US 20170298919A1

(19) **United States**
(12) **Patent Application Publication**
West
(10) **Pub. No.: US 2017/0298919 A1**
(43) **Pub. Date: Oct. 19, 2017**

(54) **DIRECT DRIVE LINEAR MOTOR FOR CONVENTIONALLY ARRANGED DOUBLE DIAPHRAGM PUMP**

(71) Applicant: **INGERSOLL-RAND COMPANY**, Davidson, NC (US)

(72) Inventor: **Joshua D. West**, Mooresville, NC (US)

(21) Appl. No.: **15/489,138**

(22) Filed: **Apr. 17, 2017**

Related U.S. Application Data

(60) Provisional application No. 62/323,884, filed on Apr. 18, 2016.

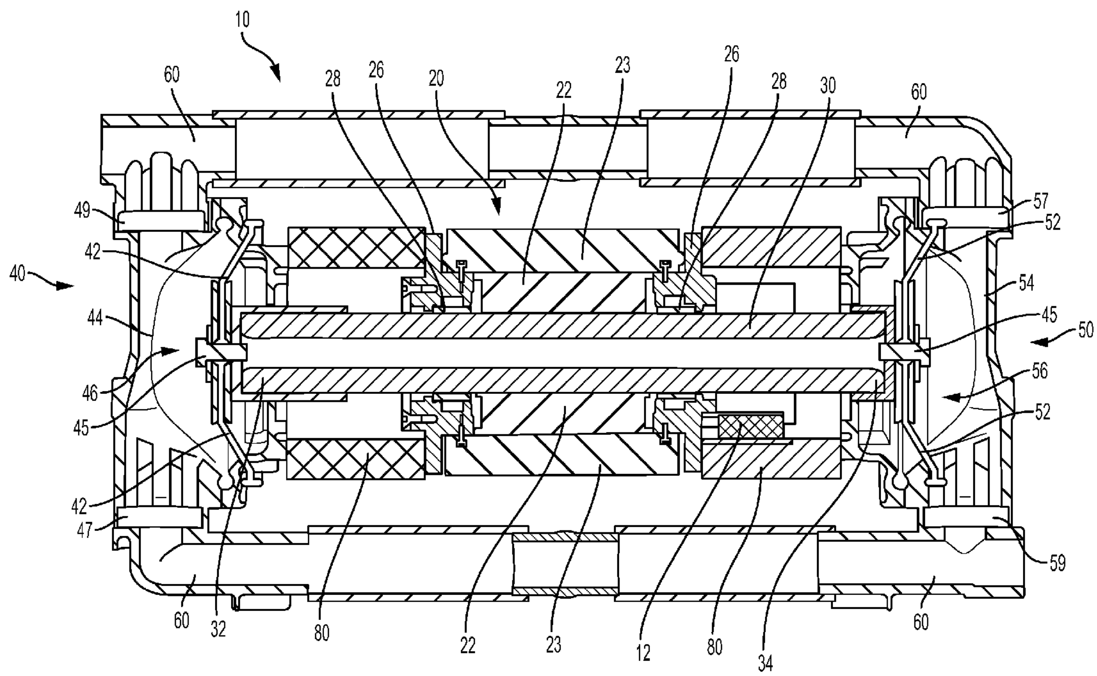
Publication Classification

(51) **Int. Cl.**
F04B 43/04 (2006.01)
F04B 53/10 (2006.01)
F04B 43/02 (2006.01)

(52) **U.S. Cl.**
CPC ***F04B 43/04*** (2013.01); ***F04B 43/026*** (2013.01); ***F04B 53/10*** (2013.01)

(57) **ABSTRACT**

A magnetically driven, linear double diaphragm pump is provided. The pump has a linear magnetic motor that includes a magnetic armature configured inside a cylindrical stator. The stator provides linear translation of the magnetic armature in a back and forth motion. A first pumping section is coupled to a first end of the magnetic armature, and a second pumping section is coupled to a second end of the magnetic armature. As the magnetic armature translates in a first direction, a first diaphragm in the first pumping section is flexed to pump fluid therethrough, and as the magnetic armature translates in a second direction a second diaphragm in a second pumping section is flexed to pump fluid therethrough. A control unit functions to control operational aspects of the motor and pump.



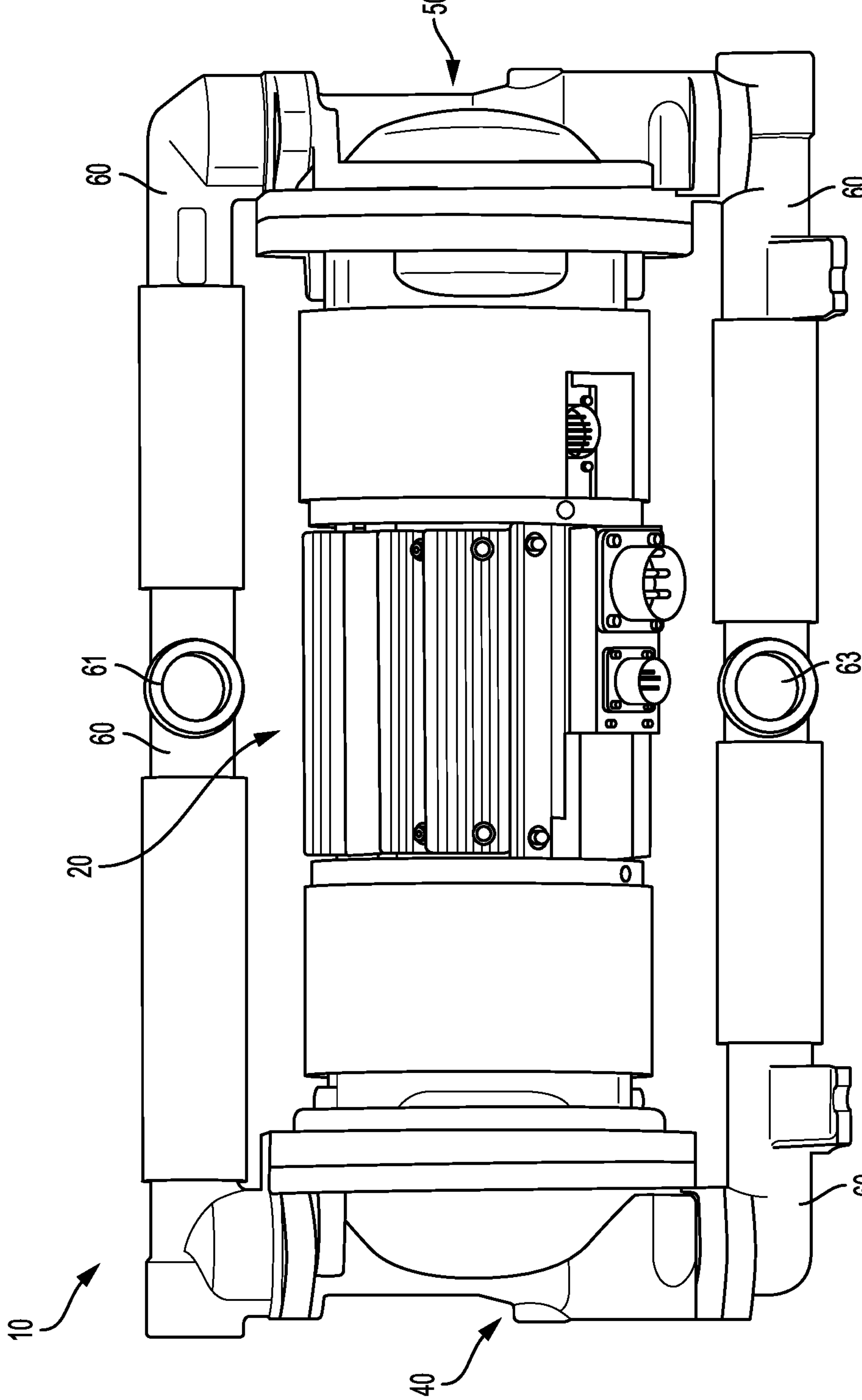


FIG. 1

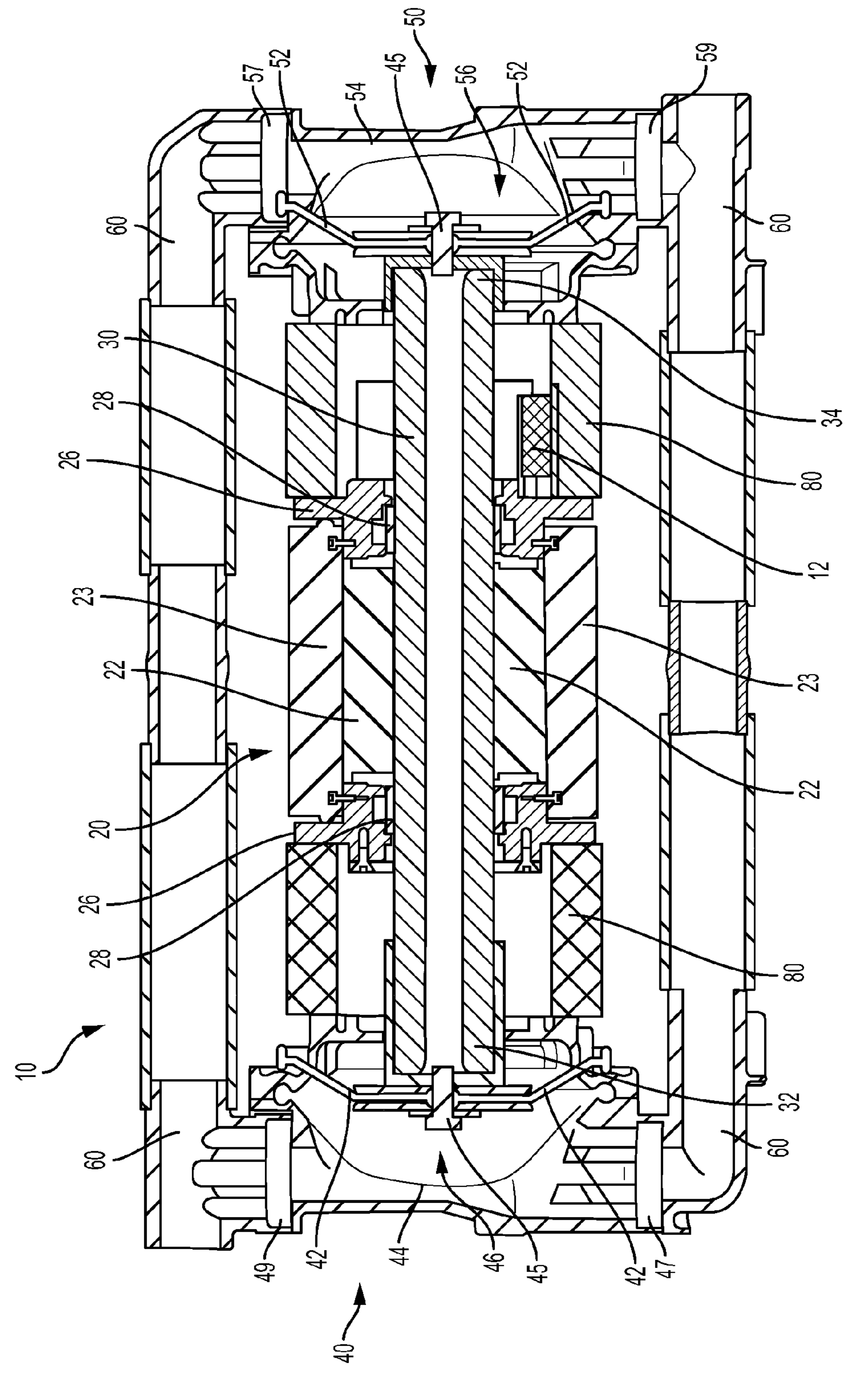

10
20
22
23
26
28
30
32
34
40
42
44
45
46
47
49
50
52
54
56
57
59
60
80
12

FIG. 2

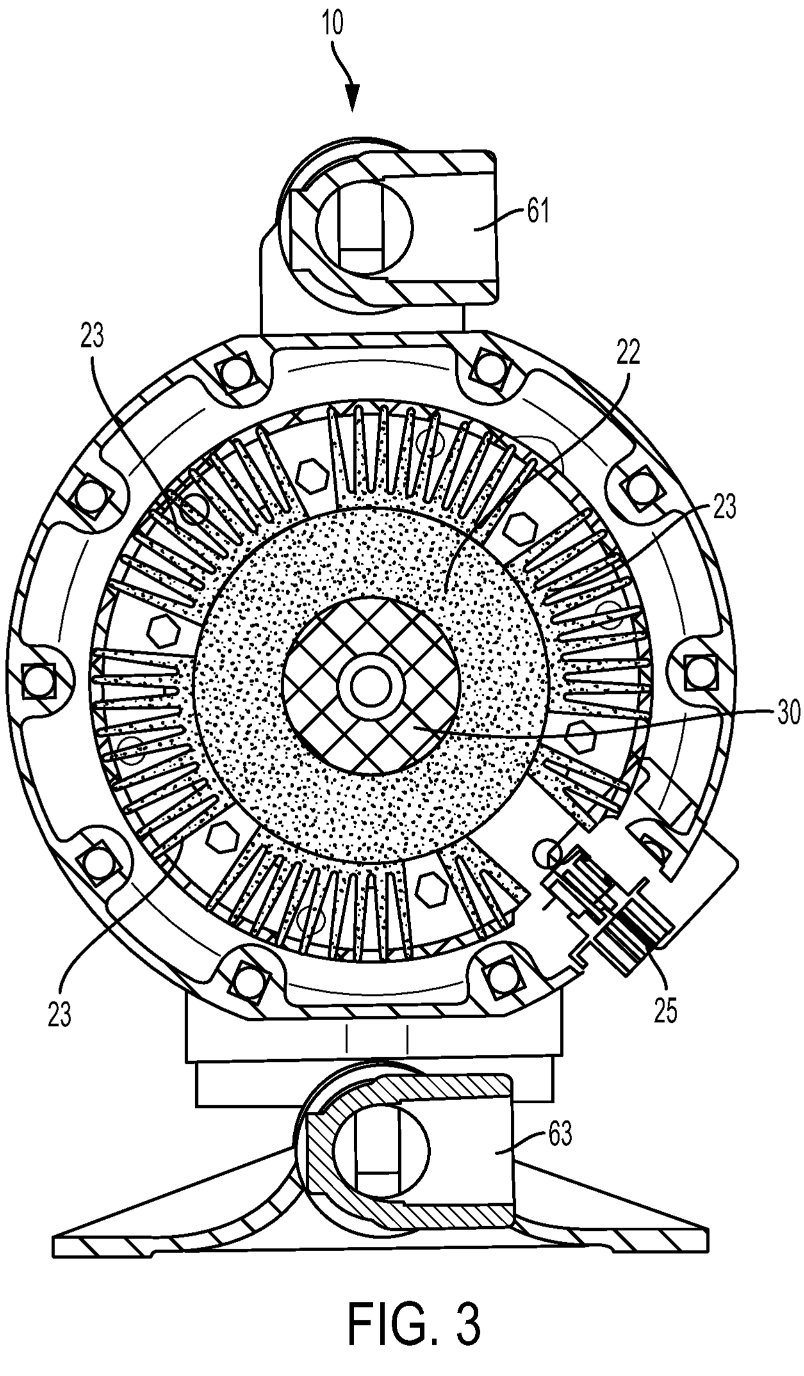


FIG. 3

DIRECT DRIVE LINEAR MOTOR FOR CONVENTIONALLY ARRANGED DOUBLE DIAPHRAGM PUMP

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Patent Application No. 62/323,884, filed Apr. 18, 2016, the disclosure of which is hereby incorporated entirely herein by reference.

BACKGROUND

Technical Field

[0002] The present disclosure relates to diaphragm pumps and other positive displacement pumps utilizing the reciprocating action of a flexible diaphragm.

State of the Art

[0003] A diaphragm pump is generally described as a positive displacement pump that uses the reciprocating action of a flexible diaphragm and corresponding valves on either side of the diaphragm to pump a fluid.

[0004] The diaphragm is typically sealed to create a pump chamber. The flexing of the diaphragm can cause the volume of the pump chamber to increase and decrease. As the volume increases, the fluid to-be-pumped is introduced to the chamber and as the volume decreases, the fluid to-be-pumped is expelled from the chamber. This pattern is repeatable, thus creating the reciprocating pumping action of the pump.

[0005] However, the repetitive nature of the reciprocating action can result in inefficiencies. There is thus a need to improve the reciprocating action of diaphragm pumps or other positive displacement pumps.

SUMMARY

[0006] The present disclosure relates to diaphragm pumps and other positive displacement pumps utilizing the reciprocating action of a flexible diaphragm.

[0007] An aspect of the present disclosure includes a double diaphragm pump comprising: a linear magnetic motor having a magnetic armature, the magnetic armature having a first and second end opposing one another; a first pumping section coupled to the first end; a second pumping section coupled to the second end, wherein the linear magnetic motor translates the magnetic armature to move a fluid through the first pumping section and the second pumping section.

[0008] Another aspect of the present disclosure includes wherein the linear magnetic motor translates the magnetic armature in first and second directions opposing one another.

[0009] Another aspect of the present disclosure includes wherein the first end of the magnetic armature is coupled to a first diaphragm in the first pumping section and the second end of the magnetic armature is coupled to a second diaphragm in the second pumping section.

[0010] Another aspect of the present disclosure includes wherein in the first direction the first diaphragm flexes to decrease a volume of a first chamber of the first pumping section and the second diaphragm flexes to increase a volume of a second chamber of the second pumping section to thereby move the fluid through the first and second pumping sections.

[0011] Another aspect of the present disclosure includes wherein in the second direction the first diaphragm flexes to increase the volume of the first chamber of the first pumping section and the second diaphragm flexes to decrease the volume of the second chamber of the second pumping section to thereby move the fluid through the first and second pumping sections.

[0012] Another aspect of the present disclosure includes a motor mount to which the linear magnetic motor is coupled, the motor mount being configured to maintain positioning of the linear magnetic motor with respect to the pump.

[0013] Another aspect of the present disclosure includes a positioner coupled to the motor mount and in functional communication with the magnetic armature to maintain positioning of the magnetic armature with respect to the linear magnetic motor.

[0014] Another aspect of the present disclosure includes wherein the first pumping section is coupled directly to the motor mount on a side of the motor and wherein the second pumping section is coupled directly to the motor mount on an opposing side of the motor.

[0015] Another aspect of the present disclosure includes a spacer positioned between the motor mount and each of the first pumping section and the second pumping section.

[0016] Another aspect of the present disclosure includes a double diaphragm pump comprising: a linear magnetic motor having a magnetic armature, the magnetic armature having a first and second end opposing one another; a first pumping section coupled to the first end; a second pumping section coupled to the second end, wherein the linear magnetic motor translates the magnetic armature without a gearbox in reciprocal first and second directions opposing one another to move a fluid through the first pumping section and the second pumping section.

[0017] Another aspect of the present disclosure includes a control unit, wherein the control unit controls operational aspects of the pump, and wherein the operational aspects further comprise real-time feedback of a position of the magnetic armature in the magnetic motor, stroke length of the magnetic armature, stroke speed of the magnetic armature, acceleration of the magnetic armature, and a flow rate of the fluid through the first pumping section and the second pumping section.

[0018] Another aspect of the present disclosure includes a method of operating a double diaphragm pump comprising: providing a magnetic armature in a linear magnetic motor, wherein the magnetic armature has first and second distal ends opposing one another; coupling a first pumping section to the first distal end; coupling a second pumping section to the second distal end; translating the magnetic armature back and forth in a reciprocal manner to move a fluid through the first pumping section and the second pumping section.

[0019] Another aspect of the present disclosure includes controlling operational aspects of the pump by a control unit, wherein the controlling operational aspects of the pump further comprises transitioning the pump between a priming mode wherein the control unit increases one or more of a speed or stroke length of the magnetic armature and a normal mode wherein the control unit returns to a normal speed and normal stroke length of the magnetic armature, and wherein the controlling operational aspects of the pump further comprises maintaining constant flow rate of the fluid exiting the pump despite changes in pressure of the fluid entering the pump or viscosity of the fluid.

[0020] The foregoing and other features, advantages, and construction of the present disclosure will be more readily apparent and fully appreciated from the following more detailed description of the particular embodiments, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Some of the embodiments will be described in detail, with reference to the following figures, wherein like designations denote like members:

[0022] FIG. **1** is a side view of an illustrative embodiment of a linear motor double diaphragm pump in accordance with the present disclosure;

[0023] FIG. **2** is a cross-sectional side view of the linear motor double diaphragm pump depicted in FIG. **1** in accordance with the present disclosure; and

[0024] FIG. **3** is a cross-sectional end view of the linear motor double diaphragm pump depicted in FIG. **1** in accordance with the present disclosure.

DETAILED DESCRIPTION OF EMBODIMENTS

[0025] A detailed description of the hereinafter described embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures listed above. Although certain embodiments are shown and described in detail, it should be understood that various changes and modifications may be made without departing from the scope of the appended claims. The scope of the present disclosure will in no way be limited to the number of constituting components, the materials thereof, the shapes thereof, the relative arrangement thereof, etc., and are disclosed simply as an example of embodiments of the present disclosure.

[0026] As a preface to the detailed description, it should be noted that, as used in this specification and the appended claims, the singular forms “a”, “an” and “the” include plural referents, unless the context clearly dictates otherwise.

[0027] The drawings depict illustrative embodiments of a double diaphragm pump **10**. These embodiments may each comprise various structural and functional components that complement one another to provide the distinct functionality and performance of the pump **10**, the particular structure and function thereof to be described in greater detail herein.

[0028] Referring to the drawings, FIGS. **1-3** depict an illustrative embodiment of a linear motor double diaphragm pump **10** in accordance with the present disclosure. Embodiments of the pump **10** may comprise, among other components, a magnetic motor **20**, opposing pumping sections **40** and **50**, and a corresponding manifold **60** having one or more inlets and outlets positioned therein, as needed.

[0029] Embodiments of the pump **10** may comprise a magnetic motor **20**. The magnetic motor **20** may comprise a stator **22** and a corresponding magnetic armature **30**. The stator **22** may comprise a coil set (not depicted) configured to be an electrical conductor, the coil set being, for example, a series of wires wound in the shape of a coil, spiral, helix, or other cylindrical-type shape, through which an electric current may pass. With the stator **22** being coupled to an electrical power source through the electric port **25**, electrical current may pass through the coil set, and the coil set may function as an electromagnetic conductor to generate a magnetic field. The coil set may be considered the winding (s) of the electromagnetic conductor and the coil set may have one or more windings. These windings may be inductively or magnetically coupled. The center of the winding(s) may define the magnetic axis of the conductor. The ends of the winding(s) of the coil set may be coupled to one or more circuits for electrical power. The number of windings or coils in the coil set, the number of separate passes of wire in the windings or coil set, and/or the given current passing through the windings or the coil set may be adjusted to change, alter, or amend the resulting magnetic field.

[0030] Embodiments of the pump **10** may further comprise the corresponding magnetic armature **30** having one or more magnets in series. For example, the magnetic armature **30** may comprise a series of permanent magnets aligned in a linear, or shaft-like, configuration, wherein the magnets may be lined up with one another end-to-end in a line. The magnetic armature **30** may have a shaft about which the magnets may be placed. The magnetic armature **10** may also have an exterior casing, or sleeve, in which the magnets are positioned. For example, the magnetic armature **30** may have a cylindrical shape, wherein the magnetic armature **30** may have an axis defined by the diameter of the shaft or the diameter of the magnets themselves. The length of the magnetic armature **30** may be the length of the shaft and/or the collective linear length of the magnets placed end-to-end. The axis of the magnetic armature **30** may be configured to align with the magnetic axis of the stator **22**. The magnetic armature **30** may therefore be configured to be set within the windings or coils of the coil set and be responsive to the magnetic forces generated by the stator **22**. In this way, the magnetic armature **30** may be configured to pass back and forth in a reciprocal linear motion through the interior diameter of the stator **22** in response to the magnetic forces of the coil set. Such a configuration may generate a 360-degree magnetic flux, wherein the magnetic armature **30** moves in a linear, back and forth motion, through the stator **22** in response to the magnetic forces generated by the coil set without physically contacting the stator **22**. Moreover, such a configuration may permit the stator **22** to directly drive the magnetic armature **30** without the need for gears, a gear box, transmissions, bearings, a scotch yoke, or the like that are common in conventional diaphragm pumps. Further, such a configuration may permit the stator **22** to directly drive the magnetic armature **30** without a series of power conversions between the motor and the diaphragms (to be discussed herein) that are common in conventional diaphragm pumps. These conventional systems (i.e., diaphragm pumps) are generally large, heavy, and have a lot of inertia.

[0031] Embodiments of the pump **10** may comprise the magnetic motor **20** being coupled to a motor mount **26**, wherein the motor mount **26** may serve to support the stator **22** in its proper orientation and position with respect to the other components of the pump **10**, and in particular the magnetic armature **30**. Furthermore, the magnetic armature **30** may be supported by a sleeve or positioner **28** that may be configured to maintain the orientation and position of the magnetic armature **30** with respect to the stator **22** and/or the magnetic motor **20**. The sleeve or positioner **28** may be configured to maintain the position of the magnetic armature **30** and yet permit the back and forth linear translation of the magnetic armature **30** within the stator **22**. The positioner **28** may be configured on the pump **10** exterior to the stator **22**. Also, one or more positioners **28** may be configured on either side of the stator **22**. The magnetic armature **30** may therefor extend beyond an end of the stator **22**. The magnetic armature **30** may have a first end **32** and a second end **34**, wherein the first and second ends, **32** and **34**, oppose one another at distal ends of the magnetic armature **30**.

[0032] Embodiments of the pump **10** may comprise one or more spacers **80** positioned between the motor mounts **26** and the first and second pumping sections, **40** and **50**, to be described in greater detail herein. The spacers **80** may be configured to properly space the first and second pumping sections, **40** and **50**, from the motor **20** to provide the magnetic armature **30** with the desired stroke length, or the like. Moreover, the size and shape of the spacers **80** may be adjusted to accommodate for the desired stroke length or power of the motor **20** and/or the pump **10**. Embodiments of the pump **10** may comprise the first and second pumping sections, **40** and **50**, being releasably coupled to the motor mounts **26** themselves. In other words, embodiments of the pump **10** may comprise the motor mounts **26** on either side of the motor **20** being physically, or at least functionally, coupled to the respective caps, **44** and **54**, with the first and second diaphragms, **42** and **52**, respectively, being positioned therebetween, which will be described in greater detail herein. Having the motor mounts **26** function as not only the support for the motor **20** but also as the retaining member or coupling member to which the caps, **44** and **54**, may be coupled, may greatly reduce the size of the pump **10**.

[0033] Embodiments of the pump **10** may comprise the motor **20** having one or more heat dissipation fins **23** in thermal communication with the stator **22**, and in particular with the coil set to dissipate heat from the coil set. The heat dissipation fins **23** may be configured in a pattern about the exterior of the stator **22** to draw heat outward and/or away from the coil set. Heat may be generated within the coil set due to the current passing through the wires. The heat dissipation fins **23** may therefore be coupled to the motor **20**, the motor mount **26**, or other components of the pump **10** so that the fins **23** are in thermal communication with the stator **22** to function as a heat sink to draw heat away from the stator **22**.

[0034] Embodiments of the pump **10** may further comprise a first pumping section **40**. The first pumping section **40** may comprise a first diaphragm **42** and a first cap **44** defining therebetween a first fluid chamber **46**. The first diaphragm **42** may be a flexible diaphragm capable of repeatedly flexing and/or bending in response to input, such as force. The first diaphragm **42** may be releasably coupled to the first end **32** of the magnetic armature **30**, such as, for example, by a fastener **45**. The diaphragm **42** may be operatively coupled, either directly or indirectly, to the first end of the magnetic armature **30**, such that the back and forth movement of the magnetic armature **30**, as described herein, may serve to flex the diaphragm **42** in a similar back and forth motion within, or in communication with, the first fluid chamber **46**. The first cap **44** may be releasably coupled to the pump **10**, and in particular may be coupled to components of the pump **10** so as to be configured to functionally communicate with the first diaphragm **42**. The first cap **44** may serve to oppose the first diaphragm **42** and define therebetween the first fluid chamber **46**. The first fluid chamber **46** may be configured to house a fluid therein, on which the diaphragm **42** may operate, or otherwise work, to create a fluid flow and/or pressure on the fluid. In other words, the fluid chamber **46** may comprise an inlet check valve **47** and an outlet check valve **49** that operate to direct a flow of fluid in and out of the fluid chamber **46** in response to the movement or displacement of the diaphragm **42**. The inlet check valves **47** and the outlet check valves **49** may be ball valves, flap valves, or other similar valves that open and close alternately to fill chambers and restrict or otherwise block back flow. The inlet check valves **47** and an outlet check valves **49** may be reversed, or flip-flopped, in their respective configuration on the first pumping section **40**, as desired for a particular flow configuration.

[0035] As the magnetic armature **30** exerts force to flex the diaphragm **42** toward the cap **44**, the diaphragm **42** may decrease the volume within the fluid chamber **46** to thereby force or displace at least a portion of the fluid within the fluid chamber **46** to close the inlet check valve **47** and open the outlet check valve **49** so that the fluid may exit the outlet check valve **49** and pass into the manifold **60**. Similarly, as the magnetic armature **30** exerts force to retract the diaphragm **42** away from the cap **44**, the diaphragm **42** may increase the volume within the fluid chamber **46** to thereby create a vacuum within the fluid chamber **46** that may serve to open the inlet check valve **47** and close the outlet check valve **49** so that the fluid in the manifold **60** may pass through the inlet check valve **47** and enter into the fluid chamber **46**. With more of the fluid in the fluid chamber **46**, the magnetic armature **30** may be set to repeat the foregoing steps by repeatedly exerting force on the diaphragm **42** to flex the diaphragm **42** back and forth in repetition, toward and away from the cap **44**, as described, to cause the fluid to repeatedly enter and exit the fluid chamber **46**. In this way, the magnetic armature **30** and the first pumping section **40** function as one half of the diaphragm pump **10** to pump a fluid through the pump **10**, the manifold **60**, and toward or away from a desired location.

[0036] Embodiments of the pump **10** may further comprise a second pumping section **50**. The second pumping section **50** may comprise a second diaphragm **52** and a second cap **54** defining therebetween a second fluid chamber **56**. The second diaphragm **52** may be a flexible diaphragm capable of repeatedly flexing and/or bending in response to input, such as force. The second diaphragm **52** may be releasably coupled to the second end **34** of the magnetic armature **30**, such as, for example, by the fastener **45**. The second diaphragm **52** may be operatively coupled, either directly or indirectly, to the second end **34** of the magnetic armature **30**, such that the back and forth movement of the magnetic armature **30**, as described herein, may serve to flex the second diaphragm **52** in a similar back and forth motion within, or in communication with, the second fluid chamber **56**. The second cap **54** may be releasably coupled to the pump **10**, and in particular may be coupled to components of the pump **10** so as to be configured to functionally communicate with the second diaphragm **52**. The second cap **54** may serve to oppose the second diaphragm **52** and define therebetween the second fluid chamber **56**. The second fluid chamber **56** may be configured to house a fluid therein, on which the diaphragm **52** may operate, or otherwise work, to create a fluid flow and/or pressure on the fluid. In other words, the fluid chamber **56** may comprise an inlet check valve **57** and an outlet check valve **59** that operate to direct a flow of fluid in and out of the fluid chamber **56** in response to the movement or displacement of the diaphragm **52**. The inlet check valves **57** and an outlet check valves **59** may be ball valves, flap valves, or other similar valves that open and close alternately to fill chambers and restrict or otherwise block back flow. The inlet check valves **57** and an outlet check valves **59** may be reversed, or flip-flopped, in their respective configuration on the second pumping section **50**, as desired for a particular flow configuration.

[0037] As the magnetic armature **30** exerts force to flex the diaphragm **52** toward the cap **54**, the diaphragm **52** may decrease the volume within the fluid chamber **56** to thereby force or displace at least a portion of the fluid within the fluid chamber **56** to close the inlet check valve **57** and open the outlet check valve **59** so that the fluid may exit the outlet check valve **59** and pass into the manifold **60**. Similarly, as the magnetic armature **30** exerts force to retract the diaphragm **52** away from the cap **54**, the diaphragm **52** may increase the volume within the fluid chamber **56** to thereby create a vacuum within the fluid chamber **46** that may serve to open the inlet check valve **57** and close the outlet check valve **59** so that the fluid in the manifold **60** may pass through the inlet check valve **57** and enter into the fluid chamber **56**. With more of the fluid back in the fluid chamber **56**, the magnetic armature **30** may be set to repeat the foregoing steps by repeatedly exerting force on the diaphragm **52** to flex the diaphragm **52** back and forth in repetition, toward and away from the cap **54**, as described, to cause the fluid to repeatedly enter and exit the fluid chamber **56**. In this way, the magnetic armature **30** and the second pumping section **50** function as one half of the diaphragm pump **10** to pump a fluid through the pump **10**, the manifold **60**, and toward a desired destination.

[0038] Embodiments of the pump **10** may comprise the first and second pumping sections, **40** and **50**, working in tandem to displace, or otherwise pump, a fluid based on the reciprocating action generated from a magnetically driven, linear double-diaphragm pump **10**, wherein the first and second pumping sections, **40** and **50**, are configured to work on opposing ends of a magnetic armature **30** that is linearly translated back and forth in response to magnetic forces exerted thereon by the stator **22**. In other words, as the magnetic armature **30** exerts force to flex the diaphragm **42** towards the cap **44** to decrease the volume of the first fluid chamber **46**, the magnetic armature **30** concurrently flexes the diaphragm **52** away from the cap **54** to increase the volume of the second fluid chamber **56**. In like manner, as the magnetic armature **30** exerts force to flex the diaphragm **42** away from the cap **44** to increase the volume of the first fluid chamber **46**, the magnetic armature **30** concurrently flexes the diaphragm **52** toward the cap **54** to decrease the volume of the second fluid chamber **56**. As a result, the magnetic armature **30**, in response to input from the stator **22**, may move back and forth in a linear manner to contemporaneously exert opposite and reciprocating forces on each of the first and second pumping sections, **40** and **50**. In this way, the pump **10** may simultaneously move fluid through, into, out of, within, or by way of each of its pumping sections **40** and **50**, as well as the manifold **60**, as the case may be.

[0039] Embodiments of the pump **10** may comprise a manifold **60** in operative communication with the fluid within the pump **10**. The manifold **60** may comprise one or more fluid inlet/outlets **70**. The manifold **60** may be configured to fluidically couple the one or more inlet/outlets **70** to the first and second pumping sections, **40** and **50**, and vice versa. In other words, the manifold **60** may comprise the tubing and/or piping that directs the flow of the fluid being processed and worked upon by the pump **10** through each of the pumping sections, **40** and **50**, and into and out of the pump **10**. The size and shape of the manifold **60** may be adapted according to the needs of the pump **10**. The manifold **60** may be configured to receive either, or both, of a pressurized or non-pressurized source of fluid.

[0040] Embodiments of the pump **10** may comprise a control unit **12** and associated control electronics **14**. For example, the control unit **12** may be a controller comprising a processor (CPU), circuit board, internal memory, encoder, software, control algorithms, inputs, outputs, and other electrical components as needed to direct the electrical operations and control electronics **14** of the pump **10**. Further in example, the associated control electronics **14** may further comprise sensors, gauges, valves, regulators, transducers, solenoids, controllers, wireless communications, and the like for measuring and controlling fluid flow through the pump **10**, counting pump cycles, controlling motor speed and power, measuring flow rate, measuring and controlling fluid pressure, detecting leaks, measuring and sensing end of stroke, offsetting the stroke length, measuring and controlling current flow through the stator **22**, and balancing the fluid flow through the pump **10**, among other important electrically-based operational and control aspects of the pump **10**.

[0041] For example, embodiments of the pump **10** may further comprise one or more hall sensors embedded in bushings positioned along the length of the magnetic armature **30** to help position the magnetic armature **30** with respect to the motor **20**, the mount **26**, or the pump **10**. Further in example, embodiments of the pump **10** may further comprise one or more hall sensors embedded in one or more of the positioners **28**. The halls sensors may provide real-time feedback of the position of the magnetic armature **30** to the control unit **12** as the magnetic armature **30** transitions back and forth in the first and second directions. The hall sensors may also provide real-time feedback to the control unit **12** of the stroke length, stroke speed, and/or acceleration of the magnetic armature **30**. The hall sensors may be positioned on an exterior of the motor **20** near where the motor **20** can be mounted to the mount **12**.

[0042] The control unit **12** may be configured to coordinate the operations of each component of the control electronics **14** to achieve, control, and/or alter any of the foregoing operational aspects of the pump **10**. Alternatively, each of the components of the control electronics **14** may be configured to communicate directly with one or more corresponding components, as needed, to perform the desired operations of the pump **10**. Further in the alternative, each of the components of the control electronics **14** may be configured to communicate with the control unit **12** as well as directly with one or more corresponding components, as needed, to perform the desired operations of the pump **10**.

[0043] Embodiments of the pump **10** may provide advantages over conventional, mechanically driven, double diaphragm pump designs. For example, the interaction between the stator **22** and the magnetic armature **30** provides that the control unit **12** may control the position of the magnetic armature **30**, and thus the relative position of the first and second diaphragms, **42** and **52**, with much more ease due to the low inertial forces of the magnetic armature **30**, as compared to conventional drive systems. The control unit **12** and associated electronics **14** may provide real-time feedback of the position of the magnetic armature **30** at any point along the stroke length. With the positional feedback and the ability to easily stop/start the motion of the magnetic armature **30**, due to relatively low inertia, the magnetic armature **30** may be controlled with much more immediate precision, which in turn provides much more immediate precision to the first and second diaphragms, **42** and **52**, and thereby the first and second pumping sections, **40** and **50**, respectively. Further, the magnetic interaction between the stator **22** and the magnetic armature **30** along the full stroke length of the magnetic armature **30** provides increased control of the acceleration and deceleration of the magnetic armature **30** at the end of the stroke length, which thereby minimizes vibration of the magnetic armature **30**.

[0044] Further still, the magnetic motor **20** provides for a single moving part—the magnetic armature **30**. As such, the wear and tear on any moving parts is minimalized compared to conventional pumps that have multiple moving parts, such as motors and gearboxes. Also, the size and/or weight of the pump **10** may be reduced due to the reduction in size of the magnetic motor **20** compared the conventional motors and gearboxes.

[0045] The magnetic control interaction between the stator **22** and the magnetic armature **30** may also be relatively quicker compared with the reaction time of conventional motors. For example, the pump **10** may respond in fractions of a second faster, to thereby more accurately and in real-time control operational aspects of the pump **10** to achieve desired results. Indeed, the configurations of the pump **10** may provide a priming mode, wherein the pump **10** may run an over-speed or over-stroke to more effectively remove air from the pump **10** while priming. Thereafter, the pump **10** may be programmed to return or revert to a normal mode having a shorter stroke length to preserve the life of the diaphragms **42** and **52**. Moreover, the inherent speed and positional controls of embodiments of the pump **10** may facilitate constant flow rate in spite of process changes, such as pressure and viscosity (within operational limits of the pump **10**, obviously). Moreover, the control unit **12** may adjust the force provided by the motor **20** to the armature **30**, even mid-stroke, to maintain fixed output pressure of the fluid in spite of process changes such as inlet pressure or viscosity of the fluid (within operational limits of the pump **10**, obviously). Moreover, the pump **10** may be configured to detect, whether through high current, pressure sensors, flow signals, input signals, or the like, that the flow through the pump **10** has stopped. In such a case, the control unit **12** may be configured to instruct the pump **10** to stop or to maintain a fixed pressure against the fluid within safe operating ranges of the pump **10**.

[0046] The materials of construction of the pump **10** and its various component parts, including embodiments of the magnetic motor **20** and the respective pumping sections, **40** and **50**, may be formed of any of many different types of materials or combinations thereof that can readily be formed into shaped objects provided that the components selected are consistent with the intended operation of double-diaphragm pumps of the type disclosed herein. For example, and not limited thereto, the components may be formed of: rubbers (synthetic and/or natural) and/or other like materials; glasses (such as fiberglass) carbon-fiber, aramid-fiber, any combination thereof, and/or other like materials; polymers such as thermoplastics (such as ABS, Fluoropolymers, Polyacetal, Polyamide; Polycarbonate, Polyethylene, Polysulfone, and/or the like), thermosets (such as Epoxy, Phenolic Resin, Polyimide, Polyurethane, Silicone, and/or the like), any combination thereof, and/or other like materials; composites and/or other like materials; metals, such as zinc, magnesium, titanium, copper, iron, steel, carbon steel, alloy steel, tool steel, stainless steel, aluminum, any combination thereof, and/or other like materials; alloys, such as aluminum alloy, titanium alloy, magnesium alloy, copper alloy, any combination thereof, and/or other like materials; any other suitable material; and/or any combination thereof.

[0047] Furthermore, the components defining the above-described pump **10** and its various component parts, including embodiments of the magnetic motor **20** and the respective pumping sections, **40** and **50**, may be purchased pre-manufactured or manufactured separately and then assembled together. However, any or all of the components may be manufactured simultaneously and integrally joined with one another. Manufacture of these components separately or simultaneously may involve extrusion, pultrusion, vacuum forming, injection molding, blow molding, resin transfer molding, casting, forging, cold rolling, milling, drilling, reaming, turning, grinding, stamping, cutting, bending, welding, soldering, hardening, riveting, punching, plating, 3-D printing, and/or the like. If any of the components are manufactured separately, they may then be coupled with one another in any manner, such as with adhesive, a weld, a fastener (e.g. a bolt, a nut, a screw, a nail, a rivet, a pin, and/or the like), wiring, any combination thereof, and/or the like for example, depending on, among other considerations, the particular material forming the components. Other possible steps might include sand blasting, polishing, powder coating, zinc plating, anodizing, hard anodizing, and/or painting the components for example.

[0048] While this disclosure has been described in conjunction with the specific embodiments outlined above, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, the preferred embodiments of the present disclosure as set forth above are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the present disclosure, as required by the following claims. The claims provide the scope of the coverage of the present disclosure and should not be limited to the specific examples provided herein.

What is claimed is:

1. A double diaphragm pump comprising:

a linear magnetic motor having a magnetic armature, the magnetic armature having a first and second end opposing one another;

a first pumping section coupled to the first end;

a second pumping section coupled to the second end,

wherein the linear magnetic motor translates the magnetic armature to move a fluid through the first pumping section and the second pumping section.

2. The pump of claim **1**, wherein the linear magnetic motor translates the magnetic armature in first and second directions opposing one another.

3. The pump of claim **2**, wherein the first end of the magnetic armature is coupled to a first diaphragm in the first pumping section and the second end of the magnetic armature is coupled to a second diaphragm in the second pumping section.

4. The pump of claim **3**, wherein in the first direction the first diaphragm flexes to decrease a volume of a first chamber of the first pumping section and the second diaphragm flexes to increase a volume of a second chamber of the second pumping section to thereby move the fluid through the first and second pumping sections.

5. The pump of claim **3**, wherein in the second direction the first diaphragm flexes to increase the volume of the first chamber of the first pumping section and the second diaphragm flexes to decrease the volume of the second chamber of the second pumping section to thereby move the fluid through the first and second pumping sections.

6. The pump of claim **1**, further comprising a motor mount to which the linear magnetic motor is coupled, the motor mount being configured to maintain positioning of the linear magnetic motor with respect to the pump.

7. The pump of claim **6**, further comprising a positioner coupled to the motor mount and in functional communication with the magnetic armature to maintain positioning of the magnetic armature with respect to the linear magnetic motor.

8. The pump of claim **6**, wherein the first pumping section is coupled directly to the motor mount on a side of the motor and wherein the second pumping section is coupled directly to the motor mount on an opposing side of the motor.

9. The pump of claim **6**, further comprising a spacer positioned between the motor mount and each of the first pumping section and the second pumping section.

10. A double diaphragm pump comprising:

a linear magnetic motor having a magnetic armature, the magnetic armature having a first and second end opposing one another;

a first pumping section coupled to the first end;

a second pumping section coupled to the second end,

wherein the linear magnetic motor translates the magnetic armature without a gearbox in reciprocal first and second directions opposing one another to move a fluid through the first pumping section and the second pumping section.

11. The pump of claim **10**, further comprising a control unit, wherein the control unit controls operational aspects of the pump.

12. The pump of claim **11**, wherein the operational aspects further comprise real-time feedback of a position of the magnetic armature in the magnetic motor.

13. The pump of claim **11**, wherein the operational aspects further comprise stroke length of the magnetic armature.

14. The pump of claim **11**, wherein the operational aspects further comprise stroke speed of the magnetic armature.

15. The pump of claim **11**, wherein the operational aspects further comprise acceleration of the magnetic armature.

16. The pump of claim **11**, wherein the operational aspects further comprise a flow rate of the fluid through the first pumping section and the second pumping section.

17. A method of operating a double diaphragm pump comprising:

providing a magnetic armature in a linear magnetic motor, wherein the magnetic armature has first and second distal ends opposing one another;

coupling a first pumping section to the first distal end;

coupling a second pumping section to the second distal end;

translating the magnetic armature back and forth in a reciprocal manner to move a fluid through the first pumping section and the second pumping section.

18. The method of claim **17**, further comprising controlling operational aspects of the pump by a control unit.

19. The method of claim **18**, wherein the controlling operational aspects of the pump further comprises transitioning the pump between a priming mode wherein the control unit increases one or more of a speed or stroke length of the magnetic armature and a normal mode wherein the control unit returns to a normal speed and normal stroke length of the magnetic armature.

20. The method of claim **18**, wherein the controlling operational aspects of the pump further comprises maintaining one of constant flow rate and pressure of the fluid exiting the pump despite changes in pressure of the fluid entering the pump or viscosity of the fluid.

* * * * *