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(75) Inventor/Applicant (for US only): **OGAWA, Kenji** [JP/JP]; 6-15, Kichijojiminami-cho 1-chome, Musashino-shi, Tokyo 1800003 (JP).

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(74) Agents: **KINOSHITA, Jitsuzo** et al.; 3rd Floor, Ogikubo TM building, 26-13, Ogikubo 5-chome, Suginami-ku, Tokyo 1670051 (JP).

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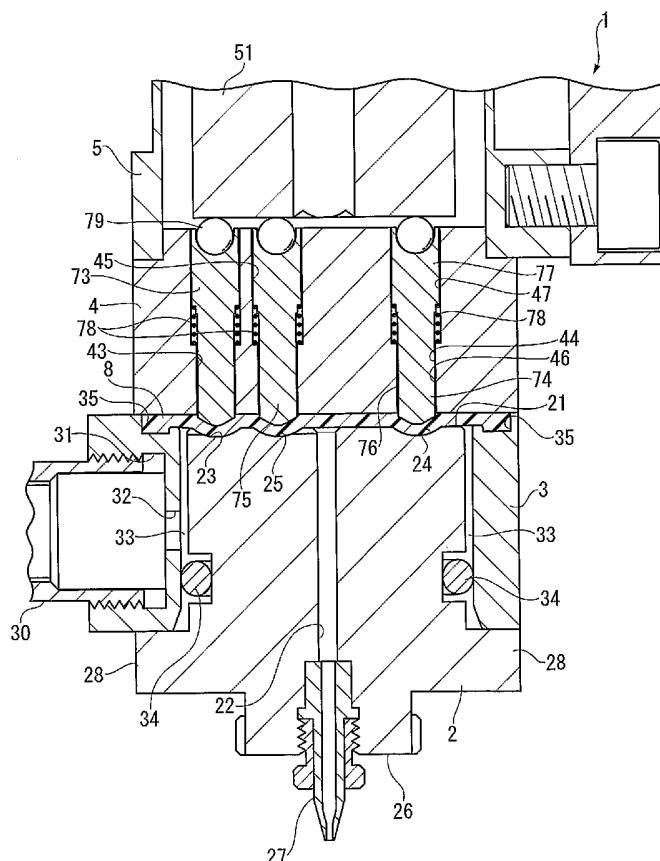
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(71) Applicant (for all designated States except US): **NEUBERG COMPANY LIMITED** [JP/JP]; 15-5, Taito 1-chome, Taito-ku, Tokyo 1100016 (JP).

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(54) Title: DIAPHRAGM PUMP AND MANUFACTURING APPARATUS OF ELECTRONIC COMPONENT



(57) Abstract: A diaphragm pump 1 has a base block 2, a diaphragm 8 and a drive section for driving the diaphragm to reciprocate. The base block 2 has three or more liquid flow paths, each having three metering chambers 23 through 25 or more metering recesses. The drive section includes pressing rods 73 through 75 arranged corresponding to the respective metering recesses with the diaphragm interposed therebetween and a pressing member drive controller adapted to execute a liquid ejecting operation and a liquid sucking operation at a predetermined timing defined for each of the pressing rods, wherein in the liquid ejecting operation, each of the pressing rods 73 through 75 is moved approaching the respective metering recess so as to gradually decrease the volume of the respective metering chamber and eventually hermetically seal the metering chamber; while in the liquid ejecting operation, each of the pressing rods 73 through 75 is moved leaving away from the respective metering recess so as to gradually decrease the volume of the respective metering chamber.



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DESCRIPTION

DIAPHRAGM PUMP AND MANUFACTURING APPARATUS OF ELECTRONIC COMPONENT

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Technical Field

The present invention relates to a diaphragm pump for transferring a predetermined volume of liquid and a manufacturing apparatus of electronic component. The diaphragm pump according to the present invention can find applications in the field of continuously transferring (ejecting) liquid, which may be selected from acidic or alkaline medicinal liquids, soldering pastes, solvents such as alcohol and adhesives with minimal pulsation. The diaphragm pump can and further find applications in manufacturing apparatuses of electronic components such as a die bonder, in which a semiconductor chip is fixed to the substrate by the adhesives ejected from a diaphragm pump, or a manufacturing apparatus for manufacturing light-emitting diode (LED), in which the LED chip is sealed by the resin ejected from a diaphragm pump, or the like.

Background Art

Diaphragm pumps using a diaphragm made of synthetic resin thin film are being used in various industrial fields including the chemical industry, the pharmaceutical industry, the semiconductor industry and the printing industry because of the advantages they provide including that the liquid can be transferred without being damaged, that it is not necessary to use an anti-leakage seal member and that liquid is structurally prevented from contacting any metal.

However, such diaphragm pumps normally give rise to pulsation because liquid is taken in and ejected by reciprocating the diaphragm.

Arrangements of combining a pair of diaphragm pumps and using them complementarily so as not to give rise to any pulsation at the liquid ejection side are proposed for the purpose of suppressing the pulsation of a diaphragm pump (see, Japanese

Patent Laid-Open Publication No. 2003-042069, for instance).

However, such combined diaphragm pumps are provided with a check valve for preventing liquid from flowing backward. In other words, they are accompanied by a problem that they cannot allow liquid to flow back.

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Disclosure of the Invention

An object of the present invention is to provide a diaphragm pump that operates with minimal pulsation and does not require the use of a check valve so that it can allow liquid to flow backward, and also provide a manufacturing apparatus of electronic
10 component.

A diaphragm pump according to the present invention includes: a flow path block; a diaphragm arranged so as to adhere to the flow path block; and a drive section for driving the diaphragm to reciprocate, in which at least three liquid flow paths are defined by the flow path block and the diaphragm so as to allow a suction flow path and an
15 ejection flow path to communicate with each other, at least three metering chambers being arranged along each of the liquid flow paths, and the drive section includes a plurality of pressing members arranged so as to correspond to the metering chambers respectively with the diaphragm interposed therebetween and a pressing member drive controller adapted to execute a volume decreasing operation and a volume increasing operation at
20 respective predetermined timings defined for each of the pressing members, in which in the volume decreasing operation, each of the pressing members is moved approaching the flow path block in order to cause a part of the diaphragm corresponding to the metering chambers to move until it adhere to the flow path block so as to gradually decrease the internal volume of each of the metering chambers and eventually hermetically seal the
25 metering chambers; while in the volume increasing operation, each of the pressing members is moved leaving away from the flow path block in order to cause the part of the diaphragm corresponding to the metering chambers adhering to the flow path block to leave away from the flow path block so as to gradually increase the internal volume of each of the metering chambers..

With the above-described arrangement according to the present invention, the volume of each of the metering chambers can be increased and decreased by driving each of the pressing members corresponding to the metering chambers arranged along each of the liquid flow paths to reciprocate at predetermined timings. Therefore, liquid is prevented from flowing backward without using a check valve when each of the pressing members is moved at predetermined timings while it is being transferred. Thus, since no check valve is provided, each of the pressing members can be driven to move reversely so as to allow liquid to flow backward.

Additionally, since at least three liquid flow paths are formed and metering chambers are arranged along each of the liquid flow paths, while pressing members are provided to correspond to the respective metering chambers so as to define the timing of transferring liquid for each of the flow paths, a predetermined volume of liquid can be transferred continuously simply by shifting the timings of transferring liquid of the liquid flow paths by a predetermined phase in order to allow the pump to operate with minimal pulsation.

Still additionally, in a diaphragm pump according to the present invention, only the parts of the single diaphragm that corresponds to the respective metering chambers are driven to move separately unlike conventional diaphragm pumps in which the entire diaphragm is driven to move back and forth. Therefore, only a small region of the diaphragm may be driven and hence the error in the volume of liquid to be transferred that may arise due to deformation or the like of the diaphragm is minimized. As a result, a diaphragm pump according to the present invention can accurately transfer a very small amount of liquid.

Further, the side of the drive section for driving the pressing members and the side where the liquid flow paths and the metering chambers are provided and hence liquid flows are divided simply by arranging the diaphragm. Therefore, it is not necessary to provide seal members and hence the number of components is reduced accordingly.

Furthermore, since the diaphragm is made of a resiliently deformable material such as rubber, particle-containing liquid such as silver paste, solder paste, resin with

silica powder contained, or the like can be ejected without crushing particles contained therein so that liquid can be transferred without being damaged.

In a diaphragm pump according to the present invention, It is preferred that each of the liquid flow paths has a suction side metering chamber, an intermediate metering
5 chamber, an ejection side metering chamber, a communication path for allowing the suction side metering chamber and the suction flow path to communicate with each other, a communication path for allowing the suction side metering chamber and the intermediate metering chamber to communicate with each other, a communication path for allowing the intermediate metering chamber and the ejection side metering chamber to
10 communicate with each other and a communication path for allowing the ejection side metering chamber and the ejection flow path to communicate with each other and the pressing member drive controller is adapted to execute for each of the liquid flow paths a suction step of hermetically sealing the intermediate metering chamber by moving the intermediate pressing member arranged corresponding to the intermediate metering
15 chamber so as to approach the flow path block in order to cause the part of the diaphragm corresponding to the intermediate metering chamber to adhere to the flow path block and sucking liquid into the suction side metering chamber from the suction flow path by moving the suction side pressing member arranged corresponding to the suction side metering chamber to leave away from the flow path block in order to cause the part of the
20 diaphragm corresponding to the suction side metering chamber to leave away from the flow path block, a first transfer step of hermetically sealing the ejection side metering chamber by moving the ejection side pressing member arranged corresponding to the ejection side metering chamber so as to approach the flow path block in order to cause the part of the diaphragm corresponding to the ejection side metering chamber to adhere to the
25 flow path block and transferring liquid from the suction side metering chamber to the intermediate metering chamber by moving the intermediate pressing member so as to leave away from the flow path block to cause the part of the diaphragm corresponding to the intermediate metering chamber to leave away from the flow path block so as to increase the volume of the intermediate metering chamber while moving the suction side

pressing member so as to approach the flow path block to move the part of the diaphragm corresponding to the suction side metering chamber toward the flow path block so as to decrease the volume of the suction side metering chamber, a metering step of hermetically sealing the suction side metering chamber by moving the suction side pressing member so as to approach the flow path block in order to cause the part of the diaphragm corresponding the suction side metering chamber to adhere to the flow path block while the ejection side metering chamber is maintained in the condition of being hermetically sealed, isolating the liquid in the intermediate metering chamber and metering the volume of the liquid, a second transfer step of transferring liquid from the intermediate metering chamber to the ejection side metering chamber by moving the intermediate pressing member so as to approach the flow path block to decrease the volume of the intermediate metering chamber and moving the ejection side pressing member so as to leave away from the flow path block to increase the volume of the ejection side metering chamber while the suction side metering chamber is maintained in the condition of being hermetically sealed, and an ejection step of transferring liquid from the ejection side metering chamber to the ejection flow path by hermetically sealing the intermediate metering chamber and moving the ejection side pressing member so as to approach the flow path block to decrease the volume of the ejection side metering chamber.

With the above-described arrangement, since the intermediate metering chamber is hermetically sealed in the suction step and the ejection step, liquid no longer flows back from the intermediate metering chamber to the suction side metering chamber in the suction step and from the ejection side metering chamber to the intermediate metering chamber in the ejection step. Therefore, any liquid is prevented from flowing back simply by operating the pressing members and hence it is not necessary to provide a check valve.

Additionally, since a metering step of hermetically sealing the suction side metering chamber and the ejection side metering chamber and isolating the liquid in the intermediate metering chamber to meter liquid is provided, the volume of liquid that is transferred through each of the liquid flow paths can be secured accurately.

Preferably, in a diaphragm pump according to the present invention, the pressing member drive controller is adapted to execute both the suction step and the ejection step simultaneously by moving the suction side pressing member so as to leave away from the flow path block to suck liquid from the suction flow path into the suction side metering chamber while the intermediate metering chamber is maintained in the condition of being hermetically sealed and moving the ejection side pressing member so as to approach the flow path block in order to transfer liquid from the ejection side metering chamber to the ejection flow path.

With the above-described arrangement, since both the suction step and the ejection step are executed simultaneously, the cycle time of the liquid transferring step is curtailed to transfer liquid efficiently.

Preferably, in a diaphragm pump according to the present invention, the ejection step includes an ejection rate increasing step of gradually increasing the ejection rate and an ejection rate decreasing step of gradually decreasing the ejection rate and, among the ejection steps of the plurality of the ejection side metering chambers, if the ejection step of one of the ejection side metering chambers is in the ejection rate increasing step, then the pressing member drive controller provides control to have the ejection step of other one of the ejection side metering chambers in the ejection rate decreasing step so that the rate of ejection is maintained to a constant level.

With the above-described arrangement, when a session of transferring liquid from one of the liquid flow paths into the corresponding ejection flow path comes to an end, another session of transferring liquid from other one of the liquid flow path into the corresponding ejection flow path can be started in an overlapping manner. Thus, the operation of switching a liquid transfer operation from one of the liquid flow paths to another liquid transfer operation from other one of the liquid flow paths is conducted smoothly so that the overall liquid transfer operation is made to continue, maintaining a constant liquid transfer rate. In other words, the overall liquid transfer operation is conducted with minimal pulsation.

Preferably, in a diaphragm pump according to the present invention, the flow path

block has either one of the suction flow path and the ejection flow path formed along the central axis of the diaphragm-adhering surface to be adhered to the diaphragm and the other of the ejection flow path and the suction flow path formed on the outer periphery of the diaphragm-adhering surface and the suction side metering chamber, the intermediate
5 metering chamber and the ejection side metering chamber formed along each of the liquid flow paths are displaced from each other by a first predefined angle in the circumferential direction of a circumference centered at the central axis of the diaphragm-adhering surface with the respective dimensions from the central axis differentiated from each other while the suction side metering chambers, the intermediate metering chambers and the ejection
10 side metering chambers arranged along the respective flow paths are displaced from each other by a second predefined angle in the circumferential direction of the circumference centered at the central axis of the diaphragm-adhering surface, the metering chambers being arranged to extend spirally from the central axis of the diaphragm-adhering surface.

Preferably, the first predefined angle is 30° while the second predefined angle is
15 72° and a total of five sets of liquid flow paths are provided, each having a suction side metering chamber, an intermediate metering chamber and an ejection side metering chamber.

With the above-described arrangement, since the metering chambers are arranged to extend spirally from the central axis, it is possible to realize a down-sized arrangement
20 of metering chambers and compact diaphragm pump.

Additionally, the metering chambers of each set are displaced from each other by a first predetermined angle. Therefore, if the pressing members driven by a cam are arranged so as to correspond to the respective metering chambers, it is not necessary to shift the phases of the cam faces of the cam and the areas of the cam faces can be arranged
25 radially as viewed from the central axis. Thus, it is easy to manufacture such a cam.

When the cam faces are angularly shifted from each other by 90° so that a cycle of operation is performed by rotating the cam by 90° , each of the liquid flow paths can realize four cycles of liquid transfer operation when the cam is driven to make a full turn. Therefore, if five liquid flow paths are provided, for instance, a total of $5 \times 4 = 20$ cycles

of liquid transfer operation are realized by the entire pump during a full turn of the cam. With this arrangement, the volume of transferred liquid for each full turn of the cam is increased to reduce pulsation.

Preferably, in a diaphragm pump according to the present invention, the pressing
5 member drive controller has a motor, an end facet cam adapted to be driven to revolve by the motor and an urging section for urging the pressing members to abut the end facet cam and each of the pressing members reciprocates following the cam face of the end facet cam as the end facet cam revolves.

With the above-described arrangement, as the end facet cam is driven to revolve
10 by the motor, each of the pressing members is driven repeat its operation at predetermined timings. Since the volume of liquid to be transferred can be defined to a predetermined level for a cycle of operation of each of the pressing members, the liquid transfer rate per unit time can be regulated simply by regulating the rotary speed of the end facet cam. Thus, the volume to be transferred by the diaphragm pump can be controlled in a very
15 simple manner.

Preferably, in a diaphragm pump according to the present invention, the
diaphragm-adhering surface of the flow path block to be adhered to the diaphragm is formed with recessed grooves and the flow-path-block-adhering surface of the diaphragm to be adhered to the flow path block is formed to show a planar profile, the liquid flow
20 paths being defined by the respective recessed grooves of the flow path block and the flow path block adhering surface of the diaphragm.

As recessed grooves are formed on the flow path block to provide respective liquid flow paths, the diaphragm can be made to show a simple planar profile. Thus, the diaphragm that is a consumable and needs to be replaced whenever it is worn can be
25 provided at low cost. Additionally, the liquid flow paths formed on the flow path block can be made to show an enhanced level of dimensional precision so that the liquid transfer rate can be controlled accurately on a stable basis to reduce fluctuations in the liquid transfer rate.

Alternatively, in a diaphragm pump according to the present invention, the

diaphragm-adhering surface of the flow path block to be adhered to the diaphragm may be formed to show a planar profile and the flow-path-block-adhering surface of the diaphragm to be adhered to the flow path block may be provided with recessed grooves, the liquid flow paths being defined by the diaphragm-adhering surface of the flow path
5 block and the respective recessed grooves of the diaphragm.

When recessed grooves are formed on the diaphragm to provide liquid flow paths, diaphragm-adhering surface of the flow path block can be made to show a planar profile. When, on the other hand, recessed grooves are formed on the flow path block that is made of metal, the flow path block needs to be manufactured by preparing a metal mold or by
10 cutting recessed grooves. When a metal mold is used to produce a molded metal product, the cost of initial investment will be high. When, recessed grooves are formed by cutting, the processing cost will be high and it is impossible to produce very small metering chambers and very small flow paths. Then, transfer of liquid at a very low rate will be difficult.

15 Alternatively, when recessed grooves are formed on the diaphragm, a rubber die used to mold the rubber diaphragm is relatively inexpensive so that the cost of initial investment is reduced. In addition, the metering chambers and the flow paths can be dimensionally reduced when a rubber die is used. Then, the manufactured diaphragm pump can transfer a very small amount of liquid without difficulty.

20 Still alternatively, in a diaphragm pump according to the present invention, both the diaphragm-adhering surface of the flow path block and the flow-path-block-adhering surface of the diaphragm may be provided with recessed grooves. In a diaphragm pump according to the present invention, the recessed grooves may include metering recesses for defining the metering chambers, communication grooves for allowing each of the
25 metering recesses to communicate with the suction flow path or the ejection flow path and communication grooves for allowing the metering recesses to communicate with each other. The metering recesses may have a width same as or larger than the width of the communication grooves. The values of the widths may be selected appropriately according to the liquid transfer rate.

A manufacturing apparatus of electronic component according to the present invention includes the diaphragm pump, a liquid supplier for supplying the liquid to the suction flow path of the diaphragm pump, an ejecting nozzle provided to the ejection flow path, and a controller for controlling the drive section of the diaphragm pump, in which
5 liquid supplied by the liquid supplier is ejected from the ejection nozzle through the diaphragm pump to manufacture electric component.

In such a manufacturing apparatus of electronic component, since the diaphragm pump capable of accurately transferring a trace quantity of liquid is employed, a trace quantity of liquid is enabled to be accurately ejected. Further, particle-containing liquid
10 such as silver paste, solder paste, resin with silica powder contained, or the like can be ejected without crushing particles contained. Accordingly, by applying the technology to the manufacturing process such as fixing the semiconductor chip, sealing the LED chip or the like, defective products can be reduced and manufacturing efficiency can be improved.

15 **Brief Description of Drawings**

FIG. 1 is a schematic view of the first embodiment of the present invention;

FIG. 2 is a schematic plan view of the metering recess forming surface of a base block of the aforesaid embodiment;

FIG. 3 is a schematic cross sectional view of a principal part of the aforesaid
20 embodiment;

FIG. 4 is a schematic illustration of the positional arrangement of the metering recesses on the metering recess forming surface;

FIG. 5 is a schematic plan view of a guide block of the aforesaid embodiment;

FIGS. 6A and 6B are schematic illustrations of the cam of the aforesaid
25 embodiment, and FIG. 6A is a schematic cross sectional view of the cam and FIG. 6B is a schematic plan view of the cam faces;

FIG. 7 is a schematic cam diagram of the cam of the aforesaid embodiment;

FIGS. 8A and 8B are schematic illustrations of the operation of the aforesaid embodiment, and FIG. 8A is an illustration of the embodiment when a first pressing rod is

at the 0° position of the cam faces and FIG. 8B is an illustration of the embodiment when the first pressing rod is at the 15° position of the cam faces;

FIGS. 9C and 9D are schematic illustrations of the operation of the aforesaid embodiment, and FIG. 9C is an illustration of the embodiment when the first pressing rod
5 is at the 27° position of the cam faces and FIG. 9D is an illustration of the embodiment when the first pressing rod is at the 45° position of the cam faces;

FIGS. 10E and 10D are schematic illustrations of the operation of the aforesaid embodiment, and FIG. 10E is an illustration of the embodiment when the first pressing rod is at the 57° position of the cam faces and FIG. 10F is an illustration of the embodiment
10 when the first pressing rod is at the 75° position of the cam faces;

FIG. 11 is a graph showing the displacements of the first through third pressing rods relative to the angle of revolution of the cam of the aforesaid embodiment;

FIG. 12 is a graph showing the change in the liquid transfer rate of the aforesaid embodiment;

15 FIG. 13 is a schematic cross sectional view of a principal part of the second embodiment of the present invention;

FIGS. 14A, 14B and 14C are schematic illustrations of a diaphragm of the second embodiment; FIG. 14A is a schematic plan view of the pressing rod abutting surface of the diaphragm, FIG. 14B is a schematic cross sectional view taken along line A-A in FIG.
20 14A and FIG. 14C is a schematic plan view of the flow-path-block-adhering surface of the diaphragm;

FIG. 15 is a schematic plan view of a modified embodiment of the present invention; and

FIG. 16 is a schematic cross sectional view of a principal part of another
25 modified embodiment of the present invention.

Best Mode for Carrying out the Invention

Now, embodiments of the present invention will be described in more detail by referring to the accompanying drawings.

FIG. 1 is a schematic view of the first embodiment of diaphragm pump 1 according to the present invention.

The diaphragm pump 1 has a base block 2, a holder ring block 3, a guide block 4, a fitting block 5 and a drive unit 6.

5 Each of the blocks 2 through 5 is provided with through holes (not shown) at the four corners thereof. Each of the blocks 2 through 5 is assembled by means of a coupling bolt that is driven through the base block 2 and the holder ring block 3 into the guide block 4, a coupling bolt driven into the guide block 4 via the fitting block 5, a coupling bolt driving into the drive unit 6 via the fitting block 5 and so on. Positioning
10 pins are also used to align the blocks.

As shown in FIGS. 2 and 3, the base block 2 has a metering recess forming surface 21 that is the diaphragm-adhering surface located vis-à-vis the guide block 4. The metering recess forming surface 21 is formed by a planar area defined to show a substantially circular boundary. A port 22 is formed around the central axis of the
15 metering recess forming surface 21 so as to make an ejection flow path or suction flow path of liquid and a plurality of metering recesses 23 through 25 are formed around it.

The port 22 is formed by boring through the base block 2 from the center of the metering recess forming surface 21 to the opposite surface 26.

In this embodiment, a nozzle member 27 is fitted to the opening at the other end
20 of the port 22 on the opposite surface 26 and the port 22 is utilized as ejection port (ejection flow path).

The metering recess forming surface 21 is provided with first metering recesses 23 formed along the outer periphery of the metering recess forming surface 21, second metering recesses 24 formed inside relative to the first metering recesses 23 and third
25 metering recesses 25 arranged inside relative to the second metering recesses 24 and hence around the port 22. Each of metering recesses 23 through 25 is a recess made to show a semispherical profile. The first metering recesses 23 communicate with the outside of the outer periphery of the metering recess forming surface 21 via communication grooves 281. The second metering recesses 24 communicates with the first metering recesses 23

via communication grooves 282 and with the third metering recesses 25 via communication grooves 283. The third metering recesses 25 communicate with the port 22 via communication grooves 284.

In other words, the recessed grooves formed on the diaphragm-adhering surface include the first metering recesses 23, the second metering recesses 24, the third metering recesses 25 and the communication grooves 281 through 284 formed on the metering recess forming surface 21, which is the diaphragm-adhering surface of the base block 2. Fluid flow paths 280 are formed by the spaces defined by the recessed grooves and the diaphragm 8. A total of five sets of fluid flow paths 280 are provided in this embodiment.

More specifically, the first metering recesses 23 include five metering recesses 23A through 23E and the second metering recesses 24 include five metering recesses 24A through 24E, while the third metering recesses 25 include five metering recesses 25A through 25E.

In this embodiment, the first metering recesses 23 (23A through 23E) and the second metering recesses 24 (24A through 24E) are arranged in such a way that the lines connecting the centers of the metering recesses 23, 24 and the center of the port 22 form an angle of intersection, or the first defined angle, which is equal to 30° as shown in FIG. 4. Similarly, the second metering recesses 24 (24A through 24E) and the third metering recesses 25 (25A through 25E) are arranged in such a way that the lines connecting the centers of the metering recesses 24, 25 and the center of the port 22 form an angle of intersection, or the first defined angle, which is equal to 30° .

Additionally, the metering recesses 23, 24, 25 are arranged in such a way that the length of the lines connecting the center of the port 22 and the centers of the metering recesses 23, the length of the lines connecting the center of the port 22 and the centers of the metering recesses 24, and the length of the lines connecting the center of the port 22 and the centers of the metering recesses 25 decreases in the mentioned order.

Thus, as a result, the metering recesses 23A through 23E, 24A through 24E and 25A through 25E are arranged to extend spirally from the center of the port 22.

In this embodiment, a total of five sets of metering recesses 23 through 25 are provided and the first metering recesses 23A through 23E are arranged around the port 22 at an angular pitch of $360/5 = 72^\circ$ (the second defined angle). Similarly, the second metering recesses 24A through 24E are arranged at an angular pitch of 72° (the second defined angle) and so are the third metering recesses 25A through 25E.

The holder ring block 3 has a substantially hollow cylindrical profile and fitted to the outer periphery of the base block 2. More specifically, the holder ring block 3 is pinched between the flange 28 of the base block 2 and the guide block 4. The holder ring block 3 is provided with a port 31 that operates as liquid supply hole or ejection hole. In this embodiment, the port 31 is threaded and a liquid transfer tube 30 is arranged in it.

The port 31 of the holder ring block 3 communicates with space 33 that is formed at the inner periphery side of the holder ring block 3, or between the holder ring block 3 and the base block 2, by way of a through hole 32.

A seal member 34 that is typically an O-ring is arranged in the space 33 at a position closer to the flange 28 than the through hole 32 in order to prevent liquid in the space 33 from leaking to the outside through the abutting surfaces of the flange 28 and the holder ring block 3.

The diaphragm 8 is fitted to the end facet of the holder ring block 3 that faces the guide block 4. More specifically, a ring-shaped recessed groove 35 is formed on the end facet of the holder ring block 3 and the peripheral edge of the diaphragm 8 is fitted to the recessed groove 35. The peripheral edge of the diaphragm 8 is pinched between the holder ring block 23 and the guide block 4.

Thus, the space 33 is defined by the seal member 34 and the diaphragm 8 so that liquid in the space is prevented from leaking to the outside. In this embodiment, a suction flow path of liquid is formed by the space 33 and a flow path block is formed by the base block 2 and the holder ring block 3.

Therefore, in this embodiment, the first metering recesses 23 operate as suction side metering recesses and the second metering recesses 24 operate as intermediate metering recesses, while the third metering recesses 25 operate as ejection side metering

recesses.

The diaphragm 8 is made of elastically deformable rubber (synthetic rubber, natural rubber) or the like and has a substantially disk-shaped profile. The flow-path-block-adhering surface of the diaphragm 8 that is made to adhere to the base block 2 shows a planar profile. The pressing-rod-abutting surface of the diaphragm 8 that is made to abut pressing rods 73 through 75 also shows a planar profile. In this embodiment, the diaphragm 8 has a thickness of about 1 mm.

The gap between the metering recess forming surface 21 and the end facet 41 of the guide block 4 that faces the metering recess forming surface 21 is made equal to 0.9 mm, or slightly smaller than the thickness of the diaphragm 8. Thus, when the blocks 2 through 5 are assembled, the diaphragm 8 is pinched between the planar area other than the metering recesses 23 through 25 and the guide block 24 and pressed against the metering recess forming surface 21 under predetermined pressure. Therefore, each of the metering recesses 23 through 25 is defined by the diaphragm 8 that is made to adhere to the metering recess forming surface 21 and hence can communicate with all the other metering recesses 23 through 25 only by way of the communication grooves 281 through 284. With this arrangement, the spaces defined by the first metering recesses 23 and the diaphragm 8 operate as suction side metering chambers and the spaces defined by the second metering recesses 24 and the diaphragm 8 operate as intermediate metering chambers, while the spaces defined by the third metering recesses 25 and the diaphragm 8 operate as ejection side metering chambers. Additionally, the spaces defined by the communication grooves 281 through 284 and the diaphragm 8 operate as communication paths. The liquid flow paths 280 include the metering chambers and the communication paths.

As shown also in FIG. 5, the guide block 4 is provided with guide holes 43 through 45 that run through it in an axial direction at respective positions corresponding to the metering recesses 23 through 25 of the base block 2. More specifically, the first guide holes 43A through 43E are arranged so as to be coaxial respectively with the first metering recesses 23A through 23E and the second guide holes 44A through 44E are

arranged so as to be coaxial respectively with the second metering recesses 24A through 24E, while the third guide holes 45A through 45E are arranged so as to be coaxial respectively with the third metering recesses 25A through 25E.

Each of the guide holes 43 through 45 is provided with a step at an axially intermediate position to make it show different diameters. The guide hole has a small diameter hole section 46 at the side of the end facet 41 and a large diameter hole section 47 at the side of the fitting block 5. The large diameter hole section 47 has a diameter larger than the small diameter hole section 46.

Pressing members, or pressing rods 73 through 75, are inserted into the respective guide holes 43 through 45. More specifically, the first pressing rods 73 are inserted respectively into the first guide holes 43A through 43E and the second pressing rods 74 are inserted respectively into the second guide holes 44A through 44E, while the third pressing rods 75 are inserted respectively into the third guide holes 45A through 45E. The first pressing rods 73 that are arranged to correspond to the suction side metering chambers operate as suction side pressing members and the second pressing rods 74 that are arranged to correspond to the intermediate metering chambers operate as intermediate pressing members, while the third pressing rods 75 that are arranged to correspond to the ejection side metering chambers operate as ejection side pressing members.

The pressing rods 73 through 75 respectively have small diameter sections 76 that are inserted into the small diameter hole sections 46 and large diameter sections 77 that are inserted into the large diameter hole sections 47 of the respective guide holes 43 through 45. The axial length of the small diameter sections 76 is larger than the axial length of the small diameter hole sections 46 so that a space is produced between the step formed by the small diameter hole section 46 and the large diameter hole section 47 and the step formed by the small diameter section 76 and the large diameter section 77 as shown in FIG. 3. Coil springs 78 are arranged respectively in the spaces to urge the pressing rods 73 through 75 away from the diaphragm 8.

The end facet of each of the pressing rods 73 through 75 facing the diaphragm 8 is made to show a semispherical profile. Thus, as the pressing rods 73 through 75 are

driven to move toward the diaphragm 8, the diaphragm 8 is forced to adhere to the semispherical surfaces of the metering recesses 23 through 25. However, since the communication grooves 281 through 284 have a small width, the diaphragm 8 would not be forced into the communication grooves 281 through 284 and hence liquid can always
5 move through the communication grooves 281 through 284.

On the other hand, a substantially semispherical recess is formed on the other end facet of each of the pressing rods 73 through 75 and a ball 79 is contained in the recess.

The fitting block 5 shows a hollow cylindrical profile with a through hole running in the inside. The through hole has a substantially circular cross section and a cam 51
10 that is driven to revolve by the drive unit 6 is arranged in it. The cam 51 may be directly fitted to an output shaft 61 of the drive unit 6, although it is fitted to the output shaft 61 via a spline boss 52 and a spline shaft 53 in this embodiment. More specifically, the spline shaft 53 is fitted to the output shaft 61 by means of a pin 54 so that it can revolve integrally with the output shaft 61. The spline boss 52 is press-fitted into the cam 51.
15 The spline boss 52 and the cam 51 are arranged in such a way that they can slide relative to the spline shaft 53 in the axial direction of the output shaft 61 and revolve integrally with the spline shaft 53 and the output shaft 61.

The cam 51 and the spline boss 52 are supported by ball bearing 55 so as to be revolvable relative to the fitting block 5. The ball bearing 55 and the cam 51 are urged
20 toward the guide block 4 by a coned disk spring 57 and via a spacer ring 56 while the pressing rods 73 through 75 are urged toward the cam 51 by the respective coil springs 78. Thus, cam faces 511 of the cam 51 respectively constantly abut the corresponding balls 79. In other words, the coned disk spring 57 and the coil springs 78 operate as urging section that forces the balls 79 of the pressing rods 73 through 75 to respectively abut the
25 corresponding cam faces 511 of the cam 51.

As shown in FIGS. 6A and 6B, the cam 51 is an end cam (solid cam) having end facets that operates as cam faces 511. The cam faces 511 show respective profiles as illustrated in the diagram of FIG. 7. More specifically, the cam 51 has a through hole that runs along the central axis thereof and cam faces 511 are formed around the through

hole to show a ring-shaped profile as a whole.

FIG. 7 shows a cam diagram illustrating the profiles of the cam faces 511. The y-axis of the cam diagram is so selected as to define the lowest position of the cam ($y = 0$) where the cam faces 511 are located closest to the diaphragm 8 and the highest positions of the cam (e.g., $y = 0.5$ mm in this embodiment) where the cam faces 511 are located remotest from the diaphragm 8. On the other hand, the x-axis of the cam diagram is so selected as to define a state where the balls 79 of the first pressing rods 73 abut the corresponding cam faces of the cam at the lowest positions thereof ($y = 0$). This state corresponds to 0° . The angle of revolution of the cam 51, or the angle of revolution of the cam faces 511 relative to the corresponding balls 79 to be more accurate, is expressed by the value relative to 0° . Note that the cam diagram of FIG. 7 also illustrates the loci of movement of the center positions of the balls 79.

In this embodiment, the cam faces 511 operate with a cycle of 90° and the above operation is repeated for every 90° , or from 90° to 180° , from 180° to 270° and from 270° to 360° . Therefore, only the cycle from 0° to 90° will be described below.

When the angle of revolution of the cam 51 is between 0° and 15° , a cam face 511A is held to the lowest position ($y = 0$). In other words, the cam face 511A is formed by a plane that rectangularly intersects the rotary shaft of the cam 51.

When the angle of revolution of the cam 51 is between 15° and 27° , the radial profile of the cam face 511B is expressed, for instance, by a quadratic curve of $y = (x - 15)^2 / 864$.

When the angle of revolution of the cam 51 is between 27° and 33° , the radial profile of the cam face 511C is expressed, for instance, by a straight line of $y = x / 36 - 7 / 12$.

When the angle of revolution of the cam 51 is between 33° and 57° , the radial profile of the cam face 511D is expressed, for instance, by a quadratic curve of $y = 0.5 - (x - 45)^2 / 864$.

When the angle of revolution of the cam 51 is between 57° and 63° , the radial profile of the cam face 511E is expressed, for instance, by a straight line of $y = -x / 36 +$

23 / 12.

When the angle of revolution of the cam 51 is between 63° and 75°, the radial profile of the cam face 511F is expressed, for instance, by a quadratic curve of $y = (x - 75)^2 / 864$.

5 When the angle of revolution of the cam 51 is between 75° and 90°, the radial profile of the cam face 511G is a plane same as that of the cam face 511A.

The cam faces 511A through 511G are radially arranged from the central axis of the cam faces 511. In other words, the boundary lines of the cam faces 511A through 511G are straight lines extending radially from the central axis of the cam faces 511.

10 Thus, as the spline shaft 53, the spline boss 52 and the cam 51 are driven to revolve by the drive unit 6, the balls 79 and the pressing rods 73 through 75 axially retreat along the profile of the cam faces 511. Then, as the pressing rods 73 through 75 move toward the respective metering recesses 23 through 25, the volumes of the metering chambers defined by the parts of the diaphragm 8 that correspond to the metering recesses
15 (parts of the diaphragm 8 corresponding to the metering recesses that the pressing rods 73 through 75 respectively abut) and the metering recesses 23 through 25 decrease until the parts of the diaphragm 8 corresponding to the metering recesses eventually adhere to the inner surfaces of the respective metering recesses 23 through 25. In other words, the pressing rods 73 through 75 operate for volume decrease.

20 Then, as the pressing rods 73 through 75 move away from the respective metering recesses 23 through 25, the parts of the diaphragm 8 corresponding to the metering recesses leave the inner surfaces of the respective metering recesses 23 through 25, to which they have been adhering, to consequently increase the volumes of the metering chambers defined between the metering recesses 23 through 25 and the
25 diaphragm 8. In other words, the pressing rods 73 through 75 operate for volume increase.

The materials of the pressing rods 73 through 75, the balls 79 and the cam 51 are selected and the surfaces of any of them may or may not be coated by a selected coating method so as to make the coefficient of friction between the pressing rods 73 through 75

and the balls 79 lower than the coefficient of friction between the balls 79 and the cam faces 511.

More specifically, the balls 79 are hard balls made of a super hard alloy such as tungsten carbide. The cam 51 is also made of metal such as carbon tool steel that is
5 subjected to quenching and polishing so as to make the cam faces 511 very hard.

On the other hand, the pressing rods 73 through 75 and the spline boss 52 may be made of plastic (synthetic resin). The pressing rods 73 are normally made of a resin material and hence softer than the balls 79, although their surfaces may be subjected to DLC coating or the like to make them as hard as those of the balls 79. In short, it is
10 sufficient for the materials of the related components to make the coefficient of friction between the pressing rods 73 through 75 and the balls 79 lower than the coefficient of friction between the cam faces 511 and the balls 79. However, it should be noted that, although the pressing rods 73 through 75 are mentioned to be softer compared to the balls 79, but they should be harder enough so as not to be deformed when they abut the balls 79
15 because the displacements of the cam faces 511 have to be transmitted to the diaphragm 8 via the balls 79 and the pressing rods 73 through 75.

The drive unit 6 may take any form so long as it is a drive source that can drive the output shaft 61 to revolve. Any of various motors may be used for it. In this embodiment, it is formed by using a servo motor provided with a reduction gear.

20 A fitting plate 9 is secured to the fitting block 5 by means of screws. The diaphragm pump 1 can be fitted to any of various manufacturing apparatus or robot arms by way of the fitting plate 9.

Since liquid is transferred through each of the liquid flow paths 280 in this embodiment, it may be safe to say that each of the liquid flow paths 280 operates as pump.
25 More specifically, in this embodiment, the metering chambers (metering recesses 23 through 25), the pressing rods 73 through 75, the communication paths (communication grooves 281 through 284) and the diaphragm 8 arranged along the liquid flow paths 280 form a plurality of pumps for transferring liquid and these plurality of pumps constitute the diaphragm pump 1 so that the pump 1 can continuously transfer liquid at a constant

rate with minimal pulsation.

Additionally, in this embodiment, a pressing member drive controller is formed by the cam 51, the spline boss 52, the spline shaft 53, the coned disk spring 57, the drive unit 6 and the coil springs 78 to control the operation of driving the pressing rods 73 through 75 and a drive section for driving the diaphragm 8 to reciprocate is formed by the pressing member drive controller and the pressing rods 73 through 75.

Next, an operation of the embodiment will be described with reference to FIGS. 8A to 12.

[Operation of the pressing rods]

10 Firstly, the operation of the pressing rods 73 through 75 will be described. The pressing rods 73 through 75 operate to correspond to the profile of the cam faces 511 of the cam 51.

As pointed out above, when the angle of revolution of the cam 51 is between 0° and 15°, the cam faces 511 are held to the lowest position ($y = 0$) so that the balls 79 and the pressing rods 73 through 75 are held to a state where they make the diaphragm 8 adhere to the inner surfaces of the metering recesses 23 through 25 and do not move axially.

When the angle of revolution of the cam faces 511 is found between 15° and 27°, the balls 79 and the pressing rods 73 through 75 move away from the diaphragm 8 at a constant acceleration.

When the angle of revolution of the cam faces 511 is found between 27° and 33°, the balls 79 and the pressing rods 73 through 75 move away from the diaphragm 8 at a constant speed.

When the angle of revolution of the cam faces 511 is found between 33° and 45°, the balls 79 and the pressing rods 73 through 75 move away from the diaphragm 8 at a constant acceleration.

When the angle of revolution of the cam faces 511 is found between 45° and 57°, the balls 79 and the pressing rods 73 through 75 move toward the diaphragm 8 at a constant acceleration.

When the angle of revolution of the cam faces 511 is found between 57° and 63° , the balls 79 and the pressing rods 73 through 75 move toward the diaphragm 8 at a constant speed.

When the angle of revolution of the cam faces 511 is found between 63° and 75° ,
5 the balls 79 and the pressing rods 73 through 75 move away from the diaphragm 8 at a constant acceleration.

When the angle of revolution of the cam 51 is between 75° and 90° , the cam faces 511 are held to the lowest position ($y = 0$) so that the balls 79 and the pressing rods 73 through 75 are held to a state where they make the diaphragm 8 adhere to the inner
10 surfaces of the metering recesses 23 through 25 and do not move axially.

The cam faces 511 operate with a cycle of 90° and the above operation is repeated for every 90° , namely, from 90° to 180° , from 180° to 270° and from 270° to 360° .

Therefore, the pressing rods 73 through 75 axially reciprocate as the balls 79 abut
15 the respective cam faces 511 and revolve to move (rotate) along the cam faces 511. By the time when the cam 51 makes a full turn, the pressing rods 73 through 75 finish four cycles of reciprocation. The stroke of each cycle is defined to be equal to 0.5 mm in this embodiment.

As the pressing rods 73 through 75 reciprocate, the diaphragm 8 moves toward
20 the metering recesses 23 through 25 so as to decrease the volume of the metering chambers until they completely adhere to the diaphragm 8 and then back from the metering recesses 23 through 25 so as to increase the volume of the metering chambers. As a result, liquid is taken into and discharged from the metering chambers.

[Operation of the pumps (three pressing rods)]

25 Now, the operation of the pumps of the diaphragm pump 1 will be described by way of the operation of the first pressing rods 73, the second pressing rods 74 and the third pressing rods 75 that are inserted respectively into the first guide holes 43A, the second guide holes 44A and the third guide holes 45A.

In the following description, it is assumed that the cam 51 revolves

counterclockwise relative to the metering recess forming surface 21 (or clockwise if the cam 51 is viewed from the side of the cam faces 511) and operates so as to take in liquid from the space 33 at the outer peripheral side of the metering recess forming surface 21 and discharge liquid from the central port 22.

5 FIG. 8A illustrates a state where the ball 79 of each of the first pressing rods 73 is at the 0° position of the cam faces 511. In this state, the corresponding second pressing rod 74 is located at a position behind the first pressing rod 73 by 30° and hence the ball 79 thereof is located at the position of 330° of the cam faces 511. Similarly, in this state, the corresponding third pressing rod 75 is located at a position behind the second pressing rod
10 74 by 30° and hence the ball 79 thereof is located at the position of 300° of the cam faces 511.

Thus, the first pressing rod 73 is at the position of displacement 0, where it presses the diaphragm 8 against the corresponding metering recess 23A so as to make it adhere to the diaphragm 8, and hence the corresponding first metering chamber (suction
15 side metering chamber) defined by the first metering recess 23A and the part of the diaphragm 8 corresponding to the metering recess 23A is held to a hermetically sealed condition. The second pressing rod 74 is at the position of displacement of 0.25, or the position of a half of the stroke of movement. The third pressing rod 75 is also at the position of displacement of 0.25, namely, the position of a half of the stroke of movement.
20 Since the pressing rods 74, 75 are located respectively at the those positions, the volume of the second metering chamber (intermediate metering chamber) defined by the second metering recess 24A and the part of the diaphragm 8 corresponding to the metering recess 24A and the volume of the third metering chamber (ejection side metering chamber) defined by the third metering recess 25A and the part of the diaphragm 8 corresponding to
25 the metering recess 25A reflect the respective positions of the pressing rods 74, 75.

As the cam 51 is rotated by 15° from the state of FIG. 8A, a state as shown in FIG. 8B arises. More specifically, the ball 79 of the first pressing rod 73 gets to the position of 15° of the cam faces 511 but, since the cam faces 511A are planes in this phase of operation, the first pressing rod 73 is not displaced and keeps the first metering chamber to

a hermetically sealed condition.

At this time, the second pressing rod 74 revolves from the position of 330° to the position of 345° of the cam faces 511 and moves from the position of displacement 0.25 mm to the position of displacement 0 mm to come closer to the diaphragm 8. As a result
5 of this movement, the volume of the second metering chamber (intermediate metering chamber) is gradually decreased so that the liquid in the second metering chamber is transferred to the third metering chamber (ejection side metering chamber) via the communication groove 283.

Similarly, the third pressing rod 75 revolves from the position of 300° to the
10 position of 315° of the cam faces 511 and moves from the position of displacement 0.25 mm to the position of displacement 0.5 mm to move away from the diaphragm 8. As a result, the volume of the third metering chamber (ejection side metering chamber) is gradually increased so that the liquid transferred from the second metering chamber is taken into the third metering chamber. In this way, the second transfer step is carried out
15 between the state of FIG. 8A and that of FIG. 8B.

As the cam 51 is rotated by 12° from the state of FIG. 8B, a state as shown in FIG. 9C arises. More specifically, the ball 79 of the first pressing rod 73 moves from the position of 15° and gets to the position of 27° of the cam faces 511 and the first pressing rod 73 moves away from the diaphragm 8 from the position of displacement 0 mm to the
20 position of displacement 1/6 mm. As a result of the movement, the volume of the first metering chamber (suction side metering chamber) is gradually increased so that liquid is taken into the first metering chamber from the space 33 at the outer periphery of the metering recess forming surface 21 via the communication groove 281.

At this time, the second pressing rod 74 revolves from the position of 345° to the
25 position of 357° of the cam faces 511 but remains at the position of displacement 0 mm because it does not move axially. Thus, the diaphragm 8 is kept adhering to the second metering recess 24A and hence the second metering chamber is held to a hermetically sealed condition so that no liquid is moved via the second metering chamber.

On the other hand, the third pressing rod 75 revolves from the position of 315° to

the position of 327° of the cam faces 511 and axially moves toward the diaphragm 8 from the position of displacement 0.5 mm to the position of displacement $1/3$ mm. As a result of the movement, the volume of the third metering chamber is gradually decreased so that the liquid in the third metering chamber is transferred to the port 22 via the communication groove 284. Thus, liquid is ejected from the nozzle member 27 at the end of the port 22 at a rate corresponding to the rate of decrease of the volume of the third metering chamber.

In this way, the liquid suction step and the liquid ejection step are carried out simultaneously between the state of FIG. 8B and that of FIG. 9C.

Although not shown in the drawings, as the ball 79 of the first pressing rod 73 moves from the position of 27° to the position of 33° of the cam faces 511 in response to the revolution of the cam 51, the first pressing rod 73 moves further away from the diaphragm 8 from the position of displacement $1/6$ mm to the position of displacement $1/3$ mm. As a result of this movement, the volume of the first metering chamber is gradually increased so that liquid is taken into the first metering chamber from the outer periphery of the metering recess forming surface 21 via the communication groove 281 to continue the suction step.

At this time, the second pressing rod 74 revolves from the position of 357° to the position of 3° of the cam faces 511 but remains at the position of displacement 0 mm because it does not move axially. Thus, the diaphragm 8 is kept adhering to the second metering recess 24A and hence the second metering chamber is held to a hermetically sealed condition so that no liquid is moved via the second metering chamber.

On the other hand, the third pressing rod 75 revolves from the position of 327° to the position of 333° of the cam faces 511 and axially moves toward the diaphragm 8 from the position of displacement $1/3$ mm to the position of displacement $1/6$ mm. As a result of the movement, the volume of the third metering chamber is gradually decreased so that the transfer of liquid in the third metering chamber to the port 22 and the ejection of liquid from the nozzle member 27 continue to by turn continue the ejection step.

As the cam 51 is further rotated and the ball 79 of the first pressing rod 73 gets to

the position of 45° from the position of 33° of the cam faces 511, a state as shown in FIG. 9D arises.

More specifically, the first pressing rod 73 moves away from the diaphragm 8 from the position of displacement $1/3$ mm to the position of displacement 0.5 mm. As
5 the first pressing rod 73 gets to the position of 0.5 mm, the stroke of movement toward the cam 51 comes to an end and the volume of the first metering chamber is maximized so that the liquid suction step of sucking liquid from the space 33 into the first metering chamber is completed.

At this time, the second pressing rod 74 revolves from the position of 3° to the
10 position of 15° of the cam faces 511 but remains at the position of displacement 0 mm because it does not move axially. As a result, the second metering chamber is held to a hermetically sealed condition.

On the other hand, the third pressing rod 75 revolves from the position of 333° to the position of 345° of the cam faces 511 and moves axially toward the diaphragm 8 from
15 the position of displacement $1/6$ mm to the position of displacement 0 mm. As a result, the volume of the third metering chamber is further decreased so that the transfer of liquid from the third metering chamber to the port 22 and the ejection of liquid from the nozzle member 27 continue until the third pressing rod 75 gets to the position of 345° of the cam faces 511. As the third pressing rod 75 revolves to get to the position of 345° of the cam
20 faces 511, the diaphragm 8 adheres to the third metering recess 25A to hermetically close the third metering chamber so that the ejection of liquid from the third metering chamber, namely, the liquid flow path 280, to the port 22 stops to complete the liquid ejection step.

In this way, the liquid suction step and the liquid ejection step continue between the state of FIG. 8B and that of FIG. 9D.

25 As the cam 51 is further rotated and the ball 79 of the first pressing rod 73 gets to the position of 57° from the position of 45° of the cam faces 511, a state as shown in FIG. 10E arises.

More specifically, the first pressing rod 73 moves toward the diaphragm 8 from the position of displacement 0.5 mm to the position of displacement $1/3$ mm. As a result

of this movement, the volume of the first metering chamber is gradually decreased so that liquid is transferred from the first metering chamber to the second metering chamber by way of the communication groove 282.

At this time, the second pressing rod 74 revolves from the position of 15° to the position of 27° of the cam faces 511 and moves away from the diaphragm 8 from the position of displacement 0 mm to the position of displacement 1/6 mm. As a result of this movement, the volume of the second metering chamber is increased gradually so that liquid is taken into the second metering chamber from the first metering chamber by way of the communication groove 282. In this way, the first transfer step is carried out.

On the other hand, the third pressing rod 75 revolves from the position of 345° to the position of 357° of the cam faces 511 but remains at the position of displacement 0 mm because it does not move axially. Thus, the third metering chamber is held to a hermetically sealed condition and the suspension of ejection of liquid from the third metering chamber to the port 22 is maintained.

Although not shown in the drawings, as the ball 79 of the first pressing rod 73 moves from the position of 57° to the position of 63° of the cam faces 511 in response to the revolution of the cam 51, the first pressing rod 73 moves further closer to the diaphragm 8 from the position of displacement 1/3 mm to the position of displacement 1/6 mm. As a result of this movement, the volume of the first metering chamber is further decreased so that the transfer of liquid from the first metering chamber to the second metering chamber (first transfer step) continues.

At this time, the second pressing rod 74 revolves from the position of 27° to the position of 33° of the cam faces 511 and moves away from the diaphragm 8 from the position of displacement 1/6 mm to the position of displacement 1/3 mm. As a result of this movement, the volume of the second metering chamber is gradually increased and hence the suction of liquid from the first metering chamber into the second metering chamber (first transfer step) continues.

On the other hand, the third pressing rod 75 revolves from the position of 357° to the position of 3° of the cam faces 511 but remains at the position of displacement 0 mm

because it does not move axially. Thus, the third metering chamber is held to a hermetically sealed condition so that the suspension of ejection of liquid from the third metering chamber to the port 22 is maintained.

As the cam 51 is further rotated and the ball 79 of the first pressing rod 73 gets to the position of 75° from the position of 63° of the cam faces 511, a state as shown in FIG. 10F arises.

More specifically, the first pressing rod 73 moves further closer to the diaphragm 8 from the position of displacement 1/6 mm to the position of displacement 0 mm. As a result of this movement, the volume of the first metering chamber is decreased further so that the transfer of liquid from the first metering chamber to the second metering chamber continues. When the first pressing rod 73 is moved to the position of displacement 0 mm, the diaphragm 8 comes to adhere to the first metering recess 23A to hermetically seal the first metering chamber so that the transfer of liquid is stopped to complete the first transfer step.

At this time, the second pressing rod 74 revolves from the position of 33° to the position of 45° of the cam faces 511 and moves away from the diaphragm 8 from the position of displacement 1/3 mm to the position of displacement 0.5 mm. As a result of this movement, the suction of liquid from the first metering chamber into the second metering chamber continues until the second pressing rod 74 moves to the position of displacement 0.5 mm and the first transfer step is completed when the second pressing rod 74 gets to the position of 0.5 mm.

On the other hand, the third pressing rod 75 revolves from the position of 3° to the position of 15° of the cam faces 511 but remains at the position of displacement 0 mm because it does not move axially. Thus, the third metering chamber is held to a hermetically sealed condition so that the suspension of ejection of liquid from the third metering chamber to the port 22 is maintained.

In this way, the first transfer step is carried out between the state of FIG. 9D and that of FIG. 10F. When the state of FIG. 10F arises, both the first metering chamber and the third metering chamber are hermetically sealed and liquid is held to the second

metering chamber and hence metered by the volume of the second metering chamber so that the metering step is carried out at this time.

As the cam 51 is further rotated and the ball 79 of the first pressing rod 73 gets to the position of 90° from the position of 75° of the cam faces 511, the state as shown in FIG. 8A is restored. In other words, the first pressing rod 73 remains to the position of displacement 0 mm and does not move. Therefore, both the hermetically sealed condition of the first metering chamber and the suspension of liquid transfer to the second metering chamber are maintained

At this time, the second pressing rod 74 revolves from the position of 45° to the position of 60° of the cam faces 511 and moves toward the diaphragm 8 from the position of displacement 0.5 mm to the position of displacement 0.25 mm. As a result of this movement, the volume of the second metering chamber is gradually decreased so that liquid is transferred from the second metering chamber to the third metering chamber.

On the other hand, the third pressing rod 75 revolves from the position of 15° to the position of 30° of the cam faces 511 and moves away from the diaphragm 8 from the position of displacement 0 mm to the position of displacement 0.25 mm. As a result of this movement, the volume of the third metering chamber is gradually increased so that the liquid transferred from the second metering chamber is taken into the third metering chamber. In this way, the second transfer step is carried out between the state of FIG. 10F and that of FIG. 8B.

The angular strokes of the cam faces 511 from 90° to 180° , from 180° to 270° and from 270° to 360° are identical with the angular stroke from 0° to 90° . In other words, the state where the ball 79 of the first pressing rod 73 is at the position of 90° of the cam faces 511 is identical with the state illustrated in FIG. 8A and hence the above-described operation is repeated from that state. Therefore, it will not be described here any further.

FIG. 11 is a graph illustrating the change of displacement relative to the angle of revolution of each of the pressing rods 73 through 75.

Note that in FIG. 11 the above-described angular stroke of 90° from 15° to 105° is translated to the angular stroke of 90° from 0° to 90° for the purpose of simplicity.

Additionally, in FIG. 11, the first pressing rod 73, the third pressing rod 75 and the second pressing rod 74 are respectively referred to as "external", "internal" and "intermediate" pressing rods they are arranged respectively at the outer peripheral side, at the inner peripheral side and at a position between the pressing rods 73 and 75.

5 As shown in FIG. 11, the first pressing rod 73 moves away from the diaphragm 8 between 0° and 12° (between 15° and 27° in the above description) at a constant acceleration. The change per unit angle (e.g., 1°) of displacement during this period is so defined as to gradually increase.

10 Subsequently, the first pressing rod 73 moves away from the diaphragm 8 between 12° and 18° (between 27° and 33° in the above description) at a constant speed. The change per unit angle of displacement during this period is so defined as to be constant.

Then, the first pressing rod 73 moves away from the diaphragm 8 between 18° and 30° (between 33° and 45° in the above description) at a constant acceleration. The
15 change per unit angle of displacement during this period is so defined as gradually decrease.

Then, the first pressing rod 73 moves toward the diaphragm 8 between 30° and 42° (between 45° and 57° in the above description) at a constant acceleration. The
20 change per unit angle of displacement during this period is so defined as to gradually increase.

Thereafter, the first pressing rod 73 moves toward the diaphragm 8 between 42° and 48° (between 57° and 63° in the above description) at a constant speed. The change per unit angle of displacement during this period is so defined as to be constant.

25 Subsequently, the first pressing rod 73 moves toward the diaphragm 8 between 48° and 60° (between 63° and 75° in the above description) at a constant acceleration. The change per unit angle of displacement during this period is so defined as to gradually decrease.

Further more, the first pressing rod 73 is at halt with displacement 0 between 60° and 90° (between 75° and 105° in the above description).

On the other hand, the second pressing rod 74 moves in the same manner with a delay of 30° relative to the first pressing rod 73. In other words, the second pressing rod 74 is at halt between 0° and 30° but moves between 30° and 90° just like the first pressing rod 73 between 0° and 60°.

5 Similarly, the third pressing rod 75 moves in the same manner with a delay of 30° relative to the second pressing rod 74 (and with a delay of 60° relative to the first pressing rod 73). In other words, the third pressing rod 75 is at halt between 30° and 60° but moves between 60° and 30° just like the first pressing rod 73 between 0° and 60°.

While the pressing rods operate in the above-described manner, liquid is ejected
10 into the port 22 during the period where the third pressing rod 75 moves from the position of displacement 0.5 mm to the position of displacement 0 mm (between 0° and 30° in FIG. 11).

FIG. 12 is a graph illustrating the change in the liquid ejection rate from each of the third metering chambers (third metering recesses 25A through 25E) during the period
15 where the cam 51 revolves by 90°. In FIG. 12, the liquid ejection rates from the third metering chambers (third metering recesses 25A through 25E) are denoted respectively by numbers 1 through 5.

Between 0° and 12°, the third pressing rod 75 that corresponds to the third metering recess 25A moves at a constant acceleration so as to gradually increase the
20 change per unit angle of displacement. Therefore, the liquid ejection rate also gradually increases as shown in FIG. 12. Thus, an ejection rate increasing step is carried out.

Between 12° and 18°, the third pressing rod 75 ejects liquid at a constant seep so as to maintain the change per unit angle of displacement to a constant value. Therefore, the liquid ejection rate is maintained to a constant level. Thus, a constant ejection rate
25 step is carried out.

Between 18° and 30°, the third pressing rod 75 moves at a constant acceleration so as to gradually decrease the change per unit angle of displacement. Therefore, the liquid ejection rate also gradually decreases. Thus, an ejection rate decreasing step is carried out.

On the other hand, as shown in FIG. 12, liquid is ejected from the third metering chamber (third metering recess 25B) between 18° and 48° as in the case of the third metering recess 25A because the third pressing rods 75 are angularly shifted from each other by 72° and the cam faces 511 of the cam 51 cyclically change at every 90°. The cam faces 511 are defined in such a way that, while the liquid ejection rate of the third metering recess 25A gradually decreases (ejection rate decreasing step), the liquid ejection rate of the third metering recess 25B gradually increases (ejection rate increasing step) so that the combined ejection rate, or the sum of the ejection rates of the two third metering recesses 25A, is held to a constant level. The combined ejection rate is so selected as to be equal to the ejection rate that is observed when each of the third pressing rods 75 is moving at a constant speed (for example, the ejection rate of the third metering recess 25A between 12° and 18°).

Since the remaining third metering chambers (third metering chambers 25C through 25E) operate to eject liquid with the same mutual phase difference of 18°, liquid is ejected from the diaphragm pump 1 at a constant rate.

Since the diaphragm pump 1 has five liquid flow paths 280 that operate as so many pumps and the cam faces 511 are adapted to make a single cycle of back and forth movement during the time it revolves by 90°, a total of 20 pumps operates when the cam 51 makes a full turn. During this time period, a predetermined volume of liquid is continuously ejected and taken in. In other words, liquid is sucked and ejected continuously without pulsation.

Since a constant volume is always ejected for a full turn of the cam 51, the volume of liquid to be ejected per unit time can be controlled by regulating the rate of revolution of the cam 51.

The above-described embodiment provides the following advantages.

(1) Since a plurality of metering recesses 23A through 23E, 24A through 24E, 25A through 25E are formed on the metering recess forming surface 21 and a diaphragm 8 is arranged to cover the metering recesses 23A through 23E, 24A through 24E, 25A through 25E, while a plurality of pressing rods 73, 74, 75 are arranged to correspond to the

respective metering recesses 23A through 23E, 24A through 24E, 25A through 25E so as to produce five pumps and the operations of the pressing rods 73 through 75 are defined by way of a cam 51. Liquid can be sucked and ejected, or transferred, at a constant rate in response to the revolution of the cam 51, and liquid can be transferred continuously
5 without pulsation by regulating the rate of revolution of the drive unit 6 constant.

Particularly, since a metering step where the first and the third metering chambers are hermetically sealed and the second metering chamber is used to define a volume of liquid, it is possible to accurately transfer even a very small amount of liquid.

Additionally, since the rate at which liquid is transferred per unit time by the
10 diaphragm pump 1 can be regulated only by regulating the rate of revolution of the drive unit 6, the operation of the diaphragm pump can be controlled very easily.

(2) Since a pulsation-free continuous pump can be formed by using a diaphragm 8, the limitation to the types of liquid that can be ejected from the pump is minimized and hence a diaphragm pump according to the present invention can find a broad scope of
15 application. In other words, since only the base block 2, the holder ring block 3 and the diaphragm 8 contact liquid, liquid of various different types can be transferred when appropriate materials are selected for those components. Additionally, since the diaphragm 8 is made of a resiliently deformable material such as rubber, liquid such as silver paste or solder paste can be ejected without crushing particles contained therein so
20 that liquid can be transferred without being damaged.

When a plunger pump is used and a seal member is applied to the plunger to prevent leakage of liquid, the plunger is forced to slide on the seal member so that friction occurs between liquid and the plunger and the seal member. Then, if liquid of a material that can be polymerized as a result of friction with the seal member such as an ultraviolet
25 curing adhesive or an aerophobic adhesive is transferred, the liquid can often be damaged as it is partly polymerized and set. To the contrary, this embodiment employs a diaphragm 8 and hence eliminates the use of a seal member so that no friction occurs between the embodiment and liquid. Therefore, liquid such as an ultraviolet curing adhesive or an aerophobic adhesive can be transferred without any damage.

Therefore, the diaphragm pump 1 can transfer liquid of various different types, and can find a broad scope of application in various industrial fields including the chemical industry, the semiconductor industry and the printing industry.

(3) Since at least one of the three metering chambers of each of the liquid flow paths 280 is hermetically sealed as the diaphragm 8 is forced to adhere to the corresponding one of the metering recesses 23 through 25, liquid is prevented from flowing back without a check valve. Therefore, liquid can be transferred from the port 22 to the space 33 at the outer periphery of the metering recess forming surface 21 by driving the cam 51 to revolve in the opposite direction. In short, according to the present invention, a diaphragm pump 1 that allows liquid to flow back can be formed without difficulty.

Additionally, if a check valve is provided, liquid can leak out from the check valve when the liquid supply side and the liquid ejection side of the check valve show a pressure difference so that it is not possible to apply pressure to the liquid supply side in order to transfer liquid under pressure. To the contrary, with this embodiment, the metering recesses 23 through 25 are hermetically sealed to make the use of a check valve unnecessary. Therefore, the embodiment operates properly when pressure is applied to the liquid supply side and/or the liquid ejection side is held to negative pressure to give rise to a pressure difference. In other words, liquid can be supplied by applying pressure thereto and transferred while the liquid flow paths 280 are filled with liquid without any space so that the accuracy of the liquid ejection rate can be improved. Additionally, this embodiment can be used to transfer highly viscous liquid to broaden the number of types of liquid that can be transferred. In other words, this embodiment can be used as a dispenser for a variety of different types of liquid.

(4) The drive side including the pressing rods 73 through 75, the cam 51 and the like and the pump side for transferring liquid of the embodiment are separated by the diaphragm 8 so that it is not necessary to additionally provide a seal member that prevents liquid from leaking to the drive side. Additionally, the pressing rods 73 through 75 are only required to simply reciprocate with a stroke of 0.5 mm so that the overall configuration of the embodiment can be simplified and downsized. Therefore, it is

possible to provide a small diaphragm pump 1 that is designed to eject liquid at a very small rate. Then, it can be fitted to a robot arm on a semiconductor manufacture line.

(5) The metering recesses 23A through 23E, 24A through 24E, 25A through 25E and the pressing rods 73 through 75 are arranged to extend spirally from the port 22 so that the
5 metering recess forming surface 21 can be made to show small area. Then, the diaphragm pump 1 can be downsized.

(6) The first pressing rods 73, the second pressing rods 74 and the third pressing rods 75 needs to be operated with phase differences. Such phase differences can be realized by shifting the regions that correspond to the respective pressing rods 73 through 75 on the
10 cam faces 511. However, such an arrangement makes the cam manufacturing process a cumbersome one. To the contrary, with this embodiment, the first metering recesses 23A through 23E, the second metering recesses 24A through 24E and the third metering recesses 25A through 25E are shifted from each other by 30° in the sense of revolution that is centered at the port 22. With this arrangement, it is not necessary to shift the
15 regions that correspond to the respective pressing rods 73 through 75 on the cam faces 511 of the cam 51 and the cam faces 511 can be formed linearly to facilitate the operation of manufacturing the cam 51.

(7) A single diaphragm 8 that covers the metering recess forming surface 21 is required. Such a diaphragm 8 can be manufactured with ease at low cost. In
20 conventional diaphragm pumps 1, the entire diaphragm 8 is driven to reciprocate in order to eject liquid so that ejection errors may occur because the diaphragm 8 itself can be easily deformed. Then, it is difficult to transfer liquid accurately at a very small rate.

To the contrary, in this embodiment, not the entire diaphragm 8 is reciprocated but only the parts of the diaphragm 8 that correspond respectively to the first metering
25 recesses 23A through 23E, the second metering recesses 24A through 24E and the third metering recesses 25A through 25E (metering-recess-corresponding parts) are reciprocated so that the diaphragm 8 can be moved so as to accurately follow the respective motions of the pressing rods 73 through 75. Additionally, since liquid is transferred by moving small parts of the diaphragm 8 that correspond to the respective

metering recesses 23 through 25, it is possible to transfer only a small volume of liquid. In other words, it is possible to realize a pump that can transfer a very small amount of liquid. Such a pump can find applications in the field of apparatus for ejecting a very small amount of liquid (dispensers).

5 Additionally, the diaphragm 8 can be manufactured at low cost because both the surface to be adhered to the flow path block and the surface to be abutted to the pressing rods thereof have a simple planar profile. In other words, when the diaphragm 8 is worn, it can be replaced at low cost.

(8) Since the cam followers that abut the cam faces 511 include the pressing rods 73 through 75 and the balls 79 held respectively by the pressing rods 73 through 75 in this embodiment, it is possible to downsize the drive section of the embodiment that is formed by the cam faces 511 and the followers. If rollers are used instead of the balls 79, rotary shafts need to be provided so as to project in a radial direction in order to revolvably support the rollers. Then, the tracks of the rollers moving (revolving) along the cam needs to have a large diameter. To the contrary, since the balls 79 are used in this embodiment, no roller shafts are needed and hence the tracks of the rollers can be made to show a small diameter accordingly. Thus, the diaphragm pump 1 can be downsized.

(9) When rollers are used, the planar cam has to be made of oil-impregnated resin in order to make the rollers less liable to be worn because side slips may occur between the planar cam and the rollers. Then, the oil-impregnated resin of the planar cam is deformed when it is pressed against the rollers to give rise to an error in the stroke of the plunger to consequently reduce the accuracy of ejection of liquid.

To the contrary, in this embodiment, the balls 79 are made to abut the cam faces 511 and the coefficient of friction between the pressing rods 73 through 75 and the balls 79 is made lower than the coefficient of friction between the cam faces 511 and the balls 79. Therefore, if radial force is applied to the revolving balls 79, the force is absorbed as the balls 79 revolve on the respective pressing rods 73 through 75. Thus, no side slip occurs between the cam faces 511 and the balls 79 and the balls 79 can revolve and move without slipping on the cam faces 511. Therefore, it is no longer necessary to consider

friction and use oil-impregnated resin for the cam faces 511. In other words, the cam 51 can be made of a hard material such as metal and the balls 79 can also be made of a hard material to reduce the error, if any, in the stroke of the pressing rods 73 through 75 and improve the accuracy of liquid ejection.

5 Additionally, the reciprocating motions of the pressing rods 73 through 75 are unequivocally defined by the profile of the cam faces 511 so that it is possible to accurately control the motions of the pressing rods 73 through 75 by appropriately defining the profile of the cam faces 511. Thus, the embodiment can accurately eject liquid without pulsation.

10 (10) Still additionally, while the pressing rods 73 through 75 are made of a resin material that is softer than the material of the balls 79, each of the balls 79 is held in the semispherical recess of the corresponding pressing rod that is adapted to receive about a half of the ball 79. Therefore, if the ball 79 slides in the recess, the force generated by the slide can be absorbed by the large area of the recess. Thus, the pressing rods 73
15 through 75 are prevented from being deformed.

As a result, no error occurs in the movements of the pressing rods 73 through 75 so that the pressing rods 73 through 75 can be accurately controlled for their movements and hence it is possible for the embodiment to accurately transfer a very small amount of liquid.

20 (11) The coil springs 78 are provided to urge the respective pressing rods 73 through 75 toward the cam faces 511 so that the pressing rods 73 through 75 reliably follow the cam faces 511. Additionally, since the entire cam 51 is urged toward the diaphragm 8 by the coned disk spring 57, the positions of displacement 0 of the pressing rods 73 through 75, where they press the diaphragm 8 against the respective metering recesses 23 through
25 25, can be automatically aligned relative to each other to a certain extent. In other words, as the pressing rods 73 through 75 are pressed against the diaphragm 8 by force of a certain magnitude, the diaphragm 8 adheres to the metering recesses 23 through 25 and the positions of the pressing rods 73 through 75 come to be defined when the diaphragm 8 is compressed to a certain extent and the repulsive force of the diaphragm 8 is balanced with

the force being applied to the pressing rods 73 through 75. Therefore, when the cam 51 is placed approximately at the designed position by referring to the height or the like of the spacer ring 56, the positions of the pressing rods 73 through 75 and hence the position of the cam 51 are automatically regulated as the cam 51 is pressed against the diaphragm 8 by the coned disk spring 57. Thus, the cam 51 is accurately placed in position when the diaphragm pump 1 is assembled without requiring accurate machining for the related components. In other words, the efficiency of machining the components can be improved to relatively reduce the manufacturing cost of the diaphragm pump.

Now, the second embodiment of the present invention will be described by referring to FIGS. 13 and 14.

Diaphragm pump 1A of the second embodiment differs from the diaphragm pump 1 of the first embodiment in terms of the configuration of base block 2A and that of the diaphragm 8A. More specifically, of the base block 2A of the second embodiment, the diaphragm-adhering surface 21A that adheres to the diaphragm 8A is flat and planar. In other words, neither grooves nor recesses are formed there unlike the metering recess forming surface 21 of the first embodiment where metering recesses 23 through 25 and communication grooves 281 through 284 are formed.

The diaphragm 8A shows a substantially disk-like profile and has a flow-path-block-adhering surface 81 that faces the base block 2A and a pressing-rod-abutting surface 82 that faces the pressing rods 73 through 75.

The flow-path-block-adhering surface 81 is not planar unlike the diaphragm 8 of the first embodiment. As shown in FIGS. 14B and 14C, metering recesses 23 through 25 and communication grooves 281 through 284 are formed there instead. In other words, like the metering recess forming surface 21 of the first embodiment, the metering recesses 23 through 25 and the communication grooves 281 through 284 are formed on the flow-path-block-adhering surface 81.

On the other hand, as shown in FIG. 14A, spherical projections 83 through 85 are formed on the pressing-rod-abutting surface 82 at positions corresponding to the respective metering recesses 23 through 25. With this arrangement, the diaphragm 8A

has a thickness at the parts thereof where the metering recesses 23 through 25 are formed substantially the same as the thickness of the remaining parts as shown in FIG. 14B. The diaphragm 8A is made of rubber and can be molded by means of a rubber die (rubber molding metal mold).

5 As shown in FIG. 13, the diaphragm 8A is pinched between a flow path block that is formed by the base block 2A and a holder ring block 3 and a guide block 4. The projections 83 through 85 are arranged at the positions corresponding to respective guide holes 43 through 45 of the guide block 4 and adapted to abut respective pressing rods 73 through 75.

10 Thus, metering chambers are formed by the spaces defined respectively by the metering recesses 23 through 25 of the diaphragm 8A and the diaphragm adhering surface 21A of the base block 2A. Additionally, communication paths are formed by the spaces defined respectively by communication grooves 281 through 284 and the diaphragm adhering surface 21A.

15 The end facets of the pressing rods 73 through 75 that face the diaphragm 8A are made to show a planar profile so that they are adapted to entirely press down the respective projections 83 through 85, although pressing rods 73 through 75 showing a semispherical profile like those of the first embodiment may alternatively be used.

20 Thus, this embodiment is identical with the first embodiment in terms of that it is provided with metering chambers and communication paths between the diaphragm 8A and the base block 2A and the volume of each of metering chambers changes as the corresponding one of the pressing rods 73 through 75 is driven to move back and forth. Therefore, liquid is transferred by this embodiment just like the first embodiment.

25 This embodiment provides the following advantages in addition to the advantages of the first embodiment.

 Since the metering recesses 23 through 25 and the communication grooves 281 through 284 are formed not in the base block 2A but in the diaphragm 8A, the cost of initial investment can be reduced further so that the manufacturing cost can be lowered if the number of diaphragm pumps 1A to be manufactured is small and it is possible to

manufacture a diaphragm pump 1A adapted to transfer a very small volume of liquid with ease. More specifically, the metal base block 2 having metering recesses 23 through 25 of the first embodiment is formed by using a metal mold or by using machine tools. If a metal mold is used, the manufacturing cost of the base block 2 is reduced but the cost of preparing the metal mold is high so that by turn the cost of initial investment is raised. If, on the other hand, machine tools are used, the machining cost is high and it is difficult to reduce the volumes of the metering recesses 23 through 25 for machining reasons.

To the contrary, when the metering recesses 23 through 25 and the communication grooves 281 through 284 are formed in the diaphragm 8A, the rubber diaphragm 8A is molded by using a rubber die. Such a rubber die is less expensive if compared with a metal mold for forming metal products so that by turn the cost of initial investment is reduced. Additionally, the metering chambers and the flow paths can be dimensionally reduced when a rubber die is used. Then, the manufactured diaphragm pump is adapted to transfer a very small amount of liquid without difficulty.

The present invention is by no means limited to the above-described embodiments, which may be modified and/or altered in various different ways without departing from the scope of the present invention.

For instance, in the aforesaid embodiments, while a plurality of sets of metering recesses 23A through 23E, 24A through 24E, 25A through 25E are arranged to extend spirally, they may alternatively be arranged radially as shown in FIG. 15. With such an arrangement, the first cam face that corresponds to the first metering recesses 23A through 23E, the second cam face that corresponds to the second metering recesses 24A through 24E and the third cam face that corresponds to the third metering recesses 25A through 25E are shifted by 30° from each other. For example, the cam faces may be made to show a ring-shaped profile and combined so as to be displaced by 30° from each other.

However, the above-described embodiments are advantageous in that the diameter of the metering recess forming surface 21 can be made to have a small diameter and hence the diaphragm pump 1 can be downsized. While the sets of metering recesses 23A through 23E, 24A through 24E, 25A through 25E that are arranged spirally in each of the

above-described embodiments may require a complicated processing operation if compared with those that are arranged radially, it is in reality not difficult to prepare such sets of metering recesses when an advanced numerically controlled machine is used. . Further, the metering recesses 23A through 23E, 24A through 24E, 25A through 25E have
5 curved surfaces and are slight dent, and therefore can be formed by using a metal mold. They can be easily by preparing a metal mold.

Additionally, it may be so arranged that the metering recesses 23 through 25 are formed in the diaphragm or the flow path block and the communication grooves 281 through 284 are formed in the flow path block or the diaphragm, whichever appropriate.
10 In short, it is only necessary that the diaphragm and the flow path block are so configured as to define liquid flow paths including metering chambers and communication paths.

The number of the liquid flow paths 280, or the individual pumps, is not limited to 5 of the above-described embodiments if it is 3 or more than 3. More specifically, each of the individual pumps is adapted to show any of three states including a state where
15 transfer of liquid is stopped, a state where the liquid transfer rate is gradually decreasing and a state where the liquid transfer rate is gradually increasing so that the transfer of liquid is accompanied by pulsation if a diaphragm pump has only a single individual pump. Such pulsation cannot be eliminated if a diaphragm pump has two individual pumps because they cannot be used to transfer liquid simultaneously. In other words, at least
20 three individual pumps are indispensable. If, on the other hand, a large number of individual pumps are involved, the influence of the increase and that of the decrease in the liquid transfer rate can be minimized because a plurality of pumps can be driven to operate simultaneously in order to transfer liquid. Then, it is possible to minimize pulsation and transfer liquid at a constant rate. However, as the number of individual pumps increases,
25 the number of metering recesses 23 through 25 and that of pressing rods 73 through 75 also increase to consequently increase the dimensions of the diaphragm pump 1. Thus, the use of five pumps as in the case of the above-described embodiments is advantageous because it possible to relatively reduce the dimensions of the pump and realize a constant liquid transfer rate with minimal pulsation.

The number of metering recesses 23 through 25 arranged in each of the liquid flow paths 280 is not limited to 3 and may alternatively be 4 or more than 4. However, a diaphragm pump that can effectively prevent liquid from flowing back can be realized by arranging three metering recesses in each of the liquid flow paths. Therefore, the use of
5 three metering recesses in each of the liquid flow path is advantageous from the viewpoint of forming a compact diaphragm pump.

Additionally, the first defined angle of intersection and the second defined angle of intersection of the metering recesses 23 through 25 are not limited to the above-described respective values 30° and 72° and other values may be appropriately
10 selected depending on the number of metering recesses and the number of liquid flow paths 280.

The profile of the cam faces 511 of the cam 51 is not limited to those illustrated by the cam diagrams of the above-described embodiments. For instance, the parts of the cam faces that are used for the respective pressing rods 73 through 75 to move at a
15 constant acceleration may be modified to show a profile of sinusoidal curves. In short, it is only necessary to design the cam faces in such a way that the total liquid transfer rate produced by the pressing rods 73 through 75 is held to a constant level.

The drive mechanism for driving the cam 51 is not limited to the one that is used in the above-described embodiments. For instance, the cam 51 may be directly and
20 rigidly secured to the output shaft without using a spline boss 52 and a spline shaft 53. The cam 51 may be aligned without using a coned disk spring 57 or the like. A drive mechanism that does not involve the use of a cam may be utilized.

The motor that can be used for a diaphragm pump according to the present invention may be selected from stepping motors, servo motors, synchronous motors, DC
25 motors, induction motors, reversible motors, air motors and other motors.

Further, a biasing section for biasing the guide block 4 toward the diaphragm 8 can be provided. The biasing section can be arranged as appropriate. One example of the arrangement of the biasing section is shown in FIG.16 in which the guide block 4 is axially movably provided on the inner side of the case block 10, and the guide block 4 is biased

toward the diaphragm 8 by a biasing section constituted of a disk spring 11 and a cylindrical pressing member 12.

Incidentally, in the case as shown in FIG.16, a resin-made guide ring 13 is pressed into the inner periphery side of the case block 10, the teeth formed on the inner periphery surface of the guide ring 13 is engaged with the teeth formed on the outer periphery surface of the guide block 4. By such arrangement, the guide block 4 is movable in the axial direction without rotating. Further, the cam 51, the spline boss 52, the ball bearing 55 and the disk spring 57 are provided on the inner periphery side of the pressing member 12.

By providing a biasing section for biasing the guide block 4 toward the diaphragm 8, even in the case that the base block 2 and the guide block 4 have relatively low processing accuracy, the accuracy of the liquid transfer rate can be prevented from being dropped. In other words, in the aforesaid embodiment, since the diaphragm 8 is disposed in the space between the base block 2 and the guide block 4, and the width of the space is determined depending on processing accuracy of the base block 2, the holder ring block 3 and the guide block 4, if the dimension of the space is larger than that of the diaphragm 8, the liquid may leak out due to the unclosed contact between the diaphragm 8 and the metering recess forming surface 21, thereby the accuracy of the liquid transfer rate is dropped. Also, if the dimension of the space is smaller than that of the diaphragm 8, then the diaphragm 8 may be excessively pressed, so that a part of the diaphragm 8 may protrude into the metering recesses 23 through 25 or communication grooves 281 through 284 so as to clog the fluid flow paths 280 and thereby rise possibility that the transfer of the liquid cannot be continued. Therefore, in the aforesaid embodiment, high processing accuracy for both the base block 2 and the guide block 4 is necessary to get an accurate dimension of the space between the base block 2 and the guide block 4.

In contrast, by providing a biasing section for biasing the guide block 4 toward the diaphragm 8, even in the case that the base block 2 and the guide block 4 do not have very high processing accuracy, the diaphragm 8 can be kept in close contact with the metering recess forming surface 2, and the diaphragm 8 can be prevented from being excessively pressed to clog the fluid flow paths 280, thereby the accuracy of the liquid transfer rate can be prevented from being dropped, and liquid can be transferred without

failure.

In the aforesaid embodiment, the width dimensions of the communication grooves 281 through 284 are specified to 1/6 of the width dimensions (diameters) of the metering recesses 23 through 25, but the width dimensions of the communication grooves 281 through 284 also can be optionally specified to 1/2 of the width dimensions (diameters) of the metering recesses 23 through 25 or even be specified as the same as the width dimensions (diameters) of the metering recesses 23 through 25 according to the kind of the liquid to be transferred. Incidentally, in the case that the width dimensions of the communication grooves 281 through 284 are specified wide, if the diaphragm 8 is excessively pressed, the diaphragm 8 may protrude into the communication grooves 281 through 284 to possibly clog the fluid flow paths 280. Accordingly, if the width dimensions of the communication grooves 281 through 284 are needed to be specified wide, it is preferred to either get a high processing accuracy for both the base block 2 and the guide block 4 to obtain an accurate dimension of the space between the base block 2 and guide block 4, or provide a biasing section for biasing the guide block 4 toward the diaphragm 8.

The profiles, the structures and the materials of any other components are not limited to those described above by referring to the preferred embodiments, which may be modified and/or altered appropriately.

Since a diaphragm pump 1 according to the present invention is adapted to drive liquid to flow reversely by driving the cam 51 to revolve reversely. Therefore, a diaphragm pump 1 according to the present invention can find applications where liquid is sucked through the port 22 in addition to those where liquid is ejected through the port 22.

In addition to that a diaphragm pump 1 according to the present invention can find applications in the field of apparatus for ejecting a small amount of liquid (dispensers) as described above by referring to the preferred embodiments having the nozzle member 27, it can also be used for ejecting a minute amount of liquid into a production line, where a predetermined liquid is flowing, to form a mixture according to the reading of a flow meter installed at the line and/or sampling liquid from the line.

Additionally, a diaphragm pump 1 according to the present invention may be installed to intervene somewhere in a production line, where a predetermined liquid is flowing, and operate the drive unit 6 so as to establish an equilibrated state between the pressure of the line upstream relative to the pump and the pressure of the line downstream relative to the pump and meter the flow rate of the liquid from the number of revolutions or pulses per unit time of the drive unit 6 in the equilibrated state. Particularly, a diaphragm pump 1 according to the present invention is suited for sucking and ejecting a very small amount of liquid and hence it can be utilized as a flow meter for metering a very low flow rate.

10 The material of the diaphragm 8 is not limited to rubber and the diaphragm 8 may be formed by a multilayer material prepared by laying fluorine resin and rubber. With such an arrangement, the surface layer of the diaphragm 8 that is brought to contact liquid may be formed by fluorine resin that is highly resistive against chemicals to remarkably broaden the number of types of liquid that can be used with the diaphragm 8 and consequently find a broader scope of applications. In short, any resiliently deformable material may be used for the diaphragm 8 so long as it can be deformed by the pressure applied by the pressing rods 73 through 75 and resiliently restore the original state when the pressure of the pressing rods 73 through 75 is removed.

When fluorine resin or the like that is less deformable than rubber is used for the diaphragm 8, it may be necessary to reduce the depth of the metering recesses 23 through 25 to about 0.1 mm and design the profile in a specific way so that the less deformable diaphragm 8 may tightly adhere to the metering recesses 23 through 25. In short, it is only necessary to appropriately design the profile and select the dimensions of the metering recesses 23 through 25 depending on the material of the diaphragm 8 and the liquid transfer rate of the diaphragm pump.

While the metering recesses 23 through 25 are made to show a width larger than the width of the communication grooves 281 through 284 in the above-described embodiments, they may alternatively be made to show the width same as that of the communication grooves. Then, the volume of each of the metering chambers can be

reduced to by turn reduce the liquid transfer rate to a very low level.

The diaphragm pump according to the present invention can be incorporated into a manufacturing apparatus of electronic component. The manufacturing apparatus of electronic component is preferred to have the diaphragm pump, a liquid supplier for
5 supplying the liquid to the suction flow path of the diaphragm pump, an ejecting nozzle provided to ejection flow path, and a controller for controlling the drive section of the diaphragm pump, in which liquid supplied by the liquid supplier is ejected from the ejection nozzle through the diaphragm pump to manufacture electric component.

In such a manufacturing apparatus of electronic component, since the diaphragm
10 pump capable of accurately transferring a trace quantity of liquid is employed, a trace quantity of liquid is enable to be accurately ejected by the ejection nozzle, and even particle-containing liquid with silver powder, silica powder or the like contained therein can be ejected without crushing and particles contained. Thus, the diaphragm pump not only can be used as a dispenser for discharging every kinds of liquid such as adhesive and
15 resin, but can be used to every kinds of manufacturing apparatus of electronic component in which such a dispenser is incorporated. In particular, since a trace quantity of particle-containing liquid can be accurately transferred, it is most suitable to the manufacturing apparatuses of electronic components such as a die bonder, in which a semiconductor chip is fixed to the substrate by the adhesive such as silver paste, or a
20 manufacturing apparatus for manufacturing light-emitting diode (LED), in which the LED chip is sealed by the resin with silica powder contained.

Industrial Availability

The present invention is applicable to diaphragm pumps 1 that can transfer liquid
25 at a constant rate without pulsation. Further, the present invention is applicable to manufacturing apparatus of electronic component such as a die bonder, in which a semiconductor chip is fixed to the substrate by the adhesive such as silver paste ejected from a diaphragm pump, or a manufacturing apparatus for manufacturing light-emitting diode (LED), in which the LED chip is sealed by the resin with silica powder contained

ejected from a diaphragm pump.

CLAIMS

1. A diaphragm pump comprising a flow path block, a diaphragm arranged so as to adhere to the flow path block and a drive section for driving the diaphragm to reciprocate,
5 characterized in that

at least three liquid flow paths are defined by the flow path block and the diaphragm so as to allow a suction flow path and an ejection flow path to communicate with each other, at least three metering chambers being arranged along each of the liquid flow paths, and

10 the drive section includes:

a plurality of pressing members arranged so as to correspond to the metering chambers respectively with the diaphragm interposed therebetween, and

a pressing member drive controller adapted to execute a volume decreasing operation and a volume increasing operation at respective predetermined timings defined
15 for each of the pressing members, wherein in the volume decreasing operation, each of the pressing members is moved approaching the flow path block in order to cause a part of the diaphragm corresponding to the metering chambers to move until it adhere to the flow path block so as to gradually decrease the internal volume of each of the metering chambers and eventually hermetically seal the metering chambers; while in the volume
20 increasing operation, each of the pressing members is moved leaving away from the flow path block in order to cause the part of the diaphragm corresponding to the metering chambers adhering to the flow path block to leave away from the flow path block so as to gradually increase the internal volume of each of the metering chambers.

2. The diaphragm pump according to claim 1, characterized in that
25 each of the liquid flow paths has a suction side metering chamber, an intermediate metering chamber, an ejection side metering chamber, a communication path for allowing the suction side metering chamber and the suction flow path to communicate with each other, a communication path for allowing the suction side metering chamber and the intermediate metering chamber to communicate with each other, a communication

path for allowing the intermediate metering chamber and the ejection side metering chamber to communicate with each other and a communication path for allowing the ejection side metering chamber and the ejection flow path to communicate with each other, and

5 the pressing member drive controller is adapted to execute for each of the liquid flow paths

 a suction step of hermetically sealing the intermediate metering chamber by moving the intermediate pressing member arranged corresponding to the intermediate metering chamber so as to approach the flow path block in order to cause the part of the diaphragm corresponding to the intermediate metering chamber to adhere to the flow path block and sucking liquid into the suction side metering chamber from the suction flow path by moving the suction side pressing member arranged corresponding to the suction side metering chamber to leave away from the flow path block in order to cause the part of the diaphragm corresponding to the suction side metering chamber to leave away from the flow path block,

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 a first transfer step of hermetically sealing the ejection side metering chamber by moving the ejection side pressing member arranged corresponding to the ejection side metering chamber so as to approach the flow path block in order to cause the part of the diaphragm corresponding to the ejection side metering chamber to adhere to the flow path block and transferring liquid from the suction side metering chamber to the intermediate metering chamber by moving the intermediate pressing member so as to leave away from the flow path block to cause the part of the diaphragm corresponding to the intermediate metering chamber to leave away from the flow path block so as to increase the volume of the intermediate metering chamber while moving the suction side pressing member so as to approach the flow path block to move the part of the diaphragm corresponding to the suction side metering chamber toward the flow path block so as to decrease the volume of the suction side metering chamber,

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 a metering step of hermetically sealing the suction side metering chamber by moving the suction side pressing member so as to approach the flow path block in order to

cause the part of the diaphragm corresponding the suction side metering chamber to adhere to the flow path block while the ejection side metering chamber is maintained in the condition of being hermetically sealed, isolating the liquid in the intermediate metering chamber and metering the volume of the liquid,

5 a second transfer step of transferring liquid from the intermediate metering chamber to the ejection side metering chamber by moving the intermediate pressing member so as to approach the flow path block to decrease the volume of the intermediate metering chamber and moving the ejection side pressing member so as to leave away from the flow path block to increase the volume of the ejection side metering chamber while the
10 suction side metering chamber is maintained in the condition of being hermetically sealed, and

 an ejection step of transferring liquid from the ejection side metering chamber to the ejection flow path by hermetically sealing the intermediate metering chamber and moving the ejection side pressing member so as to approach the flow path block to
15 decrease the volume of the ejection side metering chamber.

3. The diaphragm pump according to claim 2, characterized in that
 the pressing member drive controller is adapted to execute both the suction step and the ejection step simultaneously by moving the suction side pressing member so as to leave away from the flow path block to suck liquid from the suction flow path into the
20 suction side metering chamber while the intermediate metering chamber is maintained in the condition of being hermetically sealed and moving the ejection side pressing member so as to approach the flow path block in order to transfer liquid from the ejection side metering chamber to the ejection flow path.

4. The diaphragm pump according to claim 2 or 3, characterized in that
25 the ejection step includes an ejection rate increasing step of gradually increasing the ejection rate and an ejection rate decreasing step of gradually decreasing the ejection rate and,

 among the ejection steps of the plurality of the ejection side metering chambers, if the ejection step of one of the ejection side metering chambers is in the ejection rate

increasing step, then the pressing member drive controller provides control to have the ejection step of other one of the ejection side metering chambers in the ejection rate increasing step so that the rate of ejection is maintained to a constant level.

5. The diaphragm pump according to claim 2 or 3, characterized in that

5 the flow path block has either one of the suction flow path and the ejection flow path formed along the central axis of the diaphragm-adhering surface to be adhered to the diaphragm and the other of the ejection flow path and the suction flow path formed on the outer periphery of the diaphragm-adhering surface and

the suction side metering chamber, the intermediate metering chamber and the
10 ejection side metering chamber formed along each of the liquid flow paths are displaced from each other by a first predefined angle in the circumferential direction of a circumference centered at the central axis of the diaphragm-adhering surface with the respective dimensions from the central axis differentiated from each other

while the suction side metering chambers, the intermediate metering chambers
15 and the ejection side metering chambers arranged along the respective flow paths are displaced from each other by a second predefined angle in the circumferential direction of the circumference centered at the central axis of the diaphragm-adhering surface,

the metering chambers being arranged to extend spirally from the central axis of the diaphragm-adhering surface.

20 6. The diaphragm pump according to claim 5, characterized in that

the first predefined angle is 30° while the second predefined angle is 72° and a total of five sets of liquid flow paths are provided, each having a suction side metering chamber, an intermediate metering chamber and an ejection side metering chamber.

7. The diaphragm pump according to any of claims 1 through 3, characterized in
25 that

the pressing member drive controller has a motor, an end facet cam adapted to be driven to revolve by the motor and an urging section for urging the pressing members to abut the end facet cam and

each of the pressing members reciprocates following the cam face of the end

facet cam as the end facet cam revolves.

8. The diaphragm pump according to any of claims 1 through 3, characterized in that

the diaphragm-adhering surface of the flow path block to be adhered to the
5 diaphragm is formed with recessed grooves and

the flow-path-block-adhering surface of the diaphragm to be adhered to the flow path block is formed to show a planar profile,

the liquid flow paths being defined by the respective recessed grooves of the flow path block and the flow path block adhering surface of the diaphragm.

10 9. The diaphragm pump according to any of claims 1 through 3, characterized in that

the diaphragm-adhering surface of the flow path block to be adhered to the diaphragm is formed to show a planar profile and

the flow-path-block-adhering surface of the diaphragm to be adhered to the flow
15 path block is formed with recessed grooves,

the liquid flow paths being defined by the diaphragm-adhering surface of the flow path block and the respective recessed grooves of the diaphragm.

10. The diaphragm pump according to claim 8, characterized in that
each of the recessed grooves is provided with metering recesses for defining the
20 metering chambers, communication grooves for allowing each of the metering recesses to communicate with the suction flow path or the ejection flow path and communication grooves for allowing the metering recesses to communicate with each other.

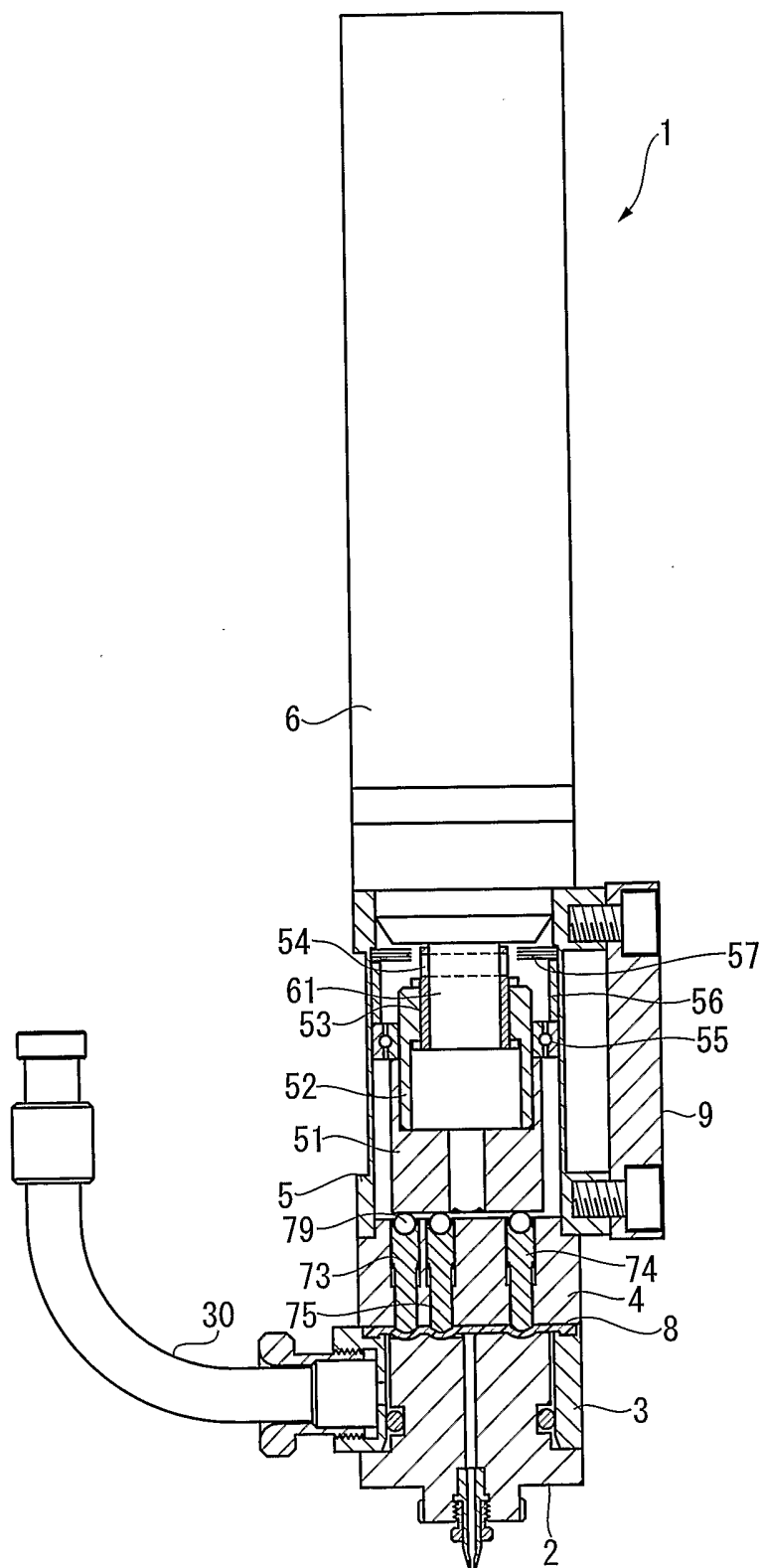
11. The diaphragm pump according to claim 9, characterized in that
each of the recessed grooves is provided with metering recesses for defining the
25 metering chambers, communication grooves for allowing each of the metering recesses to communicate with the suction flow path or the ejection flow path and communication grooves for allowing the metering recesses to communicate with each other.

12. A manufacturing apparatus of electronic component comprising the diaphragm pump according to any of claim 1 through 11, a liquid supplier for supplying the liquid to

the suction flow path of the diaphragm pump, an ejecting nozzle provided to ejection flow path, and a controller for controlling the drive section of the diaphragm pump,

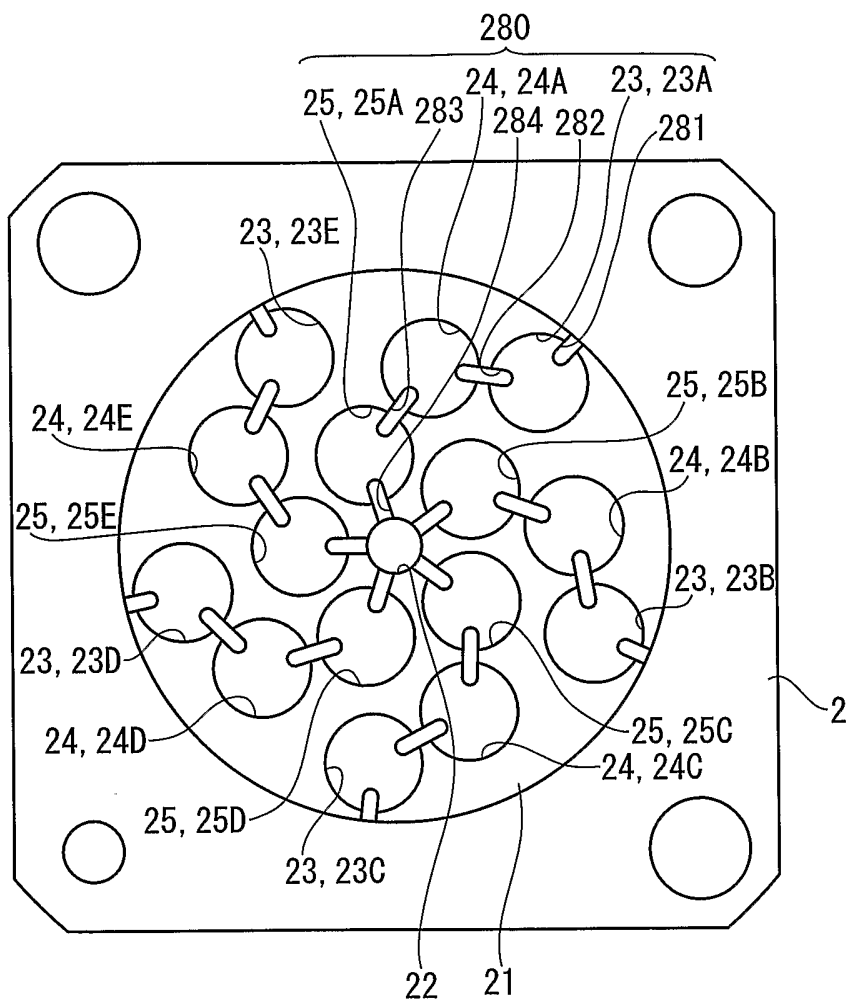
wherein the liquid supplied by the liquid supplier is ejected from the ejection nozzle through the diaphragm pump to manufacture electric components.

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FIG. 1



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FIG. 2



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FIG. 3

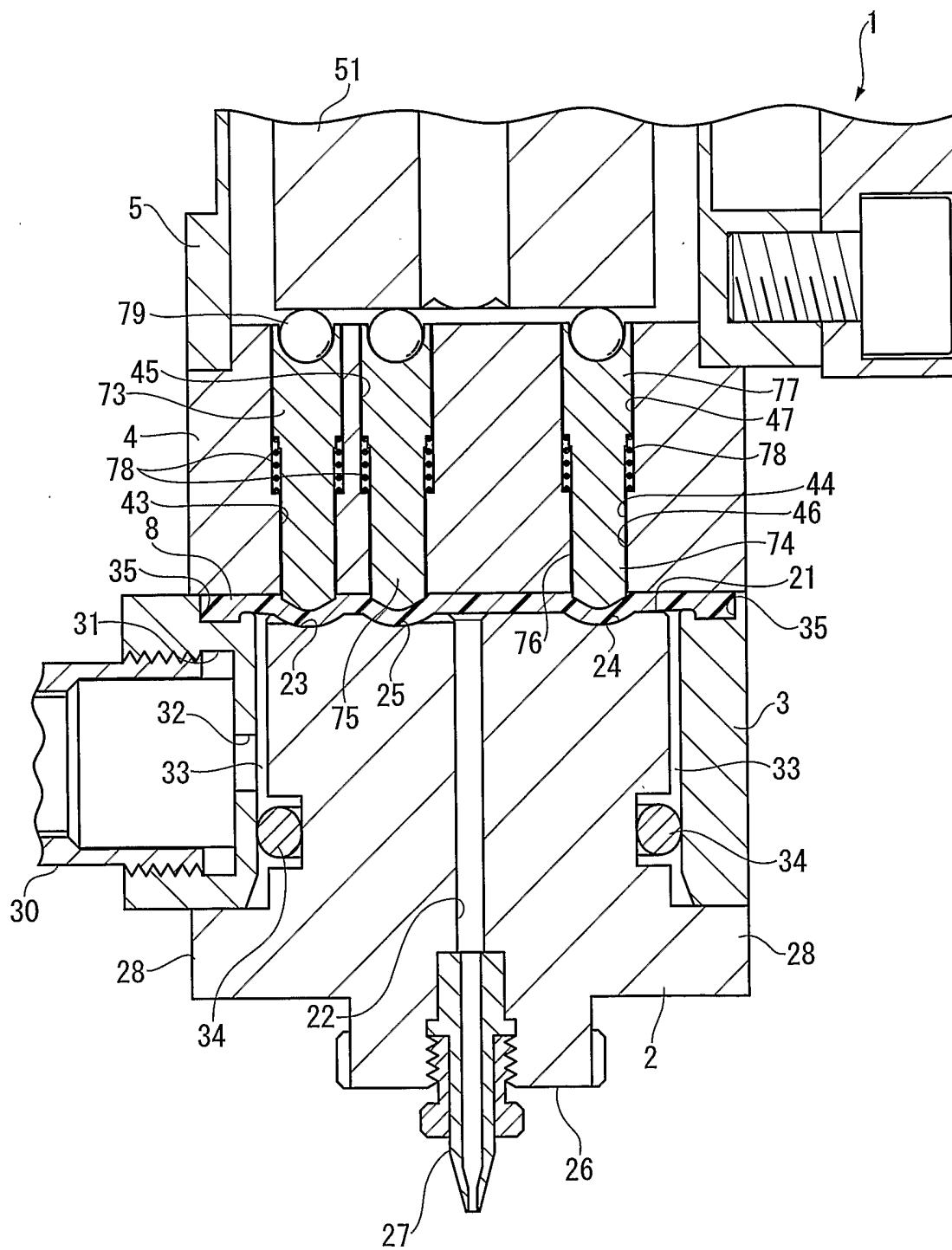
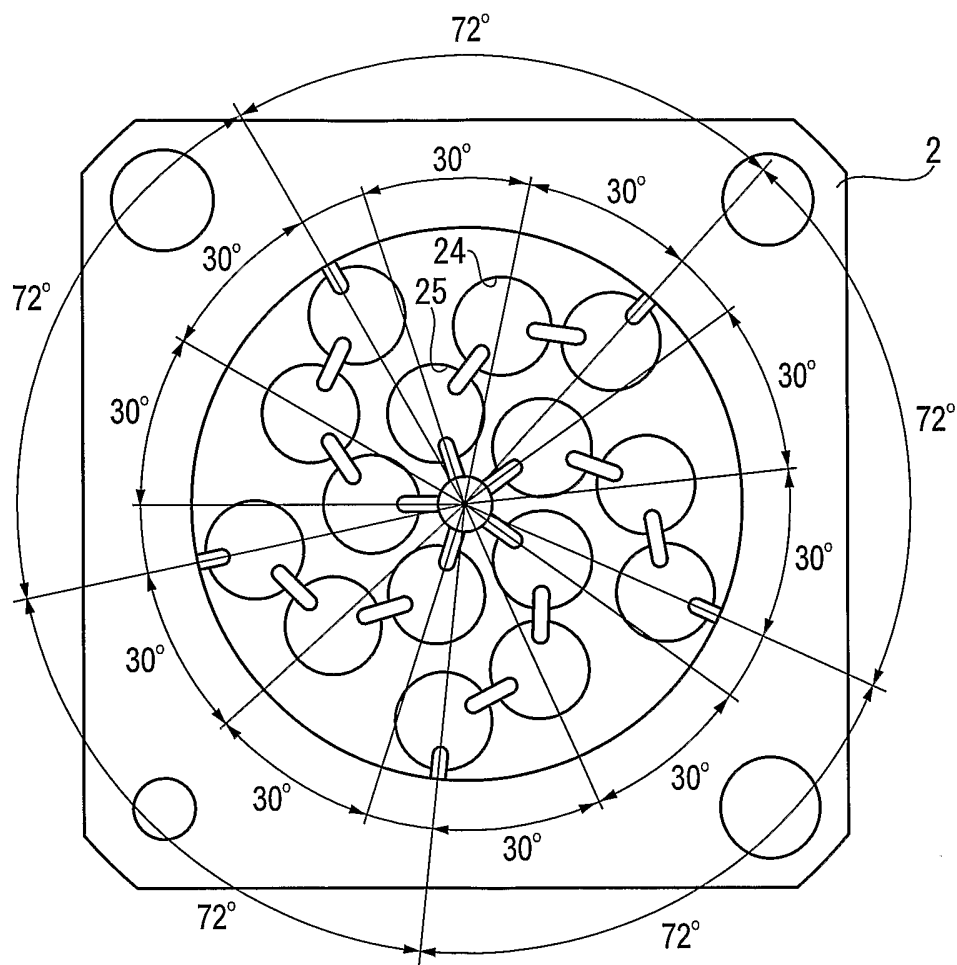


FIG. 4



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FIG. 5

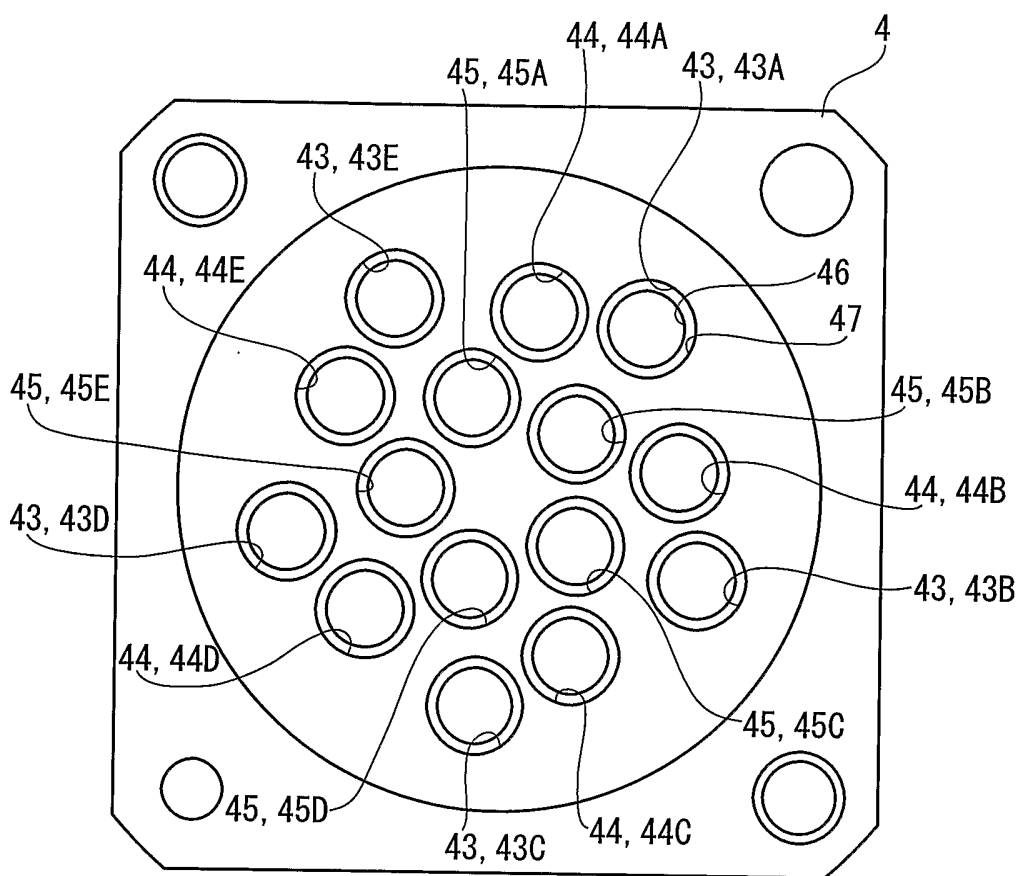


FIG.6A

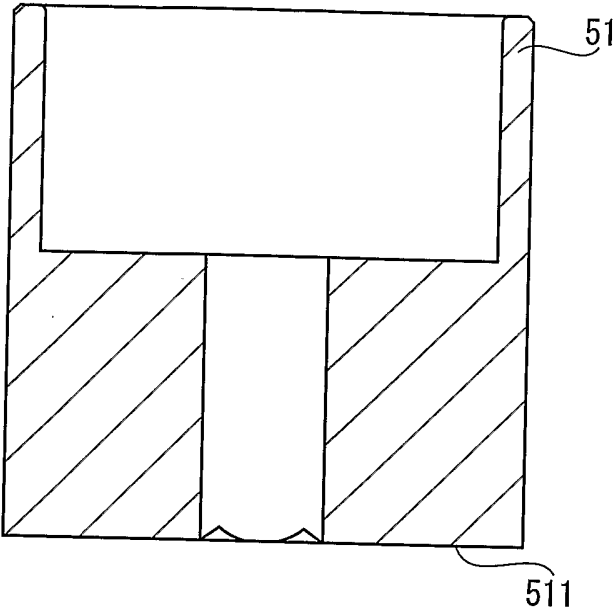


FIG.6B

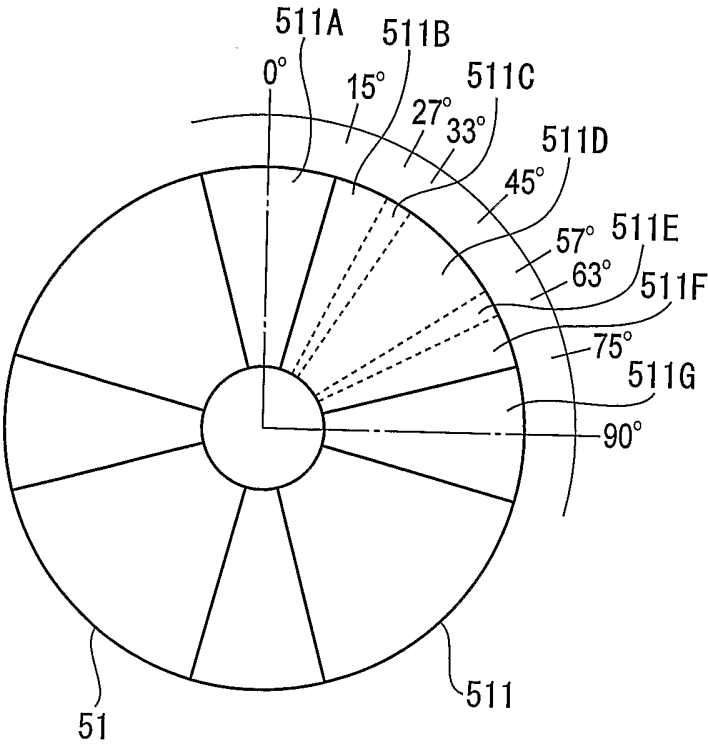


FIG. 7

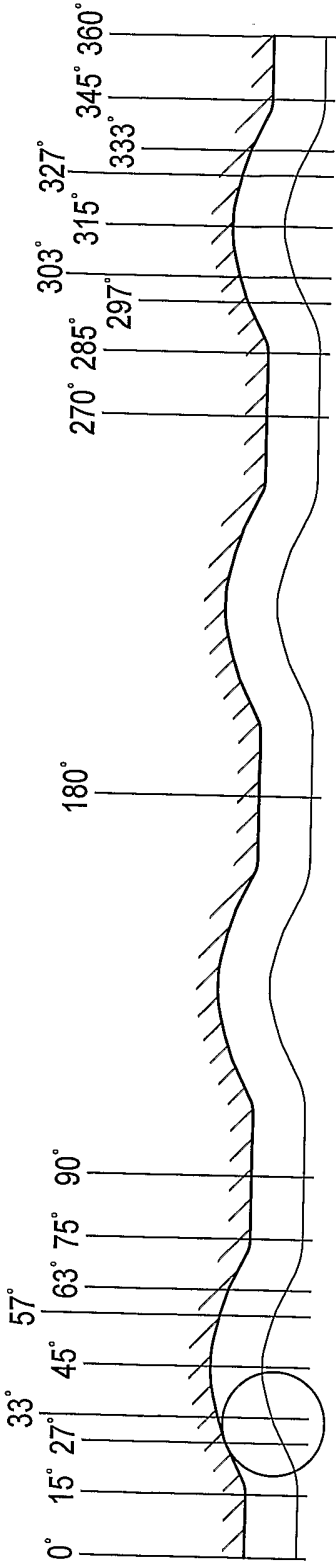


FIG. 8A

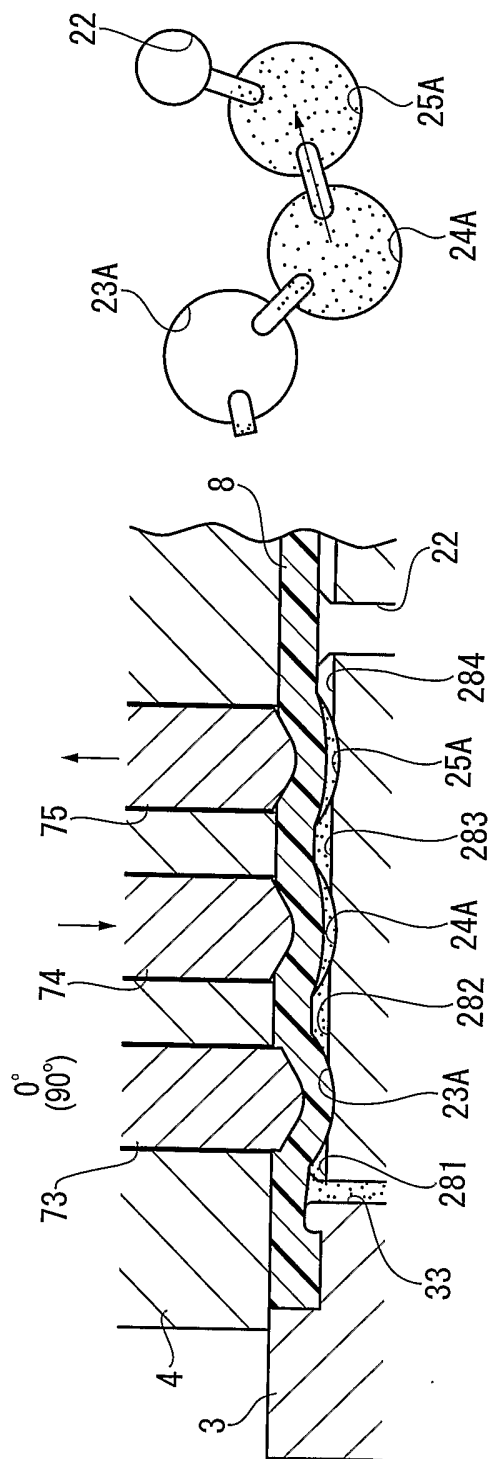


FIG. 8B

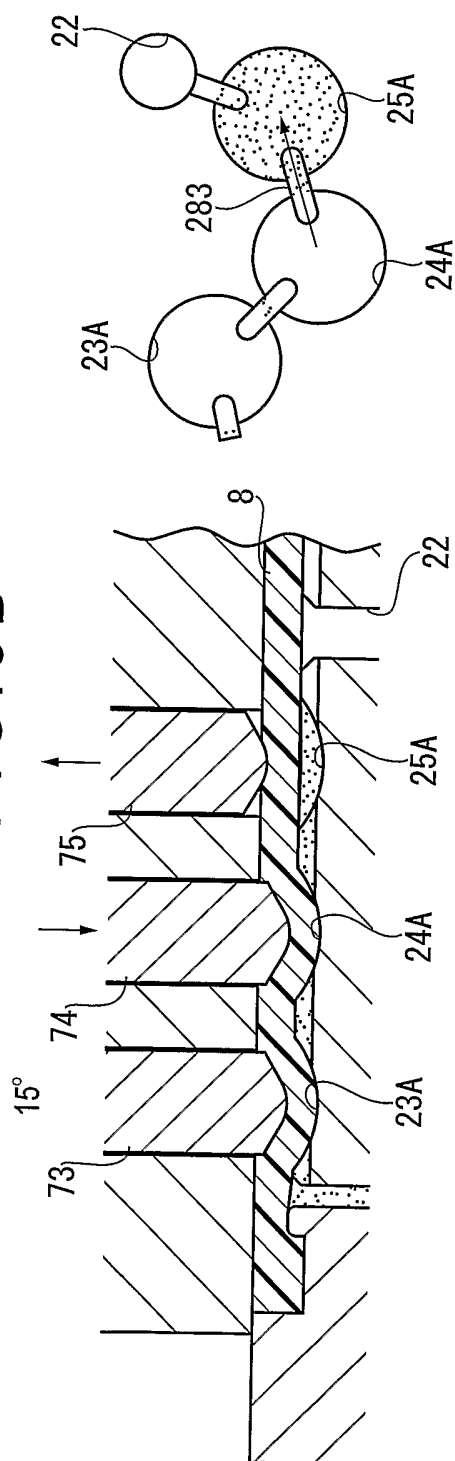


FIG. 9C

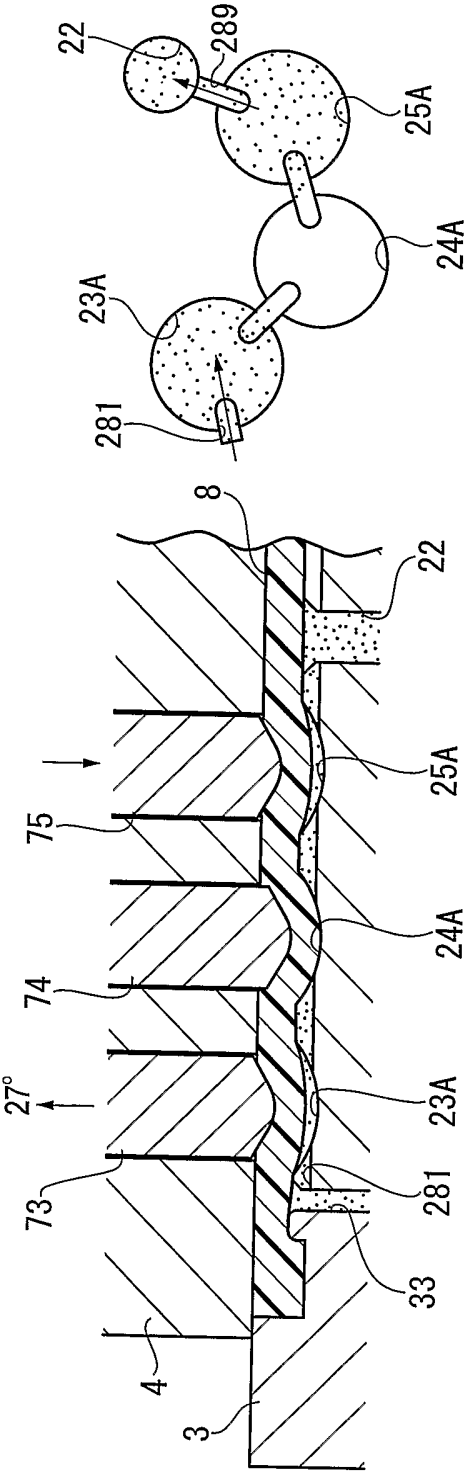


FIG. 9D

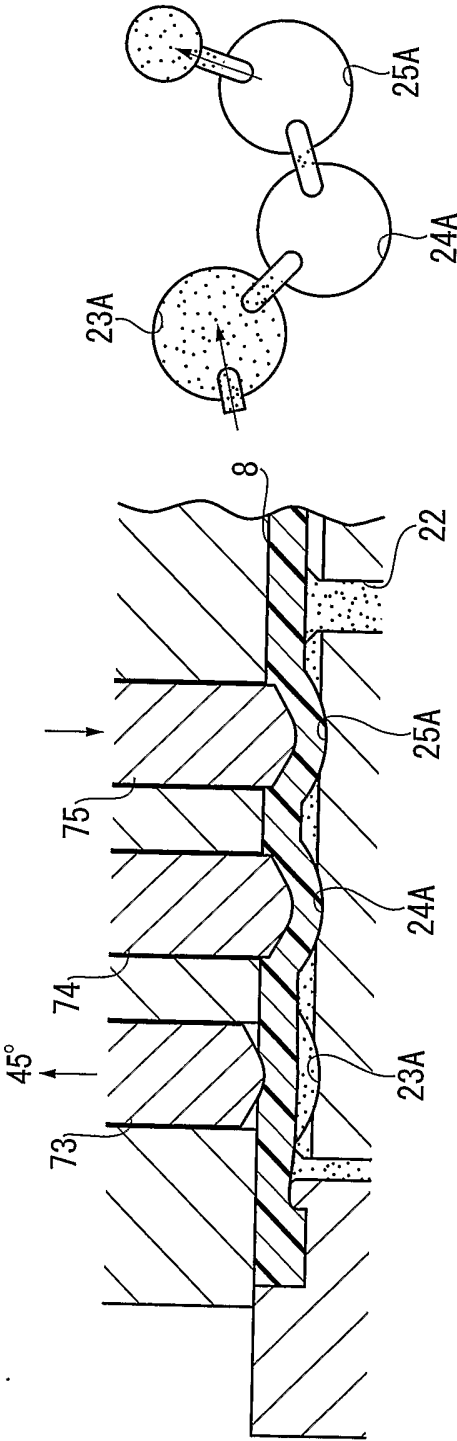


FIG. 10E

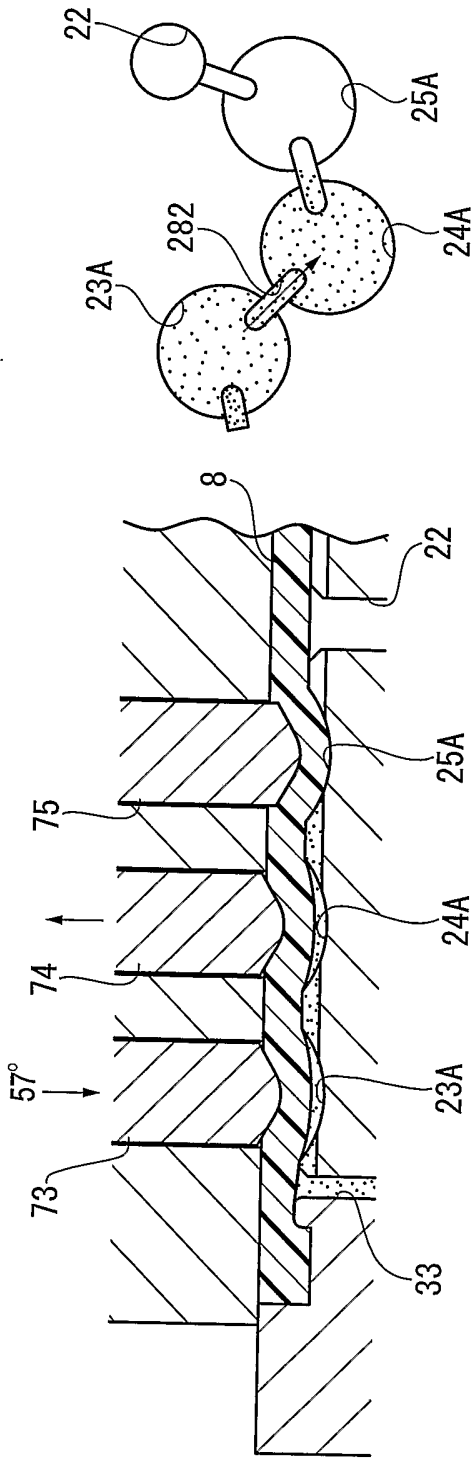


FIG. 10F

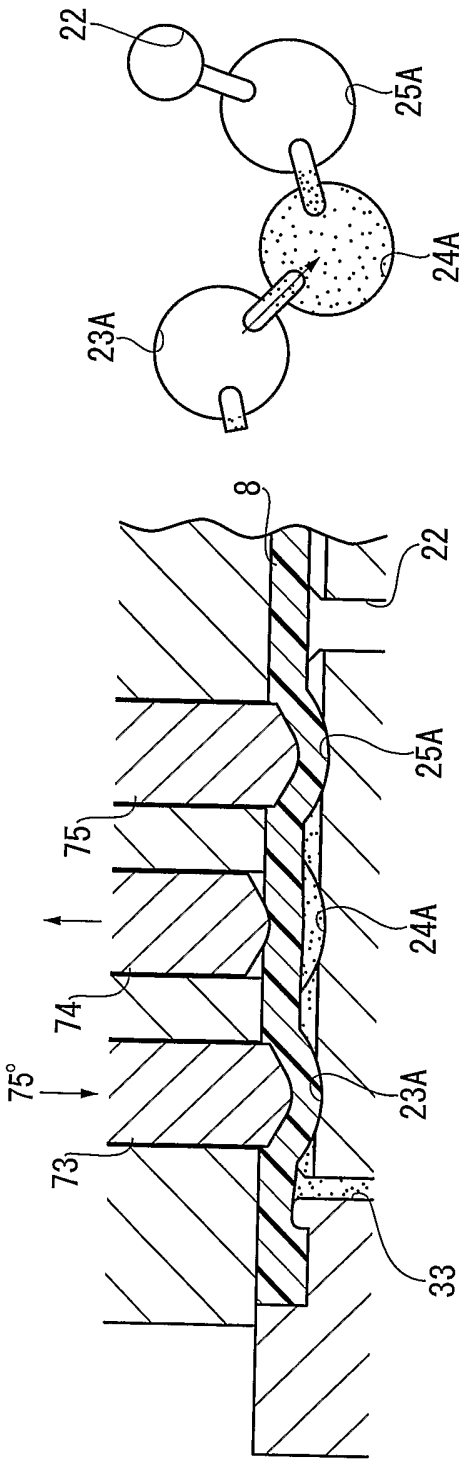
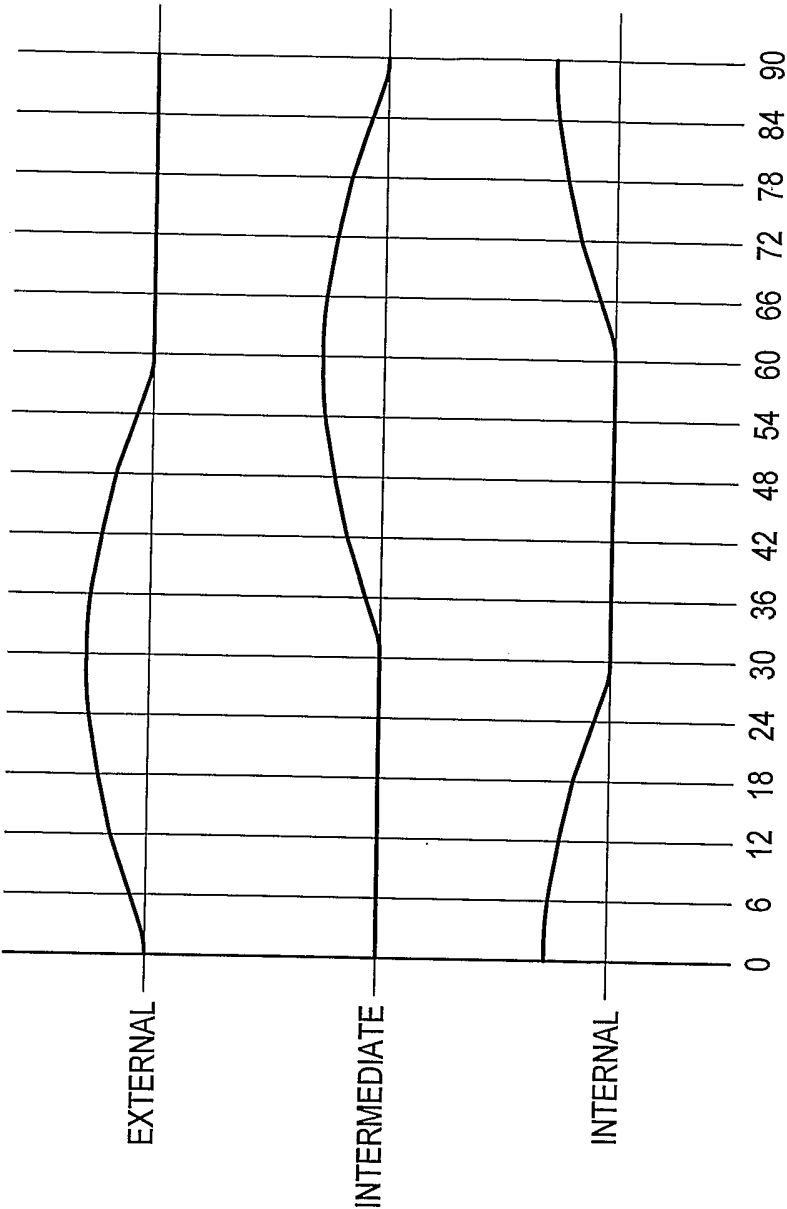
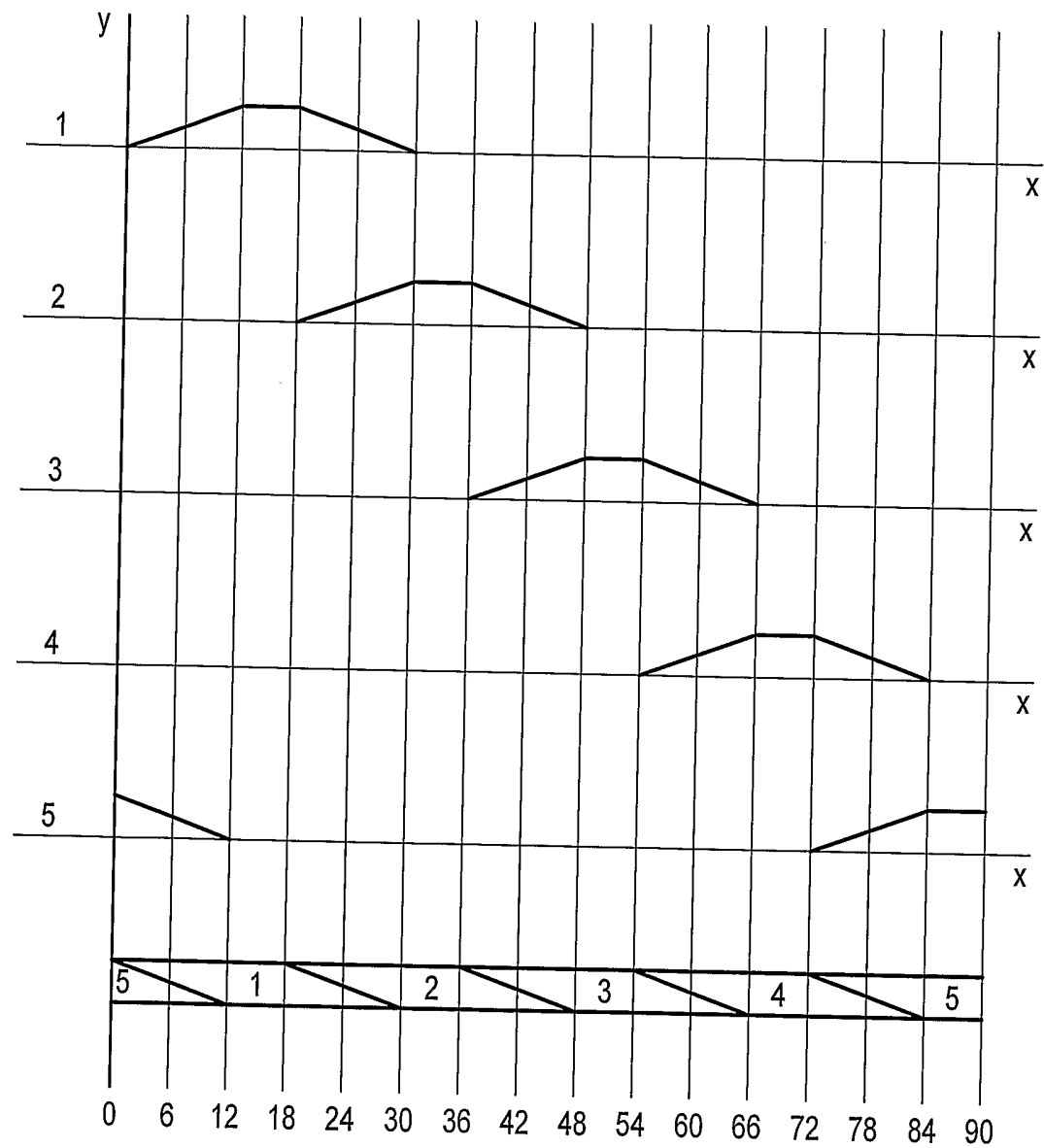


FIG. 11



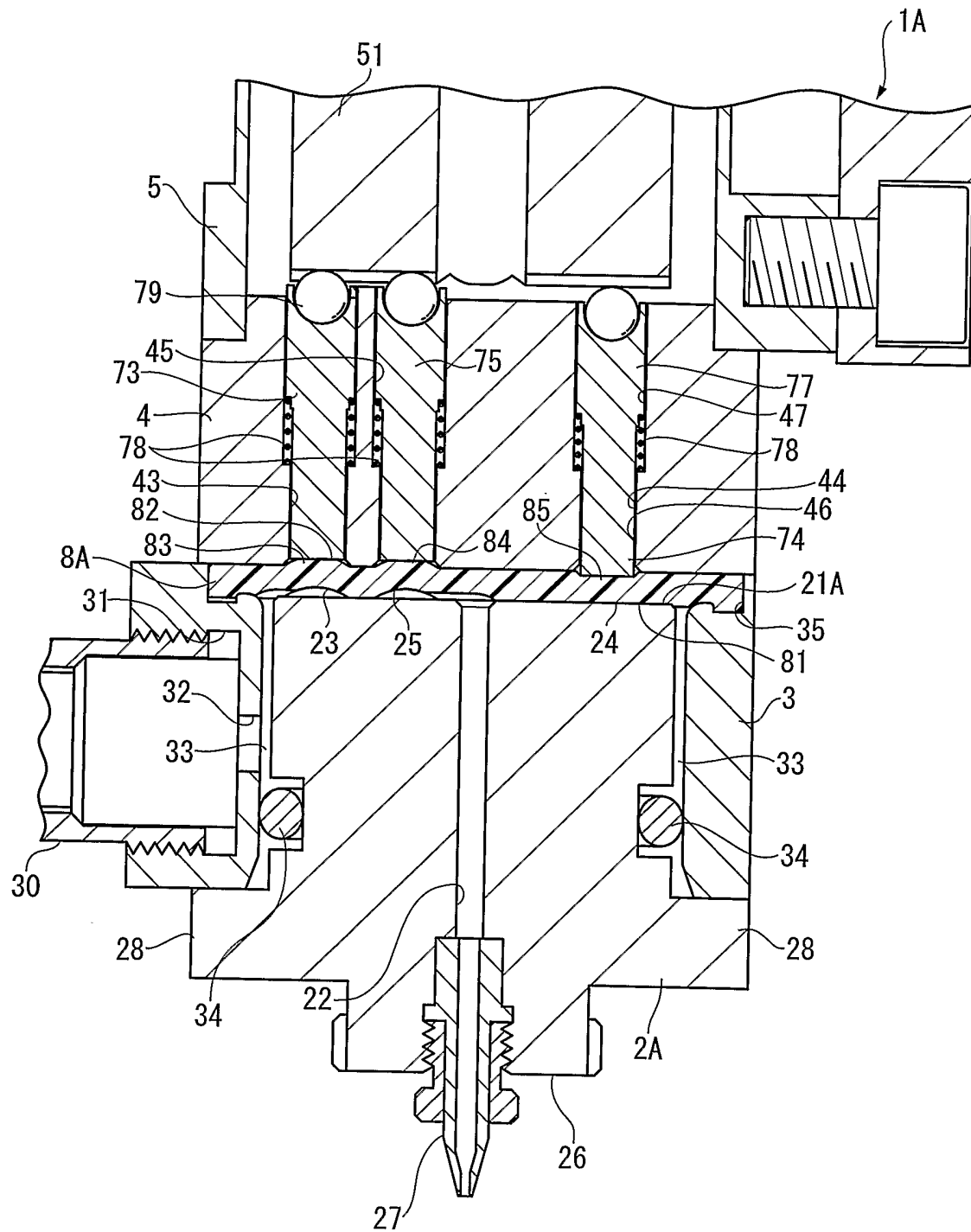
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FIG. 12



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FIG. 13



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FIG. 14A

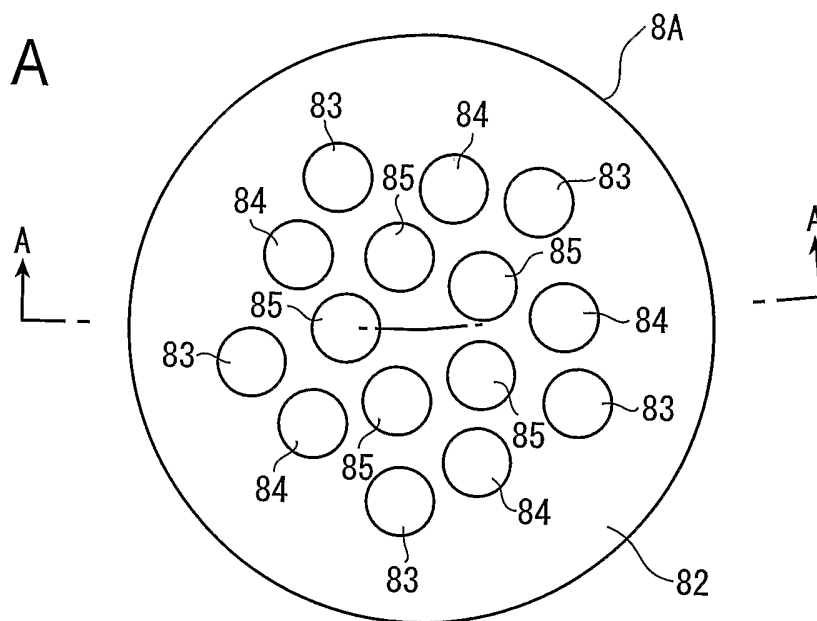


FIG. 14B

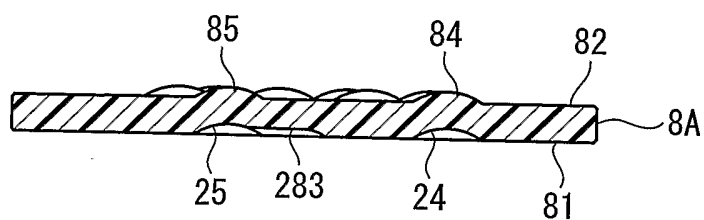
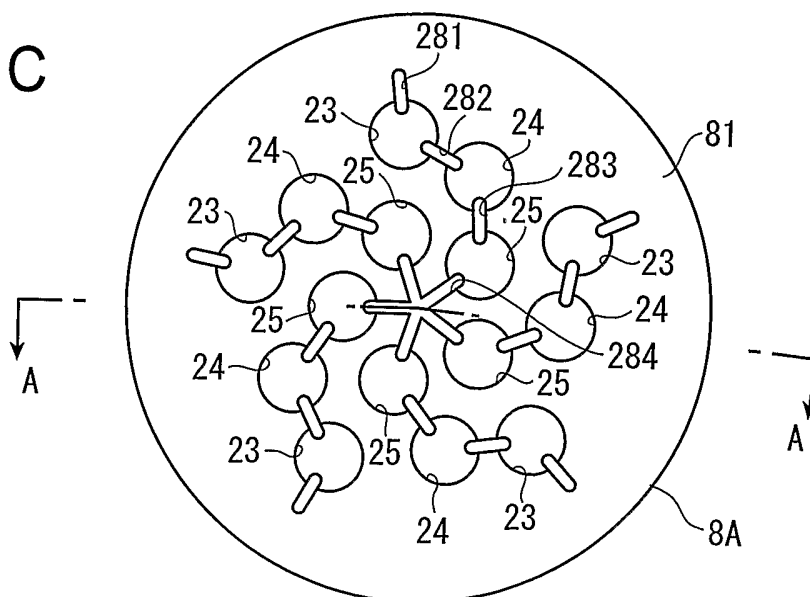
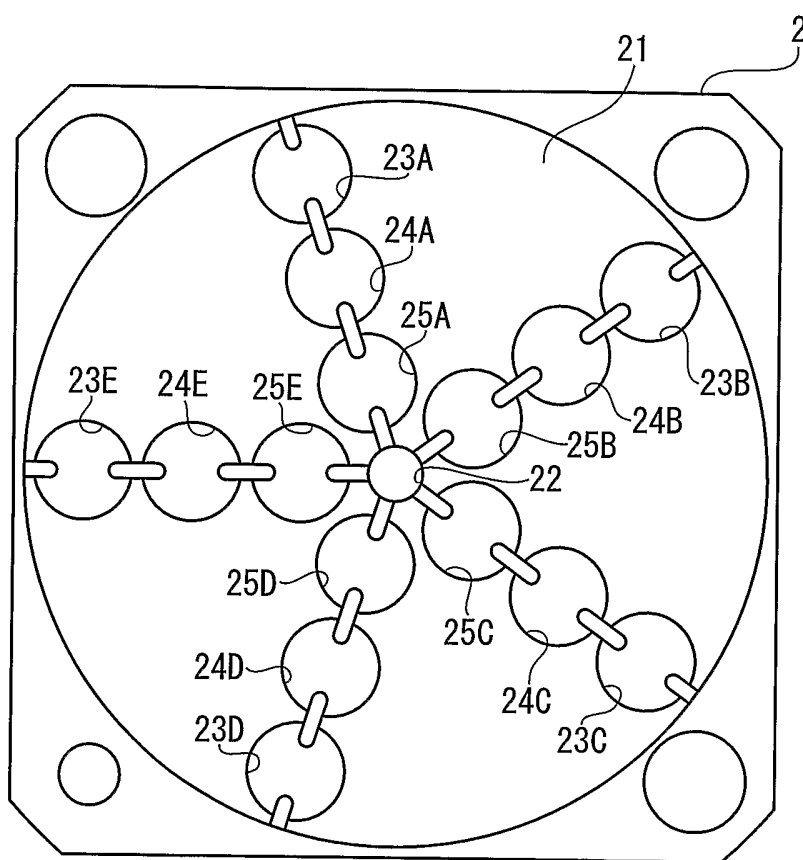


FIG. 14C

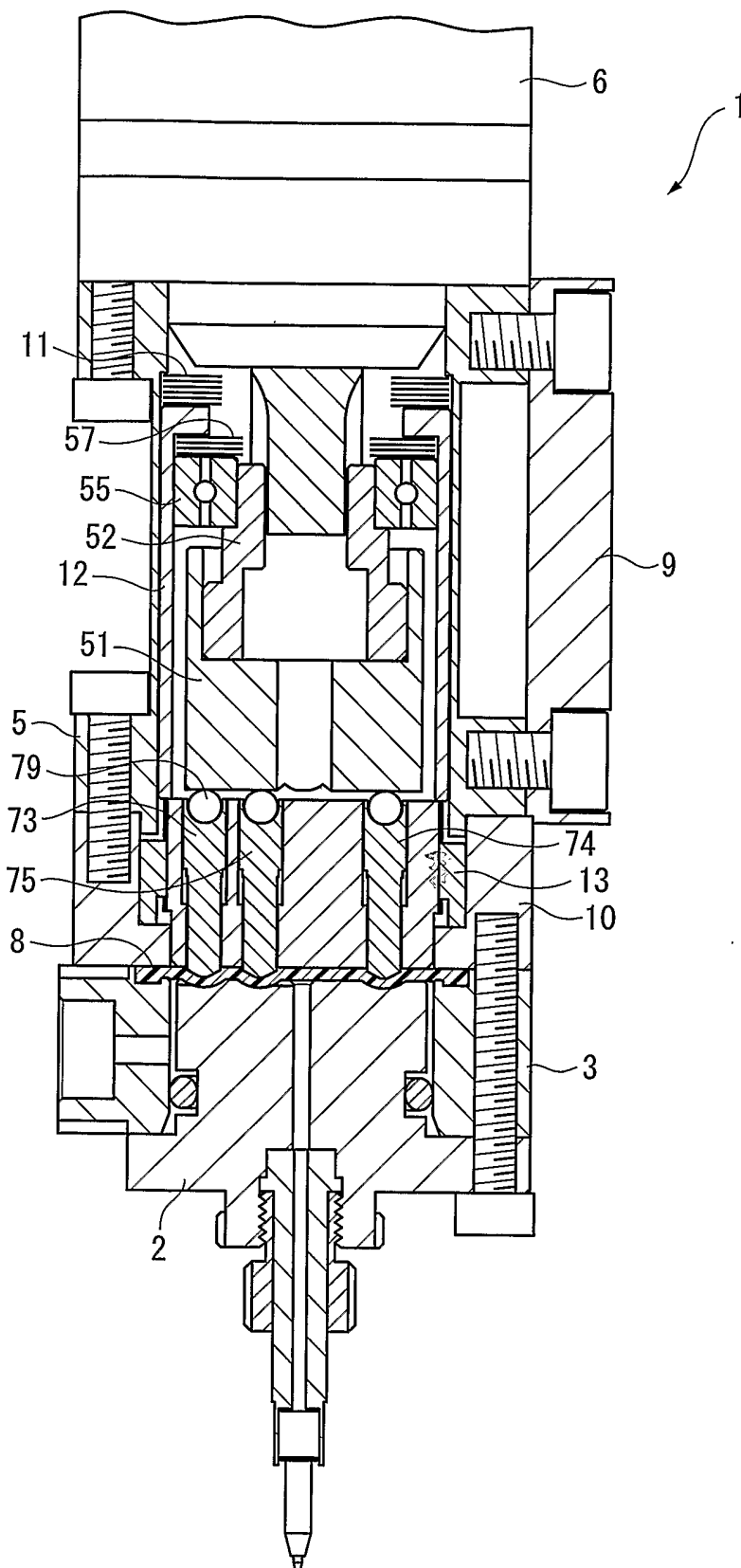


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FIG. 15



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FIG. 16



INTERNATIONAL SEARCH REPORT

International Application No

PCT/JP2004/009298

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F04B43/08

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)

IPC 7 F04B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 593 290 A (GREISCH DANNY L ET AL) 14 January 1997 (1997-01-14) column 5, line 60 - column 10, line 29; figures 1-14 abstract	1-4,7-12
X	US 4 199 307 A (JASSAWALLA JAL S) 22 April 1980 (1980-04-22) abstract; figures 3,4 column 4, line 10 - column 4, line 66	1-4,7-12
X	US 4 236 880 A (ARCHIBALD G KENT) 2 December 1980 (1980-12-02) abstract; figures 3,7	1-4

-/--



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

15 September 2004

Date of mailing of the international search report

22/09/2004

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
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INTERNATIONAL SEARCH REPORT

International Application No

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	abstract; figures -----	2-12
X	GB 2 257 478 A (YEDA RES & DEV) 13 January 1993 (1993-01-13)	1
A	abstract; figures -----	2-12
A	US 4 867 744 A (BORSANYI ALEXANDER S) 19 September 1989 (1989-09-19) column 3, line 9 - column 4, line 60; figures 2-4 -----	1-12

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Information on patent family members

International Application No

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