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(54) **SLIDING VANE PUMP**

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(57) **ABSTRACT**

A sliding vane pump is provided including a pump assembly having a housing with a fluid inlet and a fluid outlet formed therein, a lining member received in the housing defining a substantially cylindrical inner surface and a rotor arranged inside the lining member, defining a substantially cylindrical outer surface. The inner surface of the lining member and outer surface of the rotor define a working space therebetween. The pump assembly also comprises a plurality of vanes received in slots formed about the rotor outer surface. Each vane is arranged to slide in the radical direction with respect to the rotor such that an outer edge of the vane contacts the lining member inner surface, thereby dividing the working space into working chambers. Rotation of the
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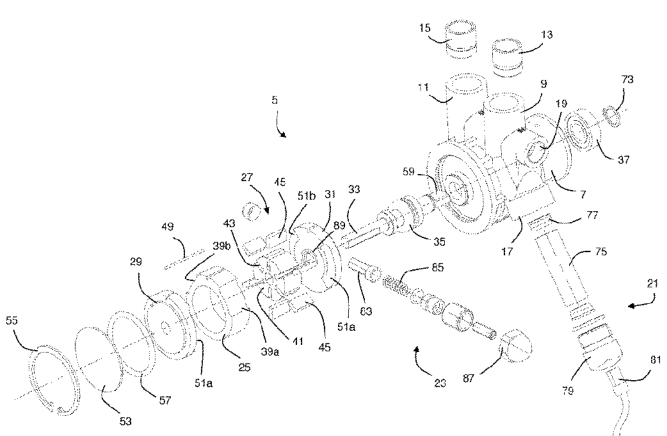

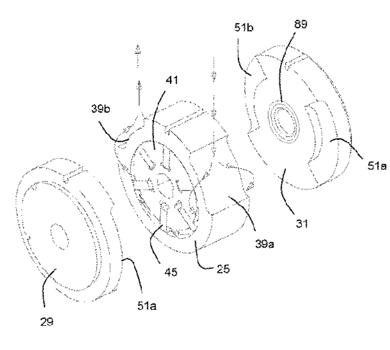

rotor draws fluid from the fluid inlet working into the working chambers, which is ejected into the fluid outlet.

41 Claims, 5 Drawing Sheets

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F04C 2/00	(2006.01)
F04C 18/00	(2006.01)
F01C 21/08	(2006.01)
F04C 2/344	(2006.01)
F04C 15/00	(2006.01)

(52) **U.S. Cl.**
CPC ***F04C 2/3442*** (2013.01); ***F04C 15/0038*** (2013.01); *F04C 2240/20* (2013.01); *F04C 2240/50* (2013.01); *F04C 2240/802* (2013.01); *F04C 2240/81* (2013.01); *F05C 2203/08* (2013.01)

(58) **Field of Classification Search**
USPC 418/259–260, 104, 152–153, 266–268, 418/82
See application file for complete search history.

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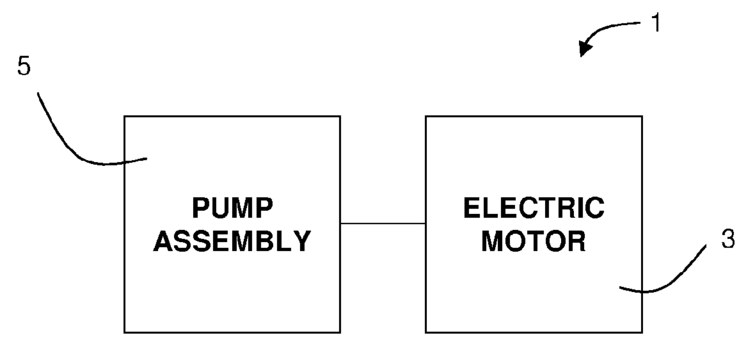

Fig. 1

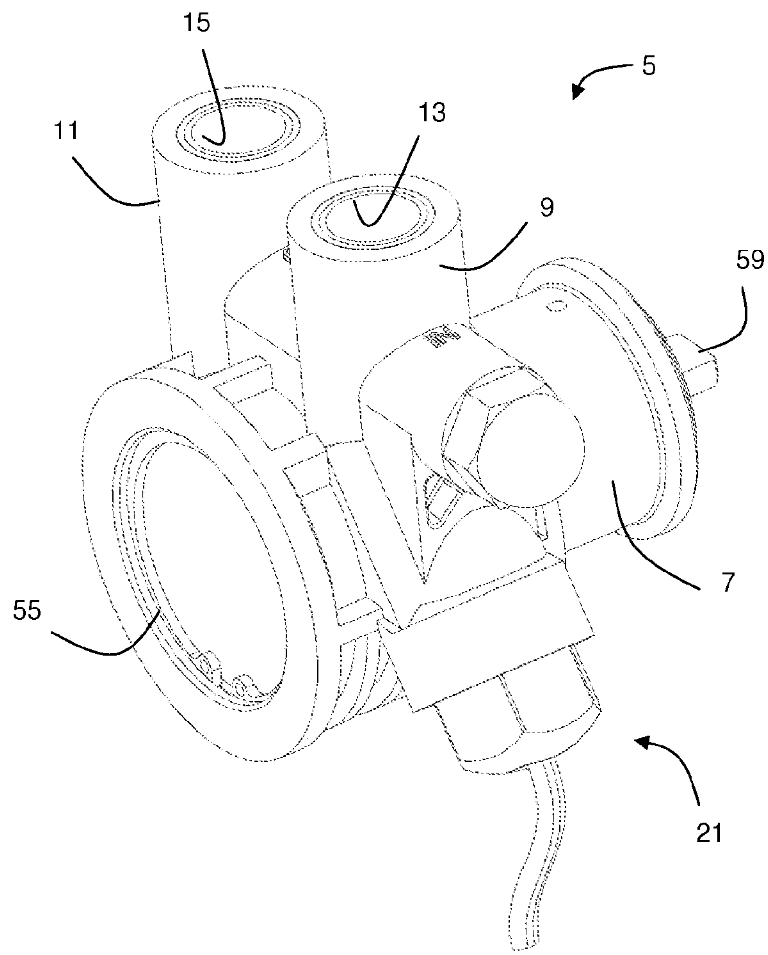

Fig. 2

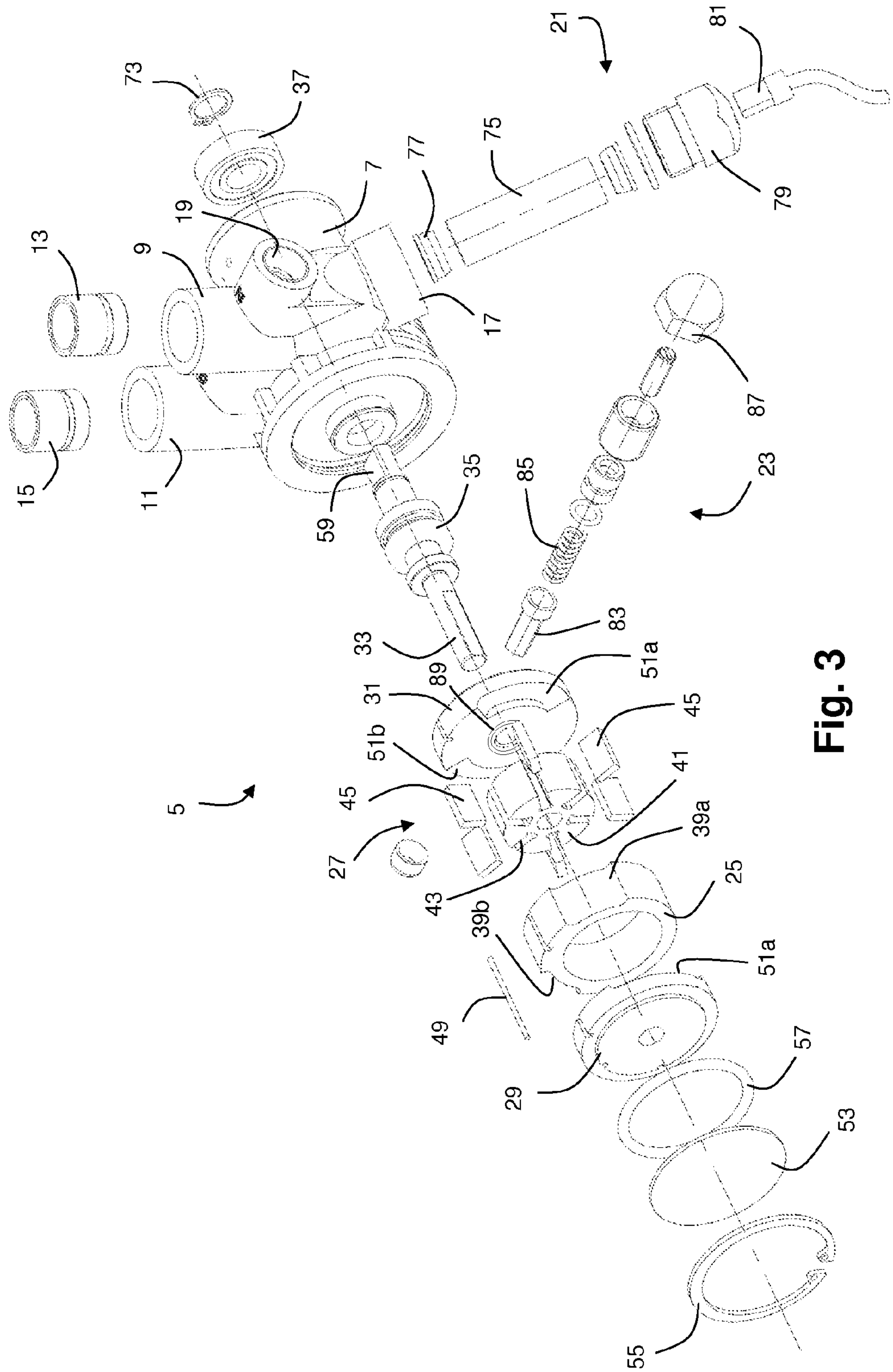

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Fig. 3

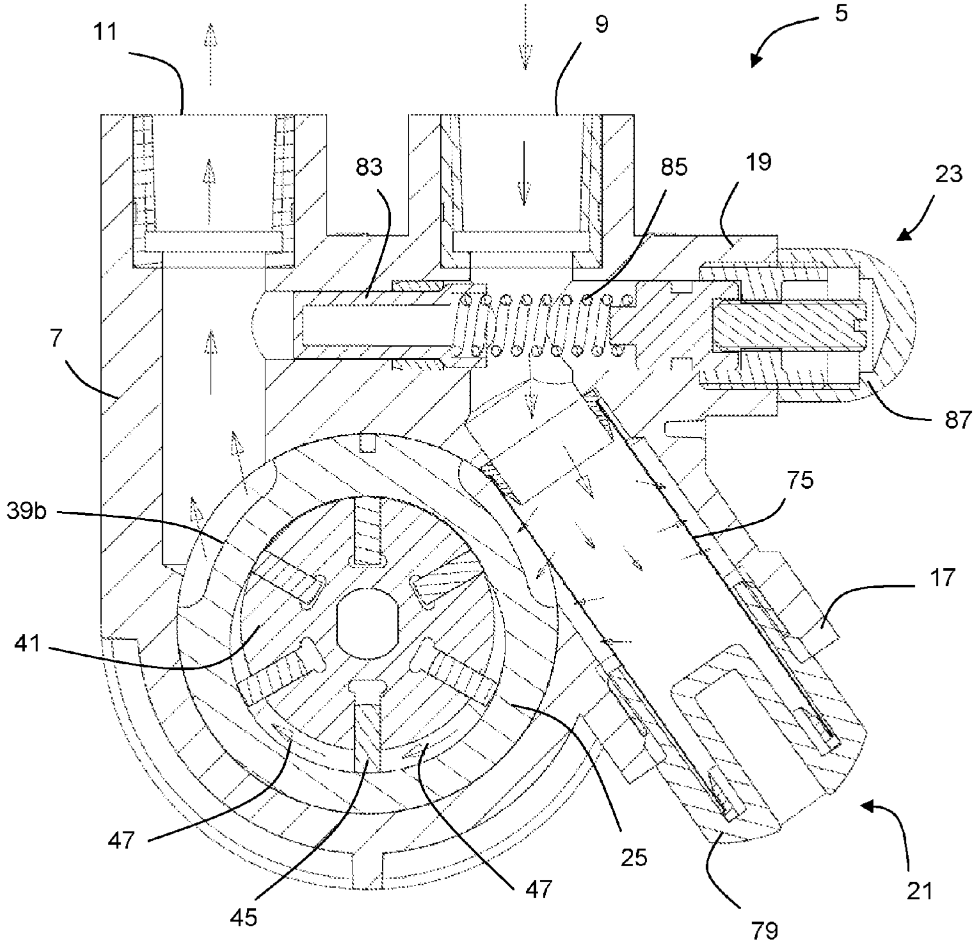

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Fig. 4

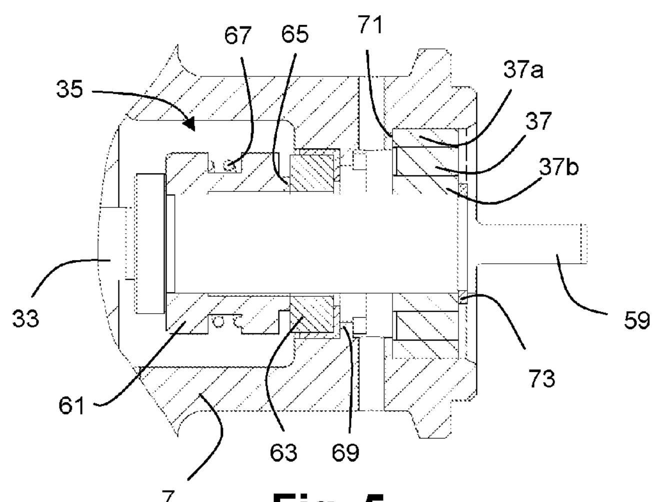

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Fig. 5

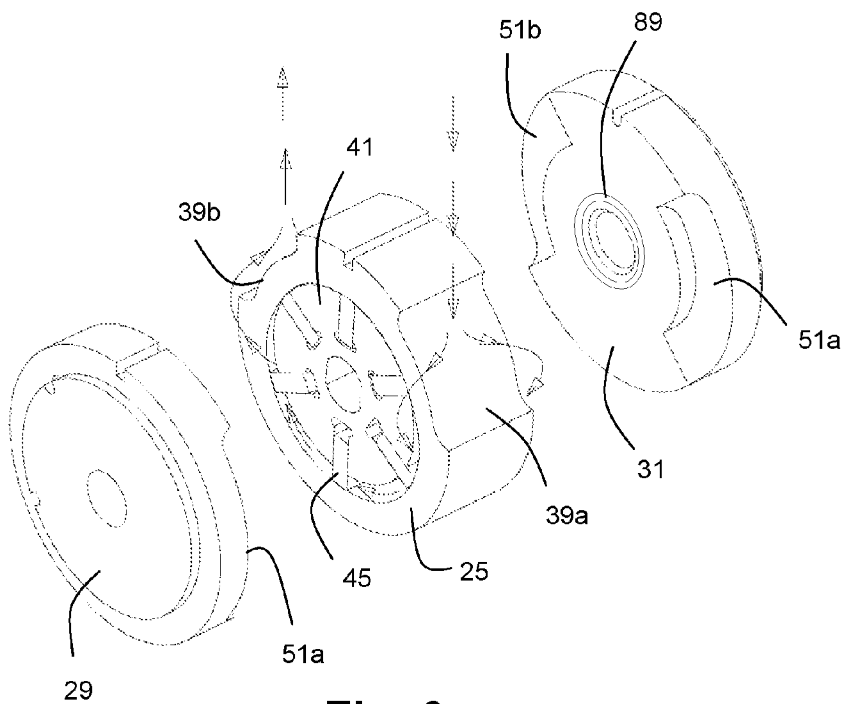

Fig. 6

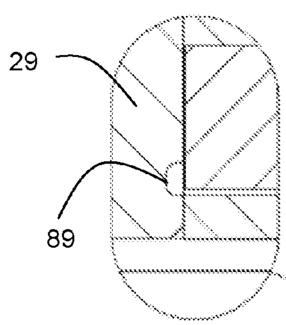

Fig. 7b

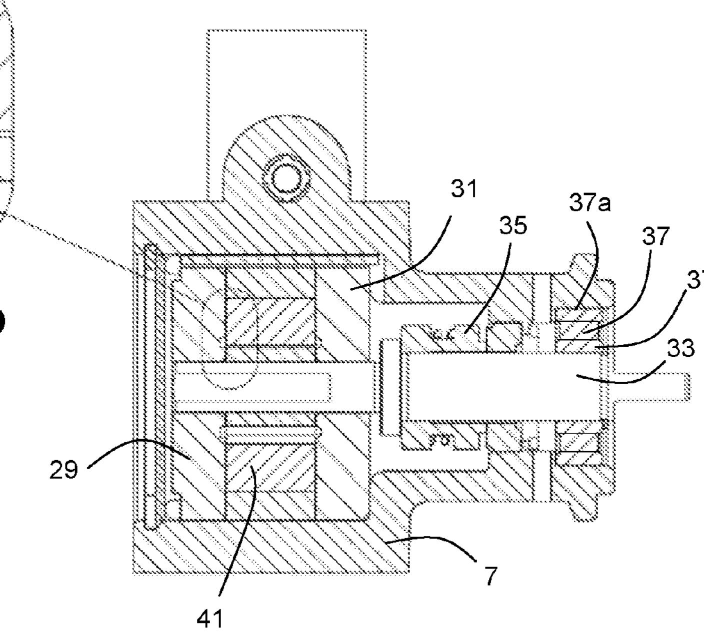

Fig. 7a

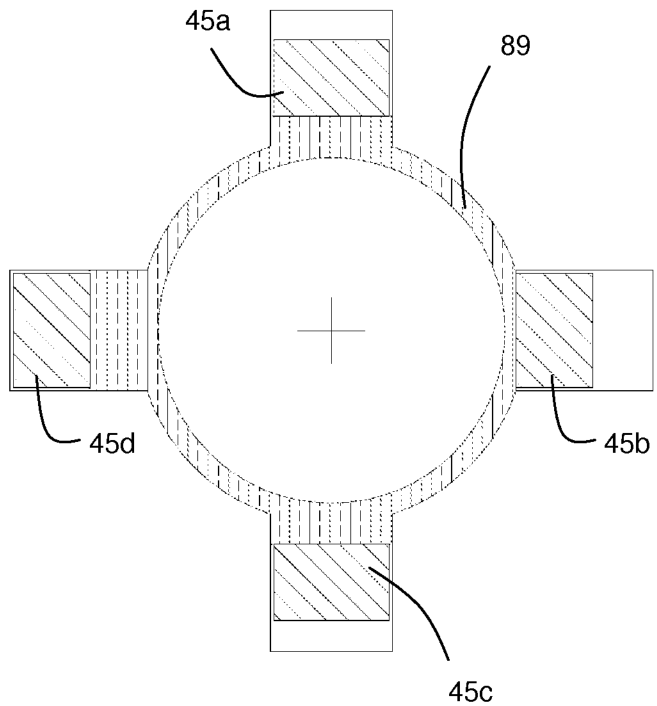

Fig. 8

SLIDING VANE PUMP

CROSS-REFERENCE TO RELATED APPLICATIONS

This application corresponds to international patent application Ser. No. PCT/GB2011/052361, filed 30 Nov. 2011, which claims benefit to GB patent application Ser. No. 1020335.4, filed 1 Dec. 2010, which is incorporated by reference in its entirety.

FIELD OF THE INVENTION

This invention relates to a sliding vane pump. In particular, the invention relates to a sliding vane pump of the type in which a rotor is provided with a plurality of radially-extending vanes which are slidably mounted in slots. The rotor is arranged within a tubular lining member and outer edges of the sliding vanes contact an internal surface of the lining member, thereby defining a plurality of working chambers between the rotor and the lining member. The volume of the working chambers varies as the rotor is rotatably driven by a prime mover, such that a pumped fluid can be transferred from an inlet to an outlet of the pump.

BACKGROUND TO THE INVENTION

Sliding vane pumps are well known. They typically find favour in a wide variety of applications, such as ambient carbonation systems for producing beverages, commercial espresso coffee making equipment and cooling equipment in which a coolant is circulated. These diverse applications have in common the need for a positive displacement pump having a relatively high working pressure and flow rate, together with a long, maintenance-free operational life. These needs are met by the sliding vane pump.

Although the characteristics and performance of sliding vane pumps are adequate in many respects, there remains scope for improvement. For example, the housings of many sliding vane pumps are formed of brass alloys containing small amounts of lead. However, the use of lead in the pump housing is generally undesirable and may render a pump unsuitable for use in potable water applications, including the ambient carbonation systems and espresso coffee making equipment mentioned hereinabove. It is known to avoid this problem by forming the pump housing from stainless steel, but this comes at significantly increased cost. Plastics materials have also been proposed, but the associated moulding processes and strength issues introduce further complexity.

Another performance issue relates to the operating of sliding vane pumps in the so-called bypass mode. Sliding vane pumps are usually provided with a bypass valve which allows the pumped fluid to be transferred from an outlet to an inlet of the pump when the pressure at the outlet exceeds a predetermined level. In many applications, such as the ambient carbonation systems and espresso coffee making equipment mentioned hereinabove, the pump operates in the bypass mode for prolonged periods of time. Such operation can cause a build up of heat in the pumped fluid which, in turn, causes thermal expansion of pump components together with increased wear and premature failure of the pump. The inventors have identified a particular failure mode whereby thermal expansion of the rotor causes the vanes to become jammed in their slots.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a sliding vane pump assembly for providing positive displacement of a fluid, the pump assembly comprising:

a housing having a fluid inlet and a fluid outlet formed therein;

a lining member received in the housing and defining a substantially cylindrical inner surface;

a rotor arranged inside the lining member to rotate about a rotational axis, the rotor defining a substantially cylindrical outer surface, the inner surface of the lining member and the outer surface of the rotor defining a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis; and

a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor, each of the vanes being arranged to slide in the radial direction with respect to the rotor such that an outer edge of the vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers,

wherein rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet,

and wherein base portions of the slots formed in the rotor are in fluid communication with each other.

The inventors have found that the base portions of the slots formed in the rotor of a known sliding vane pump typically behave as partially or imperfectly sealed volumes during use of the pump. The partially sealed volumes are bounded in the radially outwards direction by inner surfaces of the sliding vanes. As the rotor rotates in the lining member, the sliding of the vanes is resisted by pressure variations across the inner and outer faces of the vanes. In particular, sliding in a radially outwards direction is resisted by a pressure drop underneath the vanes and sliding in a radially inwards direction is resisted by a pressure increase underneath the vanes. The pressure variations arise because large volumes of fluid cannot quickly flow into our out of the partially or imperfectly sealed volumes underneath the vanes. This problem can be exacerbated by pump assemblies which are manufactured to small tolerances and/or which experience significant thermal expansion, for example as a consequence of operating in a bypass mode for prolonged periods of time.

By arranging the pump assembly so that base portions of the rotor slots are in fluid communication with each other, preferably constantly during use of the pump, the disadvantageous pressure variations across the vanes which resist the sliding movement of the vanes can be reduced or even substantially avoided. In this way, the risk of pump malfunctions may be reduced and pump efficiency may be improved.

In preferred embodiments, the fluid communication may be provided by at least one fluid conduit in the pump assembly. It has been found that fluid flow through the at least one fluid conduit may be used to assist in making the sliding movement of the vanes. For example, when a vane is urged in the radially inwards direction by direct contact of its radially outer face with the lining member, the increased pressure underneath the vane can be transmitted through the conduit to assist in urging another vane to move in the radially outwards direction. In this way, the fluid communication between the base portions may positively contribute to the reduction of malfunctions caused by improper sliding of the vanes.

The at least one fluid conduit may take the form of a passageway or bore formed in one or more of the pump components. For example, a plurality of radially extending fluid conduits may be formed in the rotor and extend from the inner faces of the slots to the centre of the rotor. The base portions of the slots may be coupled in groups. For example, opposite pairs of the slots may be independently coupled by a conduit extending through the centre of the rotor. The passageway or bore may have any cross-sectional shape, such as circular.

The at least one fluid conduit may alternatively take the form of at least one groove or channel formed into one or more of the pump components. For example, a substantially circular groove may be formed in one or both end surfaces of the rotor and/or in surfaces of other components that face the end surfaces of the rotor. The circular groove may be coaxial with the rotational axis of the rotor. The radius of the circular groove may correspond to the radial position of the base portions of the slots formed in the rotor. In other embodiments, the at least one conduit may comprise a plurality grooves or channels shaped as circular arcs which may be coupled together by other grooves in any suitable configuration. The at least one groove or channel may have any cross-sectional shape, such as semi-circular or U-shaped.

In embodiments of the invention, the rotor may be formed of a ceramic material. Compared to conventional materials for rotors, such as brass alloys and stainless steels, ceramic materials exhibit a lower amount of thermal expansion across a given temperature range. This reduced thermal expansion helps to prevent the vanes from becoming jammed in their slots when the temperature of the pump assembly becomes elevated, for example during operation in a bypass mode for a prolonged period of time. In this way, the risk of pump failures in the form of jammed or broken vanes may be reduced. The reduced friction between the components may also provide reduced wear and increased pump efficiency.

The ceramic material of the rotor may be any engineering-grade ceramic material. For example, the material of the rotor may comprise at least one of alumina ceramic (Al_2O_3), silicon nitride ceramic (Si_3N_4) and zirconia ceramic (ZrO_2). Other ceramic materials which may be suitable include silicon carbide ceramic (SiC), titania ceramics, mullite ceramics and cordierite ceramics. A particularly preferred ceramic material for the rotor is alumina ceramic (Al_2O_3) having a purity of 96.0 to 99.9 wt %. The entire rotor may be formed of the ceramic material or the rotor may be a sub-assembly in which certain components are formed of the ceramic material.

For example, particularly suitable ceramic materials may have an expansivity α of less than or equal to 10.0×10^{-6} K^{-1}, preferably less than or equal to 8.0×10^{-6} K^{-1}, and more preferably less than or equal to 6.0×10^{-6} K^{-1}, all at 293K.

The vanes may be formed of a carbon graphite material or may alternatively be formed of a ceramic material, such as the same or a different ceramic material to that of which the rotor is formed. The vanes may in particular be formed of at least one of the materials described hereinabove in respect of the rotor, i.e. alumina ceramic (Al_2O_3), silicon nitride ceramic (Si_3N_4), zirconia ceramic (ZrO_2), silicon carbide ceramic (SiC), titania ceramics, mullite ceramics and cordierite ceramics.

A base portion of each of the slots formed in the rotor may have an enlarged width and a rounded, lobed cross-sectional shape. The base portion extends substantially in the axial direction. Such an enlarged base portion may be easier to form, for example by typical machining operations and, in use of the pump, peak stresses around the slots may be reduced by the omission of sharp internal corners.

The lining member may be formed of a carbon graphite material, such as a metal impregnated carbon graphite material or a resin-bonded carbon graphite material. Alternatively, the lining member may be formed of a ceramic material, such as those described above with respect to the rotor and vanes. An outer surface of the lining member may be provided with a first recessed area in fluid communication with the fluid inlet and a second recessed area in fluid communication with the fluid outlet. The recessed areas and an inner surface of the housing may together define fluid passageways for transferring fluid between the fluid inlet and fluid outlet and the working chambers. In this way, the geometry of the fluid passageways may be substantially independent of the housing design. In other words, the inner surfaces of the housing which face the outer surface of the lining member need not have any recessed areas. By providing the recessed areas in the lining member, the geometry of the fluid passageways may be more adaptable and may, for example, provide less flow resistance. The lining member is preferably a moulded component in which the recessed areas are formed by the mould profile.

The pump assembly preferably further comprises a drive shaft arranged to rotate about the rotational axis, such that a drive end of the drive shaft extends out of the housing. The drive shaft is preferably releasably engaged with the rotor for rotationally driving the rotor, such that the rotor can be separated from the drive shaft for replacement or repair. The engagement between the drive shaft and the rotor may be such that the rotor is able to move along the drive shaft to some degree.

The pump assembly may also comprise a bearing and a mechanical seal. The bearing is arranged to rotatably support the drive shaft adjacent to its drive end and may comprise a rotatable part coupled to the drive shaft and a static part received in an end portion of the housing. The mechanical seal is arranged between the rotor and the bearing for preventing fluid leakage along the drive shaft and out of the end portion of the housing. The seal may comprise a rotatable part coupled to the drive shaft and a static part coupled to the housing. The rotatable part may have a low friction sealing surface which is resiliently biased into engagement with a low friction sealing surface of the static part by a spring element.

The static part of the mechanical seal may be seated on a shoulder provided in the inner surface of the housing which faces the rotatable part of the seal, the shoulder providing a reaction force opposing the resilient bias of the spring element. The shoulder provided in the inner surface of the housing may be integrally formed with the housing.

The static part of the bearing may be seated on a shoulder provided in the inner surface of the housing which faces the drive end of the drive shaft. This shoulder may also be integrally formed with the housing. The rotatable part of the bearing may be seated on a shoulder provided in the drive shaft which faces the shoulder on which the static part is seated, such that the drive shaft is prevented from moving axially under the resilient bias of the spring element. In this way, friction between components that would otherwise be caused by the thrust of the spring element can be avoided. The shoulder in the drive shaft may be provided by a circlip mounted in a circumferential groove in the drive shaft, which circlip may be mounted after the shaft has been assembled into the bearing.

The pump assembly preferably further comprises first and second bearing members received in the housing and arranged at either end of the rotor. The bearing members may define end walls of the working chambers. The bearing members may be formed of a carbon graphite material, such as a metal impregnated carbon graphite material or a resin-bonded carbon graphite material, to minimise friction with the rotating rotor. Alternatively, the lining members may be formed of a ceramic material, such as those described above with respect to the rotor and vanes.

In particular embodiments of the invention, the at least one fluid conduit providing fluid communication between the base portions of the slots in the rotor comprises a substantially circular groove formed in the end surfaces of one or both other the bearing members, in particular the end surfaces that face the end surface of the rotor. The circular groove may be coaxial with the rotational axis of the rotor. The radius of the circular groove may correspond to the radial position of the base portions of the slots formed in the rotor. The at least one groove or channel may have any suitable cross-sectional shape, such as semi-circular or U-shaped.

One or both of the bearing members may be provided with a first recessed area in fluid communication with the fluid inlet and a second recessed area in fluid communication with the fluid outlet. The recessed areas and end surfaces of the lining member together define fluid passageways for transferring fluid between the fluid inlet and fluid outlet and the working chambers.

The housing may be a moulded plastics component, for example formed of a fibre-reinforced plastics material.

The sliding vane pump assembly preferably further comprises a removable strainer assembly, the strainer assembly being received into an opening in the housing and extending across the fluid inlet for filtering particulate matter from the fluid. By filtering particulate matter, friction and wear between the components of the pump assembly may be reduced. The strainer assembly may comprise a strainer sleeve formed of porous or perforated material.

The strainer assembly may further comprise a thermal sensor for providing an electrical signal indicative of temperature. The thermal sensor may be provided in a sealing cap for the opening of the housing in which the strainer is received. Such an arrangement is advantageous because it enables the sensor to be placed in close proximity to fluid passing through the fluid inlet, so that the sensor is able to accurately detect temperature variations at the fluid inlet. Furthermore, by mounting the temperature sensor in a removable component of the pump assembly, manufacturing and maintenance operations may be simplified.

According to a second aspect of the invention, there is provided a sliding vane pump assembly for providing positive displacement of a fluid, the pump comprising:

- a housing having a fluid inlet and a fluid outlet formed therein;
- a lining member received in the housing and defining a substantially cylindrical inner surface;
- a rotor arranged inside the lining member to rotate about a rotational axis, the rotor defining a substantially cylindrical outer surface, the inner surface of the lining member and the outer surface of the rotor defining a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis;
- a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor, each of the vanes being arranged to slide in the radial direction with respect to the rotor such that an outer edge of the vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers;
- a drive shaft arranged to rotate about the rotational axis, wherein a drive end of the drive shaft extends out of the housing, the drive shaft being releasably engaged with the rotor for rotationally driving the rotor;
- a bearing arranged to rotatably support the drive shaft adjacent to its drive end, the bearing comprising a rotatable part coupled to the drive shaft and a static part received in an end portion of the housing; and
- a mechanical seal arranged between the rotor and the bearing for preventing fluid leakage along the drive shaft and out of the end portion of the housing, the mechanical seal comprising a rotatable part coupled to the drive shaft and a static part coupled to the housing, wherein the rotatable part has a sealing surface which is resiliently biased into engagement with a sealing surface of the static part by a spring element,

wherein rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet,

and wherein the static part of the bearing is seated on a shoulder provided in the inner surface of the housing which faces the drive end of the drive shaft, and wherein the rotatable part of the bearing is seated on a shoulder provided in the drive shaft which faces the shoulder on which the static part is seated, such that the drive shaft is prevented from moving axially under the resilient bias of the spring element.

This aspect provides a pump assembly in which the drive shaft is prevented from moving axially under the resilient bias of the spring element. In this way, friction between components that would otherwise be caused by the thrust of the spring element can be avoided. Instead, the thrust of the drive shaft is resisted by the shoulder provided in the drive shaft which bears against the rotatable part of the bearing.

The shoulder in the drive shaft may be provided by a circlip mounted in a circumferential groove in the drive shaft.

The drive shaft may be releasably engaged with the rotor for rotationally driving the rotor. The engagement between the drive shaft and the rotor may be such that the rotor is able to move along the drive shaft.

The static part of the mechanical seal may be seated on a shoulder provided in the inner surface of the housing which faces the rotatable part of the mechanical seal, the shoulder providing a reaction force opposing the resilient bias of the spring element. Each of the shoulders in the inner surface of the housing may be integrally formed in the housing, particularly if the housing is formed of a plastics material.

According to a third aspect of the invention, there is provided a sliding vane pump assembly for providing positive displacement of a fluid, the pump comprising:

- a housing having a fluid inlet and a fluid outlet formed therein;
- a lining member received in the housing and defining a substantially cylindrical inner surface;
- a rotor arranged inside the lining member to rotate about a rotational axis, the rotor defining a substantially cylindrical outer surface, the inner surface of the lining member and the outer surface of the rotor defining a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis;
- a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor, each of the vanes being arranged to slide in the radial direction with respect to the rotor such that an outer edge of the

vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers; and

a removable strainer assembly, the strainer assembly being received into an opening in the housing and extending across the fluid inlet for filtering particulate matter from the fluid,

wherein rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet,

and wherein the strainer assembly comprises a thermal sensor for providing a electrical signal indicative of temperature.

This aspect of the invention provides pump assembly having a strainer assembly which comprises a thermal sensor. Such an arrangement is advantageous because it enables the sensor to be placed in close proximity to fluid passing through the fluid inlet, so that the sensor is able to accurately detect temperature variations in the fluid inlet. Furthermore, by mounting the temperature sensor in a removable component of the pump assembly, manufacturing and maintenance operations may be simplified.

The strainer assembly may comprise a strainer sleeve formed of porous or perforated material and having a closed end. In use of the pump assembly, fluid is directed into the sleeve and is drawn out through the porous or perforated material into the working chambers. Any particulate matter collected inside the sleeve may be periodically removed by withdrawing the strainer assembly from the housing. The thermal sensor may be provided in a sealing cap for the opening in the housing in which the strainer is received.

Any of the pump assemblies described above may further comprise a bypass valve arranged between the fluid outlet and the fluid inlet to allow the pumped fluid to flow from the fluid outlet to the fluid inlet when the pressure at the fluid outlet exceeds a predetermined level.

The invention also provides a sliding vane pump comprising any of the sliding vane pump assemblies described hereinabove and a prime mover arranged to rotatably drive the rotor of the sliding vane pump assembly. The prime mover may be an electric motor.

The invention also provides a method of using the sliding vane pump described hereinabove for pumping water in a beverage carbonation system or an espresso coffee machine. In such applications, the pump may operate in a bypass mode for prolonged periods of time. The invention also provides a method of using the sliding vane pump described hereinabove in other applications, including pumping fluid in reverse osmosis water treatment equipment and heating or cooling circuits.

Other features and advantages of embodiments of the invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention will now be described with reference to the following drawings, in which:

FIG. **1** is a schematic view of a pump comprising a pump assembly according to the invention;

FIG. **2** is a perspective view of the pump assembly according to the invention;

FIG. **3** is an exploded view of the pump assembly shown in FIG. **2**;

FIG. **4** is an end cross-sectional view of the pump assembly shown in FIG. **2**;

FIG. **5** is a side cross-sectional view of a part of the pump assembly shown in FIG. **2** showing a bearing and a mechanical seal.

FIG. **6** is a diagram for explaining the use of the pump assembly shown in FIG. **2** for pumping a fluid;

FIGS. **7***a* and **7***b* are cross-sectional views showing the detailed design of the pump assembly shown in FIG. **2**; and

FIG. **8** is a schematic diagram for further explaining the use of the pump assembly according to the invention based on an alternative embodiment.

DETAILED DESCRIPTION

The invention provides a sliding vane pump assembly for providing positive displacement of a fluid such as water. The pump assembly comprises a housing having a fluid inlet and a fluid outlet formed therein, a lining member received in the housing and defining a substantially cylindrical inner surface and a rotor arranged inside the lining member to rotate about a rotational axis. The rotor defines a substantially cylindrical outer surface such that the inner surface of the lining member and the outer surface of the rotor define a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis. The pump assembly also comprises a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor. Each of the vanes is arranged to slide in the radial direction with respect to the rotor such that an outer edge of the vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers. In use, rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet.

According to a first aspect of the invention, base portions of the slots formed in the rotor are in fluid communication with each other and/or the rotor is formed of a ceramic material, which may reduce the risk of the pump malfunctioning and improve pump efficiency. The use of ceramic material for the rotor provides reduced thermal expansion compared to convention materials such as stainless steels. According to a second aspect of the invention, the pump assembly further comprises a drive shaft which is mounted to a bearing and a mechanical seal such that axial movement of the drive shaft under the thrust of the mechanical seal is prevented. According to a third aspect of the invention, the pump assembly further comprises a strainer assembly received into an opening in the housing and extending across the fluid inlet for filtering particulate matter from the fluid. The strainer assembly comprises a thermal sensor for sensing a temperature of fluid passing through the fluid inlet.

The invention also provides a sliding vane pump comprising the pump assembly described hereinabove and a prime mover for driving the pump assembly.

FIG. **1** is a schematic view of a rotary vane pump **1** according to the invention. The pump **1** comprises a prime mover in the form of an electric motor **3** and a pump assembly **5**, which will be described in more detail hereinbelow. The pump assembly has a drive shaft (not shown in FIG. **1**) to which the electric motor **3** is coupled in a conventional manner.

The pump assembly **5** is illustrated in more detail in the perspective view of FIG. **2**, the exploded view of FIG. **3** and the end cross-sectional view of FIG. **4**. Referring to these drawings, the pump assembly **5** comprises a housing **7** within which various components are installed. The housing **7** is preferably a moulded component formed of a plastics material, such as a fibre-reinforced plastics material. The housing **7** has a substantially tubular configuration with different axial sections of a main opening defining internal surfaces having different diameters. The ends of the housing **7** are closed by other components which will be described hereinbelow.

The housing **7** is integrally formed with a fluid inlet **9** and a fluid outlet **11** which extend upwardly from the housing **7** as shown in FIG. **2**. The fluid inlet **9** and fluid outlet **11** are provided with sleeve inserts **13**, **15** formed of a metal material for engaging fluid conduit connectors (not shown). The fluid inlet **9** and fluid outlet **11** each provide a fluid passageway which is open to the inner surface of the housing **7**. The housing **7** also has integrally formed openings **17**, **19** for receiving a strainer assembly **21** and a bypass valve **23** which will be described in more detail hereinbelow.

The components of the pump assembly which are installed in the main opening of the housing **7** will now be described with particular reference to exploded view of FIG. **3**. Received into the housing **7** are a lining member **25**, a rotor assembly **27**, first and second bearing members **29**, **31**, a drive shaft **33**, a mechanical seal **35** and a bearing **37**.

The lining member **25** is a moulded component formed of a carbon graphite or ceramic material. It has a cylindrical outer surface which matches a cylindrical inner surface of the housing **7**. The outer surface of the lining member **25** is provided with moulded recessed areas **39***a*, **39***b* which define fluid passageways in communication with the fluid inlet **9** and the fluid outlet **11**, respectively. By providing the lining member **25** with the recessed areas **39***a*, **39***b*, the need for additional machining of the inner surface of the housing **7** may be avoided. The lining member **25** also has a cylindrical inner surface having a radius which varies in the circumferential direction.

The rotor assembly **27** is received within in the lining member **25** such that it is able to rotate about a rotational axis indicated by a broken line. The rotor assembly **27** comprises a cylindrical rotor **41** formed of a ceramic material such as alumina ceramic (Al_2O_3) having a purity of 99 wt % or similar. The cylindrical outer surface of the rotor **41** is provided with a plurality of radially-extending slots **43**. In the illustrated pump assembly **5** there are six slots **43** equally spaced apart, but more or fewer slots may alternatively be provided. A vane **45** formed of a carbon graphite or ceramic material is provided in each of the slots **43** and arranged to slide in the radial direction. A base portion of each of the slots **43** has an enlarged width and a rounded cross-sectional shape, which assists in reducing peak stress levels around the base portions of the slots **43** during use of the pump assembly **5**. The enlargement also assists in machining the slots **43** during manufacture of the rotor **41**.

The inner surface of the lining member **25** and the outer surface of the rotor **41** define a working space therebetween which is divided into a plurality of working chambers **47** by the vanes **45**. In use of the pump assembly **5**, as the rotor assembly **27** is rotatably driven, the vanes **45** reciprocate in the radial direction as the working chambers **47** rotate. Fluid is drawn from the fluid inlet **9** into the working chambers **47** and ejected from the working chambers **47** into the fluid outlet **11**.

The first and second bearing members **29**, **31** are arranged on either side of the rotor assembly **27** and define side walls of the working chambers **47**. The bearing members **29**, **31** are formed of a carbon graphite or ceramic material for reducing friction between the members **29**, **31** and the rotor assembly **27**. End surfaces of each of the bearing members **29**, **31** which face the rotor assembly **27** are provided with recessed areas **51***a*, **51***b* which define fluid passageways in fluid communication with the working chambers **47** and the fluid passageways formed in the outer surface of the lining member **25**. The end surfaces of one of the bearing members **29**, **31** which face the rotor assembly **27** are also provided with circular grooves **89** (only one visible in FIG. **3**) which are coaxial with the rotor **41** and have radii corresponding to the radial positions of the enlarged base portions of the slots **43** formed in the rotor **41**. The purpose of the circular grooves **89** will be described in more detail hereinbelow. The outer surfaces of the lining member **25** and the bearing members **29**, **31** are each provided with slot which receives an alignment pin **49** for maintaining their relative alignment.

A front end of the housing **7** is closed by a circular plate **53** which is secured in place by a circlip **55**. An O-ring seal **57** is arranged in contact with the circular plate **57** for sealing purposes.

The drive shaft **33** is installed in the housing **7** from the rear end, with a drive end **59** of the drive shaft extending out of the housing **7**. The drive shaft **33** engages circular holes formed in the bearing members **29**, **31** and a drive hole formed in the rotor **41**. The drive shaft **33** releasably engages the rotor **41** and the bearing members **29**, **31** such that the rotor **41** can be dismantled from the shaft **33** for repair or replacement. The engagement is also such that the rotor **41** and the bearing members **29**, **31** are able to slide in either direction along the drive shaft **33** to a limited degree.

The mechanical seal **35** and the bearing **37** are installed on the drive shaft **33** between the second bearing member **31** and the drive end **59** of the drive shaft **33** and are shown in greater detail in FIG. **5**, which is a side cross-sectional view.

The bearing **37** is arranged to rotatably support the drive shaft **33** adjacent to its drive end **59**. The bearing **37** is a conventional type and comprises a plurality of metal balls supported between a rotatable sleeve coupled to the drive shaft **33** and a static sleeve received in an end portion of the housing **7**.

The mechanical seal **35** is arranged adjacent to the bearing **37** for preventing fluid leakage along the drive shaft **33** and out of the rear end of the housing **7**. The mechanical seal **35** comprising a rotatable sleeve **61** coupled to the drive shaft **33** and a static sleeve **63** coupled to the housing **7**. The rotatable sleeve has a sealing surface **65** which is resiliently biased into engagement with a sealing surface of the static 63 part by a spring element **67**.

The static sleeve **63** of the mechanical seal **35** is installed in the housing **7** such that it is seated in the axial direction on a shoulder **69** that is integrally formed in the housing **7**. The shoulder **69** provides a reaction force to oppose the bias of the spring element **67**.

The static sleeve **37***a* of the bearing **37** is also seated on a shoulder **71** that is integrally formed in the housing **7**. The drive shaft **33** is prevented from moving in the axial direction under the resilient bias of the spring element **67** by a circlip **73** which is mounted to a circumferential groove in the drive shaft **33** and bears against the rotatable sleeve **37***b* of the bearing **37**. In this way, friction between static components and components rotated by the drive shaft **33** is reduced.

The removable strainer assembly **21** and the bypass valve **23** will now be described with particular reference to FIGS. **3** and **4**.

The strainer assembly **21** comprises an elongated sleeve **75** formed of a porous or perforated material. The pore or perforation size is selected to prevent relevant particulate matter from passing through the material without causing an undue restriction on flow. The strainer assembly further comprises a distal end seal **77** and a sealing cap **79** which closes the sleeve **75** at a proximal end. The sealing cap **79** also seals the opening **17** in the housing **7** and is provided with a bore in which is received a temperature sensor **81**. The temperature sensor **81** is an electrical temperature sensor such as a thermocouple, thermistor or similar which provides an electrical signal indicative of a temperature.

The strainer assembly **21** is installed inside the opening **17** in the housing **7**, as described hereinabove. With reference to FIG. **4**, it will be seen that distal end seal **77** seals the sleeve **75** to the fluid inlet **9** of the housing **7**. Fluid flowing into the sleeve **75** is drawn through the porous or perforated material into the fluid passageway defined by recess **39***a* in the lining member **25**. The proximity of the temperature sensor **81** to the fluid passing through the fluid inlet **9** renders the sensor **81** particularly sensitive to temperature changes at the fluid inlet **9**. An output of the temperature sensor may be used, for example, to shut down power to the electrical motor **3** which drives the pump assembly **5** when the temperature exceeds a predetermined threshold. In this way, thermally-induced damage to the pump components may be avoided.

The bypass valve **23** is installed inside the opening **19** in the housing **7**. This opening **19** provides a fluid passageway between the fluid outlet **11** and the fluid inlet **9**. The bypass valve **23** comprises a piston **83**, a compression spring **85** and an end cap **87** which includes a pressure adjustment mechanism. The piston **83** is formed with a circumferential shoulder which abuts a valve seat provided in the opening **19**.

The shoulder is biased into engagement with the valve seat by the compression spring **85**, which is held in place by the end cap **87**. The pressure adjustment mechanism is adapted to vary the preload on the spring **85**, and thereby the pressure at which the valve opens. In use of the bypass valve **23**, the valve opens to allow high pressure fluid to flow from the fluid outlet **11** to the fluid inlet **9** when the pressure at the fluid outlet exceeds a predetermined level.

Use of the pump **1** and pump assembly **5** for pumping a fluid will now be described with reference to FIGS. **4** and **6**. FIG. **4** is an end cross-sectional view of the pump assembly. FIG. **6** is a schematic view illustrated fluid flow through fluid passageways formed by the lining member **25** and the bearing members **29**, **31**. Fluid flow is indicated in FIGS. **4** and **6** by arrows.

In use of the pump **1**, the fluid inlet **9** is connected to a low pressure supply of fluid such as water and the fluid outlet is connected to a vessel (not shown) to which the fluid is to be pumped. Since the pump **1** is a positive displacement pump, the vessel may be a pressure vessel and the pump my transfer fluid from a low pressure supply to the vessel at a higher pressure.

The electric motor **3** shown in FIG. **1** rotatably drives the drive shaft **33** of the pump assembly **5** which, in turn, drives the rotor assembly **27**. As the rotor assembly **27** rotates, the vanes **45** reciprocate in the slots **43** and the working chambers **47** rotate about the rotational axis. As the working chambers **47** rotate they initially expand in volume as they draw in fluid from the fluid inlet **9** before contracting as they expel fluid towards the fluid outlet **11**. It is this expansion and contraction cycle which is able to pump the fluid against a pressure gradient.

The fluid which is drawn into the working chambers **47** passes from the fluid inlet **9**, across the compression spring **85** of the bypass valve **23**, and through the sleeve **75** of the strainer assembly **21**. The sleeve **75** of the strainer assembly **21** collects any particulate matter in the fluid which might otherwise cause damage or excessive wear to the pump assembly **5**.

The temperature sensor **81** installed in the strainer assembly **21** is sensitive to temperature fluctuations in the fluid passing through the fluid inlet **9**. If the sensed temperature exceeds a predetermined threshold, then the power supply to the electric motor **3** may be cut off to shut down the pump **1** and prevent any thermally-induced damage to the pump components. Such a scenario may arise if the pump **1** operates in the bypass mode, which will be described hereinbelow, for a prolonged period of time.

The bypass valve **23** serves to regulate fluid pressure at the fluid outlet **11** by opening a fluid passageway from the fluid outlet **11** to the fluid inlet **9** when the pressure in at the fluid outlet **11** exceeds a predetermined level. The bypass valve **23** may also serve as a safety feature. When the bypass valve **23** is opened, the pump **1** is said to be operating in the bypass mode. In the bypass mode, fluid is continuously circulated through the working chambers **47** and across the fluid passageway of the bypass valve **23**, thereby leading to an increase in the temperature of the fluid as it is worked. Prolonged operation in the bypass mode can lead to thermally-induced damage to the pump components unless the pump **1** is shut down, for example by cutting off the power to the electric motor **3** in response to a predetermined signal from the temperature sensor **81**.

During use of the pump assembly **5**, there is a continuous flow of fluid in the circular grooves **89** formed in the bearing members **29**, **31** as the rotor assembly **27** rotates. This flow of fluid through the circular grooves **89** does not directly contribute to the pumping of fluid from the fluid inlet **9** to the fluid outlet **11** but instead helps to prevent malfunctions of the pump assembly **5** caused by improper sliding or jamming of the vanes **45** in their slots **43**.

Each of the circular grooves **89** defines a conduit which provides fluid communication between the base portions of the slots **43** of the rotor **41**. The base portions of the slots **43** define volumes which are bounded in the radially outer direction by the radially inner ends of the vanes **45** and which, were it not for the radial grooves **89**, would be partially or imperfectly sealed. The fluid communication between the base portions of the slots **43** allows fluid to quickly flow between the slots **43** as the vanes **45** slide radially inwards and outwards. In this way, significant pressure variations across the radially inner and outer surfaces of the vanes **45**, which can lead to vanes sticking, can be avoided. More specifically, a pressure drop underneath the vanes **45** caused by sliding in a radially outwards direction is relieved by fluid flowing into the base portion through the circular grooves **89**. A pressure increase underneath the vanes **45** caused by sliding in a radially inwards direction is relieved by fluid flowing out of the base portion through the circular grooves **89**. The sum of the volumes under all of the vanes **45** remains substantially constant at all times during use of the pump assembly **45**, so that there is a flow of fluid between the slots **43**.

It has also been found that the fluid flow through the circular grooves **89** may assist in the sliding movement of the vanes **45**. More specifically, when a vane **45** is urged in the radially inwards direction by direct contact of its radially outer face with the lining member **25**, the increased pressure underneath the vane **45** can be transmitted through the grooves **91** to assist in urging another vane **45** to move in the radially outwards direction. In this way, the fluid communication between the base portions of the slots **43** may positively contribute to the reduction of malfunctions caused by improper sliding of the vanes **45**.

Compared to use of a conventional pump, friction between the components is also reduced in a number of ways, as is the risk of pump failures. For example, the provision of a rotor **41** formed of a ceramic material reduces friction between the rotor **41** and the vanes **45** caused by thermally-induced expansion of the rotor material. Pump failures caused by jammed and broken vanes may also be reduced.

Furthermore, the drive shaft **33** is prevented from moving axially by the circlip **73** bearing against the inner rotatable sleeve of the bearing **37**. In this way, friction between static components and the drive shaft **33** and components rotationally driven by the drive shaft **33** may be reduced.

FIGS. **7***a* and **7***b* illustrate in more detail the provision of the fluid communication between the base portions of the slots **43** of the rotor **41** according to the invention. The reference numerals used in FIGS. **7***a* and **7***b* correspond to those used in the other drawings. As shown in the FIGS., the circular grooves **89** are formed in the surfaces of the first and second bearing members **29**, **31** which face the rotor **41**. The grooves **89** define fluid passageways which connect together the base portions of the slots **43** formed in the rotor **41**. The fluid passageways serve to equalise the pressures underneath the vanes **45** as the vanes **45** reciprocate during use of the pump assembly **5**.

FIG. **8** is a schematic diagram for further explaining the use of the pump assembly **5** based on an alternative embodiment having four vanes instead of the six vanes shown in FIGS. **3** to **6**. As illustrated, the four vanes **45***a*, **45***b*, **45***c*, **45***d* are arranged in respective slots of the rotor. The circular grooves **91** formed in the bearing members provide fluid communication between base portions of the slots. In FIG. **8**, the four vanes **45***a*, **45***b*, **45***c*, **45***d* are arranged at different radial positions. As the rotor assembly rotates, the vanes **45***a*, **45***b*, **45***c*, **45***d* slide radially inwardly and outwardly such that their radially outer surfaces remain in contact with the lining member (not shown in FIG. **8**). There is a constant flow of fluid from slots in which the vanes are sliding radially inwardly to slots in which the vanes are sliding radially outwardly. The total volume of fluid under the vanes and in the circular grooves **89** remains substantially constant.

As explained hereinabove, the flow of fluid between the slots minimises disadvantageous pressure differentials across the vanes which can cause sticking of the vanes. Furthermore, the flow of fluid can also establish advantageous pressure differentials across the vanes which promote the sliding movement of the vanes, particularly in the radially outwards direction. It will be appreciated that the precise flow of fluid between the slots is determined by the radial positions and movements of the vanes, which are determined by the shape of the inner surface of the lining member.

Preferred embodiments of the invention have been described in detail hereinabove. Various changes may be made to these embodiments without departing from the scope of the invention, which is defined by the accompanying claims.

For example, the rotor of the pump assembly described above is formed of alumina ceramic. However, other ceramic materials may be used, such as silicon nitride and zirconium dioxide.

Another aspect of the invention provides a sliding vane pump assembly for providing positive displacement of a fluid, the pump assembly comprising:

- a housing having a fluid inlet and a fluid outlet formed therein;
- a lining member received in the housing and defining a substantially cylindrical inner surface;
- a rotor arranged inside the lining member to rotate about a rotational axis, the rotor defining a substantially cylindrical outer surface, the inner surface of the lining member and the outer surface of the rotor defining a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis; and
- a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor, each of the vanes being arranged to slide in the radial direction with respect to the rotor such that an outer edge of the vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers,
- wherein rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet,
- and wherein the rotor is formed of a ceramic material.

The invention claimed is:

1. A sliding vane pump assembly for providing positive displacement of a fluid, the pump assembly comprising:

- a housing having a fluid inlet and a fluid outlet formed therein;
- a lining member received in the housing and defining a substantially cylindrical inner surface;
- a rotor arranged inside the lining member to rotate about a rotational axis, the rotor defining a substantially cylindrical outer surface, the inner surface of the lining member and the outer surface of the rotor defining a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis;
- a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor, each of the vanes being arranged to slide in a radial direction with respect to the rotor such that an outer edge of the vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers, and
- first and second bearing members received in the housing and arranged at either end of the rotor, the bearing members defining end walls of the working chambers;
- wherein rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet, and
- wherein base portions of the slots formed in the rotor are in fluid communication with each other continuously throughout each revolution of the rotor,
- wherein the fluid communication is provided by a substantially circular groove formed in at least one of the end faces of the rotor and end faces of the bearing members; and
- wherein, in use of the pump assembly, the total volume of fluid under the vanes and in the substantially circular groove is substantially constant, so that there is a flow of fluid between the slots to equalize the pressure under the vanes; and
- wherein when the vane is urged in the radially inwards direction by direct contact of a radially outer face of the vane with the lining member, the increased pressure underneath the vane is transmitted through the groove to assist in urging another vane to move in the radially outwards direction.

2. The sliding vane pump assembly according to claim **1**, wherein the fluid communication is provided by at least one fluid conduit in the pump assembly.

3. The sliding vane pump assembly according to claim **2**, wherein the at least one fluid conduit is formed in the rotor.

4. The sliding vane pump assembly according to claim **1**, wherein the at least one fluid conduit is formed, or further formed, in at least one of the first and second bearing members.

5. The sliding vane pump assembly according to claim **1**, wherein the circular groove is coaxial with the rotor and has a radius corresponding to radial positions of the base portions of the slots of the rotor.

6. The sliding vane pump assembly according to claim **1**, wherein the circular groove has a semi-circular or U-shaped cross-section.

7. The sliding vane pump assembly according to claim **1**, wherein, except for the circular groove, the base portions of the slots of the rotor define substantially sealed volumes.

8. The sliding vane pump assembly according to claim **1**, wherein the rotor is formed of a ceramic material.

9. The sliding vane pump assembly according to claim **8**, wherein the ceramic material of the rotor comprises at least one of Al_2O_3, Si_3N_4 and ZrO_2.

10. The sliding vane pump assembly according to claim **9**, wherein the ceramic material of the rotor consists of Al_2O_3 having a purity of 96.0 to 99.9 wt %.

11. The sliding vane pump assembly according to claim **1**, wherein the base portion of each of the slots formed in the rotor has an enlarged width and defines a rounded cross-sectional shape.

12. The sliding vane pump assembly according to claim **1**, wherein the lining member is formed of a carbon graphite or ceramic material.

13. The sliding vane pump assembly according to claim **12**, wherein an outer surface of the lining member is provided with a first recessed area in fluid communication with the fluid inlet and a second recessed area in fluid communication with the fluid outlet, and wherein the recessed areas and an inner surface of the housing together define fluid passageways for transferring fluid between the fluid inlet and fluid outlet and the working chambers.

14. The sliding vane pump assembly according to claim **13**, wherein inner surfaces of the housing which face the outer surface of the lining member do not have any recessed areas.

15. The sliding vane pump assembly according to claim **13**, wherein the lining member is a moulded component, and wherein the recessed areas are moulded into the outer surface of the lining member.

16. The sliding vane pump assembly according to claim **1**, further comprising a drive shaft arranged to rotate about the rotational axis, wherein a drive end of the drive shaft extends out of the housing.

17. The sliding vane pump assembly according to claim **16**, wherein the drive shaft is releasably engaged with the rotor for rotationally driving the rotor.

18. The sliding vane pump assembly according to claim **16**, further comprising:

a bearing arranged to rotatably support the drive shaft adjacent to its drive end, the bearing comprising a rotatable part coupled to the drive shaft and a static part received in an end portion of the housing; and

a mechanical seal arranged between the rotor and the bearing for preventing fluid leakage along the drive shaft and out of the end portion of the housing, the mechanical seal comprising a rotatable part coupled to the drive shaft and a static part coupled to the housing, wherein the rotatable part has a sealing surface which is resiliently biased into engagement with a sealing surface of the static part by a spring element.

19. The sliding vane pump assembly according to claim **18**, wherein the static part of the mechanical seal is seated on a shoulder provided in the inner surface of the housing which faces the rotatable part of the mechanical seal, the shoulder providing a reaction force opposing the resilient bias of the spring element.

20. The sliding vane pump assembly according to claim **19**, wherein each of the shoulders in the inner surface of the housing are integrally formed in the housing.

21. The sliding vane pump assembly according to claim **18**, wherein the static part of the bearing is seated on a shoulder provided in the inner surface of the housing which faces the drive end of the drive shaft, and wherein the rotatable part of the bearing is seated on a shoulder provided in the drive shaft which faces the shoulder on which the static part is seated, such that the drive shaft is prevented from moving axially under the resilient bias of the spring element.

22. The sliding vane pump assembly according to claim **21**, wherein the shoulder in the drive shaft is provided by a circlip mounted in a circumferential groove in the drive shaft.

23. The sliding vane pump assembly according to claim **1**, wherein the bearing members are formed of a carbon graphite or ceramic material.

24. The sliding vane pump assembly according to claim **1**, wherein each bearing member is provided with a first recessed area in fluid communication with the fluid inlet and each bearing member is provided with a second recessed area in fluid communication with the fluid outlet, and wherein the recessed areas and end surfaces of the lining member together define fluid passageways for transferring fluid between the fluid inlet and fluid outlet and the working chambers.

25. The sliding vane pump assembly according to claim **1**, wherein the housing is a moulded plastics component.

26. The sliding vane pump assembly according to claim **1**, wherein the vanes are formed of a carbon graphite material.

27. The sliding vane pump assembly according to claim **1**, wherein the vanes are formed of a ceramic material.

28. The sliding vane pump assembly according to claim **1**, further comprising a removable strainer assembly, the strainer assembly being received into an opening in the housing and extending across the fluid inlet for filtering particulate matter from the fluid.

29. The sliding vane pump assembly according to claim **28**, wherein the strainer assembly comprises a strainer sleeve formed of porous or perforated material.

30. The sliding vane pump assembly according to claim **28**, wherein the strainer assembly comprises a thermal sensor for providing an electrical signal indicative of temperature.

31. The sliding vane pump assembly according to claim **30**, wherein the thermal sensor is provided in a sealing cap for the opening in the housing in which the strainer is received.

32. A sliding vane pump comprising:

the sliding vane pump assembly according to claim **1**; and

a prime mover arranged to rotatably drive the rotor of the sliding vane pump assembly.

33. The sliding vane pump according to claim **32**, wherein the prime mover is an electric motor.

34. The sliding vane pump according to claim **32**, wherein the sliding vane pump is configured for pumping water in a beverage carbonation system.

35. The sliding vane pump according to claim 32, wherein the sliding vane pump is configured for pumping water in an espresso coffee machine.

36. The sliding vane pump according to claim 32, wherein the sliding vane pump is configured for pumping fluid in reverse osmosis water treatment equipment.

37. The sliding vane pump according to claim 32, wherein the sliding vane pump is configured for pumping fluid in a heating or cooling circuit.

38. A sliding vane pump assembly for providing positive displacement of a fluid, the pump assembly comprising:

a housing having a fluid inlet and a fluid outlet formed therein;

a lining member received in the housing and defining a substantially cylindrical inner surface;

a rotor arranged inside the lining member to rotate about a rotational axis, the rotor defining a substantially cylindrical outer surface, the inner surface of the lining member and the outer surface of the rotor defining a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis; and

a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor, each of the vanes being arranged to slide in a radial direction with respect to the rotor such that an outer edge of the vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers,

wherein rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet,

wherein base portions of the slots formed in the rotor are in fluid communication with each other,

wherein the lining member is formed of a carbon graphite or ceramic material, and

wherein an outer surface of the lining member is provided with a first recessed area in fluid communication with the fluid inlet and a second recessed area in fluid communication with the fluid outlet, and wherein the recessed areas and an inner surface of the housing together define fluid passageways for transferring fluid between the fluid inlet and fluid outlet and the working chambers.

39. The sliding vane pump assembly according to claim 38, wherein inner surfaces of the housing which face the outer surface of the lining member do not have any recessed areas.

40. The sliding vane pump assembly according to claim 38, wherein the lining member is a moulded component, and wherein the recessed areas are moulded into the outer surface of the lining member.

41. A sliding vane pump assembly for providing positive displacement of a fluid, the pump assembly comprising:

a housing having a fluid inlet and a fluid outlet formed therein;

a lining member received in the housing and defining a substantially cylindrical inner surface;

a rotor arranged inside the lining member to rotate about a rotational axis, the rotor defining a substantially cylindrical outer surface, the inner surface of the lining member and the outer surface of the rotor defining a working space therebetween, the working space having a radial cross-sectional area which varies about the rotational axis; and

a plurality of vanes received in substantially radial slots formed about the outer surface of the rotor, each of the vanes being arranged to slide in a radial direction with respect to the rotor such that an outer edge of the vane contacts the inner surface of the lining member, thereby dividing the working space into working chambers,

wherein rotation of the rotor draws the fluid from the fluid inlet into the working chambers and ejects the fluid from the working chambers into the fluid outlet,

wherein base portions of the slots formed in the rotor are in fluid communication with each other, and

wherein each bearing member is provided with a first recessed area in fluid communication with the fluid inlet and each bearing member is provided with a second recessed area in fluid communication with the fluid outlet, and wherein the recessed areas and end surfaces of the lining member together define fluid passageways for transferring fluid between the fluid inlet and fluid outlet and the working chambers.

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