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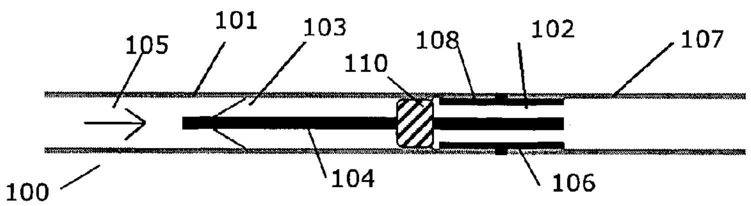


Fig. 1

(57) Abstract: The invention relates to a tube pump comprising an at least partly flexible tube and a pump element inserted in the tube, where the pump element comprises no more than one non-return valve member and a flow blocking member positioned a distance apart on a rod element. The non-return valve member is oriented on the rod element so as to allow for a fluid flow in the tube through the valve member along the rod element in the direction towards the flow blocking member. The flow blocking member is in a closed configuration placed to block the tube by engaging with the tube walls, and is in an open configuration configured to deform by a deformation of the tube such as to allow for fluid passage. The flow blocking member further is configured to attain its closed configuration when not opened by the tube deformation. The tube comprises an at least partly flexible tube portion between the valve member and the flow blocking member, such that a repeated deformation of the flexible tube portion acts to alternately close and open the valve member and the flow blocking device thereby generating a fluid flow through the tube. The invention further relates to an infusion pump comprising such tube pump as mentioned above.

WO 2013/107456 A1

A TUBE PUMP

Field of the invention

The present invention relates to a tube pump comprising a pump element inserted in a tube for the generation of a fluid flow within the tube and for the prevention of free flow and back flow within the tube. The invention furthermore relates to an infusion pump comprising such tube pump.

Background

Different kinds of positive displacement tube pumps such as roller pumps or peristaltic pumps are known for pumping a fluid through a flexible tube or hose and are widely used in e.g. medical applications such as for instance in infusion pump systems, dialysis pumps, or bypass pumps for circulatory support.

A benefit of such pump types making them especially advantageous in medical applications is the absence of moving parts in contact with the fluid, whereby the pumps may be relatively easily sterilized. The peristaltic pumps, roller pumps and tube pumps however suffer from a number of drawbacks. Firstly, the pumping involves a complete or near complete compression or squeezing of the tube either by rollers, contact plates, or shoes to obtain the desired fluid flow within the tube. This inevitably leads to large wear on the part of the tube within the pump. The tube therefore regularly needs to be moved relative to the pump for the compression to be exerted on another part of the tube or exchanged completely thereby resulting in an excessive use of tube material and a need for longer tubes. The extra tube length or the moving of the pressure zones makes the known tube pumps more expensive and increases the time needed to setup and operate the pump. Further, the large wear increases the risk of damaging the hose considerably, leading to a loss of pumping fluid and contamination of the surroundings, and a reduction or loss of pumping effect which depending on the circumstances may be unacceptable and even fatal. Extra surveillance of the pump and tubes is therefore required to prevent such situations.

Further, the complete or near complete compression of the tube or hose may result in excessive large stresses and shear forces experienced by the fluid causing damages to the fluid molecules or separation of colloids and slurry fluids.

Another drawback of the known tube pumps is their often considerable size necessitating a large amount of space which in many medical situations is limited.

Another concern of the known tube pumps is to awoid any undesired back flow in the tube which otherwise will make both the pump less efficient and less accurate in determining the pump flow.

Another drawback of the known tube pumps when used in infusion pumps is the inherent risk of free flow leading to uncontrolled delivery of an infusion to a patient. Free-flow of intravenous infusions has been the cause of several deaths, and "Near Misses" nationwide according to several health organizations. Usually the problem occurs when the tubing is removed from the pump and the infusion flows by gravity (free-flows) overdosing the patient. In known tube pumps, the problem of free flow is tried to be removed by built-on applications to the pump system such as clamps or the like regulation means which must be opened and closed by a nurse before and after use. However, these systems are disadvantageous by the extra complexity and time needed to operate the systems, and the increased risk of human errors in the operation of the pumps.

Description of the invention

It is therefore an object of embodiments of the present invention to overcome or at least reduce some or all of the above described disadvantages of the known tube and peristaltic pumps by providing a tube pump and a pump element with improved pumping efficiency and reduced wear of the tube material. It is a further object of embodiments of the invention to provide pump elements and tube pumps with minimized risk of leakages.

It is a further object of embodiments of the invention to provide a tube pump without or with reduced risk of free flow and back flow and thereby to increase the safety of using the pump. Yet a further objective is to provide a tube pump with with a more stable and precise flow.

It is a further object of embodiments of the invention to provide a tube pump which is simple and intuitive to operate and yet effective. It is a yet further object of embodiments of the invention to provide an effective tube pump of minimal number of parts and which may be manufactured fastly by a minimum of operations and a low manufacturing cost.

In accordance with the invention this is obtained by a tube pump comprising an at least partly flexible tube and a pump element inserted in the tube, where the pump element comprises a rod element, no more than one non-return valve member, and a flow blocking member. The non-return valve member and the flow blocking member are positioned a distance apart on the rod element, and the non-return valve member is oriented on the rod element so as to allow for a fluid flow in the tube through the valve member along the rod element in the direction towards the flow blocking member. The flow blocking member is in a closed configuration placed to block the tube by engaging with the tube walls in a fluid tight fashion, and the flow blocking member is in an open configuration configured to deform by a deformation of the tube such as to allow for passage of a fluid between the flow blocking member and the tube walls, and wherein the flow blocking member is configured to attain its closed configuration when not opened by said tube deformation. The tube comprises an at least partly flexible tube portion between the valve member and the flow blocking member, such that a repeated deformation of the flexible tube portion acts to alternately close and open the valve member and the flow blocking device thereby generating a fluid flow through the tube.

By a tube pump according to the above may by very simple means be obtained an effective pump for and mechanism for pumping a fluid through the tube. The fluid flow is generated as the deformation of the tube opens the flow blocking member and thereby acts to squeeze the fluid out of the tube space past the flow blocking member. When the deformation is relaxed, the flow blocking member blocks the tube and a negative pressure is created in the space in turn opening the valve member drawing in fluid from upstream the tube. A repeated deformation repeats the above described alternately opening and closing of the flow blocking member and the valve member thereby generating a fluid flow within the tube.

It is noted that whereas the flow blocking member is opened by the deformation of the tube, the non-return valve member is opened by the pressure difference between each side of the valve created as the deformation is relaxed. The flow blocking member is not opened by a pressure difference across the flow blocking member.

The flow blocking member is advantageous in preventing any fluid flow when the tube is not deformed and pumping is not intended. Hereby, a reliable and automatic closing of the tube may be achieved without the need for any manual interaction such as the conventional manually placing of clamps, fittings, extra valves or the like on the tube.

Hereby is obtained that the flow blocking member works to prevent both back flow and free flow in the tube pump.

In contrast hereto, the non-return valve member may not in itself completely prevent any free flow throught the tube, as the valve in some situations could allow unintended flow for example due to gravitational forces.

A pumping of the fluid could likewise be obtained by the replacement of the flow blocking member by a further second non-return valve. However, in comparison to this, the use of the flow blocking member according to the invention is advantageous by effectively preventing both back flow as well as free flow while maintaining or improving the pumping efficiency and with the use of only one non-return valve member.

The flow blocking member further acts to make the open and closed configurations of the pump, and the phases of the pumping more distinct.

By means of the flow blocking memeber in combination with the only one non-return valve may be obtained an efficient tube pump while on the same time obtaining an effective free-flow and back-flow prevention at all times when the flow blocking member is not activated. Also, these effects are obtained with the use of a minimum number of elements as only one non-return valve is needed, and thereby potentially lower manufacturing time and costs.

The flow blocking member according to embodiments of the invention is furthermore advantageous in preventing the free flow while still allowing the pumping with only small pressure forces on the tube. The stiffness of the flow blocking member may be tailored to require a desired minimum deformation of the tube or minimum deformation force on the tube to enable any fluid flow.

The prevention of any free flow in the tube pump is especially important in relation to applications of the tube pump in infusionpumps, where the unintended free flow of medicine is estimated to have added to or been the direct cause of death of about 500 persons in the USA.

By the tube pump according to the invention incorporating a flow blocking member is obtained a pump system with a built-in safety and not – unlike traditional infusion pump systems – with built-on safety functions. Hereby safety risks and the risk of human errors are removed or at least greatly reduced as the free flow prevention is obtained without human interaction and operation on the tube. Rather, the anti-free flow and anti-back flow is obtained automaticely.

This is obtained while at the same time having a very simple construction which is very simple and intuitive to employ and operate and thereby being very user friendly.

The deformation may in an embodiment of the invention involve a compression of the tube from one or more sides and/or may involve a decompression of the tube.

The the flow blocking member may simply comprise an elastic element initially filling out the interior of the tube but deforming differently from the tube, so that one or more openings between the element and the tube may occur when the tube is deformed e.g. as a part of the pumping, and such that the tube will again be closed when the deformation of the tube seizes.

The flow blocking member may comprise a foam member preferably of a foam with closed cells and e.g. of a cubic shape. The foam member is easily deformed with minimal forces and may be manufactured and assembled efficiently and at low costs.

The flow blocking member may comprise an elastic or flexible member or body of a larger outer circumference than the interior circumference of the tube. Hereby may be obtained an efficient prevention of free flow and back flow when the flow blocking member is in its closed configuration.

The non-return valve may be a so-called check valve, a clack valve, or one-way valve, and is a mechanical device, a valve, which normally will allow a fluid (liquid or gas) to flow through it in only one direction. The non-return valve may close the fluid passageway off partly or fully in its closed position. By orienting the non-return valve as specified above is obtained that the valve member when in its open position will allow for a fluid flow in the tube in the desired pumping direction.

The whole tube may be flexible and may be made in a material such as a thermoplastic or a rubber, and may be reinforced. Alternatively or additionally, only a portion of the tube may be flexible, such as comprising a length of a flexible hose or comprising flexible tube wall portions.

The tube pump is further advantageous in comprising only very few parts and which may be easily and fast assembled with a minimal number of assembling operations. Also the tube pump is inexpensive to manufacture and therefore advantageous as a disposable product, which may be advantageous for medical applications or in the food industry where hygiene or sterile equipments are of outmost importance.

The pump element is further advantageous in being easy and fast to insert in a tube whereby a tube pump may be made ready for operation fast and easily.

Further, because of the pump element construction, the different components of the pump element (the non-return valve member and the flow blocking member) will inevitably be inserted in a tube at the predefined distance apart as given by their position on the rod element, whereby the amount of pumping may be equally well defined for a given deformation of the tube.

Further, the simple construction and way of activating the tube pump ensures a more stable flow over time leading to a higher medication precision when used for infusion pumps.

Unlike many conventional tube pumps such as roller pumps, the tube need not be completely compressed or squeezed to generate an efficient pumping motion of the fluid. Rather, even relatively small deformations of the tube may be enough to obtain a relatively high pumping efficiency due to the construction of the tube pump with the pump element comprising only one non-return valve member and a flow blocking member. This is further advantageous in minimizing the wear on the tube caused by the repeating deformation and thereby minimizing the risk of leaking and loss of the fluid and contamination of the surroundings.

The smaller amount of deformation of the tube needed for obtaining an efficient pump further leads to lower stresses and shear forces experienced by fluid, which may prevent damaging of fluid molecules and help to keep colloids and slurry fluids from separating. This may be especially advantageous in pumping of specific types of fluid such as e.g. blood or other fluids comprising fragile or vulnerable components.

Due to the construction of the pump element of the no more than one i.e. a single non-return valve member and a flow blocking member positioned on a rod element, a tube may fast and easily made ready for pumping by simply inserting a pump element into the tube. Similarly, the pump element may be extracted from the tube in an equally simple fashion, whereby the interior of the tube which then is the only part of the pump in contact with the fluid is left without obstacles and may be cleaned and sterilized easily and effectively. The extracted pump element is likewise simple to clean and sterilize effectively before reuse or may simply be disposed of. This makes the tube pump especially advantageous for medical applications and in the food industry.

The tube pump is further advantageous in that it may be operated to deliver a pulsed flow e.g. like the heart which may be advantageous in e.g. bypass pumps or in some infusion pumps.

The pump element may be pre-manufactured in one or more sizes dimensioned to tubes of different diameters and/or shapes.

The tube pump in comprising one single non-return valve member and the flow blocking member is advantageous in having very few parts, and can therefore be fast and easily assembled and made ready for pumping. Further, the tube pump is inexpensive to manufacture and inexpensive to maintain as the use of a hose or tube makes for a relatively low-cost maintenance item compared to other pump types.

A further advantage is that the tube pump may be constructed to yield a compact yet robust and efficient pump.

Because of rod element of the pump element, the valve members will be positioned in the tube at a predefined distance apart given by and fixed by the rod element whereby the amount of pumping may be equally well defined for each deformation of the tube and possible to determine on beforehand.

Furthermore, by the rod element being relatively stiff and inelastic compared to the flexible tube portion, the rod element aids the tube portion to relax and return to its undeformed shape after each deformation and each pumping movement. Hereby, the tube portion may be ready for a new deformation and pumping cycle faster.

Further, the rod element enable a fast and simple assembly of the pump element and the tube pump as all the parts of the pump element may by mounted one after another on the rod element. The assembly may advantageously be performed from only one side which enables a high-speed and automated mass production.

Also, the rod element enables a fast yet precise and well-controlled insertion of the pump element into the tube.

The rod element may further be provided with recesses for the different parts of the pump element to be placed in. This facilitates the mounting and positioning of the parts on the rod element. Furthermore, the distances between the parts and especially the distance between the valve members and thereby the pumping volume may hereby be determined and controlled accurately.

Also, the predetermined and fixed distance between the valve members eases the mounting or placing of the tube pump in a pumping apparatus such as an infusion pump.

The rod element may attain elongate shapes of different and/or varying cross sections such as e.g. a circular cylindrical shape, a rectangular cylindrical shape, a hollow cylindrical shape, or a helical shape. The rod element may further comprise two or more parallel or non-parallel bars.

According to an embodiment of the invention, the pump element extends into the tube from one end of the tube, and the pump element further comprises at least one sealing part engaging with the tube wall in a fluid tight fashion in one end of the tube. Hereby is obtained that the pumping element is easily inserted into a tube portion and that the pump element may also act as a coupling member for coupling the tube to another part such as e.g a further tube, an infusion bag, a syringe or the like without or with only minimal leaking. In this way the assembled tube pump may be made ready with only one connection or coupling.

The sealing part may engage with the tube wall by friction. The sealing part may comprise one or more gaskets e.g. in the shape of a ring or band of rubber or another deformable or flexible material.

In a further embodiment of the invention, the pump element extends through the entire length of the tube and comprises sealing parts engaging with the tube wall in a fluid tight fashion in both ends of the tube. Hereby a tube length of a predetermined length may be pre-manufactured and pre-assembled with the pump element already inserted and secured to the tube wall. Hereby the sealing parts may be brought to engage with the tube wall such as to be able to withstand a higher fluid pressure e.g. by involving heat sealing or shrinking.

In a further embodiment of the invention, the tube is connected to a further tube via a connection part. The connection part may be configured as a pipe connection part on the end of the pumping element. Hereby the tube pump may be easily fastened and secured to e.g. another tube, an infusion bag, syringe or the like for pumping the fluid to or from such other part. This further yields the possibility to use less expensive tubes or hoses leading to or from the tube pump without being constrained by any tube diameter or tube material applied in the tube pump.

In a further embodiment of the invention, the pump element further comprises a filter placed on the rod element. Hereby, the fluid may effectively be filtered and undesired particles removed from the fluid flow. The use of a particle filter may be a requirement in some applications e.g. in infusion where microscopic clots, cellular debris or undesired particles. By the placing of the filter on the rod element may be obtained a simple and effective placing e.g. by pushing the filter onto the rod prior to inserting the pump element into the tube. Further, the precise placing of the filter may be ensured by corresponding marks or indentations on the rod.

The filter may be disk shaped and be substantially flat or curved. A curved shape may be advantageous in providing a larger surface compared to a flat filter whereby the pressure drop across the filter may be reduced. This may be especially advantageous in e.g. blood pumping applications due to the higher viscosity of the blood.

In yet a further embodiment of the invention, the tube pump comprises at least one actuator comprising a movable contact plate arranged for deforming the flexible tube portion by compressing the tube when actuated. The actuator may be linear or non-linear and may comprise one or more contact plates placed to move towards each other and/or towards a base, so that the tube may be compressed from one or more sides.

According to a further embodiment, two or more tube pumps may be placed serially. By the use of a number of pumping elements placed after each other, the pumping effect may be increased equivalently by repeatingly deforming the tube in several positions between sets of valve members. The tube may hereby be deformed in a peristaltic movement.

In an embodiment, the valve member comprises a flexible diaphragm and/or membrane fitted onto the rod element and sized to at least partly engage in its closed position with the inner wall of the tube. The pump element and thereby the tube pump may hereby be constructed of very few parts in that the valve function is simply obtained by the flexible membrane moving relative to the inner tube wall. Further, the valve member may be easily positioned onto the rod element and may be easily exchanged if needed. The pump element and thereby the tube pump may hereby be manufactured at very low costs.

In a further embodiment of the tube pump according to any of the above described, the non-return valve member comprises a valve placed in a valve housing which at least partly engage with the inner wall of the tube. Here, the valve opening is primarily established in the valve housing, whereby the valve opening is not dependent on the positioning within the tube and therefore may be determined precisely beforehand and independent of the tube properties. Further, such construction may be more robust.

In a further embodiment of the tube pump according to any of the above, the non-return valve member may comprise a flexible funnel shaped membrane in combination with a perforated disk fitted onto the rod element, the disk being sized to engage with the interior of the tube in a fluid tight fashion. The membrane may be sized to cover the disk perforations if pressed against the disk.

Hereby is established a very compact yet efficient non-return valve which may be configured to completely or partly close off any flow effectively in the one direction while allowing for a full flow in the other direction caused by a pressure difference across the valve. The valve may be opened by only a small pressure in dependence of the material properties and stiffness of the funnel shaped membrane. The funnel shaped (i.e. conical, cup shaped, or trumpet shaped) membrane increases the efficiency of the valve and provides for a smooth continuous transition from its closed to its open position and vise versa without any 'flapping' or sudden changes of its shape. Hereby, a more even pumping motion without or with only minimal cudden changes in the flow speed may be obtained.

In both the open and closed position of the valve, the disk lies sealingly against the interior of the tube so that the only possible fluid flow is through the perforations or openings in the disk. The funnel shaped membrane is mounted on the rod element only allowing for any possible fluid flow around the membrane in the space between the membrane and the tube walls. The membrane is oriented so that the interior of funnel is oriented towards the disk. In the closed and relaxed position of the valve, the membrane lies against the disk. The membrane may lie completely or partly against the disk surface. Hereby the membrane covers at least some of the perforations in the disk preventing the fluid flow therethrough. In the open configuration of the valve, the membrane is deformed due to the increased pressure on the disk side of the valve so that a gap is established between the disk and the membrane allowing for a fluid flow through the perforations in the disk and around the membrane.

The perforations in the disk may be applied as openings or holes through the disk placed randomly or in a pattern. The perforations may be placed a distance from the rod element or next to the rod element. The perforations may e.g. be applied to the disk by the punching of a star shaped central hole in the disk both functioning as the hole for the disk to be mounted on the rod element and providing the perforations for the valve function.

The disk may be manufactured from e.g. a thermoplast, a metal, or a rubber material.

The funnel shaped membrane may be punched or cut out from a foil, a film or a cloth of e.g. a silicone material. The membrane may have a circular or oval shape with a central hole of a smaller diameter than the diameter of the rod element (optionally of the diameter of the recessed rod element) where the membrane is to be placed. As the membrane then is pushed or drawn onto the rod element, the initially flat membrane naturally attains a funnel shape and seals against the rod element. Alternatively, the membrane may be shaped e.g. by thermoshaping or thermoforming. In an embodiment of the invention the central part of the funnel shaped membrane attains an angle in the range of 10-40 degrees relative to the rod element. In a preferred embodiment the cone angle lies in the range of 20-35 degrees such as approximately 30 degrees.

Further, the tube pump may comprises a pipe connection part configured for connecting the tube pump to a further tube, syringe, infusion bag or the like. Hereby is obtained that a tube in which a pumping motion is generated is easily connected and coupled to another part via the pump element such that fluid may be pumped on to this other part. In this way a minimum of couplings are needed and the risk of leaks is minimized.

In a further embodiment, the non-return valve member comprises a valve belonging to the group of ball valves, duckbill valves, diaphragm valves, wafer valves, check valves, swing check valves, disc check valves, split disc check valves, tilting disk check valves, cross slit valves, umbrella valves, and lift-check valves. Hereby may be obtained an effective valve and which may be pre-manufactured and positioned in the valve member in a simple yet effective manner.

In a further embodiment of the invention, the connecting rod is made of a bendable material such as a thermoplast. Hereby is obtained that the pump element may be easily inserted into bended tubes or hoses or that the tube may be bended without affecting the efficiency of the pumping. Further, a more compact tube pump may be obtained by allowing the tube to bend.

In a further embodiment of the invention, the connecting rod is made of a plastic material such as e.g. PE (polyethylene), PP (polypropylene), a rubber, or a metal alloy.

The invention further relates to an infusion pump comprising a tube pump according to any of the embodiments described in the preceding. The advantages hereof are as given in relation to the tube pump. Further, the infusion pump is advantageous in making the use of a drip counter and a flow regulator superfluous, as otherwise conventionally applied in infusion pumps, as the tube pump can be controlled and regulated to give a certain number of pulses per time whereby the flow may be accurately determined. Further, the infusion pump can maintain a constant flowrate throughout the entire emptying of the infusion bag and regardless of how the infusion bag is placed. In contrast hereto conventional infusion pumps uses the gravity for a continued and complete emptying of the infusion bag for which reason it may be essential that the infusion bag and the tube leading from the infusion bag must hang or be held correctly.

Brief description of the drawings

In the following different embodiments of the invention will be described with reference to the drawings, wherein:

Fig. 1 illustrates an embodiment of a tube pump with a pump element inserted in a tube as seen in a cross sectional views from the side,

Fig. 2A and 2B illustrates a flow blocking device inserted in a tube in a closed and open configuration, respectively –in side and in end views,

Figs. 3A and 3B illustrate the working principle of a tube pump according to the invention during and after deformation of the tube by an external compression force,

Fig. 4A-D illustrates the working principle of a tube pump according to the invention before, during and after deformation of the tube by compression plates,

Figs. 5 illustrates an embodiment of a tube pump and a pump element in an exploded view and a perspective view,

Figs. 6 illustrates the embodiment of a tube pump of figure 5 in a side view and as actuated by compression plates,

Fig. 7 illustrates an embodiment of a tube pump with a number of pumping elements in a serial connection, and the coupling of two tube parts by means of a pump element,

Fig. 8 illustrates an infusion pump comprising a tube pump and a pump element according to embodiments of the invention, and

Fig. 9 illustrates an embodiment of an activation mechanism suitable for deforming the tube of a tupe pump.

Detailed description of the drawings

Figure 1 shows an embodiment of a tube pump, 100 according to the invention and as seen in a cross sectional view. The tube pump 100 comprises a tube 101 (in grey) into which is inserted a pump element 102. The pump element 102 comprises a non-return valve member 103 and a flow blocking member 110 attached to a rod element 104 in a spaced apart manner. The valve member 103 is oriented relative to the flow blocking member 110, so that a fluid inside the tube portion 101 may only flow in the one direction through the valve member 103 towards the flow blocking member 110 as illustrated by the arrow 105. The valve member 103 here is illustrated as a split disc or duo check valve comprising a split disk which is dimensioned to have a larger surface area than the tube cross sectional area so that the disks only allow for a fluid flow in the one direction.Generally any type of non-return or one-way valve may be used. The rod element 104 here is in the shape of a flat bar for optimally supporting the split disk valves but could also have other shapes such as circular.

Other possible shapes are shown in some of the following figures. The pump element 102 further comprises a connecting part 106 at its end for connecting to another tube or hose 107. The connection part 106 could equally well be dimensioned and shaped to connect to tubes of smaller or larger diameters, to e.g. a syringe, or a infusion bag or the like. The pump element further comprises a sealing part 108 establishing a fluid tight connection between the pump element and the tube 101 when the pump element is inserted herein. The sealing part may optionally comprise one or more gaskets (not shown). The flow blocking member 110 is placed on the rod element such as to block the tube and prevent fluid flow in either direction in the tube when in its closed configuration. This is also illustrated in figure 2A showing to the left the tube as seen from the side, and to the right as seen in an end view. Upon deformation of the tube, the flow blocking member 110 no longer engage with the surrounding tube walls and a fluid in the tube can then flow past the flow blocking member 110. This is illustrated in figure 2B. The open configuration of the flow blocking member 110 is here obtained by the flow blocking member deforming differently from the tube yielding passages 201 between the flow blocking member and the tube walls.

The flow blocking member 110 is thus configured such that it only opens and allows for passage of a fluid when affected by a deformation of the tube e.g. a pressure from the exterior on the tube. Hereby any unintentional fluid flow through the pump (both free flow and back flow) may be prevented which may otherwise be the problem e.g. for hanging infusion pumps where the gravity forces from a bags of infusion fluids may cause a small unnoticeable leak in the infusion pump. The flow blocking member 110 may as sketched in figures 1-3 comprise a foam member of a larger diameter that the interior diameter of the tube 101. As a pressure is applied to the tube, the tube deforms differently than the flow blocking member 110 making openings between the member and the tube wall for the fluid to flow through. When the pressure is released, the flow blocking member 110 attains its undeformed shape and closes off any flow through the tube again.

Figures 3A and 3B illustrate the working principle of the tube pump 101 in general. The tube 101 surrounding the pump element 102 comprises a flexible tube wall portion 301 between the valve member 103 and the flow blocking member 110. The pumping may be generated by deforming the tube between the valve member 103 and the flow blocking member 110, which in this illustrated example is performed by an actuator compressing the tube 101 by means of two movable contact plates 302. Here, the valve member 103 will remain closed due to the increased pressure in the tube, whereas the flow blocking member 110 will be opened by its deformation. Thereby the fluid is forced in the direction of the arrow 303. As the contact plates 302 retract (as shown in figure 3B) and the tube deformation is relaxed, the flow blocking member 110 again blocks the tube and an under pressure is created in the decompressed chamber between the valve member and the flow blocking member 110. The under pressure causes the valve member 103 to open and a flow in the direction of the arrow 304. In contrast to the non-return valve member, the flow blocking member is not opened by the pressure difference across the flow blocking member and thereby acts as an effective anti free flow device. A fluid flow in the tube may thereby obtained by a simple repeating deformation of the tube between the valve member 103 and the flow blocking member 110. The tube pump may further comprise a filter 333 which may advantageously be placed upstream the non-return valve, i.e. at the inlet of the pump. The filter may filter the fluid reducing the risk of any undesired particles being pumped along with the fluid. The filter 333 may be placed on the rod 104 and thereby inserted in the tube as the pump element is inserted. In the figure, the filter is substantially flat but may likewise be of a curved shape and thereby have a larger surface.

Figures 4A – 4D illustrate the same pumping principle, but where the actuation of the pump is effected by a little more complex deformation cycle of the tube 101. In this embodiment the tube is deformed by means of two movable contact plates 302 which first (figure 4B) act to compress both the central tube portion 301 between the valve member 103 and the flow blocking member 110 and the tube portion 401 surrounding the flow blocking member 110. In a following step (figure 4C) the pressure is releaved on the flow blocking member 110 so that this closes while maintaining a deformation on the central tube portion 301. When the contact plates then retracts (figure 4D) a larger under pressure in the decompressed chamber between the valve member and the flow blocking member is then obtained. Hereby the resulting fluid flow may be increased considerably compared to the simpler pumping sequence as illustrated in figure 3 or the same fluid flow may be obtained by fewer actuations of the tube.

Figure 5 discloses an embodiment of a pump element 102 inserted into a flexible tube thereby forming a tube pump 100. The figure shows the different parts of the pump elements as assembled and in an exploded view, respectively. In this embodiment the non-return valve member 103 comprises a funnel-shaped flexible membrane 501 of a smaller diameter than the interior diameter of the tube 101. This membranes may initially be flat membranes of circular shape provided with a central hole of smaller dimension than the diameter of the rod element. The membrane may as an example be punched out or cut from films or foils of a flexible material such as silicone.

When pushed onto the rod element, the membrane deform into a funnel as illustrated in the figure. The funnel shaped membrane is placed on the rod element 104 next to a disk 502 of an outer dimension and shape so as to lie and seal against the interior of the tube. The disks 502 comprise a number of openings 503. When the non-return valve member is closed as illustrated in the lowermost assembled view in figure 5, the funnel shaped membrane 501 lies against at least the outer part of the neighbouring disk 502. In case of a larger fluid pressure to the disk side of the valve (to the left in the figure) than to the membrane side (to the right in the figure), the membrane will be pushed away from the disk allowing for a fluid flow through the openings of the disk and around the membrane. An increased fluid pressure on the membrane side of the valve member, however, will cause the membrane to press more tightly against the disk preventing any fluid flow. The rod element 104 is provided with recesses for receiving and positioning the different parts of the pump element whereby the distance between the non-return valve member and the flow blocking member 110 and thereby the pumping volume can be determined and controlled accurately.

The tube pump is configured to be attached to other tubes or hoses 507 via the connection parts 106 in each end of the pump element and placed on each end of the rod element 104. The tube pump may in this way be manufactured from a minimal number of parts which furthermore may be effectively and fast assembled in a production line from optionally just one side.

Figure 6 illustrates the same tube pump as in figure 5 as seen from the side. Figure 6 furthermore shows an embodiment of the contact plates 302 for actuating the pump. The contacting plates 302 are in this embodiment placed tiltable and of a shape to obtain a successive compression of the flow blocking member 110 and the central tube portion 301.

Figure 7 illustrates an embodiment of a tube pump 100 with a number of pump elements 102 placed in one or more tubes 101 in a serial. Hereby the pumping effect may be correspondingly increased, in that the tube or tubes 101 may be compressed in more than one place. This may advantageously be done one place after each other thereby establishing a peristaltic movement. The figure further illustrates how two or more tube parts 101 may be coupled to each other and brought in fluid connection by means of the one or more pump elements 102.

The contacting plates may be actuated by an actuation mechanism 900 as illustrated in figure 9. Here, the two contacting plates 302 are anchored in hinges 901 and a sideways movement of the element 902 causes a symmetrical compression and decompression movement of the contact plates 302.

Figure 8 illustrates an infusion pump 1301 comprising a tube pump 100 and a pump element 102 according to embodiments of the invention. Here, the pump element 101 is inserted in a tube, coupling the tube to a further tube or hose at each end of the pump element which may be coupled at one end to a syringe 1302 and at the other to an infusion bag of bottle (not shown). The infusion pump using a tube pump according to the invention is advantageous over conventional infusion pumps by being able to provide a well-controlled and steady flow irrespective of the orientation of the pump (independent of the gravity force) and irrespective of the amount of fluid left in the infusion container. Rather the infusion speed and amount can be precisely controlled and regulated by controlling the actuator force of the one or more actuators deforming the flexible tube, 1303.

The tube pump according to the various embodiments may likewise advantageously be applied in other types of pumps such as pumps driven by solar cells for instance in pumps for increased oxidisation of water where water from lower regions of for instance a lake or water basin is raised and pumped to higher regions thereby mixing the water. The disclosed tube pumps may work efficiently together with solar cells in that the tube pumps may work in a discontinuous manner whenever power is available, and may yield at least a single if not several pumping strokes with only minimal power.

While preferred embodiments of the invention have been described, it should be understood that the invention is not so limited and modifications may be made without departing from the invention. The scope of the invention is defined by the appended claims, and all devices that come within the meaning of the claims, either literally or by equivalence, are intended to be embraced therein.

Claims

1. A tube pump comprising an at least partly flexible tube and a pump element inserted in said tube, the pump element comprising a rod element, no more than one non-return valve member, and a flow blocking member, wherein the non-return valve member and the flow blocking member are positioned a distance apart on said rod element, and the non-return valve member is oriented on the rod element so as to allow for a fluid flow in the tube through the valve member along the rod element in the direction towards the flow blocking member, wherein the flow blocking member in a closed configuration is placed to block the tube by engaging with the tube walls in a fluid tight fashion, and the flow blocking member in an open configuration is configured to deform by a deformation of the tube such as to allow for passage of a fluid between the flow blocking member and the tube walls, and wherein the flow blocking member is configured to attain its closed configuration when not opened by said tube deformation, wherein the tube comprises an at least partly flexible tube portion between said valve member and said flow blocking member, such that a repeated deformation of said flexible tube portion acts to alternately close and open the valve member and the flow blocking device thereby generating a fluid flow through the tube.

2. A tube pump according to claim 1, wherein the flow blocking member comprises a foam member.

3. A tube pump according to any of the preceding claims, wherein the flow blocking member comprises a flexible member of a larger outer circumference than the interior circumference of the tube.

4. A tube pump according to any of the preceding claims, wherein the pump element extends into the tube from one end of the tube, and where the pump element further comprises at least one sealing part engaging with the tube wall in a fluid tight fashion in one end of the tube.

5. A tube pump according to any of the preceding claims, wherein the pump element extends through the entire length of the tube and comprises sealing parts engaging with the tube wall in a fluid tight fashion in both ends of the tube.

6. A tube pump according to any of the preceding claims, wherein the pump element further comprises a filter placed on said rod element.

7. A tube pump according to any of the preceding claims further comprising at least one actuator comprising a movable contact plate arranged for deforming said flexible tube portion by compressing the tube when actuated.

8. A tube pump according to claim 7, wherein the movable contact plate is arranged to successively deforme the tube surrounding the flow blocking member and the tube portion between the valve member and the the flow blocking member.

9. A tube pump according to any of the preceding claims comprising at least two pump elements placed serially.

10. A tube pump according to any of the preceding claims, where the non-return valve member comprises a flexible funnel shaped membrane and a perforated disk fitted onto the rod element, the disk being sized to engage with the interior of the tube in a fluid tight fashion and the membrane is sized to cover the disk perforations if pressed against the disk.

11. A tube pump according to any of the preceding claims, wherein the tube pump further comprises a pipe connection part configured for connecting the tube pump to a further tube.

12. A tube pump according to any of the preceding claims, wherein said non-return valve member comprises a valve belonging to the group of ball valves, duckbill valves, diaphragm valves, wafer valves, check valves, swing check valves, disc check valves, split disc check valves, tilting disk check valves, cross slit valves, umbrella valves, and lift-check valves.

13. A tube pump according to any of the preceding claims, where the connecting rod is made of a bendable material such as a thermoplast.

14. A tube pump according to any of the preceding claims, where the connecting rod is made of PE (polyethylene), PP (polypropylene), a rubber, or a metal alloy.

15. An infusion pump comprising a tube pump according to any of claims 1-14.

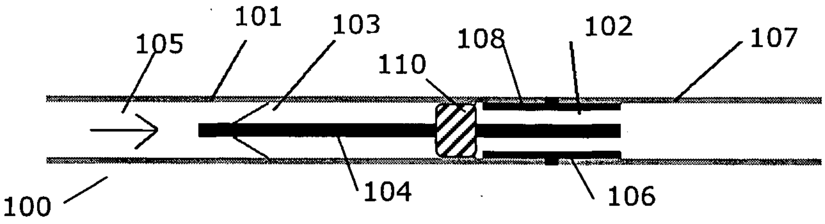


Fig. 1

Fig. 2A

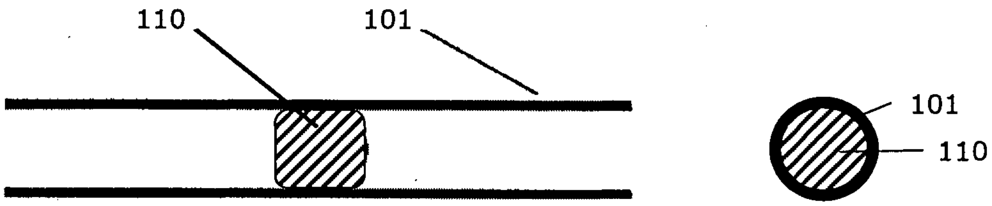


Fig. 2B

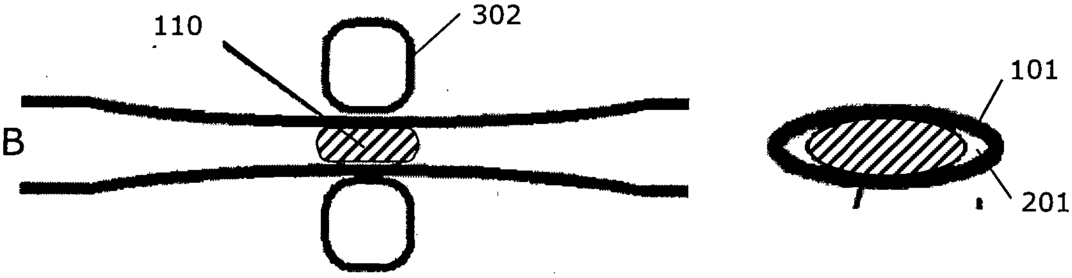


Fig. 3A

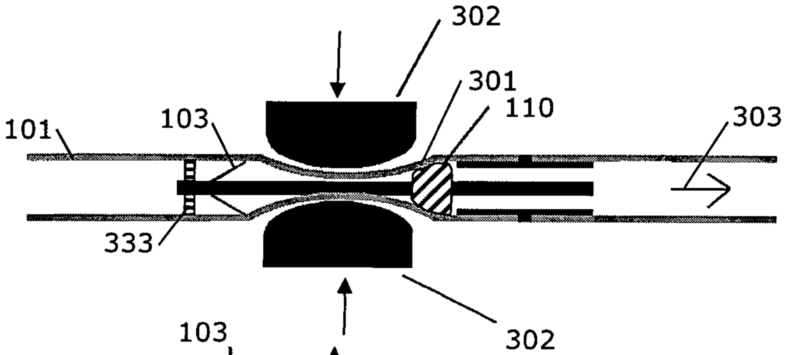


Fig. 3B

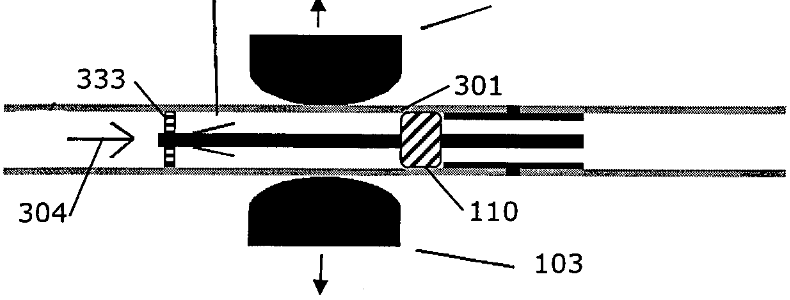


Fig. 4A

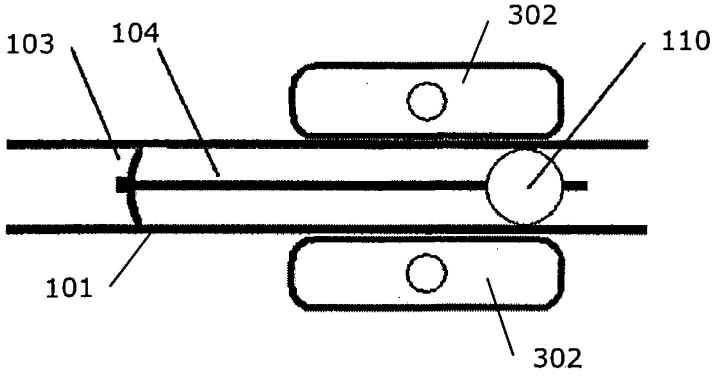


Fig. 4B

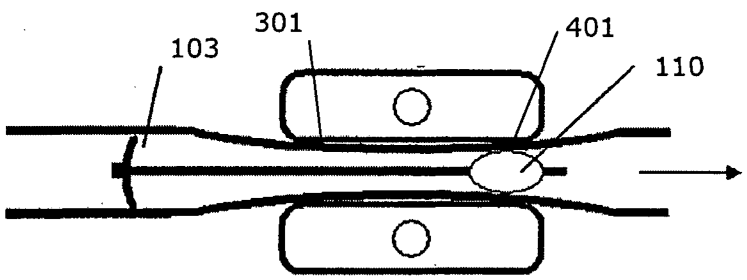


Fig. 4C

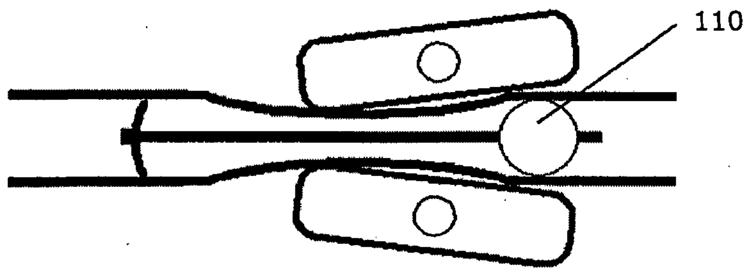
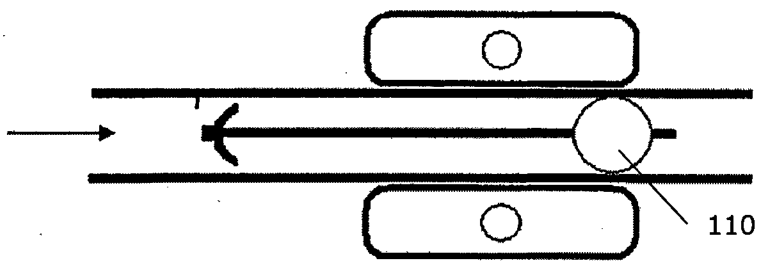
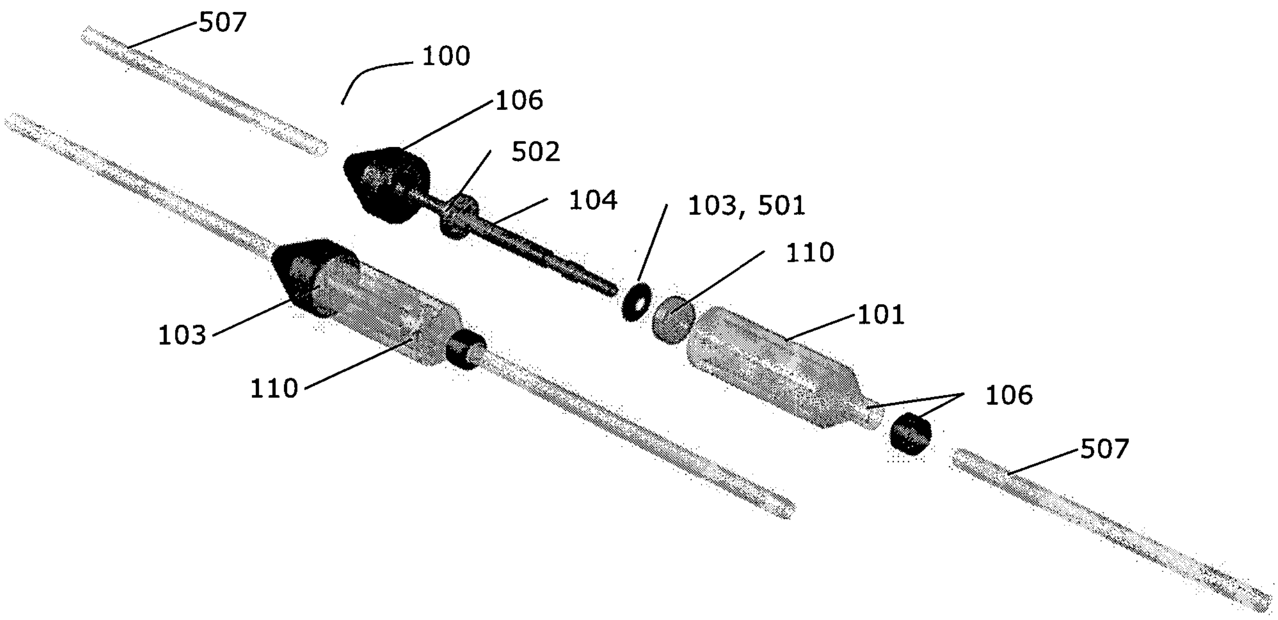


Fig. 4D

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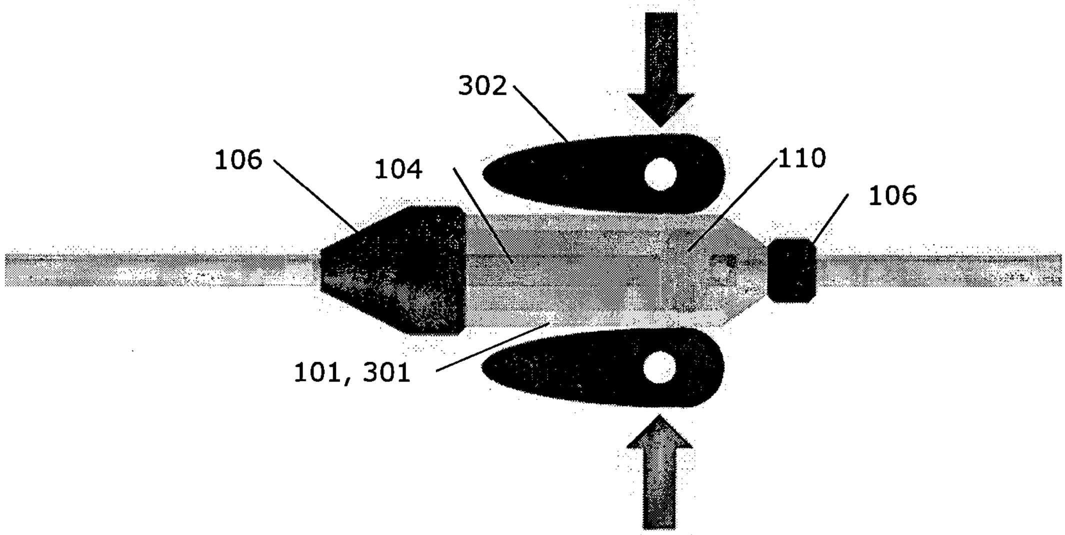
101
103
110
106
507

Fig. 5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101, 301

Fig. 6

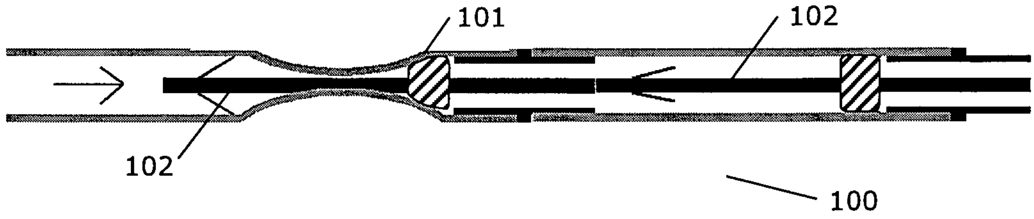

Fig. 7

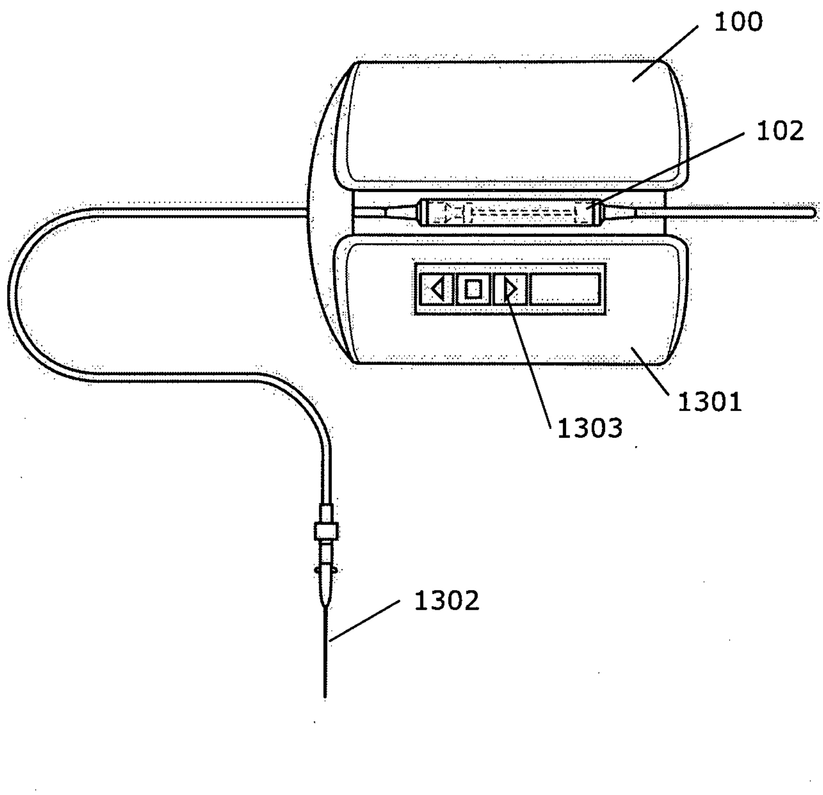

Fig. 8

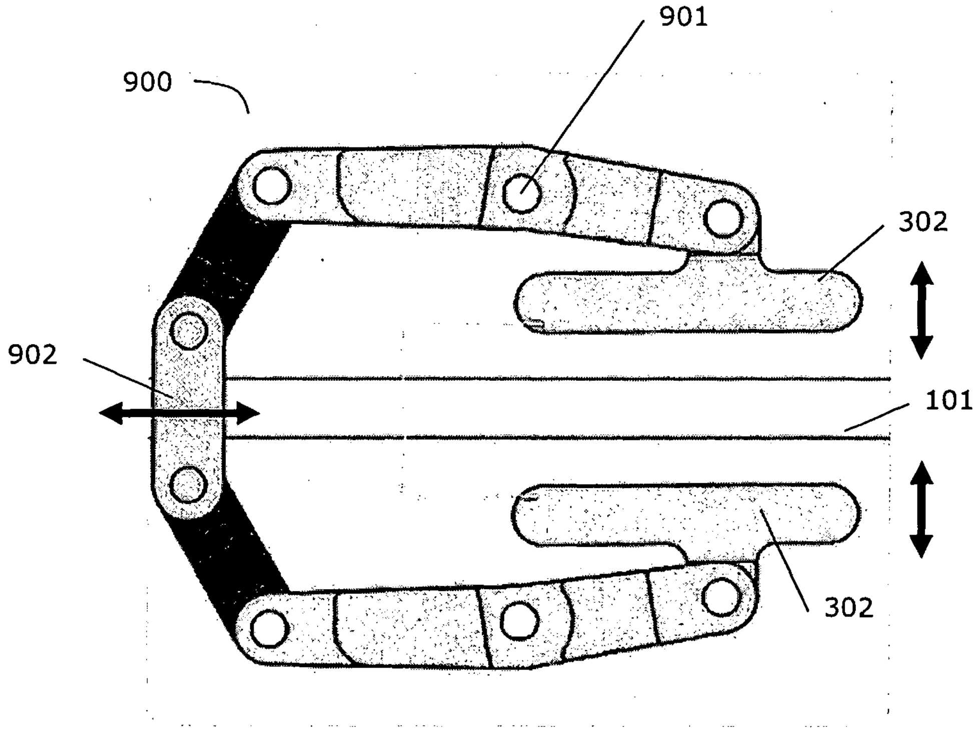

Fig. 9

INTERNATIONAL SEARCH REPORT	International application No. PCT/DK2013/000009

A. CLASSIFICATION OF SUBJECT MATTER

F04B 19/20 (2006.01), A61M 1/10 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC, CPC: F04B, A61M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

DK, NO, SE, FI: Classes as above.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2378121 A1 (VEINUX APS) 2011.10.19, see Abstract, [0008], [0024], [0025], [0026], [0029], [0040], Fig. 12,	1 – 15
Y	US 5265847 A (VORHIS DANIEL J) 1993.11.30, see Abstract	1, 2
A	US 4443216 A (CHAPPELL ANTHONY G) 1984.04.17	

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26/03/2013	02/04/2013

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/DK2013/000009

Patent document cited in search report / Publication date	Patent family member(s) / Publication date
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US 4443216	JP 58010185 A 19830120 ES 8308002 A1 19831101 ZA 8202409 A 19830223 EP 0063727 A2 19821103 EP 0063727 A3 19850502 CA 1184278 A1 19850319 NZ 200222 A 19851213 AU 8227582 A 19821021