US 20150004005A9

(19) United States
(12) Patent Application Publication
Fritsch

(10) Pub. No.: US 2015/0004005 A9
(48) Pub. Date: Jan. 1, 2015
CORRECTED PUBLICATION

(54) MEMBRANE PUMP AND METHOD FOR ADJUSTING SAME

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(21) Appl. No.: **13/818,114**

(22) PCT Filed: **Aug. 15, 2011**

(86) PCT No.: **PCT/EP11/64044**

§ 371 (c)(1),
(2), (4) Date: **May 1, 2013**

**Prior Publication Data**

(15) Correction of US 2014/0147292 A1 May 29, 2014
See Claims 4 and 9.

(65) US 2014/0147292 A1 May 29, 2014

(30) **Foreign Application Priority Data**

Aug. 26, 2010 (DE) ...................... 10 2010 039 831.4

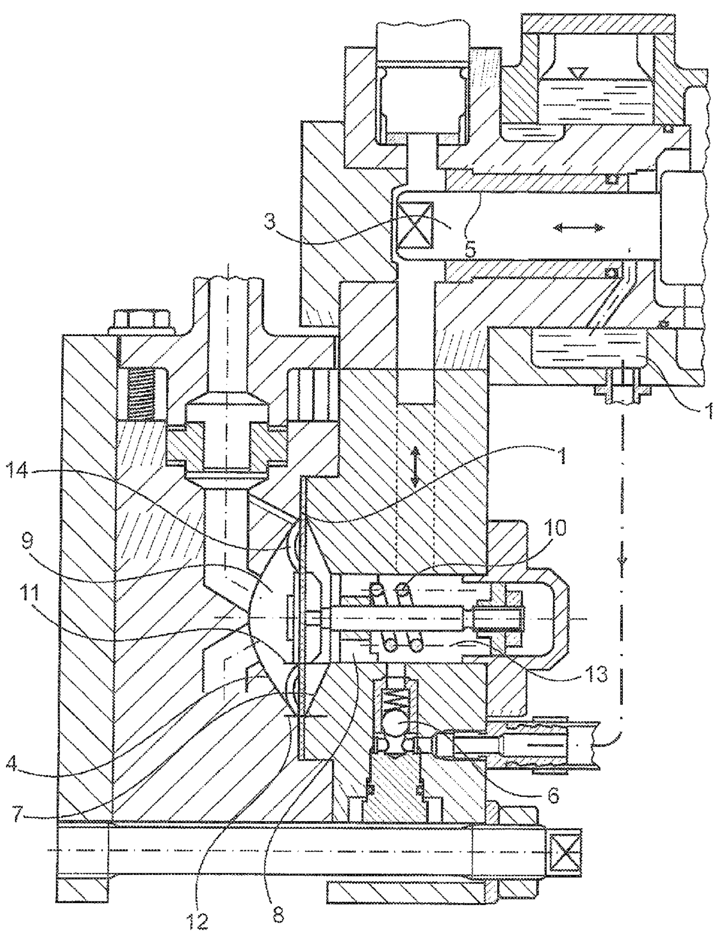
**Publication Classification**

(51) **Int. Cl.**
*F04B 45/033* (2006.01)

(52) **U.S. Cl.**
CPC .................................... ***F04B 45/033*** (2013.01)
USPC ............................................ **417/53**; 417/472

(57) **ABSTRACT**

The present invention concerns a pump adjusting method and a membrane pump having a pumping chamber, a pressure and a suction connection, wherein the pressure and the suction connections are connected to the pumping chamber, a hydraulic chamber, wherein the pumping chamber and hydraulic chamber are separated from each other by a membrane, wherein a pulsating working fluid pressure can be applied to the hydraulic chamber which can be filled with a working fluid, wherein the membrane is moved between a first and second chamber positions of different volumes, wherein the chamber is connected to a working fluid reservoir, wherein the membrane comprises exchangeable spring elements exerting different forces on the membrane. The force which is exerted by the spring element on the membrane in the direction of the second position can be adjusted.



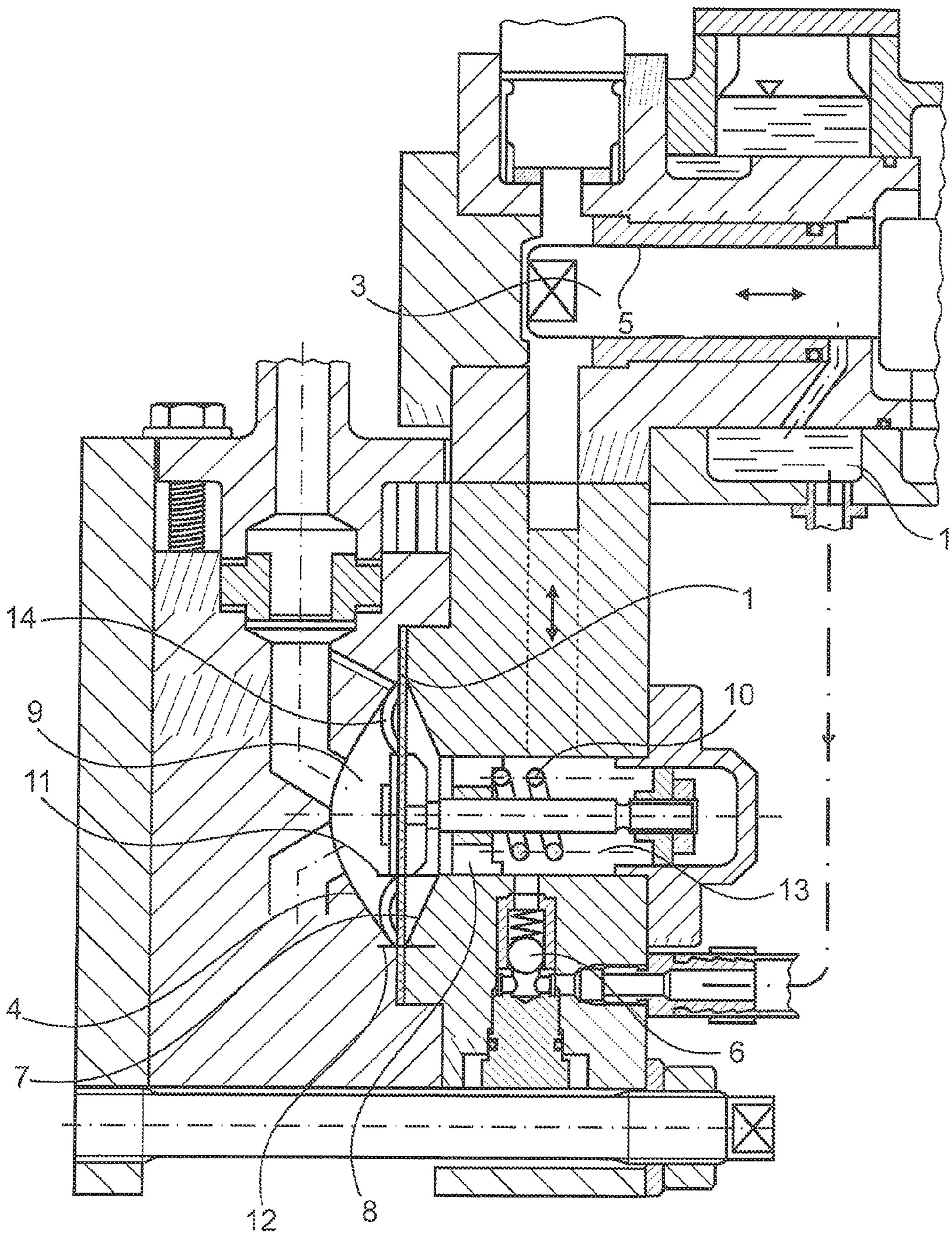



Fig. 1

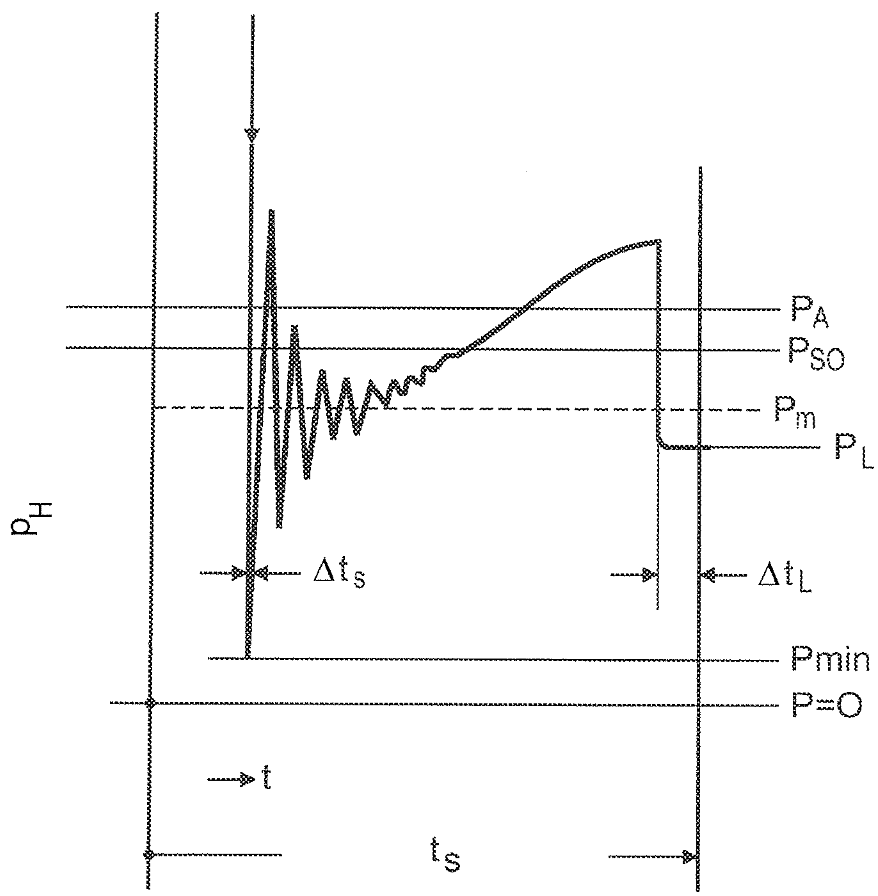



Fig.2

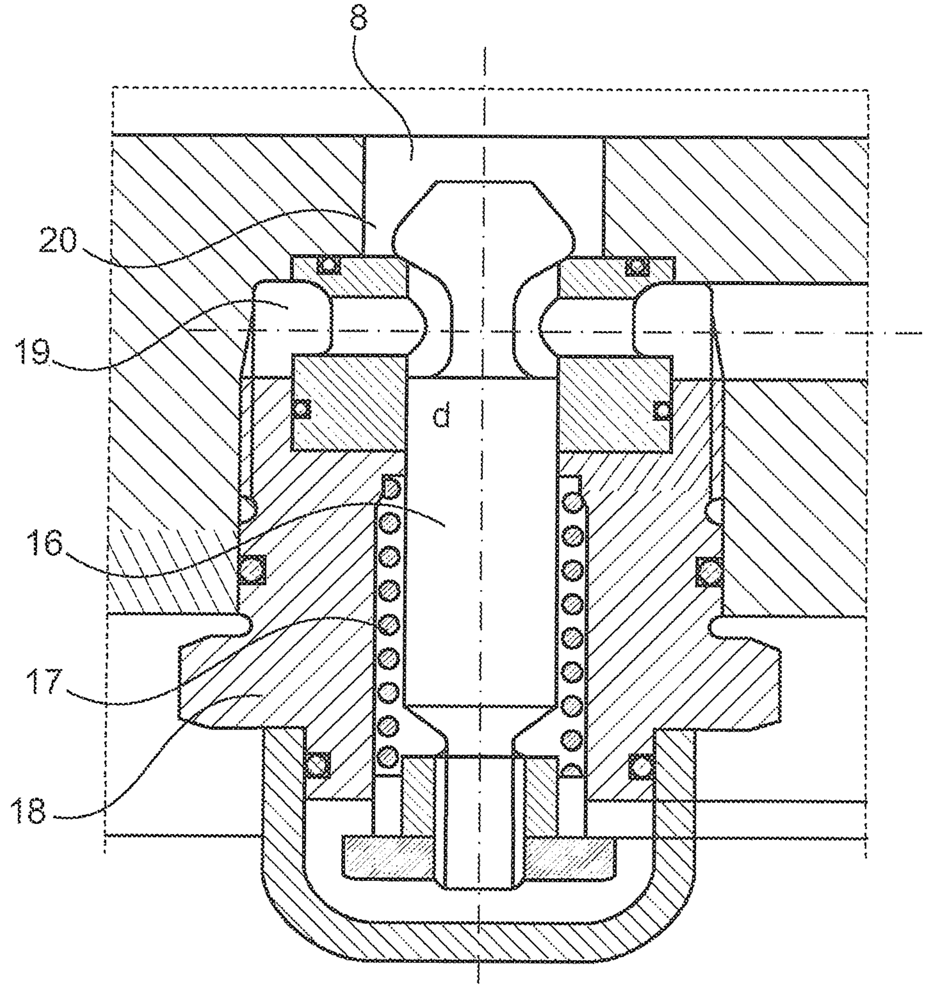



Fig. 3

# MEMBRANE PUMP AND METHOD FOR ADJUSTING SAME

**[0001]** The present invention relates to a membrane pump and to a method for adjusting a membrane pump.

**[0002]** 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, the 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 underpressure 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.

**[0003]** 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.

**[0004]** 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.

**[0005]** The pulsating working fluid pressure is usually produced by means of a movable piston which is in contact with the working fluid.

**[0006]** 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.

**[0007]** 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 on the one hand and the cylindrical hollow element on the other hand, 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.

**[0008]** 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.

**[0009]** 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.

**[0010]** 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 $p_L$. In order to prevent the leakage compensation valve from opening too soon during the suction stroke, i.e. while the piston moves backwards and thus the volume in the hydraulic chamber is expanding, the membrane is frequently provided with a spring element which is in turn designed such that it exerts a force on the membrane so that the membrane is biased in the direction of the hydraulic chamber. In this manner, the spring element assists the movement of the membrane in the direction of its suction stroke.

**[0011]** Normally, pressure pumps are required to run for a predetermined time, usually 5000 to 10000 service hours, without maintenance or repair.

**[0012]** In order to ensure this, it must be ensured that the working zone of the membrane always follows the motion of the piston and stays within the dome chamber provided for it, which dome chamber is formed by the pumping chamber and the hydraulic chamber.

**[0013]** If, therefore, for some reason too much working fluid gets into the hydraulic chamber, the membrane will move away from the piston movement in the pressure stroke direction, with the result that before the piston has completed the pressure stroke, it impinges on the walls of the pumping chamber and is perforated on the bores leading to the valves.

**[0014]** Since perforation leads to breakdown of the membrane pump, it is essential that this should be avoided.

**[0015]** It is thus extremely important that the dimensions of the leakage compensation valve be such that it only opens when the membrane becomes seated on the hydraulic side dome at the end of the suction stroke. This causes a brief under-pressure, whereupon the spring-loaded leakage compensation valve opens and the hydraulic chamber is supplemented with the exact quantity of working fluid that is missing.

**[0016]** The danger of perforating the membrane always arises if the leakage compensation valve opens before the membrane has reached its boundary position on the hydraulic side. To avoid this, the pressure in the hydraulic chamber during the suction stroke may only drop below the set pressure of the leakage compensation valve if the membrane is seated on the dome.

**[0017]** Furthermore, when the pump is stopped, even when an under-pressure develops in the pumping chamber, the pressure in the hydraulic chamber has to be at least 1 bar (=atmospheric pressure), since otherwise, because of the leaks that are always present, the membrane would move in the direction of the pressure stroke and small quantities of fluid would flow in, either via the pistons or via the leakage compensation valve, which would lead to perforation of the membrane upon start-up of the pump.

**[0018]** In order to satisfy this condition every time, EP 1 291 524 proposes that the spring force be set such that in the suction stroke, the membrane also follows the piston if there is a vacuum in the pumping chamber, i.e. the pressure applied to the working fluid by the spring force via the membrane is always more than 1 bar. The pressure only drops when, at the end of the suction stroke, the membrane is at the hydraulic side end of the dome, since the membrane can then no longer follow the piston. At that moment, working fluid can be added via the leakage compensation valve if necessary.

[0019] Since the force F on the membrane due to the pressure difference is proportional to the square of the diameter D of the membrane, but at the same time the shear and bending forces applied to the surface at the clamping rims of the membrane are only proportional to the diameter, the shear stress increases proportionally to the diameter of the membrane D; thus, particularly with large membrane pumps, this can lead to overloading of the membrane and subsequently to breakage of the membrane before the expiry of the envisaged operational lifetime.

[0020] Since the increase in the spring force F is proportional to $D^2$, with large diameter membranes a pressure of at least 1 bar requires very strong and thus expensive springs. As an example, a membrane diameter of 100 mm requires a spring force of 750N, whilst a membrane diameter of 400 mm already requires one of 12000 N.

[0021] Starting from the prior art described, the aim of the invention is to provide a membrane pump and a method for adjustment thereof, by means of which the problems discussed above can be reduced or even completely overcome.

[0022] Regarding the membrane pump, this is accomplished by means of a membrane pump with a pumping chamber, a pressure and a suction connection, wherein the pressure and the suction connections are connected to the pumping chamber, a hydraulic chamber, wherein the pumping chamber and hydraulic chamber are separated from each other by a membrane, wherein a pulsating working fluid pressure can be applied to the hydraulic chamber which can be filled with a working fluid, wherein the membrane is moved between a first position in which the pumping chamber has a small volume, and a second position, in which the pumping chamber has a larger volume, and the hydraulic chamber is connected to a working fluid reservoir via a leakage compensation valve, wherein the membrane comprises a spring element, which is designed such that it exerts a first predetermined force on the membrane in the direction of the second position. In accordance with the invention, the spring element can be exchanged for another spring element which is designed such that it exerts a second predetermined force on the membrane in the direction of the second position, or the force which is exerted by the spring element on the membrane in the direction of the second position can be adjusted.

[0023] Because of the adjustability or exchangeability of the spring element, the spring force can be matched to the prevailing conditions, such as the static pressure at the suction connection. If, for example, it is established for the desired use that the static pressure at the suction connection itself is already 1 bar and a suction valve which connects the suction connection to the pumping chamber is designed such that it opens at a pressure difference of more than 0.3 bar, then the pressure in the pumping chamber cannot fall below 0.7 bar. Consequently, the spring element too must only exert a smaller force on the membrane, which further increases the service life of the membrane.

[0024] Thus, in accordance with the invention, the spring force of the spring element can be matched to local circumstances.

[0025] In accordance with a preferred embodiment, the spring element can be detached from the membrane. Thus, the spring element can be changed without having to change the membrane. However, in principle it is also possible for the membrane itself to have appropriate resilient properties.

[0026] Furthermore, it may be advantageous for a hydraulic body and a membrane body to be provided between which the membrane is clamped such that the hydraulic chamber is disposed in the hydraulic body and the pumping chamber is arranged in the membrane body, wherein the hydraulic body comprises a closeable opening arranged in the direction of force of the spring element through which the spring element can be changed or its spring constant can be adjusted. In general, the drive piston is disposed behind the spring element in the direction of force, so that changing or adjusting the spring element is only possible by means of extremely time-consuming dismantling of the pump. The closeable opening of the invention means that now, after the pump has been assembled and the static pressure has been established at the suction connection, the spring constant can easily be adjusted to the conditions. In principle, it would also be possible to dispose the spring element in the pumping chamber. In this case, it would be advantageous for the membrane body to comprise a closeable opening disposed in the direction of force of the spring element, through which the spring element can be changed or adjusted.

[0027] In a further preferred embodiment, the pulsating working fluid is supplied to the hydraulic chamber via a channel, wherein the channel is orientated, at least in the region of its opening into the hydraulic chamber, such that it forms an angle a with the direction of force of the spring element which is more than 0°, preferably more than 45°, particularly preferably more than 70° and most preferably approximately 90°. Because this results in a lateral supply of pulsating working fluid to the hydraulic chamber, there is sufficient space to gain access to the spring element in order to adjust it or change it "from the back", i.e. from the side facing away from the membrane.

[0028] Regarding the method for adjusting a membrane pump, the above-mentioned aim is achieved by providing a step wherein the spring constant is selected or adjusted such that the pressure $p_{FV}$ applied to the working fluid by the spring element via the membrane is: $p_{FV}>p_A-p_{SO}$, where $p_A$ is the atmospheric pressure and $p_{SO}$ is the static pressure at the suction connection.

[0029] In a further preferred embodiment, the pressure $p_{FV}$ applied to the working fluid by the spring element is selected such that

$$p_A>p_{FV}>p_A-p_{SO}.$$

[0030] This ensures that the hydraulic chamber is not supplied with too much working fluid via the leakage compensation valve. However, the force applied to the working fluid by the spring element can be selected so as to be substantially smaller than it is usually the case in the prior art since, in accordance with the invention, it is for the first time allowed for that a static pressure is applied to the suction connection such that as a rule, a lower pressure cannot exist in the pumping chamber.

[0031] Since in some embodiments the suction connection is connected to the pumping chamber via a non-return valve, which also has an appropriate spring element such that the non-return valve only opens when there is a pressure difference $\Delta p_{SV}$ between the pressure at the suction connection and the pressure in the pumping chamber, in a preferred embodiment, the pressure $p_{FV}$ applied to the working fluid by the spring element is set so that the following holds: $p_A>p_{FV}>p_A-p_{SO}+\Delta p_{SV}$.

[0032] In a further preferred embodiment, 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 movable 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, which closing body is held in the closed position with the aid of a pressure element, wherein the pressure element is designed such that if the pressure in the hydraulic chamber is lower than a set pressure $p_L$, the closing body moves in the direction of the open position. Advantageously, the pressure element of the leakage compensation valve and the spring element of the membrane are constructed and arranged such that at any time the sum of the pressure $p_H$ in the hydraulic chamber and the pressure $p_{FV}$ applied by the spring element to the working fluid is higher than the set pressure $p_L$.

**[0033]** In a further preferred embodiment, the mass of the closing body is such that the closing body moves by not more than 0.2 mm, preferably not more than 0.1 mm, in the direction of the open position when a pressure drop to 0 bar which lasts no longer than 1 ms occurs as a result of a pressure pulse in the hydraulic chamber.

**[0034]** Further advantages, features and possible applications will become apparent from the following description of a preferred embodiment and from the accompanying drawings, which show:

**[0035]** FIG. **1**: a diagrammatic sectional view of a membrane pump head in accordance with the invention;

**[0036]** FIG. **2**: an illustrative diagram of the pressure in the hydraulic chamber over time; and

**[0037]** FIG. **3**: a sectional view of a specially designed leakage compensation valve.

**[0038]** FIG. **1** shows a detail of a membrane pump head in a sectional view. The membrane pump comprises a membrane **1**, which is clamped between a hydraulic body **23** and a membrane body **22**. The membrane divides the dome-shaped cavity into a pumping chamber **9** and a hydraulic chamber **8**. The membrane **1** is connected by a screw connection with a bolt which is pulled into the hydraulic body with the aid of a spring element **10**. In other words, the spring element **10** exerts a force on the membrane **1** in the direction of the hydraulic chamber **8**.

**[0039]** The pumping chamber **9** is connected to a suction connection (not shown) and a pressure connection (not shown) via appropriate valves. An oscillating hydraulic pressure can be applied to the membrane **1** via the channel **24**. If the pressure rises in the channel **24**, the membrane **1** in FIG. **1** is moved to the left, i.e. the pumping chamber **9** is contracted. Any pumping medium therein is then forced out of the pressure connection via the valve. If the pressure in the channel **24** is then reduced, then the spring element **10** ensures that the membrane is drawn back into the hydraulic chamber. The pressure in the pumping chamber **9** will fall until it is lower than the static pressure at the suction connection. Then pumping medium is fed via the suction connection into the pumping chamber **9**.

**[0040]** By means of the periodic movement of the membrane, then, pumping medium is periodically drawn out of the suction connection and discharged via the pressure connection at a higher pressure. The membrane is held between the clamping rims **11**, **12**. The spring element **10** might cause the membrane **1** to bulge.

**[0041]** During operation, under certain circumstances, working fluid escapes via the piston because of leaks brought about by the pulsating working fluid pressure. In order to ensure that the right quantity of working fluid is 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. This leakage compensation valve **6** comprises a small ball **16**, which is urged into a valve seat by means of a spring **17**. The spring **17** of the leakage compensation valve **6** establishes a set pressure $p_L$. If the pressure in the hydraulic chamber **8** drops below this 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.

**[0042]** In the embodiment shown, an opening is provided in the hydraulic element **23**, which can be closed with the aid of the cap **21**. If the cap **21** is removed from the hydraulic body, then the spring element **10** can be accessed. In this manner, the spring element can easily be exchanged or re-set, in order to ensure that as little force as possible is applied to the membrane via the spring element **10**, at the same time however ensuring that the leakage compensation valve **6** only opens when needed. This ready accessibility is made possible because the pulsating working fluid is supplied via the channel **24** which is arranged essentially at a 90° angle to the direction of force of the spring element **10**.

**[0043]** FIG. **2** graphically 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 pressure 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**.

**[0044]** The suction stroke begins when the piston is moved back in order to produce the pulsating working fluid pressure. Initially, this means that 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 $p_{SO}$. If 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 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. The high frequency, rapidly fading pressure wave can initially be ignored for the following discussion.

**[0045]** The backwards movement of the piston makes the pressure in the hydraulic chamber fall. Thus, with the aid of the spring element **10**, sufficient force has to be exerted on the working fluid in the hydraulic chamber so that the pressure in the hydraulic chamber does not drop below the set pressure of the leakage compensation valve, as otherwise the leakage compensation valve would open and additional working fluid would be supplied to the hydraulic chamber.

**[0046]** Known membrane pumps are thus equipped with appropriate return springs **10**, which ensure that in all cases, the pressure in the hydraulic chamber is higher than the set pressure. Since the pressure in the pumping chamber cannot drop below zero and the pressure in the working fluid reservoir is typically below atmospheric pressure (1 bar), the springs are selected so that even at the end of the suction stroke, i.e. when the spring has drawn the membrane to its turning point in the hydraulic chamber, it is more than 1 bar. This ensures that even in the worst case, no unplanned opening of the leakage compensation valve occurs.

**[0047]** In accordance with the invention, however, it is ensured that the force exerted by the return spring **10** on the membrane is adjustable, since membrane pumps are usually employed in an environment in which a static pressure $p_{SO}$ is exerted at the suction connection which is greater than zero. Depending on which pressure is applied in this case, then, the spring force can be reduced in order to prevent the membrane from being drawn unnecessarily strongly into the hydraulic chamber by the spring element **10**. The lower the set force, the longer is the service life of the membrane. In addition, the drive of the pump can also be reduced, since it only has to work against a small spring force of the spring element **10**.

**[0048]** By means of the inventive adjustment of the force applied to the membrane by the spring element **10**, then, the energy consumption of the membrane pump can be substantially reduced.

**[0049]** Later on, if the membrane pump has to be adjusted to another static pressure on the intake line, then the spring element **10** only has to be adjusted or replaced by another one.

**[0050]** The configuration of the invention makes this possible without great expense.

**[0051]** As already mentioned, 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 ($\Delta p_{ST}$). Shortly thereafter, it rises again sharply so that a high frequency, rapidly fading pressure oscillation occurs (Joukowsky pulse). It will immediately be seen that the maximum pressure pulse could result 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.

**[0052]** Because of this brief drop in the pressure, the pressure might drop below the set pressure $p_L$, so that the leakage compensation valve opens.

**[0053]** In order to prevent opening upon a pressure pulse drop to $p_{min}$, in the prior art, it is usual to select the set pressure of the leakage compensation valve so that $p_L<p_{min}$. However, this has the result that appropriate constructive measures have to be taken to ensure that at the end of the suction stroke, the pressure will actually drop below the set pressure of the leakage compensation valve when too little working fluid is contained in the hydraulic chamber. This increases the costs of the membrane pump.

**[0054]** Thus, it is proposed that the mass of the closing element of the leakage compensation valve be raised so that a pressure pulse for a period of up to 1 ms is not sufficient to move the closing body by more than 0.1 mm.

**[0055]** These inventive measures mean, however, that 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.

**[0056]** The invention is based on the fact that the pressure pulse occurs over only a very brief time interval Δts<1 millisecond.

**[0057]** 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.

**[0058]** An appropriate leakage compensation valve is shown in FIG. **3**.

**[0059]** 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 FIG. **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 FIG. **3** is moved upwards, so that a connection is opened between the line **19** and the hydraulic chamber **8**.

**[0060]** 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.

**[0061]** The stroke of the closing body, Δs, is calculated as follows:

$$\Delta s = b \cdot \frac{\Delta t^2}{2} \tag{1}$$

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:

$$b=F/m \tag{2}$$

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

$$\Delta s = \frac{F}{m} \cdot \frac{\Delta t^2}{2} \tag{3}$$

or

$$m = \frac{\Delta t^2}{2\Delta s} \cdot F \tag{4}$$

**[0062]** Assuming that the pressure pulse does not last longer than 1 millisecond, i.e. $\Delta t_s$=1 millisecond, that the movement of the closing body should be a maximum of 0.1 mm, i.e. $\Delta s_s$=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 $p_L$, i.e. 0.7 bar, then for a diameter of the closing element of 8 mm, i.e. a corresponding surface area of about 0.5 $cm^2$:

$$F=p_L \cdot A=0.7\cdot 10\cdot 0.5=3.5\text{ N} \tag{5}$$

and thus

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

**[0063]** 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.

**[0064]** If the mass of the closing body is selected so as to be of this magnitude, 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.

**[0065]** 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

**[0066]** **1** membrane
**[0067]** **6** leakage compensation valve
**[0068]** **8** hydraulic chamber
**[0069]** **9** pumping chamber
**[0070]** **10** spring element
**[0071]** **11**, **12** clamping wheels
**[0072]** **15** working fluid reservoir
**[0073]** **16** ball
**[0074]** **17** spring
**[0075]** **18** valve body
**[0076]** **19** line
**[0077]** **20** closing element
**[0078]** **21** cap
**[0079]** **22** membrane body
**[0080]** **23** hydraulic body
**[0081]** **24** channel

**1**. A membrane pump with
a pumping chamber;
a pressure and a suction connection,
wherein the pressure and the suction connections are connected to the pumping chamber;
a hydraulic chamber,
wherein the pumping chamber and hydraulic chamber are separated from each other by a membrane,
wherein a pulsating working fluid pressure can be applied to the hydraulic chamber which can be filled with a working fluid,
wherein the membrane is moved between a first position in which the pumping chamber has a smaller volume, and a second position, in which the pumping chamber has a larger volume,
wherein the hydraulic chamber is connected to a working fluid reservoir via a leakage compensation valve,
wherein the membrane comprises a spring element having a first spring constant, which is designed such that it exerts a first predetermined force on the membrane in the direction of the second position; characterized in that the spring element can be exchanged for another spring element which is designed such that it exerts a second predetermined force on the membrane in the direction of the second position, or the force which is exerted by the spring element on the membrane in the direction of the second position can be adjusted.

**2**. A membrane pump according to claim **1**, characterized in that the spring element can be detached from the membrane.

**3**. A membrane pump according to any one of claims **1** and **2**, characterized in that a hydraulic body and a membrane body are provided, between which the membrane is clamped, such that the hydraulic chamber is disposed in the hydraulic body and the pumping chamber is disposed in the membrane body, wherein the hydraulic body comprises a closeable opening disposed in the direction of force of the spring element, through which the spring element can be changed or adjusted.

**4**. A membrane pump according to one of claims **1** to **2**, characterized in that the pulsating working fluid is supplied to the hydraulic chamber via a channel, wherein the channel is orientated, at least in the region of its opening into the hydraulic chamber, such that it forms an angle α with the direction of force of the spring element which is >0°, preferably >45°, particularly preferably >70° and most preferably approximately 90°.

**5**. A membrane pump according to one of claims **1** to **2**, characterized in that 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 movable 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, which closing body is held in the closed position with the aid of a pressure element, wherein the pressure element is designed such that if the pressure in the hydraulic chamber is lower than a set pressure $p_L$, the closing body moves in the direction of the open position.

**6**. A membrane pump according to claim **5**, characterized in that the pressure element of the leakage compensation valve and the spring element of the membrane are constructed and arranged such that at any time the sum of the hydraulic chamber pressure $p_H$ and the force $p_{FV}$ applied by the spring element to the working fluid is higher than the set pressure $p_L$.

**7**. A membrane pump according to claim **6**, characterized in that the mass of the closing body (**16**) is such that the closing body (**16**) moves by not more than 0.2 mm, preferably not more than 0.1 mm, in the direction of the open position when a pressure drop to 0 bar which lasts no longer than 1 ms occurs as a result of a pressure pulse in the hydraulic chamber (**8**).

**8**. A method for adjusting a membrane pump having a pumping chamber;
a pressure and a suction connection,
wherein the pressure and the suction connections are connected to the pumping chamber;
a hydraulic chamber,
wherein the pumping chamber and hydraulic chamber are separated from each other by a membrane,

wherein a pulsating working fluid pressure can be applied to the hydraulic chamber which can be filled with a working fluid,

wherein the membrane is moved between a first position in which the pumping chamber has a smaller volume, and a second position, in which the pumping chamber has a larger volume,

wherein the hydraulic chamber is connected to a working fluid reservoir via a leakage compensation valve;

wherein the membrane comprises a spring element having a first spring constant, which is designed such that it exerts a force on the membrane in the direction of the second position, characterized in that,

the spring constant is selected such that for the pressure $p_{FV}$ applied to the working fluid by the spring element via the membrane it holds that: $p_{FV}>p_A-p_{SO}$, where $p_A$ is the atmospheric pressure and $p_{SO}$ is the static pressure at the suction connection.

**9**. A method according to claim **8**, characterized in that the spring element is selected such that for the pressure $p_{FV}$ applied by the spring element to the working fluid it holds that:

$p_A>p_{FV}>P_A-P_{SO}$, where $p_A$ is the atmospheric pressure.

**10**. A method according to claim **9**, characterized in that a membrane pump is used in which the suction connection is connected to the pumping chamber via a non-return valve, wherein the non-return valve is designed such that it opens when there is a pressure difference $\Delta p_{SV}$ between the pressure at the suction connection and the pressure in the pumping chamber, wherein the spring element is selected such that for the pressure $p_{FV}$ applied to the working fluid by the spring element it holds that: $p_A>p_{FV}>p_A-p_{SO}+\Delta p_{SV}$.

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