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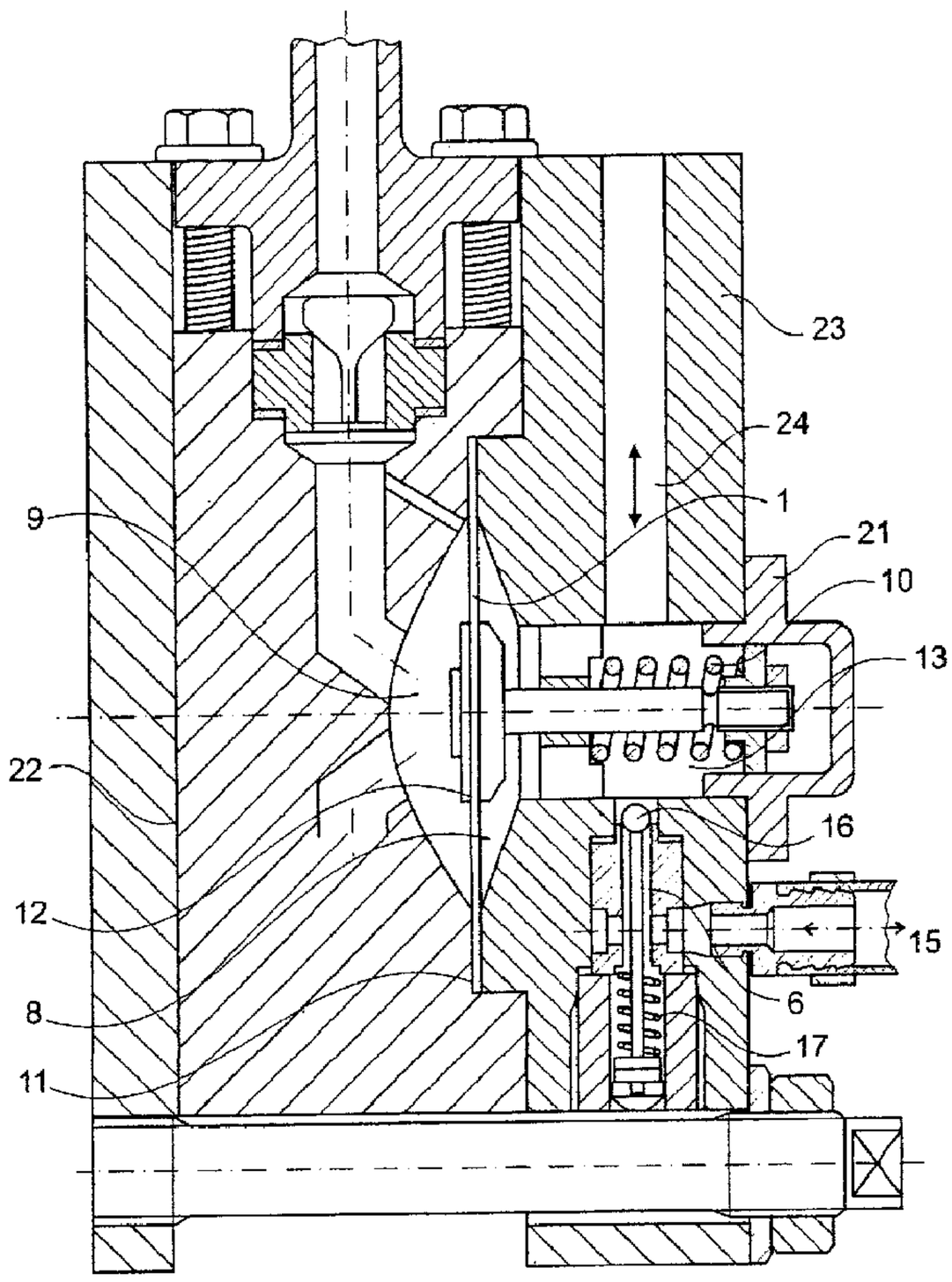
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(54) **Titre : POMPE A MEMBRANE MUNIE D'UNE SOUPAPE DE COMPENSATION DE FUITE COMMANDEE PAR INERTIE**
(54) **Title: MEMBRANE PUMP HAVING AN INERTIALLY CONTROLLED LEAKAGE COMPENSATION VALVE**



(57) **Abrégé/Abstract:**
The present invention concerns a membrane pump having a hydraulic chamber (8) separated from a pumping chamber (9) by a membrane (1), wherein the pumping chamber (9) is respectively connected with a suction connection and a pressure connection

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(57) **Abrégé(suite)/Abstract(continued):**
and a pulsating working fluid pressure can be applied to the hydraulic chamber (8) which can be filled with a working fluid, wherein the hydraulic chamber (8) is connected to a working fluid reservoir (15) via a leakage compensation valve (6), wherein the leakage compensation valve (6) comprises a closing body which is held in a closed position with the aid of a pressure element and which can be moved to and fro between the closed position in which the valve gate is closed and an open position in which the valve gate is open, wherein the pressure element is designed such that when the pressure in the hydraulic chamber (8) is lower than a set pressure p_L, the closing body (16) moves in the direction of the open position. In order to provide a membrane pump with a leakage compensation valve which reduces or even overcomes the disadvantages of the prior art, the invention proposes that the mass of the closing body (16) is large enough for the closing body (16) to move by no more than 0.2 mm in the direction of the open position when a drop in pressure to 0 bar which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8).

ABSTRACT

The present invention concerns a membrane pump having a hydraulic chamber (8) separated from a pumping chamber (9) by a membrane (1), wherein the pumping chamber (9) is respectively connected with a suction connection and a pressure connection and a pulsating working fluid pressure can be applied to the hydraulic chamber (8) which can be filled with a working fluid, wherein the hydraulic chamber (8) is connected to a working fluid reservoir (15) via a leakage compensation valve (6), wherein the leakage compensation valve (6) comprises a closing body which is held in a closed position with the aid of a pressure element and which can be moved to and fro between the closed position in which the valve gate is closed and an open position in which the valve gate is open, wherein the pressure element is designed such that when the pressure in the hydraulic chamber (8) is lower than a set pressure p_L, the closing body (16) moves in the direction of the open position. In order to provide a membrane pump with a leakage compensation valve which reduces or even overcomes the disadvantages of the prior art, the invention proposes that the mass of the closing body (16) is large enough for the closing body (16) to move by no more than 0.2 mm in the direction of the open position when a drop in pressure to 0 bar which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8).

MEMBRANE PUMP HAVING AN INERTIALLY CONTROLLED LEAKAGE COMPENSATION VALVE

The present invention relates to a membrane pump having a leakage compensation valve and to a method for dimensioning a leakage compensation valve.

Membrane pumps generally comprise a pumping chamber separated from a hydraulic chamber by a membrane, wherein the pumping chamber is connected to a suction connection and a pressure connection. A pulsating working fluid pressure can be applied to the hydraulic chamber, which can be filled with working fluid. The pulsating working fluid pressure brings about a pulsating movement of the membrane, whereupon the volume of the pumping chamber expands and contracts periodically. In this manner, pumping medium can be sucked in via the suction connection, which is connected to the pumping chamber via a respective non-return valve, when the volume of the pumping chamber is expanded, and discharged under pressure via the pressure connection, which is also connected to the pumping chamber by means of a respective non-return valve, when the volume of the pumping chamber contracts.

As a rule, the working fluid is a hydraulic oil. In principle, however, other suitable fluids can be used, such as water with a water-soluble mineral supplement, for example.

The membrane separates the medium to be pumped from the drive, whereupon on the one hand the drive is protected from damage caused by the pumping medium and on the other hand, the pumping medium is also protected from damage, for example contamination, caused by the drive.

The pulsating working fluid pressure is usually produced by means of a movable piston which is in contact with the working fluid.

To this end, for example, the piston is moved to and fro in a cylindrical hollow element, whereby the volume of the hydraulic chamber is expanded and contracted, resulting in increasing and decreasing the pressure in the hydraulic chamber and, as a result, in movement of the membrane.

Despite a very wide variety of measures aimed at preventing the working fluid from flowing around the piston, in practice it is not possible to prevent a small quantity of the working fluid from being lost on each stroke through the narrow gap that remains between the piston and the cylindrical hollow element, and so gradually, the amount of working fluid in the hydraulic chamber is reduced. This results in the fact that the pressure stroke is no longer completed by the membrane, since there is no longer sufficient working fluid available to execute the compression movement of the membrane.

As an example, then, DE 1 034 030 proposed connecting the hydraulic chamber via an interposed valve, a so-called leakage compensation valve, to a reservoir of working fluid.

By means of this leakage compensation valve, working fluid can be added to the hydraulic chamber as necessary. However, care must be taken when doing this not to add too much working fluid to the hydraulic chamber as then, the membrane would move too far into the pumping chamber during the pressure stroke and under some circumstances might come into contact with valves or other components and be damaged.

For this reason, the leakage compensation valve usually comprises a closing body, for example in the form of a closing ball, which can move to and fro between a closed position in which the valve gate is closed and an open position in which the valve gate is open. This closing body is biased into the closed position with the aid of a pressure element, for example a spring. This pressure element is designed such that the closing body only moves in the direction of the open position when the pressure in the hydraulic chamber is lower than a set pressure p_L.

Since, during the suction stroke, i.e. while the piston moves backwards, the pressure in the hydraulic chamber is inevitably reduced, the set pressure p_L must be set such that during the suction stroke no fluid can get into the hydraulic chamber via the leakage compensation valve. The leakage compensation valve should only let in any working fluid that might be missing at the end of the suction stroke when the piston is hardly moving.

Care must be taken in this case that at the end of the pressure stroke, the pressure in the pumping chamber is a maximum. In this case, when the suction stroke begins, then the membrane will move in the direction of the hydraulic chamber until the pressure in the pumping chamber has fallen to the static pressure at the suction connection. As the suction stroke continues, this gives rise to a pressure pulse, the so-called Joukowsky pulse, since in the pumping chamber, pumping medium is now supplied via the suction connection, which results in an abrupt change in velocity in the suction line. This pressure pulse gives rise to a high frequency pressure oscillation in the hydraulic chamber. The pressure in the hydraulic chamber will briefly be enormously reduced.

In order to prevent the leakage compensation valve from opening during this pressure pulse so that working fluid can flow into the hydraulic chamber, the set pressure p_L must be set correspondingly low, which means that the pressure element of the leakage compensation valve must be relatively large in size.

However, in known membrane pumps, this is a disadvantage, since at the end of the suction stroke, it is then difficult to drop below the set pressure of the leakage compensation valve. Thus, appropriate constructive measures have to be taken in order to ensure that at the end of the suction stroke, the leakage compensation valve does actually open if there is too little working fluid in the hydraulic chamber. This increases the costs of the membrane pump.

Starting from the prior art described, then, the aim of the invention is to provide a membrane pump with a leakage compensation valve which reduces or even overcomes the disadvantages mentioned. In addition, the aim of the present invention is to provide a method for dimensioning a leakage compensation valve which reduces or even overcomes the disadvantages mentioned.

This aim is achieved in accordance with the invention by means of a membrane pump of the type defined above, in which the mass of the closing body is large enough for the closing body to move by no more than 0.2 mm in the direction of the open position when a drop in pressure which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber.

It has in fact been observed that the pressure pulse, the so-called Joukowsky pulse, which occurs when the pressure in the pumping chamber falls to the pressure at the suction connection, is of a high frequency, i.e. occurs over a time interval of less than one millisecond. In accordance with the invention, then, the closing body is constructed such that its mass and thus its inertia are sufficiently large that when such a pressure pulse occurs, then due to the inertia, the closing body can move by no more than 0.2 mm in the direction of the open position. Since after one millisecond, the pressure has already climbed again, the movement of the closing body is stopped. Normally, a movement of the closing body of less than 0.2 mm is small enough for the resulting gap for the working fluid to be too small to pump a significant quantity of working fluid into the hydraulic chamber.

If the small amount should still be disadvantageous, in a preferred embodiment, the closing body moves by no more than 0.1 mm in the direction of the open position when a drop in pressure which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber.

Clearly, because of the Joukowsky pulse, the maximum pressure pulse might result in a drop in the pressure in the hydraulic chamber to 0 bar. An example of the calculation of the mass of the closing body is provided below.

In fact, despite the pressure pulse, the pressure in the hydraulic chamber will not drop to 0 bar, but to a minimum pressure p_{min}. This minimum pressure p_{min} is dependent on the process parameters, such as, for example, the static pressure at the pump suction connection, the speed of the piston and the volume of the hydraulic chamber and the pumping chamber.

While in the prior art the set pressure p_L is normally less than p_{min}, in a preferred embodiment, p_L is larger than p_{min}. The return spring of the leakage compensation valve can thus be made smaller, which significantly facilitates operation of the pump.

Regarding the method for dimensioning a leakage compensation valve of a membrane pump, the aim defined above is achieved by providing that the mass of the closing body is

selected such that the closing body moves by no more than 0.2 mm, preferably by no more than 0.1 mm in the direction of the open position when a drop in pressure which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber.

According to one aspect of the invention, there is provided a membrane pump having a hydraulic chamber separated from a pumping chamber by a membrane, wherein the pumping chamber is respectively connected with a suction connection and a pressure connection and a pulsating working fluid pressure can be applied to the hydraulic chamber which can be filled with a working fluid, wherein the hydraulic chamber is connected to a working fluid reservoir via a leakage compensation valve, wherein the leakage compensation valve comprises a closing body which is held in a closed position with the aid of a pressure element and which can be moved to and fro between the closed position in which the valve gate is closed and an open position in which the valve gate is open, wherein the pressure element is designed such that when the pressure in the hydraulic chamber is lower than a set pressure pL, the closing body moves in the direction of the open position, characterized in that the mass of the closing body is large enough for the closing body to move by no more than 0.2 mm in the direction of the open position when a drop in pressure to 0 bar which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber.

According to another aspect of the invention, there is provided a method for dimensioning a leakage compensation valve of a membrane pump having a hydraulic chamber separated from a pumping chamber by a membrane, wherein the pumping chamber is respectively connected with a suction connection and a pressure connection, and a pulsating working fluid pressure can be applied to the hydraulic chamber which can be filled with a working fluid, wherein the hydraulic chamber is connected to a working fluid reservoir via a leakage compensation valve, wherein the leakage

compensation valve comprises a closing body which can be moved to and fro between a closed position in which the valve gate is closed and an open position in which the valve gate is open, characterized in that the mass of the closing body is selected such that the closing body moves by no more than 0.2 mm, preferably by no more than 0.1 mm, in the direction of the open position when a drop in pressure which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber.

Further advantages, features and possible applications will become apparent from the following description of a preferred embodiment and from the accompanying drawings, which show:

Figure 1: a partial sectional view of a membrane pump of the prior art;

Figure 2: the profile of the pressure in the hydraulic chamber during the suction stroke; and

Figure 3: a sectional view of a leakage compensation valve in accordance with one embodiment of the invention.

Figure 1 shows the essential parts of a membrane pump in a partial sectional view. The membrane pump comprises a membrane 1, which separates the hydraulic chamber 8 from the pumping chamber 9. The pumping chamber 9 is connected to a suction connection and a pressure connection via respective non-return valves. A pulsating working fluid pressure can be applied to the hydraulic chamber 8 with the aid of a piston 3. In the embodiment shown, the membrane 1 is connected to a spring 10 installed in a mounting 13, which ensures that the membrane is biased in the direction of the hydraulic chamber. The pulsating pressure of the working fluid moves the membrane to and fro between the walls 4 and 7, whereupon the volume of the pumping chamber expands and contracts. As the volume of the pumping chamber contracts, the pumping fluid in the pumping chamber is discharged via the non-return valve at the

pressure outlet. When the volume of the pumping chamber expands due to the backwards movement of the membrane 1, pumping fluid is sucked in via the non-return valve out of the suction connection. Thus, the periodic movement of the membrane periodically sucks in pumping fluid from the suction connection and discharges it via the pressure connection at a higher pressure.

The membrane is held between the clamping rims 11, 12. The presence of the return spring 10 means that the membrane could bulge, as indicated by the dashed line 14.

During operation, under certain circumstances, working fluid escapes via the gap 5 at the piston 3. In order to ensure that the right quantity of working fluid is always present in the hydraulic chamber 8, a leakage compensation valve 6 is provided, via which the hydraulic chamber 8 is connected to a working fluid reservoir 15. This leakage compensation valve comprises a small ball, which is urged into a valve seat by means of a spring. The spring of the leakage compensation valve 6 establishes the set pressure p_L. If the pressure in the hydraulic chamber 8 drops below the set pressure p_L, the ball of the leakage compensation valve lifts from the valve seat and additional working fluid can flow from the working fluid reservoir 15, which is generally under atmospheric pressure (1 bar), into the hydraulic chamber 8 until the pressure in the hydraulic chamber 8 has risen above the set pressure p_L, since then the spring of the leakage compensation valve 6 urges the ball back into the valve seat and thus closes off the valve gate.

Figure 2 diagrammatically shows the pressure in the hydraulic chamber during the suction stroke as a function of time. At the start of the suction stroke, the pressure in the hydraulic chamber is approximately the same as the pressure with which the pump discharges the pumping medium from the delivery connection. This pressure is substantially higher than the static pressure of the suction line. It should be understood that the pressure in the hydraulic chamber is also determined by the return spring 10. This pressure difference will not be considered below, however, as it is not relevant to the invention.

The suction stroke begins when the piston 3 is moved backwards, i.e. is moved to the right in the embodiment shown in Figure 1. This means that initially, the pressure in the hydraulic chamber reduces slowly and since the pressure in the pumping chamber is higher, the membrane moves to the right, i.e. in the direction of the hydraulic chamber. Here, the pressure in the pumping chamber will drop slowly, until it reaches the static pressure at the suction connection p_{SO}. As the pressure drops still further, the respective non-return valve which connects the pumping chamber to

the suction connection will open and pumping medium will flow in via the suction connection. At the moment at which the pressure in the pumping chamber reaches the static pressure at the suction connection, an abrupt change in the velocity of the fluid occurs in the suction line. This change in velocity Δv gives rise to the so-called Joukowsky pulse, $\Delta p_{st} = \rho \times a \times \Delta V$, wherein ρ is the density of the pumping medium and "a" is the rate of wave propagation in the fluid-filled suction pipe.

This Joukowsky pulse in the pumping chamber results in a pressure pulse in the hydraulic chamber, since both chambers are connected via the membrane.

It will be seen that after a certain time from the beginning of the suction stroke "s", the pressure p_H in the hydraulic chamber drops abruptly for a brief interval of time (Δp_{st}). Shortly thereafter, it rises again sharply, so that a high frequency, rapidly fading pressure oscillation occurs. It will immediately be seen that the pressure pulse could result at most in a drop to $p = 0$. However, the pressure in the hydraulic chamber will not actually drop to zero, but to a minimum pressure p_{min}, which is set by the operational parameters and the construction of the membrane pump.

In order to prevent opening of the leakage compensation valve when a pressure pulse drop to p_{min} occurs, in the prior art, the set pressure p_L of the leakage compensation valve is smaller than p_{min}.

However, according to the techniques of the invention, the set pressure p_L can be selected to be substantially higher than p_{min}, as long as p_L is below a mean pressure p_m in the hydraulic chamber.

The invention is based on the recognition that the pressure pulse occurs over only a very brief time interval $\Delta ts < 1$ millisecond.

In accordance with the invention, the mass of the closing body is selected to be sufficiently large such that such a pressure pulse only results in a lift of less than 0.2 mm or, preferably, less than 0.1 mm.

A leakage compensation valve in accordance with the invention is shown in Figure 3.

This leakage compensation valve comprises a closing body 16 accommodated in a valve body 18, which comprises a closing element 20 which closes a bore in the valve body 18 in the closed position, so that the line to the working fluid reservoir 19 is separated from the hydraulic chamber 8. The closing body is biased into the closed position with the aid of a spring element 17, as shown in Figure 3. The pressure of the working fluid in the working fluid reservoir, and thus also the pressure in the line 19, remain essentially constant. When the pressure in the hydraulic chamber 8 drops below the set pressure p_L, which is essentially provided by the spring 17, then the closing body 16 in the position shown in Figure 3 is moved upwards, so that a connection is opened between the line 19 and the hydraulic chamber 8. In principle, it is assumed that if the closing body moves by only 0.2 millimetres, the gap between the valve body 18 and the closing element 20 is not sufficient to discharge a significant quantity of working fluid through the line 19 into the hydraulic chamber.

The stroke of the closing body, Δs, is calculated as follows:

$$\Delta s = b \cdot \frac{\Delta t^2}{2} \quad (1)$$

where Δt is the duration of the pressure pulse and b is the acceleration of the closing body due to the pressure pulse. The acceleration is calculated as follows:

$$b = F/m \quad (2)$$

wherein F is the force on the closing body and m is the mass of the closing body. Thus, we have:

$$\Delta s = \frac{F}{m} \cdot \frac{\Delta t^2}{2} \quad (3)$$

or

$$m = \frac{\Delta t^2}{2\Delta s} \cdot F \quad (4)$$

Assuming that the pressure pulse does not last longer than 1 millisecond, i.e. Δt_s = 1 millisecond, that the movement of the closing body should be a maximum of 0.1 mm, i.e. Δs_s = 0.1 mm, and that the pressure pulse reduces the pressure to 0 bar, i.e. the pressure pulse is

the same magnitude as the set pressure p_L, e.g. 0.7 bar, then for a diameter of the closing element of 8 mm, i.e. a corresponding surface area of about 0.5 cm^2:

$$F = p_L \cdot A = 0.7 \cdot 10 \cdot 0.5 = 3.5\ N \qquad (5)$$

and thus

$$m = 3.5 \cdot \frac{10^{-4}}{2.10^{-4}} = 1.75 \cdot 10^{-2}\ kg \equiv 17.5\ g \qquad (6)$$

In the example shown, then, the mass of the closing body has to be at least 17.5 g in order to prevent a movement of the closing body by more than 0.1 mm.

If the mass of the closing body is selected so as large as this, then even a pressure pulse to 0 bar will not move the closing body so far that a significant quantity of working fluid will be released into the hydraulic chamber.

The method described may be further improved by considering that the pressure pulse generally does not result in a pressure drop to 0 bar, but only to a minimum pressure p_{min}. In equation (5) above, then, instead of the set pressure p_L, the difference $p_L - p_{min}$ between the set pressure p_L and the minimum pressure p_{min} due to the pressure pulse can be used, whereupon the mass can be reduced still further. Alternatively, the set pressure p_L can be increased, whereupon the spring 17 can be made weaker, simplifying operation of the pump.

LIST OF REFERENCE NUMERALS

1	membrane
3	piston
4	wall
5	gap
6	leakage compensation valve
7	wall
8	hydraulic chamber
9	pumping chamber
10	return spring
11	clamping rim
12	clamping rim
13	mounting
14	diagrammatical representation of a bulged membrane
15	working fluid reservoir
16	closing body
17	spring
18	valve body
19	line
20	closing element

CLAIMS

1. A membrane pump having a hydraulic chamber (8) separated from a pumping chamber (9) by a membrane (1), wherein the pumping chamber (9) is respectively connected with a suction connection and a pressure connection and a pulsating working fluid pressure can be applied to the hydraulic chamber (8) which can be filled with a working fluid, wherein the hydraulic chamber (8) is connected to a working fluid reservoir (15) via a leakage compensation valve (6), wherein the leakage compensation valve (6) comprises a closing body which is held in a closed position with the aid of a pressure element and which can be moved to and fro between the closed position in which the valve gate is closed and an open position in which the valve gate is open, wherein the pressure element is designed such that when the pressure in the hydraulic chamber (8) is lower than a set pressure p_L, the closing body (16) moves in the direction of the open position, characterized in that the mass of the closing body (16) is large enough for the closing body (16) to move by no more than 0.2 mm in the direction of the open position when a drop in pressure to 0 bar which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8).

2. The membrane pump according to claim 1, characterized in that the mass of the closing body (16) is selected such that the closing body (16) moves by no more than 0.1 mm in the direction of the open position when a drop in pressure which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8).

3. The membrane pump according to claim 1 or 2, characterized in that the closing body (16) moves by no more than 0.2 mm, in the direction of the open position when a drop in pressure to a minimum pressure p_{min} which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8), wherein p_{min} is the minimum

pressure in the hydraulic chamber arising on the occurrence of a pressure pulse as a result of a change in the velocity of the fluid through the suction connection during the suction stroke.

4. The membrane pump according to claim 3, characterized in that the closing body (16) moves by no more than 0.1 mm, in the direction of the open position when a drop in pressure to a minimum pressure p_{min} which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8), wherein p_{min} is the minimum pressure in the hydraulic chamber arising on the occurrence of a pressure pulse as a result of a change in the velocity of the fluid through the suction connection during the suction stroke.

5. The membrane pump according to any one of claims 1 to 4, characterized in that p_L is higher than the minimum pressure in the hydraulic chamber (8).

6. A method for dimensioning a leakage compensation valve (6) of a membrane pump having a hydraulic chamber (8) separated from a pumping chamber (9) by a membrane (1), wherein the pumping chamber (9) is respectively connected with a suction connection and a pressure connection, and a pulsating working fluid pressure can be applied to the hydraulic chamber (8) which can be filled with a working fluid, wherein the hydraulic chamber (8) is connected to a working fluid reservoir (15) via a leakage compensation valve (6), wherein the leakage compensation valve (6) comprises a closing body (16) which can be moved to and fro between a closed position in which the valve gate is closed and an open position in which the valve gate is open, characterized in that the mass of the closing body (16) is selected such that the closing body (16) moves by no more than 0.2 mm, preferably by no more than 0.1 mm, in the direction of the open position when a drop in pressure which lasts

no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8).

7. The method according to claim 6, wherein the mass of the closing body (16) is selected such that the closing body (16) moves by no more than 0.1 mm, in the direction of the open position when a drop in pressure which lasts no longer than 1 millisecond occurs as a result of a pressure pulse in the hydraulic chamber (8).

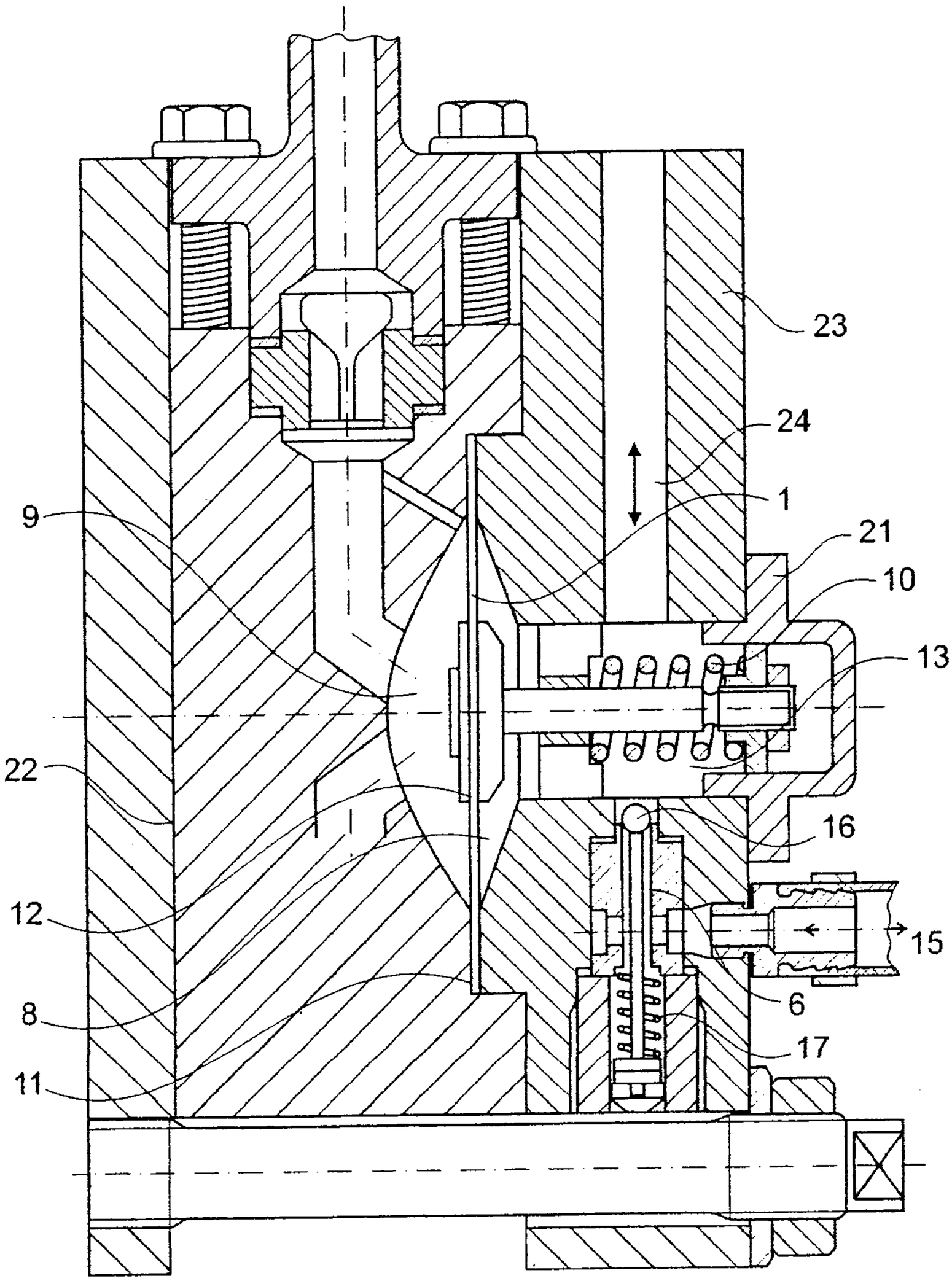


Fig. 1

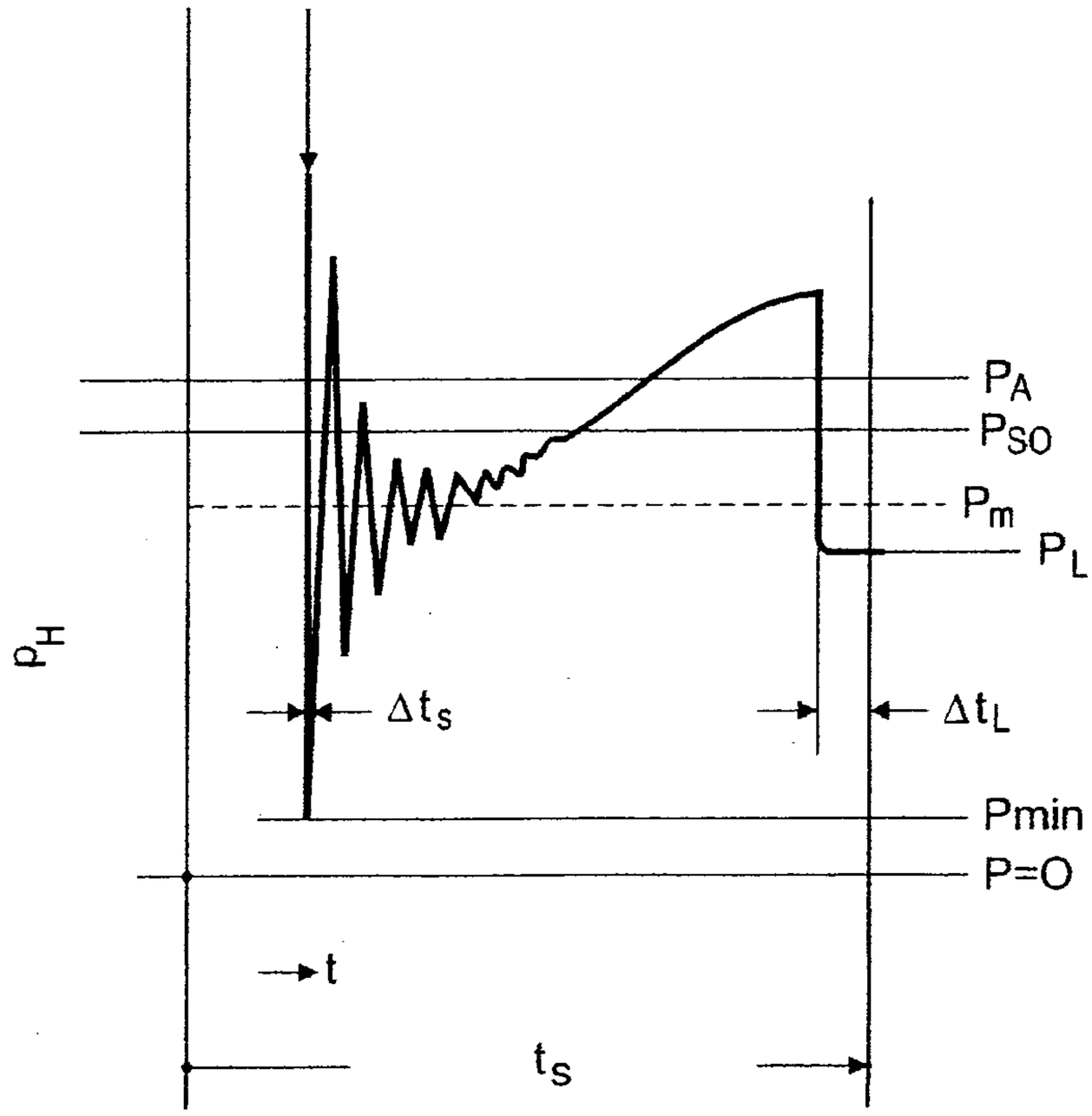


Fig. 2

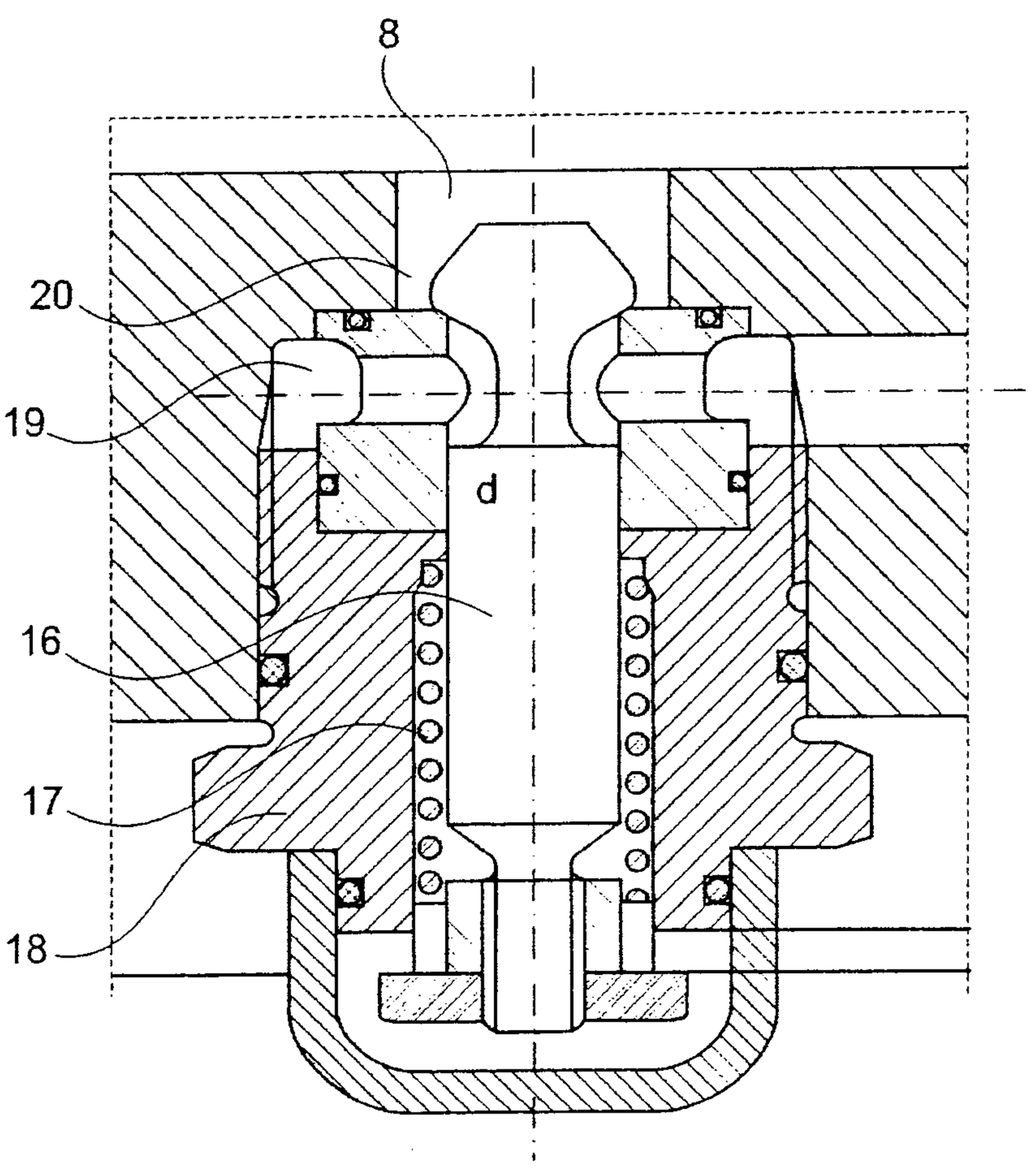
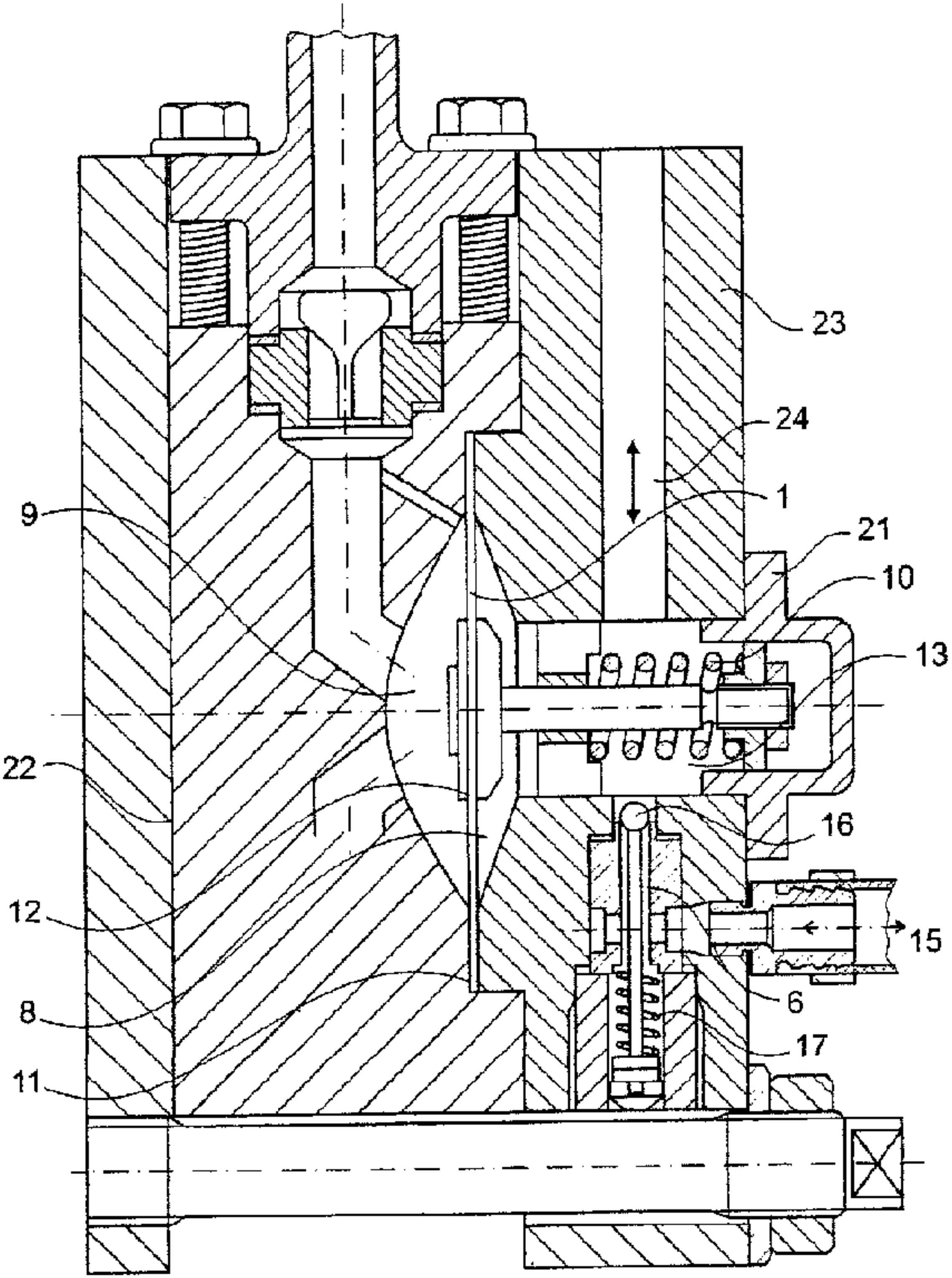


Fig. 3


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