(19) Europäisches Patentamt / European Patent Office / Office européen des brevets

(11) EP 2 418 385 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.02.2012 Bulletin 2012/07

(51) Int Cl.:
F04B 43/02 *(2006.01)* ***F04B 45/04*** *(2006.01)*

(21) Application number: **11250360.2**

(22) Date of filing: **23.03.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **30.03.2010 GB 1005350**

(71) Applicant: **Safety-Kleen Europe Limited**
Sheffield S25 3SH (GB)

(72) Inventors:
- **Dawes, Richard Gordon**
  Sheffield
  South Yorkshire S25 3SH (GB)
- **Ellis, Steven**
  Sheffield
  South Yorkshire S25 3SH (GB)

(74) Representative: **Hardy, Rosemary et al**
Marks & Clerk LLP
1 New York Street
Manchester, M1 4HD (GB)

Remarks:
Claims 16-21 are deemed to be abandoned due to non-payment of the claims fees (Rule 45(3) EPC).

(54) Diaphragm pump

(57) The present invention relates to a wear reduction member 310 for use in a diaphragm pump 300, whereby the wear reduction member is a low-friction member configured to be locatable in the diaphragm pump between a diaphragm 312 and an adjacent surface so as to form low-frictional mating contact with the diaphragm and inhibit frictional mating contact between the diaphragm and the adjacent surface. The wear reduction member may have a substantially planar configuration. Alternatively, the wear reduction member may have a cap-like configuration whereby a peripheral portion of the wear reduction member is configured to bend over an edge of the adjacent surface away from the diaphragm. The present invention also relates to a diaphragm pump comprising at least one wear reduction member. The wear reduction member may be located between the diaphragm and the piston 306 or between the diaphragm and clamping member 314. The present invention further relates to a pumping system comprising a diaphragm pump with a wear reduction member.

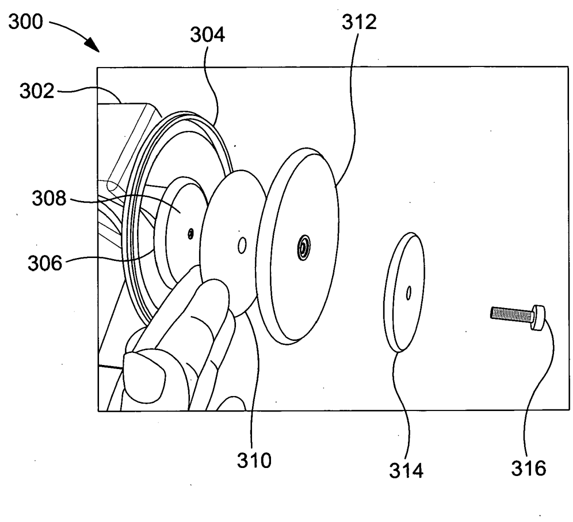

Figure 4b

EP 2 418 385 A1

Description

FIELD OF INVENTION

[0001] This invention relates to diaphragm pumps. The invention relates particularly to a member for improving the lifetime of a diaphragm pump and further relates to a pumping system comprising a diaphragm pump with the member.

BACKGROUND OF INVENTION

[0002] A diaphragm pump uses a reciprocating diaphragm to pump fluid. Certain types of diaphragm pump comprise a reciprocating piston to mechanically drive the diaphragm in a reciprocating motion. In such pumps, the diaphragm is arranged to form a barrier between the piston and the pumping chamber by securing a peripheral region of the diaphragm to the housing of the pump. Typically, a central region of the diaphragm is secured to the piston such that the central region of the diaphragm is reciprocally displaced relative to the peripheral region as the piston drives the diaphragm. During an intake stroke of the piston, the diaphragm is driven to form a concave configuration such that the volume of the pumping chamber increases and fluid is drawn into the pumping chamber via at least one inlet. During a discharge stroke of the piston, the diaphragm is driven to form a convex configuration such that the volume of the pumping chamber decreases and the fluid is forced out of the pumping chamber via at least one outlet.

[0003] Figure 1 a depicts an exploded view of a conventional diaphragm pump whereby a diaphragm (D) is clamped between a piston (P) and clamping washer (W) and secured via a screw (S).

[0004] Unfortunately, diaphragms in this type of diaphragm pump are susceptible to mechanical fatigue (wear) during use. Mechanical fatigue is induced due to the abrasive (frictional) contact formed between the diaphragm and adjacent surfaces. Abrasive wear typically occurs on the underside of the diaphragm as it moves (slides) across the driving surface (PS) of the piston. Abrasive wear may also occur on the upperside of the diaphragm as it moves (slides) relative to the abutting surface (WS) of the clamping washer. The abrasive action is particularly pronounced as the diaphragm slides across or over the edge of the clamping washer/piston.

[0005] Mechanical fatigue may also be induced due to the bending (flexing) of the diaphragm during the operating cycle. Bending wear may occur on the upperside of the diaphragm because the diaphragm is subject to bending stress as it is driven to form a concave configuration. Bending wear may occur on the lowerside of the diaphragm because the diaphragm is subject to bending stress as it is driven to form a convex configuration.

[0006] Since the diaphragm follows the same motion profile with every intake stroke and discharge stroke of the piston, the abrasive action and bending action occurs repeatedly in the same regions of the diaphragm. Hence, wear is concentrated in localised regions of the diaphragm and may ultimately lead to tears or perforations in the diaphragm.

[0007] Figure 1b depicts a diaphragm that has suffered mechanical fatigue whilst being utilised in the diaphragm pump of Figure 1a. It can be seen in Figure 1b that a pronounced wear line (L) has formed on the underside of the diaphragm. The wear line corresponds to an underside region of the diaphragm that was subject to repeated abrasion by the piston and bending stress during the operating cycle.

[0008] Unfortunately, the operational lifetime of a diaphragm is shortened due to the problem of mechanical fatigue.

[0009] The problem of diaphragm pump failure may be avoided by regularly replacing the diaphragm. However, this is both time consuming, requires operational downtime and is expensive. Moreover, this may not be a practicable solution if the diaphragm pump must remain sealed or the diaphragm pump/diaphragm is inaccessible. Accordingly, conventional diaphragm pumps with a reciprocating piston are not considered to be suitable for continuous, long-term applications and are generally only provided for intermittent or occasional use.

[0010] In an attempt to extend the useful service life of a diaphragm, CA 2 251 222 describes how a portion of the diaphragm exposed to the greatest abrasive wear may be made thicker so that the diaphragm is able to resist abrasive contact between the diaphragm and piston. Although this design helps to improve the lifetime of a diaphragm, it is complex and expensive to manufacture.

[0011] GB 304 105 describes a diaphragm pump having a diaphragm mounted above a flexible piston. The flexible piston comprises a series of separate and relatively slidable concentric rings coupled together or supported by angularly-movable parts, operated by a piston rod, so that they advance sequentially or progressively in an axial direction during a working stroke. A leather disc is disposed between the diaphragm and flexible piston so that the diaphragm does not become torn or otherwise damaged by the peripheral edges of the concentric rings. The leather disc is provided to address the specific problems associated with the sharp peripheral edges of the concentric rings of flexible pistons and as a result is only configured to extend across the concentric rings. It can be seen in Figure 1 of GB 304 105 that a central region of the diaphragm is in abrasive mating contact with the central region of the piston (sleeve 7, bush 8 and the upper end 9 of the piston rod 10). Accordingly, the central region of the diaphragm will be susceptible to abrasive wear during operation and may fail.

[0012] JP 3160172 describes a diaphragm comprising a centre plate part 14 and a holding part 15 formed from a hard rubber material so as to minimise wear from mutual rubbing. Disadvantageously, this integrated diaphragm is complex and unduly expensive to manufacture.

[0013] Embodiments of the present invention seek to address or overcome at least some of the above-mentioned problems associated with conventional diaphragms and diaphragm pumps. Embodiments of the present invention seek to improve the operational lifetime of the diaphragm pump by minimising the wear of the diaphragm. Embodiments of the present invention seek to minimise the wear of the diaphragm by providing a wear reduction member.

STATEMENTS OF INVENTION

[0014] A first aspect of the present invention relates to a wear reduction member that is suitable for improving the operational lifetime of a diaphragm pump by restricting the wear of a diaphragm. The wear reduction member is a low-friction member configured to be locatable in a diaphragm pump between a diaphragm and an adjacent surface so as to form low-frictional mating contact with the diaphragm and inhibit frictional mating contact between the diaphragm and the adjacent surface.

[0015] Providing a wear reduction member that inhibits frictional mating contact between the diaphragm and an adjacent surface and forms a low-frictional mating contact with the diaphragm restricts abrasive wear of the diaphragm. The provision of the wear reduction member thereby helps to extend the lifetime of the diaphragm.

[0016] The wear reduction member is a low-friction member that exhibits a low coefficient of friction. The wear reduction member exhibits a sufficiently low coefficient of friction such that the low-frictional contact formed between wear reduction member and diaphragm induces limited or minimal abrasive wear of the diaphragm. The coefficient of friction may be less than approximately 0.1, preferably less than approximately 0.06.

[0017] The wear reduction member preferably comprises a first low-friction surface configured to form a low-frictional mating contact with a surface of the diaphragm and a second surface configured to form a mating contact with the adjacent surface.

[0018] The wear reduction member may be manufactured from a material having low-friction properties, whereby the wear reduction member comprises a first low friction surface and a second low friction surface. Alternatively, the wear reduction member may comprise an outer layer of material having low-friction properties so as to form the first low-friction surface. The wear reduction member may comprise a friction-reducing coating applied to an outer layer of the member so as to form the first low-friction surface. The wear reduction member may be a composite member comprising a first low-friction outer layer and a second layer.

[0019] The low-friction surface may be a self-lubricating surface so as to help restrict wear of the diaphragm.

[0020] The low-friction surface may be a sacrificially wearing surface so as to help restrict wear of the diaphragm.

[0021] A wear reduction member may be locatable between a diaphragm and a driving surface of a piston. Additionally or alternatively, a wear reduction member may be locatable between a diaphragm and a clamping surface of a clamping member.

[0022] For example, the wear reduction member may be suitable for reducing wear of a diaphragm in a diaphragm pump wherein:

the member is adapted to be locatable between the diaphragm and one of a piston or a clamping member of the diaphragm pump;
the member is configured to inhibit frictional mating contact between the diaphragm and the respective piston or clamping member; and
the member comprises a first low-friction surface to form a low-frictional mating contact with the diaphragm and a second surface to form a mating contact with the respective piston or clamping member.

[0023] The wear reduction member is preferably a flexible member so that it is able to flex (bend) in correspondence with the reciprocating diaphragm during the operating cycle of the diaphragm pump. Providing a flexible wear reduction member reduces relative movement between the diaphragm and the wear reduction member during the operating cycle and thereby helps to reduce abrasive wear of the diaphragm.

[0024] The wear reduction member is preferably a mechanically resilient member so that it is able to withstand operating stress. The resilient wear reduction member preferably provides a resilient biasing action on the diaphragm. The member may comprise a material having a Young's modulus in the range of approximately 0.3 to 1.0 GPa, and preferably in the range of approximately 0.4 to 0.7GPa.

[0025] Providing a resilient wear reduction member helps the wear reduction member to at least substantially maintain a low-frictional mating contact with the diaphragm throughout the operation of the diaphragm pump.

[0026] Providing a flexible and resilient wear reduction member helps to control the flexing of the diaphragm during the operating cycle and thereby reduce the bending stress/bending wear of the diaphragm.

[0027] Preferably, the wear reduction member is configured to be easily locatable between the diaphragm and adjacent surface so that it is simple to install.

[0028] Preferably, the wear reduction member may be retrofitted to a conventional diaphragm pump.

[0029] Preferably, the wear reduction member is removably mountable between the diaphragm and adjacent surface. Hence, the member may be replaced as and when required so as to further extend the operational lifespan of the diaphragm and pump.

[0030] The wear reduction member preferably comprises an attachment hole through which securing means may extend so as to secure the member between the diaphragm and adjacent surface. The attachment hole is preferably a centrally located aperture. The attachment hole is configured to receive any suitable securing means, such as a screw means or clip means.

[0031] So as to prevent frictional contact between the diaphragm and adjacent surface, a wear reduction member preferably comprises an outer diameter that is greater than an outer diameter of the adjacent surface.

[0032] Since the periphery of the diaphragm is secured to the housing of the pump, the outer diameter of a planar wear reduction member is preferably less than the diameter of the diaphragm.

[0033] The wear reduction member may be any suitable shape and size. For example, the wear reduction member may have a generally circular, oval, square or polygonal (e.g. hexagonal) shape. The wear reduction member may be an annulus shaped member having a centrally located attachment hole.

[0034] In an embodiment, the wear reduction member may have a substantially planar or plate-like configuration. For example, the wear reduction member may be a disc of PTFE material with a centrally located hole.

[0035] A wear reduction member having a planar configuration may comprise a central portion and a peripheral portion whereby the central portion is configured to so as to be located between the diaphragm and adjacent surface and the peripheral portion is configured so as to extend beyond the edge of the adjacent surface in a direction substantially parallel to the diaphragm.

[0036] In an alternative embodiment, the wear reduction member may have a lid or cap-like configuration such that the wear reduction may be mounted over (sit on, encase) the adjacent surface.

[0037] For example, the wear reduction member may comprise a central portion and a peripheral portion whereby the central portion is configured so as to be located between the diaphragm and adjacent surface and the peripheral portion is configured to extend (bend) over the edge of the adjacent surface in a direction away from the diaphragm.

[0038] The wear reduction member may have a generally U-shaped cross-section. The wear reduction member may have a cap-like configuration that is pre-formed during manufacturing. Alternatively, the wear reduction member may deform during use to have a cap-like configuration. The peripheral portion may have a fluted formation or substantially flat formation.

[0039] Providing a wear reduction member with a cap-like configuration helps to reduce the mechanical wear of the diaphragm without having a deleterious effect on the pumping effect of the diaphragm.

[0040] A second aspect of the present invention relates to a diaphragm pump comprising:

a diaphragm coupled to a reciprocating piston via a clamping member;

a wear reduction member located between the diaphragm and one of the piston or the clamping member;

wherein the wear reduction member is configured to inhibit frictional mating contact between the diaphragm and the respective piston or clamping member and comprises a low-frictional surface configured to form a low-frictional mating contact with the diaphragm.

[0041] Preferably, the diaphragm pump comprises securing means and the wear reduction member comprises an attachment hole through which the securing means may extend so as to secure the wear reduction member.

[0042] Preferably, the securing means are removable securing means. The securing means may comprise a screw means or clipping means.

[0043] Preferably, the diaphragm pump comprises a first wear reduction member located between the diaphragm and the piston, and a second wear reduction member located between the diaphragm and the clamping member.

[0044] By suitable selection of the wear reduction member, the improved diaphragm operational lifetime may be achieved without significantly affecting the performance of the diaphragm pump (in comparison to the volumetric change or pumping rate of a diaphragm pump without a member).

[0045] A third aspect of the present invention provides a pumping system comprising a diaphragm pump according to the second aspect of the invention.

BRIEF DESCRIPTION OF FIGURES

[0046] For a better understanding of the present invention and to show more clearly how it may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:

[0047] Figure 1a depicts an exploded view of part of a diaphragm pump according to the prior art;

[0048] Figure 1b depicts an underside view of a diaphragm that has become worn whist being used in the diaphragm pump of Figure 1a;

[0049] Figure 2a depicts a plan view of an embodiment of a wear reduction member according to a first aspect of the invention;

[0050] Figure 2b depicts a cross-sectional view through the wear reduction member of Figure 2a;

[0051] Figures 3a-3d depict cross-sectional views through four further embodiments of the wear reduction member according to the first aspect of the invention;

[0052] Figure 4a depicts an assembled view of a first embodiment of a diaphragm pump according to a second aspect of the invention;

[0053] Figure 4b depicts an exploded view of a part of the diaphragm pump of Figure 4a;

[0054] Figure 4c depicts a perspective view of an assembled part of the diaphragm pump of Figure 4a;

[0055] Figure 4d depicts a cross-sectional view of the diaphragm pump of Figure 4a;

[0056] Figure 4e depicts a cross-sectional view of the diaphragm pump of Figure 4a during a discharge stroke; and

[0057] Figure 5a depicts a cross-sectional view of a second embodiment of a diaphragm pump according to the second aspect of the invention;

[0058] Figure 5b depicts a cross-sectional view of the diaphragm pump of Figure 5a during a discharge stroke;

[0059] Figure 6 depicts a cross-sectional view of a third embodiment of a diaphragm pump according to a second aspect of the invention;

[0060] Figure 7 depicts a pumping system comprising a diaphragm pump according to a third aspect of the invention.

DETAILED DESCRIPTION

[0061] The present invention seeks to improve the longevity of a diaphragm in a diaphragm pump by limiting (inhibiting, restricting) the mechanical wear of the diaphragm.

[0062] As explained above, a diaphragm becomes worn in a conventional diaphragm pump because it is in frictional mating contact with at least one adjacent surface. Due to the frictional mating contact, the diaphragm is subject to an abrasive wearing action as it is reciprocately driven relative to the adjacent surface during the operation of the pump.

[0063] According to the first aspect of the invention, abrasive wear of a diaphragm may be restricted by providing a wear reduction member between the diaphragm and an adjacent surface that previously formed an abrasive mating contact with the diaphragm.

[0064] The wear reduction member is located between and arranged in mating contact with the diaphragm and the adjacent surface.

[0065] The wear reduction member is configured to at least limit any frictional mating contact between the diaphragm and the adjacent surface. By limiting the frictional mating contact, the abrasive wearing action that occurs between the reciprocating diaphragm and the adjacent surface during the operation of the diaphragm pump is at least reduced. The wear reduction member is preferably configured to substantially prevent any mating contact between the diaphragm and the adjacent surface such that substantially no abrasive wearing action can occur between the reciprocating diaphragm and adjacent surface during the operational cycle.

[0066] The wear reduction member is a low-friction member that is configured to form a low-frictional mating contact with the diaphragm. The wear reduction member has a lower coefficient of friction than the adjacent surface that was previously in mating contact with the diaphragm. Due to the low-frictional contact, the abrasive wearing action between the reciprocating diaphragm and wear reduction member is limited and so the diaphragm is subject to limited abrasive wear. Since the wear reduction member has a lower coefficient of friction than the adjacent surface, the diaphragm suffers less abrasive wear when it is arranged in mating contact with the wear reduction member than when it is arranged in mating contact with the adjacent surface.

[0067] By at least reducing the abrasive wearing action between the diaphragm and adjacent surface and limiting the abrasive wearing action between the diaphragm and wear reduction member, abrasive wear of the diaphragm is controlled (curbed, minimised) and so its operational lifespan is improved.

[0068] The wear reduction member preferably comprises a first low-friction surface that is configured to form a low-frictional mating contact with the diaphragm and a second, opposing surface that is configured to form a mating contact with the adjacent surface.

[0069] The first surface is a low-friction surface that exhibits a low coefficient of friction. The first surface has a lower coefficient of friction than the adjacent surface that was previously in mating contact with the diaphragm. So as to minimise the abrasive wear of the diaphragm, the coefficient of friction of the low-friction surface is preferably less than approximately 0.1 and even more preferably less than approximately 0.06.

[0070] The second surface may also be a low-friction surface that exhibits a low coefficient of friction. A wear reduction member comprising a first low-friction surface and second-low friction surface may be easier to manufacture and/or may be simpler to install because either surface can be arranged in mating contact with the diaphragm.

[0071] The wear reduction member may be manufactured from a material having a low coefficient of friction. This type of wear reduction member may be manufactured simply and cheaply. For example, by stamping, cutting etc. a wear reduction member from a sheet of low-friction material.

[0072] Alternatively, the wear reduction member may comprise an outer layer of low-friction material configured so as to form a first low-friction surface. The wear reduction member may comprise an outer coating having a friction reducing effect so as to form a first low-friction surface. The wear reduction member may be a composite member comprising a first outer layer of low-friction material and a second layer.

[0073] The wear reduction member may comprise any suitable low-friction material or coating. For example, the wear reduction member may comprise PTFE having a coefficient of friction of approximately 0.04. Other suitable low-friction materials include UHMWPE, Tufnol, PCV, acetal, oilon, HDPE, polypropylene, PEEK and/or polythene.

[0074] The first low-friction surface of the wear reduction member may be a self-lubricating surface so as to help minimise abrasive wear of the diaphragm.

[0075] The first low-friction surface of the wear reduction member may be a sacrificially wearing surface so as to help minimise mechanical wear of the diaphragm.

[0076] The wear reduction member may be any suitable thickness. The wear reduction member may have a thickness in the range of approximately 0.1mm - 2.0mm, preferably in the range of approximately 0.25mm -

0.75mm.

[0077] The wear reduction member is preferably a flexible member. The wear reduction member is preferably flexible so that it is able to flex with the diaphragm as the diaphragm is reciprocately displaced during the operating cycle of the diaphragm pump.

[0078] The thickness of the wear reduction member may be selected so as to provide a suitably flexible member. Additionally or alternatively, the wear reduction member may comprise a flexible material so as to form a suitably flexible member.

[0079] Providing a flexible wear reduction member that is able to flex in correspondence with the diaphragm reduces relative movement, and thereby abrasive action, between the wear reduction member and diaphragm during the operating cycle.

[0080] The wear reduction member is preferably a resilient member. The wear reduction member is preferably resilient so that it is able to withstand operating stress. The resilient wear reduction member preferably provides a resilient biasing action on the diaphragm and thereby helps to maintain a mating contact between the wear reduction member and diaphragm. The wear reduction member may be sufficiently resilient so as to substantially retain its pre-formed shape. Alternatively, the wear reduction may be sufficiently resilient to allow the wear reduction member to deform (change shape) in use. For example, as discussed in more detail below, the wear reduction member may be manufactured with a cap-like configuration or it may deform to develop a cap-like configuration during use.

[0081] The resilient wear reduction member may comprise a Young's modulus in the range of approximately 0.3 -1.0Pa and preferably in the range of approximately 0.4 - 0.7Pa. The wear reduction member may comprise a resilient material to form a suitably resilient member.

[0082] As mentioned above, a conventional diaphragm is also subject to bending stress, and thereby wears, as it is forced to bend during reciprocating motion.

[0083] However, providing a wear reduction member, even a flexible wear reduction member that is able to flex in correspondence with the diaphragm during the operating cycle, may moderate the flexing and thereby the bending profile of the diaphragm. As a result, the bending stress is spread over a broader region and so wear induced by bending is reduced.

[0084] The wear reduction member is preferably easily locatable in a diaphragm pump between the diaphragm and adjacent surface. The wear reduction member is not only suitable for use in new diaphragm pumps but it may also be retrofitted to existing, conventional diaphragm pumps.

[0085] The wear reduction member is preferably removably mountable in a diaphragm pump. As a result, the wear reduction member may be removed and replaced as and when required so as to continuously inhibit wear of the diaphragm.

[0086] The wear reduction member may be configured to be locatable between a diaphragm and a piston. In this case, the first low-friction surface of the wear reduction member is located in mating contact with the underside surface of the diaphragm and the second surface is located in mating contact with a driving surface of the piston.

[0087] The wear reduction member may be configured to be locatable between the diaphragm and a clamping member. In this case, the first low-friction surface of the wear reduction member is located in mating contact with the upperside surface of the diaphragm and the second surface is located in mating contact with a clamping surface of the clamping member.

[0088] Thus, according to a second aspect of the invention, a diaphragm pump may comprise a wear reduction member located between the diaphragm and the piston or the diaphragm and the clamping member. Alternatively, a diaphragm pump may comprise a first wear reduction member located between the diaphragm and the piston and a second wear reduction member located between the diaphragm and the clamping member.

[0089] The wear reduction member may comprise an attachment hole. The attachment hole is configured such that securing means may extend through the attachment hole and thereby secure the wear reduction member. The attachment hole is preferably centrally located in the wear reduction member. The securing means may be any suitable type of securing means such as a screw means, clipping means etc. The securing means is preferably a releasable securing means so that the wear reduction member may be releasably secured. The attachment hole may be any suitable shape and size. The attachment hole may be circular, oval, square or polygonal in shape. The attachment hole may comprise a diameter in the range of approximately 1.0mm -5.0mm. The size and shape of the attachment hole diameter is selected in accordance with the type and configuration of the securing means.

[0090] The wear reduction member may be any suitable shape or size. The size and shape of the wear reduction member is selected in accordance with the size and shape of the diaphragm and adjacent surface.

[0091] So as to inhibit frictional contact between the diaphragm and adjacent surface, a wear reduction member is preferably larger in size than the adjacent surface. For example, the wear reduction member may have a diameter that is greater than the diameter of the adjacent surface. A wear reduction member locatable between a diaphragm and a piston preferably has a diameter that is greater than the diameter of the driving surface of the piston. In this case, the wear reduction member may have a diameter that is at least 10mm greater, preferably at least 20mm greater, than the diameter of the driving surface of the piston. A wear reduction member locatable between a diaphragm and clamping member preferably has a diameter that is greater than the abutting surface of the clamping washer. In this case, the wear reduction member may have a diameter that is at least 10mm greater, preferably at least 20mm greater, than the diameter of the abutting surface of the clamping member.

[0092] Since the peripheral edge of the diaphragm is secured in the diaphragm pump, the wear reduction member is preferably smaller in size than the diaphragm. For example, the wear reduc4ion member may have a diameter that is preferably less than the diameter of the diaphragm. The wear reduction member may have a diameter in the range of approximately 50.0mm - 500mm.

[0093] The wear reduction member may be generally circular, oval, square or polygonal (e.g. hexagonal) in shape. The wear reduction member may be an annulus shaped member having a centrally located attachment hole and substantially circular peripheral edge.

[0094] The wear reduction member may have a substantially planar or plate-like configuration. For example, the wear reduction member may be a disc having a centrally located attachment hole and a diameter greater than the adjacent surface.

[0095] When the wear reduction member is fitted in a diaphragm pump, a central portion of wear reduction member is located between the diaphragm and adjacent surface and thereby forms a low friction mating contact with the diaphragm and inhibits frictional mating contact between the diaphragm and adjacent surface and a peripheral portion of the wear reduction member extends beyond the edge of the adjacent surface in a direction substantially parallel to the diaphragm.

[0096] The peripheral portion of a planar wear reduction member is preferably configured to form a low friction mating contact with the diaphragm. The peripheral portion of a planar wear reduction member may be configured to at least substantially remain in contact with the diaphragm throughout at least a substantial part of the operating cycle.

[0097] Alternatively, the wear reduction member may have a lid or cap-like configuration. For example, the wear reduction member may be a dish-shaped member having a bottom wall, a side wall and a centrally located attachment hole.

[0098] When a wear reduction member having a cap-like configuration is fitted in a diaphragm pump, a central portion of the wear reduction member is located between the diaphragm and adjacent surface and thereby forms a low friction mating contact with the diaphragm and inhibits frictional mating contact between the diaphragm and adjacent surface and a peripheral portion of the wear reduction member extends over the edge of the adjacent surface in a direction away from the diaphragm.

[0099] The central portion and peripheral portion are preferably arranged such that the cap-like wear reduction member has a generally U-shaped cross-section.

[0100] The cap-like wear reduction member may be configured to be mountable over the piston or clamping member such that a peripheral portion extends over the edge of the driving surface of the piston/clamping surface of the clamping member in a direction away from the diaphragm.

[0101] The wear reduction member may be manufactured (pre-formed) with a cap-like configuration. Alternatively, the wear reduction member may develop a cap-like configuration during use.

[0102] The central portion forms a bottom wall of the wear reduction member. The central portion preferably conforms to the shape and size of the adjacent surface. Depending on the profile of the adjacent surface, the central portion may be substantially flat or curved. An attachment hole may be formed in the central portion. The attachment hole is preferably centrally located in the central portion.

[0103] The peripheral portion forms a side wall of the wear reduction member. The peripheral portion may have a fluted (grooved) formation or substantially flat (planar) formation.

[0104] A skilled person will appreciate that, when the peripheral portion of a wear reduction is arranged in mating contact with the diaphragm, the peripheral portion of wear reduction member may restrict (impede, hinder) the flexing of the diaphragm during the operating cycle. The restricting effect of the peripheral portion may be sufficient to compromise the pumping action of the diaphragm.

[0105] The present invention seeks to address these problems by providing a wear reduction member with a cap-like configuration. The peripheral portion of the cap-like wear reduction member is configured to bend away from the diaphragm so as to limit (restrict, control) mating contact with the diaphragm during the operating cycle.

[0106] The configuration of the peripheral portion allows the diaphragm to flex freely (without mating contact with the peripheral portion) during at least a part of the operating cycle, preferably during a substantial part of the operating cycle. When located between a diaphragm and piston, the cap-like wear reduction member may allow the diaphragm to flex freely during a discharge stroke until the diaphragm is sufficiently flexed during the discharge stroke to form a mating contact with the peripheral portion. The peripheral portion is preferably configured such that it does not form a mating contact with the diaphragm until the peak period of the discharge stroke. Accordingly, the pumping action of the diaphragm during the discharge stroke is at least substantially maintained and the bending profile of the diaphragm is moderated to reduce bending wear during the peak period of the discharge stroke. Likewise, when located between a diaphragm and clamping member, the cap-like wear reduction member may allow the diaphragm to flex freely during the intake stroke until the diaphragm is sufficiently flexed during the intake stroke to form a mating contact with the peripheral portion. The peripheral portion is preferably configured such that it does not form a mating contact with the diaphragm until the peak period of the intake stroke. Thus, the pumping action of the intake stroke is at least substantially maintained and the bending profile is moderated to reduce bending wear during the peak period of the intake stroke.

[0107] By limiting the mating contact between the diaphragm and peripheral portion, the cap-like wear reduction member is able to reduce the mechanical wear of the diaphragm without significantly reducing the pumping volume or rate of diaphragm pump.

[0108] The configuration of the peripheral portion may help to locate the wear reduction member more easily and accurately on the adjacent surface.

[0109] The wear reduction member may be snugly fitted over the driving surface of the piston/clamping surface of the clamping member.

[0110] Figures 2a and 2b depict a first embodiment of a wear reduction member according to the first aspect of the invention.

[0111] This particular wear reduction member 200 is substantially planar, has an annular shape and comprises a centrally located attachment hole 202, a first outer surface 204a, a second outer surface 204b and a substantially circular peripheral edge 206. Figure 2b shows how the peripheral edge of the wear reduction member has a substantially flat end surface that is substantially perpendicular to the first outer surface and second outer surface.

[0112] The wear reduction member has a thickness T of 0.5mm, an inner diameter D1 of 8mm and an outer diameter D2 of 70mm.

[0113] The wear reduction member is configured such that it may be located between the diaphragm and driving surface of a piston. The wear reduction member is also configured such that it may be alternatively located between the diaphragm and abutting surface of a clamping washer.

[0114] The attachment hole (202) is configured to receive attachment means (e.g. a screw or clipping means) such that the wear reduction member can be securely mounted.

[0115] The wear reduction member (200) is a low-friction, flexible, resilient, self-lubricating member. The wear reduction member is formed from PTFE with a coefficient of friction of approximately 0.04 and a Young's modulus of approximately 0.5 GPa. The wear reduction member has been simply and inexpensively punched from a sheet of PTFE. The wear reduction member is configured such that in use, either the first outer surface 204a or the second outer surface 204b may be disposed in mating contact with the diaphragm.

[0116] Figure 3a depicts a cross-sectional profile of a second embodiment of a wear reduction member (200') whereby the peripheral edge (206') of the wear reduction member is rounded. Figure 3b depicts a cross-sectional profile of a third embodiment of a wear reduction member (200") whereby the peripheral edge (206") of the wear reduction member is tapered. Advantageously, a wear reduction member with a rounded or tapered peripheral edge may help to reduce abrasive contact between the diaphragm and peripheral edge of the wear reduction member and thereby wear of the diaphragm.

[0117] Figure 3c depicts a cross-sectional profile of a fourth embodiment of a wear reduction member (200"') whereby the wear reduction member is a composite member comprising two layers - a durable layer 208 coupled to a low-friction layer 210. This wear reduction member is configured such that, in use, the low friction layer will be disposed in mating contact with the diaphragm.

[0118] In an alternative embodiment of a wear reduction member (not depicted), the wear reduction may comprise a first low-friction outer layer, central durable layer and second low-friction outer layer. This wear reduction member is configured such that, in use, the low-friction outer layers are respectively disposed in mating contact with the diaphragm and adjacent surface.

[0119] Figured 3d depicts a cross-sectional profile of a fifth embodiment of a wear reduction member (200""). This particular wear reduction member has a cap-like configuration with a generally U-shaped cross section and comprises a central portion 200a, peripheral portion 200b and a centrally located attachment hole 200c. The wear reduction member is configured such that, in use, it may be mounted on the adjacent surface so that the central region is disposed between the diaphragm and adjacent surface and the peripheral portion bends over the edge of the adjacent surface in a direction away from the diaphragm. Advantageously, a diaphragm pump with a cap-like wear reduction member has a superior pumping action than a diaphragm pump with a substantially planar wear reduction member that is configured to at least substantially maintain a mating contact with the diaphragm during at least a substantially part of the operating cycle.

[0120] A second aspect of the invention relates to a diaphragm pump comprising at least one wear reduction member so as to improve the operational lifetime of the diaphragm and thereby diaphragm pump.

[0121] The diaphragm pump may comprise a wear reduction member located between the diaphragm and piston so as to minimise wear on the underside of the diaphragm. Alternatively or additionally, the diaphragm pump may comprise a wear reduction member located between the diaphragm and clamping member so as to minimise wear on the upperside of the diaphragm.

[0122] Figures 4a-4e relate to an embodiment of a diaphragm pump 300 according to the second aspect of the invention whereby a wear reduction member 310 is located between a diaphragm 312 and a piston 306.

[0123] Figure 4a depicts an assembled view of the diaphragm pump. The diaphragm pump 300 comprises a first housing 302 releasably coupled to a second housing 318. The first housing and second housing are releasably coupled by a circumferential clamp 320.

[0124] Figure 4d depicts a cross-sectional view of the assembled diaphragm pump. Referring to Figure 4d, the first housing 302 comprises a first diaphragm sealing lip 304 and the second housing 318 comprises a second diaphragm sealing lip 326. The first diaphragm sealing lip and second diaphragm sealing lip are configured to releasably secure the periphery of a diaphragm 312 when the first housing and second housing are releasably coupled together.

[0125] The diaphragm and inner surface of the first housing define a driving chamber 319a. The diaphragm and inner surface of the second housing define a pumping chamber 319b. The diaphragm forms a barrier between the driving chamber and the pumping chamber.

[0126] The driving chamber is configured to house driving means to reciprocally drive the diaphragm. The driving means include a motor 328 or any other suitable drive mechanism configured to reciprocately drive a piston 306. The piston comprises an elongate body portion (shaft) and head portion with a driving surface 308. The reciprocating motion 330 is substantially perpendicular to the driving surface of the piston.

[0127] The central region of the diaphragm is coupled to the centre of the head portion of the piston. As the piston reciprocates, the diaphragm is driven between a concave configuration and a convex configuration.

[0128] The second housing 318 is provided with an inlet 322 and an outlet 324 through which fluid is drawn into and expelled from the pumping chamber during pumping operation.

[0129] During an intake stroke of the piston, the central region of the diaphragm is retracted relative to the peripheral region of the diaphragm so as to form a concave configuration. The volume of the pumping chamber increases as the diaphragm flexes into the concave configuration and so fluid is drawn into the pumping chamber via the inlet 322. During a discharge stroke of the piston, the central region of the diaphragm is displaced relative to the peripheral region so as to form a convex configuration (see Figure 4e). The volume of the pumping chamber decreases as the diaphragm flexes into the convex configuration and so fluid is forced out of the pumping chamber via the outlet 324.

[0130] In this particular diaphragm pump, a wear reduction member 310 is located between the diaphragm 312 and piston 306. The upperside of the wear reduction member is arranged in mating contact with the diaphragm 312 and the underside of the wear reduction member is arranged in mating contact with the driving surface of the piston 308.

[0131] The wear reduction member 310 and diaphragm 312 are clamped in place on the driving surface 308 of the piston 306 via a clamping washer 314 and releasably secured by a securing screw 316.

[0132] The wear reduction member is a substantially planar, annulus-shaped disc comprising PTFE. Hence the wear reduction member has a low coefficient of friction, is flexible and also resilient to operating stress.

[0133] As can be seen in Figures 4d and 4e, the wear reduction member is configured so as to prevent any mating contact between the underside surface of the diaphragm 312 and driving surface 308 of the piston. As a result, abrasive wearing action between the diaphragm and driving surface is avoided.

[0134] Since the wear reduction member is a low frictional member, the wear reduction member forms a low-frictional mating contact with the underside of the diaphragm. As a result, the abrasive wearing action between the diaphragm and wear reduction member is minimal and so the diaphragm is only subject to limited abrasive wear.

[0135] It can be seen in Figures 4d and 4e that the diameter of the wear reduction member is greater than the diameter of the driving surface of the piston so as to prevent any mating contact between the diaphragm and piston. The diameter of the wear reduction member is also less than the diameter of the diaphragm so that it is easily locatable between the diaphragm and piston. In this particular example, the wear reduction member comprises a diameter D2 of approximately 70mm, the driving surface of the piston has a diameter D3 of approximately 54mm and the diaphragm has a diameter D4 of approximately 98mm. Hence, the wear reduction member has a peripheral portion having a diameter of 16mm extending beyond the edge of the driving surface of the piston. Since the wear reduction member is substantially planar it extends in a direction that is generally parallel to the diaphragm so as to at least substantially maintain a mating contact with the diaphragm along the diameter length of the wear reduction member.

[0136] During the operating cycle, the wear reduction member flexes in correspondence with the diaphragm. For example, the wear reduction member flexes to form a convex shape in accordance with the diaphragm during the discharge stroke of the piston - as shown in Figure 4e. The flexing of the wear reduction member reduces relative movement between the wear reduction member and the diaphragm and thereby further inhibits abrasive wear of the diaphragm.

[0137] In the absence of the wear reduction member, as per the prior art example depicted in Figure 1a, the diaphragm would deform significantly during operation leading to bending stress and bending wear. In direct contrast, the flexible and resilient properties of the wear reduction member are such that the diaphragm bends (flexes) more gradually during reciprocating motion. Due to the reduced bending profile, the bending stress is distributed more broadly and so bending wear of the diaphragm is restricted.

[0138] The resilient properties of the wear reduction member also help the wear reduction member to at least maintain a mating contact with the diaphragm at least substantially throughout the operating cycle.

[0139] Since the peripheral portion of the wear reduction member remains in mating contact with the diaphragm at least substantially throughout the operating cycle, the flexing of the diaphragm and thereby pumping effect is somewhat impeded. However, the wear reduction member is suitably flexible and resilient so as not to have a significantly deleterious effect on the pumping volume of the diaphragm pump.

[0140] Test results have shown that the prior art diaphragm pump as depicted in Figure 1a has a continuous operating lifespan of approximately 2 weeks before the diaphragm fails due to mechanical fatigue. However, it has been found that the diaphragm pump as depicted in Figures 4a-4e has a continuous operating lifespan of at least approximately 12 months. The increase in life expectancy is a significant improvement.

[0141] The diaphragm 312 illustrated in Figures 4d and 4e is substantially planar, and accordingly may be matched with a substantially planar wear reduction member 310.

[0142] Non-planar diaphragms are known in the industry, an example of which is a diaphragm having a substantially planar inner region and a conically shaped outer region. Such a non-planar diaphragm may be coupled with a substantially planar wear reduction member with a greater diameter than the diameter of the inner region of the diaphragm.

[0143] A non-planar diaphragm may advantageously be used with a non-planar wear reduction member. For example, a diaphragm having a substantially planar inner region and a conically shaped outer region may advantageously be coupled with a wear reduction member shaped in correspondence, with a substantially planar inner region and a conically shaped outer region.

[0144] In an alternative embodiment (not shown) the wear reduction member with a substantially planar configuration may be provided between the diaphragm and the clamping washer of a diaphragm pump. Accordingly, the wear reduction member would inhibit any mating contact and thereby abrasive wearing contact between the diaphragm and clamping washer and form a low-friction mating contact with the diaphragm.

[0145] Referring now to a second embodiment of the diaphragm pump 300' according to a second aspect of the invention whereby a wear reduction member 310' having a cap-like configuration is located between a diaphragm 312' and a piston 306'.

[0146] Figured 5a depicts a cross-sectional view of the assembled diaphragm pump. Referring to 5a, the diaphragm comprises a first housing 302' releasably coupled to a second housing 318'. The first housing and second housing are releasably coupled by a circumferential clamp 320'. The first housing 302' comprises a first diaphragm sealing lip 304'and the second housing 318' comprises a second diaphragm sealing lip 326. The first diaphragm sealing lip and second diaphragm sealing lip are configured to releasably secure the periphery of a diaphragm 312P' when the first housing and second housing are releasably coupled together.

[0147] The diaphragm and inner surface of the first housing define a driving chamber 319a'. The diaphragm and inner surface of the second housing define a pumping chamber 319b'. The diaphragm forms a barrier between the driving chamber and the pumping chamber.

[0148] The driving chamber is configured to house driving means to reciprocally drive the diaphragm. The driving means include a motor 328' or any other suitable drive mechanism configured to reciprocately drive a piston 306'. The piston comprises an elongate body portion (shaft) and head portion with a driving surface 308'. The reciprocating motion 330' is substantially perpendicular to the driving surface of the piston.

[0149] The central region of the diaphragm is coupled to the centre of the head portion of the piston. As the piston reciprocates, the diaphragm is driven between a concave configuration and a convex configuration.

[0150] The second housing 318' is provided with an inlet 322' and an outlet 324' through which fluid is drawn into and expelled from the pumping chamber during pumping operation.

[0151] During an intake stroke of the piston, the central region of the diaphragm is retracted relative to the peripheral region of the diaphragm so as to form a concave configuration. The volume of the pumping chamber increases as the diaphragm flexes into the concave configuration and so fluid is drawn into the pumping chamber via the inlet 322'. During a discharge stroke of the piston, the central region of the diaphragm is displaced relative to the peripheral region so as to form a convex configuration (see Figure 5b). The volume of the pumping chamber decreases as the diaphragm flexes into the convex configuration and so fluid is forced out of the pumping chamber via the outlet 324'.

[0152] In this particular diaphragm pump, a wear reduction member 310' is located between the diaphragm 312' and piston 306'. The wear reduction member 310' and diaphragm 312' are clamped in place on the driving surface 308' of the piston 306' via a clamping washer 314' and releasably secured by a securing screw 316'.

[0153] The wear reduction member has a cap-like configuration with a generally U-shaped cross-section. The wear reduction member comprises a central portion 310a' and a peripheral portion 310b'. The peripheral portion has a fluted formation. The wear reduction member has a low coefficient of friction and is flexible. The wear reduction member is formed with a cap-like configuration during the manufacturing process and is sufficiently resiliently to at least substantially maintain its cap-like configuration during use.

[0154] The central portion of the wear reduction member 310a' is located between the diaphragm 312' and the driving surface of the piston 308. The upperside of the central portion is arranged in mating contact with the diaphragm and the underside of the central portion is arranged in mating contact with the driving surface of the piston. The central portion is configured so as to prevent any mating contact between the diaphragm and the driving surface of the piston. As a result, abrasive wearing action between the diaphragm and driving surface is avoided. Since the wear reduction member is a low friction member, the upperside of the central portion forms a low-frictional mating contact with the underside of the diaphragm. As a result, abrasive wearing action between the central portion and diaphragm is minimal.

[0155] The peripheral edge portion of the wear reduction member 310b' is configured to bend (curve) beyond the edge of the driving surface of the piston such that it extends in a direction away from the diaphragm. Hence, the peripheral edge portion only forms a mating contact with the diaphragm as the diaphragm flexes into a convex configuration during a discharge stroke of the piston - see the peripheral portion forming a mating contact with a section of the diaphragm 332' shown in Figure 5b. Indeed, the peripheral portion of the wear reduction member is preferably configured so that it only forms a mating contact with the diaphragm during the peak period of the discharge stroke as the diaphragm is flexed to its most convex configuration. Since the wear reduction member is a low friction member, the peripheral portion forms a low frictional mating contact with the diaphragm during the discharge stroke. As a result, abrasive wearing action between the peripheral portion and the diaphragm is minimal.

[0156] The flexible and resilient properties of the wear reduction member are such that the diaphragm bends (flexes) more gradually when the diaphragm forms a mating contact with the wear reduction member during the discharge stroke of the piston. Due to the reduced bending profile, the bending stress is distributed more broadly and so bending wear of the diaphragm is restricted.

[0157] The resilient properties of the wear reduction member also help the wear reduction member to maintain the mating contact with the diaphragm.

[0158] Since the peripheral portion of the wear reduction member is configured so that it only forms a mating contact with the diaphragm during the discharge stroke, the flexing of the diaphragm is unrestricted during at least the intake stroke of the piston. Indeed, the peripheral portion of the wear reduction is configured such that the flexing of the diaphragm is unrestricted during a substantial part of the operating cycle. Accordingly, the wear reduction member is able to reduce the mechanical wear of the diaphragm without significantly reducing the pumping volume or rate of the diaphragm pump. For example, in the case of a 60W diaphragm pump, a pumping rate of 15L/min may be maintained when fitted with a wear reduction member having a cap-like configuration.

[0159] Test results have shown that the diaphragm pump as depicted in Figures 5a and 5b has a continuous operating lifespan of at least approximately 12 months. The increase in life expectancy is a significant improvement. Test results have shown that the diaphragm pump depicted Figures 5a and 5b also has a better pumping volume than the diaphragm pump depicted in Figures 4a-4e because the peripheral portion of the cap-like wear reduction member does not impede the reciprocating action of the diaphragm as significantly as the peripheral portion of the planar wear reduction member.

[0160] In a further embodiment of a diaphragm pump (not shown), the wear reduction member having a cap-like configuration may be provided between the diaphragm and the clamping washer. Accordingly, the wear reduction member would inhibit mechanical wear of the diaphragm without significantly reducing the pumping rate of the diaphragm pump.

[0161] Referring now to the third embodiment of the diaphragm pump depicted in Figure 6, Figure 6 shows a diaphragm pump provided with two wear reduction members. A first wear reduction member 410 is located between the piston 408 and the diaphragm 412. The second wear reduction member 434 is located between the clamping washer 414 and the diaphragm 412.

[0162] The first wear reduction member and second wear reduction member are substantially planar wear reduction members comprising PTFE. Accordingly, the wear reduction members have a low coefficient of friction, are flexible and resilient to operating stress.

[0163] It can be seen in Figure 6 that the peripheral diameter D5 of the wear reduction members is greater than the peripheral diameters D6 of the piston 410 and clamping washer 414, and less than the peripheral diameter D4 of the diaphragm 412. In this particular embodiment, the peripheral diameter D5 of the wear reduction members is 70 mm, the peripheral diameter D6 of the piston410/clamping washer 414 is 54 mm, and the peripheral diameter D4 of the diaphragm 412 is 98 mm. Accordingly, each wear reduction member comprises a peripheral portion having a diameter of 16mm extending beyond the edge of the respective piston or clamping washer.

[0164] The diaphragm pump of figure 6 is configured such that in use the piston displaces the central region 412C of the diaphragm 412 to either side of the periphery 412P, as the piston outwardly extends and inwardly retracts with respect to the housing 402, causing the pumping chamber 419 respectively to have a minimal and maximal volume. The two wear reduction members 410 and 434 are configured to prevent contact between the diaphragm and both the driving surface 408 of the piston and the clamping surface of the clamping washer 414, thereby reducing associated abrasive wear of the diaphragm that would otherwise occur. Moreover, the two wear reduction members 410 and 434 are configured to form a low-friction mating contact with the diaphragm so as to further minimise abrasive wear.

[0165] The driving surface of the piston 408 has a curved outer edge 408R facing towards the diaphragm 412, and contacting the intervening member 410. The driving surface of the clamping washer 414 has a curved outer edge 414R facing towards the diaphragm 412, and contacting the intervening member 434. Wear reduction member 410 restricts the bending profile of the diaphragm as it flexes around edge 408R to form a convex configuration. Likewise, wear reduction member 434 restricts the bending profile of the diaphragm as it flexes around edge 414R to form a concave configuration. Hence, the wear reduction members 410 and 434 reduce the bending action and thereby wear of the diaphragm.

[0166] Wear reduction members and diaphragm pumps according to the present invention are suitable for use in pumping systems. Due to the improved life expectancy, wear reduction members and diaphragm pumps according to the present invention may now be considered to be useful in continuous pumping systems.

[0167] Examples of pumping systems in which a wear resistant member and diaphragm pump according to the present invention may be utilised include systems for pumping fluids comprising immiscible parts, such as a combination of oil and aqueous liquid (e.g. water) and systems for pumping suspensions of solids in liquid, and hot or cold fluids.

[0168] A pumping system, within which the diaphragm pump of the present invention (i.e. comprising a wear reduction member) may find use, is a separation system for separating oil floating on a body of water, an example of which is described in European patent application number EP1815900. Although diaphragm pumps using a reciprocating piston are thought to be particularly advantageous for this application because they do not impart significant additional energy to the fluid and thereby the risk of emulsification is low, diaphragm pumps have previously been deemed unsuitable due to the low operational lifetime of the diaphragms. The present invention addresses this problem by providing a wear reduction member.

[0169] Referring now to an embodiment of a pumping system depicted in Figure 7, Figure 7 shows a pumping system 500 comprising a sump 550, a diaphragm pump 552 according to the second aspect of the present invention, a separator 554 and a collection drum 556. The sump 550 contains a body of water 558, and a layer of oil 560 floating on the water. A floating pick up 562 is connected to the diaphragm pump 552 by a collection conduit 564, through which a combination of oil and water are drawn into the pump. The combination of oil and water drawn into the pump may also include entrained air. The output conduit 566 from the diaphragm pump 552 feeds the pumped combination of oil and water to the separator 554, which substantially separates the oil and water. The separated water is returned to the sump 550 through a return conduit 568. The separated oil is fed to the collection drum 556 through a collection conduit 570. Advantageously the diaphragm pump 552, separator 554 and collection drum 556 are integrated into a single separation unit 572.

[0170] The diaphragm pump 552 avoids imparting a significant level of energy to the pumped liquid, avoiding or substantially reducing the risk of forming an emulsion in a pumped combination of oil and water. Moreover, the diaphragm pump 552 is able to operate continuously with an improved lifespan.

[0171] Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", means "including but not limited to", and is not intended to (and does not) exclude other moieties, components , integers or steps.

[0172] Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

[0173] Features, integers, characteristics or compounds described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith.

Claims

1. A wear reduction member for use in a diaphragm pump, whereby the wear reduction member is a low-friction member configured to be locatable in the diaphragm pump between a diaphragm and an adjacent surface so as to form low-frictional mating contact with the diaphragm and inhibit frictional mating contact between the diaphragm and the adjacent surface.

2. A wear reduction member according to claim 1, wherein the wear reduction member is a low friction member that exhibits a low coefficient of friction of less than approximately 0.1, preferably less than approximately 0.06.

3. A wear reduction member according to claim 1 or 2, wherein the wear reduction member preferably comprises a first low-friction surface configured to form a low-frictional mating contact with a surface of the diaphragm and a second surface configured to form a mating contact with the adjacent surface.

4. A wear reduction member according to any preceding claim, whereby the low-friction surface is a self-lubricating surface and/or a sacrificially wearing surface.

5. A wear reduction member according to any preceding claim, wherein the wear reduction member is locatable between a diaphragm and a driving surface of a piston and/or the wear reduction member is locatable between a diaphragm and a clamping surface of a clamping member.

6. A wear reduction member according to any preceding claim, wherein the wear reduction member is a flexible member.

7. A wear reduction member according to any preceding claim, wherein the wear reduction member is a resilient member having a Young's modulus in the range of approximately 0.3 to 1.0 GPa, preferably in the range of approximately 0.4 to 0.7GPa.

8. A wear reduction member according to any preced-

ing claim, wherein the wear reduction member is removably mountable between the diaphragm and adjacent surface.

9. A wear reduction member according to any preceding claim, wherein the wear reduction member comprises an attachment hole through which securing means can extend.

10. A wear reduction member according to claim 9, wherein the wear reduction member is an annulus shaped member having a centrally located attachment hole and substantially circular peripheral edge.

11. A wear reduction member according to any preceding claim, wherein the wear reduction member has a substantially planar configuration.

12. A wear reduction member according to any of claims 1 to 9, wherein the wear reduction member has a cap-like configuration;
and optionally wherein the cap-like configuration is pre-formed during manufacturing or formed during use.

13. A wear reduction member according to claim 12 wherein the wear reduction member with a cap-like configuration comprises a central portion and peripheral portion,
whereby in use, the central portion is arranged between the diaphragm and adjacent surface and the peripheral portion is extends over an edge of the adjacent surface away from the diaphragm;
and optionally wherein the wear reduction member has a U-shaped cross-section.

14. A wear reduction member according to claim 13, wherein the peripheral portion has a fluted formation.

15. A wear reduction member for use in a diaphragm pump, whereby the wear reduction member is a low-friction member, has a cap-like configuration, comprises a central portion and a peripheral portion and is configured to be locatable between a diaphragm and an adjacent surface of a diaphragm pump such that the central portion forms low-frictional mating contact with the diaphragm and inhibits frictional mating contact between the diaphragm and the adjacent surface and the peripheral portion extends over an edge of the adjacent surface away from the diaphragm.

16. A wear reduction member comprising the features as defined any of claims 2 to 9, 12, 13 or 14.

17. A diaphragm pump comprising:

a diaphragm coupled to a reciprocating piston via a clamping member; and
a wear reduction member located between the diaphragm and one of the piston or the clamping member; wherein the wear reduction member is configured to inhibit frictional mating contact between the diaphragm and the respective piston or clamping member and comprises a low-frictional surface configured to form a low-frictional mating contact with the diaphragm.

18. A diaphragm pump according to claim 19, wherein the wear reduction comprises the features as defined in any of claims 1 to 15.

19. A diaphragm pump according to claim 19 or 20, wherein the diaphragm pump comprises securing means and the wear reduction member comprises an attachment hole through which the securing means extend so as to secure the wear reduction member;
and optionally wherein the securing means is a removable securing means.

20. A diaphragm pump according to any of claims 17 to 19, wherein the diaphragm pump comprises a first wear reduction member located between the diaphragm and the piston, and a second wear reduction member located between the diaphragm and the clamping member.

21. A pumping system comprising a diaphragm pump according to any of claims 19 to 21.

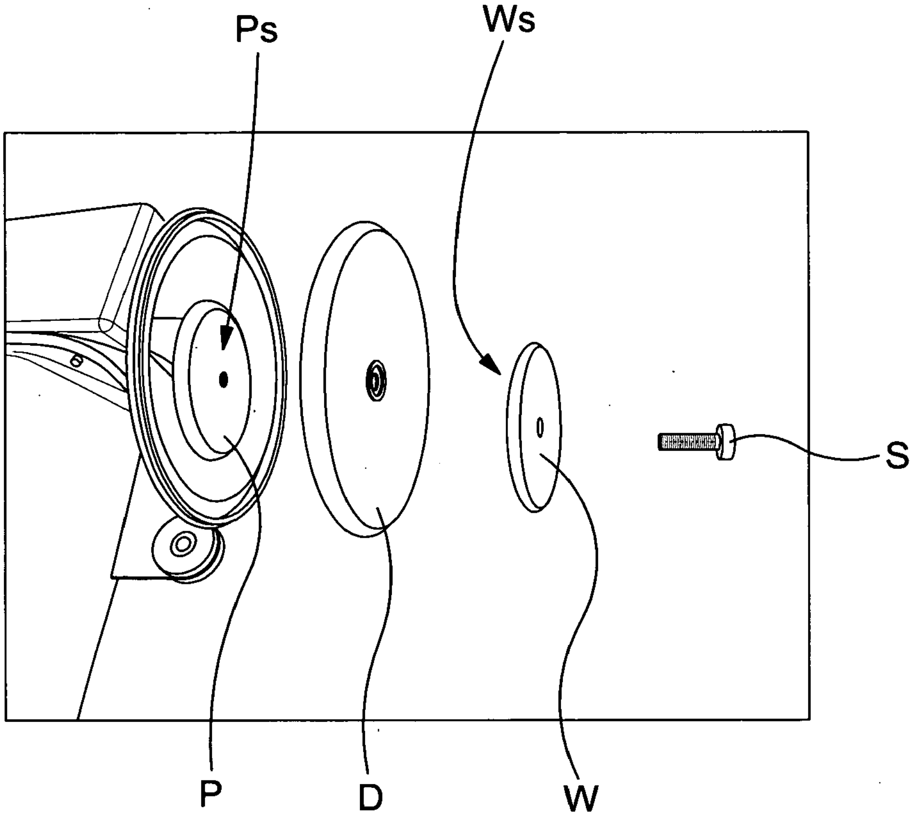

Figure 1a

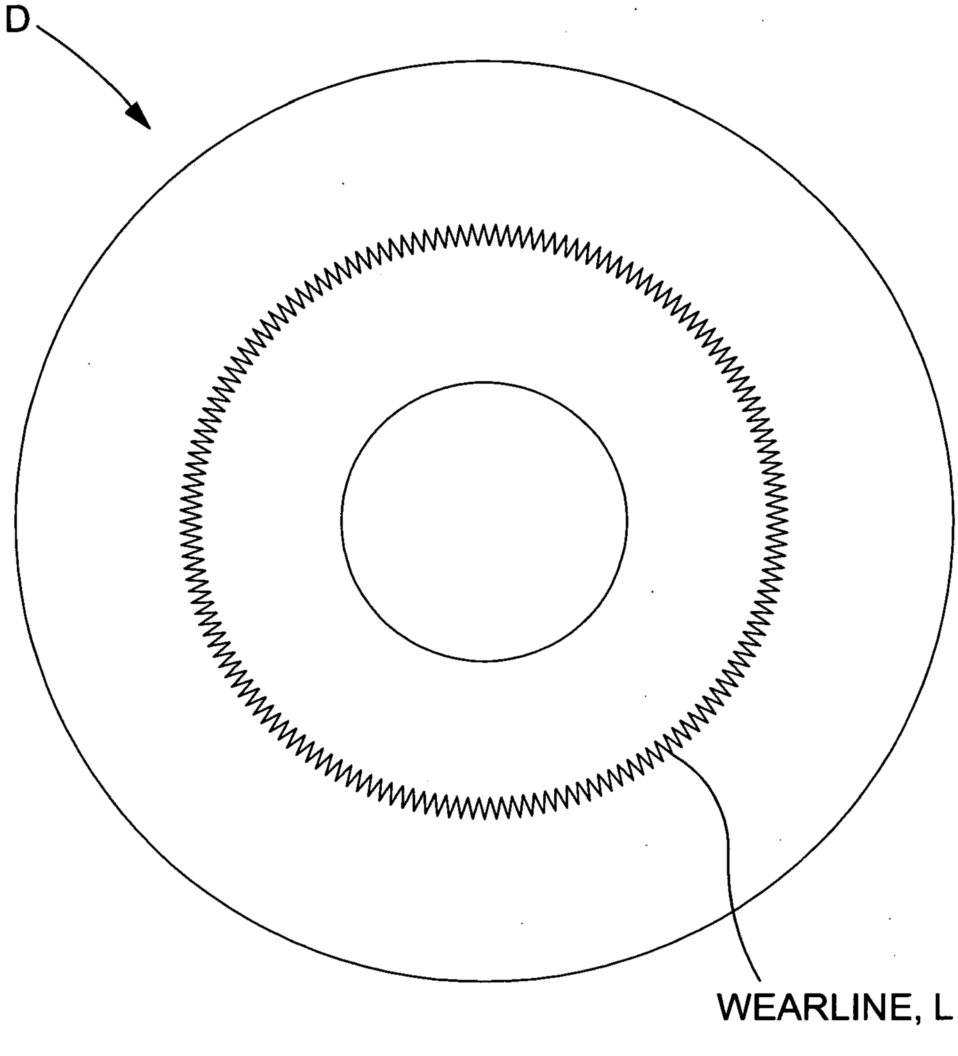

Figure 1b

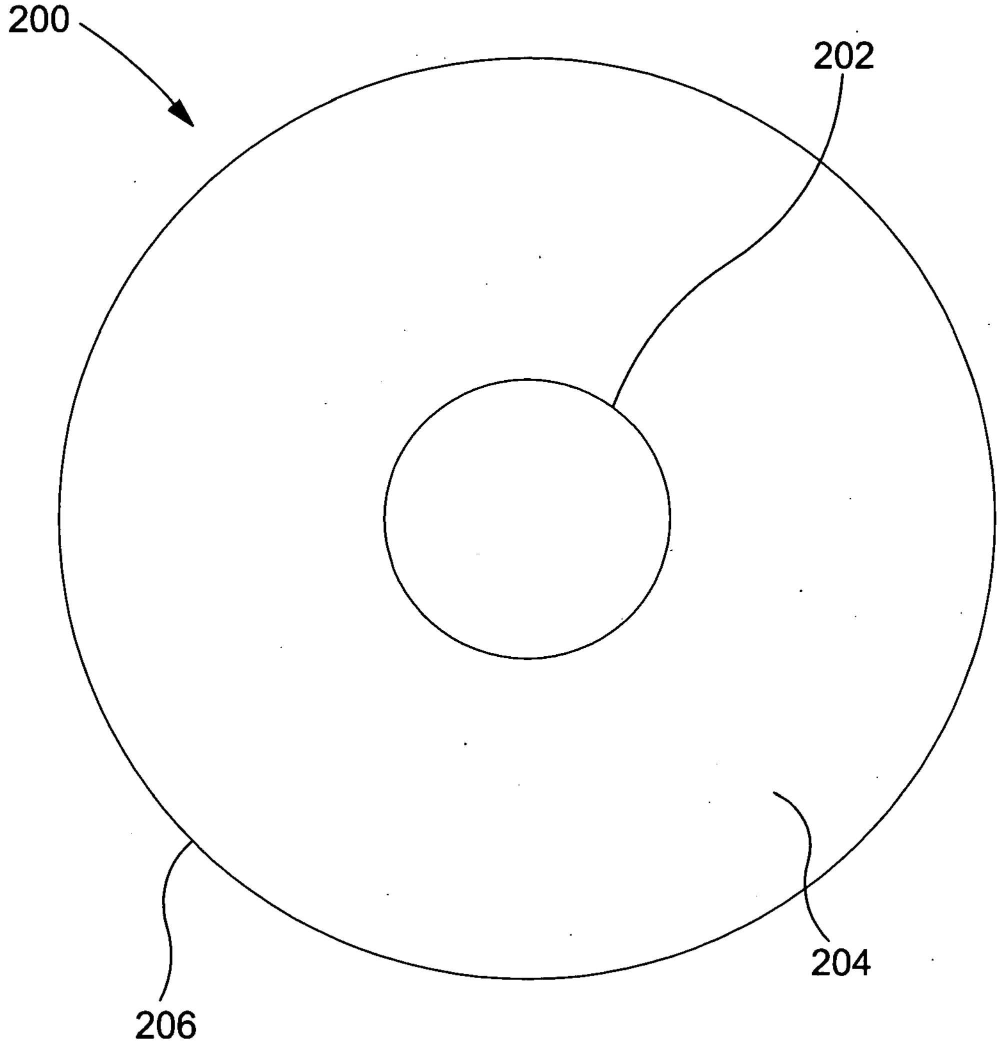

Figure 2a

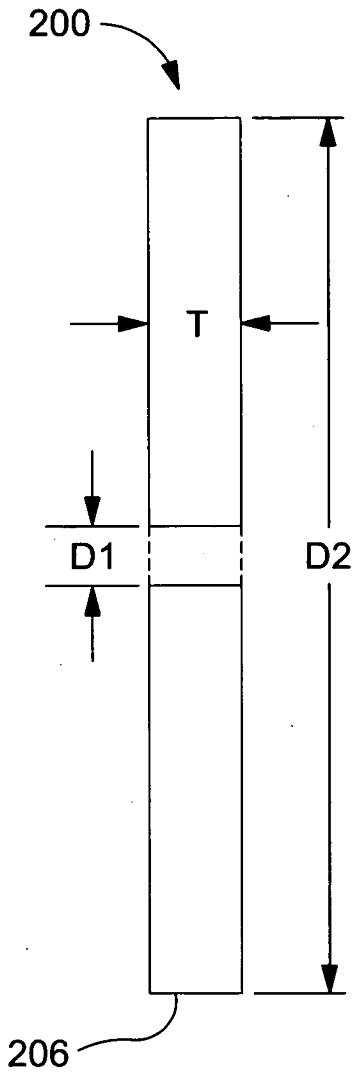

Figure 2b

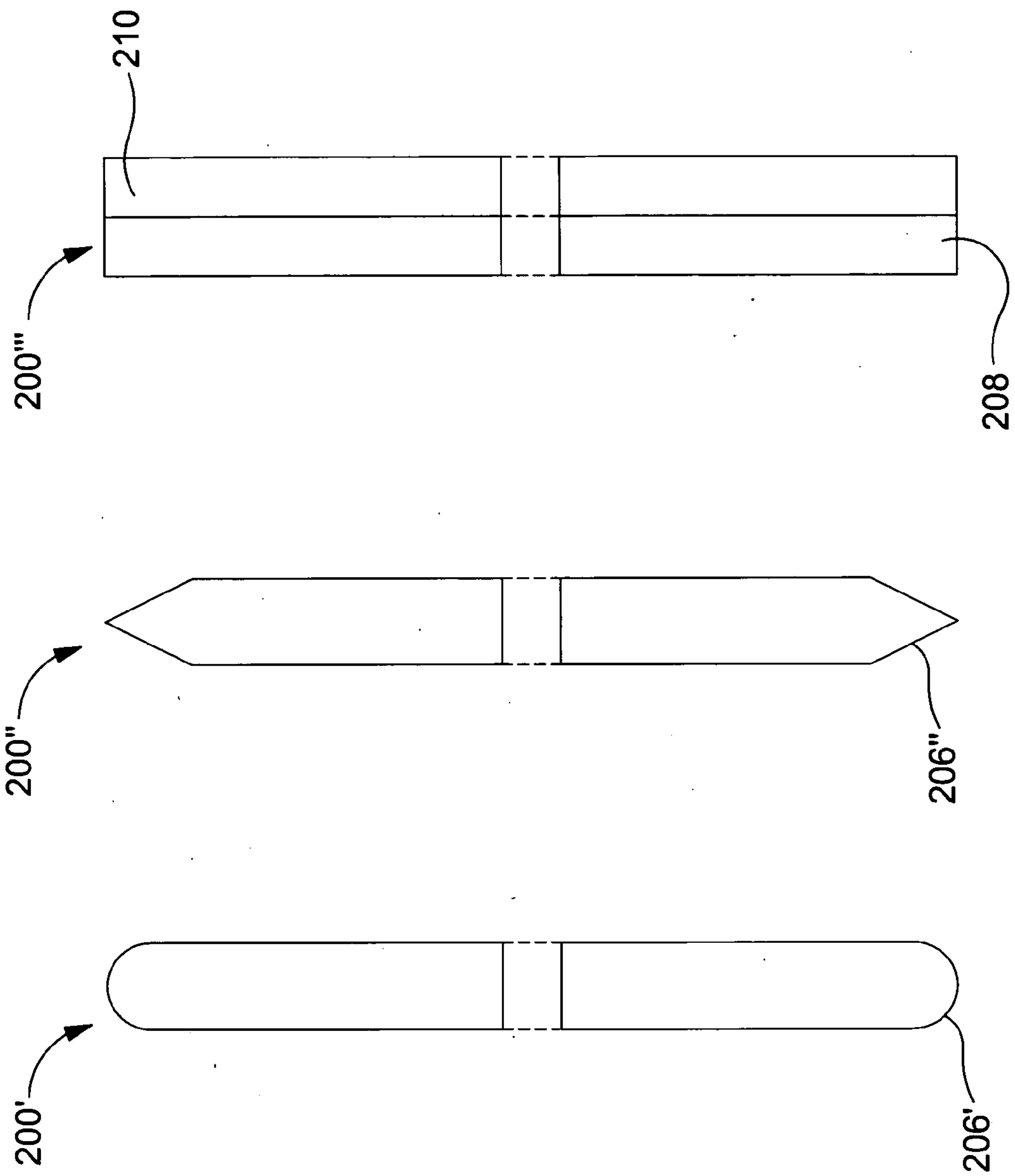

Figure 3c

Figure 3b

Figure 3a

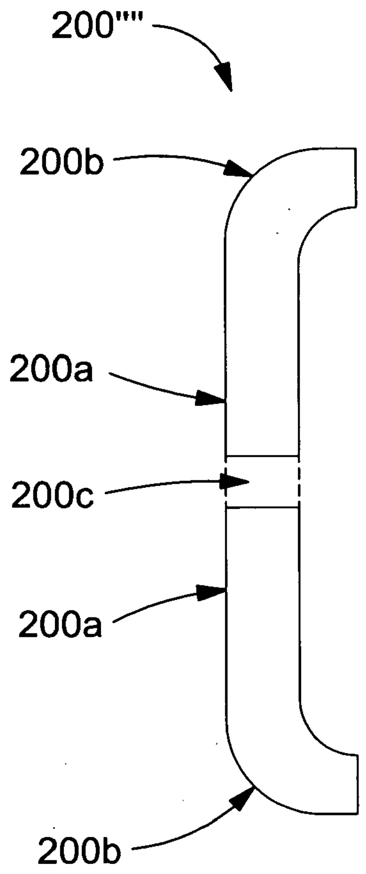

Figure 3d

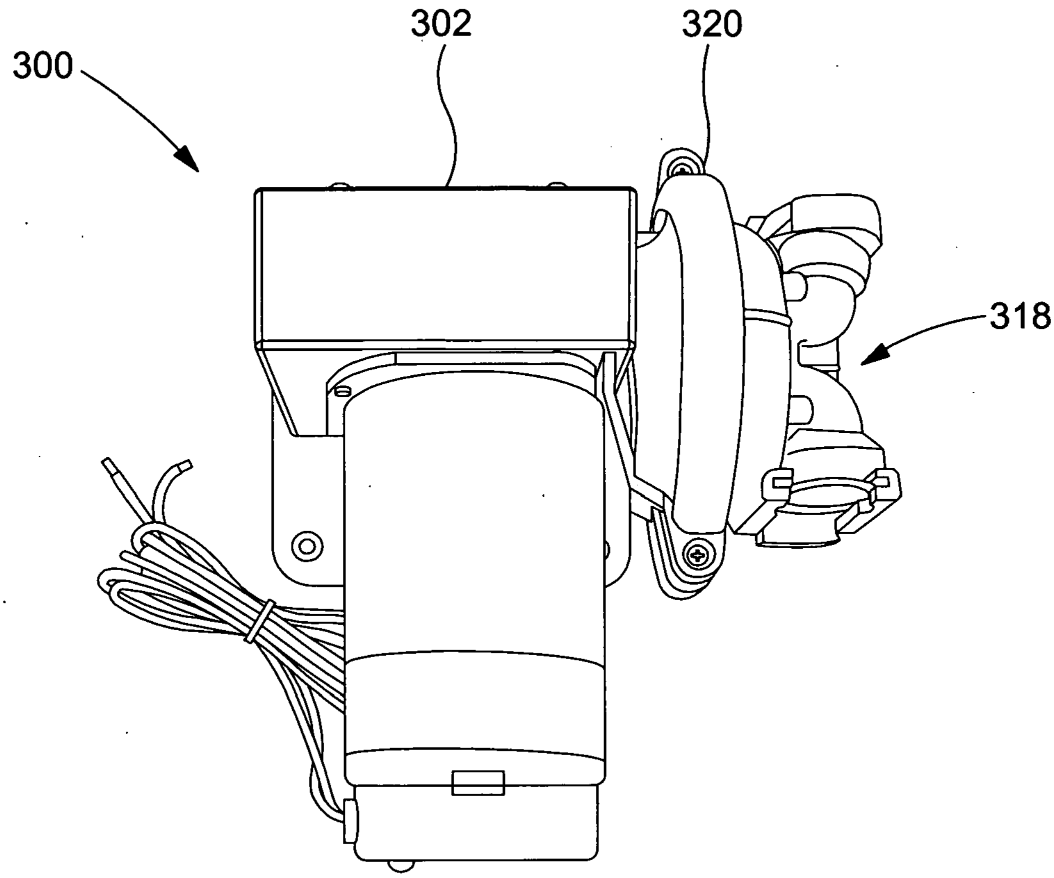

Figure 4a

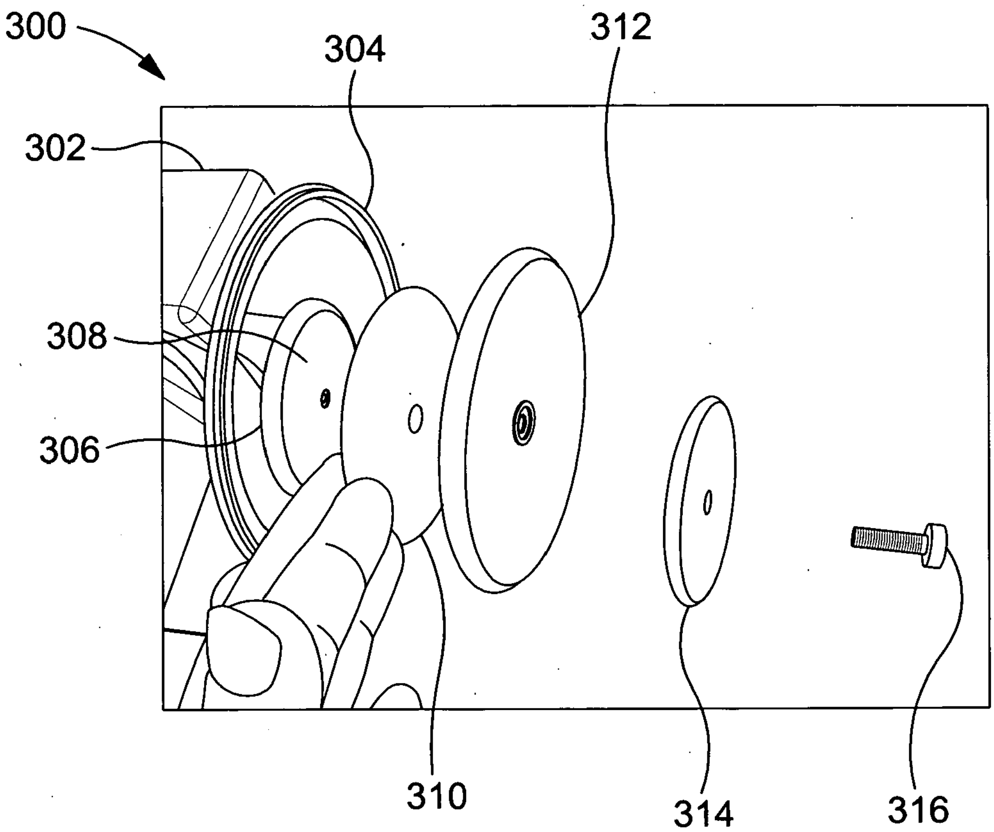

Figure 4b

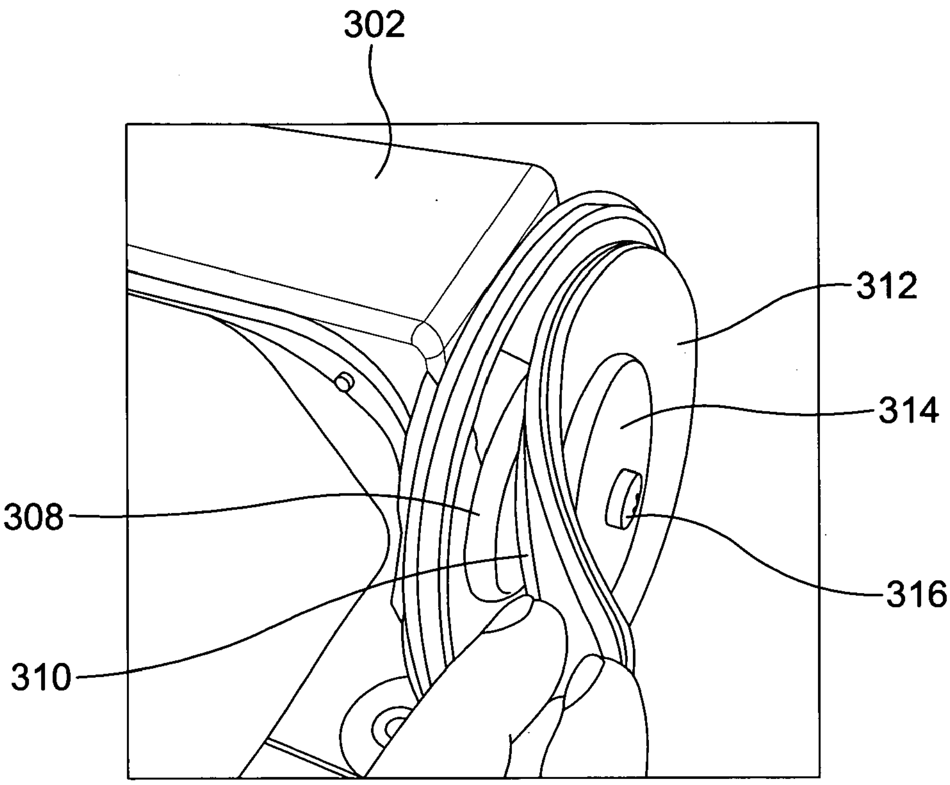

Figure 4c

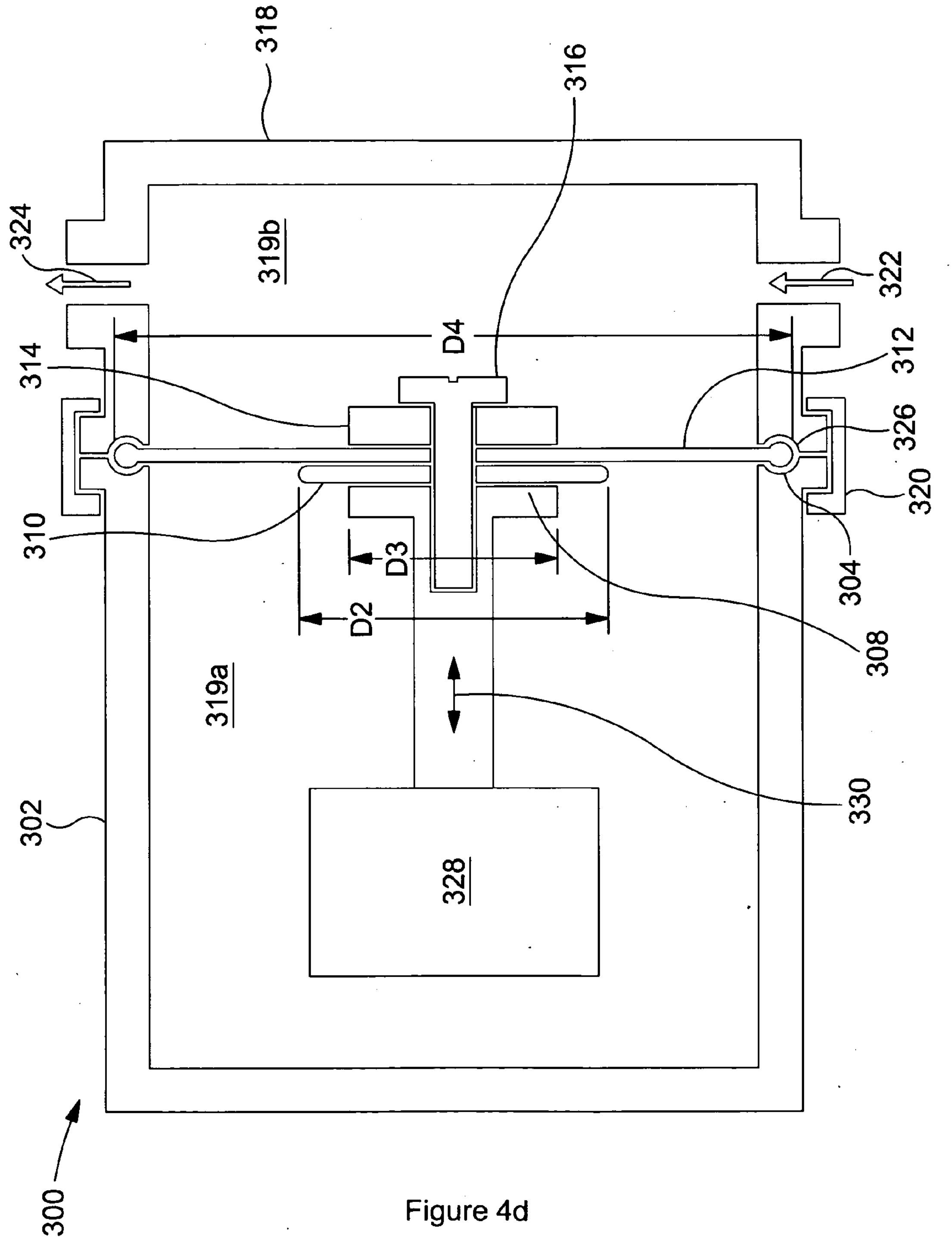
318
316
324
319b
322
314
D4
312
326
320
310
D3
304
D2
308
319a
330
302
328
300

Figure 4d

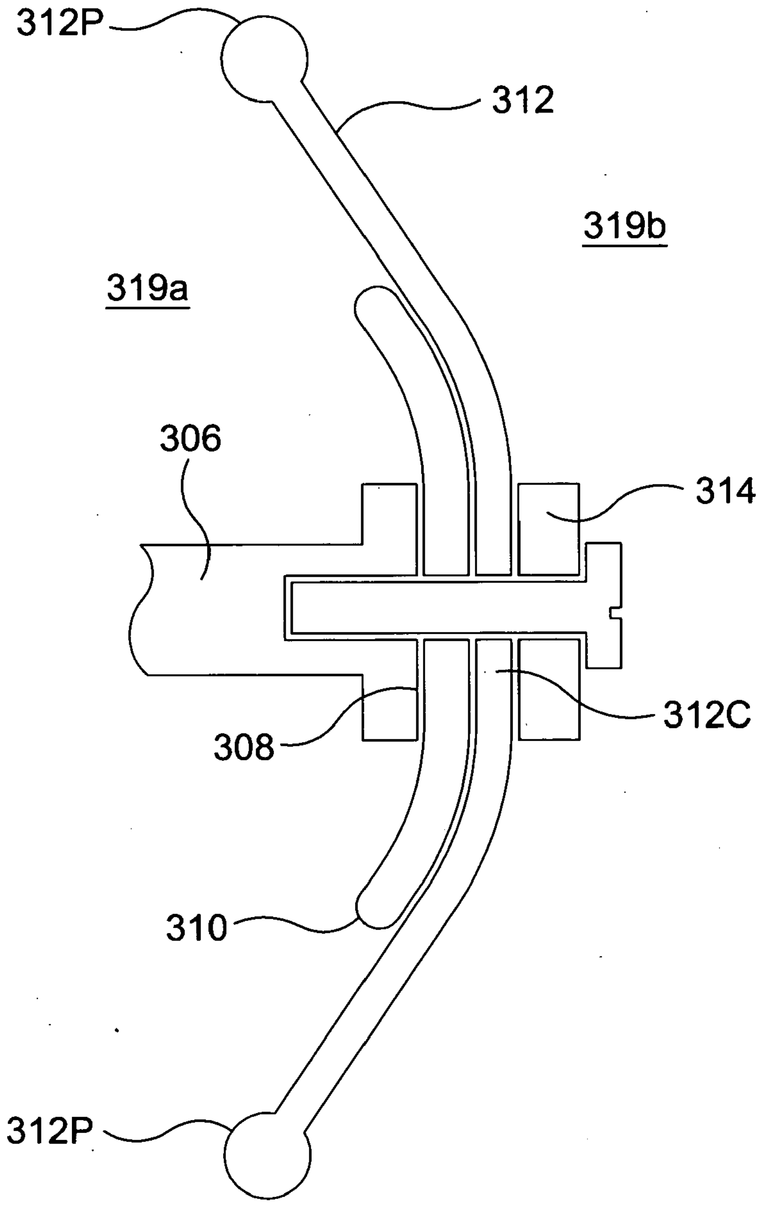

Figure 4e

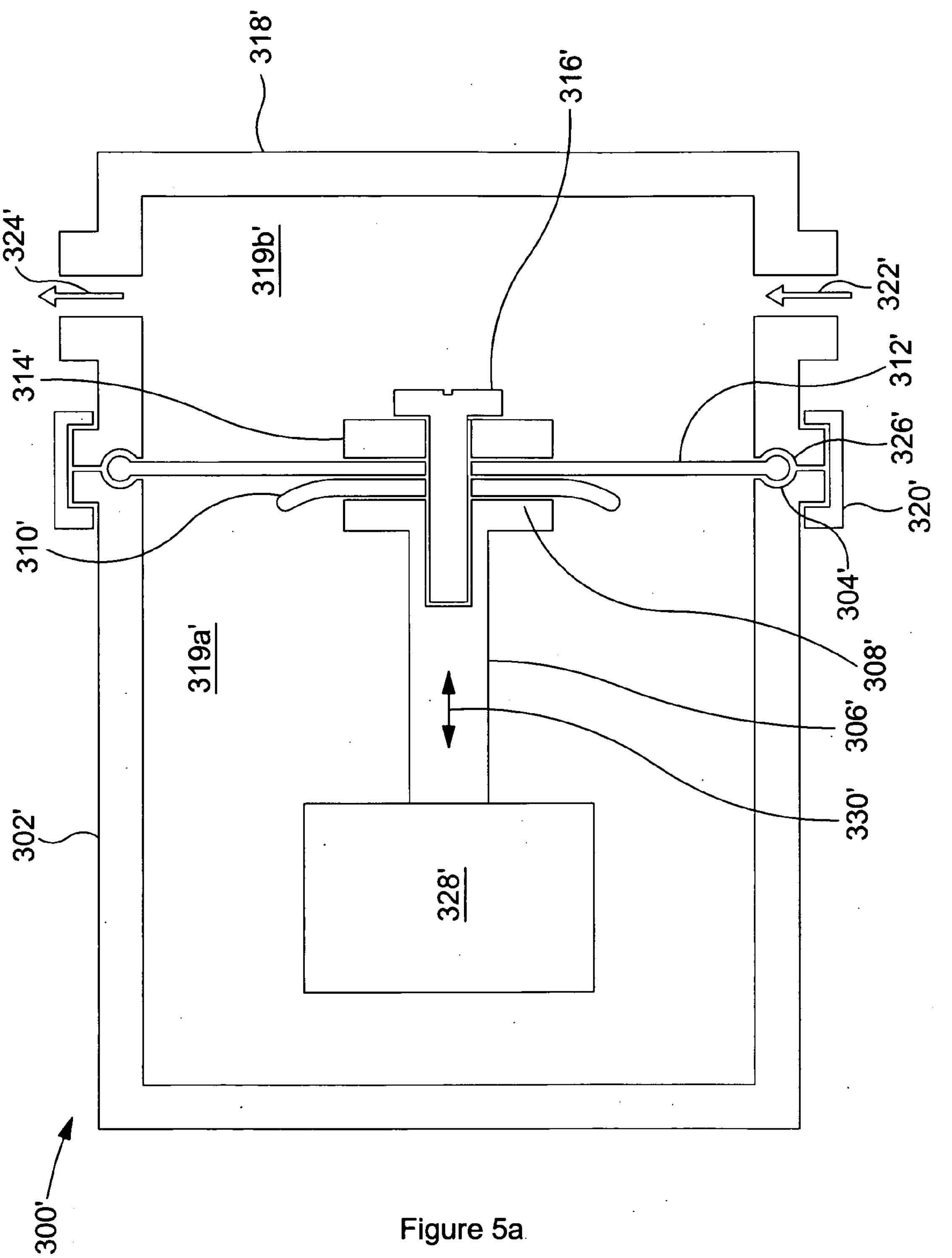
318'
316'
324'
319b'
322'
314'
312'
326'
320'
310'
304'
308'
319a'
306'
330'
302'
328'
300'

Figure 5a

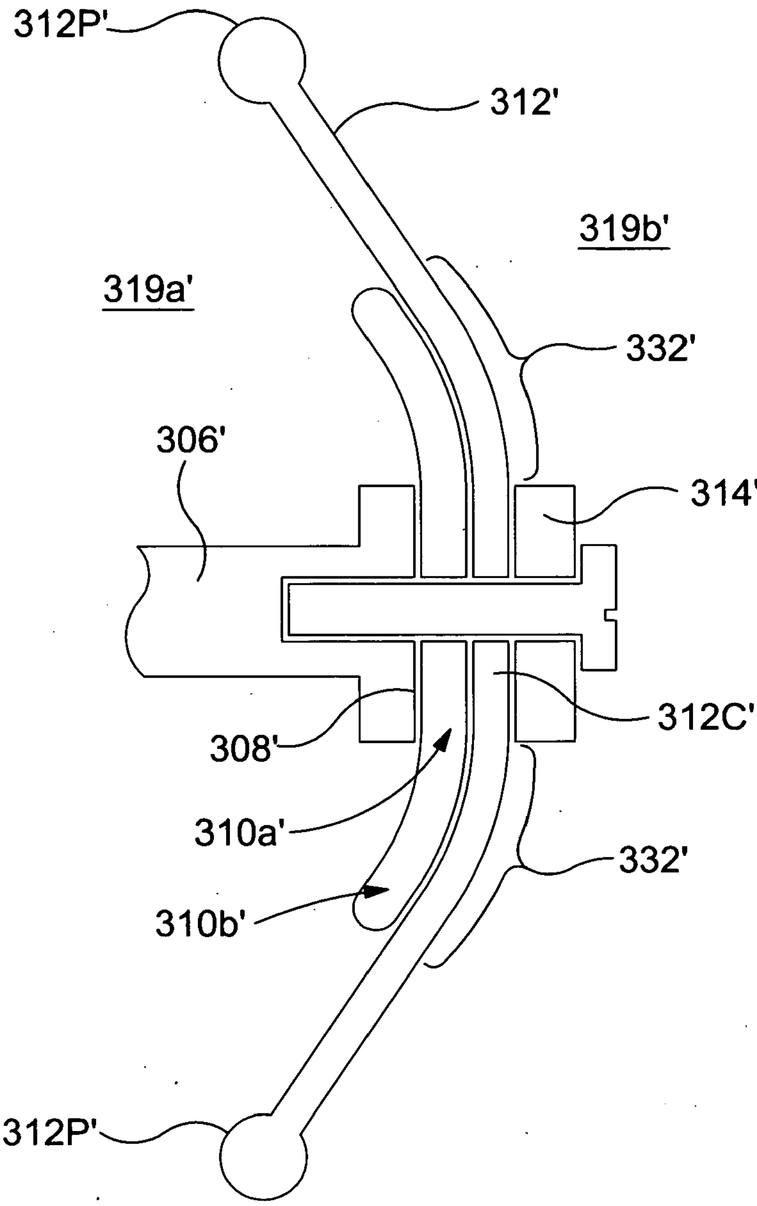

Figure 5b

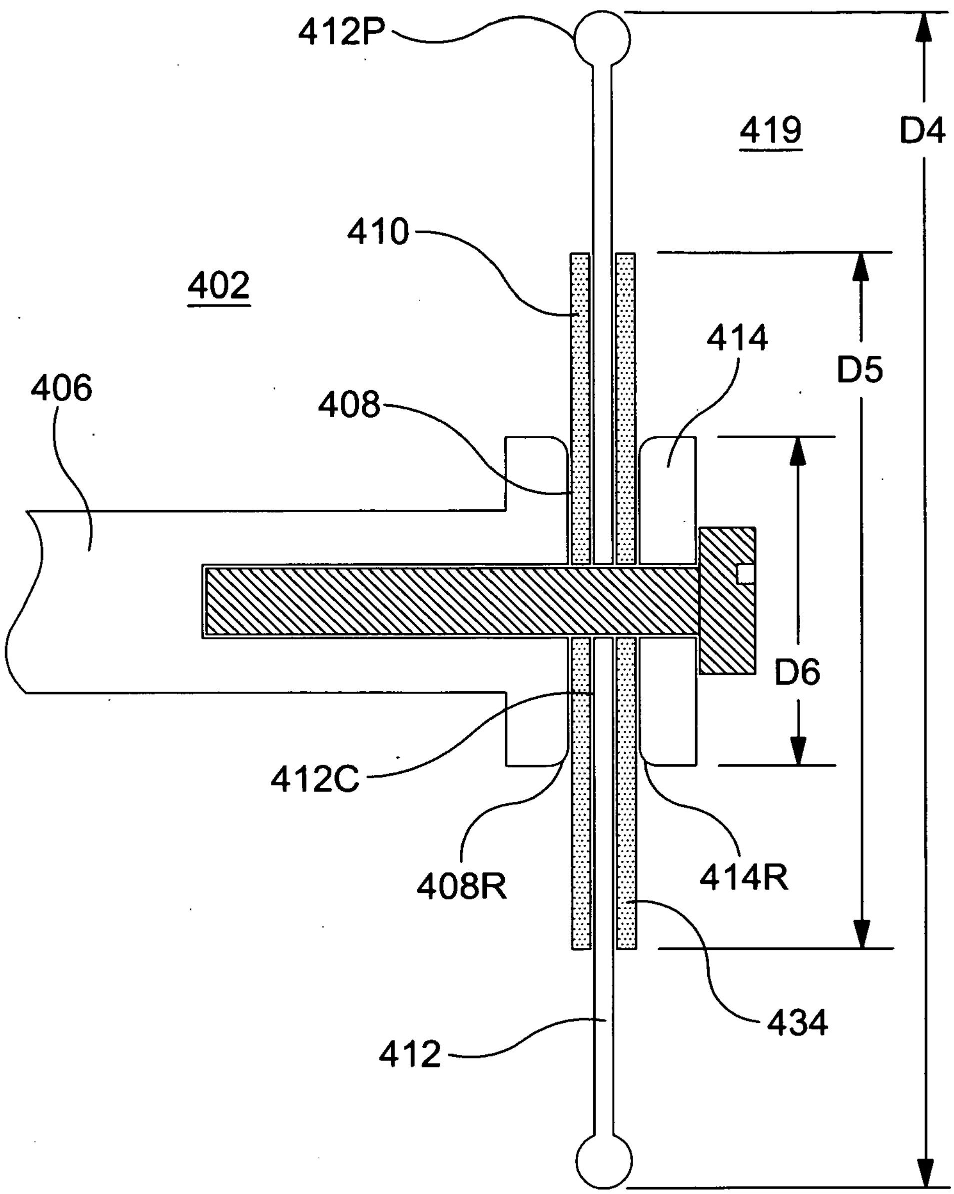

Figure 6

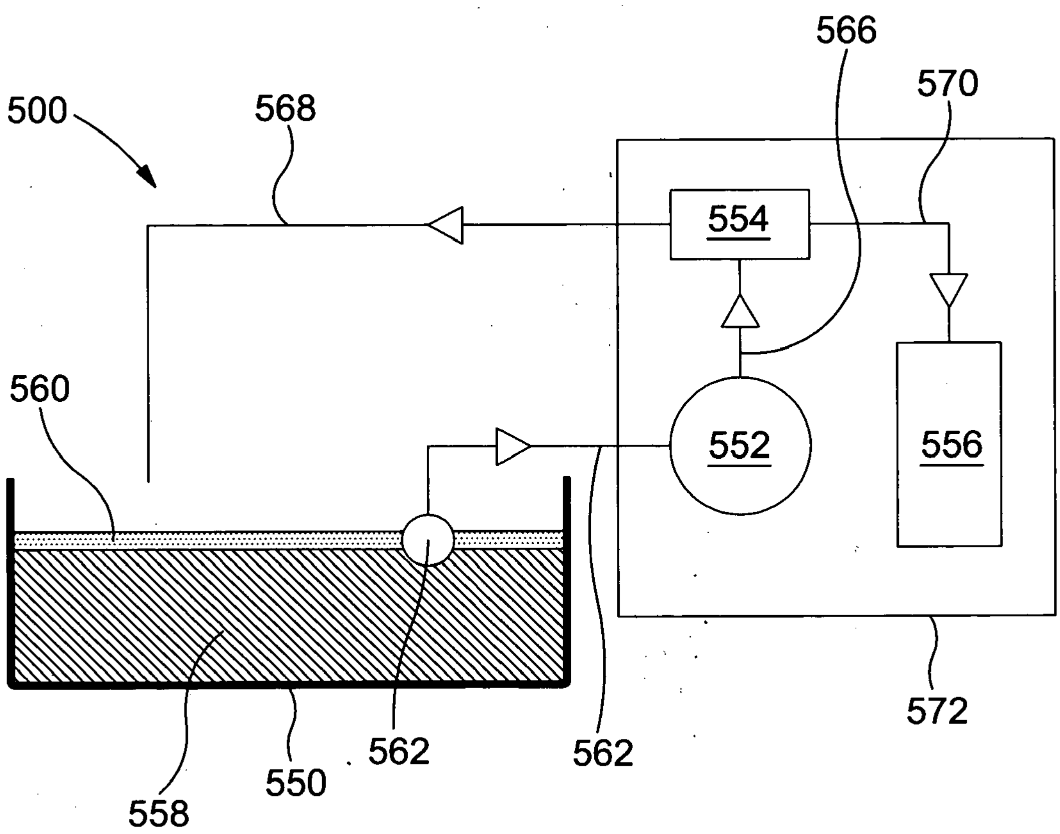

Figure 7

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 11 25 0360

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 3 166 239 A (SOMERVILLE GREENHALGH, D.M. ET AL. [US]) 19 January 1965 (1965-01-19) * abstract * * figure 1 *	1-11, 17-21 12-16	INV. F04B43/02 F04B45/04
Y	US 4 666 378 A (OGAWA, HITOSHI [JP]) 19 May 1987 (1987-05-19) * figures 1,2 *	12-16	
X	US 6 145 430 A (INGERSOLL-RAND COMPANY [US]) 14 November 2000 (2000-11-14) * column 3, line 28 - line 38 * * figure 2 *	1-11, 17-21	
X	WO 2004/044423 A1 (Z & D LTD [GB]) 27 May 2004 (2004-05-27) * page 3, line 23 - line 31 * * figure 1 *	1,2,7	
A	US 7 614 606 B2 (GEMÜ GEBR. MÜLLER GMBH [DE]) 10 November 2009 (2009-11-10) * sentence 1 - sentence 11 *	1-21	TECHNICAL FIELDS SEARCHED (IPC) F04B
A	GB 1 296 749 A (SCIENTIFIC INDUSTRIES, INC. [US]) 15 November 1972 (1972-11-15) * page 3, line 12 - line 16 * * figure 2 *	1-21	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	30 December 2011	Gnüchtel, Frank

2

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 25 0360

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

30-12-2011

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 3166239	A	19-01-1965	NONE			
US 4666378	A	19-05-1987	DE	3513423	A1	07-11-1985
			JP	60171980	U	14-11-1985
			US	4666378	A	19-05-1987
US 6145430	A	14-11-2000	NONE			
WO 2004044423	A1	27-05-2004	AU	2003278381	A1	03-06-2004
			CN	1711419	A	21-12-2005
			GB	2395237	A	19-05-2004
			GB	2409007	A	15-06-2005
			WO	2004044423	A1	27-05-2004
US 7614606	B2	10-11-2009	AT	403097	T	15-08-2008
			BR	PI0401731	A	22-02-2005
			DE	20307457	U1	31-07-2003
			EP	1477713	A1	17-11-2004
			US	2004262563	A1	30-12-2004
GB 1296749	A	15-11-1972	NONE			

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- GB 304105 A **[0011]**
- JP 3160172 B **[0012]**
- EP 1815900 A **[0168]**