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

(11) EP 3 669 080 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
06.07.2022 Bulletin 2022/27

(21) Application number: **18758713.4**

(22) Date of filing: **14.08.2018**

(51) International Patent Classification (IPC):
F04C 19/00 *(2006.01)* ***F04C 18/00*** *(2006.01)*
F04F 5/06 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F04C 18/00; F04C 19/00; F04F 5/06;
F04C 2220/10; F04C 2280/02

(86) International application number:
PCT/GB2018/052313

(87) International publication number:
WO 2019/034870 (21.02.2019 Gazette 2019/08)

(54) **A PUMP AND A METHOD OF PUMPING A GAS**

PUMPE UND VERFAHREN ZUM PUMPEN EINES GASES

POMPE ET PROCÉDÉ DE POMPAGE D'UN GAZ

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

(30) Priority: **17.08.2017 GB 201713184**

(43) Date of publication of application:
24.06.2020 Bulletin 2020/26

(73) Proprietor: **Edwards Limited**
Burgess Hill, Sussex RH15 9TW (GB)

(72) Inventor: **STONES, Ian, David**
Burgess Hill, Sussex RH15 9TW (GB)

(74) Representative: **Arnold, Emily Anne**
Edwards Limited
Innovation Drive
Burgess Hill, West Sussex RH15 9TW (GB)

(56) References cited:
GB-A- 1 282 803 **JP-A- S55 134 791**
US-A- 3 596 885

- **DATABASE WPI Week 201641 2016 Thomson Scientific, London, GB; AN 2016-29001P XP002785406, -& CN 105 536 396 A (XINJIANG INST ENG) 4 May 2016 (2016-05-04)**

EP 3 669 080 B1

Description

FIELD OF THE INVENTION

[0001] The field of the invention relates to pumps and methods of pumping a gas.

BACKGROUND

[0002] Different types of pumps for pumping gases are known. These include entrapment type pumps, where a gas is captured on a surface inside the pump prior to being removed; kinetic or momentum transfer pumps such as turbomolecular pumps where the molecules of the gas are accelerated from the inlet side towards the outlet or exhaust side, and positive displacement pumps, where gas is trapped and moved from the inlet towards the outlet of the pump.

[0003] Patent document JP S55 134791 A describes a centrifugal-type pump in which a plurality of spray liquid outlets are provided in a rotating ring. The pressurised liquid becomes a radial plate-like spray liquid and transports the gas in accordance with rotation of the rotating ring. Patent document GB 1282803 A relates to a centrifugal liquid vane compressor for causing a gaseous medium to move in the direction of rotation of the liquid vanes and for compressing it.

[0004] Positive displacement pumps provide moving pumping chambers generally formed between one or more rotors and a stator, the movement of the rotors causing the effective pumping chamber to move. Gas received at an inlet enters and is trapped in the pumping chamber and moved to an outlet. In some cases the volume of the gas pocket reduces during movement to improve efficiency. Such pumps include roots and rotary vane type pumps. In order to draw the gas into the chamber, the chamber generally expands and to expel the gas from the chamber, the chamber volume generally contracts. This change in volume can be achieved for example in a rotary vane pump by blades that extend in and out of the pump chamber using devices such as springs, which are themselves subject to wear, or using two synchronised rotors in a roots or screw pump which cooperate with each other and a stator to move a pocket of gas and generate the volumetric changes between inlet and outlet. An additional rotor requires an additional shaft, bearings and timing methods such as gears to synchronise the rotor movements.

[0005] Furthermore, in order to minimise or at least reduce leakage and move the gas efficiently while it is trapped the moving parts need to form a close seal with each other and with the static parts which form the trapped volume of gas. Some pumps use a liquid such as oil to seal between the surfaces of the trapped volume whilst others rely on tight non-contacting clearances which can lead to increased manufacturing costs and can also lead to pumps that are sensitive to locking or seizure if the parts come into contact or where particulates or impurities are present in the fluid being pumped.

[0006] A further type of positive displacement pump is a scroll pump. This uses two interleaving scrolls to pump fluids such as liquids and gases. The scroll or geometry may be involute, Archimedean spiral, or hybrid curves. Often, one of the scrolls is fixed, while the other orbits eccentrically without rotating, thereby trapping and pumping or moving pockets of fluid between the scrolls. Another method for producing the pumping motion is to co-rotate the scrolls, in synchronous motion, but with offset centres of rotation. The relative motion is the same as if one were orbiting. In either case, the two scrolls need to be carefully manufactured to fit and orbit within each other.

[0007] It would be desirable to provide a pump that is resistant to wear, offers low power consumption and a relatively small pumping mechanism and is relatively inexpensive to manufacture and operate.

SUMMARY

[0008] A first aspect of the present invention provides a positive displacement pump for pumping a gas, said pump comprising: a pump housing element and a further element; one of said pump housing element and said further element comprising a protrusion extending towards the other element, said other element comprising at least one liquid opening; said protrusion, pump housing element and further element forming a path from a gas inlet to a gas outlet; wherein said pump housing element and further element are mounted rotatably with respect to each other; and said at least one liquid opening is configured such that liquid output from said at least one liquid opening forms a liquid blade, said liquid blade being operable to drive gas along said path from said gas inlet to said gas outlet on rotation of one of said elements.

[0009] The inventor of the present invention recognised that were the elements of a pump to be configured with liquid opening(s) such that liquid output through the openings formed a surface or blade between the elements of the pump, then on rotation of one of the elements with respect to the other, the liquid blade could be used to drive the gas through the pump. Furthermore, if the elements of the pump were configured such that a protrusion extending between them formed a path from a gas inlet to a gas outlet, then such a path could lead the gas from the inlet to the outlet driven by the liquid blade extending between the elements and across the path. This would have the potential to provide a simple, compact, low power, low cost arrangement and the problems that arise due to friction and wear between contacting surfaces and the cost involved in manufacturing tolerances for tight clearances would be avoided or at least mitigated.

[0010] Such a blade could be formed by driving a liquid through one or more liquid openings. Arranging the liquid opening(s) on one of the elements allows a stream of liquid to form a liquid surface or blade between the elements. Such a liquid blade is by its nature, deformable, low cost, and able to provide good sealing between surfaces of the trapped volume without the need for tight manufacturing tolerances. Furthermore, such a blade is not subject to wear itself and provides very little wear on the surfaces that it contacts.

[0011] The blade is formed of a flowing liquid such that the liquid forming the blade is continuously replenished. A surface of the blade acts along with a surface of the elements, and protrusion to confine, trap, isolate or enclose the gas to be pumped. Rotation of one of the elements causes the trapped gas to be moved from a gas inlet to a gas outlet along a path defined by the protrusion. Gas to be pumped is located on either side of the blade.

[0012] One or other of the elements may be mounted to rotate, or both may be mounted to rotate in opposite directions. In this regard relative motion between the elements is required, it is unimportant which is the rotating element. In some embodiments, the pump housing element is mounted to be stationery and the further element is mounted to rotate.

[0013] In some embodiments, said at least one liquid opening is formed on a surface of said element that is mounted to rotate.

[0014] The element that is mounted to rotate is generally termed the rotor and it may be advantageous if this is the element having the liquid openings as the rotating motion may help in the expelling of liquid from the liquid openings to form the blades.

[0015] In some embodiments, a cross section of said path formed by said protrusion, pump housing element and further element decreases from said gas inlet to said gas outlet.

[0016] In some cases the cross section of the path may decrease between the inlet and outlet, either continually or along portions of the path. The resulting reduction in volume leads to volumetric compression of the gas as it is pumped which not only aids in the expelling of gas from the chamber but also reduces the power required for pumping a given volume of gas.

[0017] In some embodiments, said further element comprises a disk mounted axially offset from said pump housing element.

[0018] One form of pump may be a scroll type pump with the pump housing element comprising protrusion(s) forming a path from gas inlet to gas outlet. A rotating disk is mounted axially offset from the pump housing element and liquid expelled through openings in the disk forms one or more liquid blades that drives the gas along the path defined by the protrusion. This provides a pump with a similar function to a scroll pump but without the need to carefully manufacture cooperating elements with protrusions that fit and orbit within each other. The driving force is provided by a liquid blade which can deform to fit around the protrusions.

[0019] The disk is axially offset from the other component, and in some embodiments is mounted above the other component in operation as in this configuration draining of the liquid forming the blades from the pump is facilitated by gravity.

[0020] In some embodiments, said pump housing element comprises said protrusion and said at least one liquid opening extends along at least a portion of a diameter of a surface of said disk facing said protrusion.

[0021] The liquid blade should extend across the path formed by the protrusions and elements in order to be able to drive the gas along the path. Where the blade forming element is a disk, then having openings along a diameter of a surface of the disk allows liquid to be driven along a path that orbits around the pump housing element towards an outlet. The blade may extend across several protrusions acting to drive the gas in different portions of the orbiting path.

[0022] In some embodiments, said protrusion has a spiral form. In other embodiments, said protrusion comprises a plurality of concentric rings. The plurality of concentric rings may comprise blocking elements forming routing channels from one or more of the concentric ring to one or more other of the concentric ring located towards the gas outlet. In some cases volumetric compression may be provided by configuring the blocking elements and protrusions such that two paths combine into a single path.

[0023] The protrusions may have a number of forms providing a path from an inlet to outlet. Where the elements have a circular cross section then a spiral or some form of concentric ring arrangement allows for much of the area of the pump to be used for the path along which the gas can be driven. Furthermore, a blade formed along a radius of the cross section acts to drive along multiple sections of the paths.

[0024] In some embodiments, said further element is mounted within a bore of said pump housing element such that said further element comprises an inner component and said pump housing element comprises an outer component.

[0025] In some embodiments said inner component is eccentrically mounted within said bore of said outer component, while in others said inner component is concentrically mounted within said bore of said outer component.

[0026] Eccentrically mounting the inner component means that when there is relative rotation the gas pocket formed by the pump housing elements and liquid blade will change in volume around the circumference of the elements. This eccentric mounting requires the blades to change in size as the element(s) rotate, but this will happen naturally. There is no requirement for mechanical or sliding parts such as springs and solid blades to create the changing size of the blades.

[0027] The liquid outlet(s) may be arranged in a number of ways. There may be a plurality of liquid outlets arranged adjacent to each other, or there may be a single outlet in a slot form. In some embodiments, the slot or plurality of outlets has a longitudinal form running substantially parallel to an axis of the elements. Such an arrangement provides a blade substantially perpendicular to the radius of the pumping chamber.

[0028] In other embodiments the slot or adjacent outlets may be angled with respect to the axis of the elements and in some cases may form a helix such that a helical liquid blade is formed between the stator and rotor.

[0029] A pump configured to generate such a blade may be used in conjunction with a helical protrusion on the surface of the other component, or in conjunction with a protrusion of a different form. A helical protrusion provides a pump that acts in a similar way to a screw pump. Such a protrusion can be used in conjunction with an axial liquid blade or with a helical blade.

[0030] In some embodiments, an angle of said helix changes from said gas inlet towards said gas outlet such that a pitch of said helix reduces towards said gas outlet.

[0031] Reduction of the pitch of the helix towards the gas outlet provides volumetric compression to the gas as it is pumped which not only aids in the expelling of gas from the chamber but also reduces the power required for pumping a given volume of gas.

[0032] In some embodiments, at least one of said pump housing element and further element are tapered such that a distance between said stator and said rotor reduces towards said gas outlet.

[0033] In the case of a screw type arrangement a way of providing a pumping chamber which reduces in size between the inlet and outlet is to provide a tapering such that the distance between the elements reduces towards the gas outlet. In some embodiments it is the non rotating element or stator that is tapered, while in others it is the rotating element or rotor that is tapered. Tapering of the stator that does not rotate is often the simplest way of generating the reduction in size of the pumping chamber towards the gas outlet.

[0034] In some embodiments said at least one of said pump housing element and further element that are tapered are non axi-symmetrically tapered.

[0035] Although generally the taper will be axi-symmetric, in some embodiments it is the bore of the outer component that is non axi-symmetrically tapered towards said gas outlet, while in other embodiment the inner component may have an increasing diameter.

[0036] In some embodiments, said plurality of liquid outlets provide a plurality of streams of liquid which form a plurality of liquid blades between said pump housing element and further element.

[0037] Although, the pump may comprise a single liquid opening to form a single liquid blade in some embodiments it comprises a plurality of liquid openings. Liquid from the plurality of openings may form a single blade or the openings may be arranged such that liquid expelled from them forms a plurality of blades.

[0038] In some embodiments, at least one set of said plurality of liquid openings are arranged adjacent to each other and streams output from said at least one set of said plurality of liquid openings combine to form a single liquid blade.

[0039] In some cases there may be a plurality of openings and a set of these may form a single blade. Where there is only one blade this set may comprise all the liquid openings, while in other embodiments, there may be several sets each set arranged to form their own blade. Although a liquid blade may be formed from a single liquid outlet in the form of say a slot, in some embodiments it may be formed by a plurality of adjacent openings that are close enough together for the streams of liquid through each to coalesce and form a single blade. Having a plurality of openings rather than a single slot may improve the structural integrity of the elements that they are arranged on and thereby improve the mechanical integrity of the pump.

[0040] For the purposes of this patent application where the term rotor is used this refers to the pump housing element or further element that rotates and where the term stator is used this refers to the element that the rotor rotates with respect to. Furthermore, the gas to be pumped may be a vapour, or a gas vapour mixture, or a gas having particles entrained within it.

[0041] In some embodiments, the rotor is rotatably mounted within a bore of the stator and the stream of liquid forming the liquid blade between the rotor and the stator bore is operable to drive the gas through the pump on rotation of the rotor within the stator bore.

[0042] Rotation of the rotor provides relative motion between the surfaces enclosing the gas pocket, such that in some embodiments the liquid surface drives the gas along a pumping path from a gas inlet to a gas outlet. This relative motion along with, in some embodiments, a change in volume of the gas pocket can be provided without any appreciable wear on the surfaces confining the gas pocket as at least one is formed from a liquid blade and due to its deformable nature its surface shape and size will adapt to the distance between the rotor and stator during rotation.

[0043] In some embodiments said pump comprises a driving mechanism for exerting a driving force on the liquid to drive said liquid from said liquid source through said at least one liquid opening.

[0044] Although the driving force exerted on the liquid may come from a source external to the pump, the pump may for example be connected to an external pressurised liquid source, in some embodiments the pump itself comprises a driving mechanism for exerting this driving force on the liquid.

[0045] Although the liquid openings may be formed on the surface of a rotatable inner component, in some embodiments they are formed on the surface of a stationery outer component. This may have the advantage of allowing a simpler way of supplying pressurised liquid to the pump.

[0046] In some embodiments, said pump further comprises a liquid reservoir, said inner component being rotatably mounted and comprising a hollow body having an opening at a lower end extending into said liquid reservoir, an internal diameter of said hollow rotor increasing from said lower end.

[0047] One way of providing the driving force to the liquid where the liquid outlet(s) are on the rotating inner component is to use a hollow component and to spin this hollow component. In such an embodiment, the spinning of the hollow rotor will cause liquid within the hollow rotor body to be forced by centrifugal action against the outer circumference of the hollow rotor body and out through the one or more liquid outlets forming a liquid stream. Where the liquid outlets are arranged appropriately this liquid stream will form the liquid blade extending to the stator bore.

[0048] Where said hollow rotor has an opening at a lower end extending into the liquid reservoir, an internal diameter of the hollow rotor increasing from said lower end will help liquid to rise up within the rotor and be expelled through the liquid outlet(s) on spinning of the rotor. In this way at the lower end that is immersed in the liquid reservoir there is a smaller diameter and the diameter increases up the hollow body. This causes liquid pushed by a centrifugal force against the inner surface of the hollow body to rise up the increasing internal diameter towards the top of the rotor body. The increase in diameter may be a sloped increase or it may be a stepped increase or it may be a combination of the two. It may also be complemented by vanes on the internal surface of the rotor to support the acceleration of the liquid towards the larger diameter. The liquid is thrown out towards the inner surface of the hollow body and rises up pushed up by the acceleration and pressure of the following liquid. The speed of rotation will affect how high the liquid is pushed up the hollow body, as will other parameters such as the density of the liquid. Appropriate speeds and sizes of rotor can be selected according to the desired flow rate of the liquid to be pumped through the outlets to form the blades or vanes. It should be noted that sufficient liquid should be supplied from the reservoir into the hollow rotor body to maintain an uninterrupted stream of liquid between the rotor and the stator in order for the gas to be effectively pumped. This again will depend on the parameters such as the rotating speed of the rotor and also the size and number of outlets, and the height of the rotor.

[0049] In some embodiments, said pump comprises at least one hydrodynamic bearing to support at least one end of said rotating element.

[0050] Rotors of pumps are supported on bearings and typically these are roller bearings or ball bearings which can be expensive parts, requiring lubrication and subject to wear. A hydrodynamic bearing which utilises a liquid film between a cylindrical shaft and bore may be appropriate for this type of pump. In some cases the hydrodynamic bearing is filled with liquid from the same liquid source as the pump blades making efficient use of the liquid supply and mechanical features already used in the pump and avoiding the use of additional components or a different lubricant liquid.

[0051] Although the pump may be a number of things such as a compressor, in some embodiments it comprises a vacuum pump. Pumps according to embodiments, make particularly effective vacuum pumps allowing gas to be transported in an efficient manner with low wear and a low initial cost.

[0052] A second aspect of the present invention provides a wet scrubber for reducing pollutants pumped from an abatement system, said wet scrubber comprising a pump according to first aspect of the present invention.

[0053] Abatement systems are often used in conjunction with wet scrubbers which provide a stream of liquid to react with gases or remove particulates from the gases that are pumped from the abatement system. A pump that uses a liquid surface to move the gas may be used either in conjunction with an additional liquid scrubbing source or on its own, providing both the liquid source and the pumping required to move the gas and to remove particulates from it.

[0054] A third aspect of the present invention provides a method of pumping a gas, said method comprising: outputting liquid from at least one liquid opening on one of a positive displacement pump housing element or a further element, the other of said pump housing element and said further element comprising a protrusion, said protrusion, pump housing element and further element forming a path from a gas inlet to a gas outlet; rotating one of said pump housing element or said further element such that liquid output from said at least one liquid opening forms a liquid blade and drives gas along said path from said gas inlet to said gas outlet on rotation of one of said elements.

[0055] Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

[0056] Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0057] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 shows a cross section and longitudinal section of a scroll pump type embodiment;

Figure 2 shows a cross section and longitudinal section of an alternative scroll pump type embodiment;

Figures 3, 4A and 4B show screw pump type embodiments with a helical protrusion on the stator bore and liquid openings on the rotor;

Figure 3 shows an embodiment with longitudinal blades;

Figure 4A shows an embodiment with a tapered stator bore;

Figure 4B shows an embodiment with helical blades;

Figure 5 shows liquid openings on an inner component for forming longitudinal liquid blades according to embodiments;

Figure 6 shows liquid openings on an inner component for forming a helical liquid blade according to an embodiment; and

Figure 7 show a hollow shaft in a reservoir with liquid blades formed by liquid expelled from liquid openings during rotation of the shaft.

DESCRIPTION OF THE EMBODIMENTS

[0058] Before discussing the embodiments in any more detail, first an overview will be provided.

[0059] Embodiments provide a pump comprising liquid blades that are high velocity surfaces formed of liquid, which surfaces emulate some of the solid mechanical surfaces which are found in conventional vacuum pumps and which are used as the physical boundaries to isolate and move pockets of gas. The liquid may be water, other liquids may be used for example to change characteristics of the pump such as vapour pressure or process compatibility.

[0060] The size and shape of the liquid surfaces will adapt to the relative position of the other pump elements unlike a rigid solid surface found in conventional pumps and will also provide a good seal with other surfaces without either causing appreciable wear on these surfaces or relying on tight tolerances or being sensitive to particulates in any gas or fluid flow being pumped.

[0061] The liquid "blades" are formed from a continuous stream of liquid originating from holes or slots in a rotating element that forms the rotor of the pump. The streams of liquid travel at high velocity towards the other pump housing element. The pressure required to drive the liquid from one element to the other under high velocity can be achieved through centrifugal action of the rotating element, through a pressurised liquid source, or through a combination of the two.

[0062] Protrusions formed between the elements define a path that liquid blade(s) can drive gas along on rotation of one of the pumping house elements.

[0063] Figure 1 shows an embodiment of the invention that uses a 'solid scroll form' screw and a rotating disc with in this embodiment liquid openings along different radial lines of the disk, providing liquid blades 40 which extend into the page in the top figure and provide a radial blade which sweeps along a circular path as the disk rotates driving gas around the spiral path defined by protrusion 25 from the gas inlet 50 to the gas outlet 52.

[0064] A pump housing is formed of a pump housing element 20 with the rotor 10 being a disk mounted above and concentrically with the pump housing.

[0065] The liquid blades 40 may have different forms depending on the arrangement of the liquid openings provided that they extend across the path defined by the protrusion 25 and thus, on rotation of one of the elements drive the gas from the gas inlet 50 to the gas outlet 52.

[0066] The lower view is a section through the centreline of the upper diagram and shows the liquid streams from individual openings and the protrusions 25 extending from pump housing element 20 towards rotor 10. In practice the liquid streams from the openings will coalesce to form a curtain or blade for driving the gas.

[0067] The use of a liquid blade in this arrangement obviates the need for two interlocking scrolls and may offer simpler, lower cost manufacturing methods to create the scroll form and liquid slots. Although in this embodiment the disk spins, the reverse operation is also possible using a spinning scroll form and liquid surfaces injected under pressure from a stator disc inwards towards the thread form.

[0068] Figure 2 shows an alternative embodiment that operates on the same principle as the solid scroll. In this embodiment the protrusion 25 is in the form of a concentric channel arrangement with strippers 54 and crossover port 56 where two channels merge into one. Although this is shown here for a disc type pump the same arrangement could be applied to a cylinder.

[0069] For several of these liquid blade arrangements, the number of pumping stages can be increased to increase capacity and various channel combinations can be used to yield different performance characteristics as is known in the art of the conventional mechanical pumps.

[0070] Figure 3 shows an alternative embodiment where the further element 10 is mounted within the pump housing element 20. In this embodiment, the protrusion 25 is a thread extending from the inner surface of pump housing element 20. This internal thread 25 is in the form of a helix. This can be used in conjunction with the inner components of Figure 5 having longitudinal slots or that of Figure 6 having helical slots.

[0071] In this embodiment the inner component is rotatably mounted 10 with the lower end in a liquid reservoir 30. On rotation of the inner component, rotor 10, liquid rises up the hollow shaft and is output through liquid openings to form longitudinal liquid blades 40 which sweep gas along a helical path defined by thread 25, stator bore 20 and rotor 10 from gas inlet 50 to gas outlet 52. In effect the liquid surfaces 40 create trapped 'pockets' along the thread form and as the liquid surfaces rotate the pockets move from the gas inlet towards the gas outlet. The shape of the thread may be adapted to the curvature of the liquid surface to provide appropriate sealing across the channel.

[0072] Although in this embodiment the thread is on the stator and the rotor rotates, where the helical path is formed by a mechanical thread or protrusion on the surface of one of the components, it is only relative motion between the two components that is required and as such, the thread could be on the rotor and the stator could have the liquid outlets. In this regard the stator is the fixed part and the rotor the rotating part, the rotor may be the inner component or it may be the outer component. In the latter case, the stator is a cylinder within the rotating outer component. In this embodiment, the stator and rotor may be concentrically mounted. It should be noted that where the liquid openings are on the static component then a different way of driving the liquid from the liquid openings will be required, such as by connection to a pressurised liquid source.

[0073] Although in this embodiment the liquid outlets are shown as slots extending vertically, they may be a plurality of adjacent liquid outlets following this formations, or they may have a different formation, albeit they will extend along the longitudinal axis of the component between the gas inlet 50 and gas outlet 52.

[0074] An advantage of having a mechanical thread 25 is that there may be an increased tolerance to back migration of the liquid when it hits the opposing surface, driving the liquid towards the outlet and achieving higher pressure ratios across the pump.

[0075] Figure 4A shows a further embodiment similar to that of Figure 3, but where a tapered stator is used. In this embodiment the inner component is mounted concentrically within the outer component and there is a solid helical thread 25 extending from the outer component.

[0076] On relative rotation of the inner and outer component gas from an inlet 50 is driven along a helical path defined by thread 25 towards outlet 52. The tapered bore acts to compress the gas as it travels towards the outlet. Owing to the tapered bore the liquid blade towards the gas outlet is smaller than it is towards the inlet and is therefore able to support an increased differential pressure. The power required to drive the rotating component to pump the fluid in such an arrangement is also significantly reduced.

[0077] In some embodiments the liquid openings on the inner component 10 may have a longitudinal form as shown in Figure 5 to provide axial blades that drive the gas along the helical path formed by the thread 25. In other embodiments the inner component 10 may have liquid openings in a helical form as shown in Figure 6 to provide a helical blade.

[0078] Where the liquid openings have a helical form as in figure 6 to form helical blades, then the helical form of the thread and blades progress in opposite directions, such that if the helical thread descends in a clockwise direction, the helical blades descend in an anti-clockwise direction. This is shown in more detail for a non-tapered bore embodiment in Figure 4B.

[0079] Figures 5 and 6 show different arrangements of liquid openings 15 on the inner components of pumps of embodiments. In figure 5 the openings 15 are arranged longitudinally in an axial direction along the inner component 10 and in operation provide longitudinal blades for sweeping gas along a path defined by protrusions on the outer component. Each blade may be formed by one longitudinal slot or by a plurality of liquid openings arranged along a length of the inner component. A plurality of blades may be provided at different circumferential positions of the inner component.

[0080] Figure 6 shows an alternative embodiment where the liquid opening is a helix and provides in operation a helical blade. In the embodiment shown the helix is formed from one helical slot, while in other embodiments, it may be formed from a plurality of openings arranged along a helical path.

[0081] The liquid blades are formed by driving liquid through the openings. This may be done in a number of ways, by for example using a pressurised liquid source. However, in some embodiments where the liquid openings are on the rotor of the pump, the force for driving the liquid is provided by the driving mechanism used to rotate the rotor.

[0082] Figure 7 shows how on rotation of a hollow rotor 10 within a liquid reservoir 30, liquid is driven through liquid openings to form liquid blades. Figure 7 shows a cross section through a substantially circular hollow shaft 10 which is configured to rotate in a substantially circular stator bore 20. The shaft forms the rotor 10 of the pump and has an outside diameter that is smaller than the stator bore 20 inside diameter. The axes of the shaft and stator are orientated vertically and the base of the hollow open ended shaft is submerged in a liquid reservoir 30.

[0083] Figure 7 shows the liquid 32 from liquid reservoir 30 rising up the shaft 10 on rotation of the rotor. The hollow bore of the shaft 10 has an internal increase in diameter 12 positioned below the liquid reservoir level which serves when the shaft rotates to accelerate the liquid through centrifugal force and pump it up the inside of the shaft then out of holes or elongated slots (not shown) in the shaft to form a contiguous liquid surface 40 between the shaft or rotor 10 and the stator inner bore 20. The liquid flows back down the inner wall of the stator bore 20 into the reservoir 30. This is on a continuous cycle basis, such that the liquid, in some embodiments water, that contacts the stator inner bore 20 travels down the bore under gravity and replenishes the reservoir. Note that the arrows depict the direction of flow of the liquid to create a single surface or blade 40.

[0084] The liquid inside the shaft is forced through the holes / slots under centrifugal force and travels towards the stator bore to form the plurality of liquid surfaces 40, these form blades that drive the gas through the pump as the rotor 10 rotates.

[0085] Although in many of the embodiments described above the liquid circulation providing the liquid surface is generated by a rotating rotor providing a centrifugal force on the liquid, in some embodiments an alternative way of generating the liquid circulation is used, namely that of a high pressure liquid source.

[0086] Such a high pressure liquid supply or pump could be used separately or in conjunction with regulated shaft rotation - enabling independent variability of both fluid velocity and shaft frequency according to pumping performance requirements allowing controllable efficiency and pump tuning.

[0087] In some embodiments, the pump may be used in a wet scrubbing environment so that the pumping function may be integrated into the wet scrubbing, the liquid blades being an advantage in such an embodiment. In this regard, by placing one of the liquid blade pumps in line with process gas flow the pump may be used for wet scrubbing in addition to vacuum generation - for example on the outlet (or inlet) of an abatement system.

[0088] Where a means to drive the shaft is required such as a motor and frequency inverter or belt drive, such a drive system may preferentially be positioned at the top of the shaft to reduce risk of liquid leaking into the drive means.

[0089] In summary, embodiments function effectively where a circulation of liquid that meets or exceeds the emission from the liquid outlets can be achieved. This helps sustain the blades as a continuous surface. It should be noted that many parameters such as the size of the liquid outlets, the type of liquid used, the liquid velocity, the distance between elements and the length of blade and the speed of rotation all affect the formation and maintenance of the liquid surfaces. Thus, these features should be selected depending on the properties required of a particular pump, such as power consumption, pumping capacity and compression.

[0090] Although illustrative embodiments of the invention have been disclosed in detail herein, with reference to the accompanying drawings, it is understood that the invention is not limited to the precise embodiment and that various changes and modifications can be effected therein by one skilled in the art without departing from the scope of the invention as defined by the appended claims.

REFERENCE SIGNS

[0091]

10 rotating element
12 change in diameter of rotor
15 liquid openings
20 pump housing element
25 protrusion
30 liquid reservoir
32 liquid from reservoir
40 liquid blades
50 gas inlet
52 gas outlet

Claims

1. A positive displacement pump for pumping a gas, said pump comprising:

a pump housing element (20) and a further element (10);
one of said pump housing element (20) and said further element (10) comprising a protrusion (25) extending towards the other element (20,10), said other element (20,10) comprising at least one liquid opening (15);
said protrusion (25), pump housing element (20) and further element (10) forming a path from a gas inlet (50) to a gas outlet (52); wherein
said pump housing element (20) and further element (10) are mounted rotatably with respect to each other; and

said at least one liquid opening (15) is configured such that liquid output from said at least one liquid opening forms a liquid blade (40), said liquid blade (40) being operable to drive gas along said path from said gas inlet (50) to said gas outlet (52) on rotation of one of said elements (20,10).

2. A pump according to claim 1, wherein said pump housing element (20) is mounted to be stationery and said further element (10) is mounted to rotate

3. A pump according to any preceding claim, wherein said at least one liquid opening (15) is formed on a surface of said element (10) that is mounted to rotate.

4. A pump according to any preceding claim, wherein a cross section of said path formed by said protrusion (25), pump housing element (20) and further element (10) decreases from said gas inlet (50) to said gas outlet (52).

5. A pump according to any preceding claim, wherein said further element (10) comprises a disk mounted axially offset from said pump housing element (20), said pump housing element (20) comprising said protrusion (25) and said at least one liquid opening (15) extends along at least a portion of a diameter of a surface of said disk facing said protrusion (25), wherein optionally, said protrusion (25) has at least one of a spiral or concentric ring form.

6. A pump according to any preceding claim, wherein said further element (10) is mounted within a bore of said pump housing element (20) such that said further element (10) comprises an inner component and said pump housing element (20) comprises an outer component, wherein optionally, said inner component is concentrically mounted within said bore of said outer component.

7. A pump according to claim 6, wherein said at least one liquid opening (15) comprises at least one liquid opening (15) extending along at least a portion of a length of one of said pump housing element (20) or further element (10), wherein said at least one liquid opening (15) is arranged along a longitudinal direction running substantially parallel to an axis of said elements (20,10).

8. A pump according to claim 6 or 7, wherein said at least one liquid opening (15) is arranged in the form of a helix extending around a surface of said pump housing element (20) or further element (10).

9. A pump according to any one of claims 6 to 8, wherein said protrusion (25) comprises a helix, wherein optionally, an angle of said helix changes from said gas inlet (50) towards said gas outlet (52) such that a pitch of said helix reduces towards said gas outlet (52).

10. A pump according to any one of claims 6 to 9, wherein at least one of said pump housing element (20) and further element (10) are tapered such that a distance between said pump housing element (20) and further element (10) reduces towards said gas outlet (52).

11. A pump according to any one of claims 6 to 10, further comprising a liquid reservoir (30), said inner component being rotatably mounted and comprising a hollow body having an opening at a lower end extending into said liquid reservoir (30), an internal diameter of said hollow rotor increasing from said lower end.

12. A pump according to any preceding claim comprising a plurality of liquid openings (15), wherein said plurality of liquid openings (15) provide a plurality of streams of liquid which form a plurality of liquid blades (40) between said pump housing element (20) and said further element (10) and/or wherein at least one set of said plurality of liquid outlets (15) are arranged adjacent to each other and streams output from said at least one set of said plurality of liquid outlets (15) form a single liquid blade (40).

13. A pump according to any preceding claim wherein said pump is a vacuum pump.

14. A wet scrubber for reducing pollutants pumped from an abatement system, said wet scrubber comprising a pump according to any preceding claim.

15. A method of pumping a gas, said method comprising:

outputting liquid from at least one liquid opening (15) on one of a positive displacement pump housing element (20) or a further element (10), the other of said pump housing element (20) and said further element (10) comprising a protrusion (25), said protrusion (25), pump housing element (20) and further element (10) forming a path from a gas inlet (50) to a gas outlet (52);
rotating one of said pump housing element (20) or said further element (10) such that liquid output from said at least one liquid opening (15) forms a liquid blade (40) and drives gas along said path from said gas inlet (50) to said gas outlet (52) on rotation of one of said elements (20,10).

Patentansprüche

1. Verdrängerpumpe zum Pumpen eines Gases, wobei die Pumpe aufweist:

ein Pumpengehäuseelement (20) und ein weiteres Element (10); wobei eines von dem Pumpengehäuseelement (20) und dem weiteren Element (10) einen Vorsprung (25) aufweist, der zu dem anderen Element (20, 10) hin vorspringt, wobei das andere Element (20, 10) mindestens eine Flüssigkeitsöffnung (15) aufweist;
wobei der Vorsprung (25), das Pumpengehäuseelement (20) und das weitere Element (10) einem Pfad von einem Gaseinlass (50) zu einem Gasauslass (52) bilden; wobei das Pumpengehäuseelement (20) und das weitere Element (10) mit Bezug zueinander drehbar montiert sind; und
die mindestens eine Flüssigkeitsöffnung (15) so konfiguriert ist, dass ein Flüssigkeitsaustritt aus der mindestens einen Flüssigkeitsöffnung einen Flüssigkeitsschild (40) bildet, wobei der Flüssigkeitsschild (40) zum Fördern von Gas entlang des Pfads von dem Gaseinlass (50) zu dem Gasauslass (52) durch Drehung eines der beiden Elemente (20, 10) betreibbar ist.

2. Pumpe nach Anspruch 1, wobei das Pumpengehäuseelement (20) stationär montiert und das weitere Element (10) drehbar montiert ist.

3. Pumpe nach irgendeinem vorhergehenden Anspruch, wobei die mindestens eine Flüssigkeitsöffnung (15) auf einer Oberfläche des Elements (10) gebildet ist, das drehbar montiert ist.

4. Pumpe nach irgendeinem vorhergehenden Anspruch, wobei ein Querschnitt des Pfads, der durch den Vorsprung (25), das Pumpengehäuseelement (20), und das weitere Element (10) gebildet ist, vom Gaseinlass (50) zum Gasauslass (52) kleiner wird.

5. Pumpe nach irgendeinem vorhergehenden Anspruch, wobei das weitere Element (10) eine Scheibe umfasst, die axial versetzt von dem Pumpengehäuseelement (20) montiert ist, wobei das Pumpengehäuseelement (20) den Vorsprung (25) aufweist und die mindestens eine Flüssigkeitsöffnung (15) entlang mindestens eines Teils eines Durchmessers einer dem Vorsprung (25) zugewandten Oberfläche der Scheibe verläuft, wobei optional der Vorsprung (25) mindestens eine von einer spiraligen oder konzentrischen Ringform hat.

6. Pumpe nach irgendeinem vorhergehenden Anspruch, wobei das weitere Element (10) in einer Bohrung des Pumpengehäuseelements (20) derart montiert ist, dass das weitere Element (10) eine innere Komponente aufweist, und das Pumpengehäuseelement (20) eine äußere Komponente aufweist, wobei optional die innere Komponente konzentrisch innerhalb der Bohrung der äußeren Komponente montiert ist.

7. Pumpe nach Anspruch 6, wobei die mindestens eine Flüssigkeitsöffnung (15) mindestens eine entlang mindestens eines Teils einer Länge eines von dem Pumpengehäuse-element (20) oder dem weiteren Element (10) verlaufende Flüssigkeitsöffnung (15) aufweist, wobei die mindestens eine Flüssigkeitsöffnung (15) entlang einer Längsrichtung angeordnet ist, die im wesentlichen parallel zu einer Achse der Elemente (20, 10) verläuft.

8. Pumpe nach Anspruch 6 oder 7, wobei die mindestens eine Flüssigkeitsöffnung (15) in Form einer Helix angeordnet ist, die um eine Fläche des Pumpengehäuseelements (20) oder des weiteren Elements (10) herum verläuft.

9. Pumpe nach einem der Ansprüche 6 bis 8,wobei der Vorsprung (25) eine Helix aufweist, wobei optional ein Winkel der Helix sich vom Gaseinlass (50) zum Gasauslass (52) hin derart verändert, dass eine Steigung der Helix zum Gasauslass (52) hin abnimmt.

10. Pumpe nach einem der Ansprüche 6 bis 9, wobei mindestens eines von dem Pumpengehäuseelement (20) und dem weiteren Element (10) so verjüngt ist, dass ein Abstand zwischen dem Pumpengehäuseelement (20) und dem weiteren Element (10) sich zum Gasauslass (52) hin verringert.

11. Pumpe nach einem der Ansprüche 6 bis 10, die weiter einen Flüssigkeitsbehälter (30) aufweist, wobei die innere Komponente drehbar montiert ist und einen Hohlkörper aufweist, der eine Öffnung an einem in den Flüssigkeitsbehälter (30) hinein ragenden unteren Ende aufweist, wobei ein Innendurchmesser des hohlen Rotors vom unteren Ende her zunimmt.

12. Pumpe nach irgendeinem vorhergehenden Anspruch, mit einer Mehrzahl von Flüssigkeitsöffnungen (15), wobei die Mehrzahl von Flüssigkeitsöffnungen (15) eine Mehrzahl von Flüssigkeitsströmen bereitstellt, die eine Mehrzahl von Flüssigkeitsschilden (40) zwischen dem Pumpengehäuseelement (20) und dem weiteren Element (10) bilden, und/oder wobei mindestens eine Gruppe der Mehrzahl von Flüssigkeitsauslässen (15) nebeneinander angeordnet ist und Strömungsaustritte aus der mindestens einen Gruppe der Mehrzahl von Flüssigkeitsauslässen (15) einen einzigen Flüssigkeitsschild (40) bilden.

13. Pumpe nach irgendeinem vorhergehenden Anspruch, wobei die Pumpe eine Vakuumpumpe ist.

14. Nasswäscher zum Reduzieren von gepumpten Verunreinigungsstoffen aus einem Beseitigungssystem, wobei der Nasswäscher eine Pumpe nach irgendeinem vorhergehenden Anspruch aufweist.

15. Verfahren zum Pumpen eines Gases, wobei das Verfahren umfasst:

Ausgeben von Flüssigkeit aus mindestens einer Flüssigkeitsöffnung (15) an einem von einem Verdrängerpumpengehäuseelement (20) oder einem weiteren Element (10),
wobei das andere von dem Pumpengehäuseelement (20) und dem weiteren Element (10) einen Vorsprung (25) aufweist, wobei der Vorsprung (25), das Pumpengehäuseelement (20) und das weitere Element (10) einem Pfad von einem Gaseinlass (50) zu einem Gasauslass (52) bilden;
Drehen eines von dem Pumpengehäuseelement (20) oder dem weiteren Element (10) derart, dass Flüssigkeitsaustritt aus der mindestens einen Flüssigkeitsöffnung (15) einen Flüssigkeitsschild (40) bildet und Gas entlang des Pfads von dem Gaseinlass (50) zu dem Gasauslass (52) bei Drehung eines der Elemente (20, 10) fördert.

Revendications

1. Pompe volumétrique de pompage d'un gaz, ladite pompe comprenant :

un élément de carter de pompe (20) et un élément supplémentaire (10) ;
l'un parmi ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) comprenant une saillie (25) s'étendant vers l'autre élément (20, 10), ledit autre élément (20, 10) comprenant au moins une ouverture pour liquide (15) ;
ladite saillie (25), ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) formant un chemin d'une entrée de gaz (50) à une sortie de gaz (52) ; dans laquelle
ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) sont montés de manière rotative l'un par rapport à l'autre ; et
ladite au moins une ouverture pour liquide (15) est configurée de sorte qu'un liquide sortant de ladite au moins une ouverture pour liquide forme

une lame de liquide (40), ladite lame de liquide (40) étant utilisable pour entraîner le gaz le long dudit chemin de ladite entrée de gaz (50) à ladite sortie de gaz (52) lors de la rotation de l'un desdits éléments (20, 10).

2. Pompe selon la revendication 1, dans laquelle ledit élément de carter de pompe (20) est monté pour être immobile et ledit élément supplémentaire (10) est monté pour tourner.

3. Pompe selon l'une quelconque des revendications précédentes, dans laquelle ladite au moins une ouverture pour liquide (15) est formée sur une surface dudit élément (10) qui est monté pour tourner.

4. Pompe selon l'une quelconque des revendications précédentes, dans laquelle une section transversale dudit chemin formé par ladite saillie (25), ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) diminue de ladite entrée de gaz (50) à ladite sortie de gaz (52).

5. Pompe selon l'une quelconque des revendications précédentes, dans laquelle ledit élément supplémentaire (10) comprend un disque monté de manière décalée axialement par rapport audit élément de carter de pompe (20), ledit élément de carter de pompe (20) comprenant ladite saillie (25) et ladite au moins une ouverture pour liquide (15) s'étend le long d'au moins une partie d'un diamètre d'une surface dudit disque faisant face à ladite saillie (25), dans laquelle facultativement, ladite saillie (25) a au moins l'une parmi une forme de spirale ou une forme d'anneau concentrique.

6. Pompe selon l'une quelconque des revendications précédentes, dans laquelle ledit élément supplémentaire (10) est monté à l'intérieur d'un alésage dudit élément de carter de pompe (20) de sorte que ledit élément supplémentaire (10) comprenne un composant intérieur et que ledit élément de carter de pompe (20) comprenne un composant extérieur, dans laquelle facultativement, ledit composant intérieur est monté de manière concentrique à l'intérieur dudit alésage dudit composant extérieur.

7. Pompe selon la revendication 6, dans laquelle ladite au moins une ouverture pour liquide (15) comprend au moins une ouverture pour liquide (15) s'étendant le long d'au moins une partie d'une longueur de l'un parmi ledit élément de carter de pompe (20) ou ledit élément supplémentaire (10), dans laquelle ladite au moins une ouverture pour liquide (15) est agencée le long d'une direction longitudinale se présentant sensiblement parallèlement à un axe desdits éléments (20, 10).

8. Pompe selon la revendication 6 ou 7, dans laquelle ladite au moins une ouverture pour liquide (15) est agencée sous la forme d'une hélice s'étendant autour d'une surface dudit élément de carter de pompe (20) ou dudit élément supplémentaire (10).

9. Pompe selon l'une quelconque des revendications 6 à 8, dans laquelle ladite saillie (25) comprend une hélice, dans laquelle facultativement, un angle de ladite hélice change depuis ladite entrée de gaz (50) vers ladite sortie de gaz (52) de sorte qu'un pas de ladite hélice se réduise vers ladite sortie de gaz (52).

10. Pompe selon l'une quelconque des revendications 6 à 9, dans laquelle au moins l'un parmi ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) sont coniques de sorte qu'une distance entre ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) se réduise vers ladite sortie de gaz (52).

11. Pompe selon l'une quelconque des revendications 6 à 10, comprenant en outre un réservoir de liquide (30), ledit composant intérieur étant monté de manière rotative et comprenant un corps creux ayant une ouverture à une extrémité inférieure s'étendant dans ledit réservoir de liquide (30), un diamètre interne dudit rotor creux augmentant depuis ladite extrémité inférieure.

12. Pompe selon l'une quelconque des revendications précédentes comprenant une pluralité d'ouvertures pour liquide (15), dans laquelle ladite pluralité d'ouvertures pour liquide (15) fournit une pluralité de flux de liquide qui forment une pluralité de lames de liquide (40) entre ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) et/ou dans laquelle au moins une série de ladite pluralité de sorties de liquide (15) sont agencées de manière adjacente les unes aux autres et les flux sortant de ladite au moins une série de ladite pluralité de sorties de liquide(15) forment une seule lame de liquide (40).

13. Pompe selon l'une quelconque des revendications précédentes dans laquelle ladite pompe est une pompe à vide.

14. Laveur pour réduire les polluants pompés à partir d'un système de réduction, ledit laveur comprenant une pompe selon l'une quelconque des revendications précédentes.

15. Procédé de pompage d'un gaz, ledit procédé comprenant :

la sortie d'un liquide à partir d'au moins une ouverture pour liquide (15) sur l'un parmi un élément de carter de pompe volumétrique (20) ou

un élément supplémentaire (10), l'autre parmi ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) comprenant une saillie (25), ladite saillie (25), ledit élément de carter de pompe (20) et ledit élément supplémentaire (10) formant un chemin d'une entrée de gaz (50) à une sortie de gaz (52) ;
la rotation de l'un parmi ledit élément de carter de pompe (20) ou ledit élément supplémentaire (10) de sorte que le liquide sortant de ladite au moins une ouverture pour liquide (15) forme une lame de liquide (40) et entraîne le gaz le long dudit chemin de ladite entrée de gaz (50) à ladite sortie de gaz (52) lors de la rotation de l'un desdits éléments (20, 10).

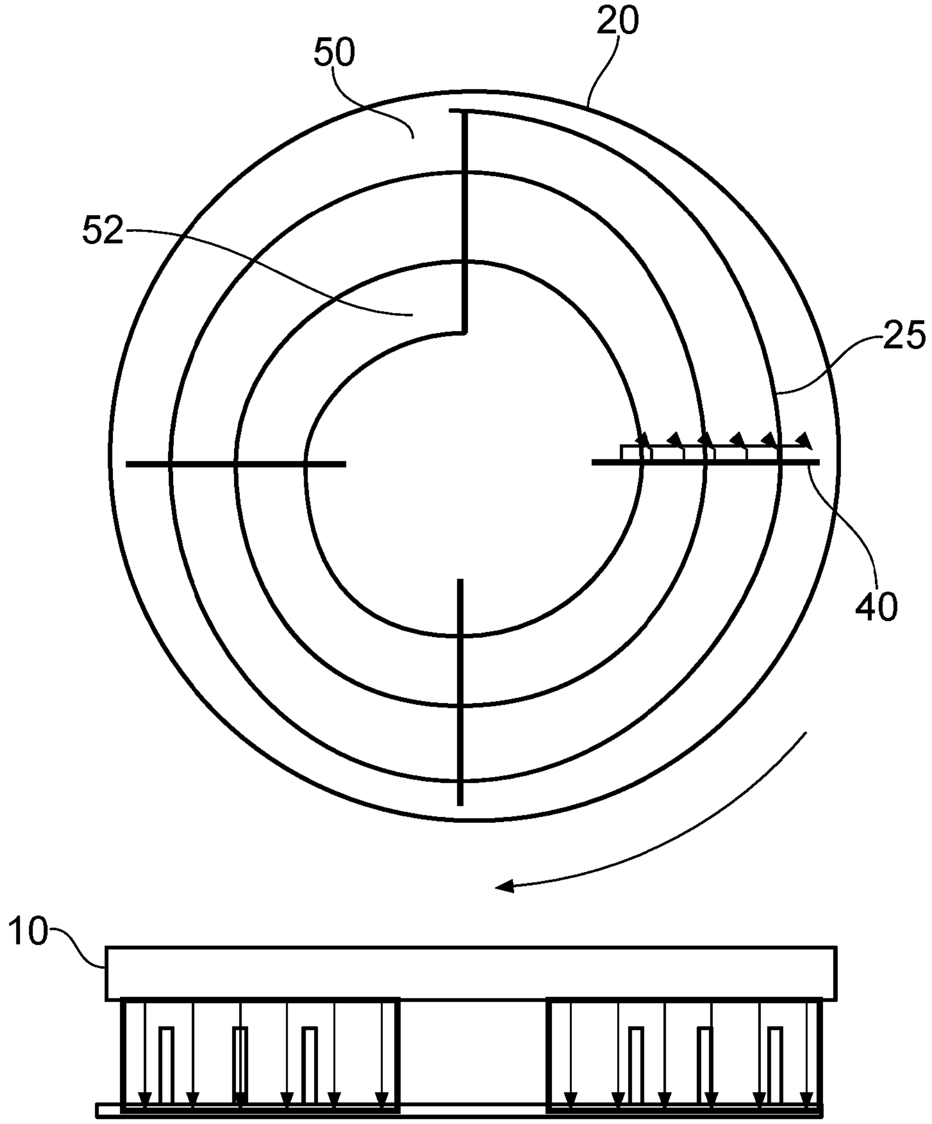

FIG. 1

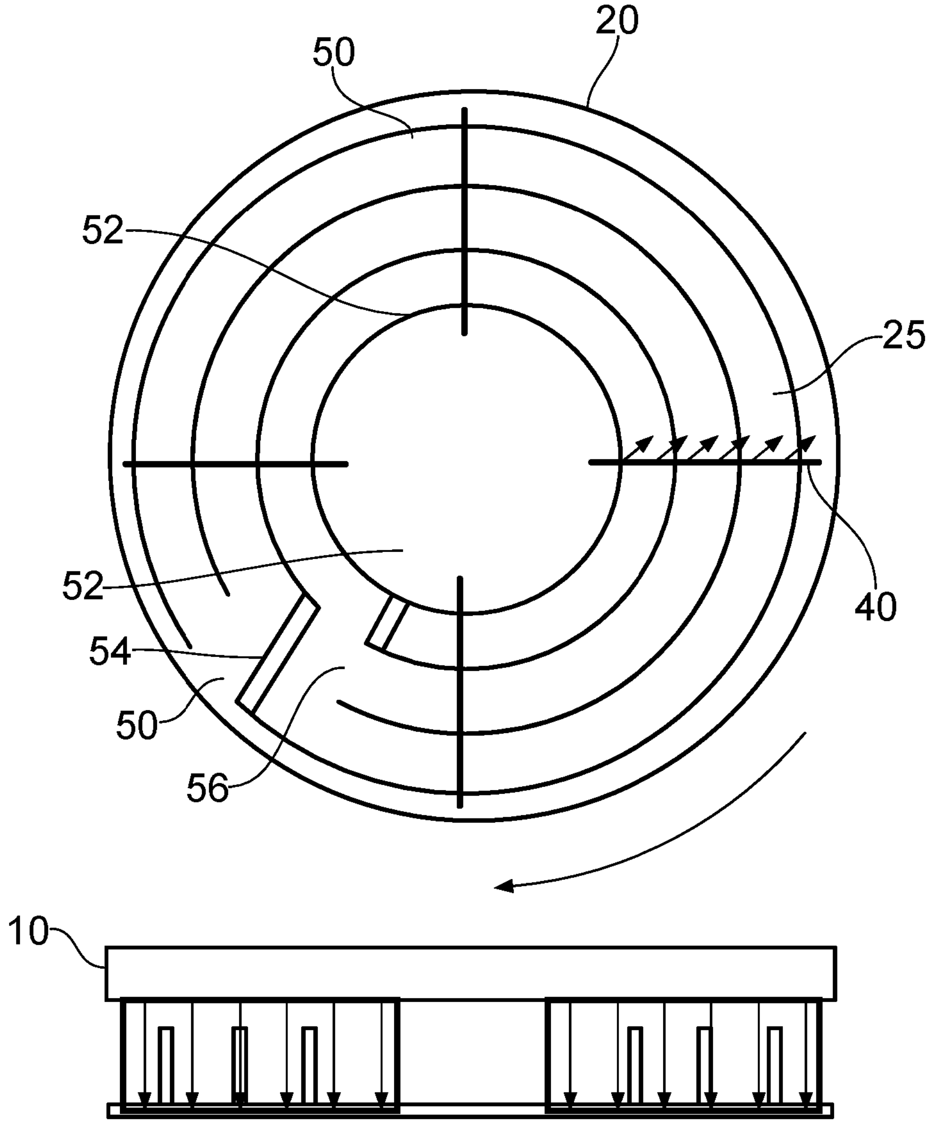

FIG. 2

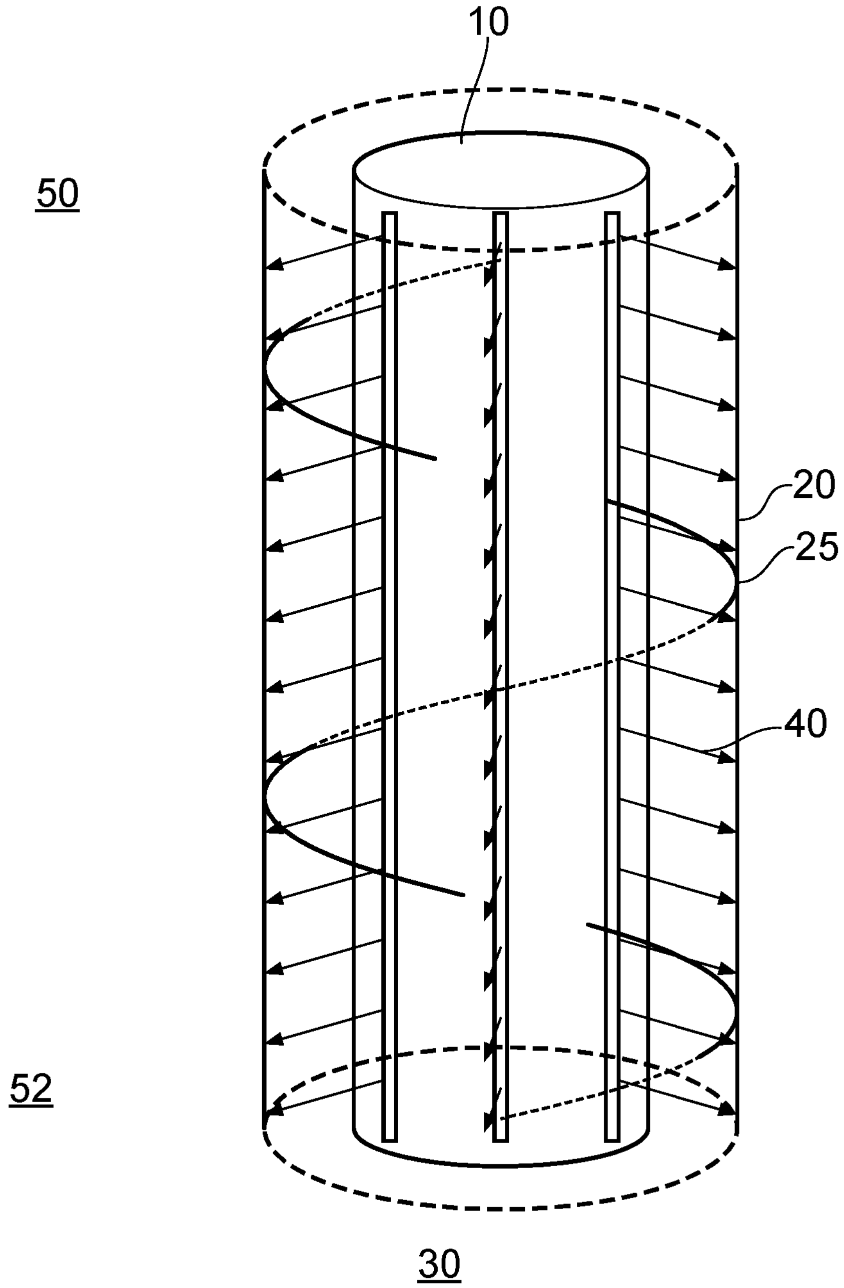

FIG. 3

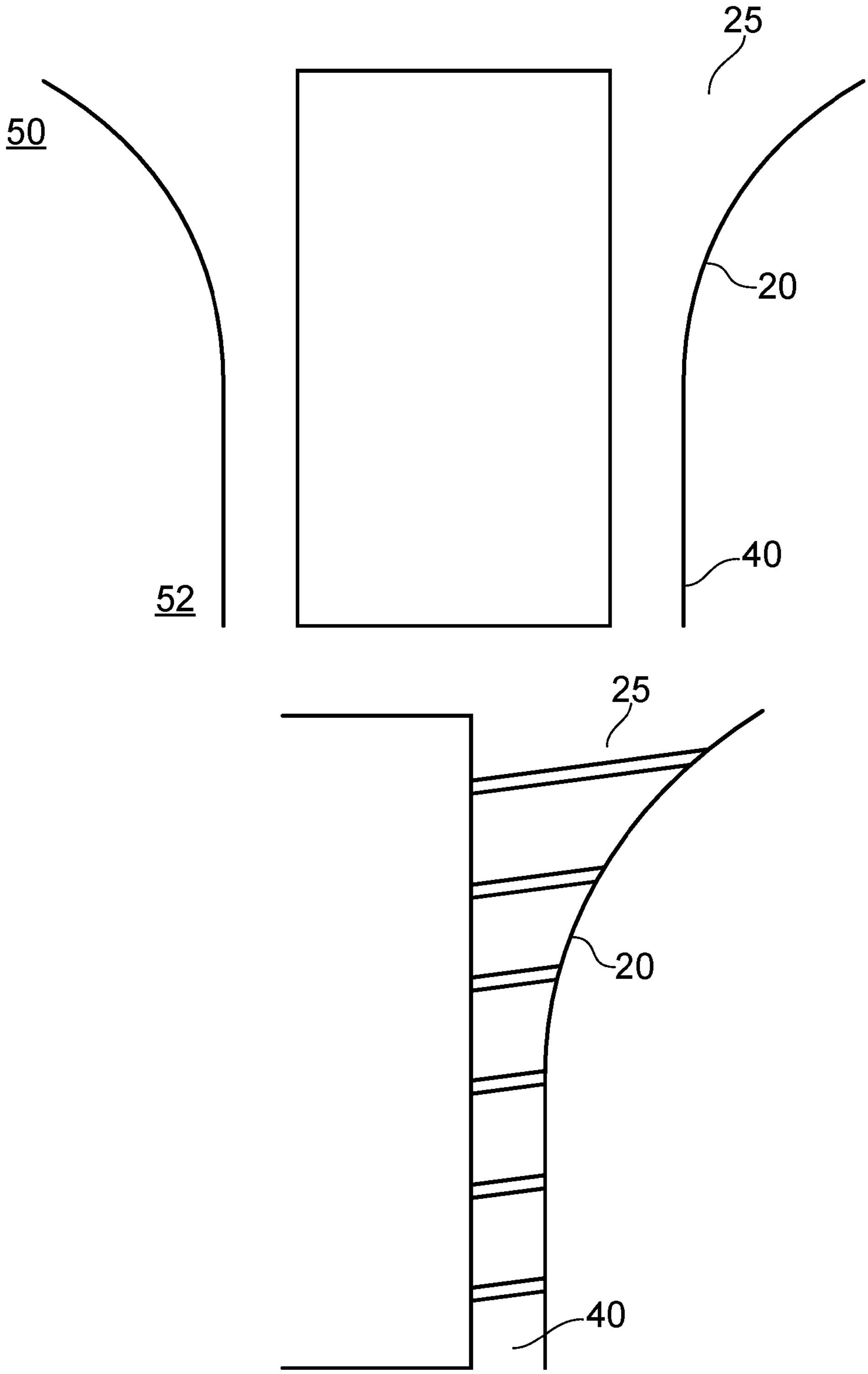

FIG. 4A

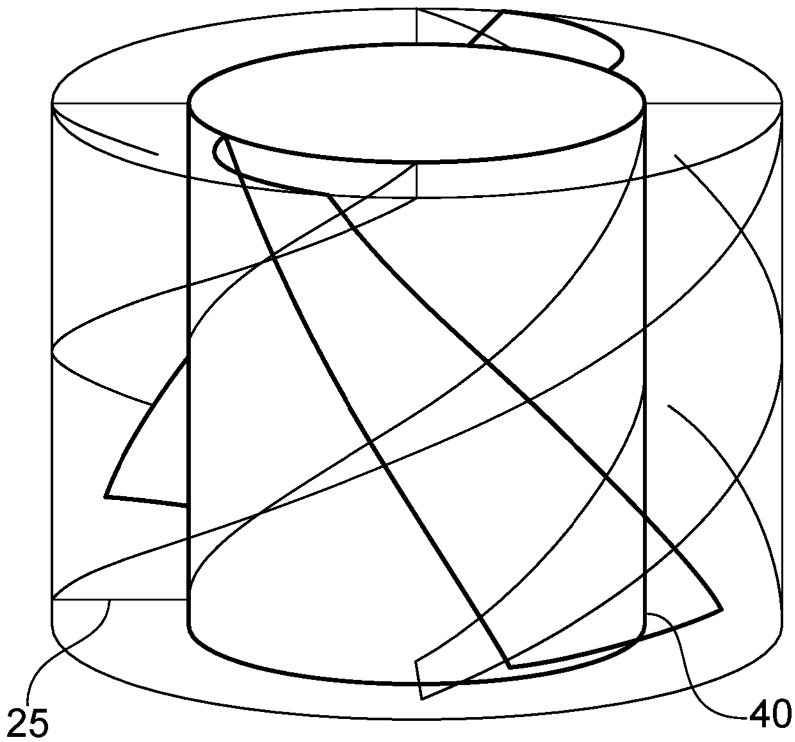

FIG. 4B

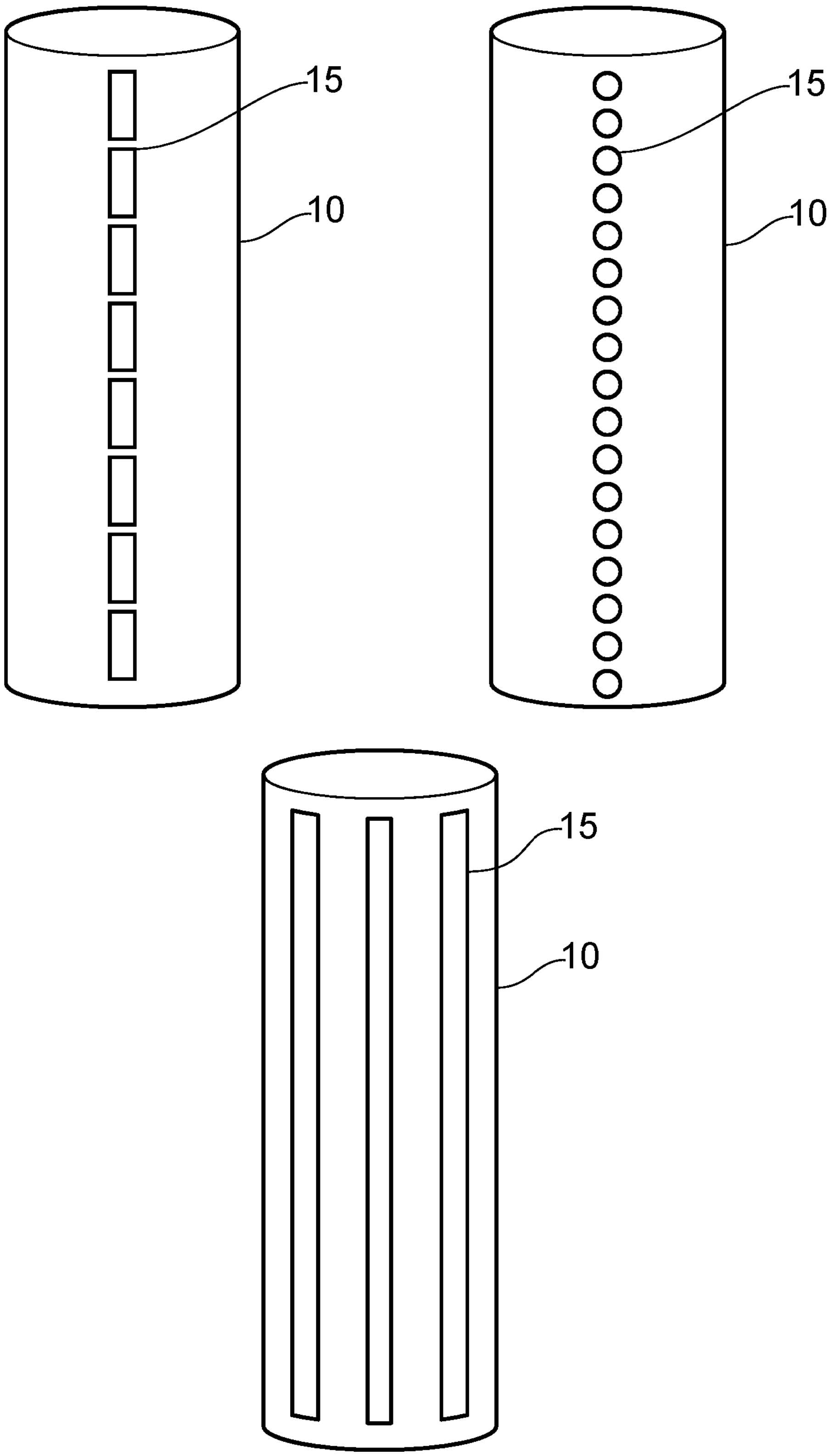

FIG. 5

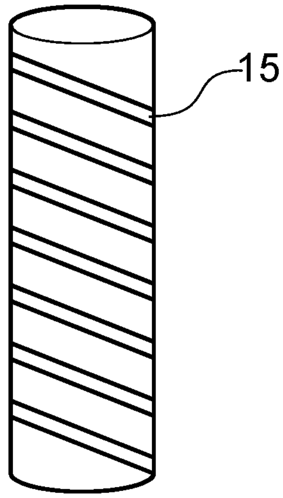

FIG. 6

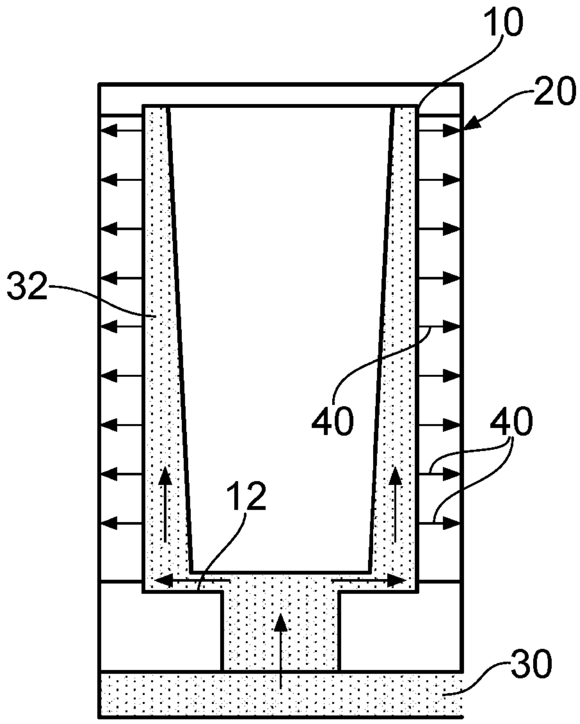

FIG. 7

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP S55134791 A **[0003]**
- GB 1282803 A **[0003]**