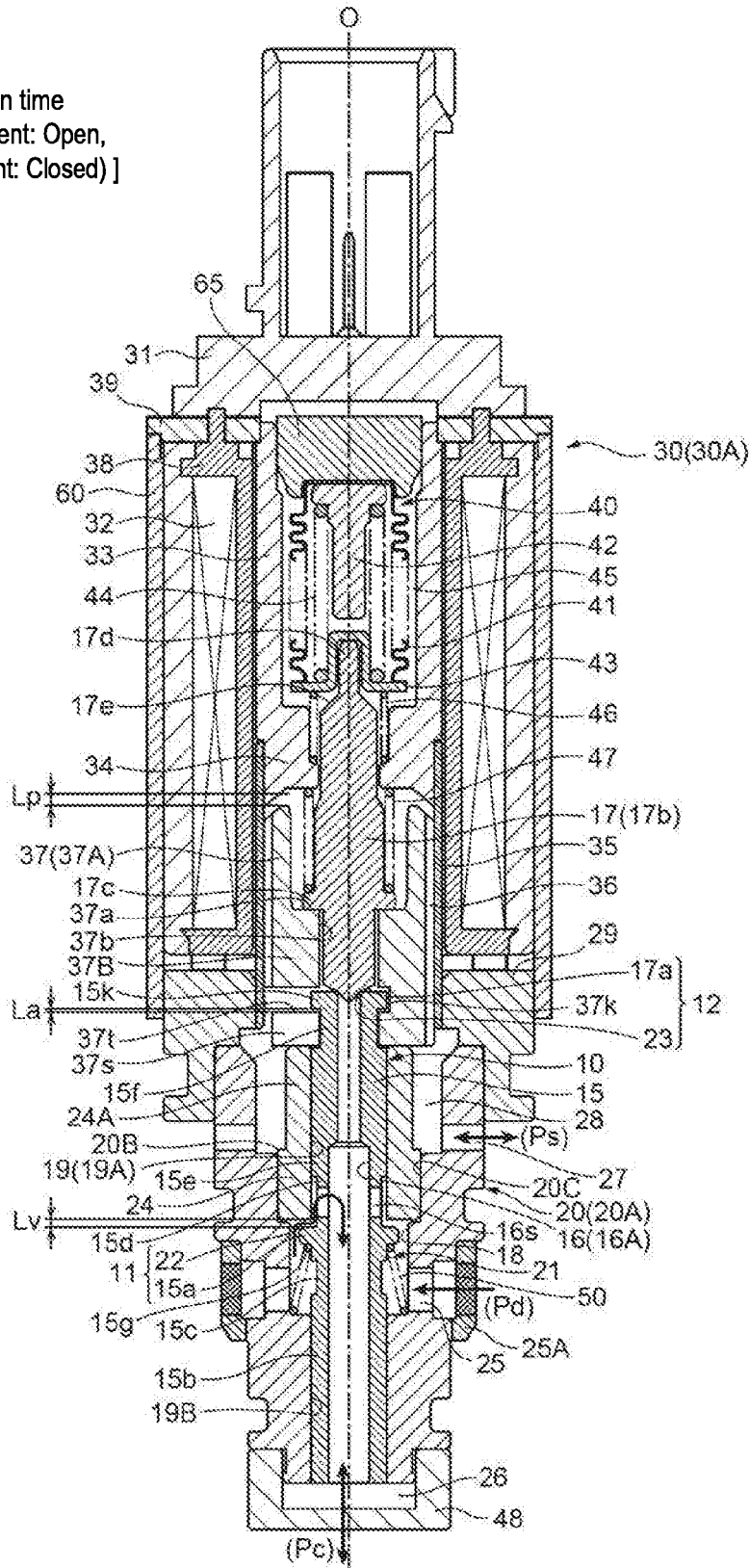


FIG. 2

[ Time of transition to compressor actuation  
 (Main valve element: Closed,  
 Sub valve element: Closed) ]

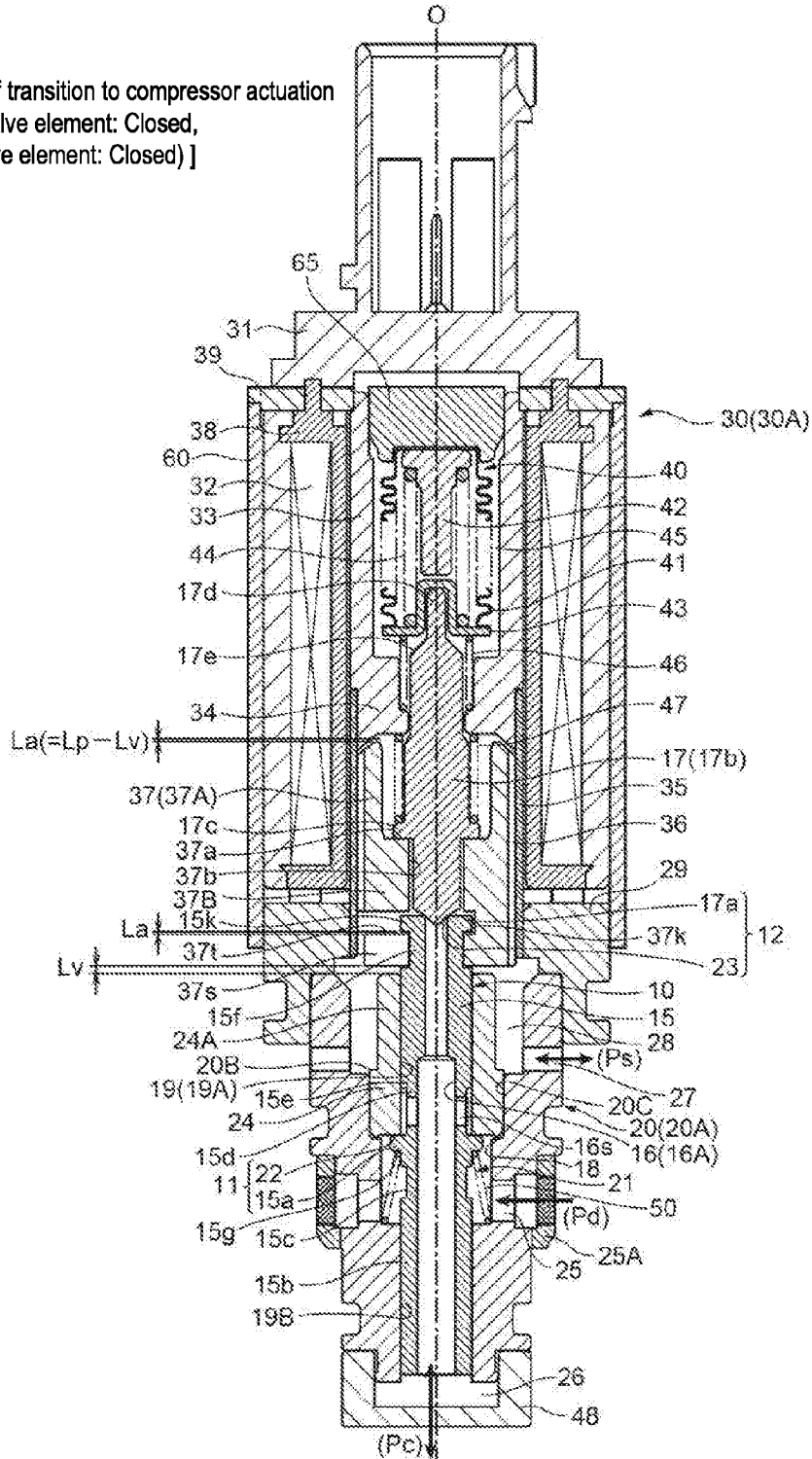


FIG. 3

[ Compressor actuation time  
 (Main valve element: Closed,  
 Sub valve element: Open) ]

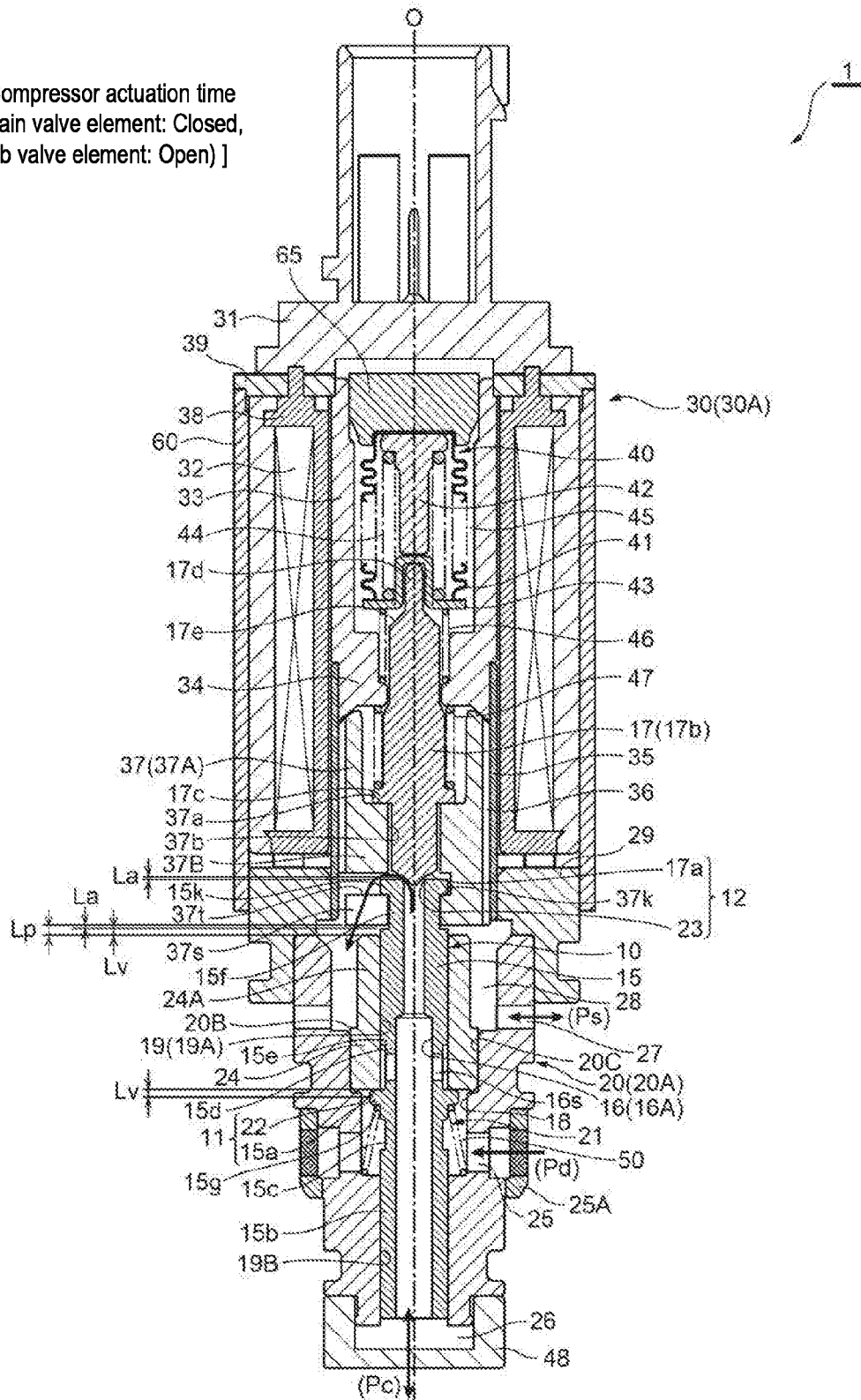


FIG. 4A

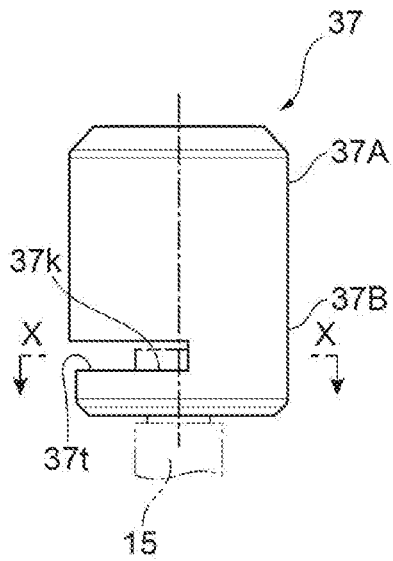


FIG. 4B

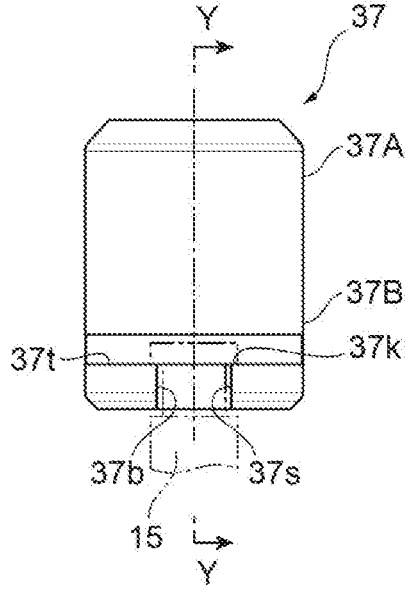


FIG. 4C

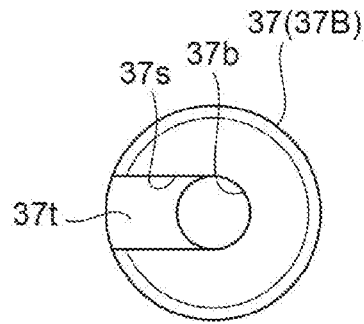


FIG. 4D

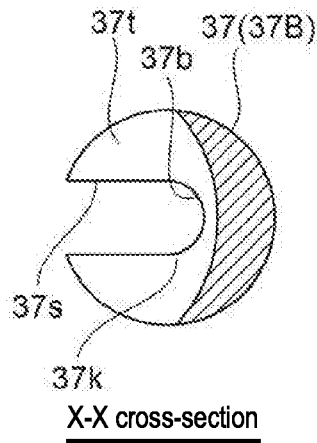


FIG. 4E

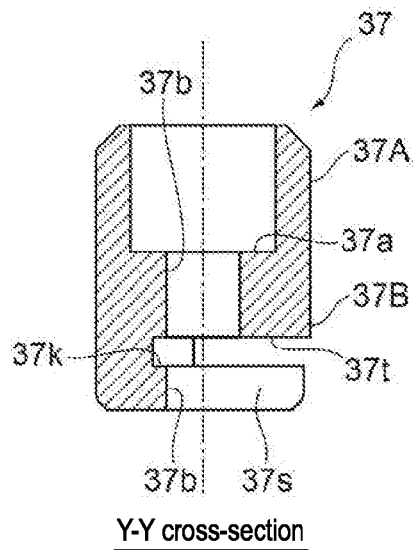


FIG. 5

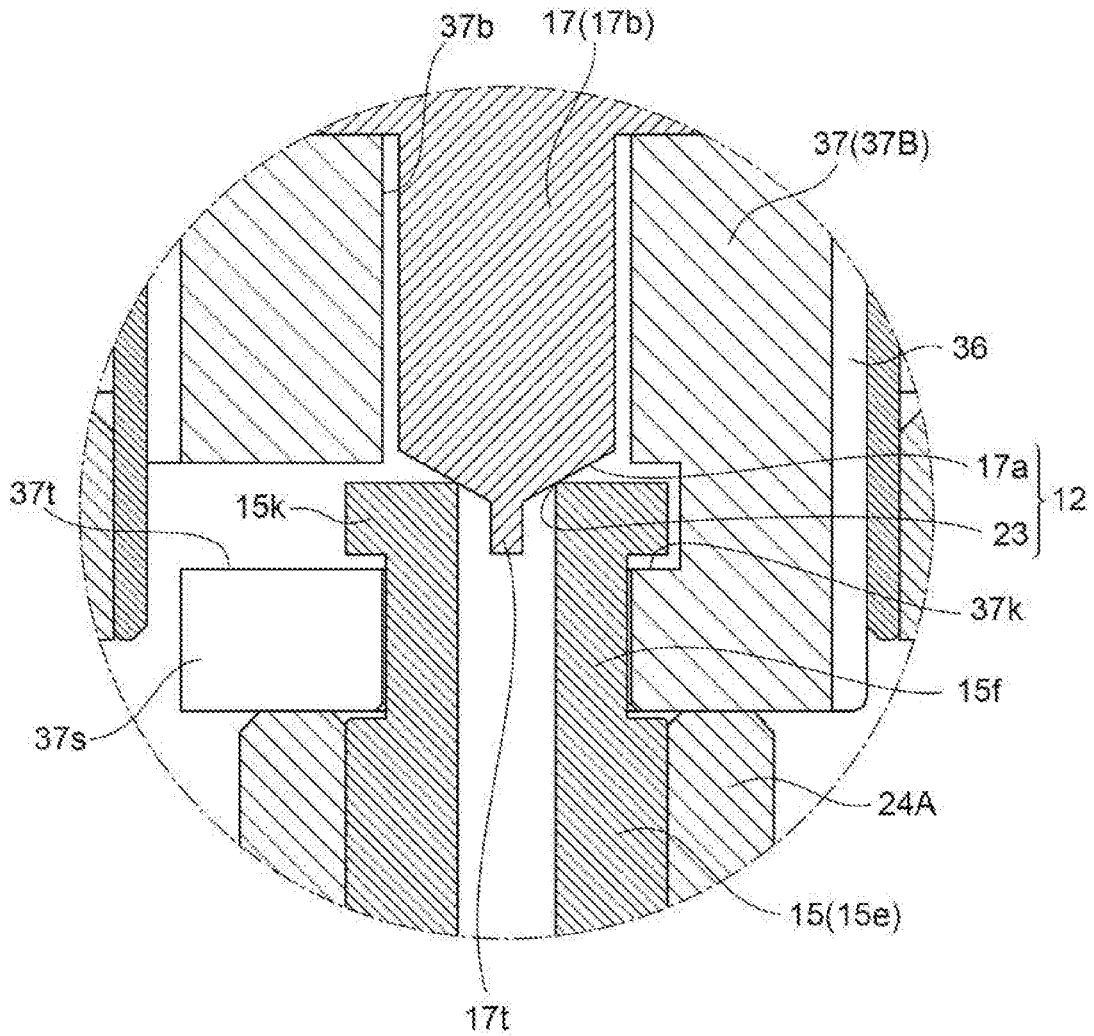


FIG. 6

[ Normal operation time  
(Main valve element: Open,  
Sub valve element: Closed) ]

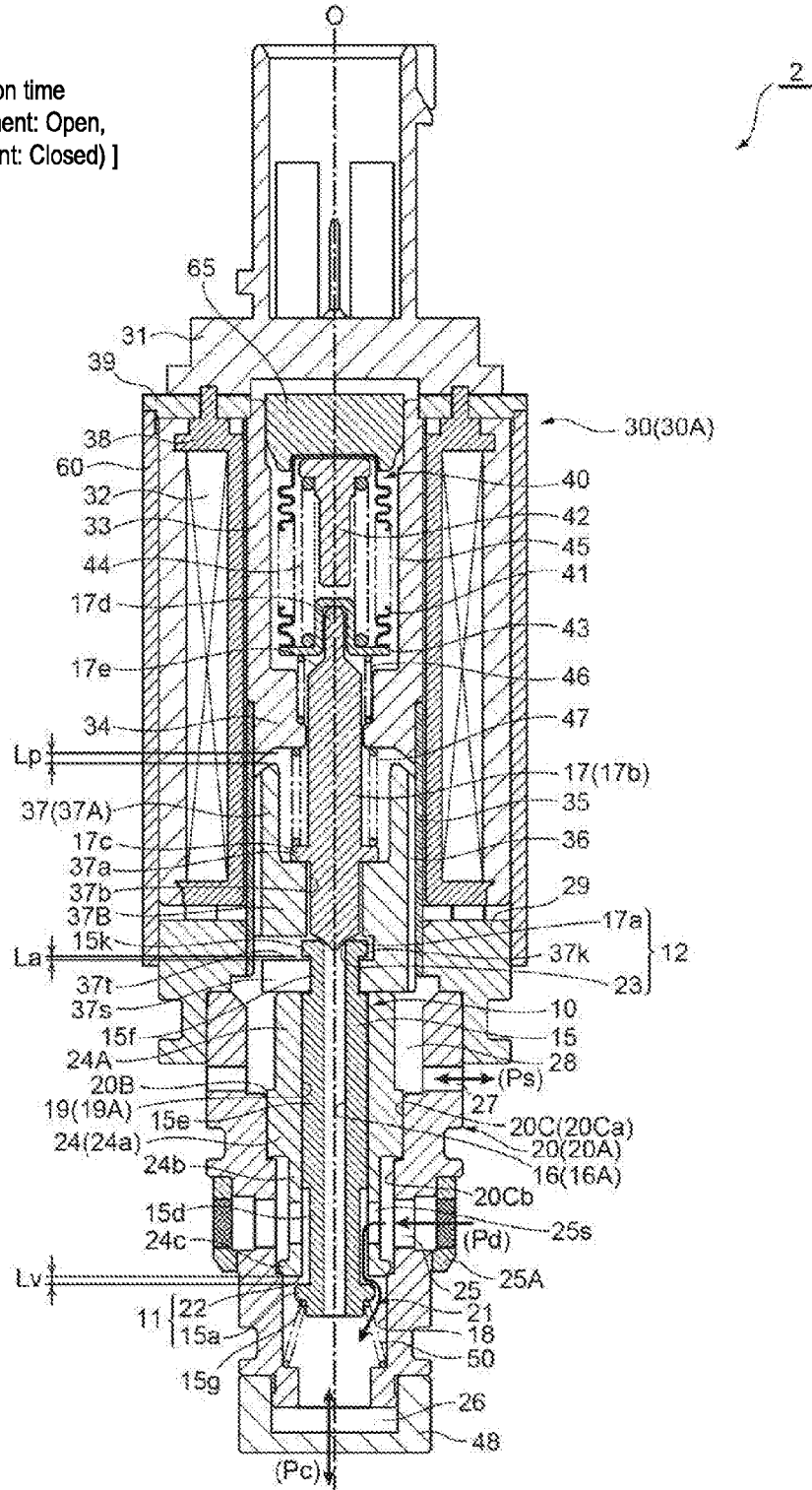




FIG. 7

[ Time of transition to compressor actuation  
 (Main valve element: Closed,  
 Sub valve element: Closed) ]

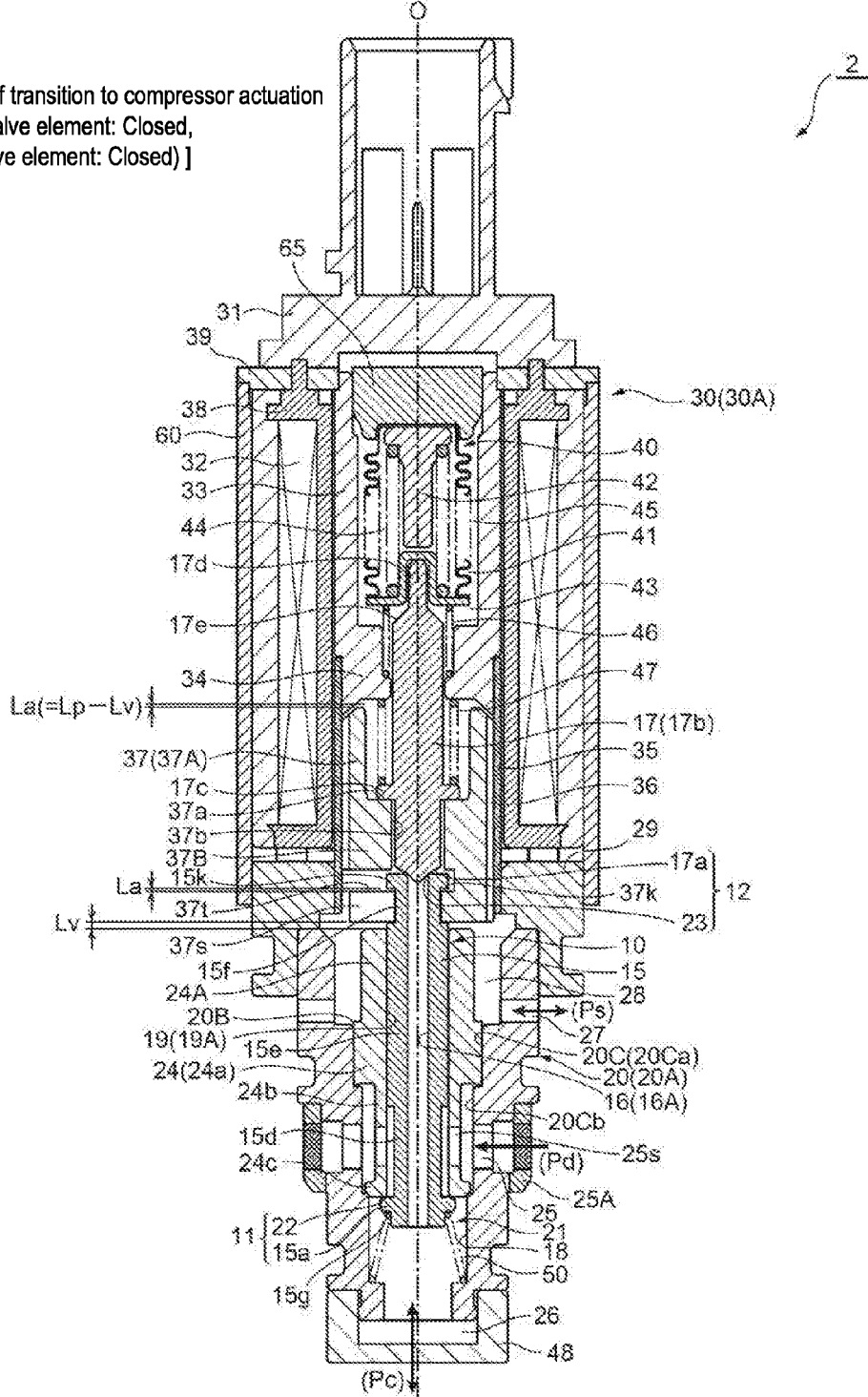


FIG. 8

[ Compressor actuation time  
 (Main valve element: Closed,  
 Sub valve element: Open) ]

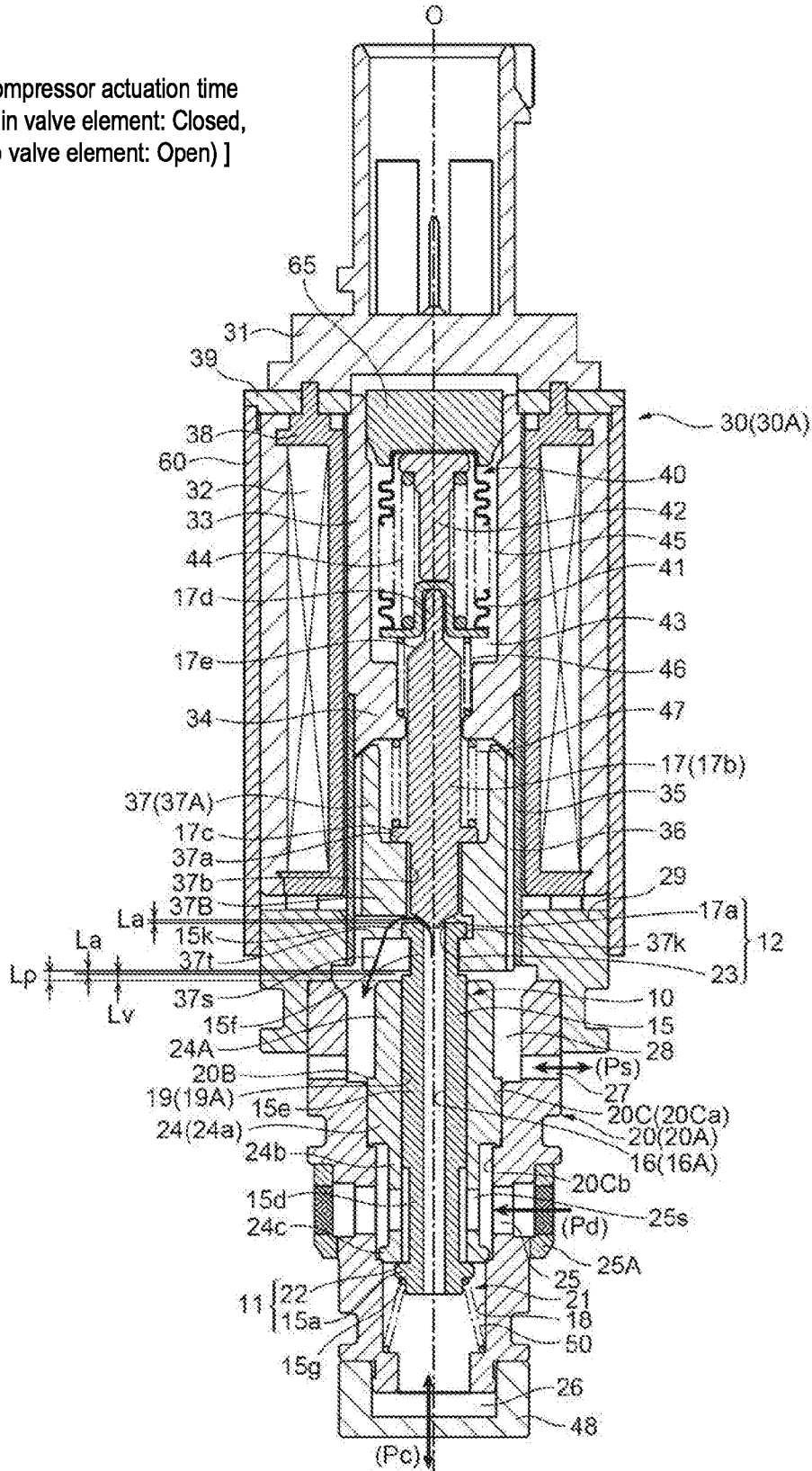
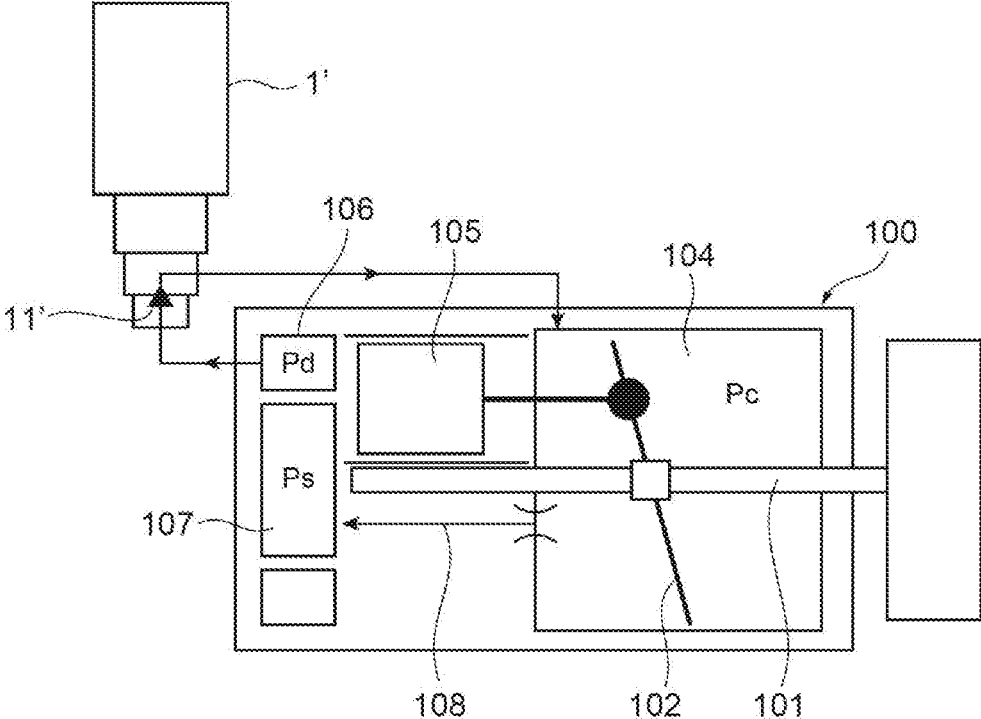


FIG. 9





## VARIABLE-CAPACITY COMPRESSOR CONTROL VALVE

### CLAIM OF PRIORITY

[0001] The present application claims priority from Japanese patent application JP 2015-245030 filed on Dec. 16, 2015, the content of which is hereby incorporated by reference into this application.

### BACKGROUND

[0002] Technical Field

[0003] The present invention relates to a variable-capacity compressor control valve for use in an automotive air conditioner or the like.

[0004] Background Art

[0005] Conventionally, a variable-capacity swash plate compressor such as the one schematically shown in FIG. 9 has been used as a compressor for an automotive air conditioner. The variable-capacity swash plate compressor **100** includes a rotating shaft **101** that is rotationally driven by an on-vehicle engine, a swash plate **102** that is attached to the rotating shaft **101**, a crank chamber **104** in which the swash plate **102** is disposed, a piston **105** that is reciprocated by the swash plate **102**, a discharge chamber **106** for discharging refrigerant compressed by the piston **105**, a suction chamber **107** for sucking refrigerant, an in-compressor release passage (fixed orifice) **108** for releasing a pressure  $P_c$  in the crank chamber **104** to the suction chamber **107**, and the like.

[0006] Meanwhile, a control valve **1'** used for the aforementioned variable-capacity compressor receives the discharge pressure  $P_d$  from the discharge chamber **106** of the compressor **100** and is configured to control the pressure  $P_c$  in the crank chamber **104** by controlling the discharge pressure  $P_d$  in accordance with the suction pressure  $P_s$  of the compressor **100**. Such a control valve **1'** has, as the basic configuration, a valve body that includes a valve chamber with a valve orifice, a  $P_s$  introduction port communicating with the suction chamber **107** of the compressor **100**, a  $P_d$  introduction port arranged upstream of the valve orifice and communicating with the discharge chamber **106** of the compressor **100**, and a  $P_c$  outlet port arranged downstream of the valve orifice and communicating with the crank chamber **104** of the compressor **100**; a valve element (valve stem) for opening or closing the valve orifice; an electromagnetic actuator with a plunger for moving the valve element in the direction to open or close the valve orifice (in the vertical direction); a pressure-sensitive chamber that receives the suction pressure  $P_s$  from the compressor **100** via the  $P_s$  introduction port; and a pressure-sensitive reaction member that urges the valve element in the direction to open or close the valve orifice in accordance with the pressure in the pressure-sensitive chamber. The valve element and the valve orifice form a valve unit indicated by reference numeral **11'** in FIG. 9 (for example, see Patent Document 1 below).

[0007] In the control valve **1'** with such a configuration, when current is flowed through a solenoid portion including a coil, a stator, an attractor, and the like of the electromagnetic actuator, the plunger is attracted by the attractor, and along with this, the valve element is moved in the direction to close the valve such that it follows the plunger by the urging force of a valve closing spring. Meanwhile, the suction pressure  $P_s$  introduced from the compressor **100** via

the  $P_s$  introduction port is introduced into the pressure-sensitive chamber from an inlet/outlet chamber via a gap formed between the plunger and a guide pipe arranged around the outer periphery of the plunger or the like. Then, the pressure-sensitive reaction member (e.g., a bellows device) is expansively or contractively displaced in accordance with the pressure (suction pressure  $P_s$ ) in the pressure-sensitive chamber (contracts if the suction pressure  $P_s$  is high, and expands if it is low), and the displacement (urging force) is then transmitted to the valve element, whereby the valve element portion of the valve element moves up or down with respect to the valve orifice to regulate the valve opening of the valve unit **11'**. That is, the valve opening is determined by the force of attracting the plunger with the solenoid portion, the urging force (expansion or contraction force) that acts with the expansive or contractive displacement of the pressure-sensitive reaction member, the urging force of a plunger spring (valve opening spring) and the valve closing spring. The pressure  $P_c$  in the crank chamber **104** (hereinafter also referred to as a crank chamber pressure  $P_c$  or simply referred to as a pressure  $P_c$ ) is controlled in accordance with the valve opening.

[0008] In response to the aforementioned variable-capacity compressor, an improved variable-capacity swash plate compressor, such as the one schematically shown in FIGS. **10A** and **10B**, for example, has already been proposed that is intended to reduce the time required to increase the discharge capacity at the compressor actuation time, and suppress or reduce a decrease in the operation efficiency of the compressor at the normal control time.

[0009] A control valve **2'** used for such an improved variable-capacity swash plate compressor **200** has a valve element (valve stem) including a main valve element and a sub valve element, and has an in-valve release passage **16'** in the main valve element. The control valve **2'** basically has a valve body that includes a valve chamber with a valve orifice, a  $P_s$  inlet/outlet port communicating with a suction chamber **107** of the compressor **200**, a  $P_d$  introduction port arranged upstream of the valve orifice and communicating with a discharge chamber **106** of the compressor **200**, and a  $P_c$  inlet/outlet port arranged downstream of the valve orifice and communicating with a crank chamber **104** of the compressor **200**; a main valve element for opening or closing the valve orifice; an electromagnetic actuator with a plunger for moving the main valve element in the direction to open or close the valve orifice; a pressure-sensitive chamber that receives the suction pressure  $P_s$  from the compressor **200** via the  $P_s$  inlet/outlet port; and a pressure-sensitive reaction member that urges the main valve element in the direction to open or close the valve orifice in accordance with the pressure in the pressure-sensitive chamber. Further, the in-valve release passage **16'** for releasing the pressure  $P_c$  in the crank chamber **104** to the suction chamber **107** of the compressor **200** via the  $P_s$  inlet/outlet port is provided in the main valve element, and the sub valve element for opening or closing the in-valve release passage **16'** is also provided so that when the plunger is continuously moved upward from the lowest position by the attraction force of the electromagnetic actuator, the sub valve element moves upward together with the plunger while closing the in-valve release passage **16'**, and the main valve element is also moved upward so as to follow the sub valve element. Then, after the valve orifice is closed by the main valve element, if the plunger is further moved upward, the sub valve

element is configured to open the in-valve release passage 16'. The main valve element and the valve orifice form a main valve unit indicated by reference numeral 11' in FIGS. 10A and 10B, while the sub valve element and the in-valve release passage form a sub valve unit indicated by reference numeral 12' (for example, see Patent Document 2 below).

**[0010]** At the normal control time (Pd→Pc control time) of the control valve 2' with such a configuration, when current is flowed through a solenoid portion including a coil, a stator, an attractor, and the like of the electromagnetic actuator, the plunger is attracted by the attractor, and along with this, the sub valve element moves upward integrally with the plunger, and following the movement of the sub valve element, the main valve element is moved in the direction to close the valve by the urging force of a valve closing spring. Meanwhile, the suction pressure Ps introduced from the compressor 200 via the Ps inlet/outlet port is introduced into the pressure-sensitive chamber from an inlet/outlet chamber via a horizontal hole in the plunger or the like, and the pressure-sensitive reaction member (e.g., a bellows device) is expansively or contractively displaced in accordance with the pressure (suction pressure Ps) in the pressure-sensitive chamber (contracts if the suction pressure Ps is high, and expands if it is low), and the displacement (urging force) is then transmitted to the main valve element, whereby the main valve element portion of the main valve element moves up or down with respect to the valve orifice to regulate the valve opening of the main valve unit 11'. That is, the valve opening is determined by the force of attracting the plunger with the solenoid portion, the urging force (expansion or contraction force) that acts with the expansive or contractive displacement of the pressure-sensitive reaction member, the urging force of a plunger spring (valve opening spring) and the valve closing spring, and force that acts on the main valve element in the valve opening direction and in the valve closing direction. The pressure Pc in the crank chamber 104 is controlled in accordance with the valve opening. In such a case, the main valve element is always urged upward by the urging force of the valve closing spring, while the sub valve element is always urged downward by the urging force of the valve opening spring. Thus, the sub valve unit 12' is closed and the in-valve release passage 16' is blocked in the main valve element. Therefore, there is no possibility that the crank chamber pressure Pc may be released to the suction chamber 107 via the in-valve release passage 16'.

**[0011]** In contrast, at the compressor actuation time, current is flowed through the solenoid portion so that the plunger is attracted by the attractor and the sub valve element moves upward together with the plunger. Following the upward movement of the sub valve element, the main valve element is moved in the direction to close the valve by the urging force of the valve closing spring, and after the valve orifice is closed by the main valve element portion of the main valve element, the plunger is further moved upward, whereby the sub valve element opens the in-valve release passage 16'. Then, the crank chamber pressure Pc is released to the suction chamber 107 via two passages that are an in-compressor release passage 108 and the in-valve release passage 16' (for details, see Patent Document 2 below and the like).

## RELATED ART DOCUMENTS

### Patent Documents

- [0012]** Patent Document 1: JP 2010-185285 A
- [0013]** Patent Document 2: JP 2013-130126 A

### SUMMARY

**[0014]** By the way, in the variable-capacity compressor control valve 2' described above, a sub valve element portion of the sub valve element that opens or closes the in-valve release passage has a flat shape, and the sub valve element is guided so as not to be tilted by a predetermined amount or more upon insertion into an insertion hole of a latch member that is fixed to the inner peripheral portion of the plunger.

**[0015]** However, in the control valve with the aforementioned configuration, it follows that the sub valve element is guided by the plunger that is a movable part (or the latch member fixed thereto). Therefore, a decrease in the sealability or the operability due to shaft misalignment is concerned, and there has also been a problem that the cost would increase if the dimensional accuracy of the guide portion is increased.

**[0016]** The present invention has been made in view of the foregoing, and it is an object of the present invention to provide a variable-capacity compressor control valve where a decrease in the sealability or the operability due to shaft misalignment can be effectively suppressed without requiring high dimensional accuracy.

**[0017]** In order to achieve the aforementioned object, a variable-capacity compressor control valve in accordance with the present invention basically includes a valve body including a valve chamber with a valve orifice, a Ps inlet/outlet port communicating with a suction chamber of a compressor, a Pd introduction port arranged upstream of the valve orifice and communicating with a discharge chamber of the compressor, and a Pc inlet/outlet port arranged downstream of the valve orifice and communicating with a crank chamber of the compressor; a main valve element adapted to open or close the valve orifice; an electromagnetic actuator with a plunger for moving the main valve element in a direction to open or close the valve orifice; a pressure-sensitive chamber adapted to receive a suction pressure Ps from the compressor via the Ps inlet/outlet port; a pressure-sensitive reaction member adapted to urge the main valve element in the direction to open or close the valve orifice in accordance with a pressure in the pressure-sensitive chamber; an in-valve release passage provided in the main valve element, the in-valve release passage being adapted to release a pressure Pc in the crank chamber to the suction chamber of the compressor via the Ps inlet/outlet port; and a sub valve element adapted to open or close the in-valve release passage. The sub valve element has a sub valve element portion with a tapered portion, and dimensions and a shape of each part are designed such that when the sub valve element closes the in-valve release passage, the tapered portion enters the in-valve release passage, and the sub valve element is thus aligned with the main valve element by the tapered portion.

**[0018]** In a preferred aspect, part of the tapered portion is located in the in-valve release passage when the sub valve element is at the highest elevated position with respect to the main valve element.

**[0019]** The sub valve element is preferably supported by the pressure-sensitive reaction member at an end portion on a side opposite to the sub valve element portion, and is pressed against the plunger by a plunger spring such that the sub valve element moves up or down with the plunger.

**[0020]** In another preferred aspect, the tapered portion has a protrusion that extends toward the in-valve release passage.

**[0021]** According to the variable-capacity compressor control valve in accordance with the present invention, a sub valve element has a sub valve element portion with a tapered portion, and the dimensions and the shape of each part are designed such that when the sub valve element closes the in-valve release passage, the tapered portion enters the in-valve release passage, and the sub valve element is thus aligned with the main valve element by the tapered portion. Therefore, in comparison with the conventional art in which a sub valve element portion of a sub valve element has a flat shape, it is possible to effectively suppress a decrease in the sealability or the operability due to shaft misalignment without requiring high dimensional accuracy.

**[0022]** Further, as part of the tapered portion is located in the in-valve release passage even when the sub valve element is at the highest elevated position with respect to the main valve element, the tapered portion surely enters the in-valve release passage when the sub valve element closes the in-valve release passage. Thus, further relaxation of the dimensional accuracy can also be achieved.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0023]** FIG. 1 is a longitudinal sectional view showing the first embodiment of the variable-capacity compressor control valve in accordance with the present invention in which the main valve element is in the open position and the sub valve element is in the closed position (at the normal control time).

**[0024]** FIG. 2 is a longitudinal sectional view showing the first embodiment of the variable-capacity compressor control valve in accordance with the present invention in which the main valve element is in the closed position and the sub valve element is in the closed position (at the time of transition to compressor actuation).

**[0025]** FIG. 3 is a longitudinal sectional view showing the first embodiment of the variable-capacity compressor control valve in accordance with the present invention in which the main valve element is in the closed position and the sub valve element is in the open position (at the compressor actuation time).

**[0026]** FIGS. 4A to 4E are views each showing a plunger used for the variable-capacity compressor control valve in accordance with the present invention; specifically, FIG. 4A is a front view, FIG. 4B is a left-side view, FIG. 4C is a bottom view, FIG. 4D is a sectional view along the direction of the arrows X-X in FIG. 4A, and FIG. 4E is a sectional view along the direction of the arrows Y-Y in FIG. 4B.

**[0027]** FIG. 5 is an enlarged sectional view of the main part showing a variation of a sub valve element portion of a sub valve element in the first embodiment.

**[0028]** FIG. 6 is a longitudinal sectional view showing the second embodiment of the variable-capacity compressor control valve in accordance with the present invention in which the main valve element is in the open position and the sub valve element is in the closed position (at the normal control time).

**[0029]** FIG. 7 is a longitudinal sectional view showing the second embodiment of the variable-capacity compressor control valve in accordance with the present invention in which the main valve element is in the closed position and the sub valve element is in the closed position (at the time of transition to compressor actuation).

**[0030]** FIG. 8 is a longitudinal sectional view showing the second embodiment of the variable-capacity compressor control valve in accordance with the present invention in which the main valve element is in the closed position and the sub valve element is in the open position (at the compressor actuation time).

**[0031]** FIG. 9 is a view showing the circulation state of a refrigerant pressure between a compressor and a control valve of the first conventional art.

**[0032]** FIGS. 10A and 10B are views each showing the circulation state of a refrigerant pressure between a compressor and a control valve of the second conventional art; specifically, FIG. 10A is a view at the normal operation time and FIG. 10B is a view at the compressor actuation time.

#### DETAILED DESCRIPTION

**[0033]** Hereinafter, embodiments of the present invention will be described with reference to the drawings.

##### First Embodiment

**[0034]** FIGS. 1 to 3 are longitudinal sectional views each showing the first embodiment of the variable-capacity compressor control valve in accordance with the present invention. Specifically, FIG. 1 is a view in which the main valve element is in the open position and the sub valve element is in the closed position (at the normal control time), FIG. 2 is a view in which the main valve element is in the closed position and the sub valve element is in the closed position (at the time of transition to compressor actuation), and FIG. 3 is a view in which the main valve element is in the closed position and the sub valve element is in the open position (at the compressor actuation time).

**[0035]** It should be noted that in the present specification, descriptions indicating the positions or directions, such as upper, lower, top, bottom, left, right, front, and rear, are used for the sake of convenience in accordance with the drawings to avoid complexity in the description, but such descriptions do not necessarily indicate the actual positions or directions when the control valve of the present invention is incorporated into a compressor.

**[0036]** In addition, in each drawing, a gap formed between members, a clearance between members, and the like may be depicted larger or smaller than their actual dimensions to help understand the present invention and also for the sake of convenience to create the drawing.

**[0037]** A control valve 1 in the shown embodiment has a valve body 20 with a valve orifice 22; a valve element 10 with a main valve element 15 for opening or closing the valve orifice 22; an electromagnetic actuator 30 for moving the valve element 10 (main valve element 15) in the direction to open or close the valve orifice (in the vertical direction); and a bellows device 40 that serves as a pressure-sensitive reaction member.

**[0038]** The electromagnetic actuator 30 includes a bobbin 38, an energization coil 32 wound around the bobbin 38, a connector head 31 attached to the upper side of the bobbin 38 with an attachment plate 39 interposed therebetween, a

stator 33 and an attractor 34 arranged on the inner peripheral side of the coil 32, a guide pipe 35 whose upper end portion is joined by welding to the outer periphery of the lower end portion (a step portion) of the stator 33 and the attractor 34, a plunger 37 having a recessed cross section and arranged vertically slidably on the inner peripheral side of the guide pipe 35 below the attractor 34, a cylindrical housing 60 externally arranged around the coil 32, and a holder 29 arranged between the lower end portion of the housing 60 and the guide pipe 35 and adapted to fix them to the top of the valve body 20. In the present example, the attractor 34 with a recessed cross section is integrally molded with the inner periphery of the bottom of the cylindrical stator 33. Herein, a portion of the electromagnetic actuator 30 including the coil 32, the stator 33, the attractor 34, and the like and excluding the plunger 37 is referred to as a solenoid portion 30A.

[0039] A stator 65 in a short columnar shape is attached to the top of the stator 33 by press fitting or the like, and a pressure-sensitive chamber 45, which receives a suction pressure  $P_s$  in a compressor 100, is formed between the stator 65 and the attractor 34 on the inner peripheral side of the stator 33. The pressure-sensitive chamber 45 has arranged therein the bellows device 40 that serves as a pressure-sensitive reaction member and includes bellows 41, an upper stopper 42 in an inverted projection shape, a lower stopper 43 in an inverted recessed shape, and a compression coil spring 44. Further, a top small-diameter portion 17d (an end portion on the side opposite to a sub valve element portion 17a) of a sub valve element 17 described below is fitted and inserted in and supported by the recess of the lower stopper 43, and a compression coil spring 46, which urges the bellows device 40 in the direction to contract the bellows device 40, is provided in a compressed state between the lower stopper 43 and the attractor 34.

[0040] The plunger 37 has a cylindrical upper half portion 37A and a columnar lower half portion 37B. Provided in the center of the columnar lower half portion 37B is an insertion hole 37b through which a waist portion 17b of the sub valve element 17 that extends downward through the attractor 34 and a top small-diameter portion 15f (described in detail below) of the main valve element 15 are inserted. The outer peripheral portion of the insertion hole 37b on the upper surface of the columnar lower half portion 37B serves as a latch portion 37a to which an intermediate large-diameter latch portion 17c of the sub valve element 17 is latched.

[0041] In addition, a plunger spring (valve opening spring) 47 constructed from a cylindrical compression coil spring, which urges the sub valve element 17 and the plunger 37 downward (in the direction to open the valve), is provided in a compressed state between the attractor 34 and the intermediate large-diameter latch portion 17c of the sub valve element 17 (plunger 37) so that the sub valve element 17 (or the intermediate large-diameter latch portion 17c thereof) is pressed against the plunger 37 by the plunger spring 47 and thus is caused to move up or down with the plunger 37.

[0042] Further, as can be understood well from FIGS. 4A to 4E, the bottom of the columnar lower half portion 37B of the plunger 37 (a portion that is above the lower end portion by a predetermined distance) has a cut-in 37t with an approximately semicircular shape in plan view (in the horizontal direction) that is formed so as to overlap the insertion hole 37b. On the side below the cut-in 37t (i.e., at a portion

between the cut-in 37t and the lower end portion of the columnar lower half portion 37B), a slit 37s with approximately the same width as the hole diameter of the insertion hole 37b is formed that extends linearly from the edge portion at the lower end of the columnar lower half portion 37B to the insertion hole 37b. The height (in the vertical direction) of the cut-in 37t is slightly larger than the height of a flanged latch portion 15k of the main valve element 15, and the height (in the vertical direction) of the slit 37s is slightly smaller than the height of the top small-diameter portion 15f of the main valve element 15. The main valve element 15 is movable in the vertical direction with respect to the plunger 37 (which will be described in detail below). The width (in the horizontal direction) of the slit 37s is set slightly larger than the outside diameter of the top small-diameter portion 15f of the main valve element 15 and smaller than the outside diameter of the flanged latch portion 15k of the main valve element 15 taking into consideration the assembling properties and the like.

[0043] The valve element 10 has the main valve element 15 and the sub valve element 17 arranged in the vertical direction (along the direction of the axial line O).

[0044] The main valve element 15 arranged on the lower side has, sequentially arranged from the bottom side, a bottom fit-insertion portion 15b, a lower small-diameter portion 15c, a main valve element portion 15a, an intermediate small-diameter portion 15d, a top fit-insertion portion 15e, the top small-diameter portion 15f, and the flanged latch portion 15k. A stepped release through-hole 16A forming part of an in-valve release passage 16 is provided in the center of the main valve element 15 such that it penetrates the center of the main valve element 15 in the vertical direction, and the upper end portion of the release through-hole 16A serves as a sub valve seat portion 23 with/from which the lower end portion (sub valve element portion) 17a of the sub valve element 17 is moved into contact or away. The intermediate small-diameter portion 15d of the main valve element 15 has a plurality of horizontal holes 16s.

[0045] The top small-diameter portion 15f of the main valve element 15 is loosely fitted in the insertion hole 37b (or a portion below the cut-in 37t thereof), and the flanged latch portion 15k of the main valve element 15 has a larger diameter than that of the insertion hole 37b so that when the plunger 37 is moved upward with respect to the main valve element 15, the flanged latch portion 15k is latched to an inner flanged latch portion 37k that is formed by the outer peripheral portion of the insertion hole 37b, and thus, latching is achieved and slippage is prevented.

[0046] The sub valve element 17 arranged above the main valve element 15 has, sequentially arranged from the bottom side, an inverted conical tapered portion 17a, which is moved into contact with or away from the sub valve seat portion 23 that is the edge portion at the upper end of the release through-hole 16A, the waist portion 17b having the intermediate large-diameter latch portion 17c formed thereon, a truncated conical portion 17e, and a top small-diameter portion 17d that is inserted in and supported by the recess of the lower stopper 43. The tapered portion 17a serves as the sub valve element portion that opens or closes the in-valve release passage 16. Herein, the sub valve seat portion 23 and the sub valve element portion 17a form the sub valve unit 12. In the present example, a portion below the intermediate large-diameter latch portion 17c of the waist portion 17 is inserted into the insertion hole 37b of the



plunger 37 with a small gap therebetween, and a portion above the intermediate large-diameter latch portion 17c and below the attractor (a portion arranged inside the cylindrical upper half portion 37A) has a slightly larger diameter than those of the other portions.

[0047] The dimensions and the shape of each part around the sub valve element 17 (e.g., a gap between the waist portion 17b and the insertion hole 37b) are designed such that even when the sub valve element 17 is slightly tilted at a position where it has been moved upward with respect to the main valve element 15 (i.e., a position where the in-valve release passage 16 is open), the lower end portion of the sub valve element portion (a tapered portion) 17a in an inverted conical shape enters the release through-hole 16A, and the sub valve element 17 is thus aligned with the main valve element 15 by the sub valve element portion 17a as the sub valve element 17 moves closer to the main valve element 15 (i.e., when the sub valve element 17 closes the in-valve release passage 16). More specifically, the dimensions and the shape of each part are designed such that part of the sub valve element portion 17a in an inverted conical shape is located in the release through-hole 16A when the sub valve element 17 is at the highest elevated position with respect to the main valve element 15 (see FIG. 3, in particular).

[0048] When the valve element 10 (the main valve element 15 and the sub valve element 17) and the plunger 37 are assembled, for example, the main valve element 15 is moved horizontally with respect to the plunger 37 so that the flanged latch portion 15k and the top small-diameter portion 15f of the main valve element 15, which has been assembled in advance to the valve body 20 (or a guide hole 19 thereof), are inserted into the cut-in 37t and the slit 37s of the plunger 37, respectively, and the top small-diameter portion 15f is fitted and inserted into the insertion hole 37b provided in the center of the plunger 37, and thereafter, the sub valve element 17 (or a portion below the intermediate large-diameter latch portion 17c thereof) may be inserted into the insertion hole 37b from above.

[0049] Meanwhile, the valve body 20 has a two-split structure that includes a body member 20A having a fit recess hole 20C in the center at the top thereof, and a support member 20B that is fixedly inserted into the recess hole 20C by press fitting or the like.

[0050] The support member 20B is produced from a material with relatively high hardness, such as stainless steel (SUS), and has a protruding stopper portion 24A for defining the lowest position of the plunger 37, on the upper side of a fit-insertion portion 24 that is fitted and inserted in the recess hole 20C. In addition, the guide hole 19 (an upper guide hole 19A) into which the top fit-insertion portion 15e of the main valve element 15 is slidably fitted and inserted is formed in the center of the support member 20B such that it penetrates the support member 20B in the vertical direction, and the lower end portion of the upper guide hole 19A serves as the valve orifice 22 (a valve seat portion) that is opened or closed by the main valve element portion 15a of the main valve element 15. Herein, the main valve element portion 15a and the valve orifice 22 form a main valve unit 11. As the support member 20B is produced from a material with high hardness, such as stainless steel, as described above, the specific gravity of the support member 20B is also high.

[0051] The body member 20A is produced from a material, such as aluminum, brass, or resin, that has relatively low

specific gravity (a material with relatively low hardness) as compared to stainless steel and the like. An inlet/outlet chamber 28 for the suction pressure Ps in the compressor 100 is formed around the outer periphery of the stopper portion 24A, and a plurality of Ps inlet/outlet ports 27 are formed around the outer peripheral side of the inlet/outlet chamber 28 in a state in which the support member 20B (or the fit-insertion portion 24 thereof) is inserted in the recess hole 20C of the body member 20A. The suction pressure Ps introduced into the inlet/outlet chamber 28 from the Ps inlet/outlet ports 27 is introduced into the pressure-sensitive chamber 45 via the slit 37s and the cut-in 37t formed at the bottom of the plunger 37, a gap formed between the waist portion 17b of the sub valve element 17 and the insertion hole 37b of the plunger 37, a gap 36 formed between the outer periphery of the plunger 37 and the guide pipe 35, and the like.

[0052] A reception hole 18, which has a larger diameter than those of the guide hole 19 and the main valve element portion 15a and has a smaller diameter than that of the recess hole 20C and is adapted to store the main valve element portion 15a of the main valve element 15, is provided continuously with the center of the bottom of the recess hole 20C of the body member 20A, and the guide hole 19 (a lower guide hole 19B) into which the bottom fit-insertion portion 15b of the main valve element 15 is slidably fitted and inserted is formed in the center of the bottom of the reception hole 18. A valve closing spring 50 constructed from a conical compression coil spring is provided in a compressed state between the corner on the outer periphery of the bottom of the reception hole 18 and a stepped portion (terrace portion) 15g provided on the outer periphery of the bottom of the main valve element portion 15a of the main valve element 15. Thus, with the urging force of the valve closing spring 50, the main valve element 15 (or a step portion between the top fit-insertion portion 15e and the top small-diameter portion 15f thereof) is pressed against the plunger 37.

[0053] The inside of the reception hole 18 (a portion below the valve orifice 22 of the support member 20B) is the valve chamber 21. The valve chamber 21 has a plurality of Pd introduction ports 25 communicating with a discharge chamber 106 of the compressor 100. A ring-like filter member 25A is arranged around the outer periphery of the Pd introduction ports 25 of the body member 20A.

[0054] The lower end portion of the body member 20A has a lid-like member 48, which functions as a filter, fixed thereto by engagement, press fitting, or the like. A Pc inlet/outlet chamber (inlet/outlet port) 26, which communicates with a crank chamber 104 of the compressor 100, is provided on the side above the lid-like member 48 below the main valve element 15. The Pc inlet/outlet chamber (inlet/outlet port) 26 communicates with the Pd introduction ports 25 via the release through-hole 16A→the horizontal holes 16s→a gap between the bottom of the upper guide hole 19A and the intermediate small-diameter portion 15d→a gap between the valve orifice 22 and the main valve element portion 15a→the valve chamber 21.

[0055] In addition, in this embodiment, the in-valve release passage 16 for releasing the pressure Pc in the crank chamber 104 to a suction chamber 107 of the compressor 100 via the Ps inlet/outlet ports 27 is formed by the release through-hole 16A formed in the main valve element 15, the cut-in 37t and the slit 37s provided in the plunger 37, the

inlet/outlet chamber 28, and the like. The in-valve release passage 16 is adapted to be opened or closed as the sub valve element portion 17a of the sub valve element 17 is moved into contact with or away from the sub valve seat portion 23 that is the upper end portion of the release through-hole 16A of the main valve element 15.

[0056] Herein, in the control valve 1 in this embodiment, when the plunger 37, the main valve element 15, and the sub valve element 17 are at the lowest position (when the bottom end surface of the plunger 37 abuts the stopper portion 24A, the main valve unit 11 is in the fully open position, and the sub valve unit 12 is in the fully closed position) as shown in FIG. 1, the clearance in the vertical direction between the main valve element portion 15a of the main valve element 15 and the valve orifice 22 (valve seat portion) is represented by a first lift amount  $L_v$ , and the clearance between the inner flanged latch portion 37k of the plunger 37 and the flanged latch portion 15k of the main valve element 15 is represented by a predetermined amount  $L_a$ . The maximum lift amount (second lift amount)  $L_p$  of the plunger 37 (the lift amount of from the lowest position to the highest position of the plunger 37) corresponds to the first lift amount  $L_v$  plus the predetermined amount  $L_a$ .

[0057] Next, the operation of the control valve 1 with the aforementioned configuration will be generally described.

[0058] At the normal control time ( $P_d \rightarrow P_c$  control time), the lift amount of the plunger 37 is slightly greater than the first lift amount  $L_v$  at the maximum, and at the compressor actuation time ( $P_c \rightarrow P_s$  control time), the lift amount of the plunger 37 is the second lift amount  $L_p$ .

[0059] That is, at the normal control time ( $P_d \rightarrow P_c$  control time), when the solenoid portion 30A including the coil 32, the stator 33, the attractor 34, and the like is supplied with current and energized, the plunger 37 is attracted by the attractor 34, and along with this, the intermediate large-diameter latch portion 17c of the sub valve element 17 is latched to the latch portion 37a of the plunger 37. Thus, the sub valve element 17 moves upward integrally with the plunger 37, and following the movement of the sub valve element 17, the main valve element 15 is moved upward (in the direction to close the valve) by the urging force of the valve closing spring 50. Meanwhile, the suction pressure  $P_s$  introduced into the  $P_s$  inlet/outlet ports 27 from the compressor 100 is introduced into the pressure-sensitive chamber 45 from the inlet/outlet chamber 28 via the slit 37s and the cut-in 37t of the plunger 37 and the like, and the bellows device 40 (the inside thereof is at a vacuum pressure) is expansively or contractively displaced in accordance with the pressure (suction pressure  $P_s$ ) in the pressure-sensitive chamber 45 (contracts if the suction pressure  $P_s$  is high, and expands if it is low), and the displacement is then transmitted to the main valve element 15 via the plunger 37 and the sub valve element 17, whereby the valve opening (the clearance between the valve orifice 22 and the main valve element portion 15a) is regulated, and the pressure  $P_c$  in the crank chamber 104 is controlled in accordance with the valve opening. Along with this, the inclination angle of the swash plate 102 and the stroke of the piston 105 in the compressor 100 are controlled to increase or decrease the discharge capacity.

[0060] In this case, the main valve element 15 is always urged upward by the urging force of the valve closing spring 50, while the sub valve element 17 is always urged downward by the urging force of the valve opening spring 47.

Therefore, the sub valve element portion 17a is in a state of being pressed against the sub valve seat portion 23 (the sub valve unit 12 is closed), and the in-valve release passage 16 is blocked in the main valve element 15. Therefore, there is no possibility that the crank chamber pressure  $P_c$  may be released to the suction chamber 107 via the in-valve release passage 16.

[0061] In contrast, at the compressor actuation time, the solenoid portion 30A is supplied with current and energized, and the plunger 37 is attracted by the attractor 34 so that the sub valve element 17 moves upward together with the plunger 37. Following such vertical movement of the sub valve element 17, the main valve element 15 is also moved upward and the valve orifice 22 is closed by the main valve element portion 15a of the main valve element 15. After that, the plunger 37 is further moved upward, whereby the sub valve element 17 is caused to open the in-valve release passage 16. Thus, the pressure  $P_c$  in the crank chamber 104 is released into the suction chamber 107 via two passages that are an in-compressor release passage 108 and the in-valve release passage 16.

[0062] Specifically, until the upward movement amount of the plunger 37 reaches the first lift amount  $L_v$ , the main valve element 15 moves in the direction to close the valve such that it follows the upward movement of the plunger 37 and the sub valve element 17 by the urging force of the valve closing spring 50. Then, when the upward movement amount reaches the first lift amount  $L_v$ , the valve orifice 20 is closed by the main valve element portion 15a of the main valve element 15 (the state shown in FIG. 2), and the plunger 37 is further moved upward by the predetermined amount  $L_a$  with the main valve unit 11 in the closed valve state (the state shown in FIG. 3). In other words, after the upward movement amount of the plunger 37 has reached the first lift amount  $L_v$ , the sub valve element 17 is elevated by the predetermined amount  $L_a$  until the inner flanged latch portion 37k of the plunger 37 is latched to the flanged latch portion 15k of the main valve element 15 (the first lift amount  $L_v$  plus the predetermined amount  $L_a$  equals the second lift amount  $L_p$ ). In such a case, the main valve element 15 remains still in the closed valve state. Thus, the sub valve element portion 17a of the sub valve element 17 is lifted from the sub valve seat portion 23 by the predetermined amount  $L_a$ , whereby the in-valve release passage 16 is opened. When the inner flanged latch portion 37k of the plunger 37 is latched to the flanged latch portion 15k of the main valve element 15, neither the plunger 37 nor the sub valve element 17 is lifted any further even if the solenoid portion 30A generates an attraction force.

[0063] As described above, in the control valve 1 in this embodiment, the dimensions and the shape of each part are designed such that when the sub valve element 17 closes the in-valve release passage 16, the tapered portion (sub valve element portion) 17a provided at the lower end portion of the sub valve element enters the release through-hole 16A of the in-valve release passage 16, and the sub valve element 17 is thus aligned with the main valve element 15 by the tapered portion 17a. Therefore, in comparison with the conventional art in which a sub valve element portion of a sub valve element has a flat shape, it is possible to effectively suppress a decrease in the sealability or the operability due to shaft misalignment without requiring high dimensional accuracy.

[0064] Further, as part of the tapered portion 17a is located in the release through-hole 16A of the in-valve release passage 16 even when the sub valve element 17 is at the highest elevated position with respect to the main valve element 15 (the state shown in FIG. 3), the tapered portion 17a surely enters the release through-hole 16A of the in-valve release passage 16 when the sub valve element 17 closes the in-valve release passage 16. Thus, further relaxation of the dimensional accuracy can also be achieved.

[0065] It should be noted that as shown in FIG. 5, a protrusion 17t, which extends downward (toward the release through-hole 16A of the in-valve release passage 16), may also be provided at the tip end portion of the sub valve element portion 17a of the sub valve element 17 for guiding purposes to allow the lower end portion of the sub valve element portion 17a of the sub valve element 17 to easily enter the release through-hole 16A.

#### Second Embodiment

[0066] FIGS. 6 to 8 are longitudinal sectional views each showing the second embodiment of the variable-capacity compressor control valve in accordance with the present invention. Specifically, FIG. 6 is a view in which the main valve element is in the open position and the sub valve element is in the closed position (at the normal control time); FIG. 7 is a view in which the main valve element is in the closed position and the sub valve element is in the closed position (at the time of transition to compressor actuation), and FIG. 8 is a view in which the main valve element is in the closed position and the sub valve element is in the open position (at the compressor actuation time).

[0067] The control valve 2 in the second embodiment basically differs from the control valve 1 in the aforementioned first embodiment only in the configurations of the valve body and the main valve element of the valve element. Thus, configurations with the same functions as those in the first embodiment are denoted by the same reference numerals and the detailed description thereof will thus be omitted. Hereinafter, only the differences will be discussed in detail.

[0068] In the control valve 2 in this embodiment, the top fit-insertion portion 15e and the intermediate small-diameter portion 15d of the main valve element 15 are formed longer than those of the control valve 1 in the first embodiment, while the lower small-diameter portion 15c and the bottom fit-insertion portion 15b on the lower side of the main valve element portion 15a are omitted.

[0069] In addition, the fit-insertion portion 24 of the support member 20B of the valve body 20 has a step formed thereon, and at a position below an upper large-diameter portion 24a (an outer shape corresponding to the fit-insertion portion 24 in the first embodiment), a lower small-diameter portion 24b, which is longer than the upper large-diameter portion 24a in the vertical direction, is provided, and at a lower end of the lower small-diameter portion 24b, a flanged abutment portion 24c adapted to abut the stepped portion (terrace portion) between the recess hole 20C and the reception hole 18 of the body member 20A is provided such that it protrudes outward.

[0070] Meanwhile, the recess hole 20C of the body member 20A of the valve body 20 also has a step formed thereon, and has an upper large-diameter hole 20Ca (an outer shape corresponding to the recess hole 20C in the first embodiment) into which the upper large-diameter portion 24a is fitted and inserted, and a lower small-diameter hole 20Cb

into which the lower small-diameter portion 24b is fitted and inserted, and further has a stepped reception hole 18 for storing the main valve element portion 15a of the main valve element 15 in a manner continuous with the center of the bottom of the lower small-diameter hole 20Cb. A valve closing spring 50 constructed from a conical compression coil spring is provided in a compressed state between the stepped portion provided on the inner periphery of the reception hole 18 and the stepped portion (terrace portion) 15g provided on the outer periphery of the bottom of the main valve element portion 15a of the main valve element 15.

[0071] The inside of the reception hole 18 (a portion below the valve orifice 22 of the support member 20B) is the valve chamber 21. Herein, the lower small-diameter hole 20Cb in the recess hole 20C has a plurality of Pd introduction ports 25 communicating with the discharge chamber 106 of the compressor 100. A ring-like filter member 25A is arranged around the outer periphery of the Pd introduction ports 25 thereof, and the lower small-diameter portion 24b of the fit-insertion portion 24 (instead of the intermediate small-diameter portion 15d of the main valve element 15) has a plurality of horizontal holes 25a communicating with the Pd introduction ports 25. The Pc inlet/outlet chamber (inlet/outlet port) 26, which communicates with the crank chamber 104 of the compressor 100, communicates with the Pd introduction ports 25 via the valve chamber 21—a gap between the valve orifice 22 and the main valve element portion 15a—a gap between the bottom of the guide hole 19 (upper guide hole 19A) and the intermediate small-diameter portion 15d—the horizontal holes 25 in the lower small-diameter portion 24b—a gap between the lower small-diameter portion 24b and the lower small-diameter hole 20Cb (which will be discussed in detail below).

[0072] In addition, in this embodiment, the outer periphery of the upper large-diameter portion 24a abuts the inner periphery of the upper large-diameter hole 20Ca (that is, the upper large-diameter portion 24a is fitted into (fits snugly inside) the upper large-diameter hole 20Ca), and the support member 20B is fixedly inserted into the recess hole 20C of the body member 20A in a posture in which a small gap is provided between the outer periphery of the lower small-diameter portion 24b and the inner periphery of the lower small-diameter hole 20Cb.

[0073] Needless to say, the control valve 2 in the second embodiment with the aforementioned configuration can also obtain operational effects that are similar to those of the control valve 1 in the first embodiment.

#### DESCRIPTION OF SYMBOLS

- [0074] 1 Variable-capacity compressor control valve (First Embodiment)
- [0075] 2 Variable-capacity compressor control valve (Second Embodiment)
- [0076] 10 Valve element
- [0077] 11 Main valve unit
- [0078] 12 Sub valve unit
- [0079] 15 Main valve element
- [0080] 15a Main valve element portion
- [0081] 15k Flanged latch portion
- [0082] 16 In-valve release passage
- [0083] 17 Sub valve element
- [0084] 17a Sub valve element portion (tapered portion)
- [0085] 19 Guide hole

- [0086] 19A Upper guide hole
- [0087] 19B Lower guide hole
- [0088] 20 Valve body
- [0089] 20A Body member
- [0090] 20B Support member
- [0091] 20C Recess hole
- [0092] 21 Valve chamber
- [0093] 22 Valve orifice
- [0094] 23 Sub valve seat portion
- [0095] 25 Pd introduction port
- [0096] 26 Pc inlet/outlet port
- [0097] 27 Ps inlet/outlet port
- [0098] 30 Electromagnetic actuator
- [0099] 30A Solenoid portion
- [0100] 37 Plunger
- [0101] 37*k* Inner flanged latch portion
- [0102] 37*s* Slit
- [0103] 37*t* Cut-in
- [0104] 40 Bellows device (pressure-sensitive reaction member)
- [0105] 45 Pressure-sensitive chamber
- [0106] 50 Valve closing spring
- [0107] Lv First lift amount
- [0108] La Predetermined amount
- [0109] Lp Second lift amount

What is claimed is:

1. A variable-capacity compressor control valve comprising:
  - a valve body including a valve chamber with a valve orifice, a Ps inlet/outlet port communicating with a suction chamber of a compressor, a Pd introduction port arranged upstream of the valve orifice and communicating with a discharge chamber of the compressor, and a Pc inlet/outlet port arranged downstream of the valve orifice and communicating with a crank chamber of the compressor;
  - a main valve element adapted to open or close the valve orifice;
  - an electromagnetic actuator with a plunger for moving the main valve element in a direction to open or close the valve orifice;

- a pressure-sensitive chamber adapted to receive a suction pressure Ps from the compressor via the Ps inlet/outlet port;
- a pressure-sensitive reaction member adapted to urge the main valve element in the direction to open or close the valve orifice in accordance with a pressure in the pressure-sensitive chamber;
- an in-valve release passage provided in the main valve element, the in-valve release passage being adapted to release a pressure Pc in the crank chamber to the suction chamber of the compressor via the Ps inlet/outlet port; and
- a sub valve element adapted to open or close the in-valve release passage, wherein
  - the sub valve element has a sub valve element portion with a tapered portion, and dimensions and a shape of each part are designed such that when the sub valve element closes the in-valve release passage, the tapered portion enters the in-valve release passage, and the sub valve element is thus aligned with the main valve element by the tapered portion.

2. The variable-capacity compressor control valve according to claim 1, wherein part of the tapered portion is located in the in-valve release passage when the sub valve element is at the highest elevated position with respect to the main valve element.

3. The variable-capacity compressor control valve according to claim 1, wherein

the sub valve element is supported by the pressure-sensitive reaction member at an end portion on a side opposite to the sub valve element portion, and is pressed against the plunger by a plunger spring such that the sub valve element moves up or down with the plunger.

4. The variable-capacity compressor control valve according to claim 1, wherein the tapered portion has a protrusion that extends toward the in-valve release passage.

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