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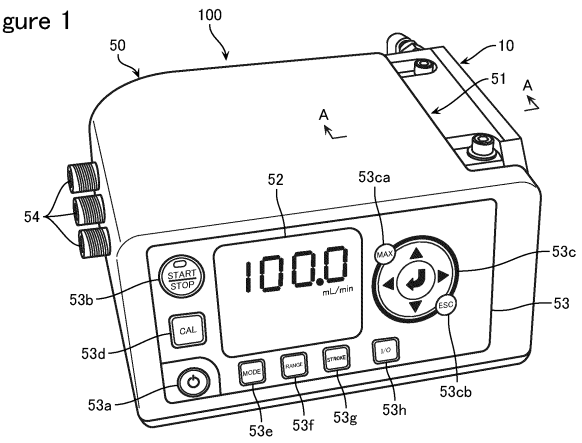
(54) PUMP DEVICE AND VALVE MODULE

(57) A pump device includes a pump head and a device main body part. The pump head includes: a valve module having a module guide that integrally holds a suction valve and a discharge valve and that has a side flow path allowing an inter-valve flow path to communicate with an outer lateral surface; a first block including a first accommodation chamber accommodating a lower part of the valve module, a suction port, a suction-side flow path that connects the suction port to the suction valve, a pump chamber of which an upper part is positioned below the side flow path, and a pump chamber communication flow path that connects the pump chamber to the side flow path; a second block including a second accommodation chamber accommodating an upper part of the valve module, a discharge port, and a discharge-side flow path that connects the discharge port to an upper part of the discharge valve; and coupling means for coupling the blocks together. The device main body part includes a diaphragm accommodated in the pump chamber of the first block and an actuator that drives the diaphragm to reciprocate.

Figure 1



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Description

Technical Field

[0001] The present invention relates to a pump device and a valve module.

Background Art

[0002] A reciprocating pump that transports a transport fluid with reciprocation of a diaphragm (see Patent Literature 1, for example) has a suction valve that introduces the transport fluid to the inside of a pump chamber and a discharge valve that discharges the transport fluid from the inside of the pump chamber. The suction valve and the discharge valve are generally structured such that the two valves are attached to a lower end and an upper end of a pump head, while being arranged on multiple stages (e.g., two stages) along a vertical direction. In this manner, the suction valve and the discharge valve are arranged diagonally below and diagonally above the pump chamber.

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Patent Laid-Open No. 9-203380

Summary of Invention

Technical Problem

[0004] In a conventional reciprocating pump disclosed in Patent Literature 1 listed above, it is necessary to connect a suction valve and a discharge valve each to a pump head via a fastening screw. For this reason, there is a problem in that it is not easy to attach and to detach the valves at the time of, for instance, replacing or performing maintenance on the suction valve and the discharge valve.

[0005] The present invention has been made in consideration of the above circumstances, and has an object to provide a pump device and a valve module capable of facilitating attachment and detachment of a suction valve and a discharge valve to and from a pump head.

Solution to Problem

[0006] A pump device according to one aspect of the present invention includes a pump head; and a device main body part to which the pump head is to be detachably attached. The pump head includes: a valve module including a suction valve, a discharge valve, and a module guide that integrally holds the suction valve and the discharge valve while the suction valve is located at a lower side and the discharge valve is located at an upper side so as to transport a transport fluid from the lower side to the upper side and that has a side flow path allowing an inter-valve flow path formed between the suction valve and the discharge valve to communicate with an outer lateral surface; a first block including a first accommodation chamber accommodating a lower part of the valve module, a suction port through which the transport fluid is suctioned, a suction-side flow path that connects the suction port to a lower part of the suction valve, a pump chamber of which an upper part is positioned below the side flow path of the valve module, and a pump chamber communication flow path that connects the pump chamber to the side flow path of the valve module; a second block including a second accommodation chamber accommodating an upper part of the valve module, a discharge port through which the transport fluid is discharged, and a discharge-side flow path that connects the discharge port to an upper part of the discharge valve; and coupling means for coupling the first block and the second block together, while the valve module is accommodated inside. The device main body part includes a diaphragm accommodated in the pump chamber of the first block and an actuator that drives the diaphragm to reciprocate.

[0007] In an embodiment of the present invention, provided are: a plurality of valve modules each being the valve module; a plurality of first accommodation chambers each being the first accommodation chamber and a plurality of second accommodation chambers each being the second accommodation chamber accommodating the plurality of valve modules; and a plurality of pump chambers each being the pump chamber, a plurality of diaphragms each being the diaphragm, and a plurality of actuators each being the actuator corresponding to the plurality of valve modules. The plurality of valve modules are arranged along a horizontal direction. The suction port is formed in a lateral surface of the first block. The suction-side flow path includes a first suction-side flow path extending horizontally and communicating with the suction port and a plurality of second suction-side flow paths that allow the first suction-side flow path to vertically communicate with the plurality of first accommodation chambers. The discharge port is formed in a lateral surface of the second block. The discharge-side flow path includes a first discharge-side flow path extending horizontally and communicating with the discharge port and a plurality of second discharge-side flow paths that allow the first discharge-side flow path to vertically communicate with the plurality of second accommodation chambers. The actuators drive the plurality of diaphragms individually in a phase shifted manner.

[0008] In another embodiment of the present invention, provided are: a plurality of valve modules each being the valve module; a plurality of first accommodation chambers each being the first accommodation chamber and a plurality of second accommodation chambers each being the second accommodation chamber accommodating the plurality of valve modules; and a plurality of

pump chambers each being the pump chamber, a plurality of diaphragms each being the diaphragm, and a plurality of actuators each being the actuator corresponding to the plurality of valve modules. The plurality of valve modules are arranged along a horizontal direction. The suction port is formed in a lateral surface of the first block. The suction-side flow path includes a first suction-side flow path extending horizontally and communicating with the suction port and a plurality of second suction-side flow paths that allow the first suction-side flow path to vertically communicate with the plurality of first accommodation chambers. The discharge port is formed in an upper surface of the second block. The discharge-side flow path is provided so as to allow the discharge port to diagonally communicate with each of the plurality of second accommodation chambers. The actuators drive the plurality of diaphragms individually in a phase shifted manner.

[0009] In yet another embodiment of the present invention, the valve module includes a gasket that is provided in an integral manner with the module guide at a lower end of the module guide. The module guide is formed to have a shape of a stepped circular cylinder including: a first guide part that is to be fitted in the first accommodation chamber and is positioned on the suction valve side; and a second guide part that is to be fitted in the second accommodation chamber, is positioned on the discharge valve side, and has a smaller diameter than an outside diameter of the first guide part. A sealing member is provided between an upper end of the first guide part and the second block.

[0010] In yet another embodiment of the present invention, the gasket has a circular cylindrical part and a flange part that sticks out from a lower end of the circular cylindrical part outwardly in a horizontal direction. The circular cylindrical part is attached to an inner circumferential side of the module guide. The flange part is positioned along a lower end part of the module guide.

[0011] In yet another embodiment of the present invention, the module guide includes a plurality of side flow paths each being the side flow path and a guide flow path structured with an annular groove that is formed in an outer circumferential part of the first guide part and that keeps the plurality of side flow paths in communication with one another.

[0012] In yet another embodiment of the present invention, the pump chamber is provided on a lateral surface of the first block; and the actuator drives the diaphragm to reciprocate in horizontal direction. Alternatively, the pump chamber is provided on a lower surface of the first block; and the actuator is provided in a position below the valve module and drives the diaphragm to reciprocate in vertical direction.

[0013] In yet another embodiment of the present invention, the pump device includes: a plurality of valve modules each being the valve module; a plurality of first accommodation chambers each being the first accommodation chamber and a plurality of second accommodation chambers each being the second accommodation chamber accommodating the plurality of valve modules; a plurality of pump chambers each being the pump chamber, a plurality of pump chamber communication flow paths each being the pump chamber communication flow path, a plurality of diaphragms each being the diaphragm, and a plurality of actuators each being the actuator corresponding to the plurality of valve modules. The plurality of valve modules are arranged along a horizontal direction. The plurality of actuators are arranged along a horizontal direction intersecting the arrangement direction of the valve modules, in such a manner that the plurality of valve modules are interposed therebetween when being viewed in a vertical direction.

[0014] A valve module according to one aspect of the present invention includes: a suction valve; a discharge valve; and a module guide that integrally holds the suction valve and the discharge valve, while the suction valve is positioned on a transport fluid suction side, whereas the discharge valve is positioned on a transport fluid discharge side. The module guide is formed to have a shape of a stepped circular cylinder including: a first guide part that has a first outside diameter and is positioned on the suction valve side; and a second guide part that has a second outside diameter smaller than the first outside diameter and is positioned on the discharge valve side. The module guide includes an inter-valve flow path provided between the suction valve and the discharge valve and a side flow path that connects the inter-valve flow path to an outer lateral surface of the first guide part. The side flow path communicates with the pump chamber, when the valve module is attached to a pump head.

[0015] In an embodiment of the present invention, further provided is a gasket provided on the transport fluid suction side of the module guide. The gasket has a circular cylindrical part and a flange part that sticks out from one end of the circular cylindrical part outwardly in a radial direction. The circular cylindrical part is attached to an inner circumferential side of the module guide. The flange part is positioned along a suction-side end part of the module guide.

[0016] In another embodiment of the present invention, the module guide includes a plurality of side flow paths each being the side flow path and a guide flow path structured with an annular groove that is formed in an outer circumferential part of the first guide part and that keeps the plurality of side flow paths in communication with one another.

[0017] In yet another embodiment of the present invention, the suction valve is held by the module guide via a valve holder. Further, the suction valve and the discharge valve are each structured by using one of a ball valve, an umbrella-type valve, and a poppet valve.

Advantageous Effects of Invention

[0018] The present invention makes it easy to attach and to detach the suction valve and the discharge valve to

and from the pump head.

Brief Description of Drawings

[0019]

[Figure 1] Figure 1 is a perspective view showing an exterior configuration of a pump device according to a first embodiment of the present invention.
[Figure 2] Figure 2 is an exploded perspective view of a pump head of the pump device.
[Figure 3] Figure 3 is a cross-sectional view taken at the line A-A in Figure 1.
[Figure 4] Figure 4 is a cross-sectional view taken at the line B-B in Figure 3.
[Figure 5] Figure 5 is a partial cross-sectional view showing an actuator to which a diaphragm of the pump device is to be attached.
[Figure 6] Figure 6 is a cross-sectional view showing another valve module used in the pump device.
[Figure 7] Figure 7 is a cross-sectional view showing yet another valve module used in the pump device.
[Figure 8] Figure 8 is a cross-sectional view showing yet another valve module used in the pump device.
[Figure 9] Figure 9 is an exploded perspective view of a pump head in a pump device according to a second embodiment of the present invention.
[Figure 10] Figure 10 is a transparent side view of the pump head.
[Figure 11] Figure 11 is a transparent top view of the pump head.
[Figure 12] Figure 12 is a cross-sectional view taken at the line C-C in Figure 11.
[Figure 13] Figure 13 is a cross-sectional view taken at the line D-D in Figure 11.
[Figure 14] Figure 14 is a cross-sectional view showing a modification example of the pump head.

Description of Embodiments

[0020] As an example of a pump device according to an embodiment of the present invention, the following will describe an electromagnetic metering pump device and a valve module in detail, with reference to the accompanying drawings. It should be noted that the following embodiments are not intended to limit the invention set forth in the claims. Also, not all the combinations of the features described in the embodiments are necessarily requisite for the means for solving the problems of the invention. In addition, in the following embodiments, some of the constituent elements that are the same as or correspond to each other will be referred to by using the same reference characters, and duplicate explanations thereof will be omitted. Furthermore, in the embodiments, the scales and the dimensions of the constituent elements may be presented differently from those in reality, and some of the constituent elements may be omitted from the presentation.

[First Embodiment]

[An exterior configuration of the electromagnetic metering pump device]

[0021] Figure 1 is a perspective view showing an exterior configuration of a pump device according to a first embodiment of the present invention. Figure 2 is an exploded perspective view of a pump head of the pump device. Figure 3 is a cross-sectional view taken at the line A-A in Figure 1. Figure 4 is a cross-sectional view taken at the line B-B in Figure 3.

[0022] As shown in Figure 1, an electromagnetic metering pump device (hereinafter "pump device") 100 according to the first embodiment includes a pump head 10 and a device main body part 50 to which the pump head 10 is to be detachably attached.

[0023] The pump head 10 is structured with a molded resin product, for example. The device main body part 50 includes a resin casing, for example, and has, on a side of one of the lateral surfaces (the right lateral surface in Figure 1), a head attachment part 51 having a recessed shape formed by removing parts of the top surface, the side surface, and the rear surface. The pump head 10 is attached to the head attachment part 51 in such a manner that the top surface, the side surface, and the rear surface thereof do not jut out from the device main body part 50. As explained herein, the pump head 10 is formed to have dimensions in such a range that, when being attached to the head attachment part 51, the pump head 10 fits into and filling a space in the head attachment part 51 so that the pump device 100 has a rectangular shape as a whole.

[0024] The device main body part 50 includes, on the inside thereof, flexible diaphragms 14 (see Figure 3) respectively attached to a plurality of pump chambers 13 (see Figure 3) of the pump head 10, which will be explained later, in a liquid-tight manner and a plurality of actuators 60 (see Figure 5) that reciprocate the diaphragms 14. In the present embodiment, two pump chambers 13 and two actuators 60 are provided.

[0025] The device main body part 50 includes: an operation panel part 53 having a display 52 and being provided on the front surface side; and a plurality of external input/output ports 54 provided on the lateral surface opposite from the head attachment part 51 of the device main body part 50. On the inside of the device main body part 50, a control unit (not shown) that controls operations of the pump device 100 is provided. The display 52 displays various types of information related to the pump device 100 including a set flow rate of the pump device 100. For example, it is possible to set the set flow rate in a flow rate range of 100 ml/min to 0.01 ml/min.

[0026] Together with the display 52, the operation panel part 53 includes a power supply button 53a, a pump operation start/stop button 53b, and a cursor/return operation part 53c. Further, the operation panel part 53 includes a calibration button 53d, a mode setting button 53e, a range setting button 53f, a stroke setting button

53g, and an I/O setting button 53h. With the cursor/return operation part 53c, a maximum volume designation button 53ca and an escape button 53cb are provided together. By carrying out various types of operation inputs via the operation panel part 53, a user of the pump device 100 is able to perform various types of operations related to the motion, the settings, and the like of the pump device 100.

[A configuration of the pump head]

[0027] As shown in Figures 2 to 4, the pump head 10 includes a suction port 11 for the transport fluid, a discharge port 12 for the transport fluid, and the plurality of pump chambers 13 communicating with the suction port 11 and the discharge port 12. The pump head 10 accommodates, on the inside thereof, a plurality of valve modules 20 arranged along a horizontal direction. Each of the valve modules 20 includes a suction valve 30 and a discharge valve 40 (see Figure 3) that are arranged along a vertical direction and are each structured with a ball valve, for example.

[0028] To the suction port 11 of the pump head 10, a suction-side hose is connected via a connection nut (not shown) so that the transport fluid from a tank is introduced to the inside of the pump chambers 13. To the discharge port 12 of the pump head 10, a discharge-side hose is connected via a connection nut (not shown) so that the transport fluid from the pump chambers 13 is discharged into the discharge-side hose.

[0029] The pump head 10 includes a first block 15 and a second block 16 structuring a plurality of pump head blocks that can be separated in the vertical direction, between the suction valves 30 and the discharge valves 40 of the plurality of valve modules 20. The first block 15 includes a first suction-side flow path 71 extending horizontally and communicating with the suction port 11 formed in the lateral surface; and a plurality of second suction-side flow paths 72 each extending vertically upward and communicating with the first suction-side flow path 71.

[0030] A plurality of first accommodation chambers 73 communicating with the second suction-side flow paths 72 and accommodating certain sections of the valve modules 20 positioned on the suction valves 30 side are formed in the first block 15. Each of the first accommodation chambers 73 opens toward the top. Further, diaphragm attachment bores 17 for forming the pump chambers 13 in collaboration with the diaphragms 14 are formed in the first block 15 so as to open in the direction intersecting the first and the second suction-side flow paths 71 and 72. The diaphragm attachment bores 17 are provided in certain positions within the first block 15 so that an upper part of each of the pump chambers 13 is positioned below a side flow path 27, which will be explained later, of the corresponding valve module 20.

[0031] The second block 16 includes a first discharge-side flow path 81 extending horizontally and communicating with the discharge port 12 formed in the lateral surface; and a plurality of second discharge-side flow paths 82 each extending vertically downward and communicating with the first discharge-side flow path 81. A plurality of second accommodation chambers 83 communicating with the second discharge-side flow paths 82 and accommodating certain sections of the valve modules 20 positioned on the discharge valves 40 side are formed in the second block 16. Each of the second accommodation chambers 83 opens toward the bottom.

[0032] Further, the first block 15 and the second block 16 structure the pump head 10, by being integrally formed through screw fastening using a plurality of fastening bolts 19 that extend vertically and serve as coupling means. When being integrally formed, the first block 15 and the second block 16 in the present embodiment have a rectangular shape of which the corner sections positioned on the operation panel part 53 side of the device main body part 50 are each chamfered. The pump head 10 structured in this manner is integrally attached to the lateral surface side of the device main body part 50, through screw fastening using a plurality of attachment screws (not shown) so as to be attached, via attachment bores 15a, to the head attachment part 51 of the device main body part 50.

[A configuration of the valve modules]

[0033] Each of the valve modules 20 includes: the suction valve 30; the discharge valve 40 having the same configuration as that of the suction valve 30; and a module guide 23 that, while the suction valve 30 is located at the lower side, and the discharge valve 40 is located at the upper side, integrally holds the two valves in a vertical direction. The module guide 23 includes a suction valve accommodation chamber 23a at the lower side and a discharge valve accommodation chamber 23b at the upper side. The suction valve 30 is accommodated in the suction valve accommodation chamber 23a via a valve holder 21. The discharge valve 40 is accommodated in the discharge valve accommodation chamber 23b. In this situation, the suction valve accommodation chamber 23a has an inner circumferential surface defining a larger diameter than that of the discharge valve accommodation chamber 23b. The inside diameter difference is absorbed by the valve holder 21.

[0034] The module guide 23 is formed to have the shape of a stepped circular cylinder including: a first guide part 24 that is positioned on the suction valve 30 side; and a second guide part 25 that is positioned on the discharge valve 40 side and has a smaller diameter than the outside diameter of the first guide part 24. As described herein, the module guide 23 is formed so as to have a step between the first guide part 24 and the second guide part 25.

[0035] In this situation, the module guide 23 has a plurality of side flow paths 27 arranged at prescribed intervals in the circumferential direction, in the vicinity

of the step of the first guide part 24 formed with the second guide part 25. The plurality of side flow paths 27 allow an inter-valve flow path 79b formed between the suction valve 30 and the discharge valve 40 to communicate with the outer lateral surface of the module guide 23. The module guide 23 includes a guide flow path 26 in which the transport fluid flows and which is structured with an annular groove recessed toward the center axis, for example, the annular groove keeping the plurality of side flow paths 27 in communication with one another, over the entire circumference of an outer circumferential part positioned in the vicinity of the step of the first guide part 24 formed with the second guide part 25. Further, as shown in Figure 3, the first block 15 includes a plurality of pump chamber communication flow paths 74 that extend diagonally upward from upper sections of the plurality of pump chambers 13, respectively, and that communicate with the plurality of first accommodation chambers 73.

[0036] The guide flow path 26 provided in the first guide part 24 of the module guide 23 is connected to the pump chamber communication flow path 74 communicating with the pump chamber 13, on the inside of the first accommodation chamber 73 of the first block 15, while the valve module 20 is set in the first accommodation chamber 73, for example.

[0037] As described above, the guide flow path 26 is provided between the suction valve 30 and the discharge valve 40 over the entire circumference corresponding to 360° and is structured so as to be connected to the pump chamber 13 via the pump chamber communication flow path 74. Accordingly, at the time of attaching and detaching the valve module 20 to and from the pump head 10, the orientation in terms of the rotation direction centered on the axial direction can be arbitrary. Thus, ease of work in module replacement and the like is enhanced. Further, the valve modules 20 are each structured so that the section on the suction valve 30 side and the section on the discharge valve 40 side can be positioned close to each other so as to be contiguous in the vertical direction. Accordingly, it is possible to reduce dead spaces by designing the valve modules 20 compact, while keeping small the number of component parts used therein.

[0038] The suction valve 30 in each of the valve modules 20 is structured with one valve ball 31 and a valve seat 32 positioned underneath the valve ball 31. The suction valve 30 is accommodated in the suction valve accommodation chamber 23a while being attached to the valve holder 21. The valve ball 31 is accommodated between the valve holder 21 and the valve seat 32 so as to be slightly movable in up-and-down direction. A lower end part of a tubular space 79a inside the valve seat 32 communicates with the second suction-side flow path 72, while an upper end thereof is in communication with the lower end side of the discharge valve 40.

[0039] The valve holder 21 is formed to have the shape of a stepped circular cylinder having a small diameter part 21a and a large diameter part 21b and is structured so that the small diameter part 21a is fitted into a space defined by a small-diameter inner circumferential surface of the suction valve accommodation chamber 23a, whereas a step part thereof formed with the large diameter part 21b abuts against a step part formed between the small-diameter inner circumferential surface and a large-diameter inner circumferential surface of the suction valve accommodation chamber 23a. The valve holder 21 has a holder flow path 33 that is formed in a position slightly below an upper end part of the valve holder 21 and that communicates with the side flow paths 27 formed in the module guide 23 and with the inter-valve flow path 79b positioned above the valve ball 31.

[0040] A gasket 34 made of PTFE, for example, is attached to a space between the outer circumferential part of the large diameter part 21b of the valve holder 21 and a lower end inner circumferential part of the module guide 23. The gasket 34 includes a circular cylindrical part 34a and a flange part 34b that sticks out radially outward from a lower end of the circular cylindrical part 34a. The circular cylindrical part 34a is sandwiched and held between the valve holder 21 and the module guide 23. The flange part 34b is positioned along a lower end (the end part on the suction side) of the module guide 23, so as to cover the lower end.

[0041] When the valve holder 21 is set with the module guide 23 via the gasket 34, the gasket 34 is in close contact with the lower outer circumference of the valve holder 21 and the lower inner circumference of the module guide 23. When the first block 15 and the second block 16 are coupled together up and down, the gasket 34 is in close contact with the bottom surface of the first accommodation chamber 73 of the first block 15. With this configuration, the gasket 34 seals the first accommodation chamber 73 on the suction valve 30 side and on the pump chamber 13 side.

[0042] Similarly to the suction valve 30, the discharge valve 40 in each of the valve modules 20 is structured with one valve ball 41 and a valve seat 42 positioned underneath the valve ball 41. The valve ball 41 is accommodated in the discharge valve accommodation chamber 23b so as to be slightly movable in up-and-down direction between the module guide 23 and the valve seat 42. A lower end part of a tubular space 79c inside the valve seat 42 is in communication with the upper end side of the suction valve 30, while an upper end thereof is in communication with a lower end part of a circular truncated cone space 84 formed above the second accommodation chamber 83 via a plurality of vertical flow paths 79d, so as to further communicate with the second discharge-side flow path 82.

[0043] An upper end part of the valve holder 21 accommodated in the suction valve accommodation chamber 23a upwardly presses a lower end part of the valve seat 42 of the discharge valve 40. Accordingly, it is possible to assemble each of the valve modules 20 with a simple process such as setting the valve ball 41 and the valve seat 42 with the module guide 23, attaching the valve ball 31 and the valve seat 32 to the valve holder 21, and

subsequently fitting the valve holder 21 and the gasket 34 into the module guide 23. In this situation, the gasket 34 may be fitted into the valve holder 21 in advance, may be fitted into the module guide 23 in advance, or may be fitted into a space between the module guide 23 and the valve holder 21 after these two have been fitted together. With this configuration, it is possible to form the valve modules 20 in each of which the suction valve 30 and the discharge valve 40 are positioned so as to be contiguous in the vertical direction. Further, because it is possible to assemble and modularize the valve modules 20 as described above, it is possible to enhance ease of assembly while keeping small the number of component parts used therein and to also keep the structure thereof compact. In addition, the suction valve 30 and the discharge valve 40 do not necessarily need to have mutually the same configuration, and it is possible to modularize the valve modules 20 while combining mutually-different valve styles (e.g., an umbrella-type valve, a poppet valve, etc.).

[0044] Each of the valve modules 20 structured as described above is provided inside the pump head 10 while being sandwiched and held by the first and the second blocks 15 and 16 in the up-and-down direction, so that the first guide part 24 is accommodated in the first accommodation chamber 73 whereas the second guide part 25 is accommodated in the second accommodation chamber 83. In this situation, leakage of the transport fluid from a mating surface between the first block 15 and the second block 16 in the pump head 10 is prevented by an O-ring 89 that is positioned on the upper end surface side of the first guide part 24 and serves as a sealing member.

[0045] The flange part 34b of the gasket 34 is positioned on the bottom surface side of the first accommodation chamber 73. The flange part 34b seals the space formed between the lower end surface of the module guide 23 of the valve module 20, the bottom surface of the first accommodation chamber 73, and the inner circumferential surface contiguous to the bottom surface of the first accommodation chamber 73. The O-ring 89 is positioned on the upper end surface side of the first guide part 24. The O-ring 89 seals the space formed between the upper end surface of the first guide part 24, the inner circumferential surface of the first accommodation chamber 73, and the outer circumferential surface of an inverted circular truncated cone part of the second block 16 protruding relative to the mating surface toward the first accommodation chamber 73. Alternatively, in place of the O-ring 89, it is also acceptable to use a gasket (not shown) made of PTFE or the like, as a sealing member.

[0046] As explained above, while being sandwiched and held between the first block 15 and the second block 16, the valve module 20 realizes a seal design concept entirely with a so-called abutting structure (a structure in which the sealing is realized with pressure in the up-and-down direction). Accordingly, as compared with a structure in which the sealing is realized in the radial direction, sealability is higher, and the sealing member wears out less. In addition, unlike the sealing structure in the radial direction, there is no possibility that the sealing member may move in up-and-down direction due to pulsation of the transport fluid. As a result, the precision level of the discharging will not be degraded, and the flow rate will not be lowered thereby, either. Furthermore, there is no need to reserve a space for providing a groove part or the like to install the sealing member. It is therefore possible to reduce dead spaces and air pocket locations. In addition, because the seal has the abutting structure, it is easier to attach and detach the valve modules 20, as compared to lateral surface seal. Consequently, it is possible to prevent inconveniences such as the flow rate being lowered when a high-pressure load is applied, while enhancing the precision level of the discharging, sealability, and ease of assembly. Further, it is also possible to reduce dead spaces.

[A configuration around the pump head]

[0047] Figure 5 is a partial cross-sectional view showing an actuator to which the diaphragm of the pump device is to be attached. As shown in Figure 5, the actuator 60 is an electromagnetic actuator, for example, and includes an actuator main body 61 having a circular cylindrical exterior shape; and a control substrate 62 provided on the basal end side of the actuator main body 61 and connected to an electrical wiring 62a and a signal wiring 62b. To the tip end side of the actuator main body 61, which is the opposite side from the control substrate 62, an attachment panel 63 to be attached to an internal attachment part (not shown) of the device main body part 50 is attached by screw fastening or the like, for example.

[0048] A drive shaft 64 which has a bar-like shape and extends toward the tip end side of the actuator main body 61 is driven by driving force of the actuator 60, so as to reciprocate in the directions shown with the arrow in the drawing. At the tip end of the drive shaft 64, the diaphragm 14 serving as a reciprocating member is attached via an insert bolt 19a. A central rear surface part of the diaphragm 14 is supported by a retainer 18 attached to the drive shaft 64.

[0049] Between the diaphragm 14 and the attachment panel 63, a bracket 66 having a circular cylindrical shape is attached. The bracket 66 has, on the inside thereof, a bush 65 for a water-proof purpose and is fitted into one of the diaphragm attachment bores 17 formed in the first block 15 of the pump head 10. A circumferential rim part of the diaphragm 14 is sandwiched and held between a bottom part of the diaphragm attachment bore 17 and the bracket 66. A front surface central part of the diaphragm 14 forms the pump chamber 13, in collaboration with the first block 15 of the pump head 10.

[Operation of the pump device]

[0050] Next, operation of the pump device 100 structured as described above will be explained.

[0051] On the basis of setting information input via the operation panel part 53, the control unit in the device main body part 50 executes, in parallel, suction operation where the diaphragm 14 is retreated horizontally together with the drive shaft 64 of one of the two actuators 60 and discharge operation where the diaphragm 14 is advanced horizontally together with the other drive shaft 64, in order to transport the transport fluid at a prescribed flow rate. In other words, the actuators 60 are configured to be able to drive the plurality of diaphragms 14 individually in a phase shifted manner.

[0052] During the suction operation, the suction valve 30 of the valve module 20 opens, whereas the discharge valve 40 closes. Thus, the transport fluid is introduced from the tank (not shown) to the inside of the pump chamber 13, via the suction port 11, the first suction-side flow path 71, the second suction-side flow path 72, the suction valve 30, the inter-valve flow path 79b, the holder flow path 33, the side flow paths 27, the guide flow path 26, and the pump chamber communication flow path 74. At that time, in the discharge valve 40, because the valve ball 41 is in close contact with the valve seat 42, the transport fluid is prevented from flowing in toward the discharge side.

[0053] During the discharge operation, the discharge valve 40 of the valve module 20 opens, whereas the suction valve 30 closes. Thus, the transport fluid is discharged from the pump chamber 13 into the discharge-side hose, via the pump chamber communication flow path 74, the guide flow path 26, the side flow paths 27, the holder flow path 33, the inter-valve flow path 79b, the discharge valve 40, the circular truncated cone space 84, the second discharge-side flow path 82, the first discharge-side flow path 81, and the discharge port 12.

[Advantageous effects of the embodiment]

[0054] In the pump device 100 according to the first embodiment, it is possible to separate the pump head 10, up and down, into the first block 15 and the second block 16, at an intermediate section of each of the valve modules 20, i.e., at the section between the suction valve 30 and the discharge valve 40. It is therefore easy to attach and to detach the valve modules 20. Consequently, it is possible to enhance ease of maintenance including replacement of the valve modules 20 and the like.

[0055] Further, the valve modules 20 each have the structure in which the suction valve 30 and the discharge valve 40 are integrally formed as a unit. Thus, as compared to a structure in which the suction valve 30 and the discharge valve 40 are individually attached to the pump head 10, the attaching and detaching processes to and from the pump head 10 is significantly simplified. Furthermore, because the guide flow path 26 structuring a part of the flow path for the transport fluid is formed over the entire circumference of the module guide 23 of the valve module 20 corresponding to 360°, the orientation (directionality) at the time of attaching the valve module 20 to the first accommodation chamber 73 of the first block 15 can be arbitrary, which makes the attachment easy.

[0056] In the pump head 10 according to the present embodiment, the volumes of the flow paths 26, 27, and 33 in the valve modules 20 reaching the pump chambers 13 are kept small in the spaces between the suction valves 30 and the discharge valves 40. It is therefore possible to keep dead volume small. As explained herein, by using the pump device 100 according to the first embodiment, while keeping the dead volume small, it is possible to facilitate the processes of attaching and detaching the suction valve 30 and the discharge valve 40 to and from the pump head 10.

[Configurations of other valve modules]

[0057] Figures 6, 7, and 8 are cross-sectional views showing other valve modules used in the pump device described above. As shown in Figure 6, another valve module 20A has a structure in which a suction valve 30A and a discharge valve 40A each configured with a poppet valve are arranged along a vertical direction.

[0058] A module guide 23A, a first guide part 24A, and a second guide part 25A of the valve module 20A are formed to have the same exterior shapes and the same exterior dimensions as those of the module guide 23, the first guide part 24, and the second guide part 25 of the valve module 20 described above. The guide flow path 26 is also formed in the same position. Accordingly, similarly to the valve module 20, it is possible to accommodate the valve module 20A in the first accommodation chamber 73 and the second accommodation chamber 83 in the first block 15 and the second block 16 of the pump head 10.

[0059] The suction valve 30A of the valve module 20A is structured with: one poppet valve 31A: and a valve holder 21A to which the poppet valve 31A is attached so as to be able to open and close and which also functions as a valve seat. The valve holder 21A forms a tubular space in which the poppet valve 31A is attached in such a manner that a valve body 31Aa of the poppet valve 31A is slightly movable in up-and-down direction.

[0060] The discharge valve 40A of the valve module 20A is structured with: one poppet valve 41A; and the module guide 23A to which the poppet valve 41A is attached so as to be able to open and close and which also functions as a valve seat. The module guide 23A forms a tubular space in which the poppet valve 41A is attached in such a manner that a valve body 41Aa of the poppet valve 41A is slightly movable in up-and-down direction.

[0061] In this situation, a chamber 28 forming an inter-valve flow path is provided between the poppet valves 31A and 41A positioned up and down. To the chamber 28, the side flow paths 27 radially communicating with the guide flow path 26 are connected. Further, between the valve holder 21A and the suction valve accommodation chamber 22, the gasket 34 having the flange part 34b is attached so as to be in close contact therewith.

[0062] Further, as shown in Figure 7, another valve module 20B has a structure in which, for example, a suction valve 30B and a discharge valve 40B each structured with an umbrella-type valve are arranged along a vertical direction. In this situation, a module guide 23B, a first guide part 24B, and a second guide part 25B of the valve module 20B are formed to have the same exterior shapes and the same exterior dimensions as those of the module guides 23 and 23A, the first guide parts 24 and 24A, and the second guide parts 25 and 25A of the valve modules 20 and 20A described above. The guide flow path 26 is also formed in the same position. Accordingly, similarly to the valve modules 20 and 20A, it is possible to accommodate the valve module 20B in the first accommodation chamber 73 and the second accommodation chamber 83 in the first block 15 and the second block 16 of the pump head 10.

[0063] The suction valve 30B of the valve module 20B is structured with: one umbrella-type valve 31B; and a valve holder 21B which is positioned underneath the umbrella-type valve 31B and which also functions as a valve seat to which a valve body 31Ba of the umbrella-type valve 31B is attached so as to be able to open and close. Formed above the suction valve accommodation chamber 22 of the module guide 23B is a tubular space 29 in which the valve body 31Ba of the umbrella-type valve 31B is movable in up-and-down direction.

[0064] The discharge valve 40B of the valve module 20B is structured with: one umbrella-type valve 41B of which a valve body 41Ba is attached to an upper end part of the module guide 23B so as to be able to open and close; and the module guide 23B that also functions as a valve seat. While being accommodated in the second accommodation chamber 83 of the second block 16, the valve body 41Ba of the umbrella-type valve 41B is able to be movable in up-and-down direction in the tubular space formed in an upper part of the interior space of the second accommodation chamber 83.

[0065] A central circular space 21Bc communicating with the second suction-side flow paths 72 in the first block 15 and a vertical flow path 21Bb communicating with the central circular space 21Bc are formed in the valve holder 21B. Between the valve holder 21B and the suction valve accommodation chamber 22, the gasket 34 having the flange part 34b is attached so as to be in close contact therewith. Further, a vertical flow path 23Bb forming an inter-valve flow path communicating with the tubular space 29, the guide flow path 26, and the side flow paths 27 are formed in the module guide 23B.

[0066] As shown in Figure 8, yet another valve module 20C has the same structure as the valve module 20 previously described in which the suction valve 30 and the discharge valve 40 each structured with a ball valve are arranged along a vertical direction. In other words, a module guide 23C, a first guide part 24C, and a second guide part 25C of the valve module 20C are formed to have the same exterior shapes and the same exterior dimensions as those of the module guides 23, 23A and 23B, the first guide parts 24, 24A, and 24B, and the second guide parts 25, 25A, and 25B of the valve modules 20, 20A, and 20B described above. The guide flow path 26 is also formed in the same position. Accordingly, similarly to the valve modules 20, 20A, and 20B, it is possible to accommodate the valve module 20C in the first accommodation chamber 73 and the second accommodation chamber 83 in the first block 15 and the second block 16 of the pump head 10.

[0067] In the valve module 20C, a gasket 34A made of PTFE, for example, is attached to an inside position in the vicinity of a lower end of the suction valve accommodation chamber 23a of the module guide 23C, so as to cover a lower end part of the valve holder 21 and a lower end part of the valve seat 32. Similarly to the gasket 34 described above, the gasket 34A includes the circular cylindrical part 34a and the flange part 34b. The circular cylindrical part 34a has, in a central part thereof, a tubular space 34d communicating with a lower end part of the tubular space 79a inside the valve seat 32 and with the second suction-side flow path 72 (not shown). The circular cylindrical part 34a is, for example, press-fitted on the inner circumferential side of the suction valve accommodation chamber 23a. The flange part 34b is positioned along a lower end (the end part on the suction side) of the module guide 23C, so as to cover the lower end.

[0068] The gasket 34A is attached after the valve holder 21 is set with the module guide 23C, is in close contact with the bottom inner circumference of the suction valve accommodation chamber 23a, and comes into close contact with the bottom surface of the first accommodation chamber 73 of the first block 15 when the first block 15 and the second block 16 are coupled together up and down. With this configuration, the gasket 34A seals the first accommodation chamber 73 on the suction valve 30 side and on the pump chamber 13 side.

[0069] The gasket 34A described above makes it easy to manage the dimension of the circular cylindrical part 34a in the radial direction. In other words, because the gasket 34A is structured so that the circular cylindrical part 34a is inserted on the inside of the suction valve accommodation chamber 23a of the module guide 23C, as for the dimension management of the gasket 34A, it is possible to assemble the valve module 20C by only taking into consideration dimension management of the inside diameter of the suction valve accommodation chamber 23a. Consequently, it is possible to easily manufacture the gasket 34A and to thus reduce costs.

[0070] Further, by using the gasket 34A structured as described above, it is possible to ensure sealability without the need to insert the circular cylindrical part 34a deep into the suction valve accommodation chamber 23a. Accordingly, it is possible to attach and to detach the gasket 34A to and from the module guide 23C. As a result, because it is possible to easily assemble and disassemble the valve module 20C, it is possible to enhance ease of work in the assembly.

[0071] As explained above, by using the structures in

which the valve modules 20A, 20B, and 20C are configured to have the same shape and the same dimensions as those of the valve module 20, while the suction valves 30, 30A, and 30B and the discharge valves 40, 40A, and 40B are each integrally formed as a unit, it is possible, in the pump head 10, to switch into or replace with an appropriate valve style (e.g., a ball valve, a poppet valve, an umbrella-type valve, etc.) corresponding to various types of conditions such as, for example, the type of the transport fluid, viscosity of the transport fluid, a set flow rate, and/or the like. It is therefore possible to easily apply various valves of mutually-different styles to the pump head 10. Further, within the valve modules 20, 20A, 20B, and 20C, the suction valves 30, 30A, and 30B and the discharge valves 40, 40A, and 40B do not necessarily need to have the same configurations as described above and may be configured with mutually-different valve styles.

[Second Embodiment]

[A configuration of another pump head]

[0072] Figure 9 is an exploded perspective view of a pump head in a pump device according to a second embodiment of the present invention. Figure 10 is a transparent side view of the pump head. Figure 11 is a transparent top view of the pump head. Figure 12 is a cross-sectional view taken at the line C-C in Figure 11. Figure 13 is a cross-sectional view taken at the line D-D in Figure 11. In the description below including Figures 9 to 13, some of the constituent elements that are the same as those in the first embodiment and the modification examples thereof will be referred to by using the same reference characters. Thus, duplicate explanations will be omitted below.

[0073] As shown in Figures 9 to 13, unlike the pump head 10 according to the first embodiment attached to the lateral surface side of the device main body part 50, a pump head 10A of the pump device according to the second embodiment is structured so as to be detachably attached onto the upper surface side of the device main body part (not shown). By using the pump head 10A structured in this manner, it is possible to realize a so-called upright pump device.

[0074] The pump head 10A is structured with a molded resin product, for example and is to be detachably attached to the upper surface side of the device main body part. The pump head 10A includes a first block 15A in which the suction port 11, the first and the second suction-side flow paths 71 and 72, the first accommodation chamber 73, and the pump chamber 13 on the lower surface thereof, are formed; and a second block 16A in which the discharge port 12, the first and the second discharge-side flow paths 81 and 82, and the second accommodation chamber 83 are formed. It is possible to separate the first block 15A and the second block 16A in the vertical direction at the section between the suction valve 30 and the discharge valve 40 in each of the plurality of valve modules 20.

[0075] The first block 15A of the pump head 10A includes: a pedestal part 91 attached to the device main body part; and a threaded engagement part 92 in a circular columnar shape which stands on the pedestal part 91, has a plurality of first accommodation chambers 73 arranged inwardly along the horizontal direction formed therein, and has a threaded part 92a formed in an outer circumferential part thereof. The pedestal part 91 of the first block 15A is formed to have a horizontally longitudinal octagonal shape in a top view, for example.

[0076] The pedestal part 91 has the suction port 11 in a longer-side lateral surface and includes the first suction-side flow path 71 extending horizontally from the suction port 11 and a plurality of second suction-side flow paths 72 extending vertically upward from the first suction-side flow path 71 and communicating with the plurality of first accommodation chambers 73. Further, the pedestal part 91 has a plurality of diaphragm attachment bores 17 that open downwardly and that form the pump chambers 13 in collaboration with the diaphragms 14 attached to the actuators 60. Formed in the range from a part of the pedestal part 91 to the threaded engagement part 92 are the plurality of first accommodation chambers 73 that open upwardly and that accommodate certain sections of the valve modules 20 positioned on the suction valves 30 side.

[0077] In this situation, the plurality of actuators 60 are positioned below the valve modules 20, while the drive shaft 64 is reciprocating in the vertical direction, within the device main body part (not shown). Further, as shown in Figure 11, the plurality of actuators 60 are arranged along a horizontal direction intersecting the arrangement direction of the first accommodation chambers 73 described above in such a manner that the plurality of valve modules 20 are interposed therebetween when being viewed in a vertical direction, so as to drive the diaphragms 14 to reciprocate in the vertical direction. The second suction-side flow paths 72 communicate with the first suction-side flow path 71 and also communicate with the first accommodation chambers 73.

[0078] The pump chamber communication flow paths 74 communicating with the pump chambers 13 are formed in the range from the pedestal part 91 to the threaded engagement part 92 of the first block 15A, so as to each extend diagonally upward in mutually-different directions, from the plurality of pump chambers 13 toward the first accommodation chambers 73. The second block 16A of the pump head 10A is formed to have a circular columnar shape protruding like a mound, while a lower-end circumferential rim part thereof is formed to have a flange shape of which the diameter is substantially equal to the outside diameter of the threaded engagement part 92 of the first block 15A.

[0079] The second block 16A has the discharge port 12 in a lateral surface of the mound part and includes the first discharge-side flow path 81 extending horizontally from

the discharge port 12 and the plurality of second discharge-side flow paths 82 extending vertically downward from the first discharge-side flow path 81 and communicating with the plurality of second accommodation chambers 83. In this situation, the mound part may be formed to have any of various types of shapes including a circular truncated cone shape, a polygonal frustum, and an elliptic truncated cone. In the second block 16A, the plurality of second accommodation chambers 83 that open downwardly and that accommodate certain sections of the valve modules 20 positioned on the discharge valves 40 side are formed so as to communicate with the second discharge-side flow paths 82 via the circular truncated cone space 84.

[0080] The second block 16A is integrally fixed with the first block 15A while the valve modules 20 are sandwiched and held, as being capped by a union nut 93, for example, and screwed together with the threaded engagement part 92 of the first block 15A, which serves as coupling means in place of the abovementioned fastening bolts 19. The pump head 10A structured in this manner is integrally attached to the device main body part (not shown) by being screw-fastened to the upper surface side via a plurality of attachment screws (not shown). Because the other configurations of the valve modules 20 and the other configurations of the functional units of the pump head 10A are the same as those of the pump head 10 to which the valve modules 20 explained in the first embodiment are attached, explanations thereof will be omitted.

[0081] It is also possible to separate the pump head 10A according to the second embodiment up and down into the first block 15A and the second block 16A, at an intermediate section of each of the valve modules 20. It is therefore possible to easily attach and detach the valve modules 20 and to thus enhance ease of maintenance including replacement of the valve modules 20 and the like. Further, it is also possible to easily perform the process of switching to a different valve module such as a valve module 20A, 20B, or 20C.

[0082] Further, because each of the valve modules 20 integrally structures the suction valve 30 and the discharge valve 40 into a unit, the attaching and detaching processes to and from the pump head 10A are easy. Further, a pump device including the pump head 10A is able to have a so-called upright structure, in contrast to the pump device 100 according to the first embodiment. Thus, even in an installation space having a small installation width for a pump device, it is possible to install the pump device capable of realizing functions equivalent to those of the pump device 100. As explained herein, the pump head 10A according to the second embodiment is able to exert the same function effects as those of the first embodiment.

[A modification example]

[0083] Figure 14 is a cross-sectional view showing a modification example of the pump head 10A.

[0084] As shown in Figure 14, a pump head 10B according to a modification example is similar to the pump head 10A described above for being attached to the upper surface side of the device main body part 50, but is different in that the discharge port 12 in a second block 16B is formed in the upper surface of a mound part, as compared to the pump head 10A in which the discharge port 12 is formed in a lateral surface of the second block 16A. Because the configurations of the other functional unit are the same as those in the pump head 10A, explanations thereof will be omitted.

[0085] When the pump head 10B is used, because it is possible to provide the discharge port 12 so as to open upwardly, it is possible to realize a structure in which air bubbles do not easily accumulate. In this situation, because the discharge port 12 opens upwardly, the first discharge-side flow path 81, which horizontally extends from the discharge port 12 in the second block 16A, is omitted from the second block 16B. The second discharge-side flow paths 82 extend diagonally upward from the circular truncated cone space 84 toward the discharge port 12.

[0086] In the pump heads 10A and 10B according to the second embodiment and the modification example, it is possible to integrally fix the first block 15A and the second block 16A (16B) together, manually by using the union nut 93, for example. It is therefore possible to carry out the attaching process, without the need to additionally use an attachment-purpose tool or the like. Further, because the pump chambers 13 are formed facing upward, so that the pump chamber communication flow paths 74 starting therefrom and being connected to the valve modules 20 are formed diagonally upward facing upward. Thus, it is possible to realize a structure in which air bubbles do not easily enter the pump chambers 13 and, even if air bubbles have entered, it is possible to easily eliminate the air bubbles.

[0087] Further, it is possible to attach the pump heads 10A and 10B, with the attachment orientation in the horizontal direction turned by 180°. It is therefore possible to easily change the opening direction of the suction port 11 by 180°. In addition, because the pump heads 10A and 10B are attached to the top surface side of the device main body part 50, for example, when the second block 16A (16B) is detached from the first block 15A, it is possible to easily check, from above, the state of the valve modules 20 provided therein, which makes the work easier at the time of replacement or the like. Further, when the first block 15A and the second block 16A (16B) are formed by using transparent resin or the like, so that it is possible to visually check the interior, it is possible to easily check the valve modules 20 provided therein, without the need to detach the second block 16A (16B).

[0088] A number of embodiments of the present invention have thus been explained. However, these embodiments have been presented as examples and are not intended to limit the scope of the invention. It is possible to

carry out these novel embodiments in other various modes and to make various omissions, substitutions, and changes without departing from the gist of the invention. The embodiments and modifications thereof are included in the scope and the gist of the invention and are also covered by the inventions set forth in the claims and equivalents thereof.

Reference Signs List

[0089]

10: pump head
11: suction port
12: discharge port
13: pump chamber
14: diaphragm
15: first block
16: second block
20: valve module
21: valve holder
22: suction valve accommodation chamber
23: module guide
23a: suction valve accommodation chamber
23b: discharge valve accommodation chamber
24: first guide part
25: second guide part
26: guide flow path
27: side flow path
30: suction valve
34: gasket
40: discharge valve
50: device main body part
60: actuator
71: first suction-side flow path
72: second suction-side flow path
73: first accommodation chamber
74: pump chamber communication flow path
81: first discharge-side flow path
82: second discharge-side flow path
83: second accommodation chamber
100: pump device

Claims

1. A pump device comprising:

a pump head; and
a device main body part to which the pump head is to be detachably attached, wherein
the pump head includes:

a valve module including a suction valve, a discharge valve, and a module guide that integrally holds the suction valve and the discharge valve while the suction valve is located at a lower side and the discharge valve is located at an upper side so as to transport a transport fluid from the lower side to the upper side and that has a side flow path allowing an inter-valve flow path formed between the suction valve and the discharge valve to communicate with an outer lateral surface;
a first block including a first accommodation chamber accommodating a lower part of the valve module, a suction port through which the transport fluid is suctioned, a suction-side flow path that connects the suction port to a lower part of the suction valve, a pump chamber of which an upper part is positioned below the side flow path of the valve module, and a pump chamber communication flow path that connects the pump chamber to the side flow path of the valve module;
a second block including a second accommodation chamber accommodating an upper part of the valve module, a discharge port through which the transport fluid is discharged, and a discharge-side flow path that connects the discharge port to an upper part of the discharge valve; and
coupling means for coupling the first block and the second block together, while the valve module is accommodated inside, and the device main body part includes a diaphragm accommodated in the pump chamber of the first block and an actuator that drives the diaphragm to reciprocate.

2. The pump device according to claim 1, comprising:

a plurality of valve modules each being the valve module; a plurality of first accommodation chambers each being the first accommodation chamber and a plurality of second accommodation chambers each being the second accommodation chamber accommodating the plurality of valve modules; and a plurality of pump chambers each being the pump chamber, a plurality of diaphragms each being the diaphragm, and a plurality of actuators each being the actuator corresponding to the plurality of valve modules, wherein
the plurality of valve modules are arranged along a horizontal direction,
the suction port is formed in a lateral surface of the first block,
the suction-side flow path includes a first suction-side flow path extending horizontally and communicating with the suction port and a plurality of second suction-side flow paths that allow the first suction-side flow path to vertically communicate with the plurality of first accommodation chambers,

the discharge port is formed in a lateral surface of the second block,
the discharge-side flow path includes a first discharge-side flow path extending horizontally and communicating with the discharge port and a plurality of second discharge-side flow paths that allow the first discharge-side flow path to vertically communicate with the plurality of second accommodation chambers, and
the actuators drive the plurality of diaphragms individually in a phase shifted manner.

3. The pump device according to claim 1, comprising:

a plurality of valve modules each being the valve module; a plurality of first accommodation chambers each being the first accommodation chamber and a plurality of second accommodation chambers each being the second accommodation chamber accommodating the plurality of valve modules; and a plurality of pump chambers each being the pump chamber, a plurality of diaphragms each being the diaphragm, and a plurality of actuators each being the actuator corresponding to the plurality of valve modules, wherein
the plurality of valve modules are arranged along a horizontal direction,
the suction port is formed in a lateral surface of the first block,
the suction-side flow path includes a first suction-side flow path extending horizontally and communicating with the suction port and a plurality of second suction-side flow paths that allow the first suction-side flow path to vertically communicate with the plurality of first accommodation chambers,
the discharge port is formed in an upper surface of the second block,
the discharge-side flow path is provided so as to allow the discharge port to diagonally communicate with each of the plurality of second accommodation chambers, and
the actuators drive the plurality of diaphragms individually in a phase shifted manner.

4. The pump device according to claim 1, wherein

the valve module includes a gasket that is provided in an integral manner with the module guide at a lower end of the module guide,
the module guide is formed to have a shape of a stepped circular cylinder including: a first guide part that is to be fitted in the first accommodation chamber and is positioned on the suction valve side; and a second guide part that is to be fitted in the second accommodation chamber, is positioned on the discharge valve side, and has a smaller diameter than an outside diameter of the first guide part, and
a sealing member is provided between an upper end of the first guide part and the second block.

5. The pump device according to claim 4, wherein

the gasket has a circular cylindrical part and a flange part that sticks out from a lower end of the circular cylindrical part outwardly in a horizontal direction,
the circular cylindrical part is attached to an inner circumferential side of the module guide, and
the flange part is positioned along a lower end part of the module guide.

6. The pump device according to claim 4, wherein

the module guide includes a plurality of side flow paths each being the side flow path and a guide flow path structured with an annular groove that is formed in an outer circumferential part of the first guide part and that keeps the plurality of side flow paths in communication with one another.

7. The pump device according to any one of claims 1 to 6, wherein

the pump chamber is provided on a lateral surface of the first block, and
the actuator drives the diaphragm to reciprocate in horizontal direction.

8. The pump device according to any one of claims 1 to 6, wherein

the pump chamber is provided on a lower surface of the first block, and
the actuator is provided in a position below the valve module and drives the diaphragm to reciprocate in vertical direction.

9. The pump device according to claim 8, comprising:

a plurality of valve modules each being the valve module; a plurality of first accommodation chambers each being the first accommodation chamber and a plurality of second accommodation chambers each being the second accommodation chamber accommodating the plurality of valve modules; and a plurality of pump chambers each being the pump chamber, a plurality of pump chamber communication flow paths each being the pump chamber communication flow path, a plurality of diaphragms each being the diaphragm, and a plurality of actuators each being the actuator corresponding to the plurality of valve modules, wherein

the plurality of valve modules are arranged along a horizontal direction, and
the plurality of actuators are arranged along a horizontal direction intersecting the arrangement direction of the valve modules, in such a manner that the plurality of valve modules are interposed therebetween when being viewed in a vertical direction.

10. A valve module comprising:

a suction valve;
a discharge valve; and
a module guide that integrally holds the suction valve and the discharge valve, while the suction valve is positioned on a transport fluid suction side, whereas the discharge valve is positioned on a transport fluid discharge side, wherein
the module guide is formed to have a shape of a stepped circular cylinder including: a first guide part that has a first outside diameter and is positioned on the suction valve side; and a second guide part that has a second outside diameter smaller than the first outside diameter and is positioned on the discharge valve side,
the module guide includes an inter-valve flow path provided between the suction valve and the discharge valve and a side flow path that connects the inter-valve flow path to an outer lateral surface of the first guide part, and
the side flow path communicates with the pump chamber, when the valve module is attached to a pump head.

11. The valve module according to claim 10, further comprising: a gasket provided on the transport fluid suction side of the module guide, wherein

the gasket has a circular cylindrical part and a flange part that sticks out from one end of the circular cylindrical part outwardly in a radial direction,
the circular cylindrical part is attached to an inner circumferential side of the module guide, and
the flange part is positioned along a suction-side end part of the module guide.

12. The valve module according to claim 10, wherein
the module guide includes a plurality of side flow paths each being the side flow path and a guide flow path structured with an annular groove that is formed in an outer circumferential part of the first guide part and that keeps the plurality of side flow paths in communication with one another.

13. The valve module according to claim 11, wherein
the suction valve is held by the module guide via a valve holder.

14. The valve module according to any one of claims 10 to 13, wherein
the suction valve and the discharge valve are each structured by using one of a ball valve, an umbrella-type valve, and a poppet valve.

Figure 1

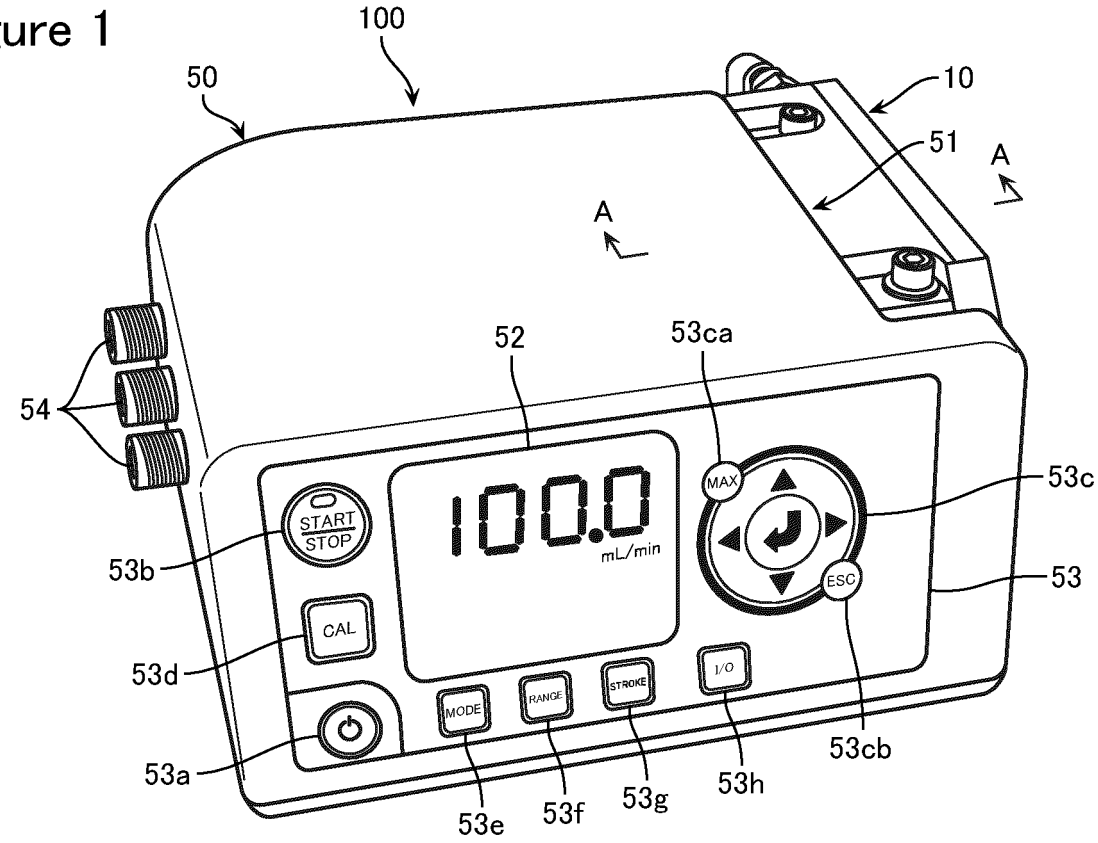


Figure 2

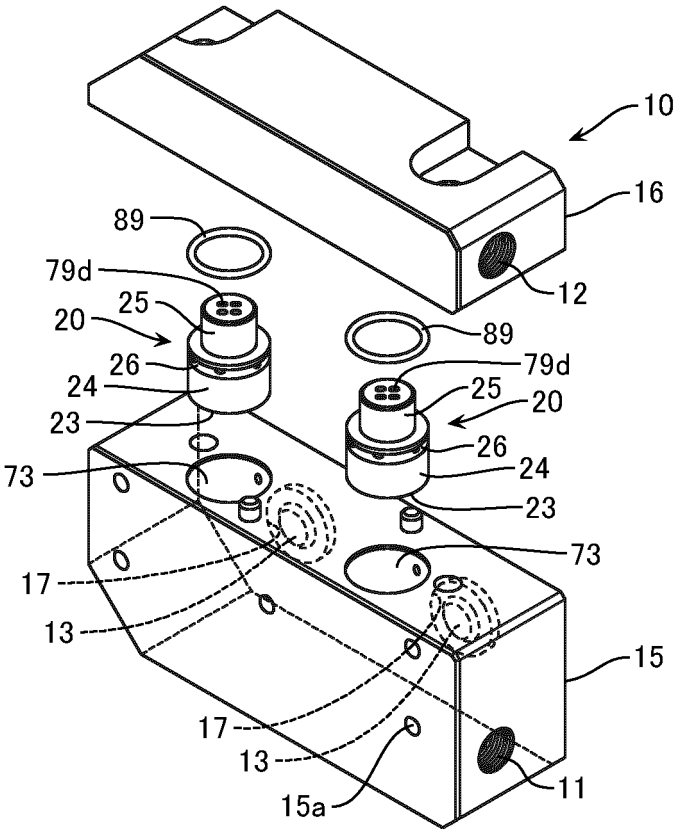
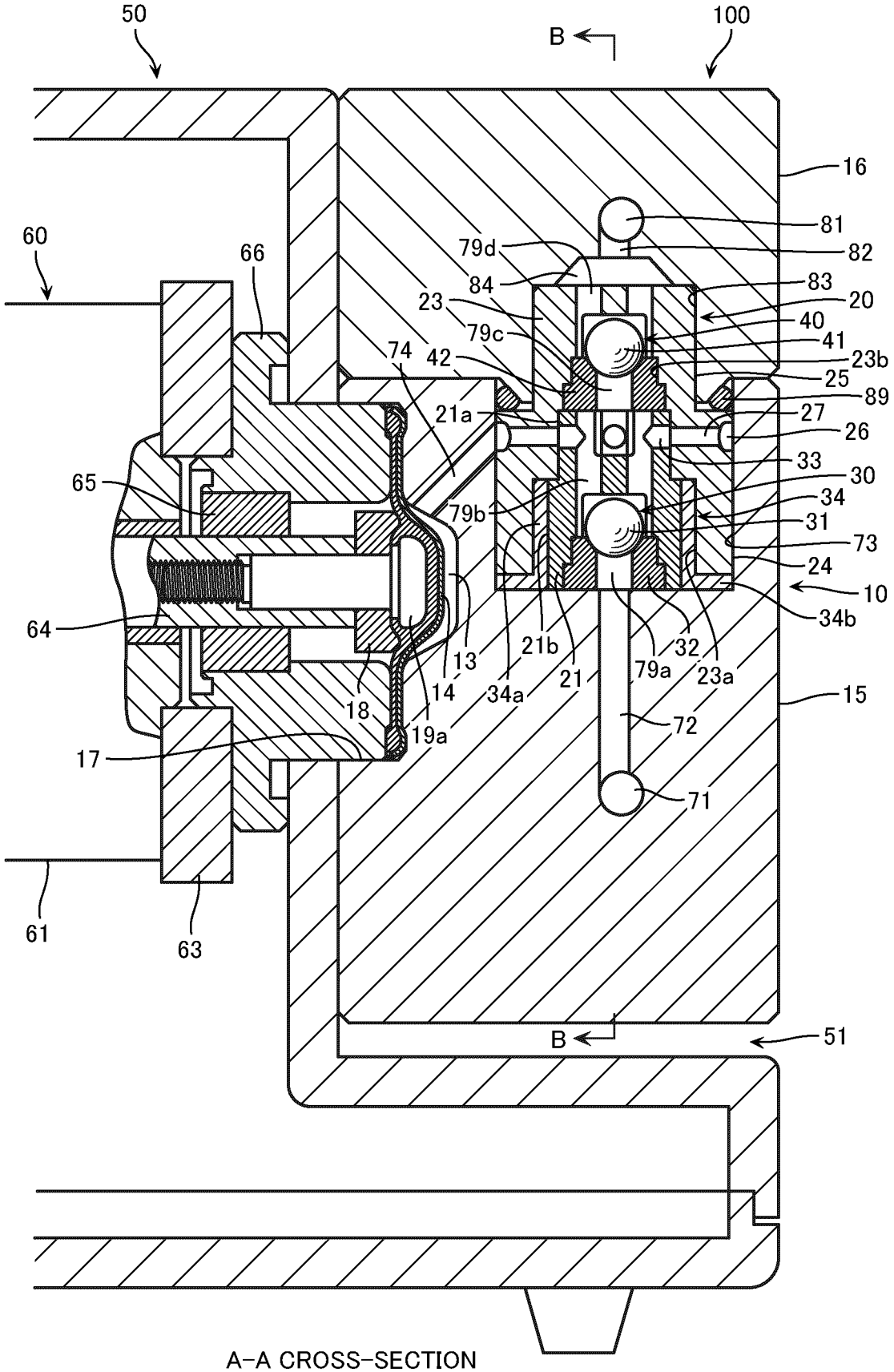
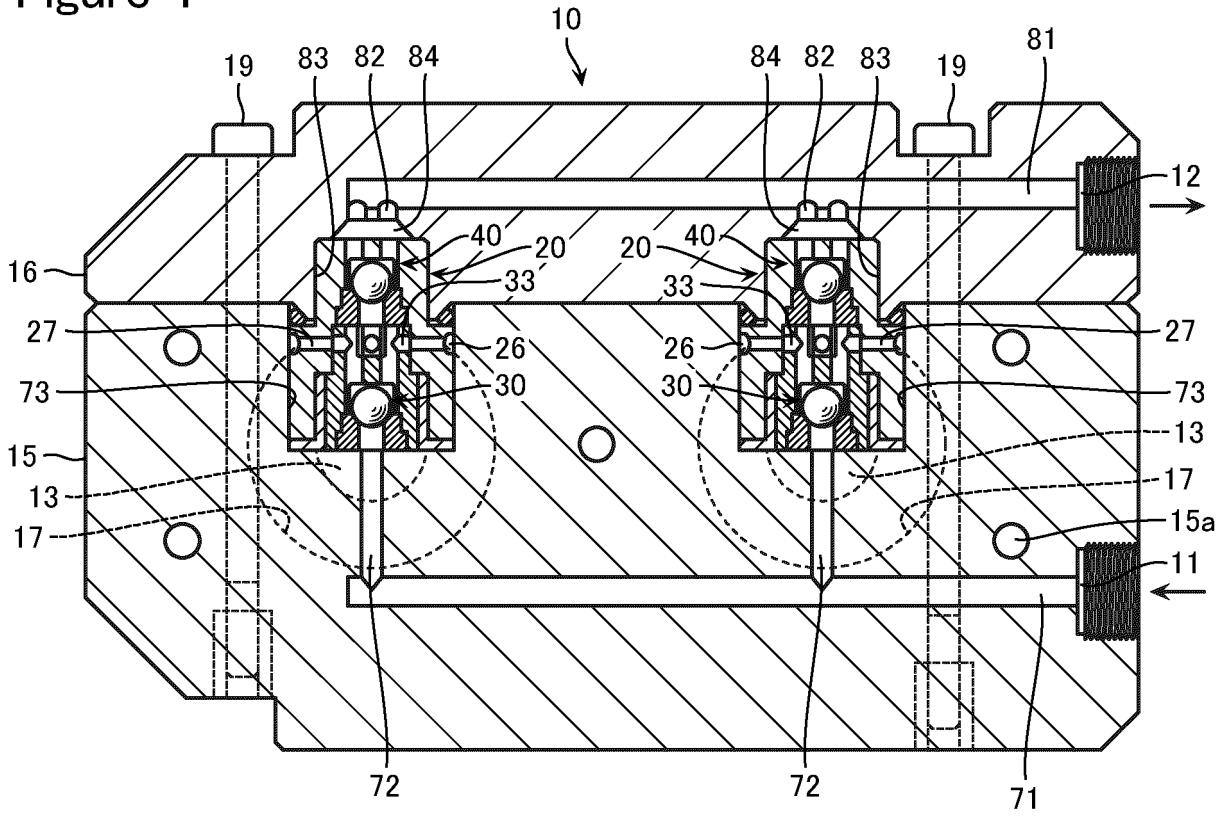


Figure 3



A-A CROSS-SECTION

Figure 4



B-B CROSS-SECTION

Figure 5

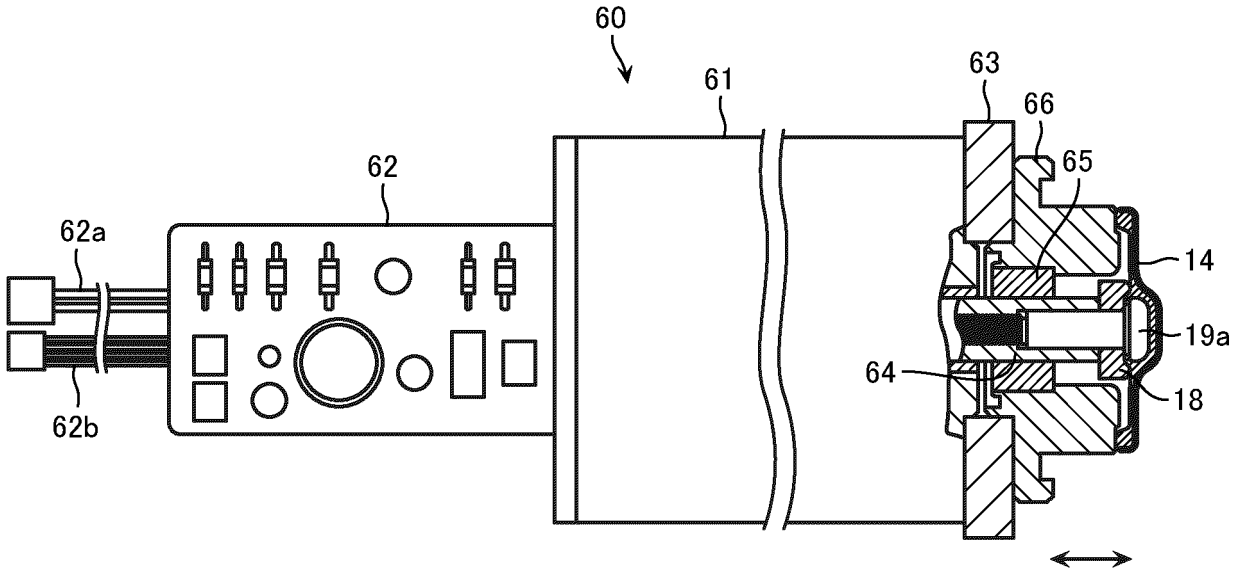


Figure 6

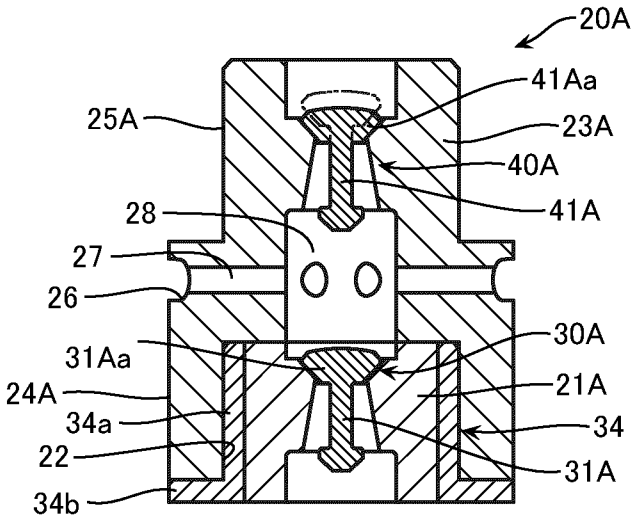


Figure 7

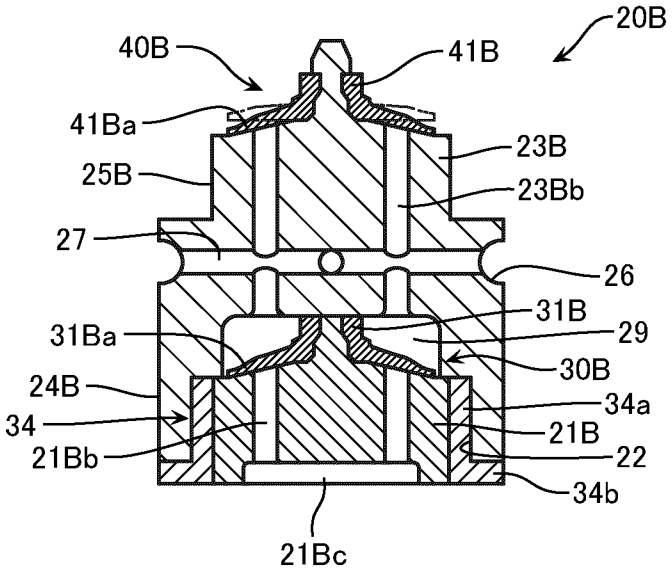


Figure 8

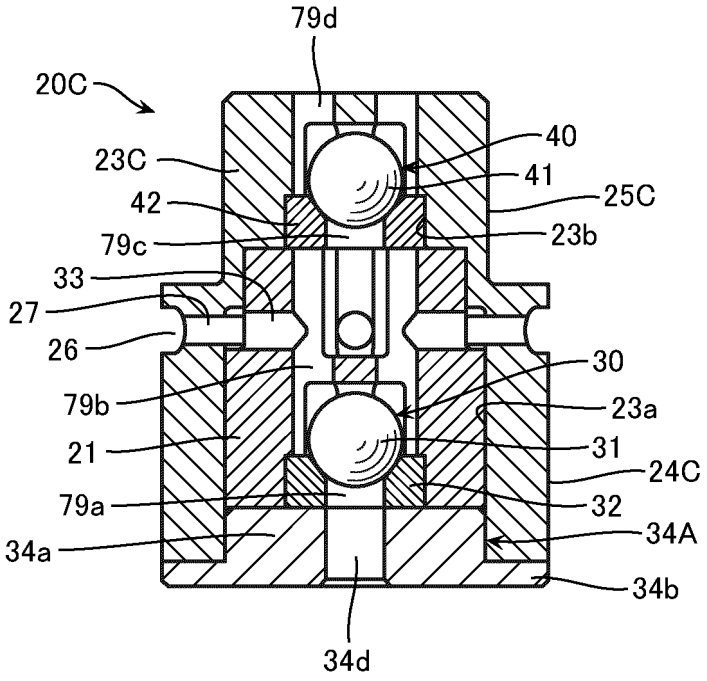


Figure 9

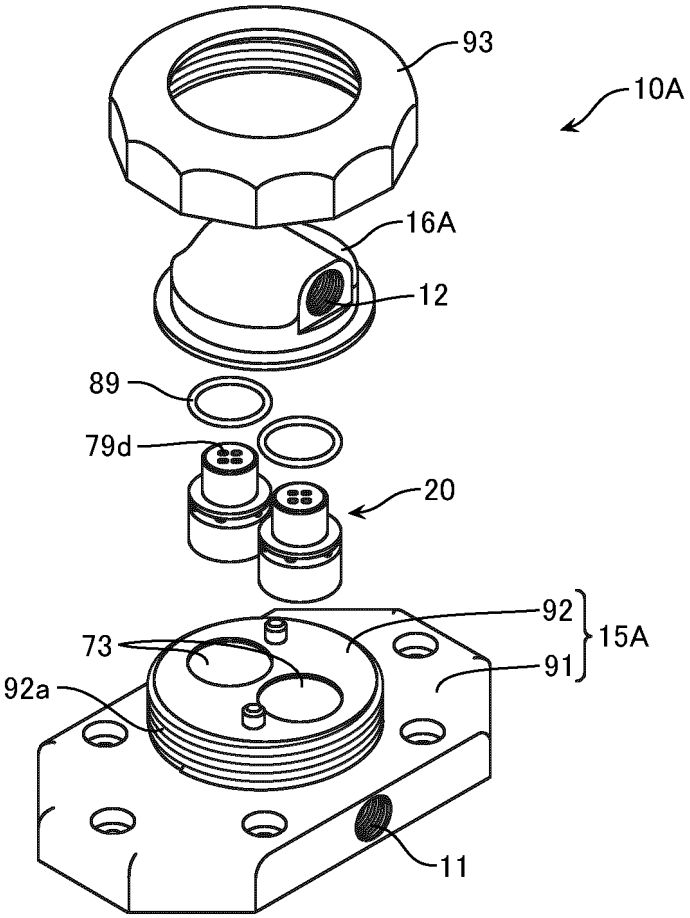


Figure 10

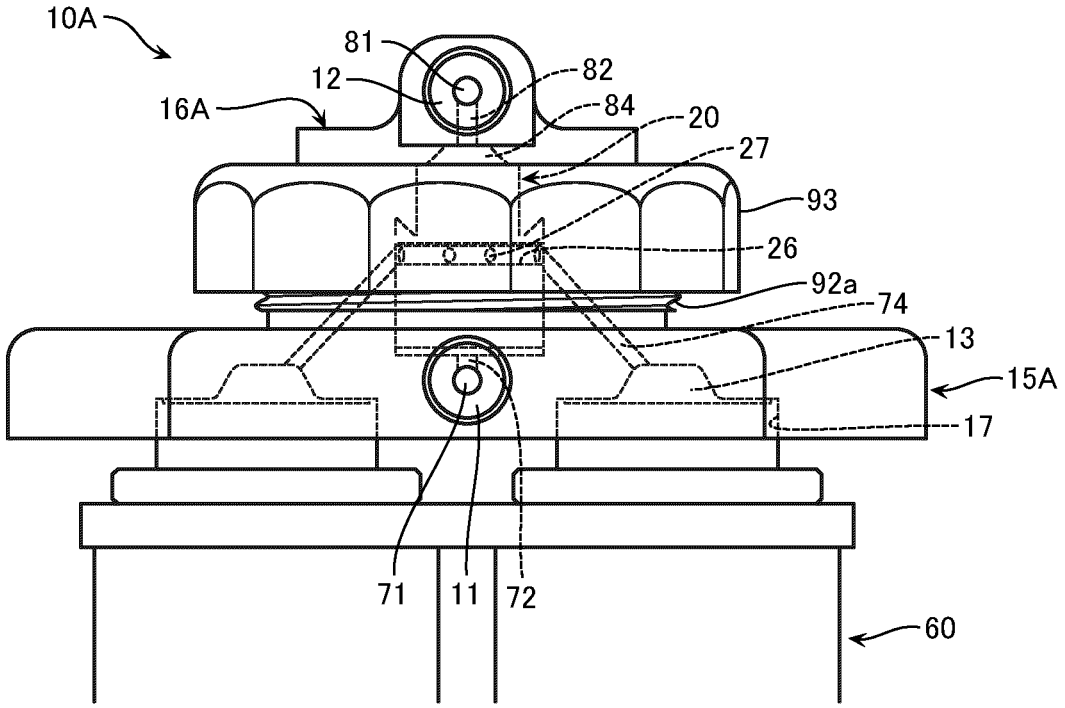


Figure 11

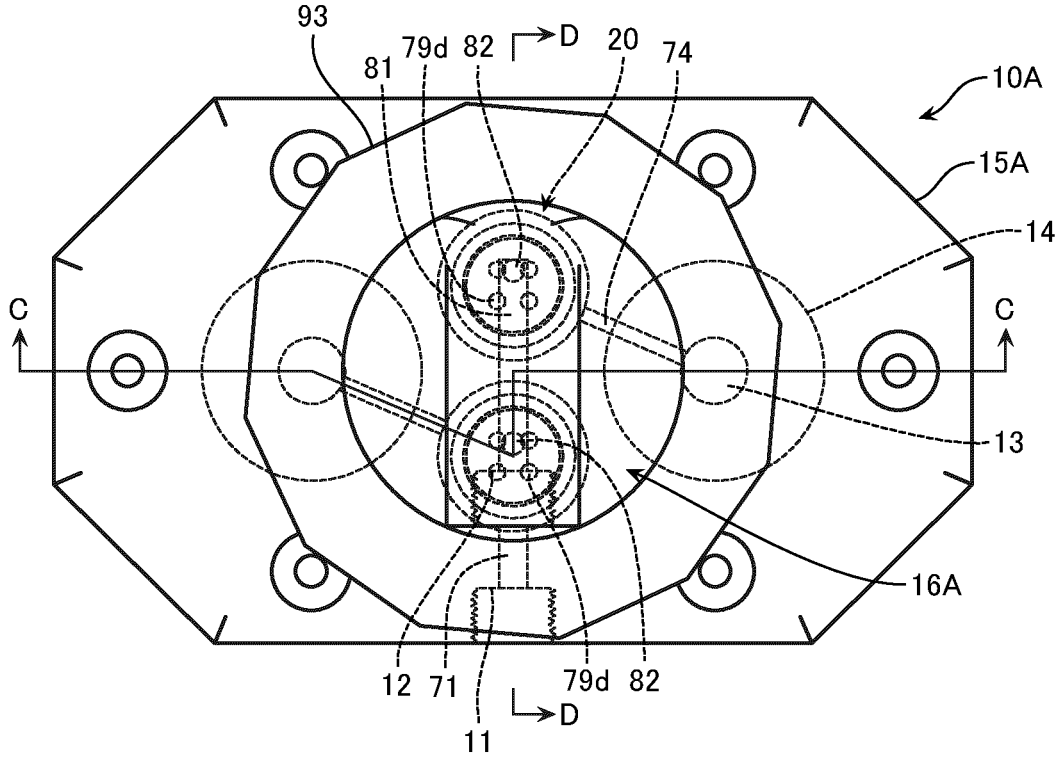
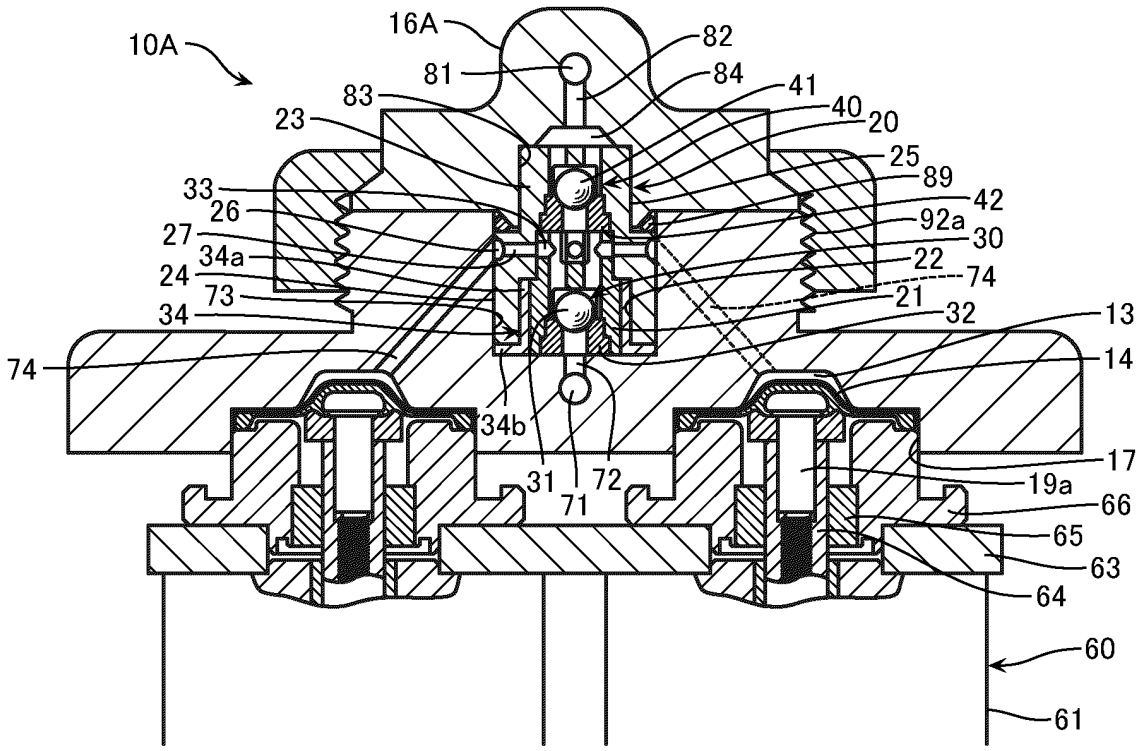
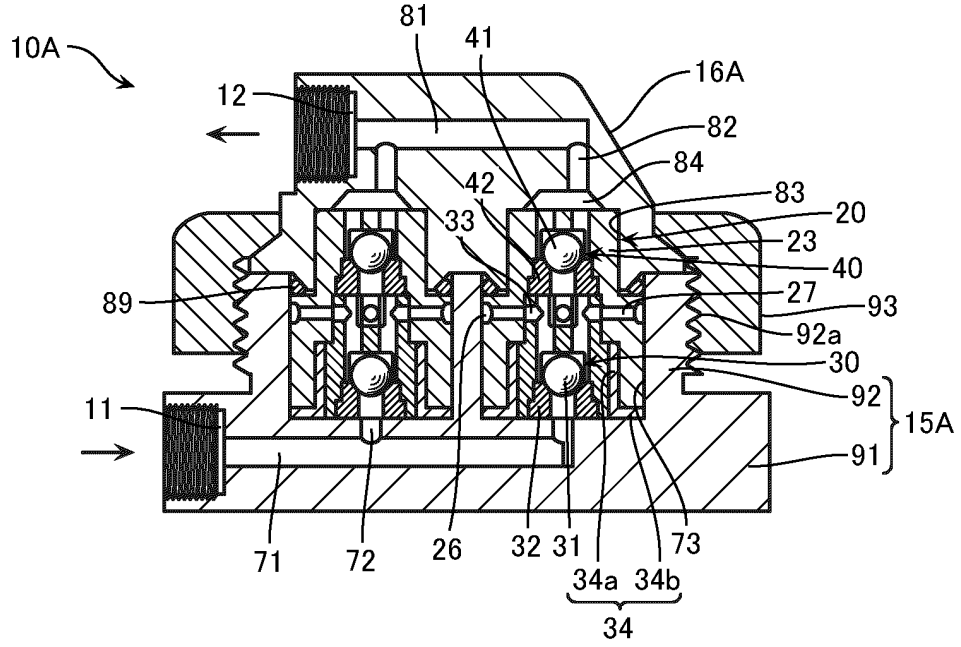


Figure 12



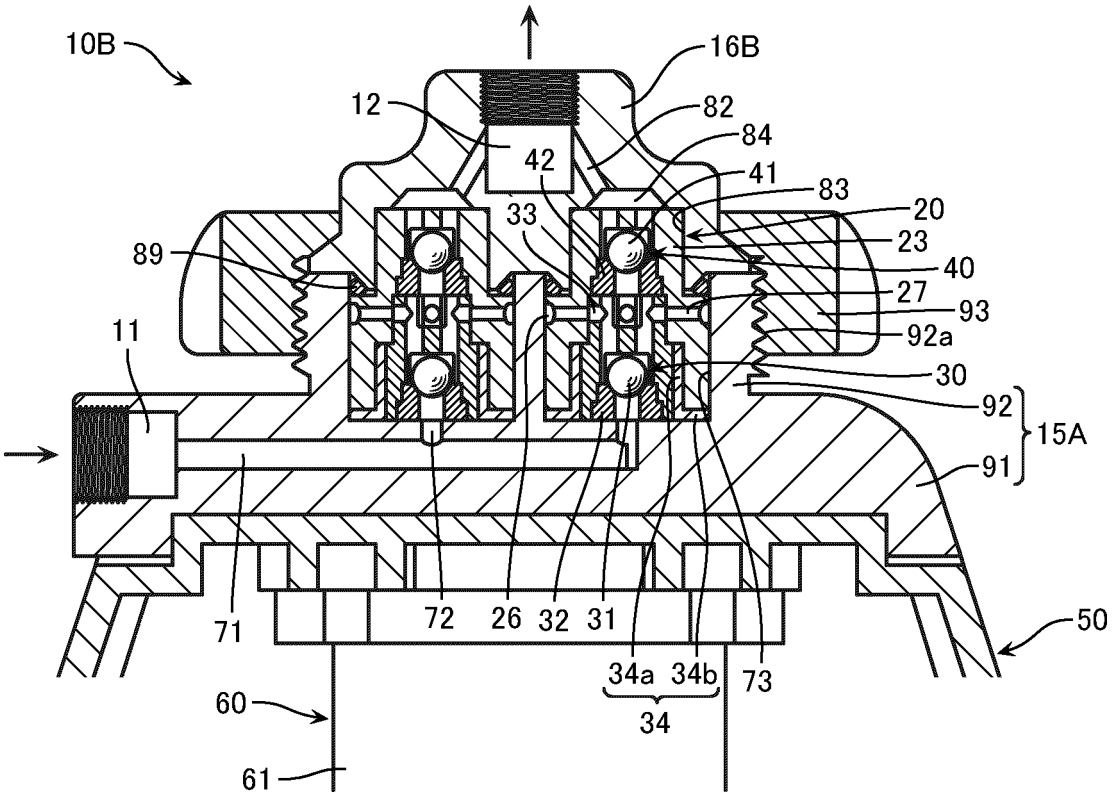
C-C CROSS-SECTION

Figure 13



D-D CROSS-SECTION

Figure 14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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/048108

A. CLASSIFICATION OF SUBJECT MATTER

F04B 43/02(2006.01)i; ***F04B 45/04***(2006.01)i; ***F04B 53/10***(2006.01)i
FI: F04B43/02 D; F04B45/04 D; F04B53/10 F

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)

F04B43/02; F04B45/04; F04B53/10

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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	JP 2016-537563 A (WANNER ENGINEERING, INC.) 01 December 2016 (2016-12-01) paragraphs [0016]-[0034], fig. 1-17	1-2, 7-8
A		3-6, 9
Y	JP 57-035176 A (NIKKISO CO LTD) 25 February 1982 (1982-02-25) p. 3, lower left column, line 17 to p. 4, upper left column, line 9, fig. 3-4	1-2, 7-8
X	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 021590/1972 (Laid-open No. 099501/1973) (OIL EQUIPMENT KOGYO CO., LTD.) 24 November 1973 (1973-11-24), specification, p. 1, line 10 to p. 3, line 2, drawings	10, 12
Y		14
A		11, 13
X	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 094040/1977 (Laid-open No. 100103/1979) (KUDO, Yoshitake) 14 July 1979 (1979-07-14), specification, p. 2, line 8 to p. 3, line 19, fig. 1	10
Y		14

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

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 January 2023	**07 February 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/048108

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 189421/1983 (Laid-open No. 097380/1985) (MARUYAMA MFG CO LTD) 03 July 1985 (1985-07-03), fig. 1	13

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/048108

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2016-537563 A	01 December 2016	US 2015/0118078 A1 paragraphs [0031]-[0048], fig. 1-17 WO 2015/066349 A2 KR 10-2016-0082519 A CN 106232989 A	
JP 57-035176 A	25 February 1982	(Family: none)	
JP 48-099501 U1	24 November 1973	(Family: none)	
JP 54-100103 U1	14 July 1979	(Family: none)	
JP 60-097380 U1	03 July 1985	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 9203380 A **[0003]**