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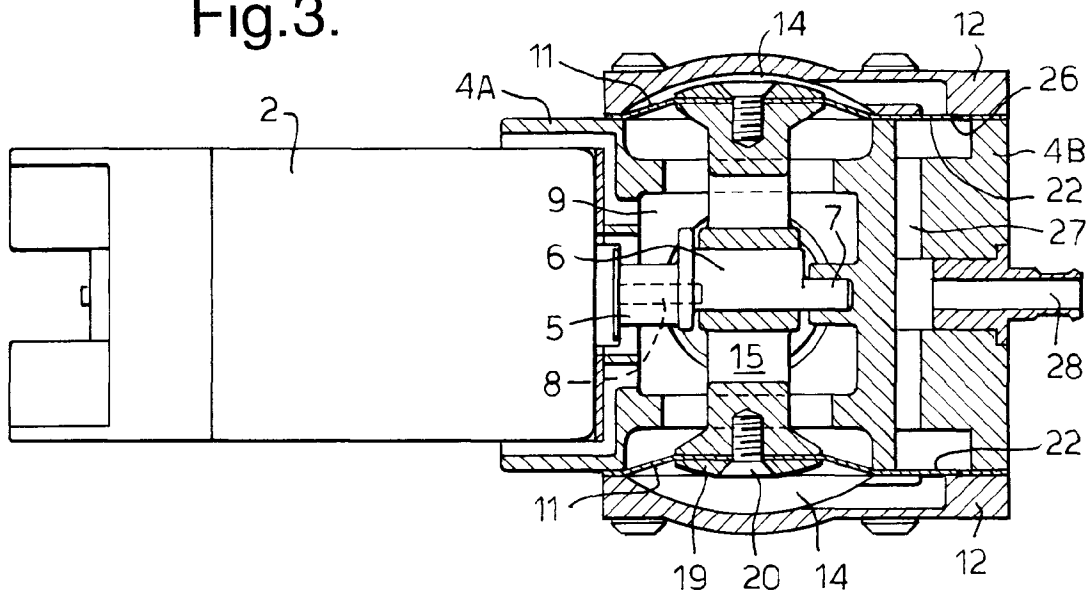
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(54) **Diaphragm pump**

(57) A motor driven diaphragm pump comprises an electric motor (2) having mounted thereon a pump assembly (3). The pump assembly (3) comprises a body (4) formed by a first body part (4a) which is mounted on the motor (2) to support the pump assembly on the motor, and a second body part (4b). A crank shaft (5) having an eccentric portion (6) is mounted in the body by a bearing (7) and is coupled to the output shaft (8) of the motor. A multiplicity of pumping chambers (14) are defined be-

tween respective diaphragms (11) and covers (12). The diaphragms (11) are coupled to the crank shaft (5) by a coupling member (15) which is a unitary plastics moulding and comprises a hub which is received on the eccentric, a head which is connected to each diaphragm and a flexible connecting web which connects each head to the hub. The pump is particularly suitable for use as an inflation pump for an inflatable bladder forming part of a vehicle seat.

Fig.3.



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## Description

This invention relates to a diaphragm pump, that is to say to a pump having one or more pumping chambers each of which is defined on one side by a diaphragm which, in use, is moved repeatedly towards and away from the opposite side of the chamber to vary the volume of the chamber. Suitable valving is associated with the or each chamber so that working fluid is admitted to the chamber during movement of the diaphragm away from the opposite side of the chamber, and is expelled from the chamber during movement of the diaphragm towards the opposite side of the chamber.

The particularly preferred embodiment of the present invention is concerned with the diaphragm pump suitable for pumping air at a relatively low volume rate. By appropriate design of the components of the diaphragm pump the preferred embodiment of the invention is able to operate at a very low noise level and is accordingly particularly suitable for use in environments in which a small volume of compressed air is required, and in which low noise levels are of critical importance. One typical application requiring these characteristics is the inflation of a pneumatic lumbar support cushion located, for example, in the seat of a car. It should be understood, however, that characteristics of the pump of the preferred embodiment render it suitable for other uses and the invention should not be construed as limited to small volume air pumps for use in the automotive industry.

According to one aspect of the present invention there is provided a diaphragm pump comprising a pumping chamber which is defined on one side by a diaphragm which is movable, in use, towards and away from the opposite side of the pumping chamber to vary the volume of the pumping chamber; a crank shaft; and a coupling member coupling the diaphragm to the eccentric of the crank shaft so that as the crank shaft rotates in use the diaphragm is reciprocated to effect a cyclic variation in the volume of the pumping chamber, wherein the coupling member is provided by a unitary plastics moulding which comprises a hub which runs on the eccentric of the crank shaft, a head which is coupled to the diaphragm and a connecting member which connects the head to the hub, the connecting member being flexible to permit articulation of the head relative to the hub.

The provision of the flexible connecting member, by permitting a small amount of articulation between the head and the hub, enables the head to be rigidly coupled to the diaphragm whilst permitting, by a combination of deformation of the diaphragm and flexing of the connecting member, the hub to follow the eccentric as the crank shaft rotates. Accordingly, the pump may be constructed in such a manner that the only connections between components which require relative sliding or translational motion are the bearing connection between the hub and the eccentric, and the bearings in

which the crank shaft is mounted. Elimination of other sliding and rotational contacts considerably simplifies construction of the pump, reduces possible noise generation and eliminates the potential for wear. Thus, the pump of the preferred embodiment may be made in a relatively economic manner, can be made very quiet, and will significantly resist deterioration in both performance and noise generation due to component wear during the life of the pump. These characteristics combine to make the pump particularly suitable for use in the automotive industry where low noise levels and long life expectancy are particularly important characteristics for components.

In a particularly preferred embodiment of the invention the diaphragm pump has a plurality of pumping chambers each of which is defined on one side by a diaphragm which, in use, is movable towards and away from the opposite side of its associated chamber to vary the volume of that chamber. Each diaphragm has associated therewith a coupling member which couples the diaphragm to a common eccentric. In a particularly preferred embodiment of the invention the coupling members are provided by a single unitary plastics moulding which comprises a single hub, the respective heads, and respective connecting members connecting each head to the hub, the connecting members all being flexible to permit articulation of the heads relative to the hub. With such a construction, a three, four or more chambered pump can be constructed in which the only sliding contact is between the eccentric of a common crank shaft and its associated hub, and the bearings in which the crank shaft is mounted.

In accordance with another aspect of the present invention a diaphragm pump comprises a body in which a crank shaft is rotatably mounted; a cover secured to the body, a portion of the cover defining one side of a pumping chamber; a diaphragm mounted sandwiched between the cover and the body to define the other side of a pumping chamber; a coupling member coupling the diaphragm to the eccentric of the crank shaft so that, in use, as the crank shaft rotates the diaphragm is reciprocated to effect a cyclic variation in the volume of the pumping chamber; and inlet and outlet valves for controlling ingress of working fluid to the pumping chamber and egress of working fluid from the pumping chamber respectively, wherein the movable members of the inlet and outlet valves are defined by portions of the diaphragm which are located exterior to the pumping chamber and which co-operate with valve seats defined by the cover and the body.

The use of portions of the diaphragm as the movable members of both the inlet and outlet valves obviates the need for separate moveable valve components. Conveniently, the portions of the diaphragm can be in the form of flaps which co-operates with the seats to prevent flow through the valves when the flaps are in engagement with the seats, and to permit flow through the valves when the flaps are spaced from the seats. By

forming the seats on the body and the cover, and by using portions of the diaphragm as the moveable components of the valves, the inlet and outlet valves are provided without the use of any separate valve components. This leads to a particularly simple construction in which a pump can be constructed from only five components viz a body, a crank shaft, a cover, a diaphragm and a coupling member for coupling the diaphragm to the eccentric of the crank shaft. Elimination of separate valve components considerably simplifies the construction and assembly of the pump, leads to reduced noise generation, and improved life expectancy.

In a particularly preferred embodiment of the invention a pump comprises four pumping chambers. Such a pump can conveniently be provided with a body which is substantially square in transverse cross-section and in which the crank shaft is mounted to rotate about an axis located at the intersection of the diagonals of the transverse cross-section. A cover is secured to and substantially covers each of the four exterior faces of the body. A diaphragm is sandwiched between each cover and the body and a respective pumping chamber is defined between each diaphragm and its associated cover. Accordingly, the pump has four pumping chambers which, when viewed in transverse cross-section, are located 90° offset from each other. With this arrangement, any noise generated at the crank shaft bearings or at the bearing between the eccentric of the crank shaft and the hub will be substantially attenuated by the body itself, the pumping chambers and the covers so that any noise escaping to the exterior of the body will be substantially less than the noise generated within the body. This arrangement additionally reduces the noise audible from the exterior of the pump.

Preferably, the body itself is formed by two moulded plastic components which, when assembled together, locate the crank shaft so that no additional means of axially locating the crank shaft is required. The covers may constitute the sole means of holding the body parts together so that the act of securing the covers in position simultaneously holds the body parts together. Preferably, however, the body is secured to the body of an associated electric motor by means of two or more screws which extend through the body parts in a direction parallel to the axis of rotation of the crank shaft. Such screws, in addition to mounting the pump on the electric motor serve to secure together the body parts.

In a particularly preferred embodiment of the invention one of the body parts includes means for engaging the body of an associated electric motor and the other of the body parts includes an outlet port which, by means of galleries internal to the body part, is connected to the outlet valves of all of the pumping chambers. Preferably, inlet air for the pumping chambers is derived from the interior portion of the body in which the crank shaft is located. Air is in turn drawn into this interior chamber via the associated electric motor. Thus, in use, air to be pumped is drawn through the motor and through the

crank shaft body chamber to effect cooling of these components.

The invention will be better understood from the following description of a preferred embodiment thereof, given by way of example only, reference being had to the accompanying drawings wherein:

Figure 1 is a side view of a preferred embodiment of a motor driven pump according to the present invention with one cover removed to expose the underlying diaphragm and body;

Figure 2 is an end view of the pump of Figure 1;

Figure 3 is a cross-section on the line A-A of Figure 1;

Figure 4 is a cross-section on the line B-B of Figure 1;

Figure 5 is a cross-section on the line C-C of Figure 2; and

Figures 6 and 7 show respectively an end view and side view of the coupling member of the embodiment of Figures 1-5.

The illustrated motor driven pump 1 comprises an electric motor 2 having mounted thereon a pump assembly 3. The pump assembly comprises a body 4 formed by a first body part 4A which is mounted on the motor 2 to support the pump assembly on the motor, and a second body part 4B. The body parts 4A, 4B are preferably plastics injection mouldings. A crank shaft 5 having an eccentric portion 6 is mounted in the body by way of a bearing 7 and is coupled to the output shaft 8 of the motor 2 for rotation therewith. The crank shaft 5 is located within an interior chamber 9 defined by the body 4.

As best seen in Figures 2 and 4, the body is generally square in exterior transverse cross-section and presents four exterior faces, each identical to the face 10 visible in Figure 1. In the complete assembly, each face is covered by a diaphragm 11 which substantially covers the entire area of the face. In the illustrated embodiment of the invention the diaphragm is transparent and accordingly details of the face 10 are visible in Figure 1 through the diaphragm. A respective cover 12 overlies each diaphragm and is secured to the underlying body by suitable fastenings 13. It will be appreciated that the covers 12 are secured to both body parts 4A and 4B and are accordingly effective to secure together the body parts.

A pumping chamber 14 is defined between each diaphragm and its associated cover 12, a respective diaphragm forming one side of each respective pumping chamber and the interior wall of the associated cover forming the opposite wall of the respective pumping chamber. In use, the diaphragms reciprocate between a bottom dead centre position as illustrated for the lowest chamber 14 of Figure 4 and a top dead centre position as illustrated for the uppermost chamber 14 of Figure 4. Appropriate valving (described in more detail be-

low) is provided to control ingress and egress of fluid so that as the diaphragms reciprocate fluid is pumped.

To effect the required reciprocating movement of the diaphragms each diaphragm 11 is coupled to the eccentric 6 of the crank shaft by a coupling member 15. The coupling member 15 is illustrated in detail in Figures 6 and 7 and will be seen to comprise a hub 16 which is received on the eccentric, a head 17 coupled to each diaphragm, and a connecting member 18 which connects each head to the hub 16. The connecting member 15 is a unitary plastics moulding. Whilst in the preferred embodiment of the invention the connecting member 15 comprises four heads and four associated connecting members, it will be appreciated that in other embodiments of the invention other numbers of heads and associated connecting members will be provided. In the most basic embodiment of the invention a single head 17 will be coupled to the hub 16 by a single connecting member 18. It is envisaged, however, that for most applications three or four pumping chambers will be required and the connecting member will accordingly either have three heads located angularly offset 120° from each other, or four heads angularly offset 90° from each other.

The heads 17 may be coupled to the diaphragms by any convenient means. In some embodiments of the invention it may be possible to mould the diaphragms integrally with the heads. However, practical considerations make such a moulding extremely difficult in the case of a four chambered pump and, accordingly, at least in this embodiment, the diaphragms are formed separately from the connecting members and are secured thereto by suitable means. The means of securing the diaphragms to the connecting members are not critical to the present invention, and any suitable means may be employed. For example, in certain applications a diaphragm may be secured by adhesive or by welding to the head. In the preferred embodiment of the invention, however, a portion of the diaphragm is sandwiched between the head and a washer 19 which is itself secured to the head by means of a screw 20. It must be stressed, however, that this is merely a preferred method of securing the head to the diaphragm and that other methods are possible within the scope of the present invention. The use of a somewhat domed washer 19 is, however, particularly desirable since, as will be clear from the uppermost chamber of Figure 4, the use of a domed washer reduces the unswept volume of the pumping chamber at top dead centre and accordingly increases the compression ratio of the pump.

As will be appreciated by those skilled in the art, as the crank shaft is rotated the head connected to each diaphragm will be subject to both longitudinal forces (i.e. forces in the direction of reciprocation of the diaphragm for the respective pumping chamber) and also to transverse forces occasioned by the translational movement of the centre of the eccentric as the crank shaft rotates. In conventional reciprocating piston devices

the application of transverse forces to the piston is reduced or substantially eliminated by use of a bearing between the connecting rod and the piston and the piston is constrained to remain parallel to the axis of its cylinder. In the case of the present invention, however, transverse movement of the eccentric is accommodated by a combination of tilting movement of the head and flexible deformation of the connecting member. The position of the heads, the shape of the diaphragm, and the deformation of the connecting members at a position of maximum crank offset is illustrated in the horizontally opposite chambers illustrated in Figure 4. As shown, the diaphragm will be somewhat deformed with the diaphragm portion 11A on one side of the head displaced towards its associated cover whilst the diaphragm portion 11B on the other side of the head is displaced somewhat towards the body. The head is tilted relevant to the longitudinal axis X-X of the relevant pumping chamber and the connecting member 18 is somewhat curved or bent to accommodate the articulation of the head. Thus, as the crank shaft rotates the diaphragms will be reciprocated to effect the required pumping and the resultant articulation of the heads will be accommodated by flexible deformation of the diaphragms and the connecting members.

According to one aspect of the present invention the valving arrangements required to effect pumping are provided by portions of a diaphragm 11 which co-operate with seats provided on the covers 12 and the body portion 4B.

Referring to Figure 1 it will be noted that a portion of the diaphragm located exterior to the pumping chamber 14 is formed with two-part circular slits 21 to form a pair of valve flaps 22, 23. The valve flap 23 co-operates with a seat 24 formed on the body part 4B to form an inlet valve. When the associated diaphragm is moving from top dead centre to bottom dead centre air will be drawn from the central chamber 9 through an inlet passage 25, through the seat 24, past the valve flap 23, and into the pumping chamber 14. During the following pumping stroke the flap 23 will lie against the seat 24 to prevent reverse flow of air. The flap 22 co-operates with a seat 26 formed on the cover to provide an outlet valve. During pumping strokes of the associated diaphragm the flap 22 will lift away from the seat 26 to permit air to flow into a gallery 27 which is connected to an outlet port 28. During the following suction stroke of the diaphragm the flap 22 will sit against the seat 26 to prevent reverse flow of air. Each of the pumping chambers is provided with such an arrangement of valves by its associated diaphragm.

It will be appreciated that the use of portions of the diaphragms to provide valve flaps 22, 23 which co-operate with seats 24, 26 provided by the body 4 and covers 12 respectively means that the valving required for operation of the pump is provided without the need for separate valve components. This considerably simplifies assembly of the pump, reduces cost, and, because

the resultant valves are inherently quiet in operation, aids the reduction of noise generation by the pump.

The body parts 4A, 4B, crank shaft 5, covers 12 and connecting member 15 are preferably provided by injection moulded plastic components. The diaphragms 11 may be stamped from suitable sheet plastic material having the required flexibility, resilience, and life expectancy.

### Claims

1. A diaphragm pump comprising a pumping chamber which is defined on one side by a diaphragm which is movable, in use, towards and away from the opposite side of the pumping chamber to vary the volume of the pumping chamber; a crank shaft; and a coupling member coupling the diaphragm to the eccentric of the crank shaft so that as the crank shaft rotates in use the diaphragm is reciprocated to effect a cyclic variation in the volume of the pumping chamber, wherein the coupling member is provided by a unitary plastics moulding which comprises a hub which runs on the eccentric of the crank shaft, a head which is coupled to the diaphragm and a connecting member which connects the head to the hub, the connecting member being flexible to permit articulation of the head relative to the hub.
2. A diaphragm pump according to claim 1 wherein the diaphragm pump has a plurality of pumping chambers each of which is defined on one side by a diaphragm which, in use, is movable towards and away from the opposite side of its associated chamber to vary the volume of that chamber, and wherein each diaphragm has associated therewith a coupling member which couples the diaphragm to a common eccentric.
3. A diaphragm pump according to claim 2 wherein the coupling members are provided by a single unitary plastics moulding which comprises a single hub, the respective heads, and respective connecting members connecting each head to the hub, the connecting members all being flexible to permit articulation of the heads relative to the hub.
4. A diaphragm pump according to any preceding claim wherein inlet and outlet valves are provided for controlling ingress of working fluid to the pumping chamber and egress of working fluid from the pumping chamber respectively, wherein the movable members of the inlet and outlet valves are defined by portions of the diaphragm which are located exterior to the pumping chamber and which cooperate with valve seats defined by the cover and the body.
5. A diaphragm pump according to any preceding claim wherein the pump comprises four pumping chambers and comprises a body which is substantially square in transverse cross-section and in which the crank shaft is mounted to rotate about an axis located at the intersection of the diagonals of the transverse cross-section; a cover secured to and substantially covering each of the four exterior faces of the body, and a diaphragm sandwiched between each cover and the body and a respective pumping chamber is defined between each diaphragm and its associated cover.
6. A diaphragm pump according to claim 5 wherein the body is formed by two moulded plastic components which, when assembled together, locate the crank shaft so that no additional means of axially locating the crank shaft is required.
7. A diaphragm pump according to claim 6 wherein one of the body parts includes means for engaging the body of an associated electric motor and the other of the body parts includes an outlet port which, by means of galleries internal to the body part, is connected to the outlet valves of all of the pumping chambers.
8. A diaphragm pump according to claim 7 wherein inlet air for the pumping chambers is derived from the interior portion of the body in which the crank shaft is located and air is in turn drawn into this interior chamber via the associated electric motor.

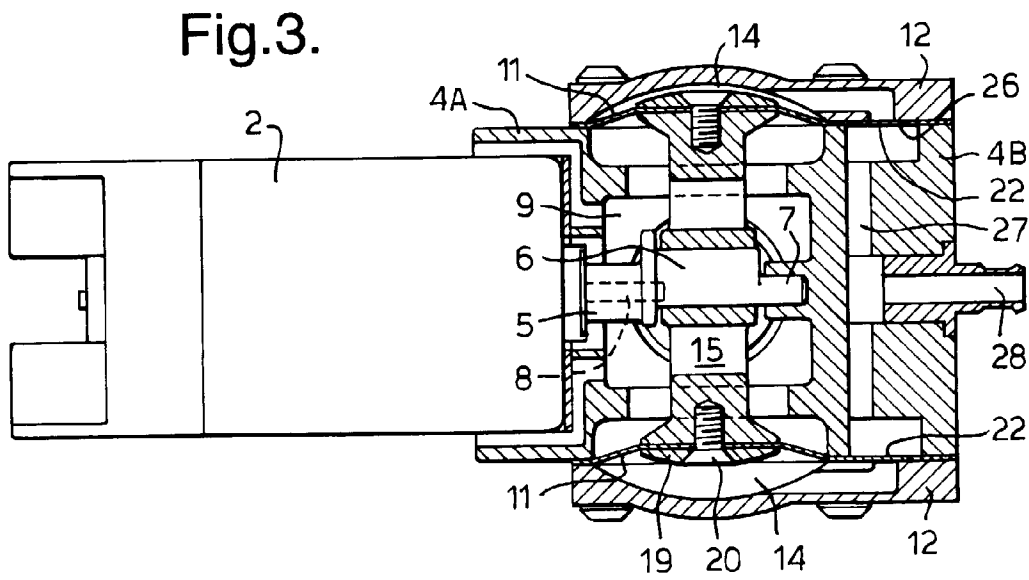
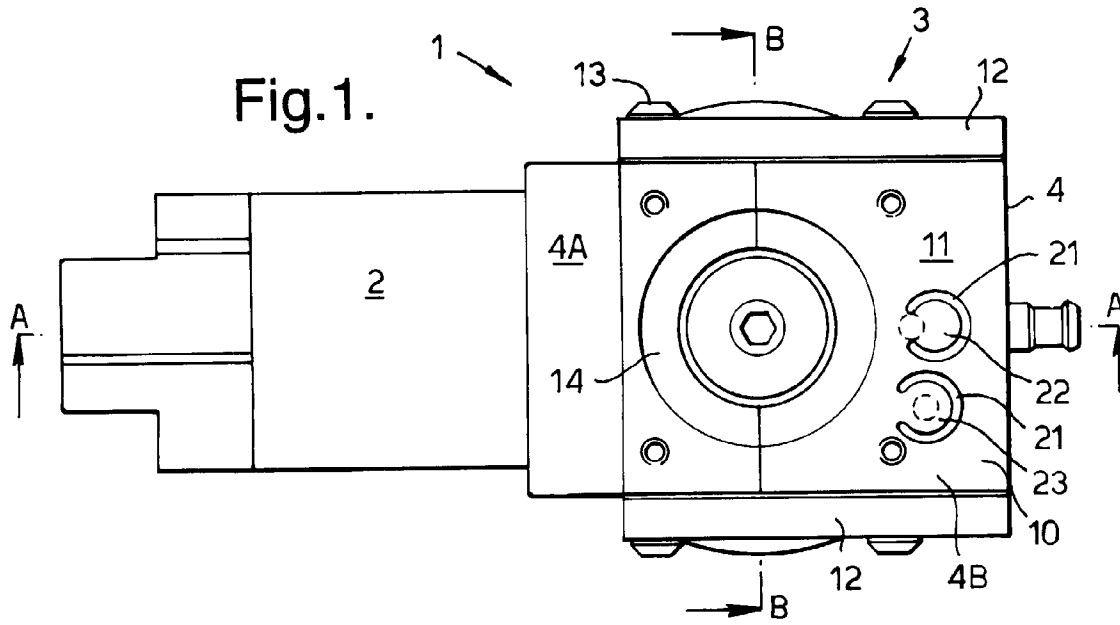


Fig.2.

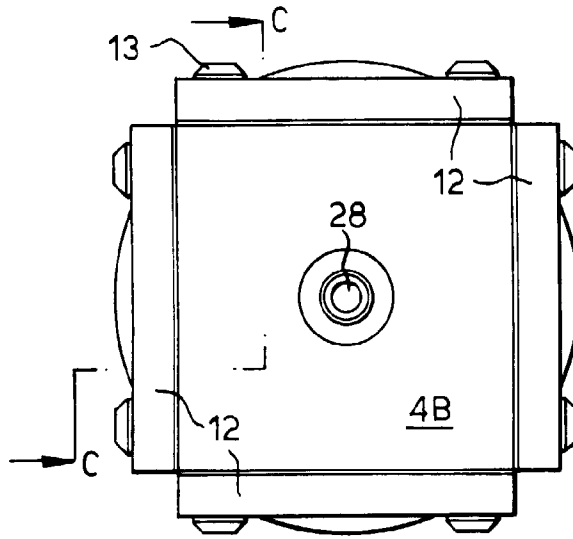


Fig.4.

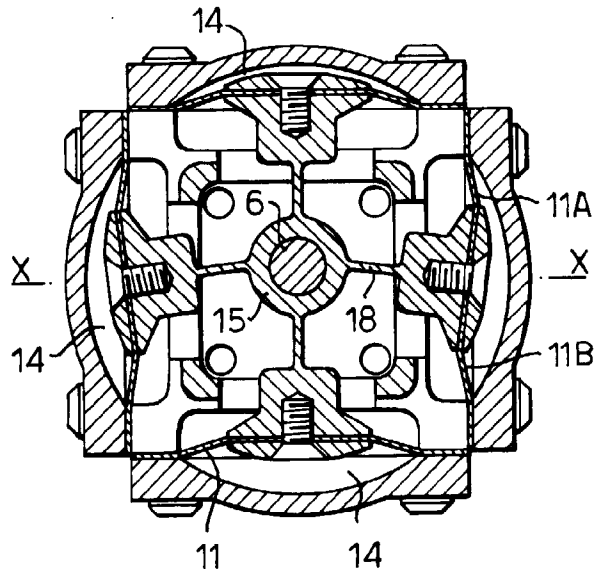


Fig.5.

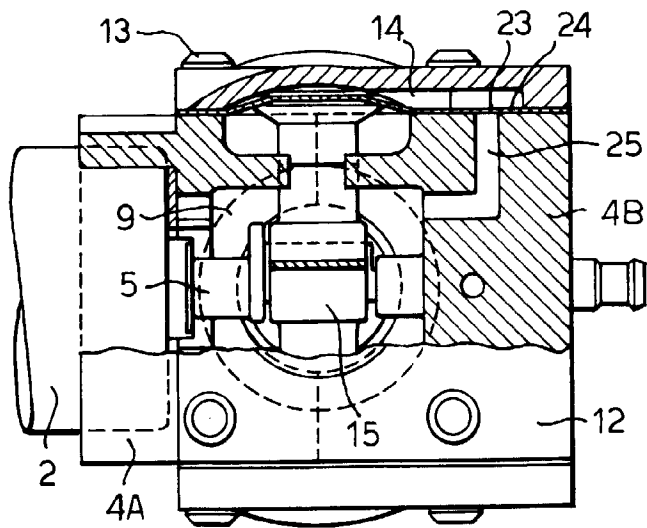


Fig.6.

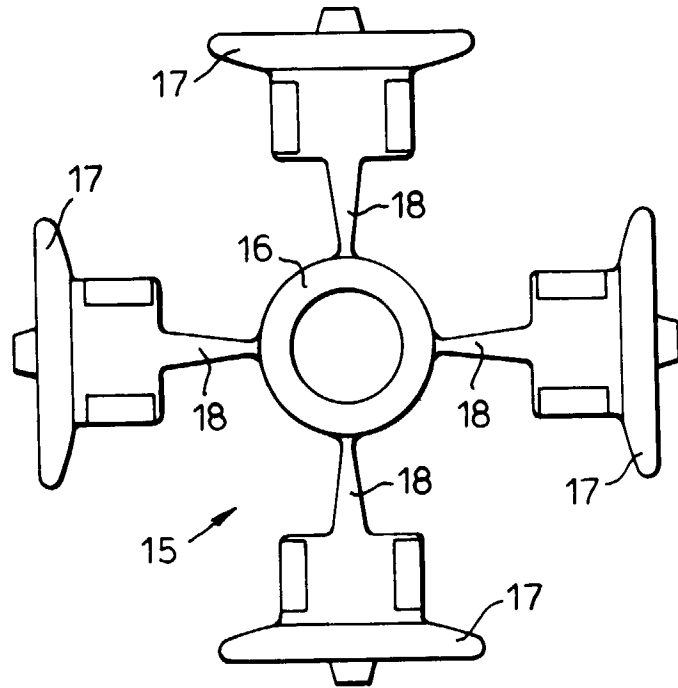
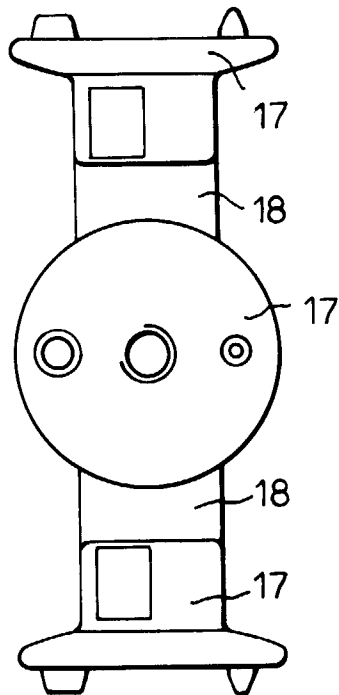


Fig.7.





European Patent  
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EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 3301

| DOCUMENTS CONSIDERED TO BE RELEVANT   |   |  |  |
|---|---|--|--|
| Category  | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim  | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
| Y   | WO-A-92 18769 (GENTEC B.V.)<br>* the whole document *                         | 1  | F04B45/04                                    |
| Y   | US-A-4 310 107 (WESNER)<br>* figures *  | 1  |  |
| A   | FR-A-1 388 721 (PIOT & TIROUFLET)<br>* the whole document *                   | 1  |  |
| A   | DE-A-38 01 515 (THOMAS IND. INC.)<br>* the whole document *                   | 1  |  |
| A   | WO-A-91 14099 (ROBERT BOSCH G.M.B.H.)<br>* line W *                           | 1-3  |  |
| A   | DE-A-19 07 454 (ROACH)<br>* page 4, line 3 - page 5, line 6; figure 3 *       | 4  |  |
| A   | GB-A-1 038 576 (BECKER)<br>* the whole document *                             | 1,5,7  |  |
|   |   |  | TECHNICAL FIELDS SEARCHED (Int.Cl.6)         |
|   |   |  | F04B   |
| The present search report has been drawn up for all claims  |   |  |  |
| Place of search   |   | Date of completion of the search   | Examiner                                     |
| THE HAGUE   |   | 25 July 1996   | Von Arx, H                                   |
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