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(54) **LIQUID SUPPLY SYSTEM**

(57) There is provided a liquid supply system that can prevent or reduce the occurrence of cavitation without an increase in the overall size of the apparatus. The liquid supply system includes a first pump chamber P1 formed by a space surrounding the outer circumference of a first bellows 141, a second pump chamber P2 formed by a space surrounding the outer circumference of a second bellows 142, a first check valve 160A provided in a fluid passage passing through the first pump chamber P1 to block backflow of fluid, and a second check valve 160B provided in a fluid passage passing through the second pump chamber P2 to block backflow of fluid. The first check valve 160A and the second check valve 160B are both provided in the container 130 and disposed on the side opposite to an actuator 110 that drives a shaft member 120, with respect to the shaft member 120.

[Fig. 1]

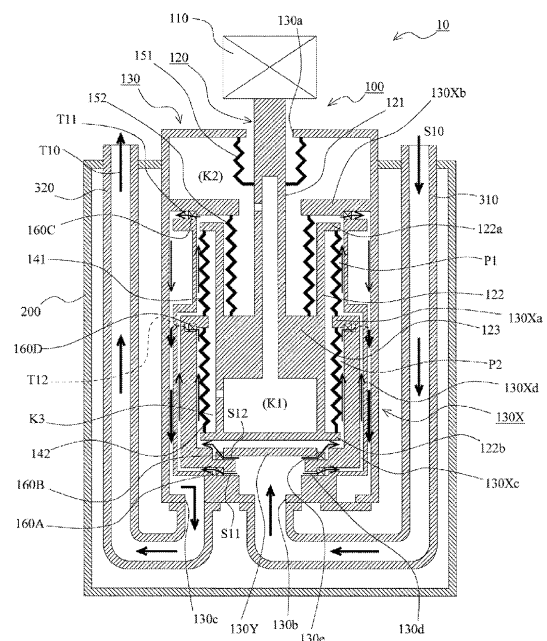


Fig.1

Description

[Technical Field]

5 **[0001]** The present invention relates to a liquid supply system used to supply liquid.

[Background Art]

10 **[0002]** It is known in prior art to use a liquid supply system having a pump chamber using a bellows to cause liquid to circulate in a circulation fluid passage (see Patent Literature 1). Such a liquid supply system uses a check valve provided in a pipe connected to a container provided with a pump chamber to block backflow of liquid.

15 **[0003]** In such a system, the smaller the valve opening area of the check valve is, the higher the flow rate is, and the more cavitation is apt to occur in the region downstream of the valve. The cavitation thus occurring causes noise and vibration and decreases the discharge efficiency of the pump. To prevent or reduce the occurrence of cavitation, it is effective to make the valve opening area large. However, the extent of enlargement of the valve opening area of the check valve provided in a pipe connected to the container is limited, or it is necessary to use a thick pipe, which leads to an increase in the size of the overall apparatus including the pipe.

[Citation List]

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[Patent Literature]

[0004]

25

[PTL 1]

WO 2015/050091

[PTL 2]

Japanese Patent Application Laid-Open No. 2016-37912

[PTL 3]

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Japanese Patent Application Laid-Open No. H4-128578

[Summary of Invention]

[Technical Problem]

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[0005] An object of the present invention is to provide a liquid supply system that can prevent or reduce the occurrence of cavitation without an increase in the overall size of the apparatus.

[Solution to Problem]

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[0006] To achieve the above object, the following features are adopted.

[0007] An aspect of the present invention is a liquid supply system comprises:

a container having an inlet and an outlet for fluid;

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a shaft member that moves vertically upward and downward in the container;

a first bellows and a second bellows disposed one above the other along the vertical direction in the container, each of which expands and contracts with upward and downward motion of the shaft member;

a first pump chamber formed in the container by a space surrounding the outer circumference of the first bellows;

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a second pump chamber formed in the container by a space surrounding the outer circumference of the second bellows;

a first check valve provided in a fluid passage passing through the first pump chamber to block backflow of fluid; and

a second check valve provided in a fluid passage passing through the second pump chamber to block backflow of fluid, wherein the first check valve and the second check valve are both provided in the container and disposed on the side opposite to an actuator that drives the shaft member, with respect to the shaft member.

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[0008] The first check valve and the second check valve are both provided in the container and disposed on the side opposite to the actuator with respect to the shaft member. Therefore, the check valves can be installed in the container relatively easily as compared to the case where check valves are provided in pipe connected to the container, and it is

not necessary to increase the size of the overall apparatus including the pipes. Furthermore, the first check valve and the second check valve can be assembled easily without interference with the actuator. Still further, it is easy to provide a large installation space for the first check valve and the second check valve, facilitating enlargement of the valve opening area.

[0009] The first check valve may include an annular first valve body that moves upward while receiving the pressure of fluid flowing in horizontal and radially outward directions away from the center axis of the shaft member to open the valve, and the second check valve may include an annular second valve body that moves upward while receiving the pressure of fluid flowing in horizontal and radially outward directions away from the center axis of the shaft member to open the valve.

[0010] The check valves configured as above can have a large valve opening area. Moreover, the check valves configured as above receive lower resistance of fluid flow and have higher responsivity in opening and closing the valve as compared to check valves that are configured to open and close the valve by fluid flowing in the vertical direction (e. g. poppet valves). Therefore, cavitation is prevented from occurring due to insufficiency of fluid flow into the pump chamber.

[0011] The first check valve and the second check valve may both be disposed in the container coaxially with the shaft member.

[0012] This allows easy assembly of the structural components of the pump chambers and the container.

[0013] The diameter of a closing portion of the first valve body and the diameter of a closing portion of the second valve body may be equal.

[0014] This allows the periods of opening and closing the valve by the first valve body and those by the second valve body to be equalized.

[0015] The above-described features may be adopted in any feasibly combination.

[Advantageous Effects of Invention]

[0016] According to the present invention, the occurrence of cavitation can be prevented without need to increase the size of the apparatus.

[Brief Description of Drawings]

[0017]

[Fig. 1]

Fig. 1 is a schematic diagram illustrating the configuration of a liquid supply system in an embodiment.

[Fig. 2]

Fig. 2 is a partly cross sectional view of a check valve in the embodiment.

[Fig. 3]

Fig. 3 is an enlarged schematic cross sectional view illustrating a portion around first and second check valves in the embodiment.

[Fig. 4]

Fig. 4 is a schematic cross sectional view of a valve structure in the embodiment in a state in which the check valve is closed.

[Fig. 5]

Fig. 5 is a schematic cross sectional view of the valve structure in the embodiment in a state in which the check valve is open.

[Fig. 6]

Fig. 6 is a schematic cross sectional view of the valve structure in the embodiment in a state in the middle of the process of closing the check valve.

[Description of Embodiments]

[0018] In the following, modes for carrying out the present invention will be described specifically on the basis of a specific embodiment with reference to the drawings. The dimensions, materials, shapes, relative arrangements, and other features of the components that will be described in connection with the embodiments are not intended to limit the scope of the present invention only to them, unless particularly stated.

Embodiment

[0019] A liquid supply system according to an embodiment of the present invention will be described with reference

to Figs. 1 to 6. The liquid supply system is suitably used for the purpose of, for example, maintaining a superconducting device in a ultra-low temperature state. Superconducting devices require perpetual cooling of components such as superconducting coils. Thus, a cooled device including a superconducting coil and other components is perpetually cooled by continuous supply of a cryogenic liquid (such as liquid nitrogen or liquid helium) to the cooled device. Specifically, a circulating fluid passage passing through the cooled device is provided, and the liquid supply system is connected to the circulating fluid passage to cause the cryogenic liquid to circulate, thereby enabling perpetual cooling of the cooled device.

<Overall Configuration of the Liquid Supply System>

[0020] Fig. 1 is a schematic diagram illustrating the overall configuration of the liquid supply system in the embodiment, where the overall configuration of the liquid supply system is illustrated in a cross section. The liquid supply system 10 includes a main unit 100 of the liquid supply system 10 (which will be referred to as the "main system unit 100" hereinafter), a vacuum container 200 in which the main system unit 100 is housed, and pipes (including an inlet pipe 310 and an outlet pipe 320). The inlet pipe 310 and the outlet pipe 320 both extend into the interior of the vacuum container 200 from outside the vacuum container 200 and are connected to the main system unit 100. The interior of the vacuum container 200 is a hermetically sealed space. The interior space of the vacuum container 200 outside the main system unit 100, the inlet pipe 310, and the outlet pipe 320 is kept in a vacuum state. Thus, this space provides heat insulation. The liquid supply system 10 is normally installed on a horizontal surface. In the installed state, the upward direction of the liquid supply system 10 in Fig. 1 is the vertically upward direction, and the downward direction in Fig. 1 is the vertically downward direction.

[0021] The main system unit 100 includes a linear actuator 110 serving as a driving source, a shaft member 120 that is moved in vertically upward and downward directions by the linear actuator 110, and a container 130. The linear actuator 110 is fixed on something suitable, which may be the container 130 or something that is not shown in the drawings. The shaft member 120 extends from outside the container 130 into the inside through an opening 130a provided in the ceiling portion of the container 130. The container 130 has an inlet 130b and an outlet 130c for liquid in its bottom portion. The aforementioned inlet pipe 310 is connected to the inlet 130b, and the outlet pipe 320 is connected to the outlet 130c.

[0022] Inside the container 130 are provided a plurality of structural components that compartment the interior space into a plurality of spaces, which constitute a plurality of pump chambers, passages for liquid, and vacuum chambers providing heat insulation. In the following, the structure inside the container 130 will be described in further detail.

[0023] The shaft member 120 has a main shaft portion 121 having a cavity in it, a cylindrical portion 122 surrounding the outer circumference of the main shaft portion 121, and a connecting portion 123 that connects the main shaft portion 121 and the cylindrical portion 122. The cylindrical portion 122 is provided with an upper outward flange 122a at its upper end and a lower outward flange 122b at its lower end.

[0024] The container 130 has a substantially cylindrical body portion 130X and a bottom plate 130Y. The body portion 130X has a first inward flange 130Xa provided near its vertical center and a second inward flange 130Xb provided on its upper portion.

[0025] Inside the body portion 130X, there are a plurality of first fluid passages 130Xc that extend in the axial direction and are spaced apart from one another along the circumferential direction. Inside the body portion 130X, there also is a second fluid passage 130Xd, which is an axially extending cylindrical space provided radially outside the region in which the first fluid passages 130Xc are provided. The bottom portion of the container 130 is provided with a fluid passage 130d that extends circumferentially and radially outwardly to join to the first fluid passages 130Xc. Furthermore, the bottom plate 130Y of the container 130 is provided with a fluid passage 130e that extends circumferentially and radially outwardly. These fluid passages 130d and 130e extend uniformly along the circumferential direction to allow liquid to flow radially outwardly in all directions, namely 360 degrees about the center axis.

[0026] Inside the container 130, there are provided a first bellows 141 and a second bellows 142, which expand and contract with the up and down motion of the shaft member 120. The first bellows 141 and the second bellows 142 are arranged one above the other along the vertical direction. The upper end of the first bellows 141 is fixedly attached to the upper outward flange 122a of the cylindrical portion 122 of the shaft member 120, and the lower end of the first bellows 141 is fixedly attached to the first inward flange 130Xa of the container 130. The upper end of the second bellows 142 is fixedly attached to the first inward flange 130Xa of the container 130, and the lower end of the second bellows 142 is fixedly attached to the lower outward flange 122b of the cylindrical portion 122 of the shaft member 120. The space surrounding the outer circumference of the first bellows 141 forms a first pump chamber P1, and the space surrounding the outer circumference of the second bellows 142 forms a second pump chamber P2.

[0027] Inside the container 130, there also are provided a third bellows 151 and a fourth bellows 152, which expand and contract with the up and down motion of the shaft member 120. The upper end of the third bellows 151 is fixedly attached to the ceiling portion of the container 130, and the lower end of the third bellows 151 is fixedly attached to the shaft member 120. Thus, the opening 130a of the container 130 is closed. The upper end of the fourth bellows 152 is

fixedly attached to the second inward flange 130Xb provided on the container 130, and the lower end of the fourth bellows 152 is fixedly attached to the connecting portion 123 of the shaft member 120. A first space K1 is formed by the cavity in the main shaft portion 121 of the shaft member 120. A second space K2 is formed outside the third bellows 151 and inside the fourth bellows 152. A third space K3 is formed inside the first bellows 141 and the second bellows 142. The first space K1, the second space K2, and the third space K3 are in communication with each other. The space constituted by the first space K1, the second space K2, and the third space K3 is hermetically sealed. In this embodiment, the hermetically sealed space constituted by the aforementioned spaces is kept in a vacuum condition to provide heat insulation.

[0028] There are four check valves 160 including a first check valve 160A, a second check valve 160B, a third check valve 160C, and a fourth check valve 160D, which are provided at different locations inside the container 130. All of these four check valves 160 are arranged coaxially with the shaft member 120 in the container 130. In other words, the center axis of the shaft member 120 and the respective center axes of the check valves 160 are in alignment with each other. The first check valve 160A and the second check valve 160B are provided in the container 130. The first check valve 160A and the second check valve 160B are disposed on the opposite side (lower side) of the linear actuator 110 with respect to the shaft member 120. The third check valve 160C and the fourth check valve 160D are arranged above the first check valve 160A and the second check valve 160B.

[0029] The first check valve 160A and the third check valve 160C are provided in the fluid passage passing through the first pump chamber P1. The first check valve 160A and the third check valve 160C block backflow of fluid pumped by the pumping effect of the first pump chamber P1. Specifically, the first check valve 160A is provided on the upstream side of the first pump chamber P1, and the third check valve 160C is provided on the downstream side of the first pump chamber P1. More specifically, the first check valve 160A is provided in the fluid passage 130d provided in the bottom portion of the container 130. The third check valve 160C is provided in the fluid passage formed in the vicinity of the second inward flange 130Xb provided on the container 130.

[0030] The second check valve 160B and the fourth check valve 160D are provided in the fluid passage passing through the second pump chamber P2. The second check valve 160B and the fourth check valve 160D block backflow of fluid pumped by the pumping effect of the second pump chamber P2. Specifically, the second check valve 160B is provided on the upstream side of the second pump chamber P2, and the fourth check valve 160D is provided on the downstream side of the second pump chamber P2. More specifically, the second check valve 160B is provided in the fluid passage 130e provided in the bottom plate 130Y of the container 130. The fourth check valve 160D is provided in the fluid passage formed in the vicinity of the first inward flange 130Xa of the container 130.

<Description of the Overall Operation of the Liquid Supply System>

[0031] The overall operation of the liquid supply system will be described. When the shaft member 120 is lowered by the linear actuator 110, the first bellows 141 contracts, and the second bellows 142 expands. Consequently, the fluid pressure in the first pump chamber P1 decreases. Then, the first check valve 160A is opened, and the third check valve 160C is closed. In consequence, liquid supplied from outside the liquid supply system 10 through the inlet pipe 310 (indicated by arrow S10) is taken into the interior of the container 130 through the inlet 130b and passes through the first check valve 160A (indicated by arrow S11). Then, the liquid having passed through the first check valve 160A is pumped into the first pump chamber P1 through the first fluid passage 130Xc in the body portion 130X of the container 130. On the other hand, the fluid pressure in the second pump chamber P2 increases. Then, the second check valve 160B is closed, and the fourth check valve 160D is opened. In consequence, the liquid in the second pump chamber P2 is pumped into the second fluid passage 130Xd provided in the body portion 130X through the fourth check valve 160D (see arrow T12). Then, the liquid passes through the outlet 130c and is brought to the outside of the liquid supply system 10 through the outlet pipe 320.

[0032] When the shaft member 120 is raised by the linear actuator 110, the first bellows 141 expands, and the second bellows 142 contracts. Consequently, the fluid pressure in the first pump chamber P1 increases. Then, the first check valve 160A is closed, and the third check valve 160C is opened. In consequence, the liquid in the first pump chamber P1 is pumped into the second fluid passage 130Xd provided in the body portion 130X through the third check valve 160C (indicated by arrow T11). Then, the liquid passes through the outlet 130c and is brought to the outside of the liquid supply system 10 through the outlet pipe 320. On the other hand, the fluid pressure in the second pump chamber P2 decreases. Then, the second check valve 160B is opened, and the fourth check valve 160D is closed. In consequence, liquid supplied from outside the liquid supply system 10 through the inlet pipe 310 (indicated by arrow S10) is taken into the interior of the container 130 through the inlet 130b and passes through the second check valve 160B (indicated by arrow S12). Then, the liquid having passed through the second check valve 160B is pumped into the second pump chamber P2.

[0033] As above, the liquid supply system 10 can cause liquid to flow from the inlet pipe 310 to the outlet pipe 320 both when the shaft member 120 moves downward and when the shaft member 120 moves upward. Hence, the phe-

nomenon called pulsation can be reduced.

<Check valve>

[0034] The check valves 160 will be described more specifically with reference to Figs. 2 to 6. The structures of the first to fourth check valves 160A, 160B, 160C, 160D are basically the same, and valve structures including these check valves are also basically the same. Fig. 2 is a partly cross sectional view of one of the check valves, where the left half illustrates a cross section of the check valve in a plane containing the center axis. Fig. 3 is an enlarged schematic cross sectional view illustrating a portion around the first check valve and the second check valve. Figs. 4 to 6 are schematic cross sectional views illustrating the basic configuration of the valve structure including the check valve. Fig. 4 shows a state in which the check valve is closed, Fig. 5 shows a state in which the check valve is open, and Fig. 6 shows a state in the middle of the process of closing the check valve.

[0035] The check valve 160 includes an annular valve body 161 and a subsidiary valve body 162 provided above the valve body 161. The valve body 161 is configured to move upward while receiving the pressure of liquid flowing in horizontal and radially outward directions away from the center axis of the shaft member 120 to open the valve. The valve body 161 has a cylindrical portion 161a, a downwardly-flaring flare portion 161b provided on the lower end of the cylindrical portion 161a, and an outward flange 161c provided on the upper end of the cylindrical portion 161a. The subsidiary valve body 162 is a disk-like member having a through hole at its center. The subsidiary valve body 162 has an outer diameter larger than the inner diameter of the cylindrical portion 161a of the valve body 161 and an inner diameter smaller than the inner diameter of the cylindrical portion 161a.

[0036] Fig. 3 is a schematic cross sectional view illustrating a portion of the valve structure including the first check valve 160A and the second check valve 160B in an enlarged manner. As illustrated, the first check valve 160A includes an annular valve body (a first valve body 161A) and a first subsidiary valve body 162A provided above the first valve body 161A. The first valve body 161A has a cylindrical portion 161Aa, a flare portion 161Ab, and an outward flange 161Ac. Similarly, the second check valve 160B includes an annular valve body (a second valve body 161B), and a second subsidiary valve body 162B provided above the second valve body 161B. The second valve body 161B has a cylindrical portion 161Ba, a flare portion 161Bb, and an outward flange 161Bc.

[0037] In this embodiment, the first check valve 160A and the second check valve 160B have the same dimensions. Accordingly, the diameter of the closing portion of the first valve body 161A and the diameter of the closing portion of the second valve body 161B are equal to each other. The diameter of the closing portion is the diameter D of the outer end of the flare portion 161b of the valve body 161 illustrated in Fig. 2.

[0038] The structures of the third check valve 160C and the fourth check valve 160D are basically the same as above, and the valve structures including these check valves are also basically the same as above, though not illustrated in the drawings. Note, however, that while the closing portion of the valve body in the third check valve 160C and the closing portion of the valve body in the fourth check valve 160D have the same diameter, it is larger than the diameter of the closing portions of the first valve body 161A and the second valve body 161B.

[0039] Now, the opening and closing operation of the check valve 160 will be described. As described above, the valve structures including the check valves have basically the same structure. Therefore, the opening and closing operation of the check valve will be described with reference to Figs. 4 to 6, which illustrate the basic structure.

[0040] The check valve 160 is mounted on a mount base 170. The mount base 170 is not necessarily a single member. In the case of the first check valve 160A, what serves as the mount base 170 is the bottom of the container 130. In the case of the second check valve 160B, what serves as the mount base 170 is the bottom plate 130Y of the container 130. In the case of the third check valve 160C, what serves as the mount base 170 is a portion of the container 130 near the second inward flange 130Xb provided on the body portion 130X. In the case of the fourth check valve 160D, what serves as the mount base 170 is a portion of the container 130 near the first inward flange 130Xa provided on the body portion 130X.

[0041] The mount base 170 is provided with a fluid passage 171 that extends horizontally and radially outwardly away from the center axis of the shaft member 120 and the check valve 160. This fluid passage 171 extends uniformly along the circumferential direction to allow liquid to flow radially outwardly in all directions, namely 360 degrees about the center axis.

[0042] The mount base 170 is also provided with a guide surface 172 that guides the direction of movement of the valve body 161. The guide surface 172 is a cylindrical surface. A small gap G is left between the inner circumference of the valve body 161 and the guide surface 172. In other words, the valve body 161 is loosely fitted on the guide surface 172. This allows the valve body 161 to move vertically upward and downward without sliding resistance.

[0043] The mount base 170 has an annular groove 173 provided on the upper portion of the guide surface 172, in which the subsidiary valve body 162 is set. The subsidiary valve body 162 is set in the annular groove 173 in such a way that its inner circumferential surface is slidable on the bottom surface 173a of the annular groove 173. The subsidiary valve body 162 is movable vertically upward and downward within the range of the width of the annular groove 173.

When the valve body 161 is in the seated state, the lower side surface 173b among the side surfaces of the annular groove 173 and the top surface 161c1 of the valve body 161 are at the same level. Thus, in the state in which the valve is closed by the valve body 160, the subsidiary valve body 162 is in contact with both the side surface 173b of the annular groove 173 and the top surface 161c1 of the valve body 161 to close the annular gap G.

[0044] The mount base 170 is provided with a valve seat 174. The valve seat 174 is a horizontal surface. When the valve body 161 moves downward due to its weight and fluid pressure acting thereon, the edge of the flare portion 161b of the valve body 161 comes in close contact with the valve seat 174 to close the valve.

[0045] The operation of the valve structure structured as above will now be described. When the fluid pressure in the fluid passage upstream of the check valve 160 becomes higher than the fluid pressure in the fluid passage downstream of the check valve 160 to such an extent that the differential pressure exceeds the weight of the check valve 160, the valve body 161 moves upward. Then, the subsidiary valve body 162 is pressed by the valve body 161 and receives fluid pressure through the annular gap G to move upward. Thus, the valve is opened. Then, liquid flows in the fluid passage 171 provided in the mount base 170 in horizontal and radially outward directions away from the center axis of the shaft member 120 (indicated by the arrow in Fig. 5). In consequence, the valve body 161 moves upward while receiving the pressure of the liquid flowing in horizontal and radially outward directions away from the center axis of the shaft member 120 to thereby open the valve.

[0046] When the aforementioned differential pressure becomes smaller than the weight of the check valve 160, the valve body 161 and the subsidiary valve body 162 moves downward due to its weight and the fluid pressure acting thereon from above. While the valve body 161 does not receive sliding resistance (or the sliding resistance acting thereon is low), the subsidiary valve body 162 receives sliding resistance from the bottom surface 173a of the annular groove 173. Hence, the valve body 161 is firstly seated on the valve seat 174, and thereafter the subsidiary valve body 162 comes in contact with both the side surface 173b of the annular groove 173 and the top surface 161c1 of the valve body 161. Fig. 6 shows a state of the check valve 160 in the middle of the process of closing the valve in which the valve body 161 is seated on the valve seat 174, and the subsidiary valve body 162 is in the middle of its downward movement.

[0047] The valve structure as above can improve the responsivity in opening and closing the valve by the valve body 161. This is because the kinetic momentum of liquid acting on the valve body 161 can be reduced. The reason will not be described here in detail, because it is well known as described in Patent Literature 1 mentioned above. Furthermore, since the valve is closed in two steps by the valve body 161 and the subsidiary valve body 162, the water hammer caused by backflow occurring upon closing the valve can be reduced. This is because the flow rate of backflow is reduced by the valve body 161 and then the valve is closed completely by the subsidiary valve body 162.

<Advantages of the Liquid Supply System According to This Embodiment

[0048] In the liquid supply system 10, the first check valve 160A and the second check valve 160B are arranged coaxially with the shaft member 120 in the container 130. Moreover, the first check valve 160A and the second check valve 160B are both configured to open and close the valve by an annular valve body (the first valve body 161A, the second valve body 161B) that moves upward while receiving the pressure of liquid flowing in horizontal and radially outward directions away from the center axis of the shaft member 120 to open the valve. Therefore, it is possible to make the valve opening area larger than that in the case where check valves are provided in pipes connected to the container, without an increase in the size of the overall apparatus including the pipes (the inlet pipe 310 and the outlet pipe 320). Therefore, it is possible to prevent the occurrence of cavitation without increasing the size of the apparatus (namely, the overall apparatus including the pipes).

[0049] The first valve body 161A and the second valve body 161B are configured to move upward while receiving the pressure of liquid flowing in horizontal and radially outward directions away from the center axis of the shaft member 120 to open the valve. Therefore, they have higher responsivity in opening and closing the valve as compared to check valves that are configured to open and close the valve by liquid flowing in the vertical direction (e.g. poppet valves).

[0050] The first check valve 160A and the second check valve 160B are both disposed on the side (lower side) opposite to the linear actuator 110 with respect to the shaft member 120. This allows the first check valve 160A and the second check valve 160B to be assembled easily without interference with the linear actuator 110. Moreover, it is easy to provide a large installation space for the first check valve 160A and the second check valve 160B, facilitating enlargement of the valve opening area.

[0051] The diameter of the closing portion of the first valve body 161A and the diameter of the closing portion of the second valve body 161B are equal. Therefore, the periods of opening and closing the first valve body 161A and the periods of opening and closing the second valve body 161B can easily be equalized. Thus, the discharging capability with the first pump chamber P1 and the discharging capability with the second pump chamber P2 can easily be equalized. This improves the reduction of pulsation.

Others

[0052] The interior space of the vacuum chamber 200 outside the main system unit 100, the inlet pipe 310, and the outlet pipe 320 is kept in a vacuum state to provide heat insulation. The hermetically sealed space constituted by the first space K1, the second space K2, and the third space K3 is also kept in a vacuum state to provide heat insulation. However, cryogenic liquid may be caused to flow also in these spaces to keep the temperature of the liquid flowing in the circulating fluid passage low.

[Reference Signs List]

[0053]

10:	liquid supply system
100:	main system unit
110:	linear actuator
120:	shaft member
121:	main shaft portion
122:	cylindrical portion
122a:	upper outward flange
122b:	lower outward flange
123:	connecting portion
130:	container
130a:	opening
130b:	inlet
130c:	outlet
130d:	fluid passage
130e:	fluid passage
130X:	body portion
130Xa:	first inward flange
130Xb:	second inward flange
130Xc:	first fluid passage
130Xd:	second fluid passage
130Y:	bottom plate
141:	first bellows
142:	second bellows
151:	third bellows
152:	fourth bellows
160:	check valve
160A:	first check valve
160B:	second check valve
160C:	third check valve
160D:	fourth check valve
161:	valve body
161A:	first valve body
161B:	second valve body
161a, 161Aa, 161Ba:	cylindrical portion
161b, 161Ab, 161Bb:	flare portion
161c, 161Ac, 161Bc:	outward flange
161c1:	top surface
162, 162A, 162B:	subsidiary valve body
170:	mount base
171:	fluid passage
172:	guide surface
173:	annular groove
173a:	bottom surface of the groove
173b:	side surface of the groove
174:	valve seat
200:	vacuum container

310: inlet pipe
 320: outlet pipe
 G: annular gap
 P1: first pump chamber
 5 P2: second pump chamber

Claims

1. A liquid supply system comprising:

a container having an inlet and an outlet for fluid;
 a shaft member that moves vertically upward and downward in the container;
 a first bellows and a second bellows disposed one above the other along the vertical direction in the container,
 15 each of which expands and contracts with upward and downward motion of the shaft member;
 a first pump chamber formed in the container by a space surrounding the outer circumference of the first bellows;
 a second pump chamber formed in the container by a space surrounding the outer circumference of the second
 bellows;
 a first check valve provided in a fluid passage passing through the first pump chamber to block backflow of fluid;
 20 and
 a second check valve provided in a fluid passage passing through the second pump chamber to block backflow
 of fluid,
 wherein the first check valve and the second check valve are both provided in the container and disposed on
 the side opposite to an actuator that drives the shaft member, with respect to the shaft member.

2. A liquid supply system according to claim 1, wherein the first check valve includes an annular first valve body that
 moves upward while receiving the pressure of fluid flowing in horizontal and radially outward directions away from
 the center axis of the shaft member to open the valve, and the second check valve includes an annular second
 valve body that moves upward while receiving the pressure of fluid flowing in horizontal and radially outward directions
 30 away from the center axis of the shaft member to open the valve.

3. A liquid supply system according to claim 1 or 2, wherein the first check valve and the second check valve are both
 disposed in the container coaxially with the shaft member.

4. A liquid supply system according to claim 1, 2, or 3, wherein the diameter of the closing portion of the first valve and
 the diameter of the closing portion of the second valve are equal.

5. A liquid supply system according to any one of claims 1 to 4, wherein the fluid is a cryogenic liquid, the space
 between the container and the pump chambers is in a vacuum state, and the actuator is disposed in the atmosphere.

[Fig. 1]

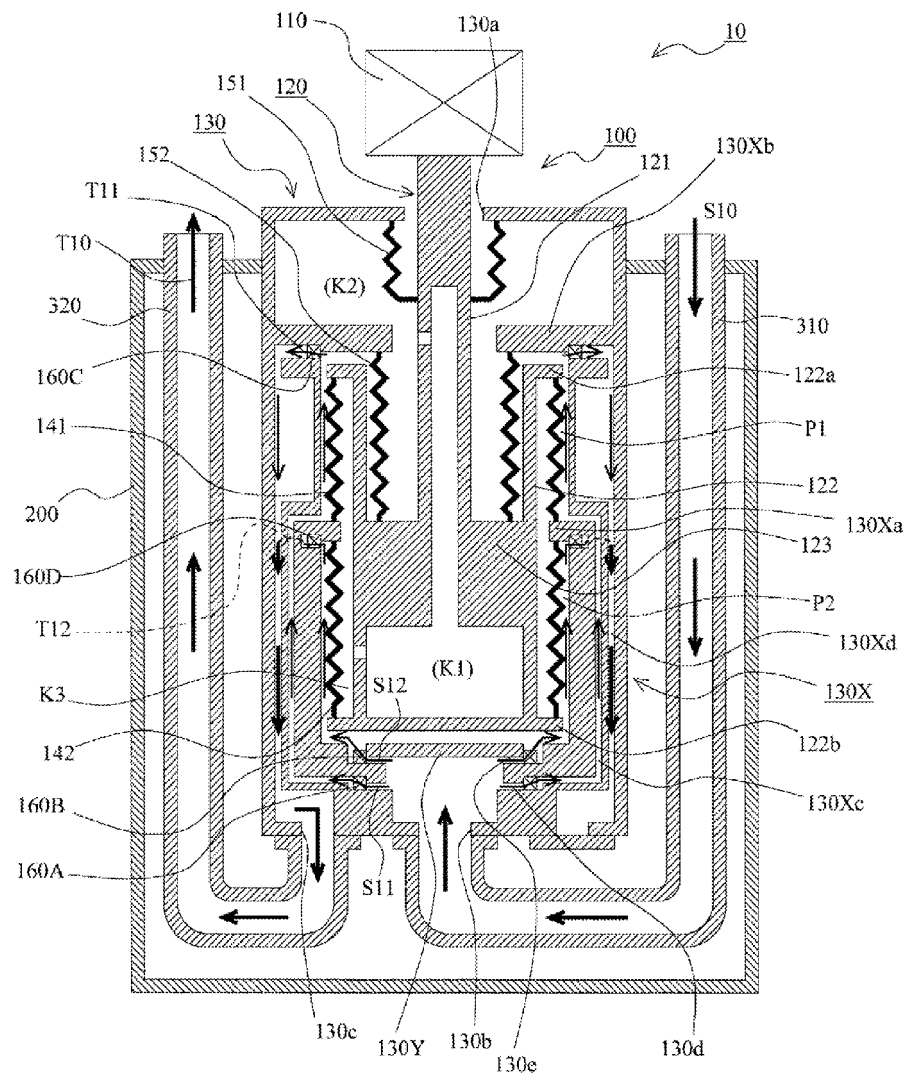


Fig.1

[Fig. 2]

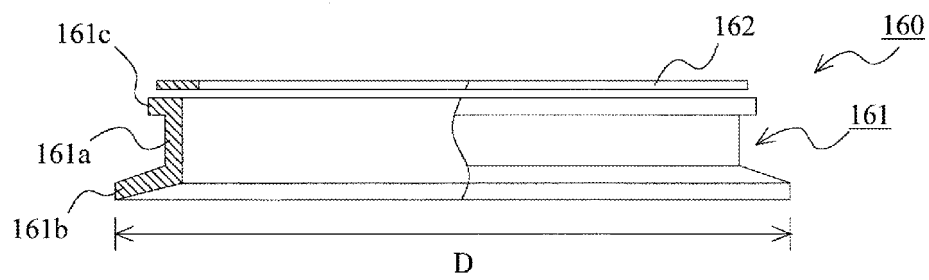


Fig.2

[Fig. 3]

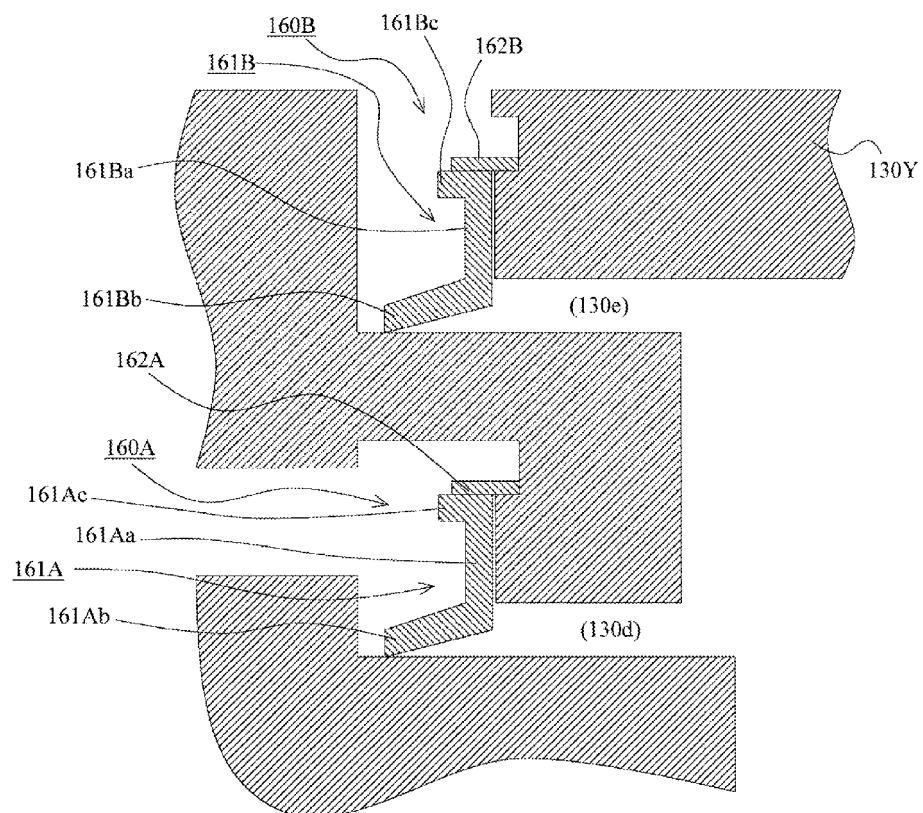


Fig.3

[Fig. 4]

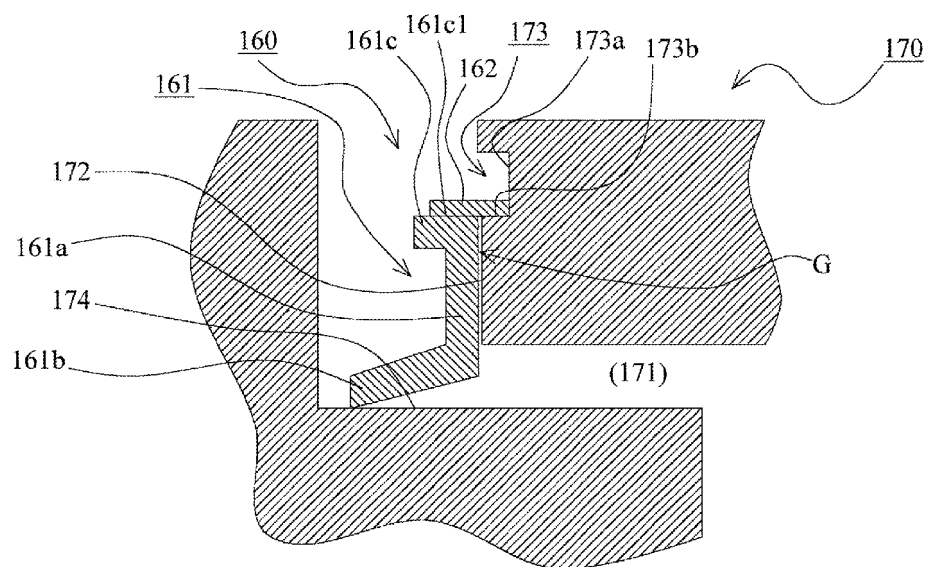


Fig.4

[Fig. 5]

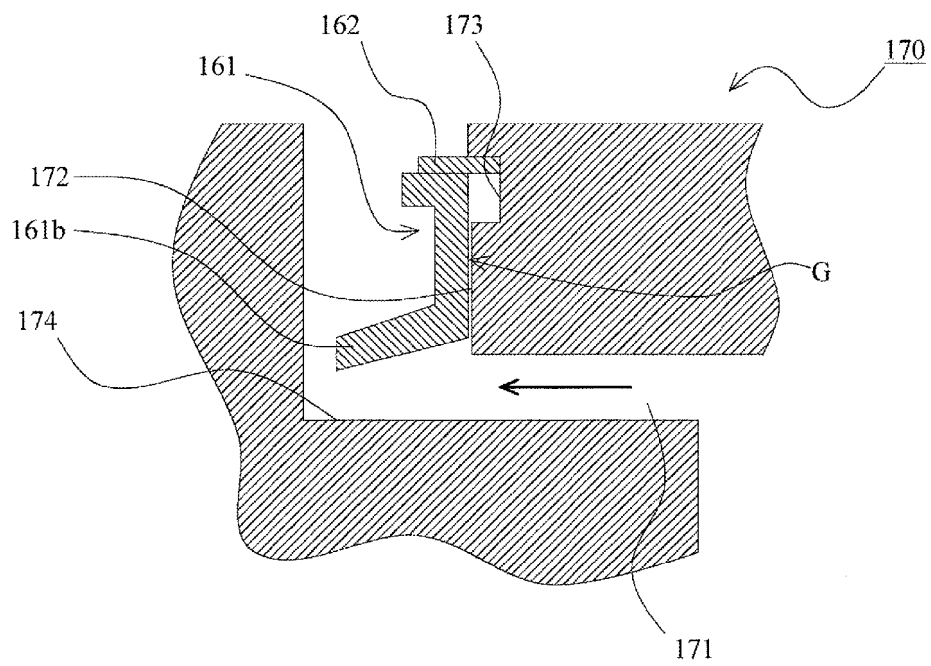


Fig.5

[Fig. 6]

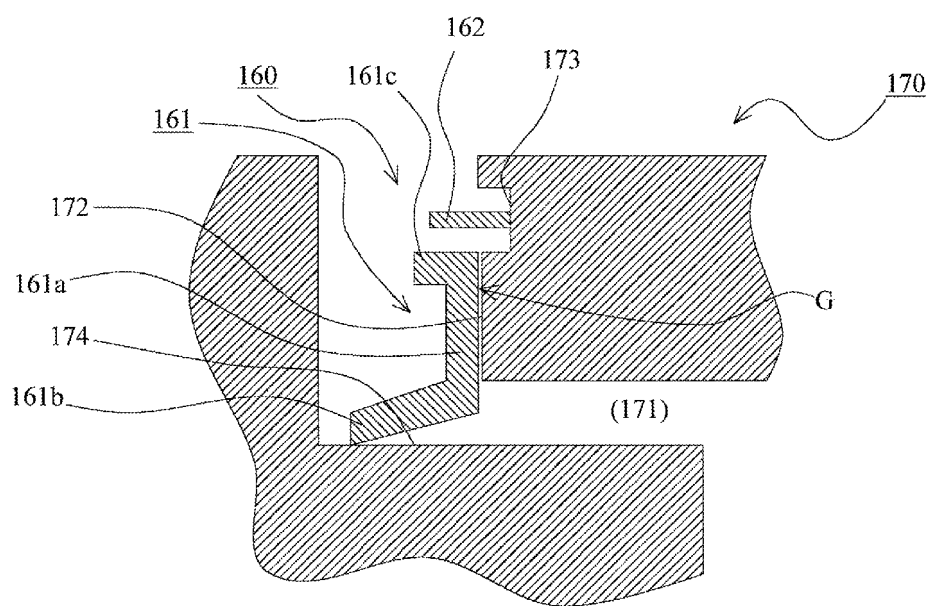


Fig.6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/003648

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F04B43/08 (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)

Int.Cl. F04B43/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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.
Y A	WO 2016/006648 A1 (EAGLE INDUSTRY CO., LTD.) 14 January 2016, paragraphs [0020]-[0041], fig. 1 & US 2017/0167475 A1, paragraphs [0024]-[0045], fig. 1 & EP 3168550 A1 & KR 10-2017-0010399 A & CN 106662372 A	1, 5 2-4

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 ☐ See patent family annex.

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Date of the actual completion of the international search
09 April 2018 (09.04.2018)Date of mailing of the international search report
01 May 2018 (01.05.2018)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 188607/1983 (Laid-open No. 097385/1985) (EAGLE INDUSTRY CO., LTD.) 03 July 1985, specification, page 6, line 12 to page 7, line 1, fig. 3 (Family: none)	1, 5 2-4
A	US 5558506 A (SIMMONS, John M.) 24 September 1996, entire text, all drawings & WO 1995/023924 A1	1-5
A	JP 2016-109022 A (NIPPON PILLARPACKING CO., LTD.) 20 June 2016, entire text, all drawings & US 2017/0191476 A1, entire text, all drawings & WO 2016/021350 A1 & EP 3179105 A1 & KR 10-2017-0013232 A & CN 106795876 A	1-5

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2015050091 A [0004]
- JP 2016037912 A [0004]
- JP H4128578 B [0004]