Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2077428 C 2003/03/18

(11)(21) 2 077 428

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(22) Date de dépôt/Filing Date: 1992/09/02

(41) Mise à la disp. pub./Open to Public Insp.: 1993/03/04

(45) Date de délivrance/Issue Date: 2003/03/18

(30) Priorités/Priorities: 1991/09/03 (HEISEI 3-250353) JP;
1992/07/28 (HEISEI 4-220617) JP

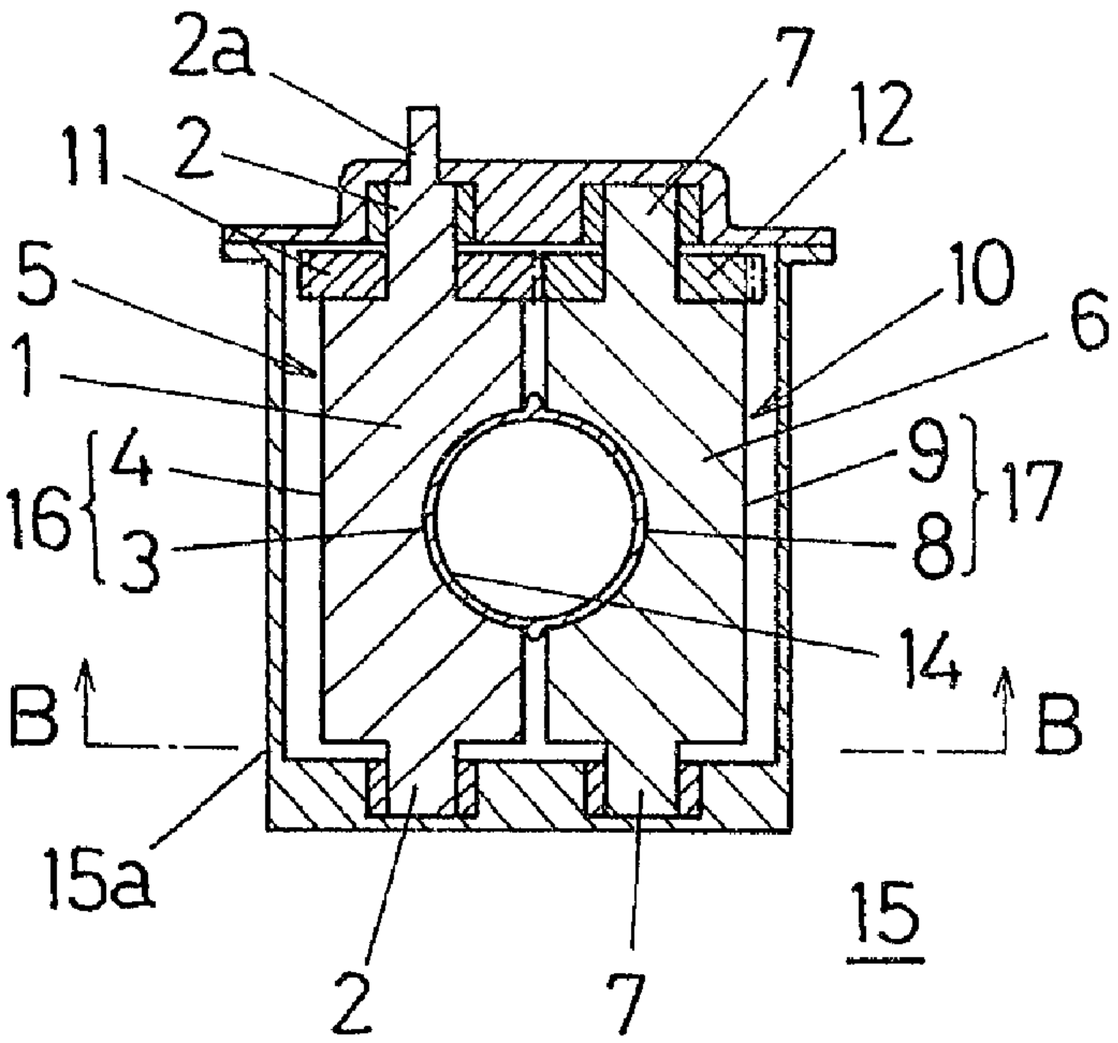
(51) Cl.Int.^{5}/Int.Cl.^{5} F16K 7/06

(72) Inventeur/Inventor:
KAWABE, RYU, JP

(73) Propriétaire/Owner:
KAWABE, RYU, JP

(74) Agent: MARKS & CLERK

(54) Titre : METHODE ET APPAREIL DESTINES A CONTROLER LE DEBIT DE FLUIDES
(54) Title: METHOD AND APPARATUS FOR CONTROLLING THE FLOW OF FLUIDS



(57) Abrégé/Abstract:
A method and apparatus is provided for controlling the flow rate of a fluid that flows through a fluid path including a resiliently deformable portion. A first roller has a cutout formed thereon on one side thereof, and a retainer is arranged in parallel with the first roller. The resiliently deformable portion of the fluid path is held between the first roller and the retainer. The first roller is rotatably supported by its rotary shaft. The first distance from the rotary shaft to the outer wall of the first roller on the side facing opposite the resiliently deformable portion may be varied in response to the variation in the angle that occurs when the first roller rotates about its rotary shaft. Thus, the second distance from the outer wall of the first roller on the side facing opposite the resiliently deformable portion to the retainer may be varied in response to the variation in the first distance, and the shape in cross section of the resiliently deformable portion may be varied according to the variation in the second distance. The flow rate of the fluid may be controlled by varying the shape in cross section of the resiliently deformable portion of the fluid path in this manner. The retainer may be replaced with the second roller having the configuration symmetrical with the first roller and being rotatably supported.

ABSTRACT OF THE DISCLOSURE

A method and apparatus is provided for controlling the flow rate of a fluid that flows through a fluid path including a resiliently deformable portion.

A first roller has a cutout formed thereon on one side thereof, and a retainer is arranged in parallel with the first roller. The resiliently deformable portion of the fluid path is held between the first roller and the retainer. The first roller is rotatably supported by its rotary shaft. The first distance from the rotary shaft to the outer wall of the first roller on the side facing opposite the resiliently deformable portion may be varied in response to the variation in the angle that occurs when the first roller rotates about its rotary shaft. Thus, the second distance from the outer wall of the first roller on the side facing opposite the resiliently deformable portion to the retainer may be varied in response to the variation in the first distance, and the shape in cross section of the resiliently deformable portion may be varied according to the variation in the second distance. The flow rate of the fluid may be controlled by varying the shape in cross section of the resiliently deformable portion of the fluid path in this manner. The retainer may be replaced with the second roller having the configuration symmetrical with the first roller and being rotatably supported.

SPECIFICATION

METHOD AND APPARATUS FOR CONTROLLING THE FLOW OF FLUIDS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a flow rate controller, and more particularly to a method of and an apparatus for controlling the flow rate of a fluid by compressing a resiliently deformable fluid path portion or releasing it from the compression.

Description of the Prior Art

As shown in Fig. 24 (a) and (b), a typical flow rate controller that is known to the relevant art, generally designated by 187, includes a fluid path 182 inside which a resiliently deformable sleeve 183, or simply a resilient sleeve, is mounted. In this construction, the resilient sleeve 183 has the peripheral marginal edges 184, 185 on the opposite sides thereof rigidly fixed to the inner wall of the fluid path 182, with a hollow space 186 formed between the inner wall of the fluid path 182 and the resilient sleeve 183. The flow rate of a fluid may be controlled by increasing or decreasing the pressure to be applied to the hollow space 186 to thereby vary the shape in cross section of the resilient sleeve 183.

According to the flow rate controller as described above, the fluid path 182 is completely closed by compressing the resilient sleeve 183 under the pneumatic pressure applied thereto, as shown in Fig. 24 (c) and (d).

This may disadvantageously cause fluid leaks or escapes through the compressed fluid path. Particularly, when the fluid flows under high pressures, more leaks or escapes may occur. Furthermore, when the resilient sleeve 183 is placed in its intermediate (half open) state between the fully opened state and fully closed state when the fluid flows under the high pressures (Fig. 24 (a) and (b)), the resilient sleeve 183 may suffer small vibrations which cause the fluid to flow therethrough at varying rates.

SUMMARY OF THE INVENTION

In one aspect of the present invention, the problems described above in connection with the prior art are solved by providing a flow rate control by using a combination of cylindrical roller and retainer that are arranged to face opposite each other and hold a resiliently deformable fluid path portion (or simply a resilient portion) therebetween, the roller having an cutout on one side which is formed such that the distance from its rotary shaft to the outer wall of the roller on the side facing opposite the fluid path varies every time the roller rotates through a particular angle. The flow rate may be controlled by rotating the roller in this manner to press upon the resilient fluid path portion or release it.

In another aspect of the present invention, those problems are also solved by providing a flow rate controller that includes a resilient fluid path and a combination of cylindrical roller and retainer arranged to face opposite each other and hold a resiliently deformable fluid path portion (or simply a resilient portion) therebetween, the roller having a cutout on one side which is formed such that the distance from its rotary

shaft to the outer wall of the roller on the side facing opposite the fluid path varies every time the roller rotates through a particular angle. The flow rate may be controlled by rotating the roller in this manner to press upon the resilient fluid path portion or release it.

According to the method of the present invention, a first roller is provided in parallel with a retainer for holding a resilient fluid path together with the first roller. The first roller is rotated on its rotary shaft, and the distance from the rotary shaft to the outer wall of the first roller on the side facing the resilient fluid path portion may be varied every time the first roller rotates through a particular angle. The distance from the outer wall of the first roller on the side facing the resilient fluid path portion to the retainer on the side facing the opposite resilient fluid path portion may be varied accordingly. The shape in cross section of the resilient fluid path portion may be varied by varying this distance. The flow rate of the fluid that can flow through the resilient portion may be varied accordingly. Alternatively, a common roller may be provided for concurrently controlling the flow rates of the fluids that flow through several fluid paths. The retainer may be formed symmetrically to the first roller so that it provides the symmetric surface, and may also be provided for rotatable.

According to the apparatus of the present invention, a casing is provided for accepting the resilient portion of the fluid path. In the casing, a first roller is provided in parallel with a retainer. The first roller is rotatably supported, and holds the resilient fluid path portion together with the retainer. The part of the first roller holding the resilient portion provides a control part, which is formed such that the distance from the rotary shaft of the first roller to the outer wall

of the first roller on the side facing the resilient fluid path portion may be varied according to every predetermined angle through which the first roller rotates about its rotary shaft. The part of the retainer on the opposite side of the resilient fluid path portion facing the first roller is provided in parallel with the rotary shaft of the first roller. A single first roller may include such several control parts.

The retainer may be formed symmetrically to the first roller so that it provides the symmetric surface, and also may be rotatably supported. The first roller has the cylindrical form, and its control part includes a cutout formed on one side of the first roller. The outer wall of the first roller on the side opposite the cutout is formed such that at least part of the outer wall of the first roller on the side opposite the cutout can engage the resilient fluid path portion when the first roller rotates about its rotary shaft. Alternatively, the first roller has the cylindrical form, and may be mounted to its rotary shaft off its center so that it can rotate eccentrically.

According to the variation of the apparatus, the first roller may include a peripheral guide track formed around its outer wall that always engages the outer peripheral wall of the resilient fluid path portion, and is formed so that it can follow any variation in the shape in cross section of the resilient fluid path portion that occurs when the first roller rotates about its rotary shaft. In an alternative form of the first roller assembly, it may include a plurality of smaller-diameter rollers supported on their respective parallel shafts. The rotary shaft supporting the first roller may be coupled with means for moving the rotary shaft. The means for moving the rotary shaft may comprise the rack and pinion arrangement in which the rotary shaft is connected with the pinion which engages the rack.

The peripheral guide track formed around the outer wall of the first roller as described above may be provided on either or both of first and second rollers, and may be formed like a strip that is raised on the surface or may be formed on the upper portion of the first roller that is diameterically enlarged to provide a raised surface.

The retainer is a roller having has the cylindrical form as described, but may instead be provided by the wall surface of the casing in which the first roller is supported.

According to the method and apparatus of the invention as described so far, the resilient portion of the fluid path may be controlled by holding it between the outer wall on the control part of the first roller and the retainer in parallel with the first roller. There is no risk that the resilient portion held between the control part of the first roller and retainer will vibrate even if the fluid flows at the high velocity through the resilient fluid path portion. Thus, the flow rate of the fluid can be controlled accurately. When the resilient portion is to be closed fully, the outer wall on the control part of the first roller and the retainer can securely hold and press upon the resilient portion, and the resilient portion can be closed completely. Therefore, no fluid escape will occur and flow through the resilient portion even when the fluid is under the high pressures.

The first roller includes the peripheral guide track formed around the outer wall of the control part on the first roller that always engages the outer peripheral surface of the resilient portion of the fluid path and follows any variation in the shape in cross section of the resilient portion, when the first roller rotates about its rotary shaft. This peripheral guide track ensures that the resilient portion can have the appropriate variations in the shape in cross section when

the shape in cross section of the resilient portion is varied by rotating of the first roller. This fully closing and fully opening sequence is repeated, if this sequence is repeated by the rotating of the first roller which does not have such peripheral guide track, it is possible that there may be irregularities in the variation in, the shape in cross section of the resilient portion every time this sequence is repeated. On this event, the resilient portion may gradually lose its resilience, and must be replaced frequently. According to the present invention, the peripheral guide track on the first roller is provided for ensuring that the shape in cross section of the resilient portion can be varied appropriately in a predetermined shape by following the guide track when the sequence is repeated. Thus, the resilient portion will be able to retain its resilience, so there is no need of replacing it frequently.

The first roller may have several control parts, and the flow rates for the fluids through several fluid paths can be controlled by the combination of the first roller having several control parts and the retainer. This construction may provide multi-way valve functions. It may be apparent from the above description that the method and apparatus of the present invention may have a broad range of applications.

In one aspect, the invention provides an apparatus for controlling the rate of fluid flow through a conduit, comprising a resiliently deformable tube extending along a first axis, and arranged to communicate in use at each end with the conduit for fluid flow along the tube, an abutment surface adjacent one side of an outer wall of a portion of the length of the tube, and a pinch roller mounted eccentrically for rotation about a second axis non-parallel with the tube axis, adjacent an opposite side of the outer wall of the portion of the tube, the pinch roller being arranged progressively to pinch the tube at its the portion by deforming its wall progressively towards the abutment surface as a function of progressive rotation of the pinch roller about the second axis, the tube varying correspondingly progressively between being completely open and being pinched closed with its walls pinched in a predetermined plane parallel to the second axis, wherein the abutment surface is a working surface of a second pinch roller mounted for rotation on the opposite side of the predetermined plane of pinching so that the tube is pinched between the two pinch rollers; and wherein the two pinch rollers are of the same configuration and are mounted on parallel axes for contrary rotation, maintaining symmetry about the predetermined plane of pinching, the apparatus being characterized in that the pinch roller is shaped and positioned such that, for the entire rotational range of operation, the part of its working surface facing the predetermined plane of pinching is smoothly curved with a constant or slowly-varying radius of curvature, being convex in a section normal to the pinch roller axis, whereby the working surface, in use, engages and deforms the tube wall progressively with a smooth camming action, throughout the rotational range of operation, towards the predetermined plane with progressive rotation of the pinch roller.

In another aspect, the invention provides a method of controlling the rate of fluid flow through a conduit, using a resilient deformable tube extending along a first axis and communicating at each end with the conduit for fluid flow along the tube, an abutment surface adjacent one side of the outer wall of a portion of the length of the tube, and a pinch roller mounted eccentrically for rotation about a second axis non-parallel with the tube axis, adjacent the opposite side of the outer wall of the portion of the tube, comprising progressively varying the degree of pinching of the tube at its the portion, and thereby the resistance to fluid flow to the conduit, by deforming the tube wall progressively towards or away from the abutment surface as a function of progressive rotation of the pinch roller about the second axis, the tube varying correspondingly progressively between being completely open and being pinched closed with its walls pinched in a predetermined plane parallel to the second axis, wherein the abutment surface is the working surface of a second pinch roller mounted for rotation on the opposite side of the predetermined plane of pinching so that the tube is pinched between the two pinch rollers, and the two pinch rollers are of the same configuration and mounted on parallel axes for contrary rotation, maintaining symmetry about the predetermined plane of pinching, wherein the pinch roller is shaped and positioned such that, for the entire rotational range of operation, the part of its working surface facing the predetermined plane of pinching is smoothly curved with a constant or slowly-varying radius of curvature, being convex in a section normal to the pinch roller axis, whereby the working surface engages and deforms the tube wall progressively with a smooth camming action, throughout the rotational range of operation, towards or away from the predetermined plane with progressive rotation of the pinch roller.

In an further aspect, the invention provides an apparatus for controlling the flow rate of a fluid flowing through a fluid path at least partially defined by a resiliently deformable conduit portion, comprising a casing having the resiliently deformable conduit portion extending therethrough, a first roller and a second roller both rotatably supported in the casing by respective rotary shafts located along respective longitudinal axes of the first and second rollers in the casing, the first roller and the second roller having the resiliently deformable conduit portion therebetween, and a control surface defined on the first roller for pressing the resiliently deformable conduit portion toward the second roller to control fluid flow through the conduit portion, the control surface comprising a first surface portion that is curved as viewed in section, the section being taken perpendicular to the rotary shaft of the first roller, and the first surface portion engaging and closing the resiliently deformable conduit portion in a closed position of the first roller, and a second surface portion that is curved as viewed in section, the section being taken perpendicular to the rotary shaft of the first roller, the second surface portion being positioned along one side of the resiliently deformable conduit portion in an open position of the first roller, wherein the first and second

surface portions of the control surface of the first roller are located at the same axial position along the first roller, and wherein the first and second surface portions are at least partially located at different radial distances from the longitudinal axis of the first roller, wherein the first roller has a plurality of the control surfaces thereon, and wherein the second roller is symmetrical with respect to the first roller, the second roller being rotatably mounted in the casing parallel to the first roller.

In a further aspect, the invention provides an apparatus for controlling the flow rate of a fluid flowing through a fluid path at least partially defined by a resiliently deformable conduit portion, comprising a casing having the resiliently deformable conduit portion extending therethrough, a first roller and a second roller both rotatably supported in the casing by respective rotary shafts located along respective longitudinal axes of the first and second rollers in the casing, the first roller and the second roller having the resiliently deformable conduit portion therebetween, and a control surface defined on the first roller for pressing the resiliently deformable conduit portion toward the second roller to control fluid flow through the conduit portion, the control surface comprising a first surface portion that is curved as viewed in section, the section being taken perpendicular to the rotary shaft of the first roller, and the first surface portion engaging and closing the resiliently deformable conduit portion in a closed position of the first roller, and a second surface portion that is curved as viewed in section, the section being taken perpendicular to the rotary shaft of the first roller, the second surface portion being positioned along one side of the resiliently deformable conduit portion in an open position of the first roller, wherein the first and second surface portions of the control surface are located on opposite sides of the first roller with respect to the longitudinal axis thereof, wherein the first roller has a plurality of the control surfaces thereon, and wherein the second roller is symmetrical with respect to the first roller, the second roller being rotatably mounted in the casing parallel to the first roller.

BRIEF DESCRIPTION OF THE DRAWINGS

Those and other objects, features, and advantages of the present invention will become apparent from the detailed description of several preferred embodiments that will follow by reference to the accompanying drawings, in which:

Fig. 1 illustrates a roller in one preferred embodiment of the present invention, as well as the states in which the indexing motion of

the roller occurs, in which Fig. 1 (a) is a front view of the roller, and Figs. 1 (b) through (g) show respective sectional views of the roller taken along the line A-A in Fig. 1 (a), when the roller are in the different states after it has rotated successively through every specific angle in the clockwise direction;

Fig. 2 (a) is a longitudinal cross-section view of the roller arrangement in Fig. 1, and Fig. 2 (b) is a sectional view of the roller arrangement taken along the line B-B in Fig. 2 (a);

Fig. 3 shows a sectional views of the roller arrangement in Fig. 2 that have rotated through every specific angle, in which Fig. 3 (a) shows that the resilient fluid path portion opens fully, Fig. 3 (b) shows that the resilient fluid path porion opens half, and Fig. 3 (c) shows that the resilient fluid path portion closes fully;

Fig. 4 shows the cross section of the rollers in the states shown in Fig. 3, in which Fig. 4 (a) is a sectional view taken along the line C-C in Fig. 3 (a), Fig. 4 (b) is a sectional view taken along the line D-D in Fig. 3 (b), and Fig. 4 (c) is a sectional view taken along the line E-E in Fig. 3 (c);

Fig. 5 is a sectional view of a roller arrangement in another embodiment;

Fig. 6 shows the mounting of the rollers, in which Fig. 6 (a) is a perspective view, Fig. 6 (b) is a longitudinal section view, and Fig. 6 (c) is a transversal section view;

Fig. 7 (a) and Fig. 7 (b) represent the variations of the roller shown as the persepctive view, respectively;

Fig. 8 is a sectional view of another embodiment including an intermediate film coating between the rollers and the resilient fluid path;

Fig. 9 shows another variation of the rollers including respective peripheral guide tracks, in which Fig. 9 (a) a perspective view, and Figs. 9 (b) through (d) are longitudinal cross sections of the rollers that have rotated through the different specific angles;

Figs. 10 (a) through (d) are front views of variations of the roller arrangement each including different peripheral guide tracks other than those shown in Fig. 9;

Fig. 11 illustrates a roller in another preferred embodiment, in which Fig. 11 (a) is a front view, Fig. 11 (b) is a sectional view taken along the line F-F in Fig. 11 (a), and Fig. 11 (c) is a longitudinal cross-section view of the roller arrangement in this embodiment;

Fig. 12 illustrates a roller in a further preferred embodiment, as well as the states in the indexing motion of the roller occurs, in which Fig. 12 (a) is a front view, and Figs. 12 (b) through (d) are sectional views taken along the line G-G through the line K-K in Fig. 12 (a) when the roller is in the different states after it has rotated through every 120° angle;

Fig. 13 illustrates the roller arrangement according to Fig. 12 that provides the fluid filtering functions, in which Fig. 13 (a) shows the filtering process, Fig. 13 (b) shows the backward cleaning process, and Fig. 13 (c) shows the forward cleaning process;

Fig. 14 shows a longitudinal cross section of a roller arrangement in another preferred embodiment when the rollers are in the different states, in which Fig. 14 (a) shows that the rollers are at the reference angle, and Fig. 14 (b) shows that the rollers have rotated through 180°;

Fig. 15 shows a section of a roller arrangement in another preferred embodiment when the rollers are in the different states, in which Fig. 15 (a) shows that the rollers are at the reference angle, and Fig. 15 (b)

shows that the rollers have rotated through a particular angle;

Fig. 16 shows different variation of the embodiment, in which Fig. 16 (a) is a plan view of one variation, Fig. 16 (b) is a side elevation of the same, and Fig. 16 (c) is s plan view of another variation;

Fig. 17 shows the roller arrangement according to another preferred embodiment, in which Fig. 17 (a) is a perspective view, and Fig. 17 (b) is a plan view;

Fig. 18 shows the roller arrangement according to a further preferred embodiment, in which Fig. 18 (a) is a plan view, and Figs. 18 (b) through (d) illustrate respective sectional views of the roller arrangement in this embodiment in the different states after it has rotated successively through every specific angle;

Fig. 19 shows the roller arrangement according to still another preferred embodiment, in which Fig. 19 (a) is a perspective view, Fig. 19 (b) is a plan view, and Fig. 19 (c) illustrates a sectional view of this roller arrangement in a particular state;

Fig. 20 shows the roller arrangement according to a further preferred embodiment, in which Fig. 20 (a) is a front view, and Fig. 20 (b) is a sectional view taken along the line M-M in Fig. 20 (a);

Fig. 21 shows the roller arrangement according to another preferred embodiment, in which Fig. 21 (a) is a perspective view, and Figs. 21 (b) and (c) illustrate a sectional view of this roller arrangement in different states;

Fig. 22 shows the roller arrangement according to another preferred embodiment, in which Fig. 22 (a) is a front view, and Figs. 22 (b) through (d) are sectional views taken along the line N-N through the line R-R, showing the states of the roller that has rotated through every angle of 120°;

Fig. 23 illustrates the roller arrangement according to Fig. 22 that provides the fluid filtering functions, in which Fig. 23 (a) shows the filtering process, Fig. 23 (b) shows the forward cleaning process, and Fig. 23 (c) shows the backward cleaning process; and

Figs. 24 (a) and (c) represent sectional views of the typical prior art roller arrangement, in which Fig. 24 (b) corresponds to Fig. 24 (a), showing a longitudinal section view, and Fig. 24 (d) corresponds to Fig. 24 (c), showing a longitudinal section view.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

EXAMPLE 1

Referring first to Figs. 1 through 5, a first preferred embodiment of the present invention is described.

A roller assembly, generally designated by 5, includes a roller 1 having a cylindrical form, and a central shaft 2 passing through the roller 1. The roller 1 has a cutout portion 3 formed centrally on one lateral side thereof and an engaging portion 4 on the opposite lateral side. See Fig. 1 (a) and (b).

Similarly, another roller assembly, generally designated by 10, includes a roller 6 having a cylindrical form, and a central shaft 7 passing through the roller 6. The roller 6 has a cutout portion 8 formed centrally on one lateral side thereof and an engaging portion 9 on the opposite lateral side. This is not shown in Fig. 1. Instead, it may be seen from Fig. 2. The roller assemblies 5 and 10 are symmetrical, and are operatively linked together.

A casing 15a houses the roller assemblies 5, 10 whose respective shafts 2, 7 are rotatably mounted to the casing 15a such that the roller

assemblies are arranged in parallel and face opposite each other with a spacing therebetween. Each of the shafts 2, 7 has a gear 11, 12 rigidly fixed to one end thereof. Those gears 11, 12 mesh with each other. The shafts 2, 7 are rotatably supported at both ends by the casing 15a. For example, the shaft 2 has an extension 2a on one side thereof, which projects out of the casing 15a. This extension 2a composes an operating part and may be coupled with an operating handle (not shown). A fluid path 13 that has a hollow cylindrical form includes a resiliently deformable portion 14 (or simply a resilient portion) which is inserted between the central cutout portions 3, 8 of the roller assemblies 5, 10. The roller assemblies 5, 10 and the resilient portion 14 together form a fluid controller 15 (Fig. 2). When the roller 5 and/or 10 is referred to hereinafter, it should be understood to include the respective roller assembly, unless othewise specified.

It may be seen from Fig. 1 (b) that the roller 5 has the cross section as shown when it engages the resilient portion 14 of the fluid path 13. In the figure, the symbol "0" is the point of center in the central cutout portion of the roller 5, about which the roller 5 rotates clockwise. When the roller 5 is in the state shown in Fig. 1 (b), the distance from the center point "0" to the outer wall of the roller 5 on the side engaging the resilient portion 14 of the fluid path 13 may be represented by L1. Fig. 1 (c) indicates the state of the roller 5 that has rotated clockwise through an angle of 90°, beginning with the state shown in Fig. 1 (b). In the state shown in Fig. 1 (c), the distance from the center point "0" to the outer wall of the roller 5 on the side engaging the resilient portion 14 of the fluid path 13 may be represented by L2. In the state shown in Fig. 1 (d), the distance from the center point "0" to the outer wall of the roller 5 on the side

engaging the resilient portion 14 of the fluid path 13 may be represented by L3. L3 is equal to the radius of the roller 5. When the roller 5 is rotated clockwise further until it reaches the state shown in Fig. 1 (f), beginning with the state shown in Fig. 1 (d), the distance from the center point "O" to the outer wall of the roller 5 on the side engaging the resilient portion 14 of the fluid path 13 remains unchanged, namely, "L3". Thus, when the roller 5 is between the states (d) and (f) in Fig. 1, the resilient portion 14 of the fluid path 13 continues to be pressed upon most strongly by the roller 5. Fig. 1 (e) and Fig. 1 (g) indicate the states of the roller 5 that has rotated clockwise through 180° and 270°, respectively, beginning with the state (b) in Fig. 1.

It may be seen from Fig. 1 that any part of the outer wall of the central cutout portion 3 of the roller 5 always engages the resilient portion 14 of the fluid path 13 while the roller 5 is rotating through every angle that corresponds to every state shown in Fig. 1. Therefore, when the roller 5 has completed one revolution, every part of the outer wall of the central cutout portion 3 of the roller 5 have engaged the resilient portion 14 at least one time. It is noted that the resilient portion 14 of the fluid path 13 may have any size such as diameter, which is not restricted to that shown in this embodiment. For example, the resilient portion 14 of the fluid path 13 may have a littel smaller diameter. In this case, there may be some parts of the outer wall of the central cutout portion of the roller 5 that do not engage the resilient portion 14 of the fluid path 13, when the roller 5 has rotated through one complete revolution. On the contrary, if the cutout portion is formed bigger than that shown in this embodiment, there may be some parts of the outer wall of the central cutout portion of the roller 5 that do not engage the resilient portion 14 of the fluid path 13, when the

roller 5 have rotated through one complete revolution as same as the before mentioned case.

As described, the side of the roller 5 opposite the cutout portion will be referred to as the "engaging portion".

The angle of rotation of the roller 5 which is shown in Fig. 2 (a), Fig. 3 (a) and Fig. 4 (a) will be referred to as the reference angle relative to all other possible angles. When the two rollers are at the reference angle with the center points aligned as shown in Fig. 2 (a), Fig. 3 (a) and Fig. 4 (a), the cutout portions 3, 8 on the rollers 5, 10 face opposite each other so that the resilient portion 14 of the fluid path 13 retains its original shape, that is, the round shape in cross section (fully opened state). When the rollers rotate through 180°, beginning with the state of the reference angle, the resilient portion 14 will be held between the engaging portions 4, 9 of the rollers 5, 10 so that the opposite lateral sides 14a, 14b of the resilient portion 14 facing the engaging portions 4, 9 are pressed upon completely (fully closed state) as shown in Fig. 3 (c) and Fig. 4 (c). In this state, the fluid cannot flow through the resilient portion 14. The shapes of the cutout portions 3, 8 and the gap between the two rollers 5, 10 may be determined by considering the design and size of the resilient portion 14 of the fluid path 13 so that the resilient portion 14 can be controlled to maintain the above states.

The part of the roller 5 consists of the cutout portion 3 and engaging portion 4 provides a control part 16, and the part of the roller 10 consists of the cutout portion 8 and engaging portion 9 provides a control part 17.

The operation of the fluid flow controller 15 described above is described below.

When the operating part 2a on the roller 5 is rotated, which usually occurs by operating the handle (not shown) associated with the operating part 2a, the gear 11 on the roller 5 is rotated, causing the gear 12 in mesh with the gear 11 to rotate oppositely which causes the roller 10 to rotate. Thus, the rollers 5, 10 rotate at the same speed but in the opposite directions.

When the fluid path 13 is to be opened fully, the handle (not shown) is operated to rotate the operating part 2a on the roller 5, which causes the rollers 5, 10 to rotate by means of the gears 11 and 12, so the rollers 5, 10 are placed at the reference angle (Fig. 3 (a), Fig. 4 (a)).

Conversely, when the fluid path 13 is to be closed fully, the handle (not shown) is operated so that the operating part 2a on the roller, which causes the rollers 5, 10 to rotate by means of the gears 11 and 12, so the rollers 5, 10 are rotated through 180°, beginning with the reference angle (Fig. 3 (c), Fig. 4 (c)).

When the fluid path 13 is to be opened half, the handle (not shown) is operated until the operating part 2a on the roller 5 is rotated to the intermediate state between the fully open state (reference angle) and the fully close state (180°). In this intermediate state, the shape in cross section of the resilient portion 14 is varied to allow the fluid to flow through the fluid path 13 at the appropriate rate. Then, the handle is stopped in its rest position. In this case, the resilient portion 14 of the fluid path 13 is firmly held between the engaging portions 4, 9 of the rollers 5, 10. Thus, there is no risk that the resilient portion 14 will vibrate even when the fluid flows at the high velocity.

This embodiment may be varied so that the engaging portion 4 on the

roller 5 includes a smaller-diameter roller 18 as shown in fig. 5. In this embodiment the engaging portion 9 on the roller 10 may include a recess 19 formed arcuately having a diameter greater than the small roller 18 by the thickness of the resilient portion 14 as shown in Fig. 5. In this variation, when the fluid path 13 is to be closed fully, the resilient portion 14 may be held between the small roller 18 and the recess 19. This provides the improved sealing effect (see Fig. 5). This variation may advantageously be used with the fluid under the high pressures. This variation may be varied further so that the engaging portions 4, 9 on both rollers 5, 10 include smaller rollers, respectively. This may reduce the friction between the engaging portions 4, 9 and the outer wall of the resilient portion 14, protecting the resilient portion 14 againt any possible wear caused by the friction. This is not shown.

In the embodiment described so far, the operating handle (not shown) is associated with the operating part 2a of the roller 5, and the roller 5 may be rotated by the operating handle. This mechanical link may be replaced by the rack and pinion mechanism wherein pinions 112, 113 may be mounted to the upper end of the shaft 2 supporting the roller 5 and to the upper end of the shaft 7 supporting the roller 10, respectively, and a rack 114 may be mounted between the pinions 112, 113, the rack 114 having teeth on the opposite sides thereof engaging the corresponding pinions 112, 113 (Fig. 6 (a), (b), (c)). The pinions 112, 113 may be mounted to the lower ends of the respective shafts 2, 7, but this is not shown. In alternative forms, the shaft supporting the operating part 2a may be coupled with the automatic rotation controller, or the rack 114 may be coupled with the automatic motion controller. In either way, the rollers 5, 10 may be rotated automatically. This is not shown.

In the embodiment described so far, the roller assembly 5 includes

the cylindrical roller 1 having the control part 16 that consists of the cutout 3 and engaging portion 4. This embodiment may be varied. In this variation, a roller assembly 115 may include a shaft 2 mounted off-center to the roller 1 to permit the roller 1 to rotate eccentrically (Fig. 7 (a)). A control part 17 thus formed on the roller assembly 115 can vary the distance from the shaft 2 to the outer wall of the roller 1. This variation may be applied to the roller assembly 10.

In the same embodiment, the cylindrical roller 1 may be formed as a triangle (Fig. 7 (b)) or a square (not shown) in cross section.

At least the area of each of the rollers 5, 10 that engages the resilient portion 14 of the fluid path 13 may have a coating of Teflon® or any other material that has a low friction coefficient. Alternatively a thin film of Teflon or any other material that has a low coefficient may be provided on that area (not shown). It is also possible that a coating or film of Teflon or any other material that has a low friction coefficient is provided on the area of the resilient portion 14 of the fluid path 13 on which engaging the rollers 5, 10. Furthermore, as shown in Fig. 8, a sheet 116 of Teflon or any other material that has a low friction coefficient may be provided between the rollers 5, 10 and the resilient portion 14 of the fluid path 13.

A variation of the embodiment described so far may be provided. In this variation as shown in Fig. 9, peripheral guide tracks 117, 118 and 119, 120 may be formed around the rollers 5 and 10 above and below the cutout 3, 8 and engaging portion 4, 9 thereof, respectively. Those guide tracks 117, 118 and 119, 120 are formed around the outer wall of respective rollers and always engage the outer peripheral wall of the resilient fluid path portion so that they can follow any variation in the shape in cross section of the resilient portion that occurs when

the rollers rotate. Fig. 9 (a) shows the guide tracks are provided on both rollers 5, 10. The distance H beween the guide tracks 117 and 118 is varied in accordance with the variation in the shape in cross section of the resilient portion such that it corresponds to the height H_1 when the fluid path is opened fully (Fig. 9 (b)), the height H_2 when the fluid path is opened half (Fig. 9 (c)), and the height H_3 when the fluid path is closed fully (Fig. 9 (d)).

As it may be undestood from the above, those guide tracks can follow the variations in the shape in cross section of the resilient portion 14 that occur from the fully closed state to the fully opened state as the rollers are rotating, and ensure that the resilient portion can have the appropriate variations in the shape in cross section when the shape in cross section of the resilient portion is varied by rotating of the rollers.

As described, the guide tracks are formed around both rollers respectively, but may be provided on either of them, such as the guide tracks 117, 118 on the roller 5 as shown in Fig. 10 (a). It is possible that only the guide track 117 is provided on the roller 5, and only the guide track 120 is provided on the roller 10. It is also possible that the guide tracks 117, 118 are provided on the roller 5, and the corresponding recesses 121, 122 that engage the guide tracks 117, 118 are provided on the roller 10 (Fig. 10 (c)). The roller 5 may include the diametrically enlarged portions 123, 124 on the upper and lower sides which are formed to provide the same configurations as the corresponding guide tracks 117, 118 shown in Fig. 9 (a). Similarly, the roller 10 may also be formed to include the diametrically enlarged portions 125, 126 (Fig. 10 (d)).

EXAMPLE 2

Referring next to Figs. 11 through 13, another preferred embodiment of the present invention is described.

In the preceding embodiment (EXAMPLE 1), one roller has one control part. In the embodiment shown in Figs. 11 through 13, a roller assembly 24 includes a roller 20 and a shaft 21 supporting the roller 20 wherein two control parts 22, 23 are provided. The control part 22 includes a cutout 22a on one side, and an engaging portion 22b on the other side. Similarly, the control part 23 includes a cutout 23a on one side, and an engaging portion 23b on the other side. This may be seen from Fig. 11 (a) and (b). A roller assembly 24a is similar to the roller assembly 24, and has a symmetrical surface. Those roller assemblies 24, 24a are supported rotatably within a casing 49a, and hold two fluid paths 25a, 25b therebetween. Thus, the flow rate controller 49 is provided as in the previous embodiment (Fig. 11 (c)).

The flow rate controller 49 may be used for controlling the flow rates of the fluids through the corresponding fluid paths 25a, 25b in the same manner as for the flow rate controller in the previous embodiment (EXAMPLE 1). As briefly described, when the roller assembly, or simply the roller 24, is assumed to be at the angle of 0° as shown in Fig. 11 (c), the resilient portion of the fluid path 25a is held between the cutout 22a on the roller 24 and the corresponding cutout on the opposite roller 24a. In this state, the resilient portion of the fluid path 25a is opened fully, as shown in Fig. 11 (c). At the same time, the resilient portion of the fluid path 25b is held between the engaging portion 23b on the roller 24 and the corresponding engaging portion on the opposite roller 24a, and the resilient portion of the fluid path 25b is closed fully as shown in Fig. 11 (c). Then, when the roller 24 rotates through

180° as shown in Fig. 11 (a), the resilient portion of the fluid path 25a is held between the engaging portion 22b on the roller 24 and the corresponding engaging portion on the opposite roller 24a, so the resilient portion of the fluid path 25a is closed fully. At the same time, the resilient portion of the fluid path 25b is held between the cutout 23a on the roller 24 and the corresponding cutout on the opposite roller 24a, so the resilient portion of the fluid path 25b is opened fully. In this way, the two control parts on the single roller 24 can control the flow rates of the two fluids through the fluid paths 25a and 25b.

The following example is the case where the roller has a number of control parts. Specifically, the flow rate controller includes a roller that has five control parts, and may be used as the fluid filtering apparatus as shown in Fig. 12. This roller arrangement is described below with an aid of Fig. 12 and Fig. 13.

A first roller assembly, generally designated by 37 includes a cylindrical roller 26 that has five control parts 27 through 31. Each of the control parts 27-31 has a respective one of the cutout 27a-31a on one side thereof, and has a respective one of the engaging portions 27b-31b.

A second roller assembly, not shown, that is provided opposite the first roller assembly 37 has the identical and symmetrical roller arrangement. Each of the resilient portions 32 through 36 of the fluid path is held between the corresponding one of the control parts 27-31 on the first roller 37 and the corresponding one of the control parts on the second roller (not shown). The first and second roller assemblies constitute the flow rate controller 38.

The flow rate controller 38 operates in the manner that it controls the flow rates of the fluids through the resilient portions 32-36 of the

fluid path by rotating the first roller 37 and the second roller through the angles of 0° ("X" position), 120° ("Y" position) and 240° ("Z" position) to enable each of the control parts 27-31 to act upon each corresponding one of the resilient portions, thereby varying the shape in cross section of each corresponding one of the resilient portions so the flow rates of the fluids through the resilient portions 32-36 can be controlled. When the roller 37 is at the angle of 0° ("X" position), the state for each of the control parts 27-31 is shown in cross section in Fig. 12 (b). In the "X" position, the control parts 27 and 31 enable the corresponding resilient portions 32, 36 to be opened fully, through which the respective fluids can flow, whereas the remaining control parts 28, 29, 30 enable the corresponding resilient portions 33, 34, 35 to be closed fully, through which the respective fluids cannot flow. Then, when the roller 37 rotates further through 120° ("Y" position), the state for each of the control parts 27-31 is shown in cross section in Fig. 12 (c). In the "Y" position, the control parts 28 and 30 enable the corresponding resilient portions 33, 35 to be opened fully, through which the respective fluids can flow, whereas the remaining control parts 27, 29, 31 enable the corresponding resilient portions 32, 34, 36 to be closed fully, through which the respective fluids cannot flow. When the roller 37 rotates further through 120° (a total of 240°) ("Z" position), the state for each of the control parts 27-31 is shown in cross section in Fig. 12 (d). In the "Z" position, the control parts 27 and 29 enable the corresponding resilient portions 32, 34 to be opened fully, through which the respective fluids can flow, whereas the remaining control parts 28, 30, 31 enable the corresponding resilient portions 33, 35, 36 to be closed fully, through which the respective fluids cannot flow.

Each of the control parts 27 - 31 has a cutout that cooperates

with the respective engaging portion for controlling the flow rate of the fluid through the respective resilient portion by opening or closing it fully, when the roller is at the angles of 0° ("X" position), 120° ("Y" position), and 240° ("Z" position).

In the flow rate controller 38, the roller 26 in the first roller assembly 37 and the roller in the second first roller assembly (not shown) which is symmetrical to the first roller assembly 37 are supported by the respective stationary shafts which are fixed in their respective positions each time the rollers rotates to the "X", "Y" and "Z" positions.

As shown in Fig. 13 (a), the fluid filtering apparatus 41 may be constructed by coupling a pump 39 and a filtering tank 40 with the flow rate controller 38 by means of a fluid path or conduit. In the schematic diagram shown in Fig. 13, 42 designates a processed fluid outlet port, and 43 designates a liquid cleaner outlet port.

When the flow rate controller 38 is in the filtering process ("X" position) as shown in Fig. 13 (a), a fluid to be filtered is delivered from the pump 39 into the fluid rate controller 38 as indicated by arrows 44, 45, from which the fluid is delivered to the filtering tank 40 as indicated by an arrow 46, through which the fluid is filtered as indicated by an arrow 47. The filtered fluid is then fed back to the flow rate controller 38 again as indicated by an arrow 48, from which it goes out through the processed fluid outlet port 42 as indicated by an arrow 49.

When the flow rate controller 38 is in the backward cleaning process ("Y" position) as shown in Fig. 13 (b), the liquid cleaner is delivered from the pump 39 into the flow rate controller 38 as indicated by arrows 44, 50, from which the liquid cleaner is delivered to the filtering tank 40 as indicated by arrows 51, 52 where the interior of the the

filtering tank 40 is cleaned as indicated by an arrow 53. The liquid cleaner goes back into the flow rate controller 38 as indicated by arrows 54, 55, from which it goes out through the outlet port 43 as indicated by an arrow 56.

When the flow rate controller 38 is in the foward cleaning process ("Z" position) as shown in Fig. 13 (c), the liquid cleaner is delivered from the pump 39 into the flow rate controller 38 as indicated by arrows 44, 45, from which the liquid cleaner is delivered to the filtering tank 40 as indicated by an arrow 46 where the filtering tank 40 is cleaned as indicated by an arrow 47. The liquid cleaner goes back into the flow rate controller 38 as indicated by arrows 48, 57, from which it goes out through the outlet port 43 as indicated by an arrow 58.

The above processes may be repeated for the fluid next to be filtered, upon completion of the forward cleaning process.

EXAMPLE 3

Referring now to Fig. 14, another preferred embodiment of the present invention is described. According to this embodiment, three rollers are provided, and the resilient portion of the fluid path is held not only between the two rollers but also between the inner wall of the supporting casing and the roller.

A first roller assembly 59 includes a cylindrical roller 60 having control parts 61, 62. A second roller assembly 64 includes a cylindrical roller 65 having a control part 66. A third roller assembly 68 includes a cylindrical roller 69 having two control parts 70, 71. The control part 61 includes a cutout 61a and an engaging portion 61b. The control part 62 includes a cutout 62a and an engaging portion 62b. The control part 66 includes a cutout 66a and an engaging portion 66b. The control

part 70 includes a cutout 70a and an engaging portion 70b. Finally, the control part 71 includes a cutout 71a and an engaging portion 71b.

A casing 73 houses the roller assemblies 59, 64, 68 whose respective rollers 60, 65, 69 are rotatably supported by their respective shafts 63, 67, 72, respectively, which in turn are rotatably mounted at their respective opposite ends to the casing. The resilient portions 74, 75, 76 of the fluid paths are engaged by those rollers. Those three roller assemblies described above constitute a flow rate controller 78 which is shown in Fig. 14 (a).

The operation of the flow rate controller 78 is described according to the embodiment shown in Fig. 14.

In the reference position (0°), the resilient portion 74 of the fluid path is located inside the cutouts 61a and 66a facing opposite each other, so it is in its fully opened state. The resilient portion 75 is located inside the cutout 62a, so it is also in its fully opened state. The resilient portion 76 is pressed against by the engaging porions 66b and 70b, so it is in its fully closed state. The resilient portion 77 is located inside the cutout 71a, so it is in its fully opened state. Those states are shown in Fig. 14 (a).

When the rollers are rotated through 180°, starting with the reference angle, i.e., 0°, the resilient portion 74 is pressed against by the engaging portions 61b and 66b, so it is in its fully closed state. The resilient portion 75 is pressed against by the engaging portion 62b and the inner wall of the casing 73, so it is in its fully closed state. The resilient portion 76 is located inside the cutouts 66a and 70a, so it is in its fully opened state. The resilient portion 77 is pressed against by the engaging portion 71b and the inner wall of the casing 73, so it is in its fully closed state. Those states are shown in Fig. 14 (b).

EXAMPLE 4

Referring next to Fig. 15, another preferred embodiment of the present invention is described. The flow rate controller according to this embodiment may be applied to the fluid path that includes a three-way (Y) resilient portion 79 consisting of three branches 80, 81 and 82. The branch 81 of the Y-resilient portion 79 is held between a larger roller 83 and a smaller roller 84, and the branch 82 is held between the larger roller 83 and a smaller roller 85. The larger roller 83 has a control part 86 including a cutout 86a and an engaging portion 86b, and the smaller roller 84 has a control part 87 including a cutout 87a and an engaging portion 87b. The smaller roller 85 has a control part 88 including a cutout 88a and an engaging portion 88b.

In the reference position (0°) as shown in Fig. 15 (a), the branch 81 is held between the engaging portions 86a and 87b, so it is in its fully closed state. The branch 82 is located inside the cutouts 86a and 88a, so it is in its fully opened state. Thus, the flow of the fluid from the branch 80 is directed to the branch 82 as indicated by arrows 89, 90 (Fig. 15 (a)).

In different positions (in which the smaller rollers 84, 85 have rotated through 180°, and the larger roller 83 has rotated through about 60°) as shown in Fig. 15 (b), the branch 81 is located inside the cutouts 86a and 87a, so it is in its fully opened state; the branch 82 is held between the engaging portions 86b and 88b, so it is in its fully closed state. Thus, the flow of the fluid from the branch 80 is directed to the branch 81 as indicated by arrows 89, 91 (Fig. 15 (b)).

EXAMPLE 5

Reffering next to Fig. 16, a further preferred embodiment of the

present invention is described. The flow rate controller according to this embodiment may be applied to a multi-way valve, wherein more than three rollers are provided for controlling the flow rates of more than four fluid paths.

The embodiment shown in Fig. 16 (a) and (b) includes one larger roller 92 and four smaller rollers 93, 94, 95, 96. The resilient portion 97 of the fluid path is controlled by the combination of the larger roller 92 and smaller roller 93, the resilient portions 98, 101 are controlled by the combination of the larger roller 92 and smaller roller 95, the resilient portions 99, 103 are controlled by the combination of the larger roller 92 and smaller roller 94, and the resilient portions 100, 102 are controlled by the larger roller 92 and smaller roller 96. Each roller has a control part including a cutout and an engaging portion.

Fig. 16 (c) illustrates a variation of the embodiment shown in Fig. 16 (a) and (b) which includes a three-way (Y) resilient portion 104 consists of branches 105, 106, and 107, and a three-way (Y) resilient portion 108 consists of branches 109, 110, and 111. The two resilient portions are controlled by the combination of a single larger roller 92 and smaller rollers 93, 94, 95, 96. Each roller has a control part including a cutout and an engaging portion.

EXAMPLE 6

Referring next to Figs. 17 through 20, another preferred embodiment and several variations thereof are described. In those embodiments, a roller assembly consists of a combination of smaller rollers.

A roller assembly, generally designated by 137, includes an upper support plate 128 and a lower support plate 129. A center shaft 130 is rotatably supported at the opposite ends by the upper and lower plates 128,

129. A shaft 132 to which a smaller roller 131 is mounted is provided a distance of L_3 away from the center shaft 130 and in parallel with the same, and is rotatably supported at the opposite ends by the upper and lower plates 128, 129. It is assumed that the center shaft 130 is located at the origin 0 and the line connecting between the shafts 130 and 132 is the reference line. Then, a shaft 134 to which a smaller roller 133 is mounted is provided a distance of L_4 away from the origin 0 and at the angle β_1 relative to the reference line, and is rotatably supported at the opposite ends by the upper and lower plates 128, 129. A shaft 136 to which a smaller roller 135 is mounted is provided a distance of L_5 away from the origin 0 and at the angle $\beta_1 + \beta_2$ relative to the reference line, and is rotatably supported at the opposite ends by the upper and lower plates 128, 129. This is shown in Fig. 17 (a) and (b). The smaller rollers 131, 133, and 135 have their respective peripheral edges located outside the peripheral marginal edges of the upper and lower plates 128, 129. The combination of the rollers 131, 133 and 135 provides the control part for the roller assembly 137.

A fluid path 144 includes two branches 142, 143 formed by the casing wall 138, 139 and resilient portions 140, 141, respectively (Fig. 18 (b)). As shown in Fig. 18 (b), the roller assembly 137a includes the smaller rollers arranged between the two resilient portions 140, 141 of the fluid path 144, at the angles of $\beta_1 = 90°$ and $\beta_2 = 90°$ and at the distances of $L_3 = L_4 = L_5$. Thus, the flow rate controller 145 is provided.

The operation of the above embodiment is described.

In the reference position as shown in Fig. 18 (b), for example, only the smaller roller 133 presses against the resilient portion 140 which engages the casing wall 138. Thus, the branch 142 is fully closed. The remaining smaller rollers 131, 135 have no effect upon the resilient

portion. Thus, the branch 143 is fully open.

When the center shaft 130 for the roller assembly 137a is rotated clockwise through 90°, beginning with the state shown in Fig. 18 (b), the smaller roller 131 presses against the resilient portion 140 which engages the casing wall 138. Thus, the branch 142 is fully closed. The smaller roller 135 presses against the resilient portion 141 which engages the casing wall 139. Thus, the branch 143 is also fully closed (Fig. 18 (c)).

When the center shaft 130 for the roller assembly 137a is rotated clockwise through an additional 90°, beginning with the state shown in Fig. 18 (c), the smaller roller 133 presses against the resilient portion 141 which engages the casing wall 139. Thus, the branch 143 is fully closed. The remaining smaller rollers 131, 135 have no effect upon the resilient portion. Thus, the branch 142 is fully open (Fig. 18 (d)). The fluid path 144 may be controlled in the above manner.

In the embodiment shown in Fig. 18, the three smaller rollers are provided, but the number of the smaller rollers may be determined, depending upon the required configuration for the control part. In the example of the variation shown in Fig. 19, a shaft 130 may be rotatably supported at the opposite ends by the upper and lower plates 138, 139, and a shaft 132 to which a smaller roller 131 is mounted may be provided a distance of L_6 away from the shaft 130 and in parallel with the same, and is rotatably supported at the opposite ends by the upper and lower plates 138, 139. In this case, a shaft 147 to which an auxiliary roller 146 is mounted may be provided adjacently to the smaller roller 131 and a distance of L_7 smaller than L_6 away from the shaft 130, and may be supported at the opposite ends by the upper and lower plates 138, 139. Thus, the roller assembly 148 may be provided (Fig. 19 (a), (b)).

According to the flow rate controller 152 shown in Fig. 19 (c), the fluid path 151 includes a resilient portion 150 which is formed by attaching its opposite marginal edges thereof inside the casing wall 149. The roller assembly 148 including the smaller roller 131 and auxilary roller 146 is mounted between the casing wall 149 and resilient portion 150. It may be seen from Fig. 19 (c) that as the fluid path has the bore diameter D less than the distance L_6, so the fully closed state can be attained when the roller assembly is rotated through a smaller angle than when it is placed perpendicularly to the fluid path 151 (Fig. 19 (c)).

Each of the rollers in the roller assemblies according to the preceding embodiments (EXAMPLE 1 to 5) may be replaced by the combination of the smaller rollers in the roller assembly according to the embodiment shown in Fig. 19. For example, the roller assembly shown in Fig. 1 may be varied to the roller assembly 153 shown in Fig. 20 (a), (b). In the roller assembly 153, a center shaft 30 is rotatably supported at the opposite ends thereof by the upper and lower plates 128, 129, and smaller rollers 131, 131 are arranged to conform to the peripheral shape formed by the cutouts 3 and engaging portions 4 in the control part of the roller 5, and are rotatably supported at their respective opposite ends by the upper and lower plates 128, 129.

EXAMPLE 7

Referring next to Figs. 21 through 23, another preferred embodiment of the present invention is described. In all of the preceding embodiments, the rollers are rotated about their respective stationary shafts. According to the current embodiment, the flow rate of the fluid can be controlled by rotating the roller while its shaft is being moved.

The roller assembly in this embodiment is similar to that in the

embodiment shown in Fig. 2, except that the shaft 2 for the roller 5 providing the control part 16 and the shaft 7 for the roller 10 providing the control part 17 have pinions 112, 113 fixied to their respective upper ends, respectively, and a rack 114 is disposed between the two pinions 112 and 113, the rack 114 having teeth on the opposite sides that are in mesh with the corresponding pinions 112, 113. Outside the pinion 112, a stationary rack 156 is provided in parallel with the rack 114 and is fixed to the casing 15a. Similarly, outside the pinion 113, a stationary rack 157 is provided in parallel with the rack 114, and is fixed to the casing 15a. Those racks 156, 157 are in mesh with the corresponding pinions 112, 113. Parallel tracks 154, 155 are provided in the bottom across the casing 15a for accepting the bottom ends of the corresponding shafts 2, 7 for the rollers 5, 10 so that the shafts can travel along the respective tracks 154, 157.

The resilient portion 159 of the fluid path 158 is held between the rollers 5, 10, which constitutes the flow rate controller 161 (Fig. 21 (a), (b), (c)).

The operation of the flow rate controller 161 according to the current embodiment is now described.

When each of the pinion 112, 113 is placed on one side of 156a, 157a the respective one of the stationary racks 156, 157 as shown in Fig. 21 (b), the resilient portion 159 is located inside the cutouts 3, 8 on the rollers 5,10, so it is in its fully open state. Then, when the rack 114 is moved from the position shown in Fig. 21 (b) in the direction of an arrow 162, the rollers 5, 10 are rolling until they reach the position shown in Fig. 21 (c) where the pinions 112, 113 are placed on the middle way 156b, 157b of the stationary racks 156, 157. In this position, the resilient portion 159 is pressed against by the engaging portions 4, 9,

so it is in its fully closed state. When the rollers 5, 10 are placed between the positions shown in Fig. 21 (b) and Fig. 21 (c), the resilient portion 159 is in its half open state. The flow rate of the fluid can be controlled in this manner.

The stationary racks 156, 157 may be replaced by tracks similar to the tracks 154, 156 that may be formed at the top across the casing for supporting the shafts 2, 7. This is not shown.

The flow rate controller 161 according to the current embodiment may be applied to the fluid filtering apparatus, as described below.

As shown in Fig. 22, a cylindrical roller 163 has four control parts 164 through 167. Each of the control parts 164 through 167 includes a respective one of the cutouts 164a through 167a on one side thereof, and a respective one of the engaging portions 164b through 167b on the opposite side thereof.

Another cylindrical roller that is symmetrical to the above roller 163 is provided (which is not shown), and the resilient portions 69 through 172 of the fluid path 168 corresponding to the control parts 164 through 167 are held between the roller 163 and the another roller (not shown). The roller assembly consisting of the rollers as described is mounted within a casing, which provides a flow rate controller 173.

The roller 163 and the other symmetrical roller (not shown) that holds the resilient portions 169 through 172 of the fluid path 168 together with the roller 163 have the rack and pinion arrangement as described in connection with the preceding embodiment shown in Fig. 21.

The flow rate controller 173 controls the flow rate of the fluid through the resilient portions 169 through 172 of the fluid path, by causing the roller 163 and the another roller to rotate through 0° ("X" position), 120° ("Y" position), and 240° ("Z" position), respectively,

and by enabling each respective one of the control parts 164 through 167 to act upon each corresponding one of the resilient portions 169 through 172. When the roller 163 is at the angle of 0° ("X" position), each of the control parts 164 through 167 has the shape in cross section as shown in Fig. 22 (b). In the "X" position, the control part 165 has no effect upon the corresponding resilient portion 170 of the fluid path 168 (fully open state), allowing the fluid to flow through the resilient portion 170, while the remaining control parts 164, 166, and 167 enable the corresponding resilient portions 169, 171, 172 to be closed fully, inhibiting the flow of the fluid through those resilient portions. When the roller 163 rotates through 120° ("Y" position), each of the control parts 164 through 167 has the shape in cross section as shown in Fig. 22 (c). In the "Y" position, the control part 164 has no effect upon the corresponding resilient portion 169 of the fluid path 168 (fully open state), allowing the flow of the fluid through the resilient portion 169, while the remaining control parts 165, 166, and 167 enable the corresponding resilient portions 170, 171, and 172 to be closed fully, inhibiting the flow of the fluid through those resilient portions. When the roller 163 rotates further through 120° (a total of 240°) ("Z" position), each of the control parts 164 through 167 has the shape in cross section as shown in Fig. 22 (d). In the "Z" position, the control part 167 has no effect upon the corresponding resilient portion 172 of the fluid path 168 (fully open state), allowing the flow of the fluid through the resilient portion 172, while the remaining control parts 164, 165, and 166 enable the corresponding resilient portions 169, 170, and 171 to be closed fully, inhibiting the flow of the fluid through those resilient portions.

It may be appreciated that each of the control parts 164 through 167

of the roller 163 and another symmetrical roller also includes a cutout that acts upon the corresponding resilient portion of the fluid path to enable it to be opened fully or closed fully, when the roller rotates through 0° ("X" position), 120° ("Y" position), and 240° ("Z" position).

The resilient portion 169 has an exit port 174, the resilient portion 170 has a processed fluid outlet port 175, the resilient portion 171 has an inlet port 177 through which the fluid to be processed and the liquid cleaner are delivered, a port 176 connected to one side (upper) of the filtering tank 180 and port 179 connected to the other side (lower) of the filtering tank 180, and the resilient portion 172 has an exit port 178. Those connections are shown in Fig. 23 (a).

When the roller assembly 163 is in the "X" position as shown in Fig. 23 (a)', it is in the fluid filtering process during which a fluid to be processed enters through the port 177, going through the resilient portions 172, 171 and then into the filtering tank 180 where the fluid is filtered via the upper side through the port 176, where the fluid is filtered. The filtered fluid goes out from the filtering tank 180, entering the resilient portion 170 through the port 179 and then going out through the port 175. Those flows are indicated by the respective arrows.

Then, the roller assembly 163 is rolled from the "X" position (as shown in Fig. 23 (a)) through 120° to the "Y" position as shown in Fig. 23 (b). This position represents the cleaning process during which as indicated by the respective arrows in Fig. 23 (b), the liquid cleaner enters through the port 177, going through the resilient portion 171 and then through the port 176 into the filtering tank 180 via the upper side from which the cleaner enters through the port 179 back into the resilient portion 169, the cleaner goes out through the port 174.

Finally, the roller assembly 163 is rolled from the "Y" position (as shown in Fig. 23 (b)) through an additional 120° to the "Z" position as shown in Fig. 23 (c). This position represents the backward cleaning process during which as indicated by the respective arrows in Fig. 23 (c), the cleaner enters through the port 177, going through the resilient portion 171 and then through the port 179 into the filtering tank 180 via the lower side where the backward cleaning occurs. Then, the cleaner enters through the port 176 back into the resilient portion 172 and then going out through the port 178.

The flow rate control may proceed as described above, and this procedure may be repeated by operating the roller assembly as described above.

In the embodiment described in connection with Fig. 23, the roller assembly 163 cooperates with its counterpart symmetrical roller assembly (not shown) to hold the resilient portions 169 through 172 therebetween and thereby control their respective fluid flows. This embodiment may be modified so that the roller assembly 163 may cooperate with the casing wall, rather than its couterpart roller assembly, to hold the resilient portions 169 through 172 and thereby control their respective fluid flows, although this is not shown. In this case, the casing wall that engages the resilient portions may have the flat or curved surface. The roller assembly 163 can roll along the appropriate configuration of the casing wall.

Although the present invention has been described in connection with the preferred embodiments thereof, it should be undestood that various changes and modifications may be made without departing from the spirit and scope of the invention as defined in the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Apparatus for controlling the rate of fluid flow through a conduit, comprising:

a resiliently deformable tube extending along a first axis, and arranged to communicate in use at each end with the conduit for fluid flow along the tube;

an abutment surface adjacent one side of an outer wall of a portion of the length of the tube; and

a pinch roller mounted eccentrically for rotation about a second axis non-parallel with the tube axis, adjacent an opposite side of the said outer wall of the said portion of the tube, the pinch roller being arranged progressively to pinch the tube at its said portion by deforming its wall progressively towards the abutment surface as a function of progressive rotation of the pinch roller about the second axis, the tube varying correspondingly progressively between being completely open and being pinched closed with its walls pinched in a predetermined plane parallel to the second axis;

wherein the abutment surface is a working surface of a second pinch roller mounted for rotation on the opposite side of the predetermined plane of pinching so that the tube is pinched between the two pinch rollers; and

wherein the two pinch rollers are of the same configuration and are mounted on parallel axes for contrary rotation, maintaining symmetry about the predetermined plane of pinching;

the apparatus being characterized in that the pinch roller is shaped and positioned such that, for the entire rotational range of operation, the part of its working surface facing the said predetermined plane of pinching is smoothly curved with a constant or slowly-varying radius of curvature, being convex in a section normal to the pinch roller axis, whereby the working surface, in use, engages and deforms the tube wall progressively

with a smooth camming action, throughout the rotational range of operation, towards the predetermined plane with progressive rotation of the pinch roller.

2. Apparatus according to claim 1, in which the, or at least one, pinch roller comprises more than one working surface spaced axially along the roller, so as to pinch a corresponding number of tubes.

3. Apparatus according to claim 2, in which the working surfaces are configured in relation to their angular position around the roller axis such as to pinch the rollers at predetermined different phases of roller rotation.

4. Apparatus according to claim 1, 2 or 3, in which the, or at least one, pinch roller working surface is continuous over its entire operational angular range.

5. Apparatus according to claim 4, in which the, or at least one, pinch roller is an eccentrically-mounted cylinder with a cut-out on one side of a central operative region of the roller leaving a waist portion whose perimeter in each transverse section consists of the remainder of the arc of the cylinder, contiguous with a convex arc defined by the cut-out.

6. Apparatus according to claim 4 or 5, in which the, or at least one, pinch roller comprises guide track means formed around its working surface for guiding each of the opposed folds of the tube wall as the tube is pinched.

7. Apparatus according to claim 6, in which the guide track means comprises, at each axial boundary of the working surface, a radially-projecting track whose axial

position varies progressively with angular position around the roller axis, to accommodate variation, with rotational position over its operating range, of the pinched width of the tube in the predetermined plane of pinching.

8. A method of controlling the rate of fluid flow through a conduit, using a resilient deformable tube extending along a first axis and communicating at each end with the conduit for fluid flow along the tube, an abutment surface adjacent one side of the outer wall of a portion of the length of the tube, and a pinch roller mounted eccentrically for rotation about a second axis non-parallel with the tube axis, adjacent the opposite side of the said outer wall of the said portion of the tube, comprising:

progressively varying the degree of pinching of the tube at its said portion, and thereby the resistance to fluid flow to the conduit, by deforming the tube wall progressively towards or away from the abutment surface as a function of progressive rotation of the pinch roller about the second axis, the tube varying correspondingly progressively between being completely open and being pinched closed with its walls pinched in a predetermined plane parallel to the second axis, wherein the abutment surface is the working surface of a second pinch roller mounted for rotation on the opposite side of the predetermined plane of pinching so that the tube is pinched between the two pinch rollers, and the two pinch rollers are of the same configuration and mounted on parallel axes for contrary rotation, maintaining symmetry about the predetermined plane of pinching;

wherein the pinch roller is shaped and positioned such that, for the entire rotational range of operation, the part of its working surface facing the said predetermined plane of pinching is smoothly curved with a constant or slowly-varying radius of curvature, being convex in a section normal to the pinch roller axis, whereby the working surface engages and deforms the tube wall progressively with a smooth camming action, throughout the

rotational range of operation, towards or away from the predetermined plane with progressive rotation of the pinch roller.

9. An apparatus for controlling the flow rate of a fluid flowing through a fluid path at least partially defined by a resiliently deformable conduit portion, comprising:

a casing having said resiliently deformable conduit portion extending therethrough;

a first roller and a second roller both rotatably supported in said casing by respective rotary shafts located along respective longitudinal axes of said first and second rollers in said casing, said first roller and said second roller having said resiliently deformable conduit portion therebetween; and

a control surface defined on said first roller for pressing said resiliently deformable conduit portion toward said second roller to control fluid flow through said conduit portion, said control surface comprising a first surface portion that is curved as viewed in section, the section being taken perpendicular to said rotary shaft of said first roller, and said first surface portion engaging and closing said resiliently deformable conduit portion in a closed position of said first roller, and a second surface portion that is curved as viewed in section, the section being taken perpendicular to said rotary shaft of said first roller, said second surface portion being positioned along one side of said resiliently deformable conduit portion in an open position of said first roller;

wherein said first and second surface portions of said control surface of said first roller are located at the same axial position along said first roller, and wherein said first and second surface portions are at least partially located at different radial distances from said longitudinal axis of said first roller;

wherein said first roller has a plurality of said control surfaces thereon; and

wherein said second roller is symmetrical with respect to said first roller, said second roller being rotatably mounted in said casing parallel to said first roller.

10. The apparatus of claim 9, wherein said first and second rollers are symmetrical about a plane extending therebetween.

11. The apparatus of claim 9 or 10, wherein said second roller has control surfaces thereon at positions corresponding to said control surfaces of said first roller.

12. The apparatus of claim 11, wherein said control surfaces of each of said first and second rollers are axially distributed along said rollers in the direction of said rotary shaft.

13. The apparatus of claim 11, wherein said control surfaces on said first roller have said first surface portions thereof located at more than one radial position on said first roller.

14. The apparatus of any one of claims 9 to 13, wherein said second surface portion of each said control surface on each said roller has a radial distance from said longitudinal axis of the respective said roller that varies both circumferentially about said roller and longitudinally of said roller.

15. An apparatus for controlling the flow rate of a fluid flowing through a fluid path at least partially defined by a resiliently deformable conduit portion, comprising:

a casing having said resiliently deformable conduit portion extending therethrough;

a first roller and a second roller both rotatably supported in said casing by respective rotary shafts located along respective longitudinal axes of said first and second rollers in

said casing, said first roller and said second roller having said resiliently deformable conduit portion therebetween; and

a control surface defined on said first roller for pressing said resiliently deformable conduit portion toward said second roller to control fluid flow through said conduit portion, said control surface comprising a first surface portion that is curved as viewed in section, the section being taken perpendicular to said rotary shaft of said first roller, and said first surface portion engaging and closing said resiliently deformable conduit portion in a closed position of said first roller, and a second surface portion that is curved as viewed in section, the section being taken perpendicular to said rotary shaft of said first roller, said second surface portion being positioned along one side of said resiliently deformable conduit portion in an open position of said first roller;

wherein said first and second surface portions of said control surface are located on opposite sides of said first roller with respect to said longitudinal axis thereof;

wherein said first roller has a plurality of said control surfaces thereon; and

wherein said second roller is symmetrical with respect to said first roller, said second roller being rotatably mounted in said casing parallel to said first roller.

16. The apparatus of claim 15, wherein said first and second rollers are symmetrical about a plane extending therebetween.

17. The apparatus of claim 16, wherein said second roller has control surfaces thereon at positions corresponding to said control surfaces of said first roller.

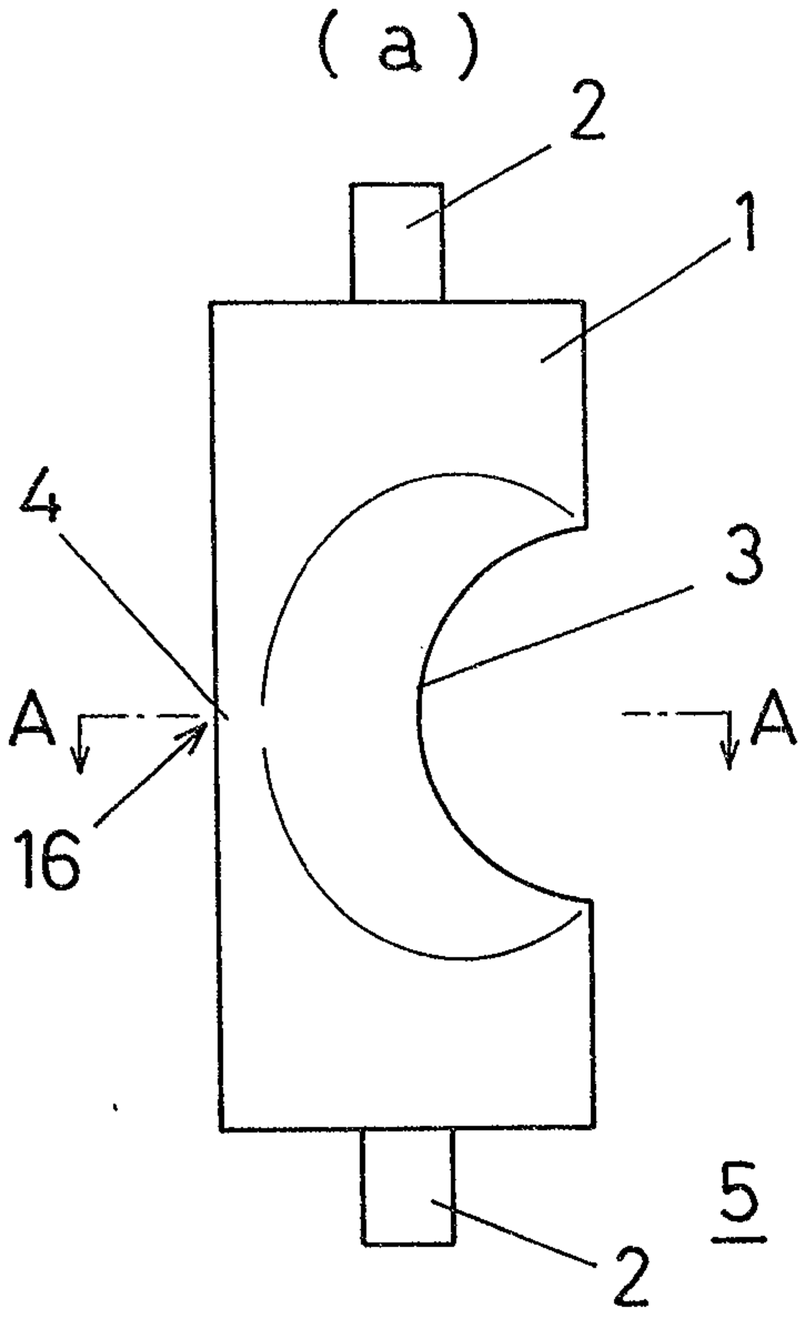
18. The apparatus of claim 17, wherein said control surfaces of each of said first and second rollers are axially distributed along said rollers in the direction of said rotary shaft.

19. The apparatus of claim 18, wherein said control surfaces on said first roller have said first surface portions thereof located at more than one radial position on said first roller.

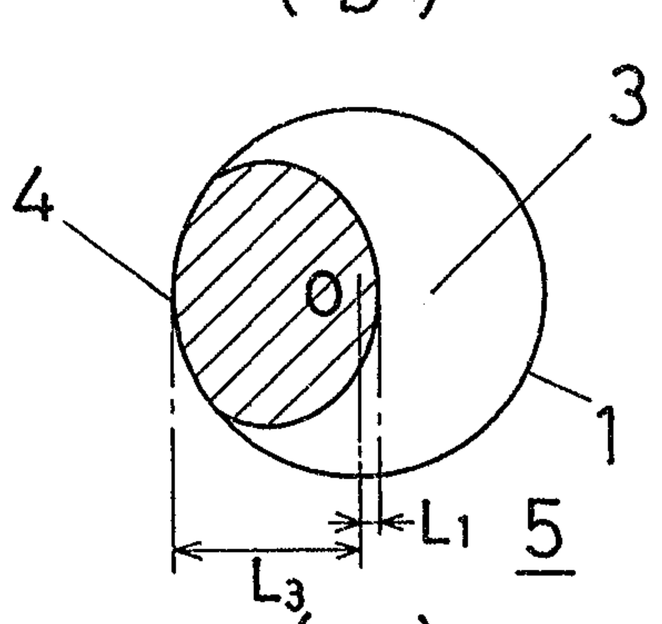
20. The apparatus of claim 19, wherein said second surface portion of each said control surface on each said roller has a radial distance from said longitudinal axis of the respective said roller that varies both circumferentially about said roller and longitudinally of said roller.

21. The apparatus of claim 20, wherein said first and second surface portions of said control surface of said first roller are located at the same axial position along said first roller, and wherein said first and second surface portions are at least partially located at different radial distances from said longitudinal axis of said first roller.

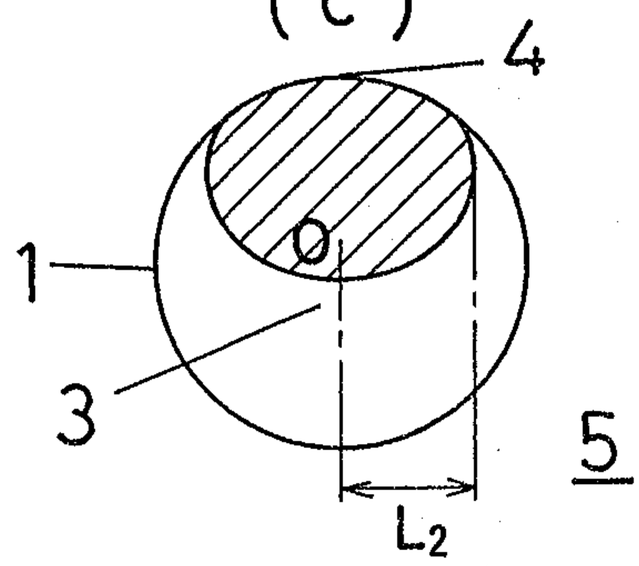
FIG. 1

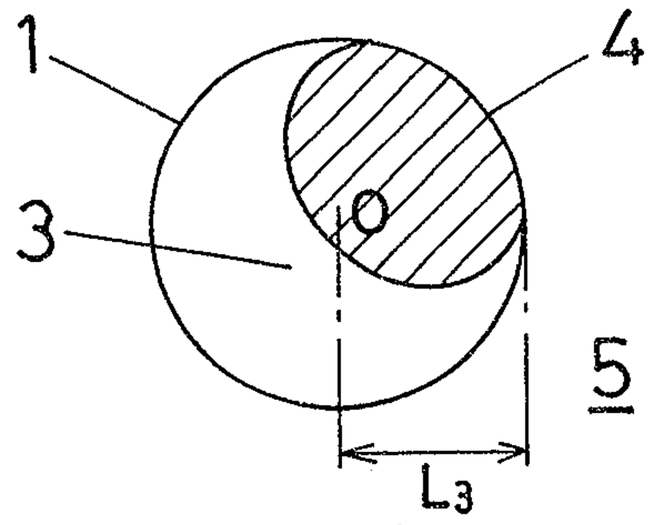


(b)



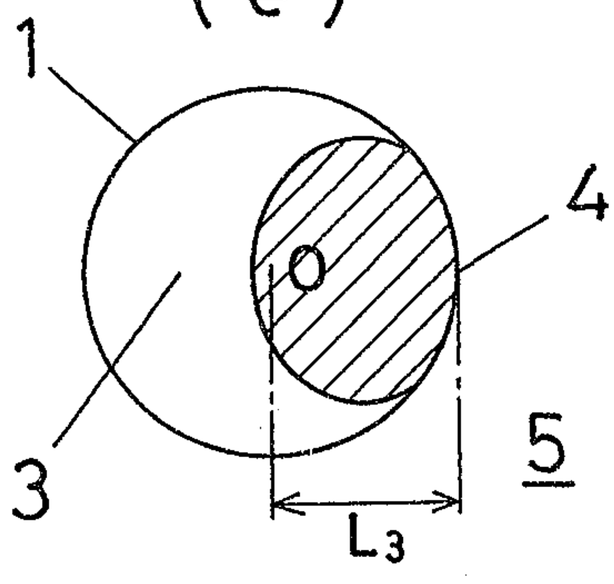
(c)



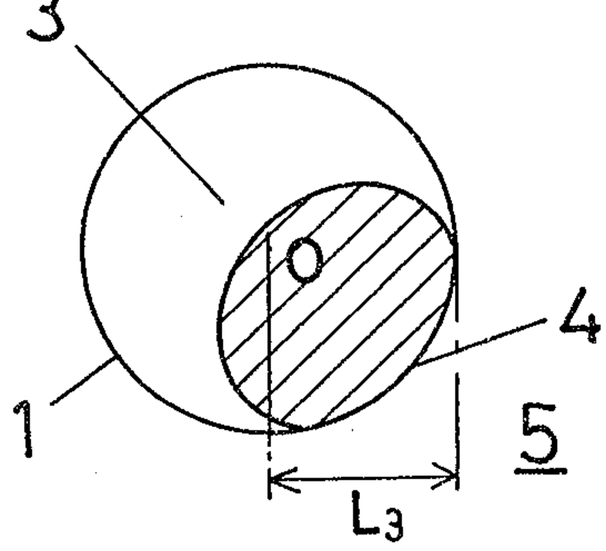


(d)

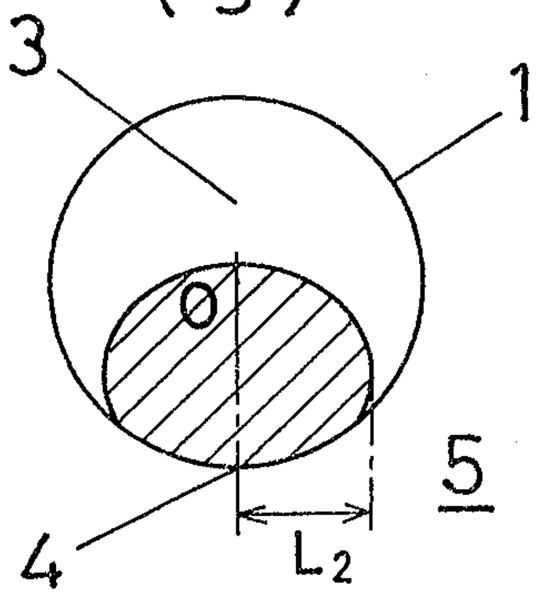
(e)



(f)



(g)



(h)

FIG. 2

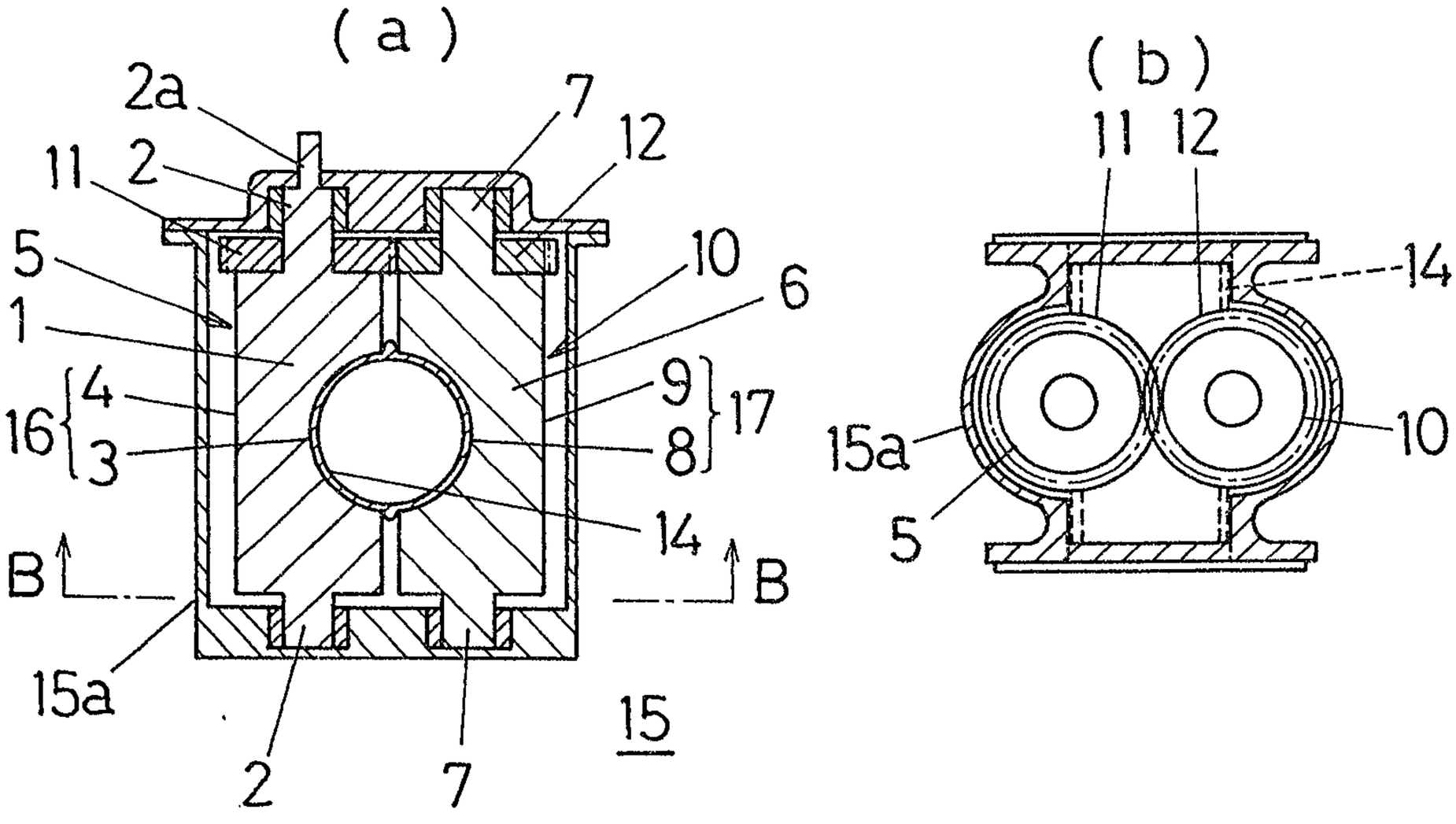

(a)
2a
7
12
11
2
5
10
6
1
4
9
17
16
3
8
14
B
B
15a
15
2
7
(b)
11
12
14
15a
10
5

FIG. 3

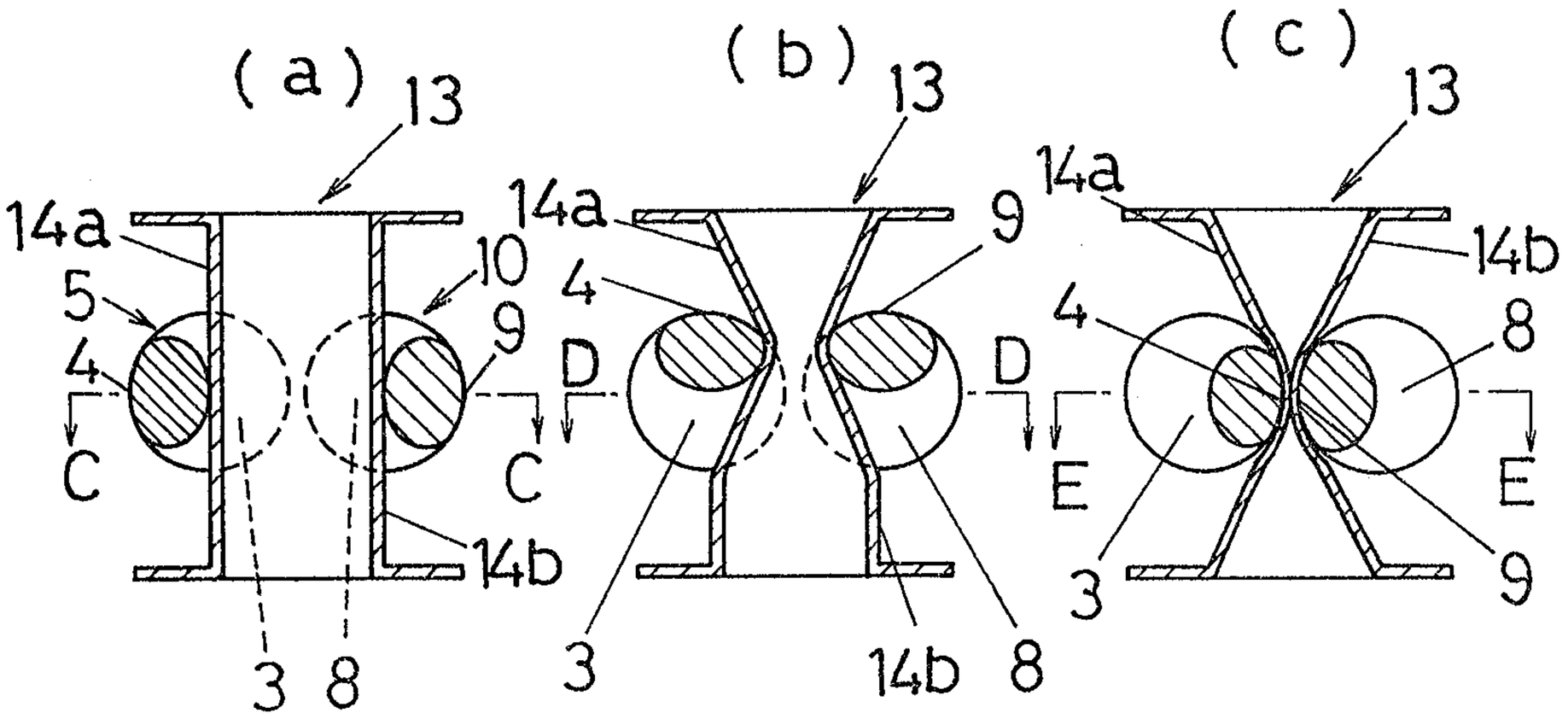

(a)
13
14a
10
5
9
4
C
C
14b
3
8
(b)
13
14a
9
4
D
D
3
14b
8
(c)
13
14a
14b
4
8
E
E
3
9

FIG. 4

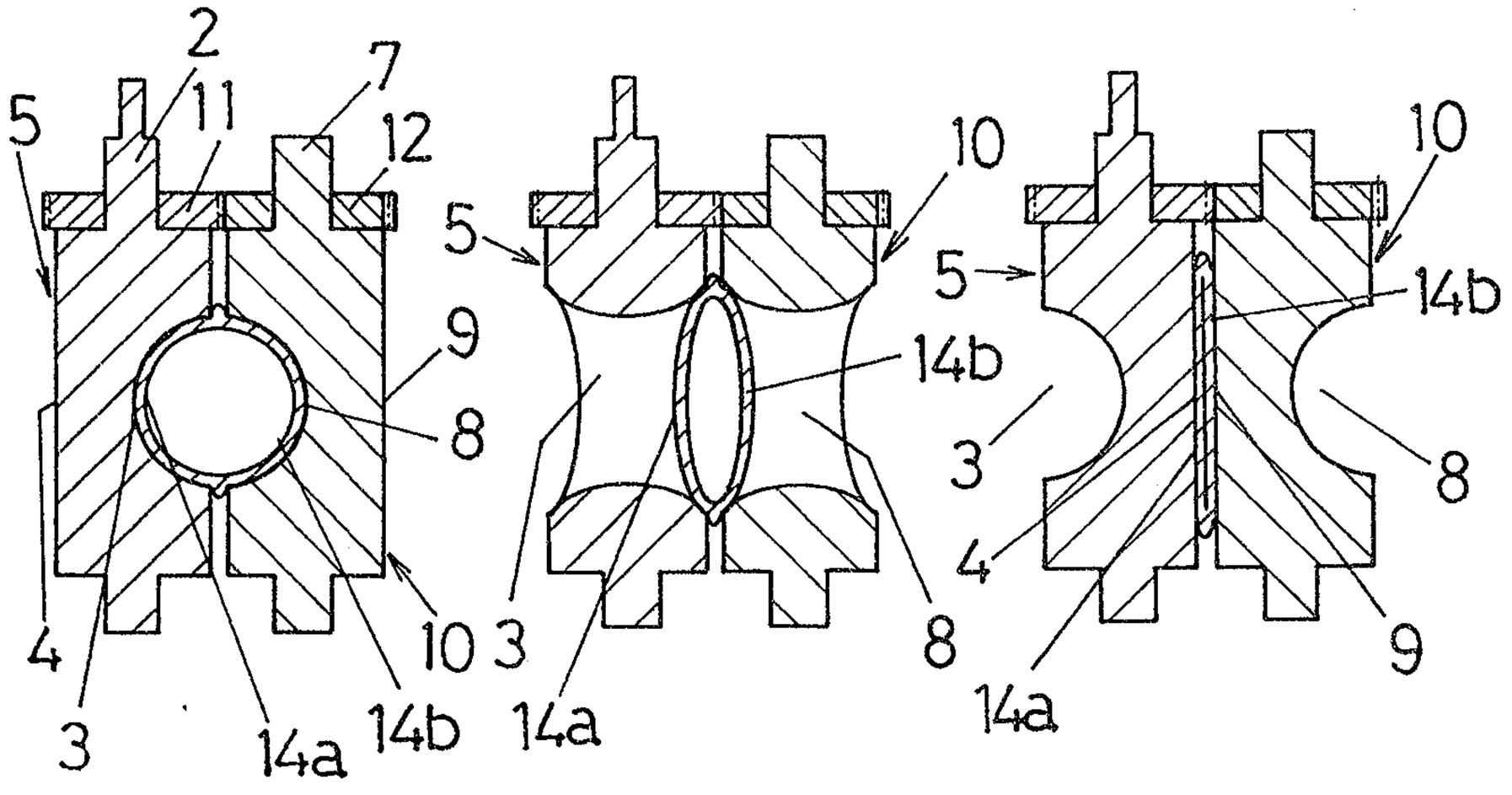
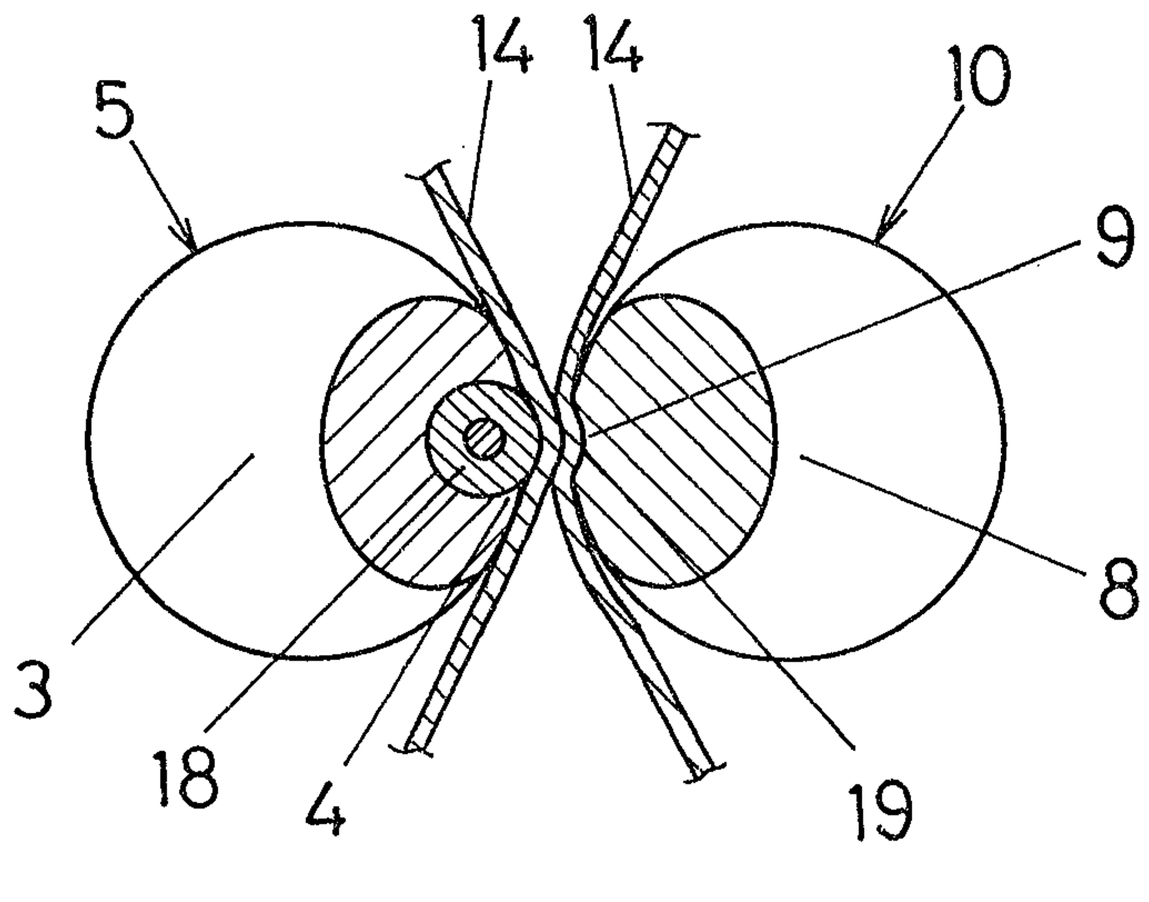


FIG. 5



Kanzaka & Ando

FIG. 6

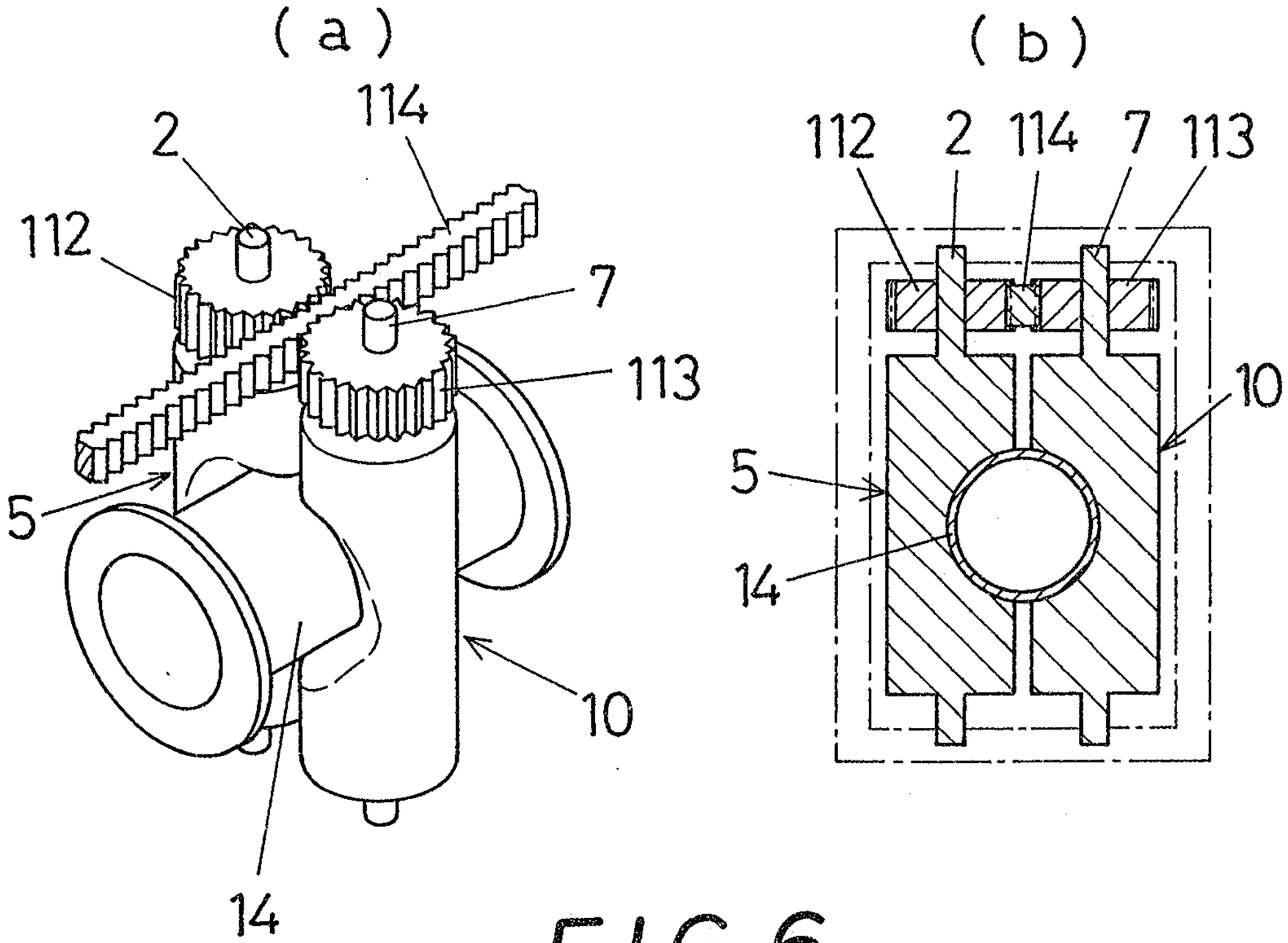

(a)
114
2
112
7
113
5
10
14
(b)
112
2
114
7
113
10
5
14

FIG. 6

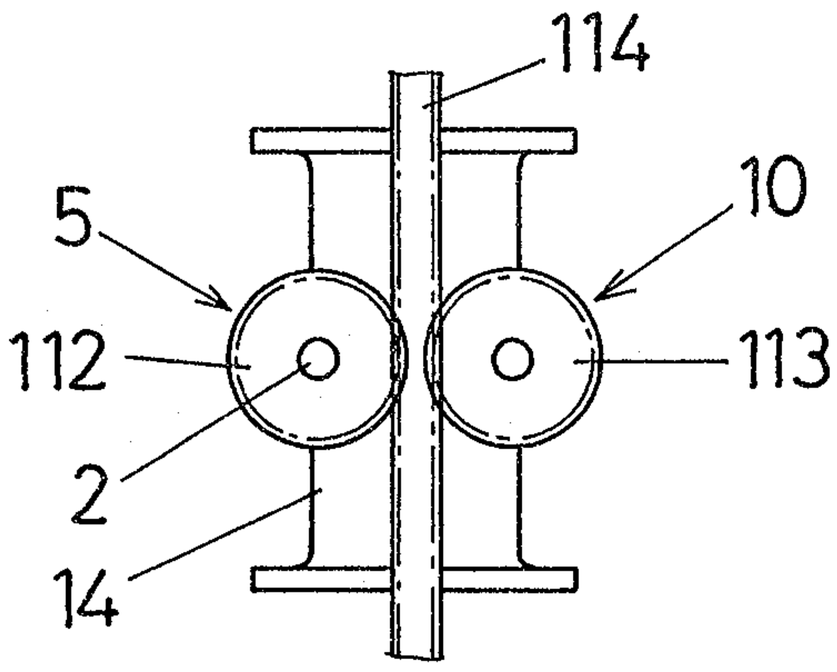
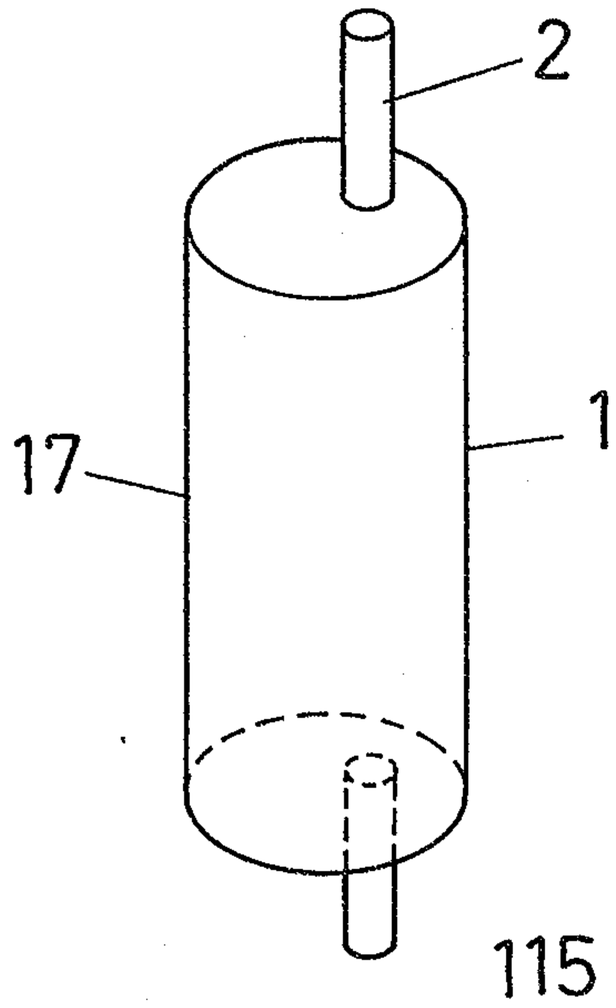

(c)
114
5
10
112
113
2
14

FIG. 7

(a)



(b)

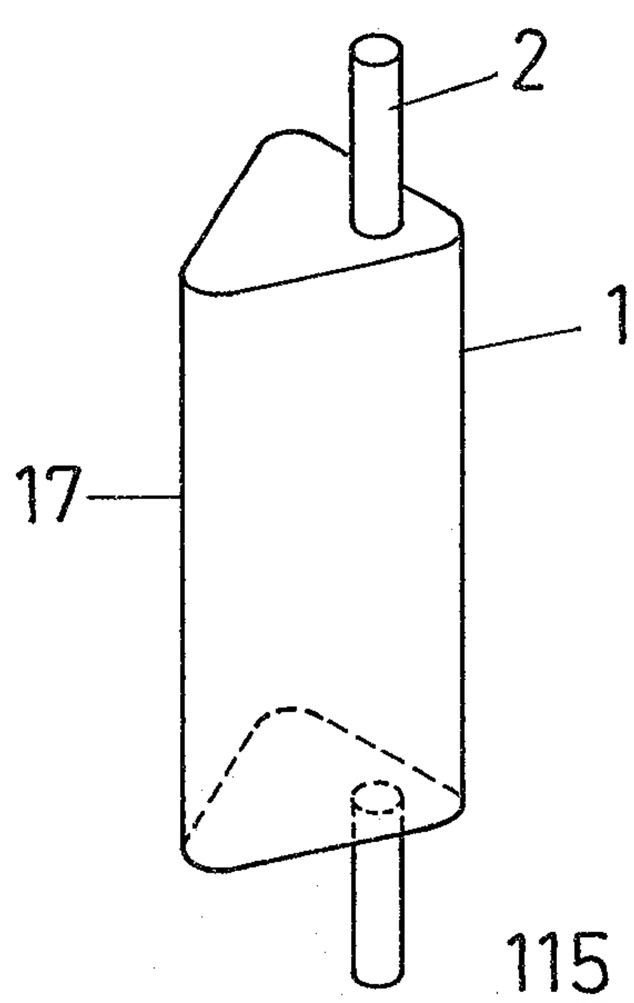


FIG. 8

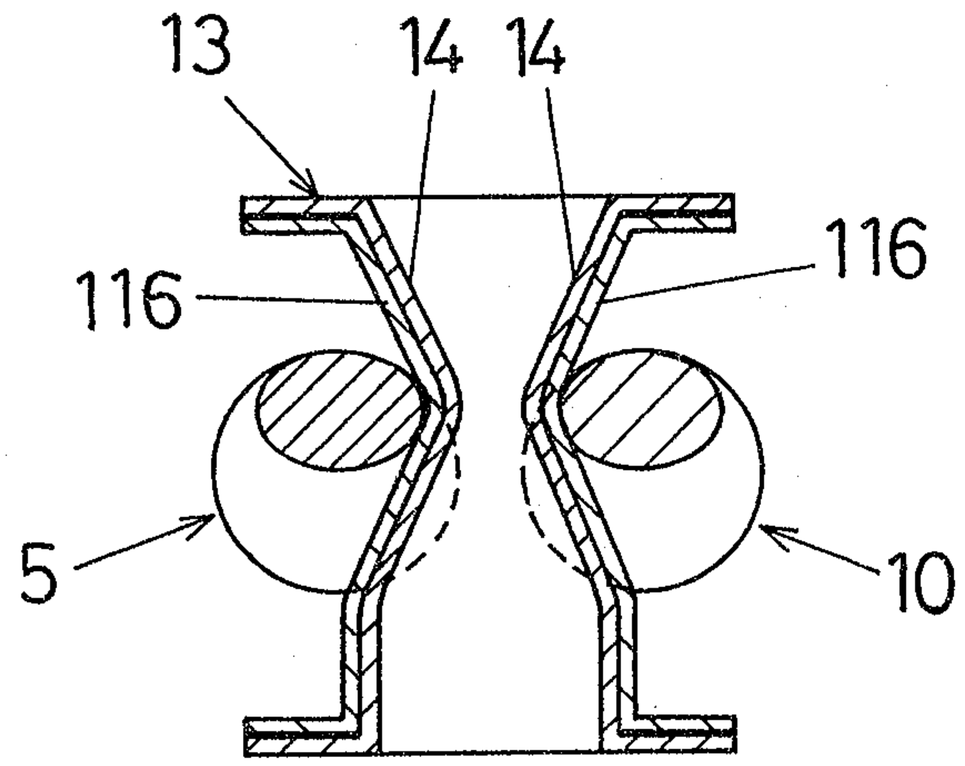


FIG. 9

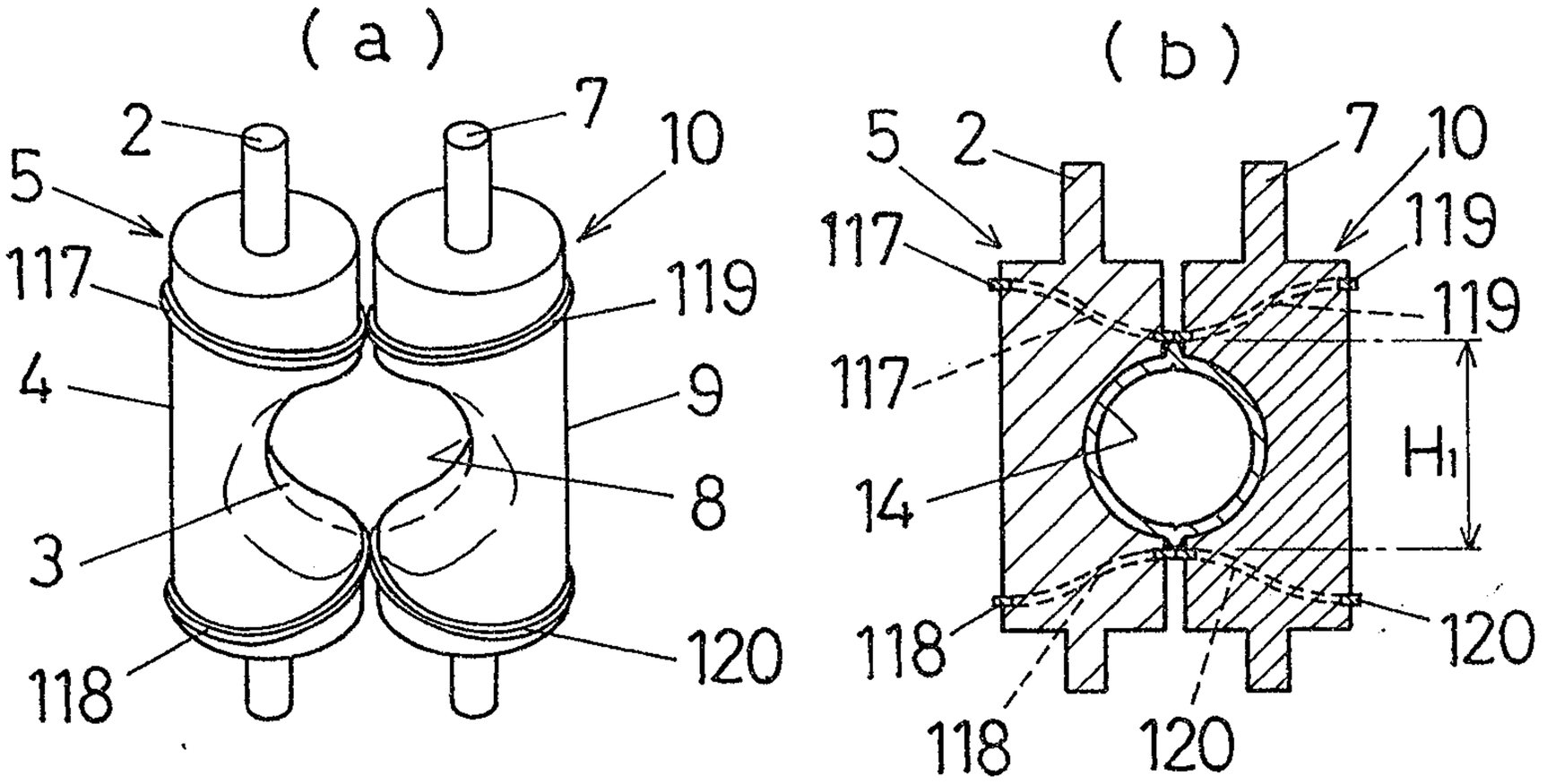

(a)
(b)
2
7
10
5
117
119
4
9
8
3
120
118
H1
14

FIG. 9

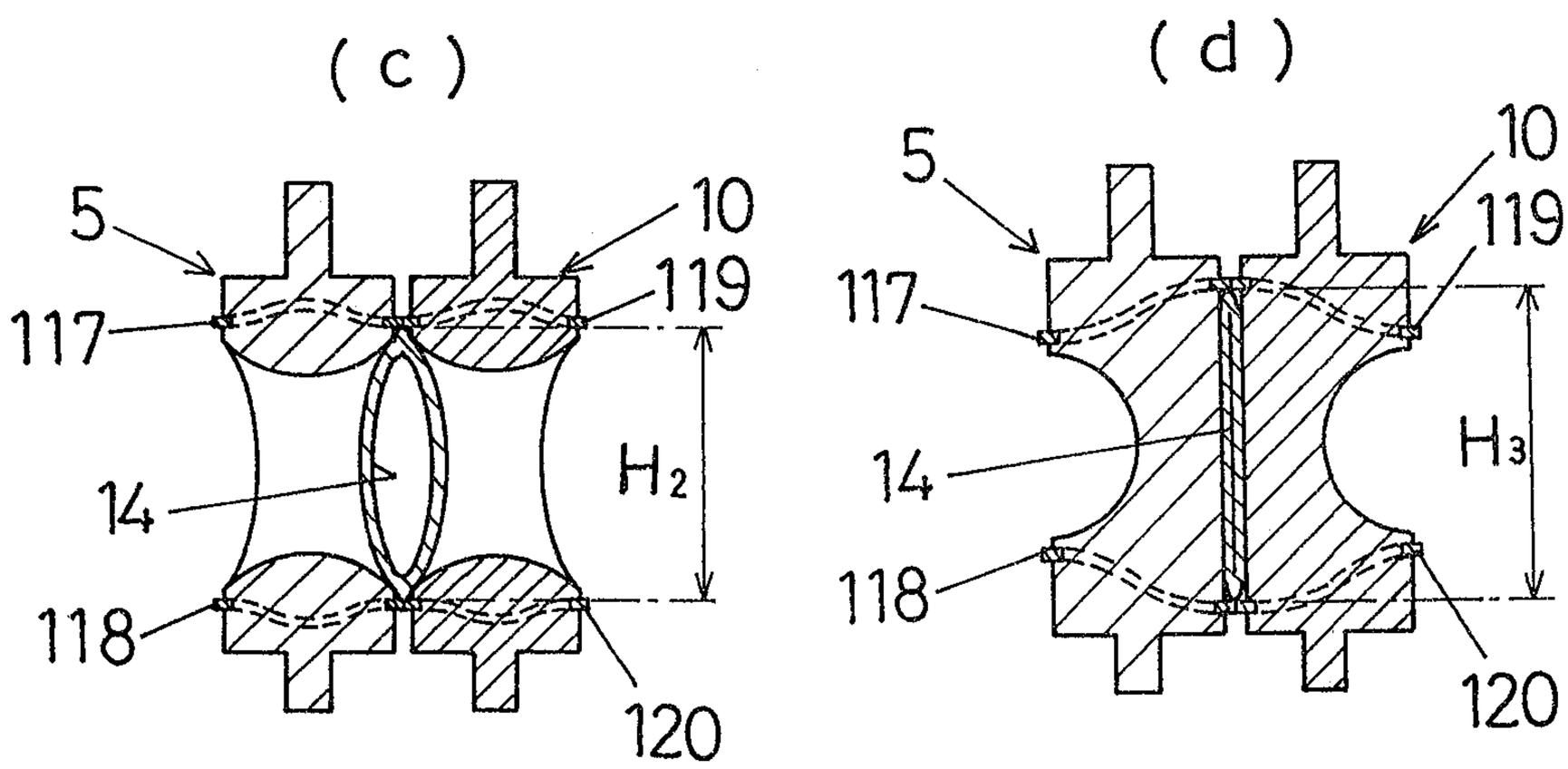
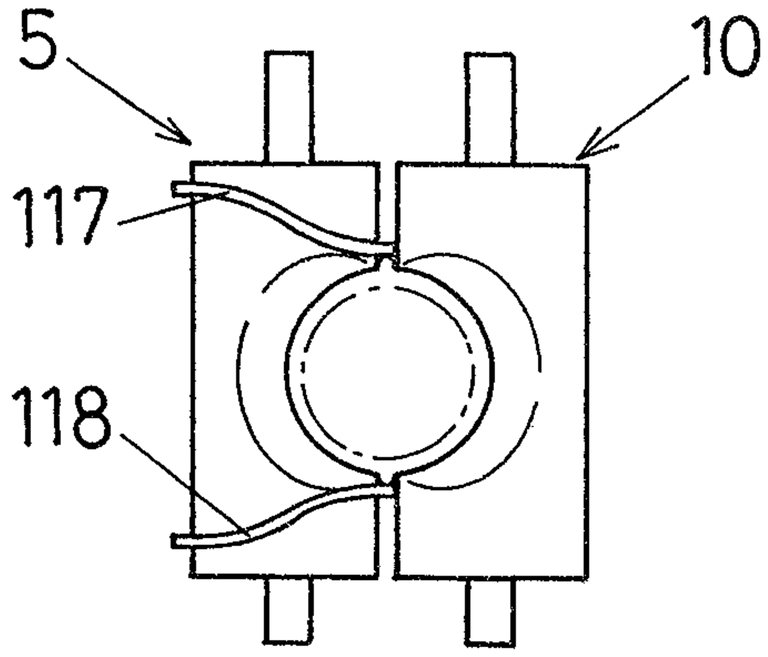

(c)
(d)
5
10
117
119
14
H2
118
120
H3

FIG. 10

(a)



(b)

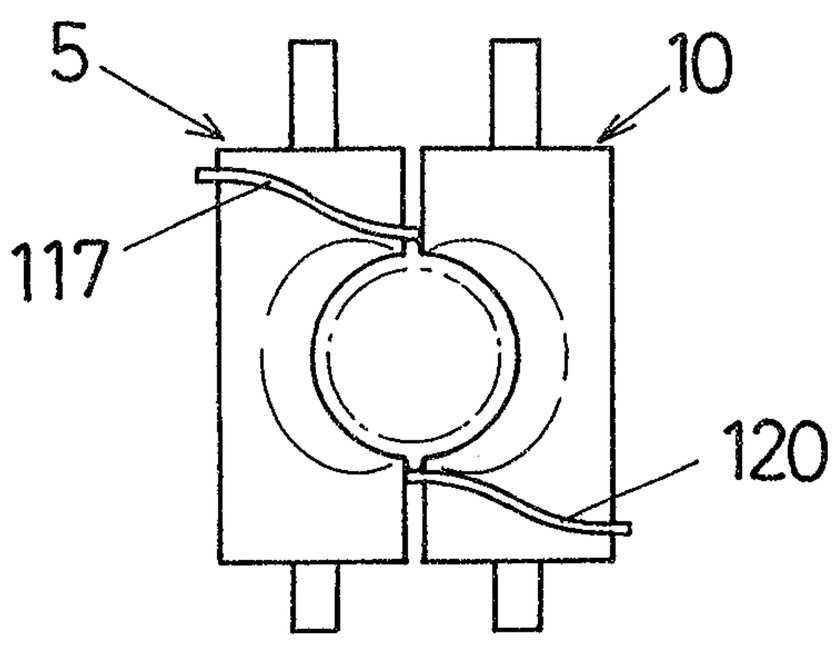
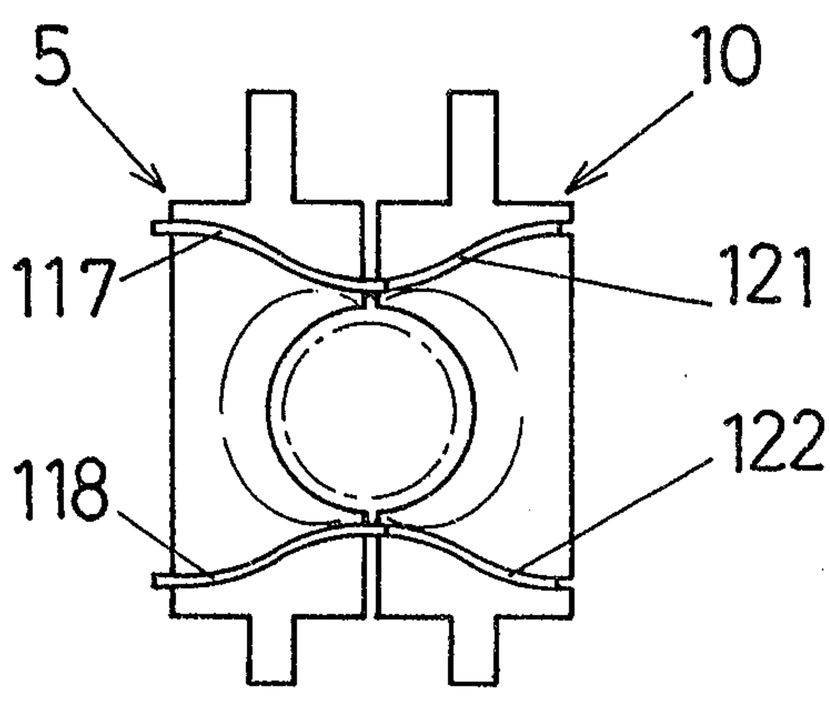


FIG. 10

(c)



(d)

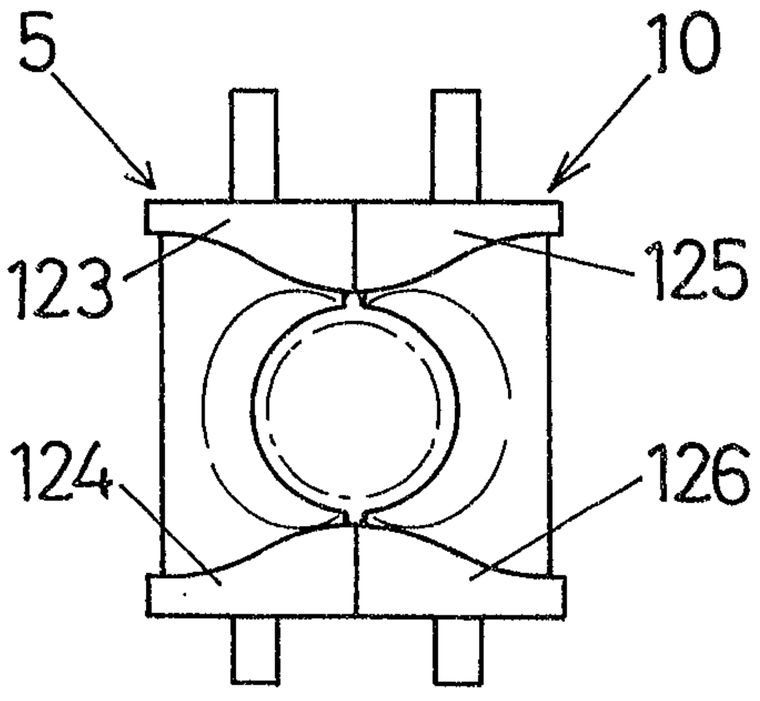


FIG. 11

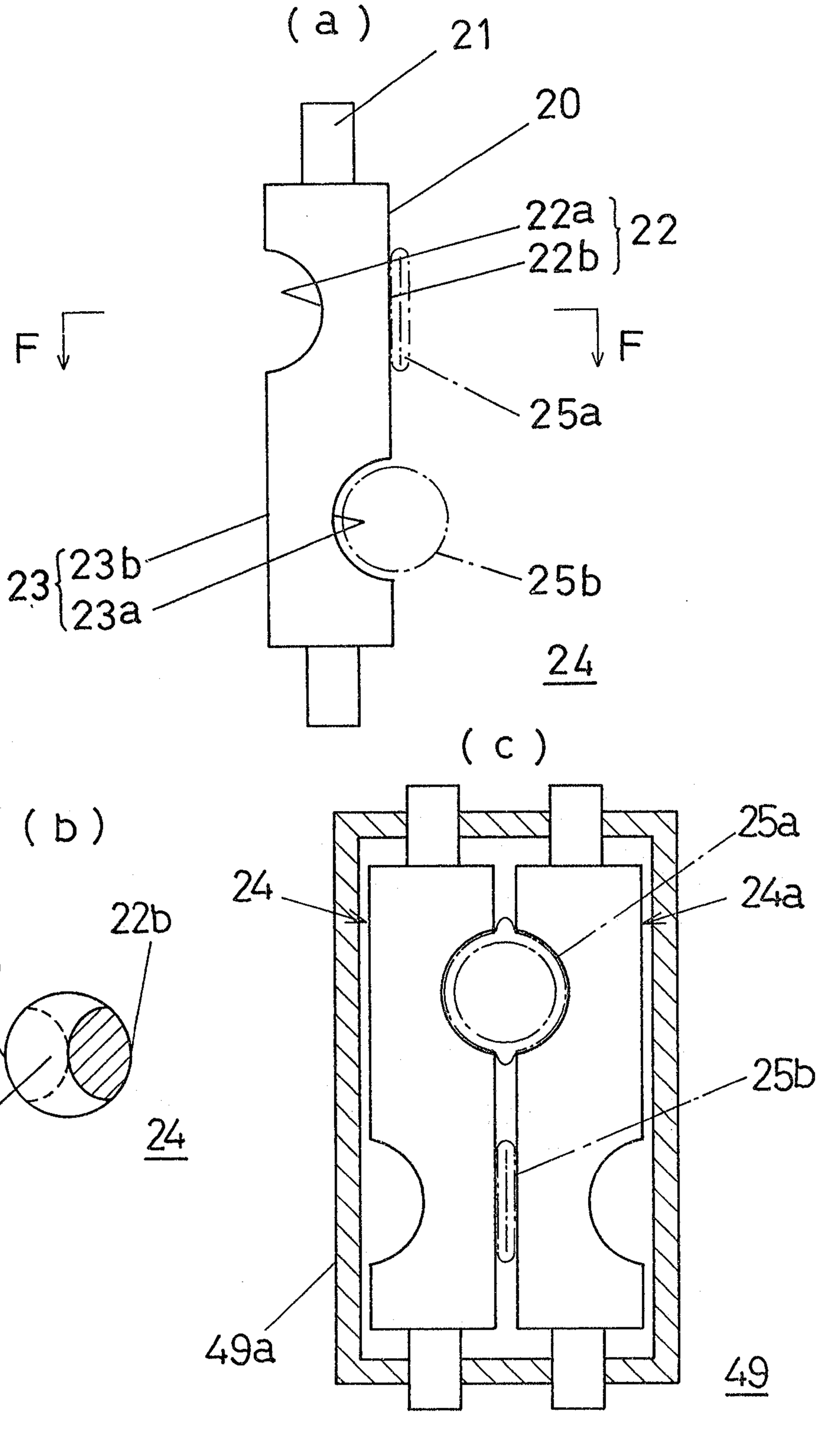
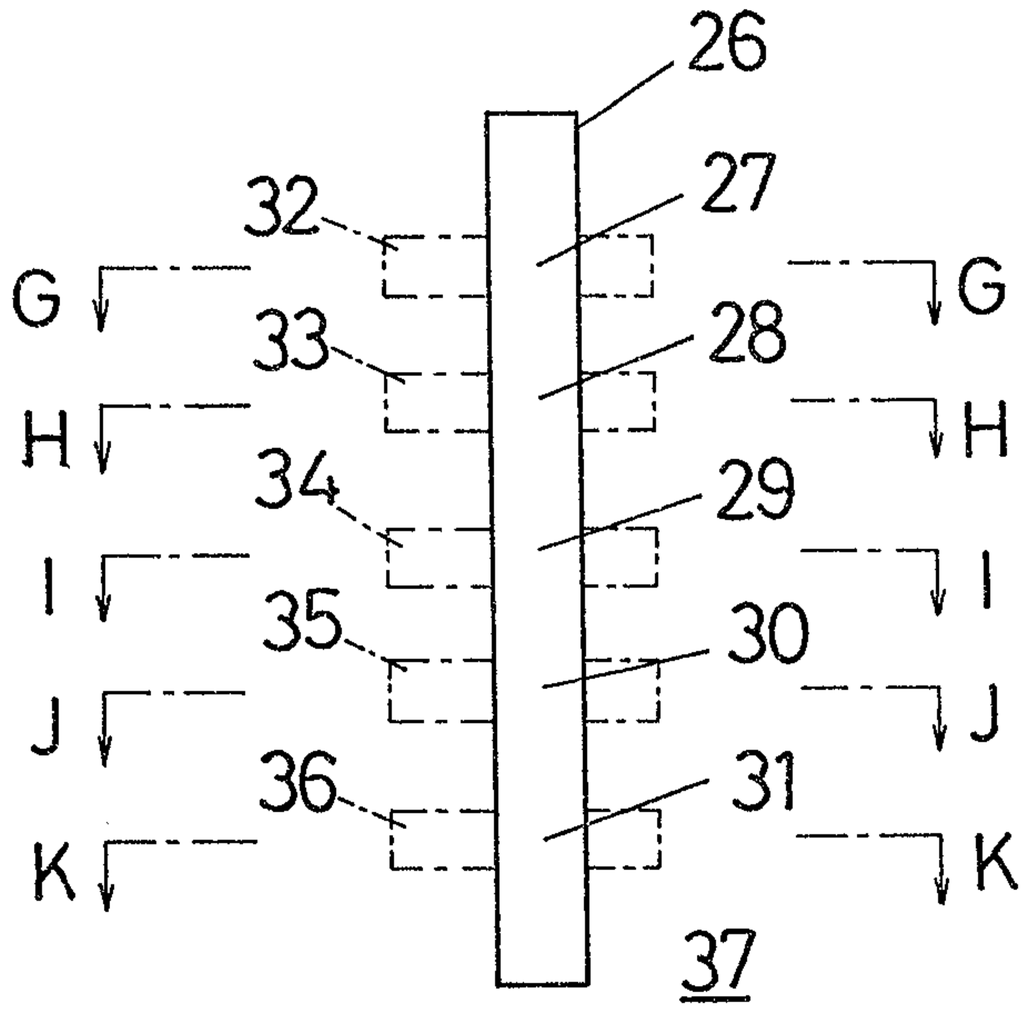
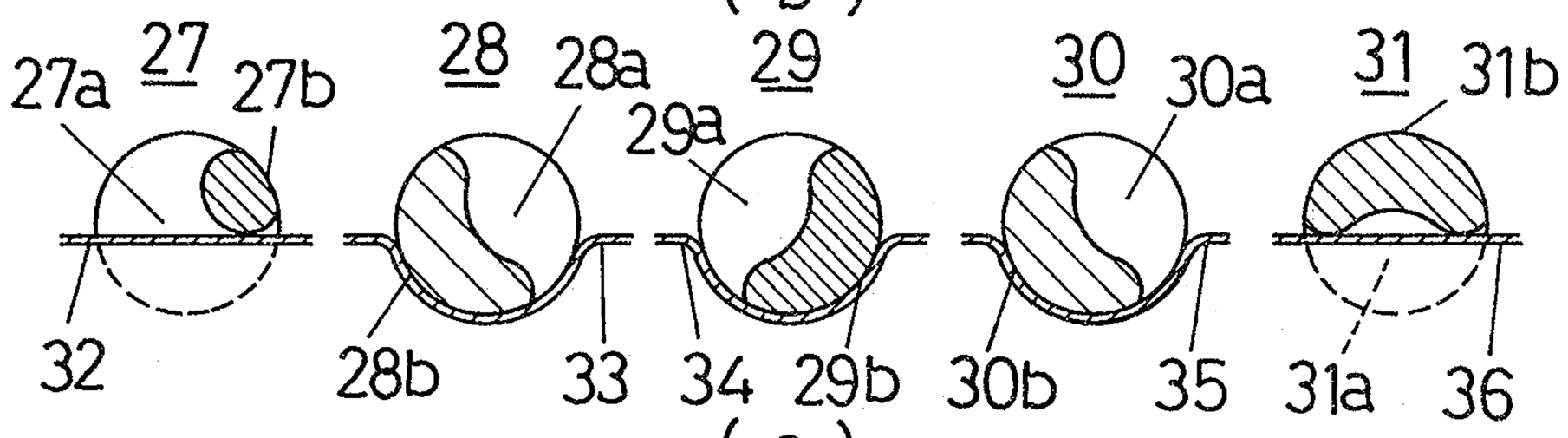

(a)
21
20
22a
22b
22
F
F
25a
23
23b
23a
25b
24
(c)
(b)
22b
23b
22a
24
24
25a
24a
25b
49a
49

FIG.12

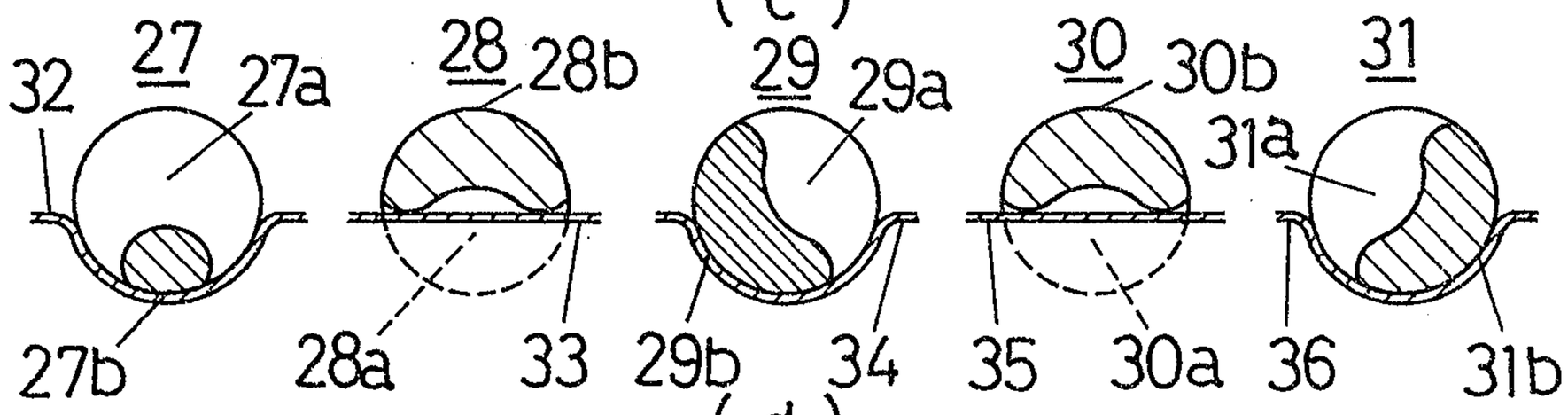
(a)



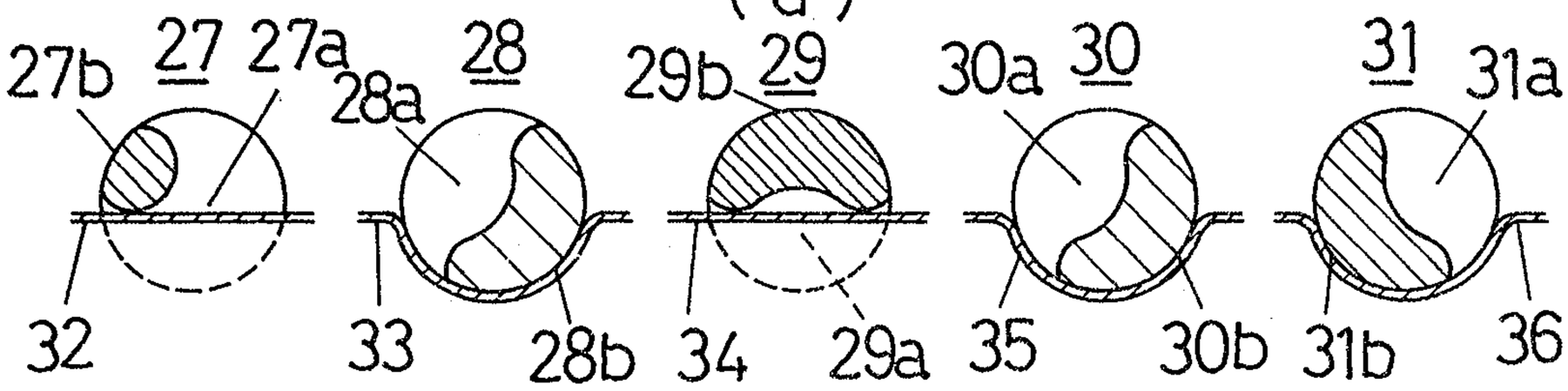
(b)



(c)



(d)



Agents et Ouvrages

FIG.13

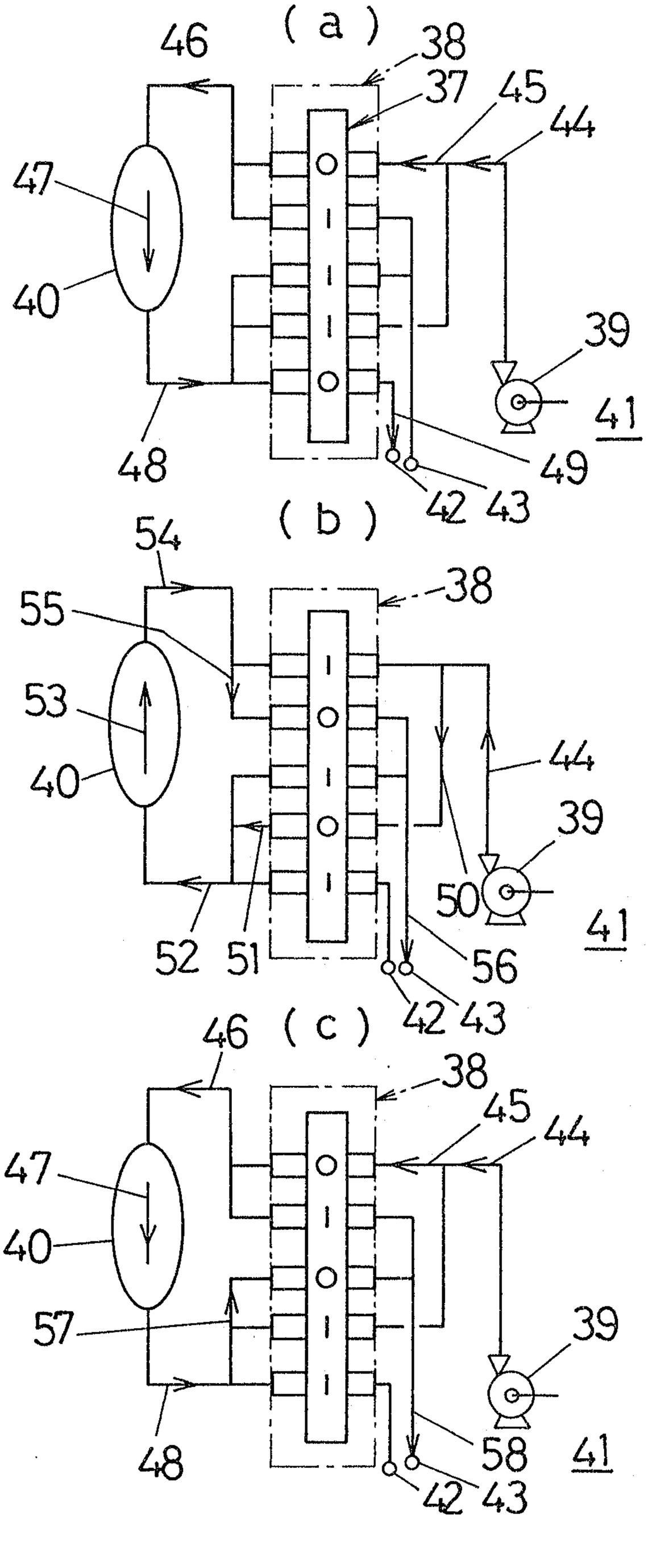
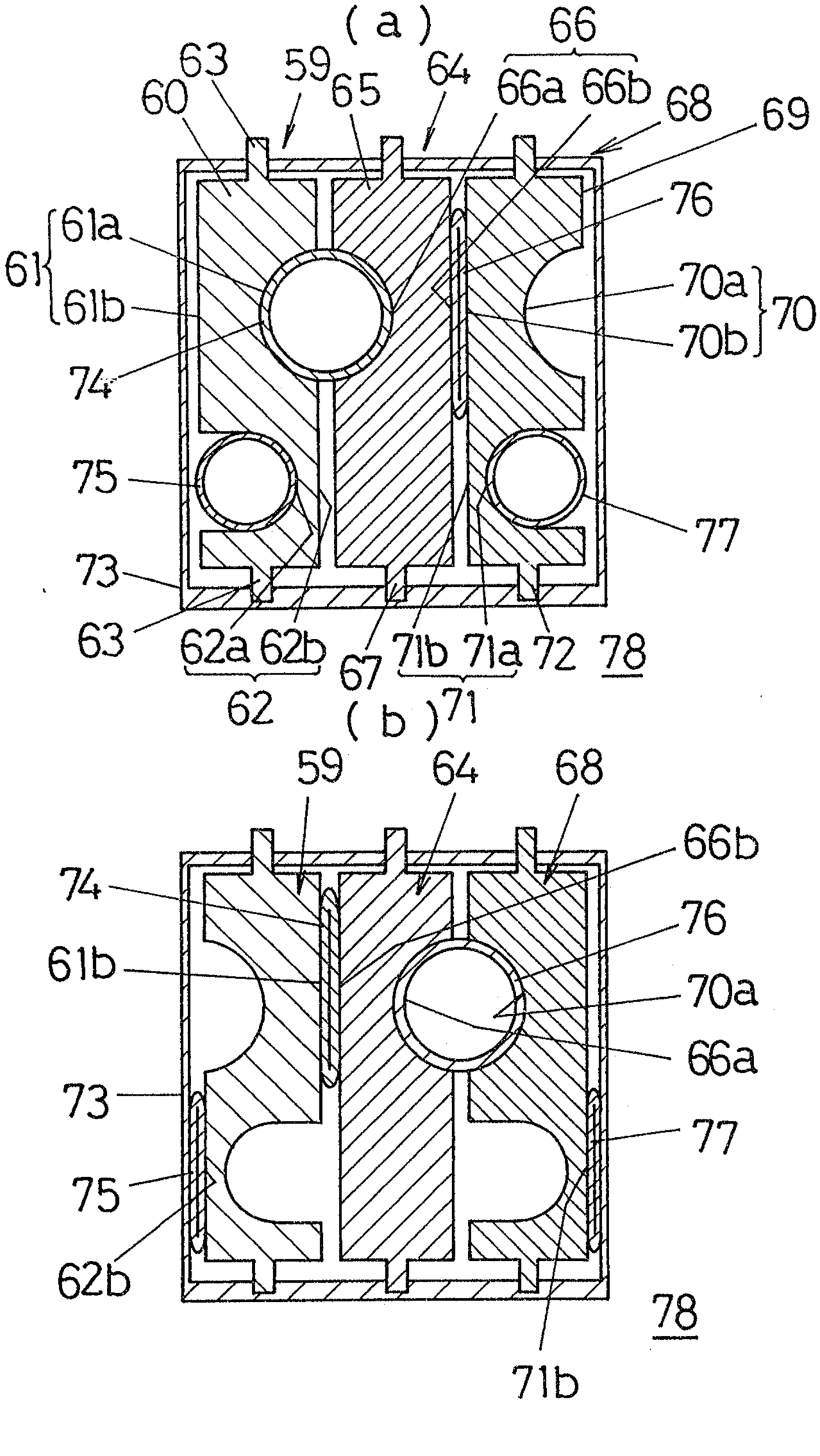
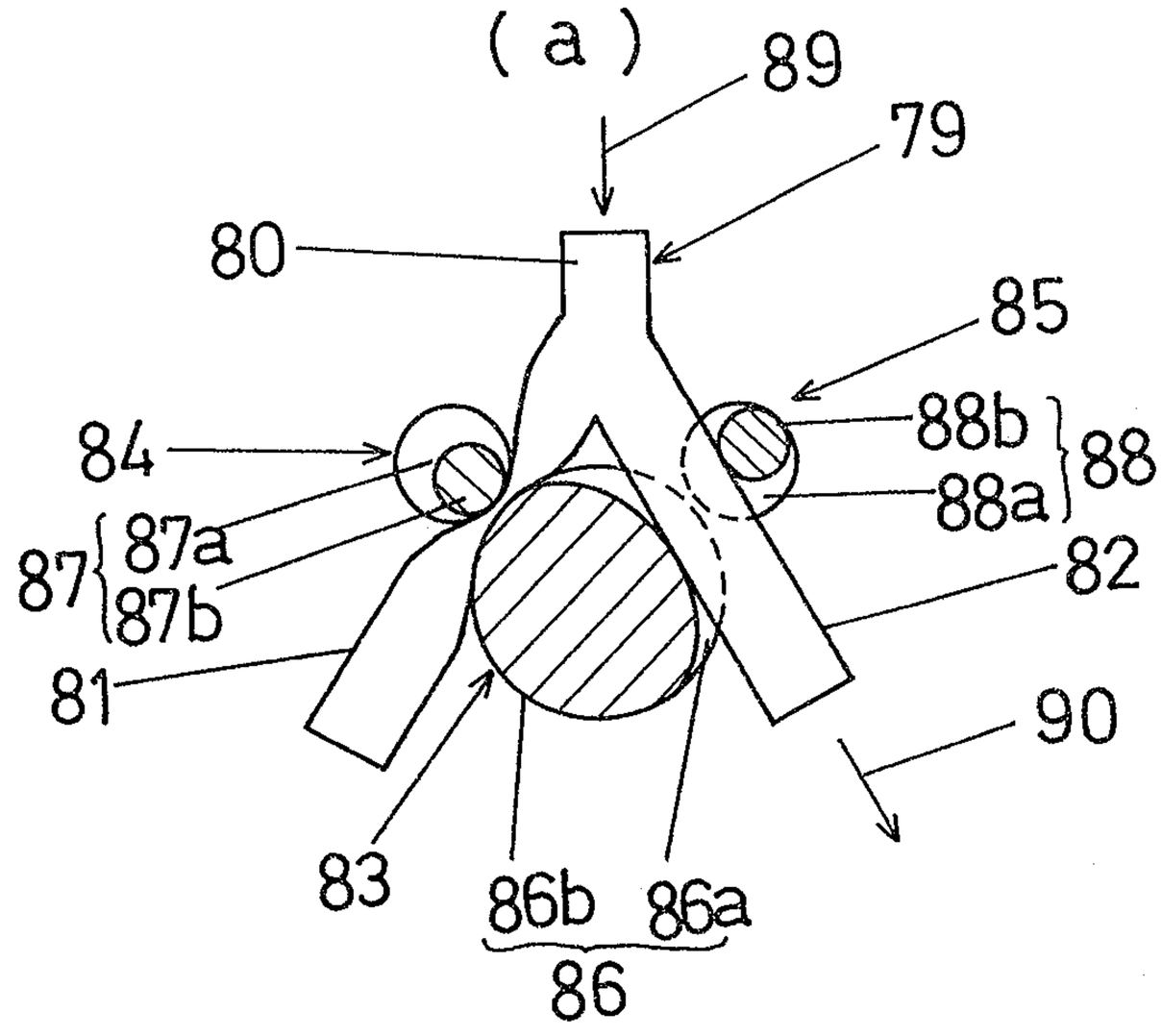

(a)
46
38
37
45
44
47
40
39
41
48
49
42
43
(b)
54
55
38
53
40
44
39
50
41
52
51
56
42
43
(c)
46
38
45
44
47
40
57
39
58
41
48
42
43

FIG.14



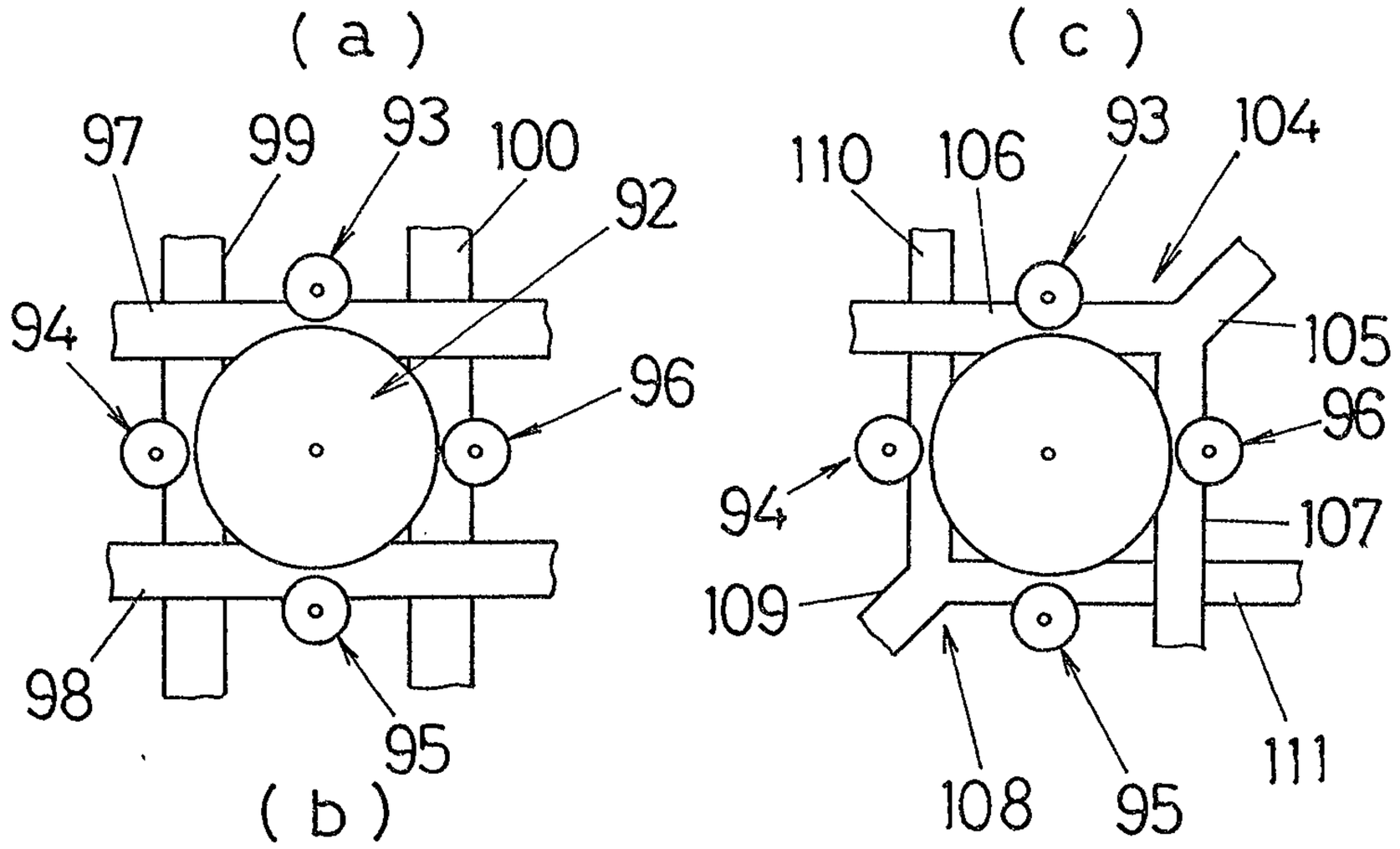
Marks & Clerk

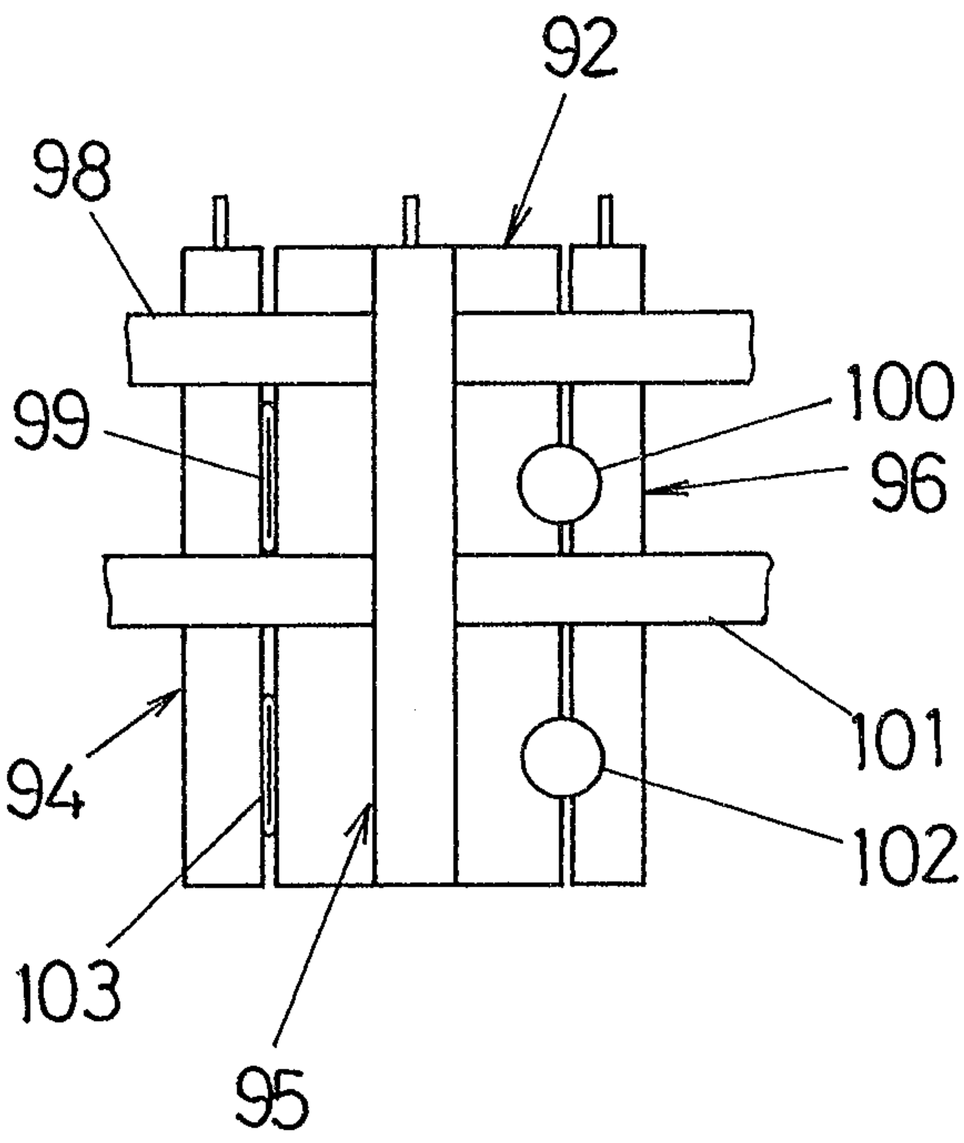
FIG.15



Agents for Applicants

FIG.16

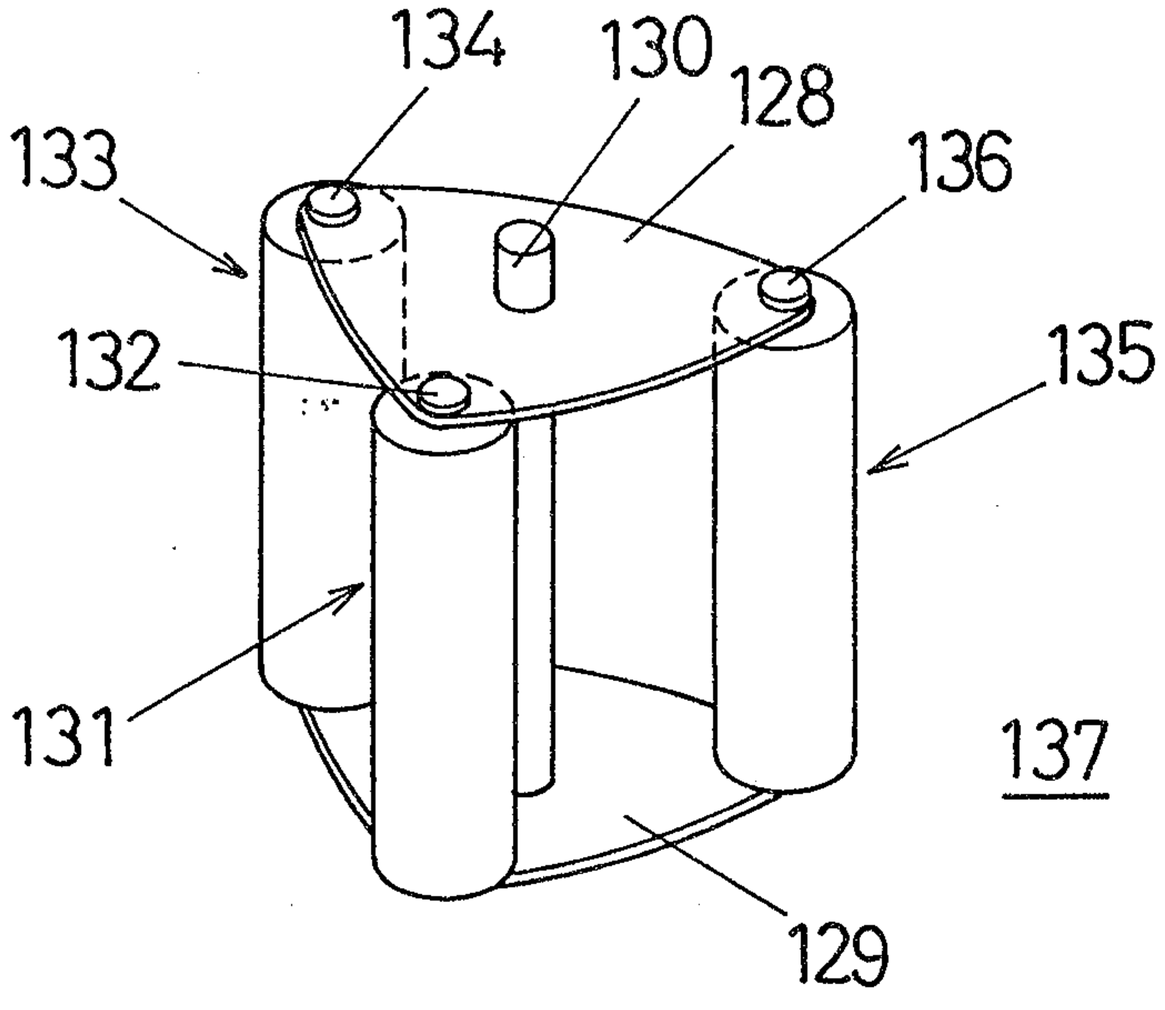




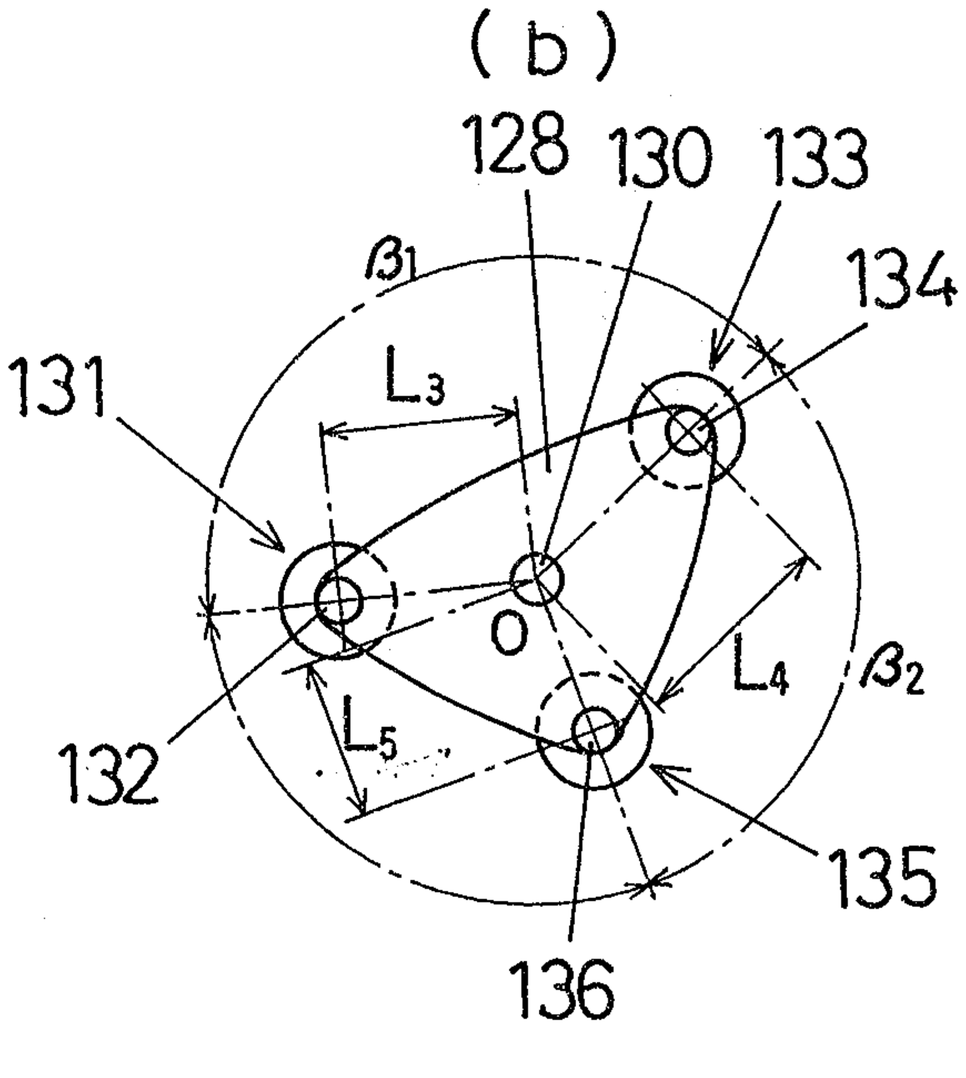
Agents et Conseils

FIG.17

(a)



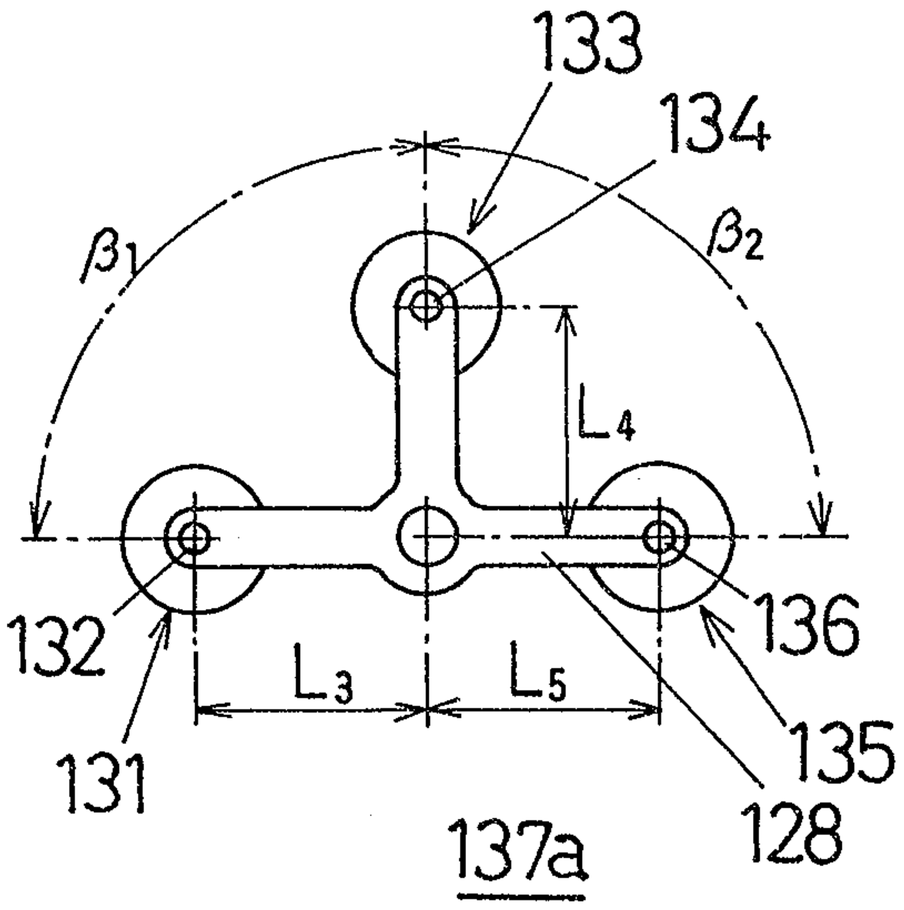
(b)



Hanke et Ohnk

FIG.18

(a)



(b)

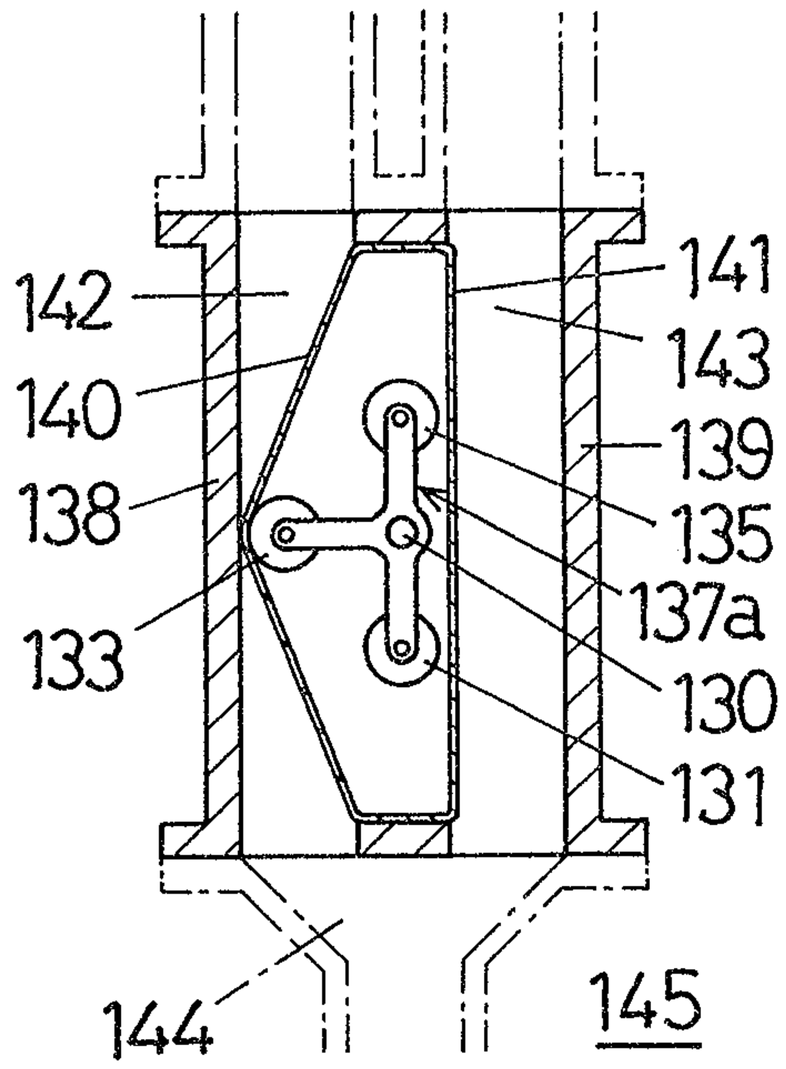
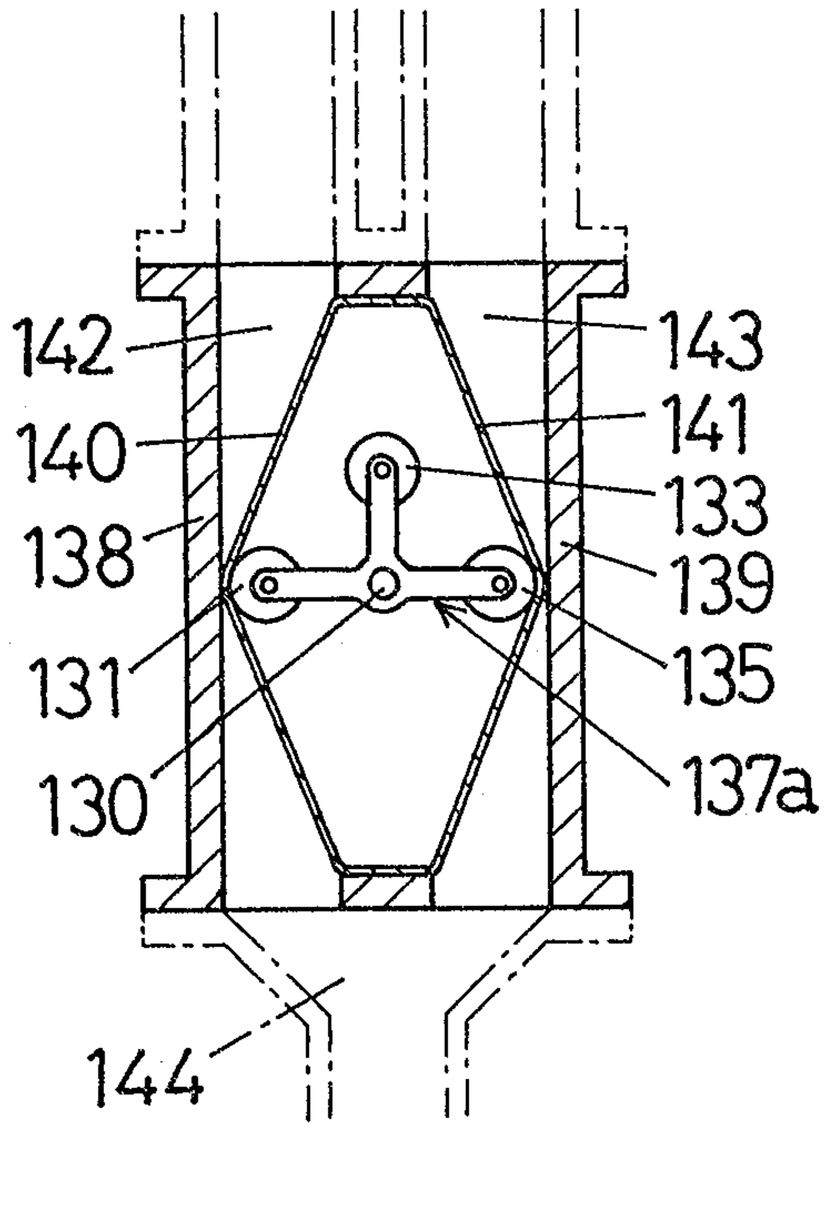


FIG.18

(c)



(d)

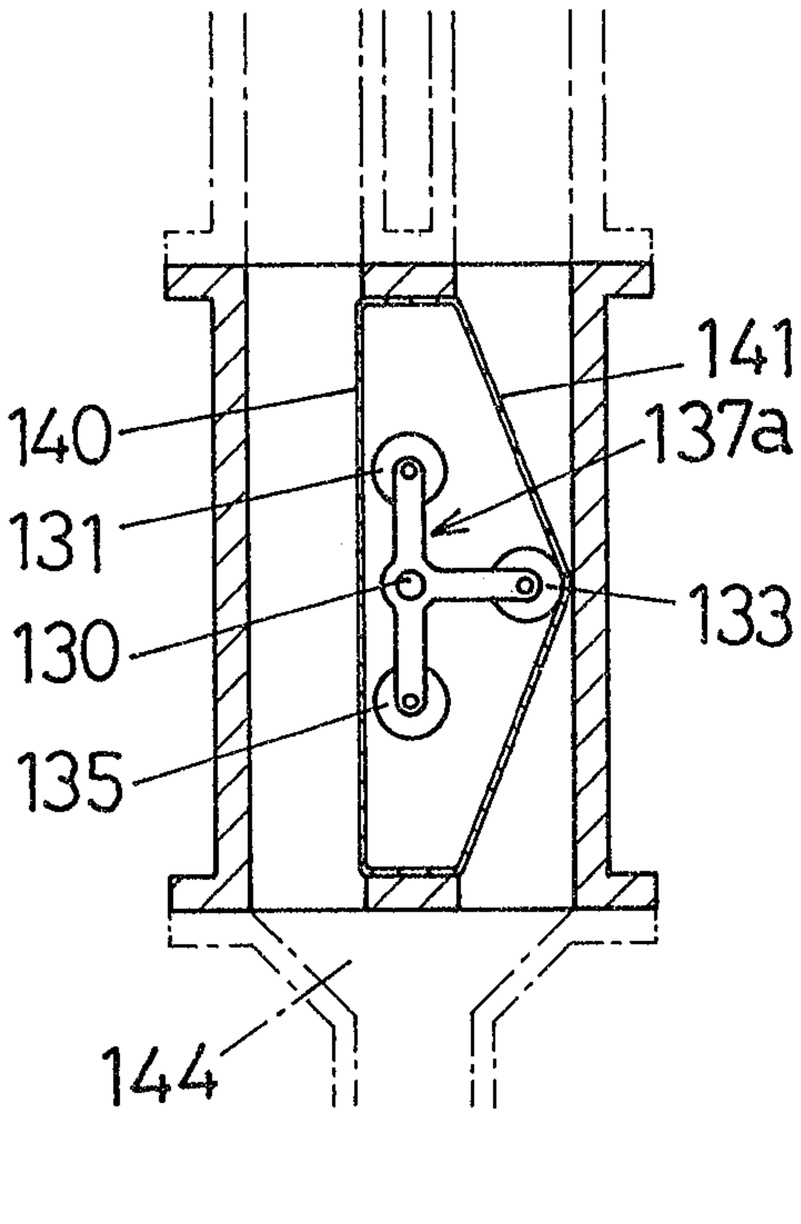
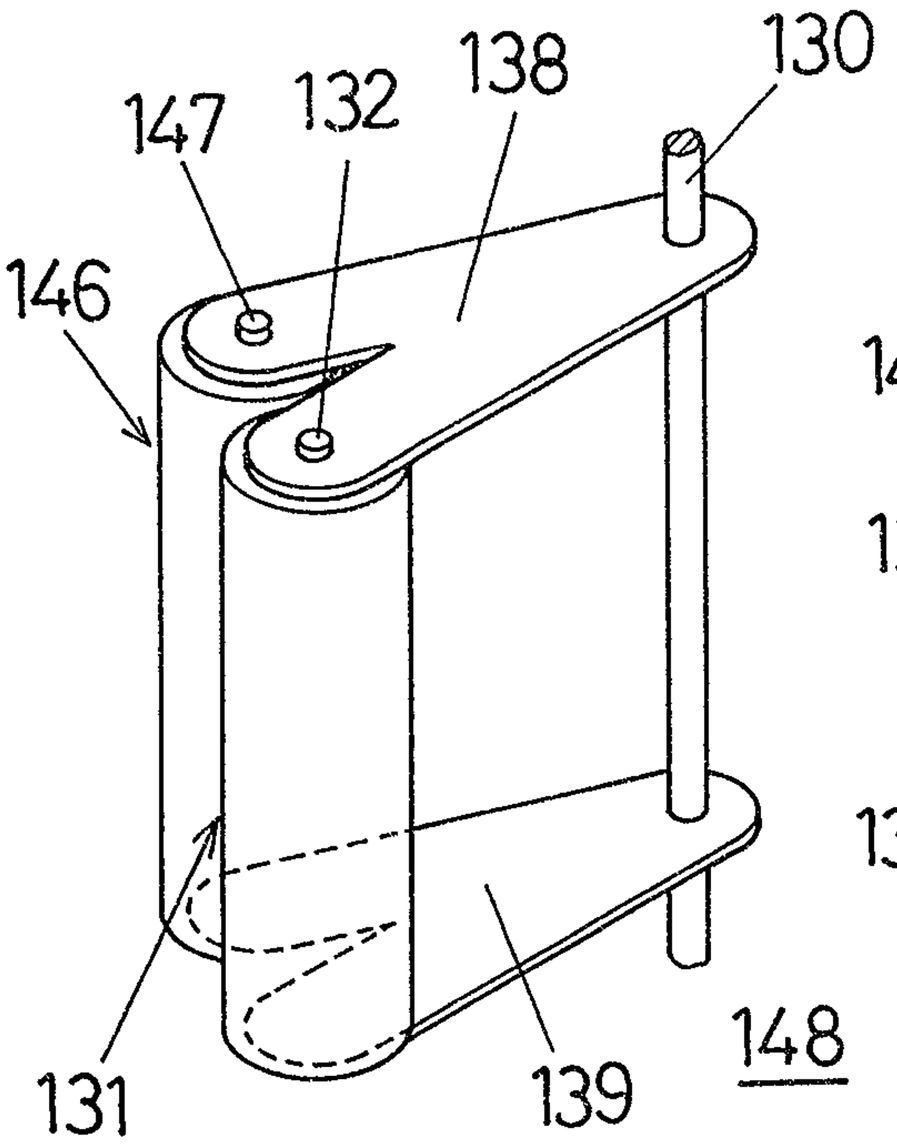


FIG.19

(a)



(b)

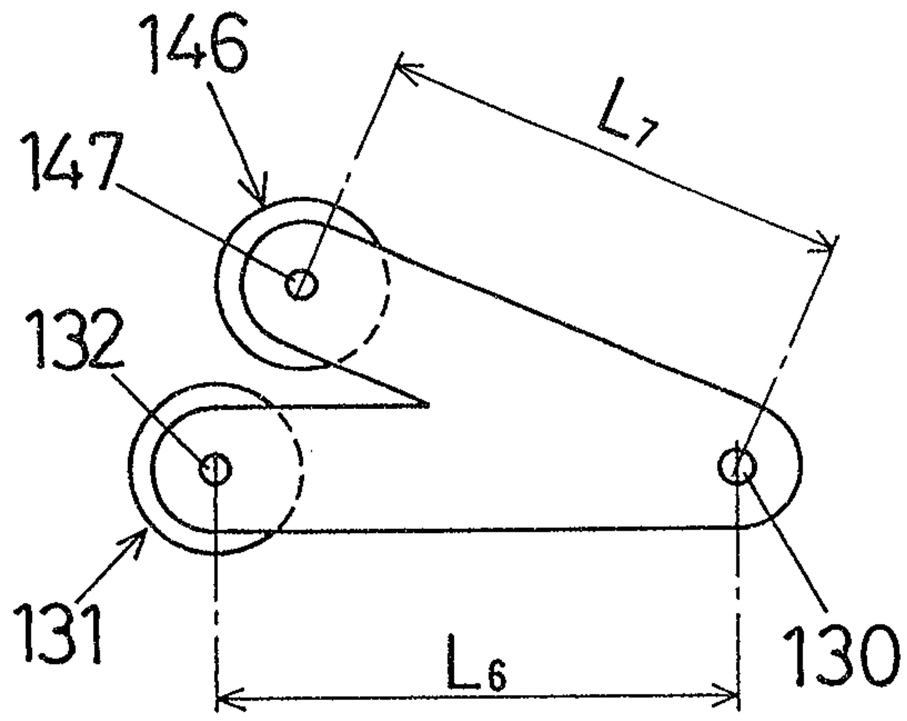
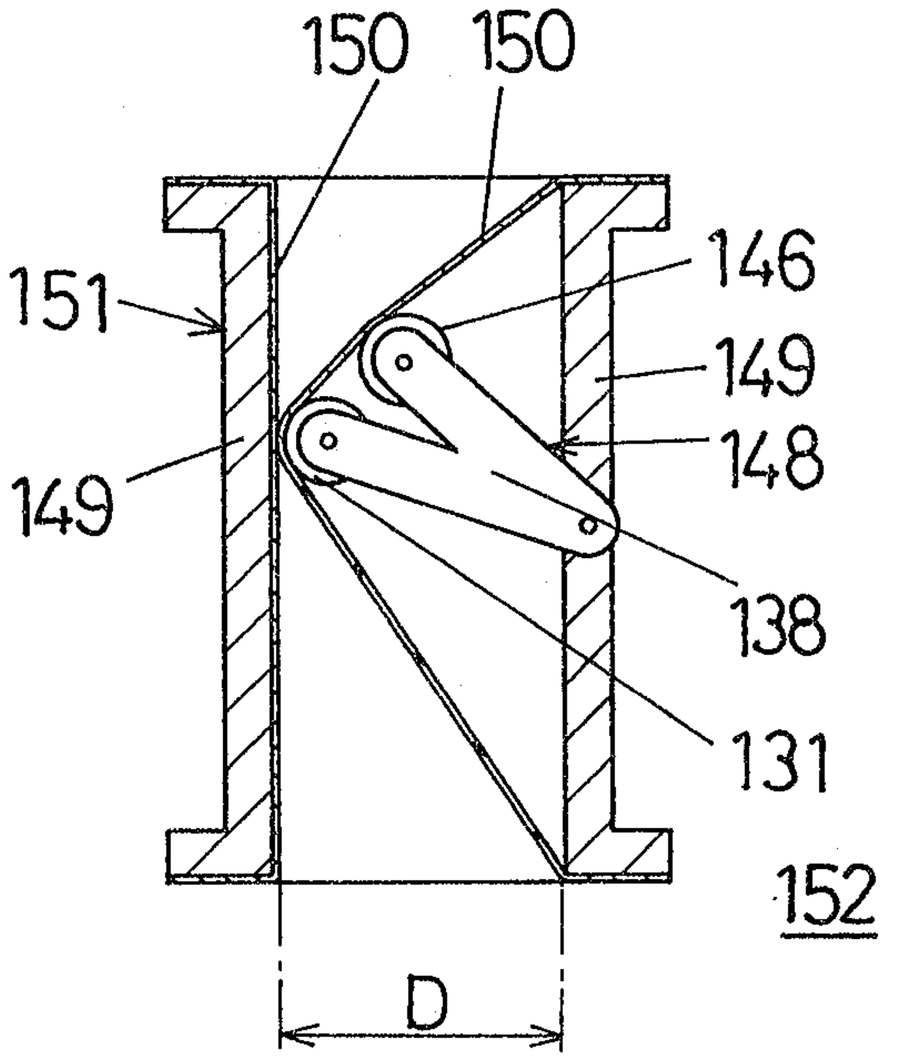


FIG.19

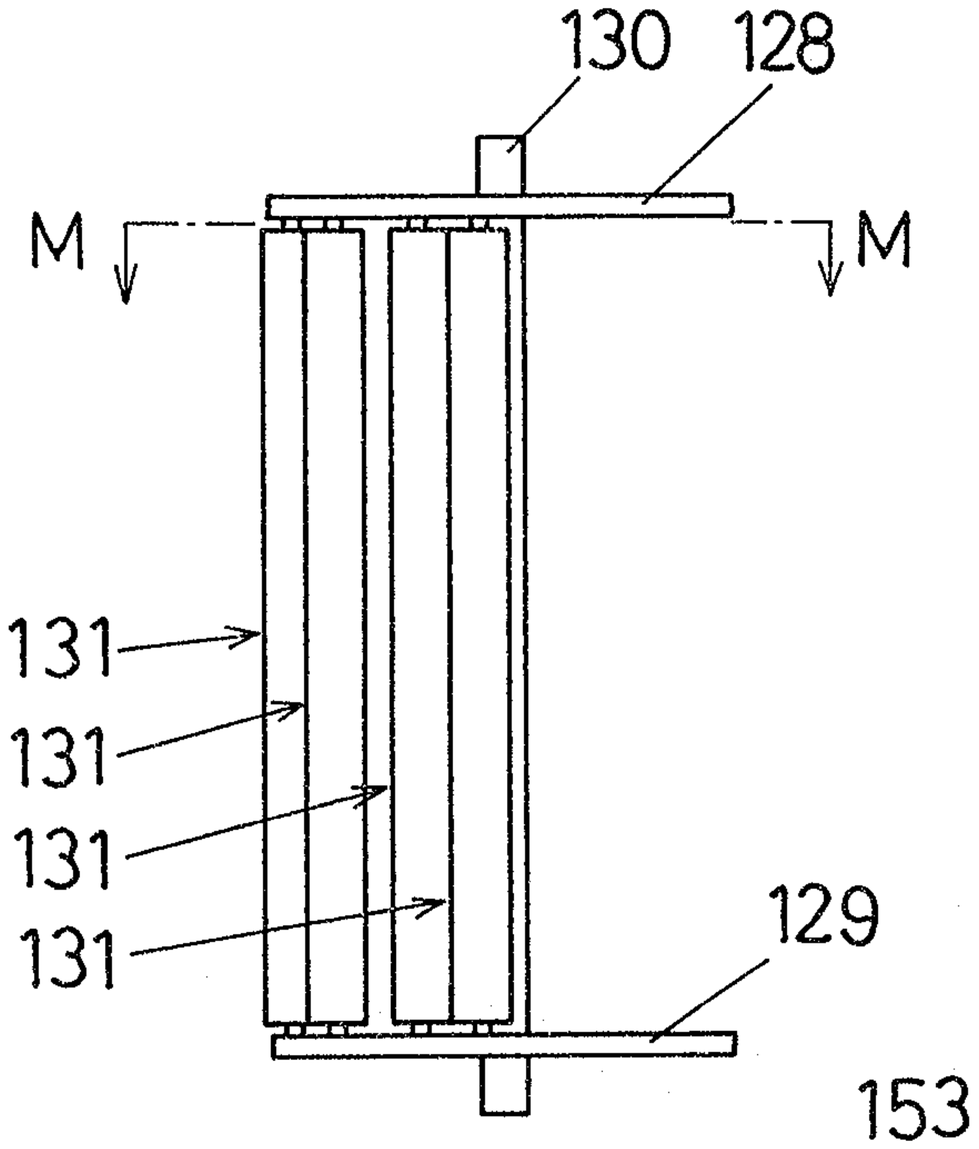
(c)



Agents et Ors

FIG.20

(a)


130
128
M
M
131
131
131
131
129
153

(b)

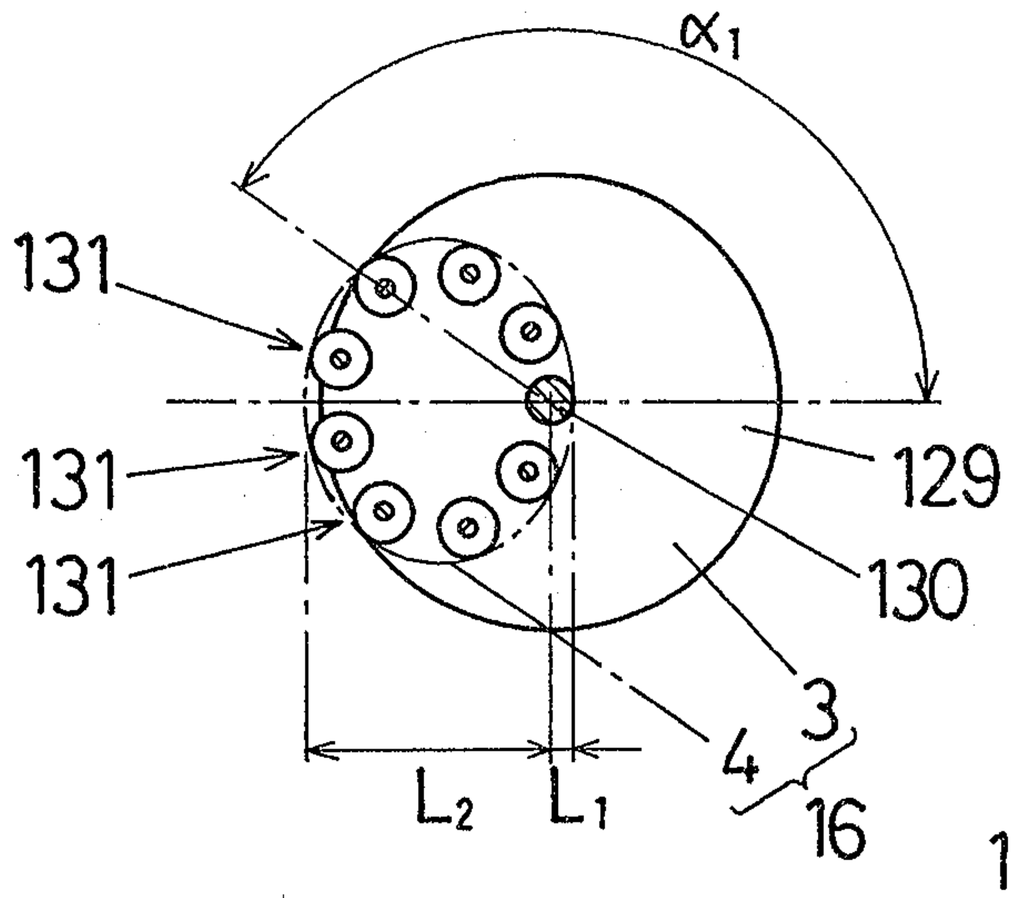
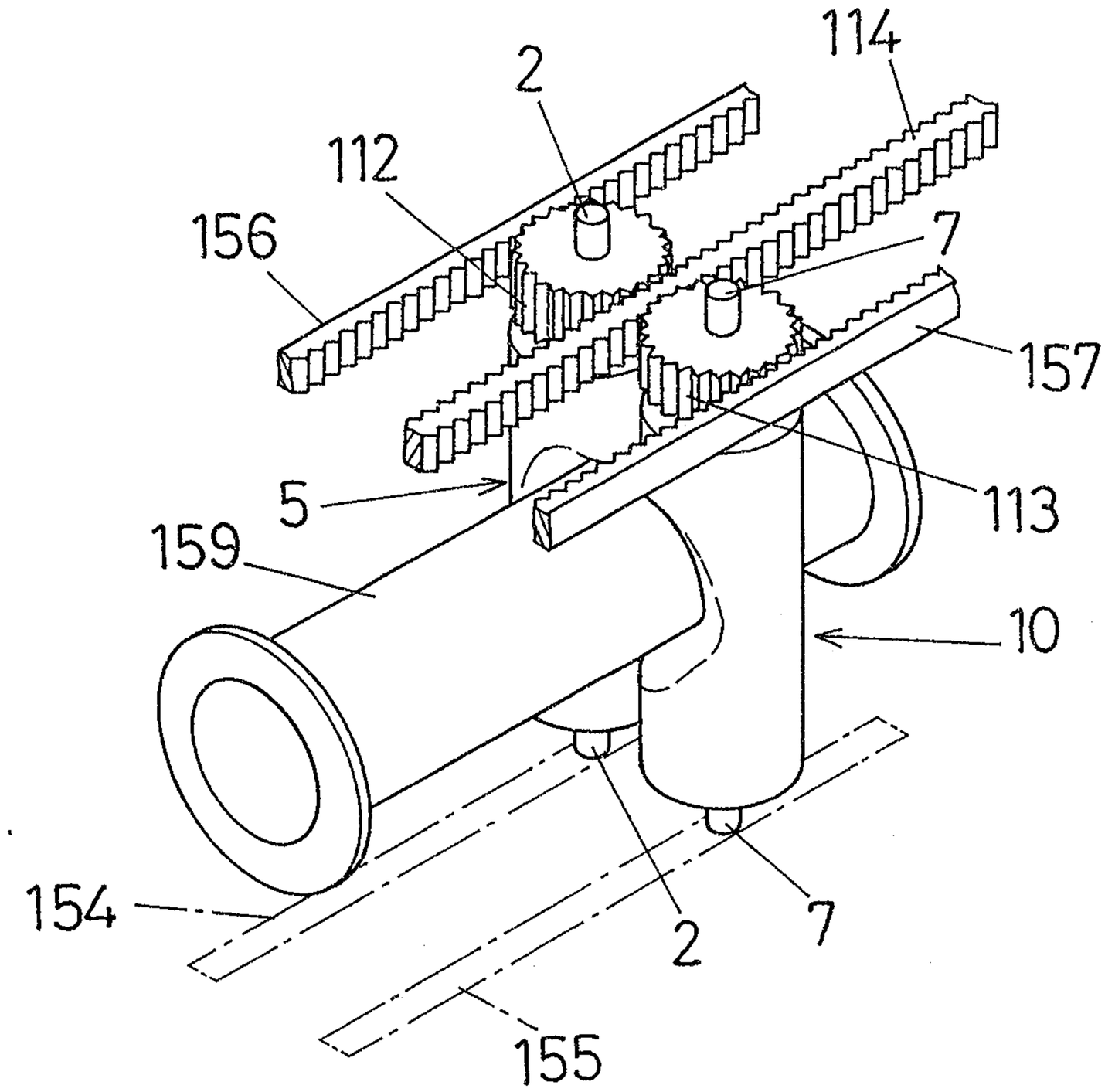
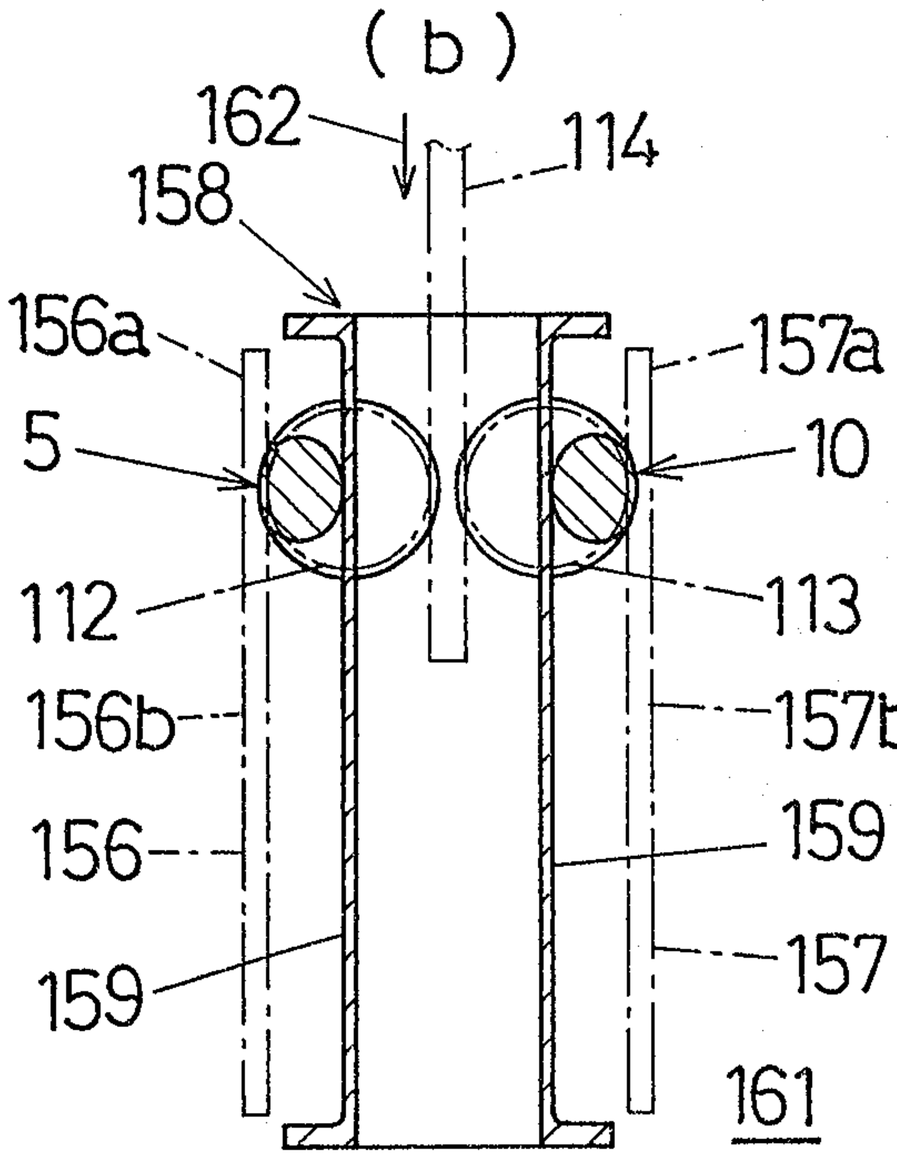
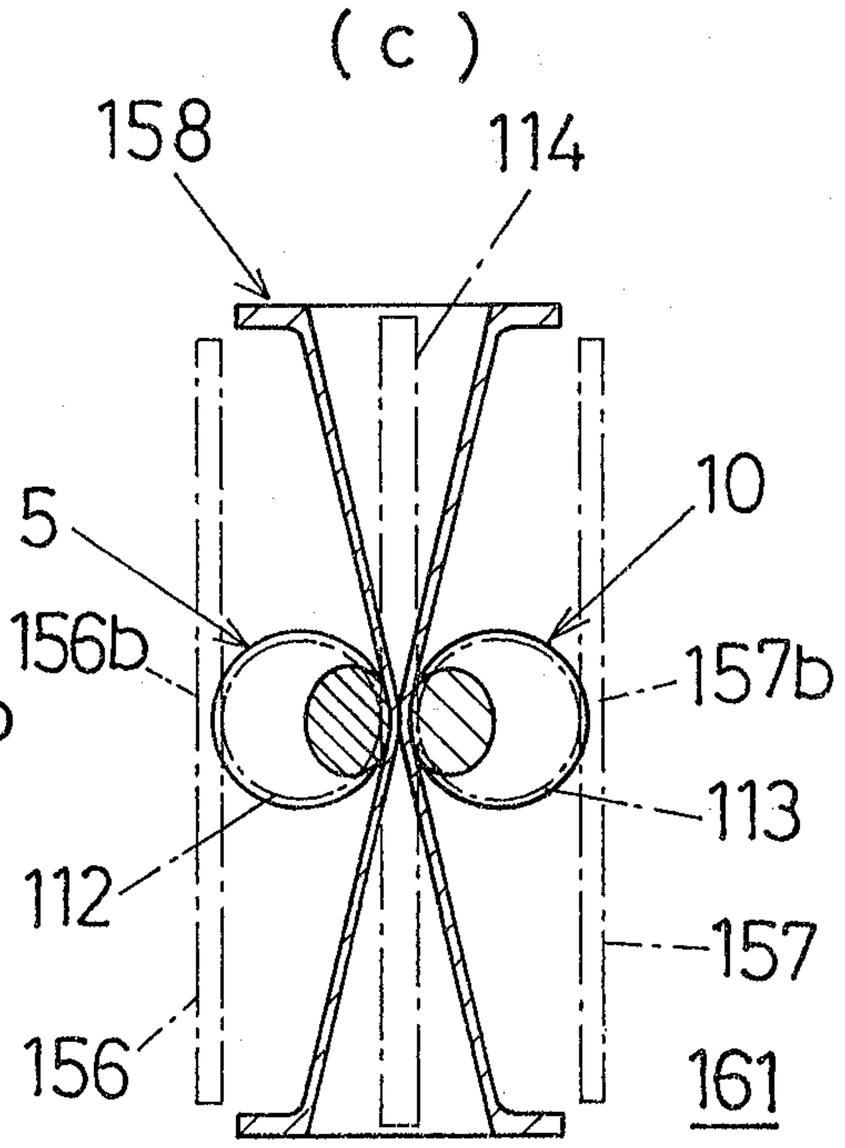

α1
131
131
131
129
130
3
4
16
L2
L1
153

FIG.21



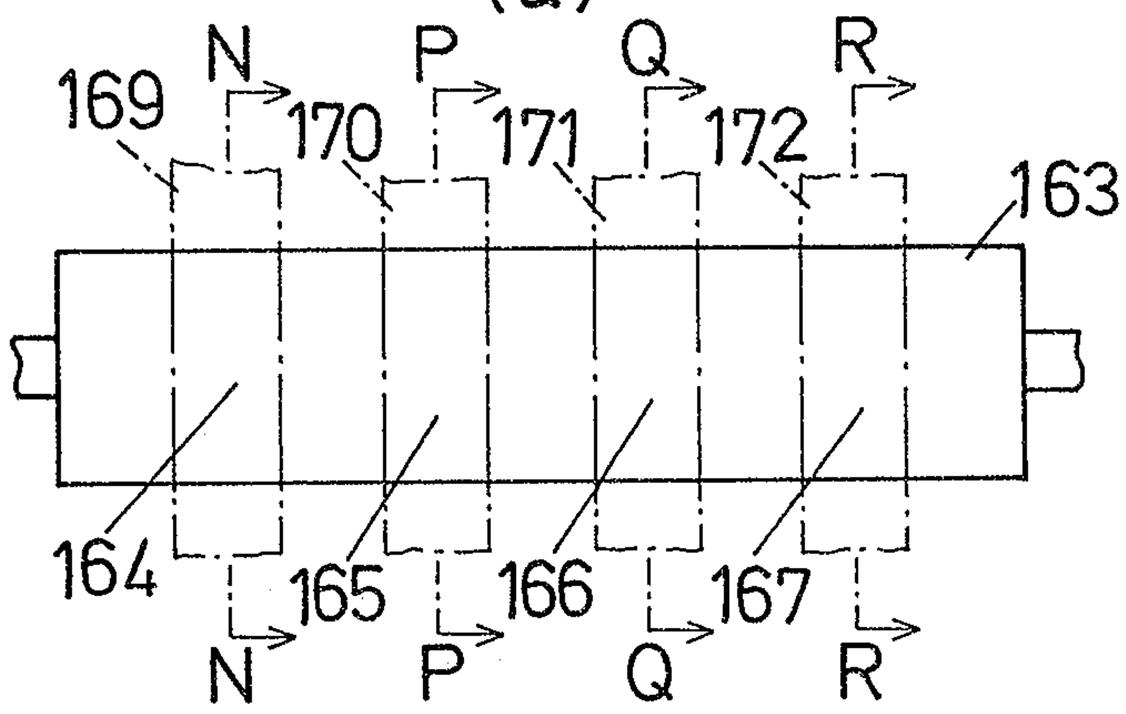




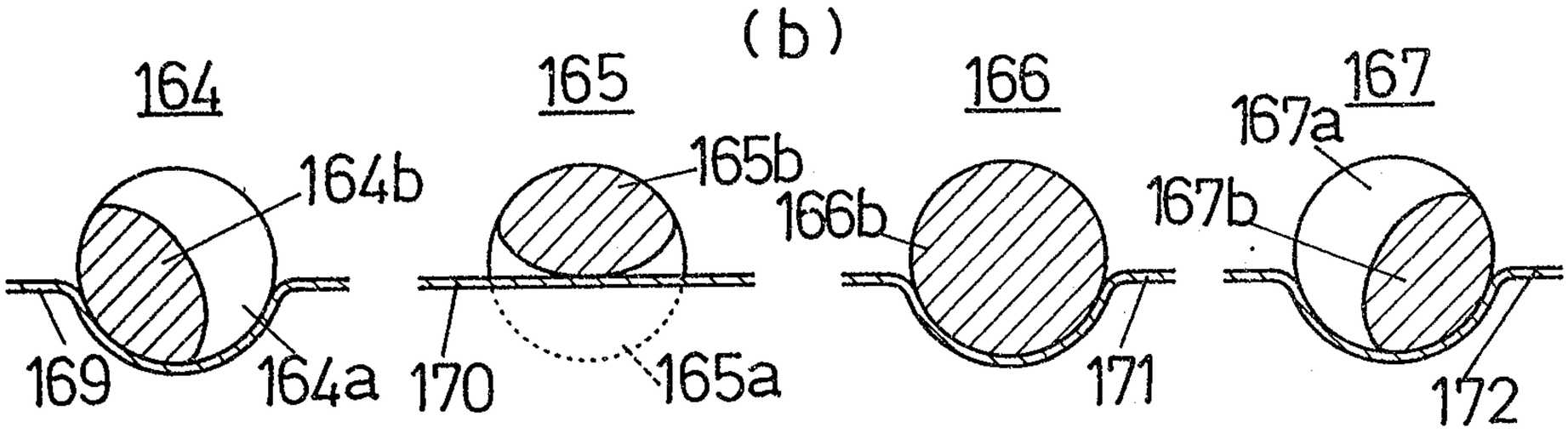
Agents & Clerk

FIG.22

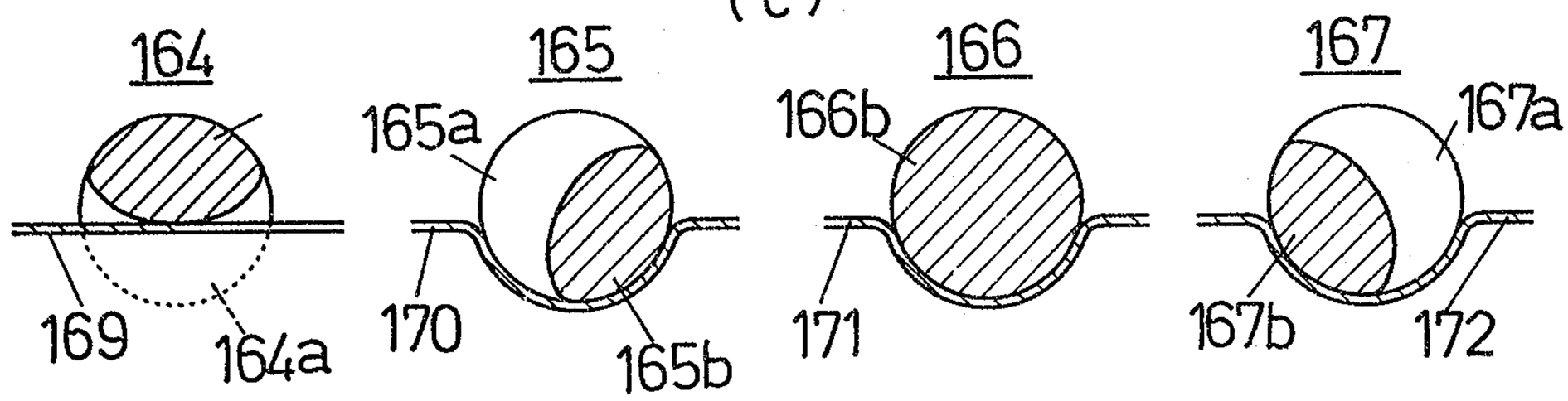
(a)


169
N
170
P
171
Q
172
R
163
164
165
166
167
N
P
Q
R

(b)


164
164b
169
164a
165
165b
170
165a
166
166b
171
167
167a
167b
172

(c)


164
169
164a
165
165a
170
165b
166
166b
171
167
167a
167b
172

(d)

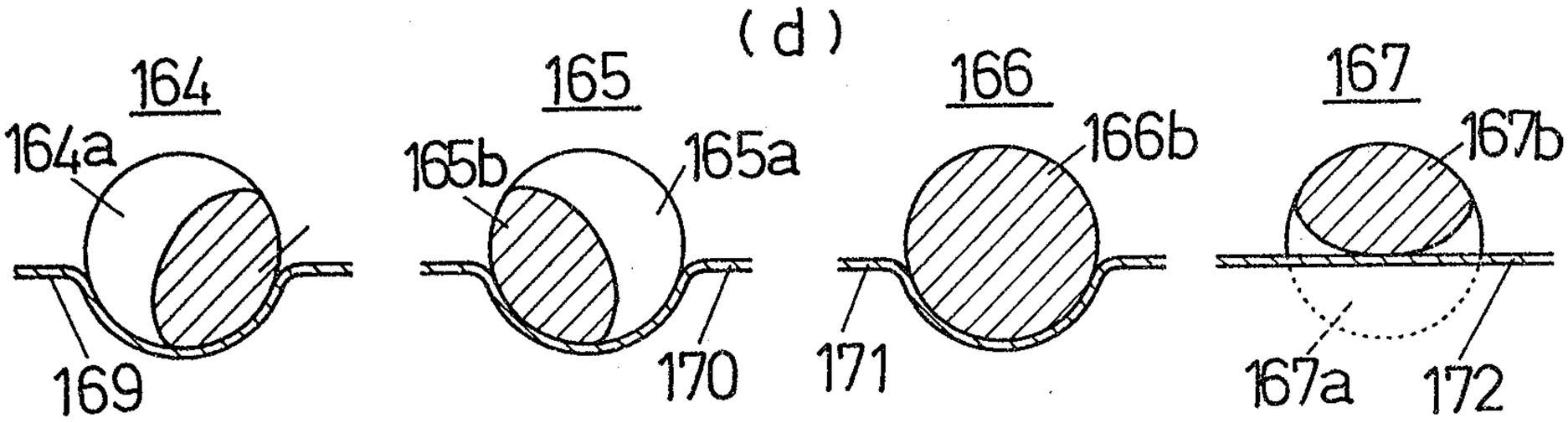

164
164a
169
165
165b
165a
170
166
166b
171
167
167b
167a
172

FIG.23

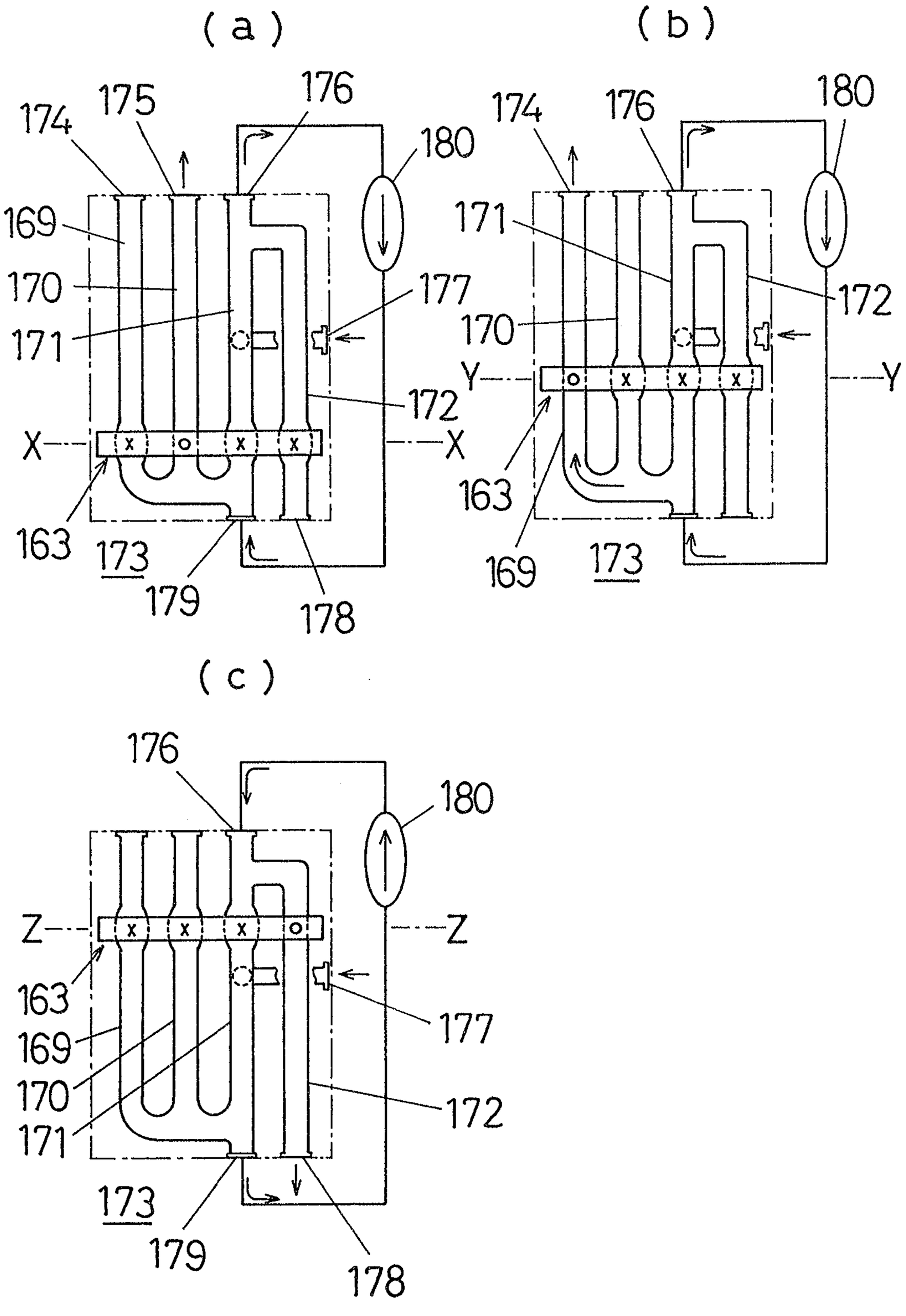
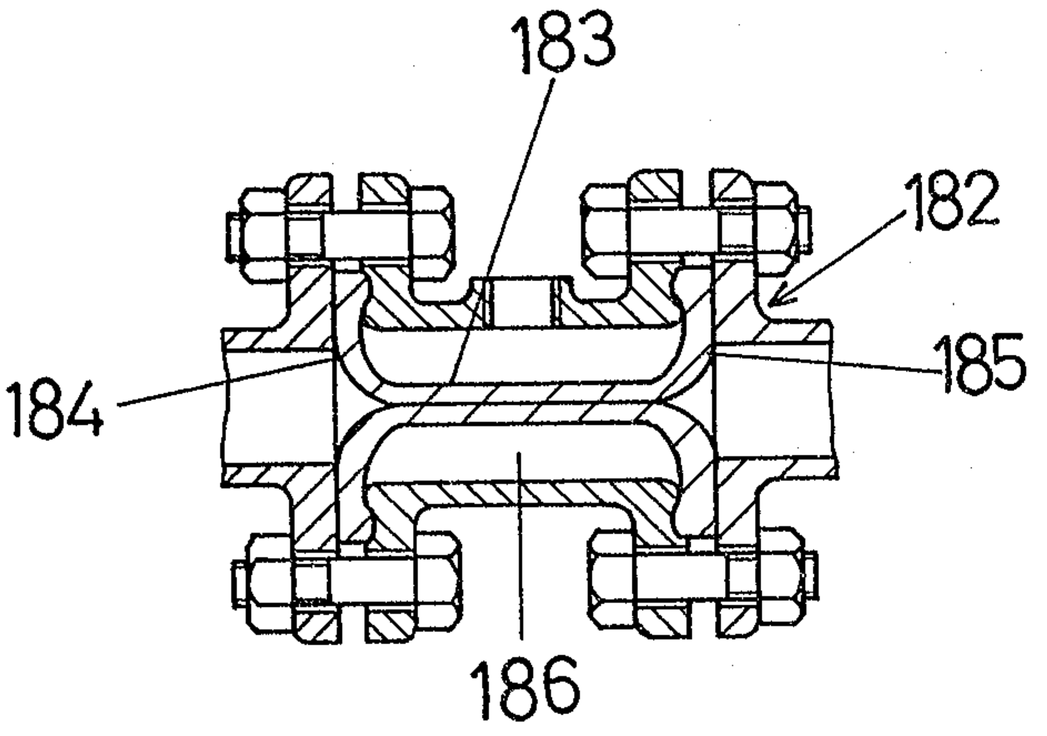
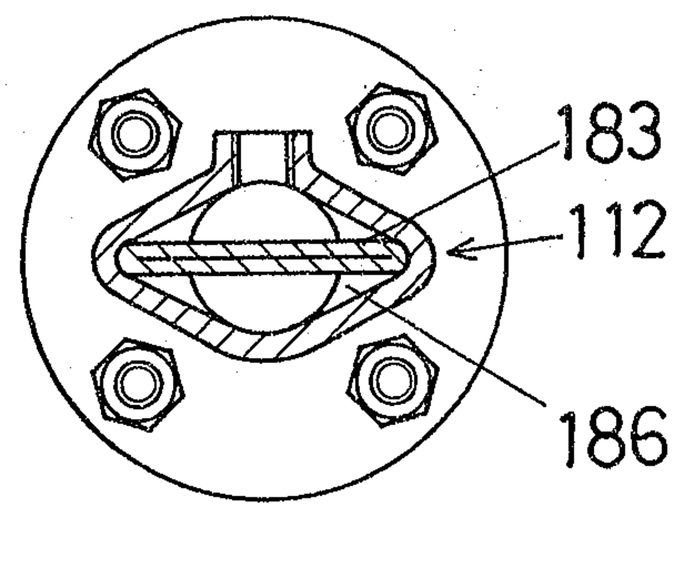


FIG.24

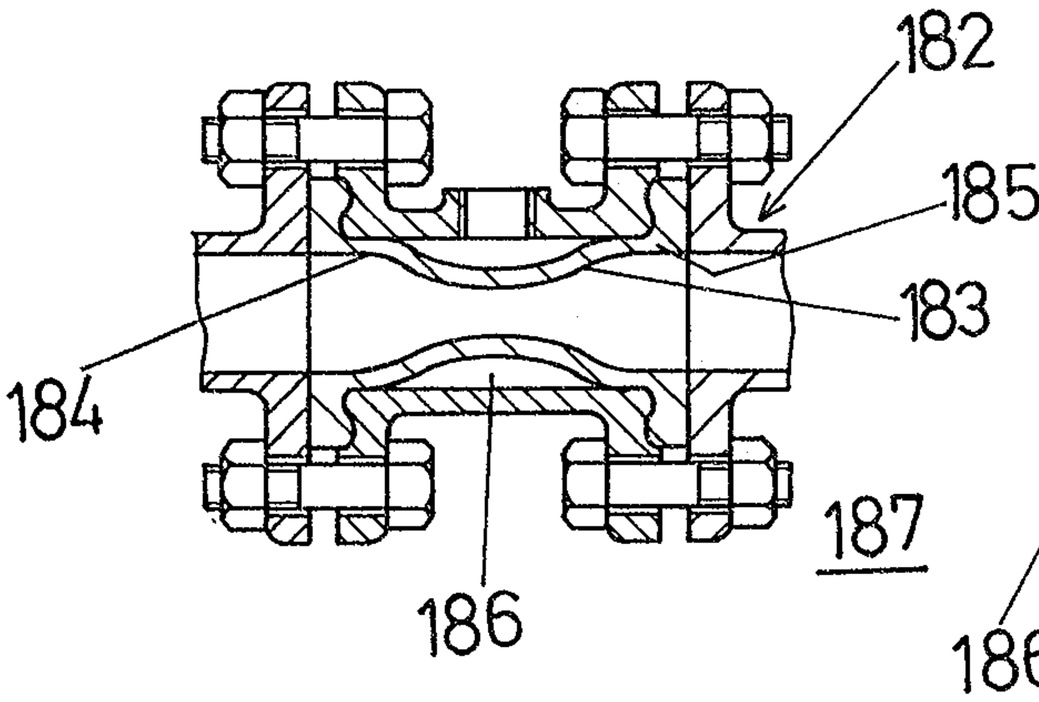
(a)



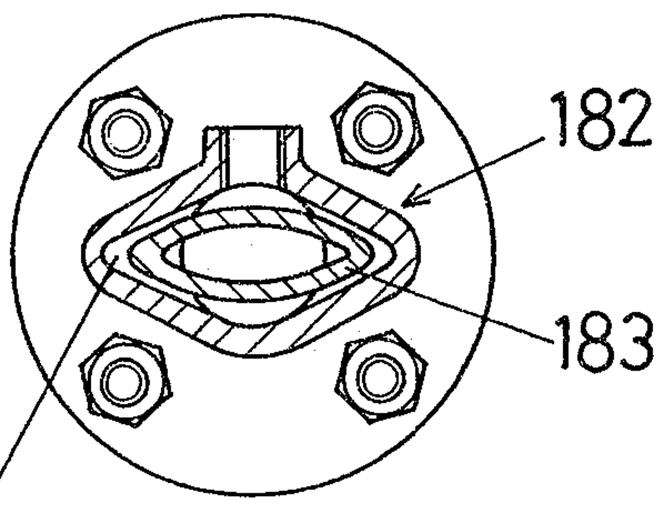
(b)



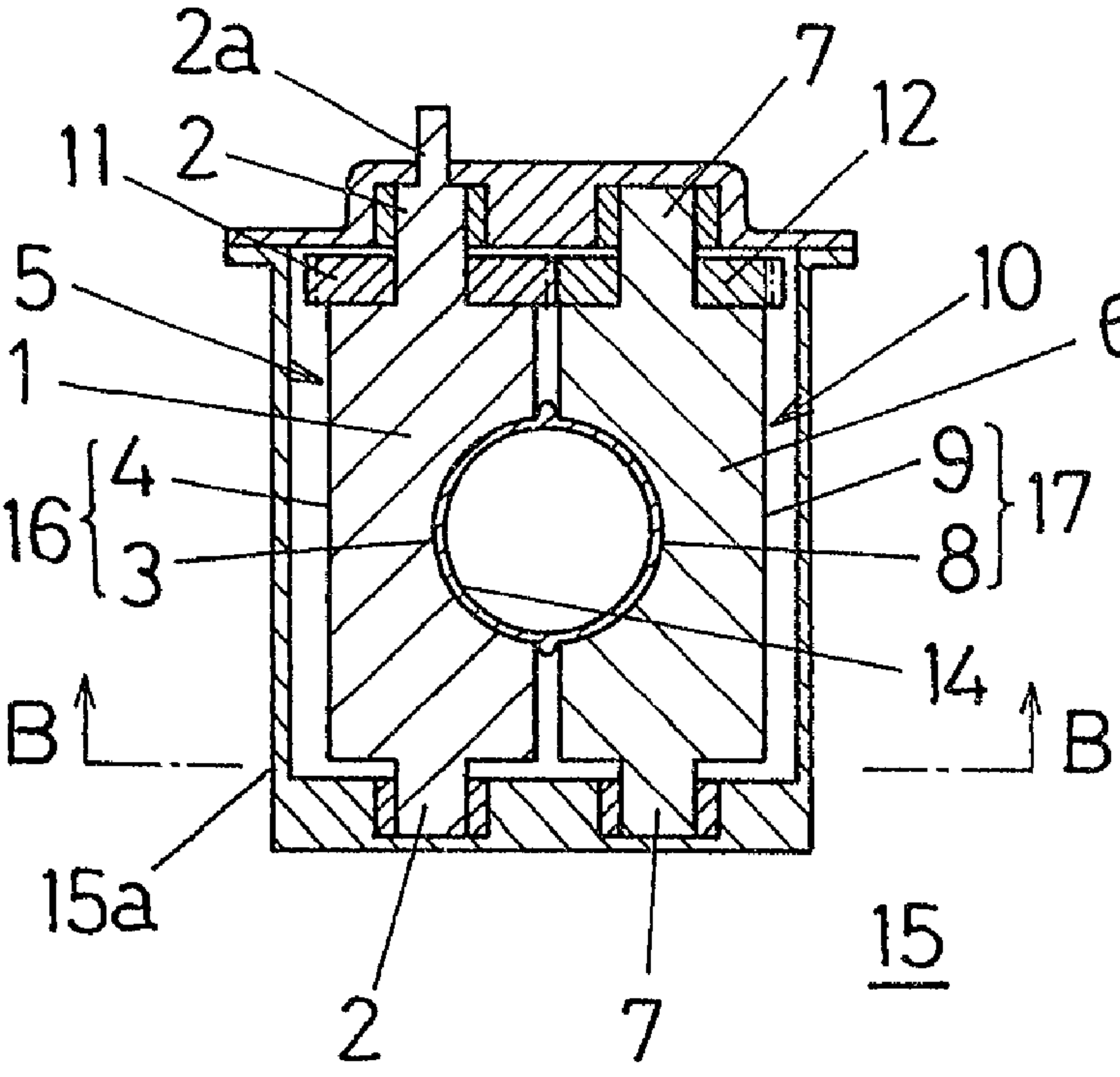
(c)



(d)



Agents de Clarke


2a
7
12
11
2
5
10
6
1
4
9
17
16
3
8
14
B
B
15a
2
7
15