A pump comprising a housing having a cavity and a diaphragm positioned therein configured to fluidly separate the cavity into a driving chamber and a fluid chamber. The pump further includes a port that connects the driving chamber to a vacuum source. The port configured to have an open state and a closed state such that a fluid enters the fluid chamber when the port is in the open state, and wherein the fluid exits the fluid chamber when the port is in the closed state.
FIG. 3
FIG. 7
PNEUMATIC PUMP SYSTEM AND RELATED METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS


BACKGROUND

[0002] 1. Field

[0003] Aspects of the present invention relate generally to a pneumatic pump system and related methods. More specifically, particular aspects of the invention relate to a pneumatic pump system configured to provide a fluid flow sufficient for use, for example, in medical applications requiring fluid irrigation.

[0004] 2. Background

[0005] During the course of certain medical and surgical procedures, there is sometimes a need to provide a relatively high volume flow of irrigating fluid to the site of the body of the patient at which the procedure is being performed. For example, sometimes this fluid flow is required during the performance of an endoscopic surgical procedure or wound cleansing.

[0006] Two common such types of endoscopic surgical procedures are laparoscopic procedures and arthroscopic procedures. In a laparoscopic surgical procedure, a specialized type of endoscope, also known as a laparoscope, as well as companion surgical instruments, are used to perform minimally invasive surgery within the abdominal cavity of the patient. In a laparoscopic surgical procedure, it is sometimes necessary to provide a large volume of irrigating fluid to wash out and clear the surgical site of surgical debris and other undesirable material. An arthroscopic surgical procedure is a procedure that is performed endoscopically on the musculoskeletal system of the patient. In an arthroscopic surgical procedure, it is sometimes necessary to provide a large volume of irrigating fluid in order to distend the tissue at the surgical site and/or to clear away debris from the surgical site.

[0007] In the related art, the pump systems used during medical and surgical procedures require electrical power to operate. The electrical power is often supplied by either a battery or a power cord connected to a power outlet. The majority of the pumps currently available are disposable battery-operated pumps that are not reliable. Alternatively, other pumps require plugging into an AC power socket in order to operate.

[0008] For a variety of reasons, use of a pump system that is powered only by a source is electricity is problematic and undesirable. As such, there is a need for a pump system that is powered, at least in part, by an alternate source, such as, for example, a vacuum or other pneumatic or hydraulic pressure/vacuum.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The features, nature, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify like components correspondingly throughout, and wherein:

[0010] FIG. 1 is an isometric view of a pneumatic pump, shown from above, according to certain aspects of the present invention;

[0011] FIG. 2 is an isometric view of the pneumatic pump of FIG. 1, shown from below;

[0012] FIG. 3 is a top view of the pneumatic pump of FIG. 1;

[0013] FIG. 4a is a cross-sectional view of the pneumatic pump of FIG. 3, shown along section line 4a-4a of FIG. 3, and depicting the pneumatic pump in a resting state thereof;

[0014] FIG. 4b is a cross-sectional view of the pneumatic pump of FIG. 3, shown along section line 4a-4a of FIG. 3, and depicting the pneumatic pump in an inlet state thereof;

[0015] FIG. 4c is a cross-sectional view of the pneumatic pump of FIG. 3, shown along section line 4a-4a of FIG. 3, and depicting the pneumatic pump in an outlet state thereof;

[0016] FIG. 5 is an exploded cross-sectional view of the pneumatic pump of FIG. 3, shown along section line 4a-4a of FIG. 3;

[0017] FIG. 6 is an exploded cross-sectional view of an upper housing of the pneumatic pump of FIG. 3, shown along section line 4a-4a of FIG. 3;

[0018] FIG. 7 is an exploded cross-sectional view of a driving mechanism of the pneumatic pump of FIG. 3, shown along section line 4a-4a of FIG. 3;

[0019] FIG. 8 is an exploded cross-sectional view of a lower housing of the pneumatic pump of FIG. 3, shown along section line 4a-4a of FIG. 3;

[0020] FIG. 9 is a cross-sectional view of a pneumatic pump according to certain alternative aspects of the present invention;

[0021] FIG. 10 is a cross-sectional view of a pneumatic pump according to certain alternative aspects of the present invention;

[0022] FIG. 11 is another isometric view of a converting mechanism, shown from above, in accordance with certain aspects of the present invention;

[0023] FIG. 12 is an isometric view of the converting mechanism of FIG. 11, shown from below;

[0024] FIG. 13 is a cross-sectional view of the converting mechanism of FIG. 11, shown along section line 13-13 of FIG. 11;

[0025] FIG. 14 is an isometric view of a hand piece for use with the pneumatic pump of FIG. 1, in accordance with certain aspects of the present invention;

[0026] FIG. 15 is a cross-sectional view of the hand piece of FIG. 14, shown along section line 16-16 of FIG. 15; and,

[0027] FIG. 16 is a close-up cross-sectional view of the hand piece of FIG. 14.

DETAILED DESCRIPTION

[0028] The detailed description set forth below, in connection with the appended drawings, is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of the various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details.

[0029] Various aspects of a fluid irrigation pump system may be illustrated by describing components that are coupled, attached, and/or joined together. As used herein, the terms “coupled”, “attached”, and/or “joined” are interchangeably
used to indicate either a direct connection between two components or, where appropriate, an indirect connection to one another through intervening or intermediate components. In contrast, when a component is referred to as being "directly coupled", "directly attached", and/or "directly joined" to another component, there are no intervening elements shown in said examples.

0030 Relative terms such as "lower" or "bottom" and "upper" or "top" may be used herein to describe one element's relationship to another element illustrated in the drawings. It will be understood that relative terms are intended to encompass different orientations of a fluid irrigation pump system in addition to the orientation depicted in the drawings. By way of example, if aspects of a fluid irrigation pump system shown in the drawings are turned over, elements described as being on the "bottom" side of the other element would then be oriented on the "top" side of the other elements as shown in the relevant drawing. The term "bottom" can therefore encompass both an orientation of "bottom" and "top" depending on the particular orientation of the drawing.

0031 The term "liquid" as used herein, does not merely refer to a state of matter as defined in the thermodynamic and/or fluid mechanics art. Instead, the term "liquid" also includes any solid particles or gasses that may incidentally flow with a liquid medium (e.g., irrigation fluid or blood) or that may be intentionally irrigated using a liquid medium. For example, when a fluid irrigation pump system is used in a surgical procedure, the term "liquid" may refer to a combination of liquid medium (e.g., irrigation fluid, blood, and other bodily liquid to and from the patient) and any solid particles including, but not limited to, resected tissue removed from the patient's body or harmful particles mixed with smoke or other particulates and/or gasses such as may occur in connection with laser, cauterization, and/or other medical procedures. The term "fluid", as used herein, may also refer to a liquid medium, solid particles, smoke, gases, particulates, and combinations thereof.

0032 Referring to Figs. 1-3, a pump 100 according to one aspect of the present invention comprises a main body 101 defined by an upper housing 120, a middle housing 122, and a lower housing 124. The upper housing 120 is affixed to a top side of the middle housing 122 by an attachment feature, such as, for example, one or more screws 136a (FIG. 3). The lower housing 124 is affixed to a lower side of the middle housing 122 by a similar attachment feature, such as, for example, one or more screws 136b (FIG. 2). Alternative attachment features may be used, such as, for example, adhesive, radiofrequency welding, sonic welding, heat welding or a snap fit mechanism, such as a mating lip and flange arrangement (not shown).

0033 It should be understood that the housing of pump 100 may be formed from any number of separate pieces which are affixed to one another. Similarly, the upper housing 120, the middle housing 122, and the lower housing 124, each may be formed from two or more pieces which are affixed to one another. Likewise, two or more of the upper housing 120, middle housing 122, and lower housing 124 may be combined into a single piece. The overall external shape of the pump 100 may be spherical or cylindrical.

0034 The lower housing 124 includes a port 102 for fluid communication with an energy source, shown schematically in FIG. 1 by reference number 104, via a conventional connector (not shown), which is operatively connected to the port 102, thereby fluidly connecting a driving chamber 134 (FIGS. 4a-4c) of the pump 100 to the energy source 104. According to one aspect of the present invention, the energy source is a tank, or other reservoir, containing a vacuum, or compressed air, together with conventional equipment, such as an external pumping system, necessary to maintain a preselected vacuum, or pressurized air, therein. According to a preferred embodiment of the present invention, the energy source 104 provides a vacuum to the port 102. However, one of ordinary skill in the art, upon reading the within specification, would understand that a pump 100 according to certain aspects of the present invention can be configured to operate with a source of compressed air, rather than a vacuum, provided to the port 102.

0035 The upper housing includes an inlet 121 adapted to be connected to a source of fluid, such as, for example, surgical irrigation fluid. According to one aspect of the present invention, the surgical irrigation solution is sterile saline provided in a conventional IV bag, which is connected to the inlet 121 by a flexible tube (not shown). The upper housing also includes an outlet 121b adapted to be connected to a handpiece 900 (FIGS. 15-17) by a flexible tube (not shown) for delivering the surgical irrigation solution, under controlled pressure provided by the pump 100 as described herein, to the surgical site.

0036 The upper housing 120 includes one or more bores 135a through which screws 136 pass to threadingly engage corresponding threaded holes 137a provided in the upper surface of the middle housing 122. The lower housing 124 includes one or more bores 135b through which screws 136 pass to threadingly engage corresponding threaded holes 137b provided in the lower surface of the middle housing 122. In this manner, middle housing 122 is clamped between upper housing 120 and lower housing 124 by screws 136a, 136b.

0037 Referring now to FIGS. 4a-4c, a drive mechanism 114, such as, for example, a generally-cylindrical piston or plunger, is positioned within a cavity 111 formed by the main body 101 of the pump 100 and is moveable therein along a main axis “Xp” of the pump 100. More specifically, the drive mechanism 114 is positioned within the cavity 111 adjacent a portion of the middle housing 122 and is axially movable therein such that an outer circumferential surface of the drive mechanism 114 is in sliding relationship with at least a portion of an inner circumferential surface of the middle housing 122.

0038 A separating mechanism 128, preferably in the form of a flexible diaphragm made from an elastomeric material, is provided within the cavity 111 and includes a central portion 128a attached to an upper surface of the drive mechanism 114, and a peripheral portion 128b attached at one or more places therearound to the main body 101 of the pump 100. Referring specifically to FIG. 5, the central portion 128a of the separating mechanism 128 is affixed to a top surface of the drive mechanism 114 by a screw 129 and the peripheral portion 128b is sandwiched between abutting surfaces of the upper housing 120 and the middle housing 122, respectively. In this manner, central portion 128a of the separating mechanism 128 remains affixed to the main body 101 of the pump 100 at the interface between the upper housing 120 and the middle housing 122. A washer 130 may be used to more securely affix the separating mechanism 128 to the drive mechanism 114 and to prevent the screw 129 from being pulled through, puncturing, or otherwise tearing, the separating mechanism 128. Alterna-
tively, an o-ring, gasket, or similar device, may be used in place of the washer 130. While the separating mechanism 128 is preferably an elastomeric diaphragm, it alternatively may be any component capable of hermetically separating a fluid disposed in a fluid chamber 132 (defined by a portion of the cavity 111 formed by the upper housing 120 and a portion of the cavity 111 formed by the middle housing 122) from a fluid disposed in the driving chamber 134 (defined by a portion of the cavity 111 formed by the middle housing 124 and a portion of the cavity 111 formed by the lower housing 124). Examples of such alternative separating mechanism 128 includes, for example, an elastomeric ring, an elastomeric chamber, a fluid reservoir, a sealed piston and/or bore, or an o-ring. The separating mechanism 128 may optionally be connected to the drive mechanism 114 by an adhesive, solvent bond, radiofrequency seal or heat seal. The fluid chamber 132 is in fluid communication with both the inlet 121a and the outlet 121b, and the driving chamber 134 that is in fluid communication with the port 102.

The drive mechanism 114 is movable axially along the main axis “Xp” of the pump 100, within the cavity 111, in response to changes in pressure within the driving chamber 134. For instance, when driving chamber 134 is exposed to a vacuum, such as by connecting the port 102, or opening the port 102 via a valve (not shown), to the energy source 104, wherein the energy source 104 is a vacuum, drive mechanism 114 is drawn downwardly along axis “Xp” in a first “inlet stroke” direction indicated generally by reference arrow “X1”. As stated above, the central portion 128a of the separating mechanism 128 is affixed to the drive mechanism 114, and as such, is drawn downwardly along with the drive mechanism 114 such that, as the volume of the driving chamber 134 is decreased thereby, the volume of the fluid chamber 132 is increased. If inlet 121a is connected, and open, to the source of surgical irrigation solution, surgical irrigation solution will be drawn into the fluid chamber 132 as the volume thereof increases.

A biasing element 108, such as a compression spring, is positioned within the cavity 111 between the drive mechanism 114 and the lower housing 124 to bias the drive mechanism 114 in a direction along axis “Xp”, away from the lower housing 124 and toward the upper housing 120 in a direction indicated generally by reference arrow “X2”. As such, unless port 102 is connected, and open, to energy source 104, biasing element 108 urges drive mechanism 114 to the “resting” position shown in FIG. 4a, wherein the upper surface of the drive mechanism 114, and thus the separating mechanism 128 affixed thereto, is disposed proximate a portion of the cavity 111 defined by the upper housing 120. Opening the port 102 to the energy source 104 draws the drive mechanism 114 downwardly against the bias of the biasing element 108 along axis “Xp” in the inlet stroke direction “X1”. The spring constant of the biasing element 108 is selected in view of the magnitude of the vacuum supplied by the energy source via the port 102 (which may or may not be adjusted with a regulator) such that vacuum draws the drive mechanism 114 downwardly until it reaches a partially-retracted position (defining an “inlet state” of the pump 100) as shown in FIG. 4a.

As mentioned above, inlet 121a fluidly connects the fluid chamber 132 to a source of fluid, such as, for example, saline or another surgical irrigation solution. As the drive mechanism 114 moves downwardly in direction “X1”, fluid flows into the fluid chamber 132 through the inlet 121a. In order to prevent backflow of the fluid, inlet 121a may include an inlet check valve 116 positioned therein. Similarly, outlet 121b includes an outlet check valve 118 positioned therein for permitting flow out of the fluid chamber 132 but preventing flow into the fluid chamber 132. As shown specifically in FIGS. 4a-4b, as the drive mechanism 114 moves downwardly in direction “X1”, the negative pressure created in the fluid chamber 132 as a result of the increasing volume thereof simultaneously opens inlet check valve 116, thereby permitting fluid to flow into the fluid chamber 132 through the inlet 121a, and further sends outlet check valve 118 within the outlet 121b, thereby preventing intake of any fluid into the fluid chamber 132 through the outlet 121b.

The drive mechanism 114 continues to move downwardly in direction “X1”, as shown in FIGS. 4a-4b, until it reaches its farthest downward position within the cavity 111, thereby defining an “outlet state” of the pump 100, as shown in FIG. 4c. Drive mechanism 114 includes a stopping mechanism 106 projecting therefrom downwardly toward port 102. The stopping mechanism 106 may include a floating plunger, variable shutoff, piston ball valve, needle valve, or any other means for plugging the port 102 when the drive mechanism 114 reaches the outlet state, thereby shutting off fluid communication between the energy source 104 and the driving chamber 134. With the port 102 closed by the stopping mechanism 106, vacuum no longer opposes the upward bias of the biasing member 108 on the drive mechanism 114. The stopping mechanism 106 may be capable of moving independently of the drive mechanism 114.

The stopping mechanism 106 may be capable of moving upwardly and downwardly within a bore 114c of the drive mechanism 114 located along the longitudinal axis “Xp” thereof. The bore 114c of the drive mechanism 114 is aligned generally along an axis that may be aligned a longitudinal axis of the port 102, such that the stopping mechanism 106 is configured to move therealong. A lower end of the stopping mechanism 106 may include, for example, a seal ring, o-ring gasket, or other sealing feature 106a, sized and adapted to engage an upper end of port 102. The stopping mechanism 106 may be mounted to the drive mechanism 114 by a biasing feature 106b, such as a tension spring, which biases the stopping mechanism 106 upwardly toward the drive mechanism 114.

Lower housing 124 includes one or more relief ports 127 for controlled fluid communication between the driving chamber 134 and atmosphere. Relief ports 127 each includes a relief valve 126 positioned therein and movable between a normally-closed position, as shown in FIG. 4a, and an open position, as shown in FIG. 4c. As shown in FIG. 4a, when port 102 is open, the vacuum supplied to the driving chamber 134 via open port 102 urges each relief valve 126 into the closed position, thereby sealing the driving chamber 134 from atmosphere such that the drive mechanism 114 will move downwardly against the bias of the biasing element 108, as described above. Moreover, relief valves 126 may be biased toward a closed position by a spring 126b. Alternatively, relief valves 126 may take the form of an atmospheric check valve, rotating valve, ball valve, duckbill valve, diaphragm valve, channels in the housing and in the drive mechanism that slide in and out of alignment, or any other means capable of providing controlled fluid communication between the driving chamber 134 and atmosphere. According to one aspect of the present invention, pump 100 includes any suitable number,
preferably six, of relief valves 126 suitable to rapidly, and controllably, restore the pressure in driving chamber 134 to
atmospheric pressure.

[0045] Relief valves 126 are configured to operate in conjunction with movement of the drive mechanism 114 along the axis “X,” of the pump 100 to be controllably opened and closed, as described herein. Each relief valve 126 is operatively connected to the drive mechanism 114, such as, for example, by an assist spring 112, and a rod 110. As drive mechanism 114 moves downwardly and upwardly in cavity 111, assist spring 112 compresses and expands, respectively, thereby imparting a varying downward force on the relief valve 126. As the drive mechanism 114 is drawn downwardly, assist spring 112 is compressed. The farther down drive mechanism 114 moves, the greater the force imparted on the relief valve 126, against the upward bias of the spring 126b, and the greater the potential energy stored by the assist spring 112. Eventually, the downward movement of the drive mechanism 114 causes the drive mechanism 114 to contact an upper surface of the relief 126, forcing the relief valve 126 to open. The potential energy stored by the compressed assist spring 112 causes the relief valve 126 to open quickly, thereby opening the driving chamber 134 to atmosphere through relief ports 127. Alternatively, as the drive mechanism 114 is drawn downwardly, the assist spring 112 may also be compressed until it reaches a threshold, at which point, the downward force imparted on the relief valve 126 is sufficient to open it against the bias of the spring 126b.

[0046] For purposes of simplicity of explanation, the methods described herein in regard to operation of the pump 100 are shown and described as a series of acts, which may, in accordance with one or more aspects, occur in different order and/or concurrently with other acts from the order shown and described herein. For example, it is to be appreciated that the methods could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a method in accordance with one or more features described herein.

[0047] According to one aspect of the present invention, port 102 is connected to the energy source 104 in order to provide a vacuum in the driving chamber 134 of the pump 100. A conventional valve (not shown) may be provided in a line connecting the port 102 to the energy source 104 such that the vacuum can be turned “on” and “off,” thereby controlling access of the vacuum to the driving chamber 134. Inlet 121a is connected, via a flexible tube (not shown), to a source of surgical irrigation fluid and outlet 121b is connected, via a flexible tube (not shown), to the handpiece 900 (FIG. 15).

[0048] Referring now back to FIG. 4b, the presence of the vacuum in the driving chamber 134 seats relief valves 126 in their respective relief ports 127, seats outlet check valve 118 in the outlet 121b and opens inlet check valve 116 in the inlet 121a. As the drive mechanism 114 is drawn downwardly in direction “X”, against the upward bias of the biasing element 108, separating mechanism 128 draws surgical irrigation fluid, through inlet 121a, into the fluid chamber 132. As the drive mechanism 114 continues to move downwardly, the assist springs 112 compress until the drive mechanism 114 reaches the bottom of its inlet stroke, at which point, stopping mechanism 106 closes off the port 102 connected to the energy source 104 and relief valves 126 open due to compression of the springs 112, which will rapidly open the relief valves 126 once the drive mechanism 114 reaches a threshold point and the stopping mechanism 106 closes the port 102. This functioning allows the relief valves 126 to open and equalize the pressure in the driving chamber 134 quickly since the port 102 is closed and the vacuum provided by the energy source 104 is closed to the port 102.

[0049] With the relief valves 126 open and the energy source 104 no longer in fluid communication with the driving chamber 134, the upward bias provided by the biasing element 108 is no longer opposed by the vacuum, yet the biasing element 108 is now in a state of compression. As such, biasing element 108 acts to move the drive mechanism 114 upwardly toward the upper housing 120, yet stopping mechanism 106 remains drawn to the port 102, due to the vacuum supplied to the underside thereof by the energy source 104. As drive mechanism 114 begins its upward movement, stopping mechanism 106 remains seated to the port 102, as tension spring 106b extends in length against its bias. Thus, the stopping mechanism 106 will stay in place (that is, closing off port 102) until either: the spring force of the tension spring 106b reaches a threshold where it pulls the stopping mechanism 106 out of the port 102, or when the drive mechanism 114 physically pulls the stopping mechanism 106 out of the port 102.

[0050] As a result of the drive mechanism 114 being drawn upwards by the biasing element 108, the volume of the fluid chamber 132 decreases. As such, in conjunction with the inlet check valve 116 closing and the outlet check valve 118 opening, fluid may be driven by the drive mechanism 114 and separating mechanism 128 out of the fluid chamber 132 via the outlet 121b. Relief valves 126 are configured, and in particular, springs 126b of the relief valves 126 are tensioned such that, once drive mechanism 114 reaches the uppermost extent of its upward movement, as shown in FIG. 4a, relief valves 126 snap into a closed position, thereby preventing driving chamber 134 from communicating with atmosphere via the relief ports 127. Since, in this position, stopping mechanism 106 will no longer plug the port 102, driving chamber 134 will, once again, be exposed to vacuum from the energy source 104, thereby repeating the cycle described above.

[0051] Referring to FIG. 9, a pump 200 according to an alternative embodiment of the present invention includes many of the components provided by the pump 100 described above, and like reference numbers are intended to represent like components. In the current embodiment, however, the pump 200 includes a separating mechanism 228 in the form of an o-ring positioned in a groove provided in the inner circumferential surface of the middle housing 122, against which an outer circumferential surface of the drive mechanism 114 slides as the drive mechanism 114 moves within the cavity 111. Separating mechanism 228, then, provides fluid separation between the fluid chamber 132 and the driving chamber 134 in order for the pump 200 to function as described above.

[0052] Referring to FIG. 10, a pump 300 according to yet another alternative embodiment of the present invention includes many of the components provided by the pump 100 described above, and like reference numbers are intended to represent like components. In the current embodiment, however, the pump 300 includes a separating mechanism 328 in the form of an annular diaphragm 328 that is affixed to an upper surface of the drive mechanism 114, for example, by adhesive. In this embodiment, screw 129 (FIG. 4a) and washer (FIG. 4a) are unnecessary.
Referring to FIGS. 11-13, aspects of a converting mechanism 500 that may optionally be included with pump 100 are shown. The converting mechanism 500 may include any mechanisms for converting a pulsatile flow of fluid coming from the pump 100 into a steady stream of fluid. For example, the converting mechanism 500 may include a pulsation damper, water hammer arrestor, or any other means of reducing pulsations. In a preferred aspect the converting mechanism may be a pulsation damper. The converting mechanism 500 (e.g., a pulsation damper) may be optionally provided in order to minimize pulsing of the fluid flowing out of the outlet 121a. Converting mechanism 500 may include lower housing 502, middle housing 504, and upper housing 506. The lower housing 502, middle housing 504, and upper housing 506 may be fastened together with one or more screws 520 and/or other fastening features (e.g., adhesives). Furthermore, it should be understood that the housing of converting mechanism 500 may be formed from any number of parts. Any of the lower housing 502, middle housing 504, and upper housing 506 may be formed from two or more pieces. Likewise, two or more of the lower housing 502, middle housing 504, and upper housing 506 may be integrally formed such that they comprise a single part. Further, the converting mechanism 500 may include a separating mechanism 508, drive mechanism 510, and primary return spring 512. Additionally, converting mechanism 500 may include valves 514 and 516.

In operation, for example, as the fluid flowing out of the outlet pressure equalizing mechanism 118 of pump 100 occurs, the drive mechanism 510 may move downwardly as shown in FIG. 13. Downward movement of the drive mechanism 510 may cause primary return spring 512 of converting mechanism 500 to compress, and may also cause separating mechanism 508 to be displaced or distorted downwardly. As a result, converting mechanism 500 acts as an accumulator where some volume of fluid is stored under pressure (e.g., while a fluid valve on a hand piece is closed). When the fluid valve on the hand piece is opened, the converting mechanism 500 causes the fluid to flow out one of the valves 514 or 516, where the fluid flows in a smooth manner without pulsing, due to the effective reservoir storing of the converting mechanism 500. Once the fluid valve on the hand piece opens, the primary return spring 512 may decompress and draw the drive mechanism 510 and the separating mechanism 508 upward. The converting mechanism 500 may optionally include a screw 518 for adjusting the preload on drive mechanism 510. By adjusting screw 518, the preload on drive mechanism 510 may be adjusted from no preload to an appropriately varied amount of preload.

A variety of hand pieces may be used in conjunction with the pumps described in this application. In one embodiment, the hand piece may have capabilities of delivering fluids to the surgical site from a fluid source via a pump. In another embodiment, the hand piece may deliver suction and/or compressed air to the surgical site in addition to delivering fluids from a fluid source via the pump.

One embodiment of a hand piece 900 for use with a fluid pump 100 is shown in FIGS. 14-16. As shown in FIG. 14, the hand piece 900 comprises a housing 910, a probe 920, a fluid valve 930, a suction valve 950, and a tubing set 960. The housing 910 may comprise a main channel 911 having a probe opening 912 that communicates with the lumen of the probe 920. The main channel 911 of the housing 910 also has a fluid opening 913 that communicates with the outlet 934 of the fluid valve 930, and a suction opening 914 that communicates with an outlet of the suction valve 950. The probe 920 has a distal end 921 that is positioned near the surgical site during use, and a proximal end 922 that connects to the housing 910. A hub 923 may be used to connect the probe 920 to the housing 910, and may be attached to or integrally formed with the proximal end 922 of the probe 920.

The hand piece 900 is connected to a suction source and a fluid pump via a tubing set 960. The tubing set has a suction tube 961, an irrigation tube 962, and electrical wire 963. The irrigation tube 962 connects a fluid pump to the irrigation valve. Preferably, the irrigation tube 962 is connected to a fluid pump powered by a source of vacuum as described in the present disclosure. However, the irrigation tube may be connected to any fluid pump, including a fluid pump powered by an electronic motor, compressed air, or any other energy source. The suction tube preferably connects to the same source of vacuum used to power the fluid pump. However, if the pump is not powered by a source of vacuum, or a different source of vacuum is otherwise required, a separate source of vacuum can be connected to the suction tube.

FIGS. 15-16 show cross-sectional views of the hand piece 900 and the fluid valve 930, respectively. The fluid valve 930 may be connected to the fluid opening 913 in the housing 910. The fluid valve may comprise a fluid valve housing 931, a spring 937, a button 936, and a plunger 940. The fluid valve housing 931 may have a valve inlet 933 that connects to the irrigation tube 962, and a valve outlet 934 that connects to the fluid opening 913 in the housing 910. The valve inlet 933 and the valve outlet 934 may be connected by a valve channel 932. The plunger 940 may be connected to the button 936, and the assembly of the plunger 940 and the button 936 may be inserted into a button opening 935 within the fluid valve housing 931, which may align with the valve channel 932. In use, the user depresses the button 936, which may compress the spring 937 and move the plunger from a closed position to an open position within the valve channel 932. Releasing the button 936 may allow the spring 937 to decompress and return the button 936 and the plunger 940 to the closed position.

The plunger 940 may have a plunger body 941 having a plunger channel 942 extending therethrough. The plunger body 941 may have two annular grooves, one of which may be positioned on the opposite side of the other annular groove 944. A first annular groove 944 may be located on a first side of the plunger channel 942 nearer to the button 936, and a second annular groove 945 may be located on a second side of the plunger channel 942 distal from the button 936. A first o-ring 946 may be placed within the first annular groove 944 and a second o-ring 947 may be placed within the second annular groove 945.

When the plunger is in a closed position, the plunger 940 may be positioned within the valve channel 932 such that the plunger channel 942 is not aligned with one or both of the valve inlet 933 and the valve outlet 934. The first o-ring 946 may seal with the valve channel 932 at a point between the valve inlet 933 and the button opening 935, such that fluid does not exit the valve through the button opening 935. The second o-ring 947 may seal with the valve channel 932 at a point between the valve inlet 933 and the valve outlet 934, thus preventing fluid from flowing through the valve and into the main channel of the hand piece.

When the plunger is in an open position, the plunger 940 may be positioned within the valve channel 932 such that
fluid may flow from the valve inlet 933, through the plunger channel 942, and through the valve outlet 934. The first o-ring 946 may seal with the valve channel 932 at a point between the valve inlet 933 and the button opening 935, such that fluid may not exit the valve through the button opening 935. The second o-ring 947 may move out of the valve channel 932, such that it no longer forms a seal in the valve channel 932 between the valve inlet 933 and the valve outlet 934, and fluid may be able to flow through the valve and into the main channel of the hand piece.

The plunger channel 942 may have a flow-directing feature 943 that ensures proper fluid flow throughout the valve. Instead of directing fluid at flat surfaces, the flow-directing feature 943 may ensure that fluid entering the plunger channel 942 is guided out of the plunger channel and through the valve outlet. The flow-directing feature 943 may comprise a single surface angled toward the valve outlet 934, a v-shaped surface, or a curved surface that slopes toward the valve outlet 934.

The suction valve 950 may have a similar design to the fluid valve 930, except that instead of applying fluid to the surgical site, the suction valve 950 may apply suction to the surgical site. However, other valve designs may be used for the suction valve 950.

The pumps described in this application do not need to be used in combination with the hand pieces described in this application. Likewise, the hand pieces described in this application do not need to be used in combination with the pumps described in this application. However, the optimal fluid flow rates occur when the pump is connected to the fluid valve of the hand pieces described in this application.

The pump may be used during endoscopic surgical procedures, including laparoscopic procedures and arthroscopic procedures. The pump may also be used for wound cleansing. An explanation of these procedures is provided above.

The previous description is provided to enable any person skilled in the art to practice the various example implementations described herein. Various modifications to these variations will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other implementations. All structural and functional equivalents to the elements of the various illustrous examples described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference.

What is claimed is:

1. A pump comprising:
a pump housing having a diaphragm configured to form a
seal between a driving chamber and a fluid chamber;
a port that connects the driving chamber to a vacuum
source, the port configured to have an open state and a
closed state; and
a pressure equalizing mechanism that connects the driving
chamber to a source of atmospheric pressure;
wherein a fluid enters the fluid chamber when the port is in
the open state, and
wherein the fluid exits the fluid chamber when the port is in
the closed state.

2. The pump of claim 1, wherein at any given time, one
of the port and the pressure equalizing mechanism are closed.

3. The pump of claim 1, wherein the pressure equalizing
mechanism is configured to have an open state and a closed
state.

4. The pump of claim 2, wherein at any given time, one
of the port and the pressure equalizing mechanism are open.

5. The pump of claim 1, further comprising a stopping
mechanism capable of closing the port.

6. The pump of claim 5, wherein the port has a longitudinal
axis, and the stopping mechanism is configured to move
along the longitudinal axis of the port.

7. The pump of claim 1, further comprising a piston located
within the driving chamber, wherein movement of the piston
causes a change in the volume of the fluid chamber.

8. The pump of claim 7, further comprising a floating
plunger capable of moving independently of the piston,
wherein the floating plunger is capable of closing the port.

9. The pump of claim 1, wherein the fluid chamber has an
inlet pressure equalizing mechanism and an outlet pressure
equalizing mechanism.

10. The pump of claim 1, further comprising a spring
located within the driving chamber.

11. The pump of claim 10, wherein decompression of
the spring causes a decrease in the volume of the fluid chamber.

12. A pump comprising:
a pump housing having a diaphragm configured to form a
seal between a driving chamber and a fluid chamber;
a port that connects the driving chamber to a compressed
air source, the port configured to have an open state and a
closed state; and
a pressure equalizing mechanism that connects the driving
chamber to a source of atmospheric pressure;
wherein a fluid enters the fluid chamber when the port is
closed, and
wherein the fluid exits the fluid chamber when the port is
open.

13. The pump of claim 12, wherein at any given time, one
of the port and the pressure equalizing mechanism are closed.

14. The pump of claim 12, wherein the pressure equalizing
mechanism is configured to have an open state and a closed
state.

15. The pump of claim 14, wherein at any given time, one
of the port and the pressure equalizing mechanism are open.

16. The pump of claim 12, further comprising a stopping
mechanism capable of closing the port.

17. The pump of claim 12, wherein the port has a longitudi-
nal axis, and the stopping mechanism moves along the
longitudinal axis of the port.

18. The pump of claim 12, further comprising a piston
located within the driving chamber, wherein movement of the
piston causes the volume of the fluid chamber to change.

19. The pump of claim 17, further comprising a floating
plunger capable of moving independently of the piston,
wherein the floating plunger is capable of closing the port.

20. The pump of claim 12, wherein the fluid chamber has
an inlet pressure equalizing mechanism and an outlet pressure
equalizing mechanism.

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